Rail Accident Investigation Branch

Rail Accident Report

Derailment of a freight train at Carrbridge, Badenoch and Strathspey 4 January 2010

Department for Transport

Report 03/2011
February 2011

This investigation was carried out in accordance with:

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

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Derailment of a freight train at Carrbridge, Badenoch and Strathspey, 4 January 2010

Contents

Summary

On 4 January 2010, in freezing temperatures and snowy conditions, the front portion of a freight train which was travelling from Inverness towards Perth on the Highland Main Line, derailed at Carrbridge station. The derailed portion of the train came to rest on an embankment, close to some houses. The driver and technician onboard the train suffered minor injuries. Damage was caused to private property, to the derailed train and to the infrastructure of the railway.

The freight train's braking performance prior to derailing was much reduced from that which would normally be expected. The train's driver was unaware of this reduction prior to attempting to brake the train on the approach to Carrbridge.

A combination of factors led to the derailment occurring. These included:

- snow and ice ingress reducing the effectiveness of the train's brakes;
- the way that the driver of the train applied the rules for operating trains in snowy conditions on steep climbing gradients;
- the train ploughing into and/or disturbing lying snow during the journey from Inverness to Carrbridge; and
- the presence of deep lying snow close to the railway line.

The RAIB has made four recommendations. These are:

- to freight operating companies, in conjunction with the Rail Safety and Standards Board (RSSB), concerning changes to the rules for operating trains in snowy conditions on steep climbing gradients;
- to Network Rail, relating to the assessment of risk at locations including steep gradients when trains are operating over them in snowy conditions;
- to Network Rail, relating to the assessment of risk when deep lying snow is left close to railway lines following the prolonged use of a certain type of snow clearance equipment; and
- to Network Rail, concerning the assessment of risk should trains fail to stop when requested to do so at the signal controlling the approach to Carrbridge from Inverness.

Preface

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents and improve railway safety.

2 The RAIB does not establish blame, liability or carry out prosecutions.

Key Definitions

3 All dimensions and speeds in this report are given in metric units, except speed and locations on Network Rail, which are given in imperial dimensions, in accordance with normal railway practice. In this case the equivalent metric value is also given.

4 The report contains abbreviations and technical terms (shown in *italics* the first time they appear). These are explained in appendices A and B.

The Accident

Summary of the accident

5 At 16:04 hours on 4 January 2010, train 4N47, the late running 13:14 hrs Inverness to Mossend Yard[1] service, derailed on exiting the *run-out* located at Carrbridge station, Badenoch and Strathspey, Scotland (see figure 1), having previously passed over *trap points* located within the station's *passing loop*.

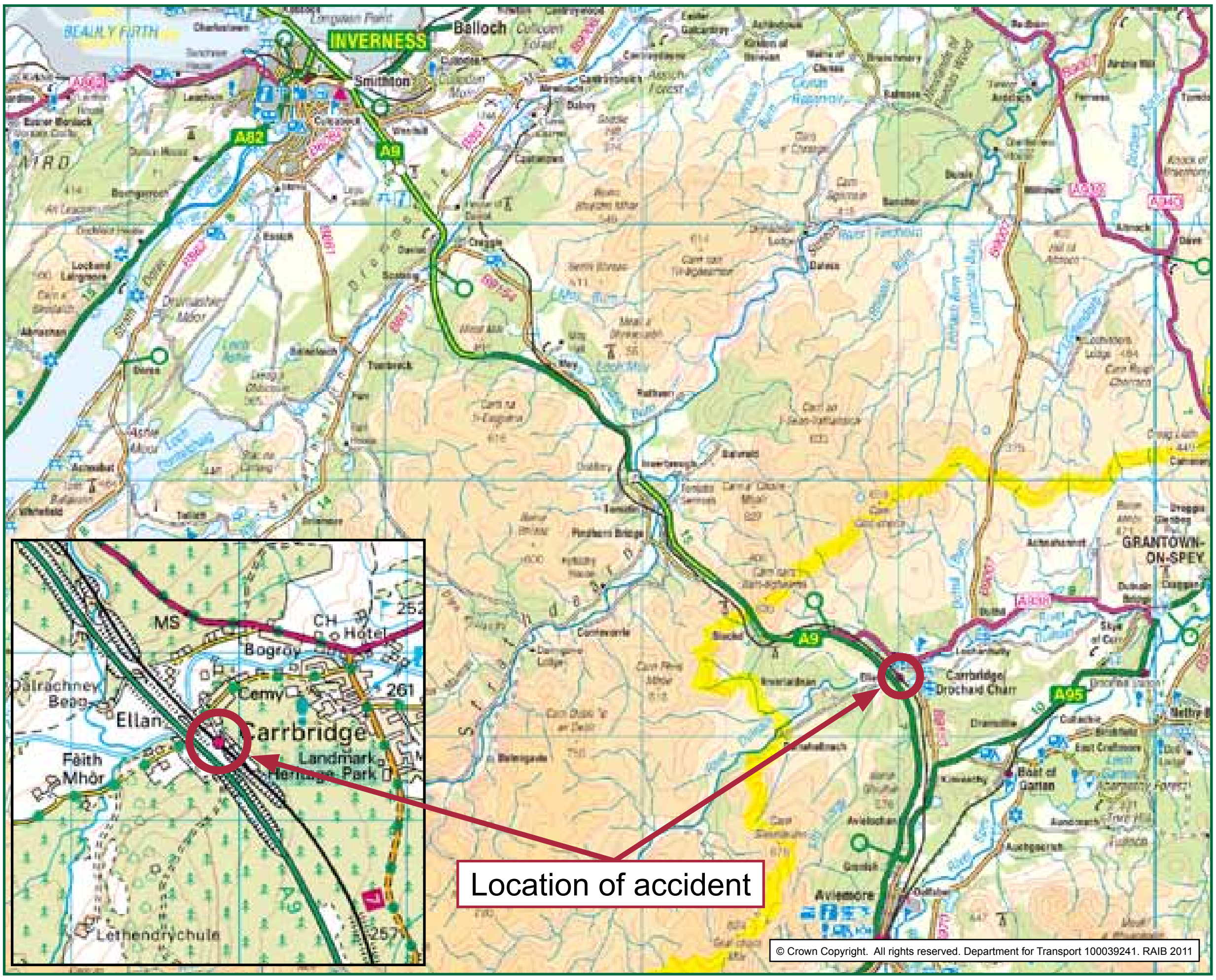

Figure 1: Extract from Ordnance Survey map showing location of accident

6 The train came to rest amongst trees on an embankment east of the railway, close to some houses (see figure 2). The locomotive and the front six 'twin' wagons (each wagon consisting of two element vehicles) derailed and they, and their container loads, came to rest in a number of locations including in the gardens of the houses and foul of the running lines through Carrbridge station. The rear four wagons (eight elements) did not derail or lose their containers.

7 The driver and technician onboard the train suffered minor injuries. Damage was caused to private property, the station platform, the *permanent way*, signalling equipment and the locomotive, wagons and containers which derailed.

[1] Situated in North Lanarkshire.

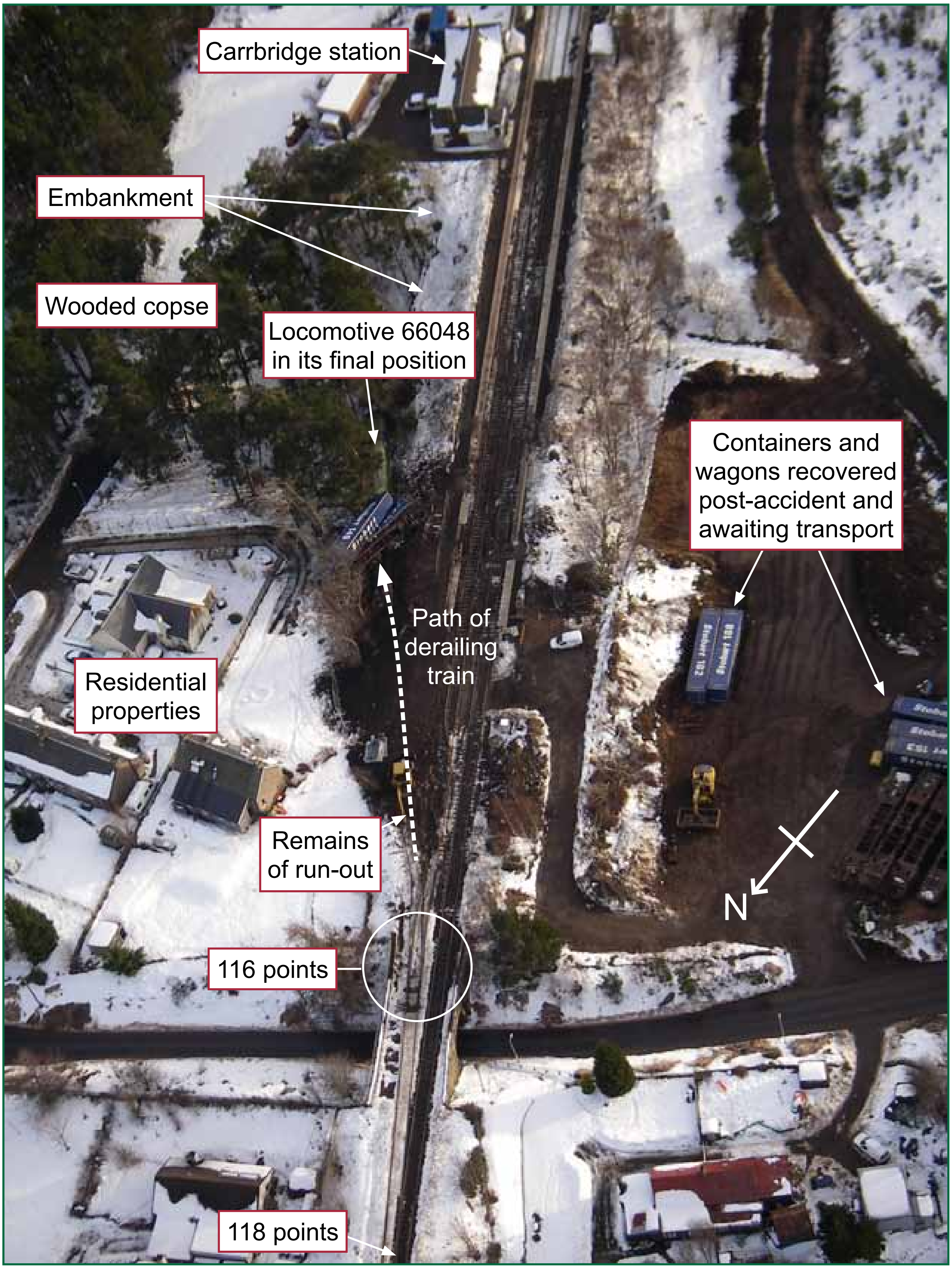

Figure 2: Aerial view of Carrbridge from the north during post-accident recovery operations (image courtesy of the Ministry of Defence)

Organisations involved

8 DB Schenker Rail (UK) Ltd[2] operated the train under contract to Stobart Rail. DB Schenker employed the traincrew and the yard staff involved in preparing the train at Inverness.

9 Angel Trains Ltd owned the locomotive, which was maintained by DB Schenker.

10 Porterbrook Leasing Company Ltd owned the wagons, which were maintained by DB Schenker.

11 Network Rail owned and maintained the track on which the derailment happened.

12 DB Schenker, Angel Trains Ltd, Porterbrook Leasing Company Ltd and Network Rail have freely co-operated with the investigation.

Location

13 Carrbridge station is located on the Highland Main Line which runs from Inverness to Perth. The *down* direction is from Perth to Inverness and the *up* direction is from Inverness to Perth.

14 The derailment took place at the exit of the run-out located at the north end of Carrbridge station loop. The train was travelling in the up direction (towards Perth) when it derailed.

External circumstances

15 A forensic weather report prepared on behalf of the RAIB (see paragraph 72) provided evidence that weather conditions were poor, although not extreme, during the preparation of 4N47 and along the length of its journey from Inverness to Carrbridge. Winds along the route varied in strength from gentle (less than 12 mph (19 km/h)) to fresh (less than 25 mph (40 km/h)) with gusts of between 25 to 30 mph (40 to 56 km/h) in the area of the Culloden Viaduct. Temperatures were at or just above freezing and humidity values were high. Visibility during the journey varied from moderate to poor. There was light falling snow on the route of around 50 to 100 mm over the whole day, with a maximum of around 20 mm falling in the hour around the passage of train 4N47.

16 Lying snow had been present in the area of the journey since mid-December 2009 (see figure 3). By 4 January 2010 the depth of lying snow[3] on the line from Inverness to Carrbridge was between 300-400 mm, around 150-250 mm above rail height[4].

[2] Referred to as DB Schenker throughout the report.

[3] On the day of the accident the actual depth of lying snow may have varied from this at specific locations; photographs show that the depth of lying snow was lower than this during shunting at Inverness and there is also evidence that the snow may have drifted higher in other places.

[4] Network Rail procedures relevant to adverse weather conditions assume a rail height of 150 mm.

Figure 3: View towards the north end of Carrbridge station on 2 January 2010 (image courtesy of Roy Brown)

17 At 06:02 hrs on 4 January, Network Rail's Route Control Manager for Scotland issued a Weather Alert Status Red. This signified that there was a combination of adverse weather conditions which presented a high degree of risk to the operational integrity of the rail network[5]. This alert was applied to the whole mainline rail network in Scotland and was triggered by a forecast combination of a very severe frost, freezing fog and a moderate snow-fall. The issuing of this alert would subsequently trigger an *Extreme Weather Action Team* (EWAT) conference call within Network Rail (see paragraph 43).

18 During the evening immediately following the derailment, weather conditions deteriorated at Carrbridge, with temperatures dropping to below freezing and the snow fall becoming heavier.

The train

19 Train 4N47 consisted of Class 66 diesel-electric locomotive number 66048 and 10 FKA type twin container flat wagons. Each FKA wagon is made up of two *semi-permanently coupled* vehicles, known as 'elements'; the train therefore consisted of a total of 21 rail vehicles. The *train document* produced by the *total operations processing system* (TOPS) for 4N47 gave a maximum train speed of 75 mph (120 km/h).

[5] The criteria for issuing alerts are contained within Network Rail Standard NR/L2/OPS/021 Issue 2 *Weather – managing the operational risks*.

20 Locomotive 66048 has two bogies, each of which has three powered axles. It is equipped with air operated *tread brakes* which apply 'high friction' composition brake blocks directly to all *wheel treads*. The brakes on the locomotive are applied either using the *straight air brake* or by operation of the *automatic air brake* system. Class 66 locomotives are equipped with *wheelslip protection* but not with *wheelslide protection*.

21 The locomotive provides compressed air for its own braking system and to the single brake pipe which controls train braking and supplies air to the wagons' braking systems (a simplified explanation of the single pipe brake system is provided within appendix D). The locomotive is fitted with a regenerative air dryer to reduce the level of moisture in the air entering the braking system. It does this by depressing the *dew point* of the air so that it does not precipitate excessive water if the braking system is vented to atmospheric pressure.

22 The day of the accident was the locomotive's first day back in revenue earning service following a two month long scheduled maintenance period. This included a six-monthly safety and reliability examination[6], during which the locomotive's air system was inspected and the braking systems were tested. The *wheelsets*, traction motors and *brake cylinders* were also replaced. A locomotive safety examination[7] was undertaken on 3 January 2010, the day prior to the accident.

23 Each FKA wagon was carrying two empty 'forty foot' containers, one on each element. Each wagon had a *gross laden weight* (GLW) of between 56.6 and 57.6 tonnes; their specified *tare* weight was 48 tonnes[8]. The TOPS train document calculated that the train required 279 tonnes of *equivalent braking force* but had 462 tonnes of equivalent braking force available, a large surplus. The TOPS train document calculated that the locomotive would provide around 15%, and the wagons collectively around 85%, of the total equivalent braking force.

24 Each element vehicle is mounted on two bogies, each of which has two unpowered axles. They are equipped with air operated tread brakes, with each element having a single *distributor* connected to a separate *variable load valve* and a brake cylinder on each bogie. Air entering the brake cylinders operates the bogie's brake rigging to apply 'high-friction' composition brake blocks to all four wheel treads. Each wheel has a single brake block operating to one side (the 'inner' side), a braking arrangement known within the rail industry as 1Bg (see figure 20). With the brakes in the *released* position, there is a designed minimum clearance of 5 mm between the face of the brake block and the wheel tread surface.

25 During the process of *engineering acceptance* which the wagons went through in the late 1990s, evidence was provided to a *vehicle acceptance body* (VAB) that the wagon's braking system would continue to operate correctly down to -20 ºC and in the weather conditions foreseeable during operations in the UK (see paragraph 184). This evidence was based on the prior performance in winter conditions and/or the prior certification of the various components which made up the wagon's braking equipment.

26 There is no evidence that any of the wagons which formed train 4N47 were overdue any maintenance activity.

[6] Known within the rail industry as a 'B' Examination.

[7] Known within the rail industry as an 'A' Examination.

[8] The specified *part-laden* GLW of an FKA wagon is 112 tonnes.

27 A visual *train examination* of the locomotive and wagons which formed train 4N47 was undertaken prior to the train's departure from Inverness on 4 January (see paragraph 45).

28 As it was a *class 4* freight service, train 4N47 was using passenger *brake timings*. On 4 January, the locomotive and the distributors on each element were correctly set to use this timing.

Rail infrastructure involved

29 On leaving Inverness the Highland Main Line ascends a steep gradient (1 in 60 maximum slope) towards the 400 metre high Slochd summit. Once over the summit the line has a steep descent (1 in 60 maximum slope) towards Carrbridge where the gradient flattens out on the approach to and through the station, before generally descending towards Aviemore (see figure 4).

30 The line is double track from Inverness until Culloden Moor, where it becomes single track until it reaches Aviemore. In this part of the line, passing loops are located at Moy, at Tomatin, at Slochd Summit (on the approach to the peak from Inverness) and at Carrbridge station.

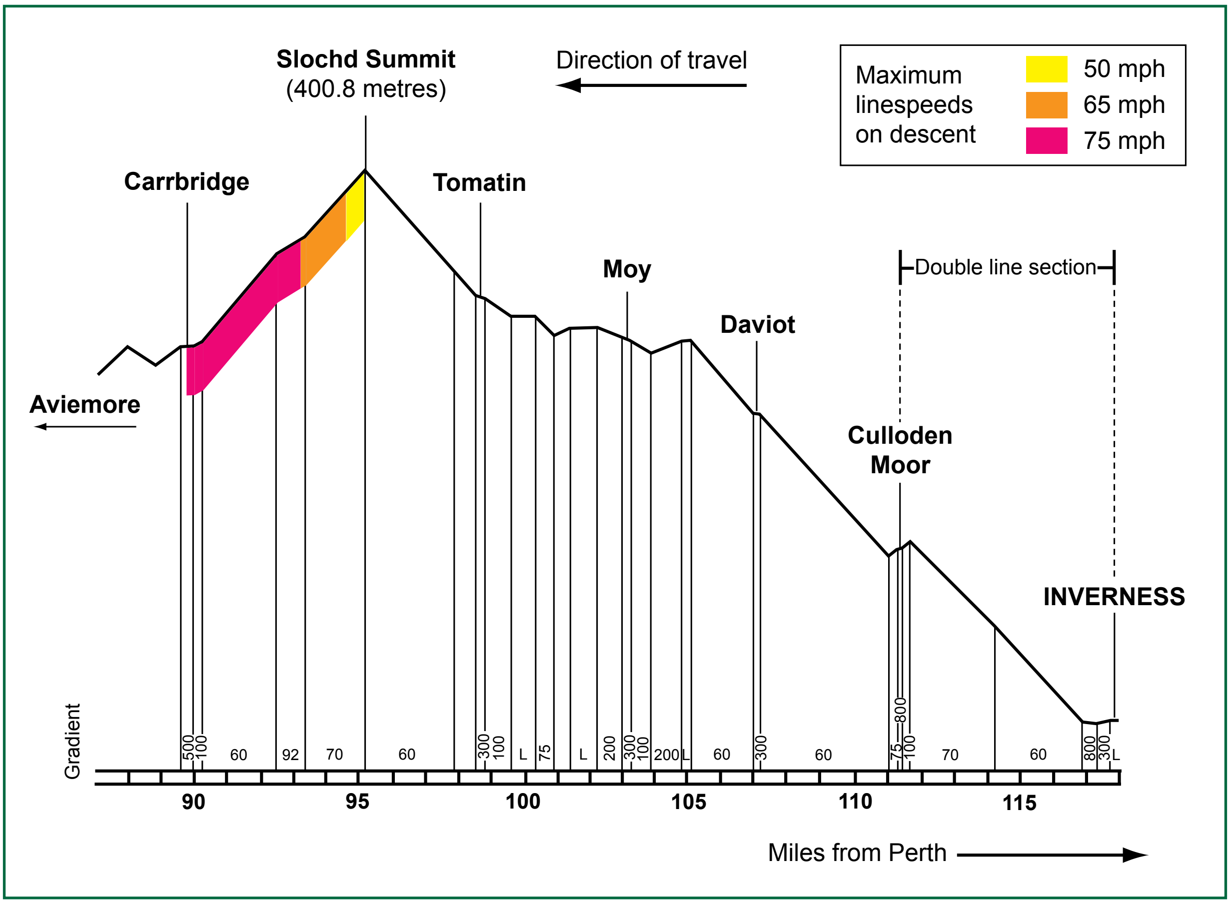

Figure 4: Diagram of line gradients between Inverness and Carrbridge

31 Once the line has left Inverness, the maximum permitted line speed rises from 40 mph (64 km/h) to between 55 and 80 mph (88 to 129 km/h) on the ascent[9]. Once trains have passed over Slochd summit there is a 50 mph (80 km/h) *permanent speed restriction* (PSR) in place for 33 chains (663 metres) on the descent. On exiting the PSR, the maximum permitted line speed rises to 65 mph (104 km/h) and then to 75 mph (120 km/h) through the mainline at Carrbridge station, with a 40 mph (64 km/h) limit for trains using the station loop.

32 Just prior to Slochd summit there is a lineside sign next to the track featuring a pictogram of a snowflake (see figure 5). Network Rail's Scotland Route Sectional Appendix requires that drivers of Class 158 *Diesel Multiple Units* (DMUs) travelling in the up direction (ie those about to descend towards Carrbridge) must make a *full service brake application* and bring their trains to a stop at this board during freezing or snowy conditions. This requirement did not apply to train 4N47.

Figure 5: Lineside snow sign on approach to Slochd summit (taken on 18 January 2010).

33 The railway at Carrbridge consists of the single track main line with *points* located north (118 points) and south (115 points) of the station which allow access to and from the 560 metre long loop. Because of the risks posed by the steep descent which leads into the station from Slochd summit (see paragraph 188), the passing loop is fitted with trap points (116 points) which can be set either to allow trains to enter into the loop or on to a 27 metre long run-out (see figures 6 and 7).

[9] Lower maximum permitted line speeds apply to the loops on the ascent but these were not used by 4N47 on 4 January 2010.

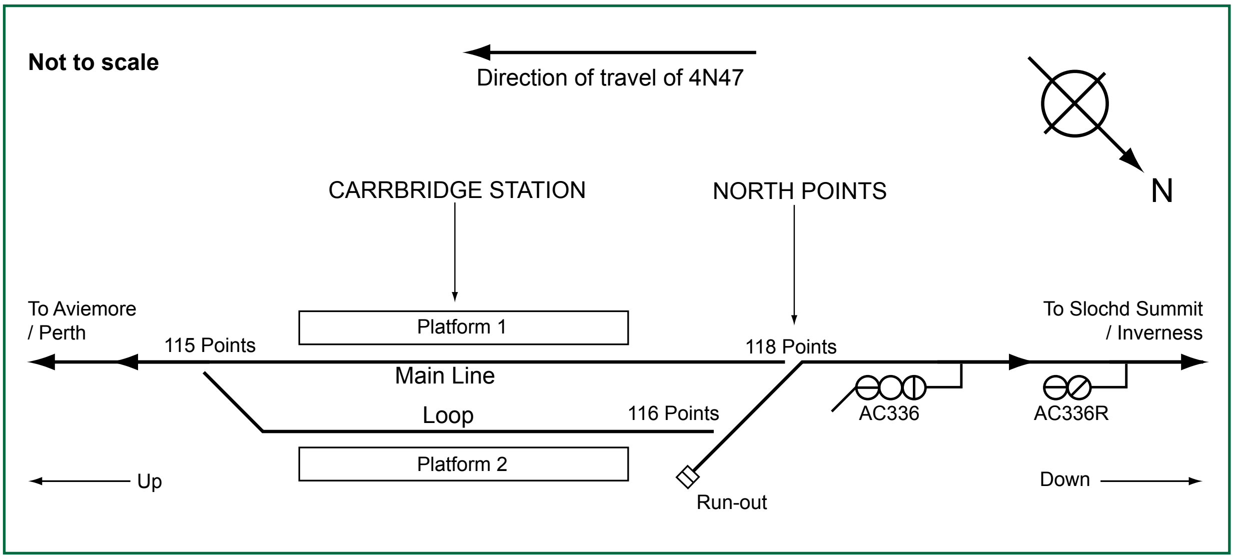

Figure 6: The layout of the track at Carrbridge

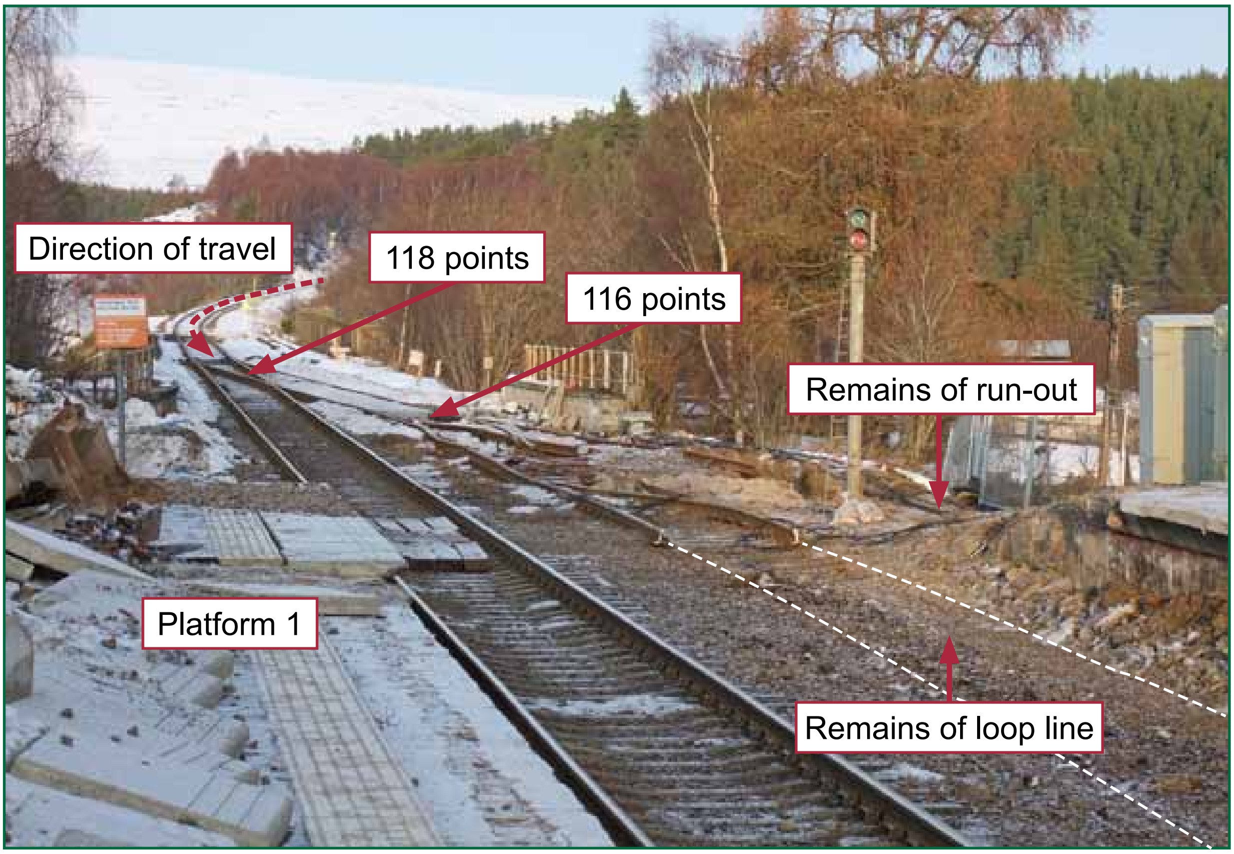

Figure 7: View of the north of Carrbridge station taken whilst post-accident repair work was ongoing (image courtesy of Trevor Roots).

34 The railway at Carrbridge is signalled using the *track circuit block system* and is controlled from Aviemore Power Signal Box. Entry by a train approaching from Slochd summit into the section of line which includes Carrbridge station and its loop is controlled by signal AC336, a *three aspect colour light signal* which is fitted with a *route indicator* for the loop. This signal is situated around 500 metres before 118 points and is fitted with equipment for both the *Automatic Warning System* (AWS) and the *Train Protection and Warning System* (TPWS).

35 Signal AC336 is preceded by *distant signal* AC336R, a *two aspect colour light signal* situated approximately 2,400 metres before 118 points. This signal is fitted with AWS equipment only.

36 At Carrbridge 118 and 116 points are configured so that, when they are in the *normal* position, any train passing over them will be directed into the run-out. This means that the signaller at Aviemore must command both sets of points (normally via *route setting)* to either allow a train approaching from Slochd summit to access the main line (via the *reversal* of 118 points) or to access the loop (via the reversal of 116 points). Once the *route* has been released, these points will automatically revert to the normal position and, once again, direct trains approaching from Slochd summit over the run-out.

Events preceding the accident

37 At 07:45 hrs on 2 January 2010, an *emergency speed restriction* (ESR) was put in place between Carrbridge and Aviemore because snow was causing branches to obstruct the driving cabs of passing trains. If an ESR is to last for more than a short time, its presence is normally marked with portable equipment and lineside warning boards. In the case of this ESR, however, the length of the line affected by the restriction was being varied depending on the reports being received from trains as to the extent of the obstruction. Snow was also causing blockages to roads in the area, making it difficult for track engineering staff to access the line.

38 For these reasons, this ESR was not marked by warning boards and equipment. Instead, all trains approaching Carrbridge from Slochd summit, and which were not due to stop in the loop, would be stopped at signal AC336 so that the signaller at Aviemore could warn drivers verbally of the hazard and the extent of the speed restriction using the *signal post telephone*.

39 At 02:50 hrs on 4 January 2010 a *line proving locomotive* arrived at Inverness from Perth and reported that there were no further problems on the line other than the over-hanging branches between Carrbridge and Aviemore. This locomotive subsequently departed Inverness to undertake the same journey in reverse, passing back through Carrbridge at 03:17 hrs.

40 At 06:02 hrs on 4 January 2010 Network Rail's Route Control Manager for Scotland issued a Weather Alert Status Red (see paragraph 17).

41 At 06:19 hrs, train 4H47 left Mossend Yard in North Lanarkshire en route to Inverness Millburn Yard. This train was formed of the locomotive and wagons which were later to form train 4N47. Loaded containers were being carried on the wagons. The driver was accompanied by an additional member of engineering staff, known as a technical rider. The train was late leaving Mossend, as snow had affected the operation of points within the yard during marshalling.

42 At 11:00 hrs train 4H47 arrived at Inverness Millburn Yard, 82 minutes late (see figure 8). On arrival the train crew did not report any problems relating to the train's braking during the journey. The train was split into two portions and shunted in order to allow loaded containers to be exchanged with empty ones. These portions were then reformed to make train 4N47. Staff working in the yard scraped ice from the *solebar* and *spigots* of some of the wagons. No ice or snow was reported as being in the brake rigging, wheels or brake blocks, although almost all of the brake rigging on an FKA wagon is hidden when the wagon is viewed from a standing position. While shunting was underway a new driver arrived to take over the train. He booked on, checked for *engineering notices* and then completed the shunting. It was this driver, along with the existing technical rider, who would form the crew of train 4N47.

Figure 8: Train 4H47 on arrival at Inverness Millburn Yard on 4 January 2010 (image courtesy of Steven Robertson)

43 At 11:29 hrs, train 1Z99, a line proving locomotive fitted with a *miniature snow plough* (MSP), passed through Carrbridge en route to Inverness.

44 At 12:00 hrs, because of the earlier issuing of a Weather Alert Status Red, Network Rail's Scotland Route convened an Extreme Weather Action Team (EWAT) conference call. There was no specific discussion of conditions in the Highlands and Inverness areas.

45 Once marshalled, train 4N47 was subjected to a train examination (see paragraph 27) by a *train examiner*. This involved an inspection of the wagons' wheels and axles, suspension, braking equipment and structure for safety critical defects. The train's loading and formation was also checked by a *train preparer*[10] who signed the *driver's slip* on the TOPS train document to confirm that TOPS correctly reflected the actual configuration of the train. The train preparer and another member of yard staff then undertook an operational pre-departure check of the train to ensure that vehicles and braking equipment were correctly coupled and that the container loads were secure.

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[10] On this occasion the same member of the yard staff served as both train examiner and train preparer.

46 At 14:52 hrs, the driver of train 4N47 successfully conducted a *brake continuity test* with the help of the yard staff. The train departed Inverness Millburn Yard at 15:10 hrs, 1 hour and 56 minutes later than scheduled[11]. As it left, light snow started to fall. On leaving the depot the train was almost immediately required to brake to a stand from 9 mph (14 km/h) in order to obey a signal (see figure 9). At 15:17 hrs the train moved off again and started its ascent towards Slochd summit, following behind a passenger service, train 1T99.

Figure 9: Train 4N47 stopped outside Inverness awaiting a signal to clear just prior to ascending the Slochd summit on 4 January 2010 (image courtesy of Steven Robertson)

47 At 15:15 hrs, train 1Z99, a line proving locomotive (see paragraph 43) which had departed Inverness prior to the departure of train 4N47, passed through Carrbridge en route to Aviemore. This train had travelled, and ploughed, the same route over Slochd summit that train 4N47 was to subsequently take.

48 At 15:27 hrs, train 4N47 was on the approach to Culloden Moor at 30 mph (48 km/h) (Point A on figure 10). On seeing an upcoming distant signal at *caution*, the driver reduced the setting on the locomotive's throttle for several minutes and the train gradually decelerated to 10 mph (16 km/h). The driver's later recollection was that he had applied the train's brakes at this point and that they had retarded the train as he would have expected. Analysis of data downloaded from train 4N47's *on train data recorder* (OTDR) recorded no brake application being made at this location.

49 At 15:45 hrs, train 4N47 passed through Moy at 50 mph (80 km/h) (Point B on figure 10). The driver made an *initial application* of the automatic brake lasting 10 seconds with the locomotive's throttle at its maximum setting of 8. There was no reduction in train speed during this brake application. It had been 28 minutes since the train's brakes had previously been operated.

[11] Although 4N47 left Inverness later than originally timetabled it remained on-time in relation to a revised schedule throughout the journey from Inverness to Carrbridge.

50 At 15:49 hrs, train 4N47 was continuing to climb towards the summit at 51 mph (82 km/h). Prior to passing through Tomatin (Point C on figure 10), the driver made another initial application of the automatic brake of 10 seconds duration, again with the throttle set at 8. There was no reduction in train speed during this brake application, which came four minutes after the previous one and which was the last undertaken on the ascent. The driver's later recollection was that he had made a brake application on or near the summit in order to slow the train down for the approaching PSR and that the brakes had functioned correctly. The OTDR recorded no brake application being made at or near the approach to the summit.

51 At 15:53 hrs, passenger service train 1T99 was stopped at signal AC336 and its driver was warned of the ESR by the signaller at Aviemore. Signal AC336 was then cleared in order to allow 1T99 to pass into *section*. Once it had started to enter the section, signal AC336 would have automatically reverted to *danger* in order to provide *protection* for this train and, once 1T99 had passed and cleared the appropriate track circuits,118 and 116 points would have correctly automatically been positioned to direct trains towards the run-out. AC336 signal would from this point on be held at danger in order to give train 4N47 the same warning concerning the ESR which train 1T99 had received.

52 At 15:57 hrs, train 4N47 passed over the top of Slochd summit (Point D on figure 10) at 27 mph (43 km/h) and started to descend towards Carrbridge. As the train started to descend, the driver noted that there was a slight covering of snow across the rail head and that snow was swirling around, but that visibility was not a problem.

53 At 15:59 hrs the train was descending towards Carrbridge at 44 mph (Point E on figure 10) when the driver shut-off the throttle and made an initial application of the automatic brake which lasted 21 seconds. Train speed increased slightly during this brake application, which came 10 minutes after the final one made during the ascent.

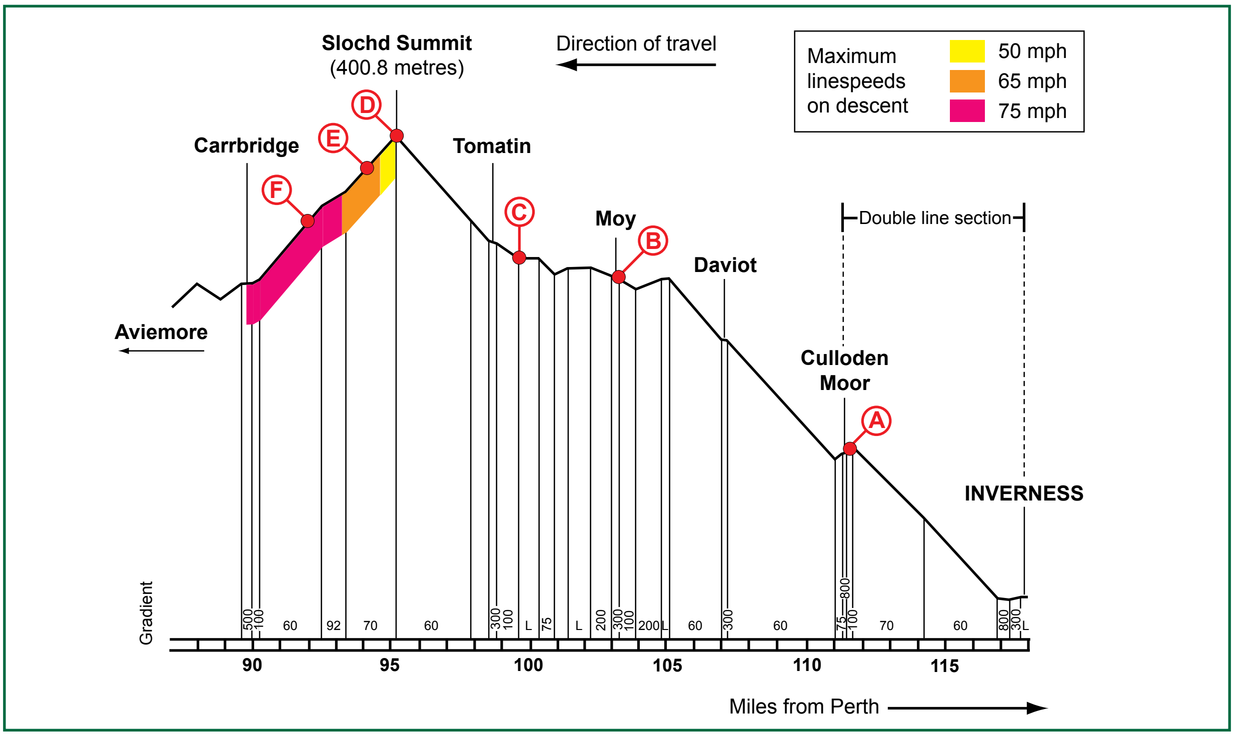

Figure 10: Key events during passage of 4N47 between Inverness and Carrbridge on 4 January 2010

Events during the accident

54 At 16:01 hrs, train 4N47 was approaching signal AC336R (Point F on figure 10) at 67 mph (107 km/h), with the locomotive's throttle just below its maximum setting. This was around 46 minutes after line proving locomotive 1Z99 had passed through Carrbridge and around 8 minutes after passenger service 1T99 had stopped at signal AC336.

55 As signal AC336 was displaying a red danger aspect, signal AC336R, its associated distant signal, would have been displaying a single yellow caution aspect. The driver of train 4N47 shut off the throttle and made an initial application of the automatic brake on the approach to this caution signal. At this point, and during the events which immediately followed, the train was on a section of line with a 1 in 60 descending slope.

56 The driver increased the automatic brake application slightly but noticed that the train did not appear to be slowing down. Because of this, 21 seconds after making the initial application, the driver increased the application of the automatic brake to close to its full service application setting. After another 17 seconds the driver still could not feel any effect from the brakes and so, with the train's speed now at 69 mph (111 km/h), the driver also applied the locomotive's straight air brake.

57 After a further 12 seconds the driver, aware that he had passed AC336R signal, operated the *emergency brake plunger*. At this point the train was around 1,800 metres from 118 points and was travelling at 67 mph (107 km/h).

58 By 16:03 hrs a total of 1 minute and 21 seconds had passed since the driver had started this brake application. By now he could feel that the brakes were starting to work and the train's speed had reduced slightly. At this point the train passed over the TPWS *Overspeed Sensor System* (OSS) for the approaching AC336 signal. TPWS detected that the train was travelling too quickly on the approach to this red danger signal and automatically initiated an *emergency brake application*. However because the driver's use of the emergency brake plunger had already effectively vented the train's *brake pipe*, this additional demand had no effect.

59 The train then passed AC336 signal. At this point the train was around 500 metres from 118 points and was travelling at 62 mph (100 km/h). The driver, now believing that the train was not going to stop before entering Carrbridge station loop, used the locomotive's horn to sound the 'train in distress' signal.

60 The descending gradient of the line reduces to a 1 in 100 slope on the immediate approach to Carrbridge station. The train continued to slow down whilst passing through this section. By the time it reached 118 points[12] it was travelling at 56 mph (90 km/h). Around 100 metres later it traversed 116 points and entered the run-out, from which it subsequently derailed.

[12] After this point the speed recorded by the OTDR is considered by the RAIB to have become unreliable.

Consequences of the accident

61 The locomotive and the front six wagons (twelve elements) derailed. They, and some container loads which had become loose, came to rest in a number of locations, including within the gardens of nearby houses and foul of the running lines through Carrbridge station. The rear four twin wagons (eight elements) did not derail or lose their containers.

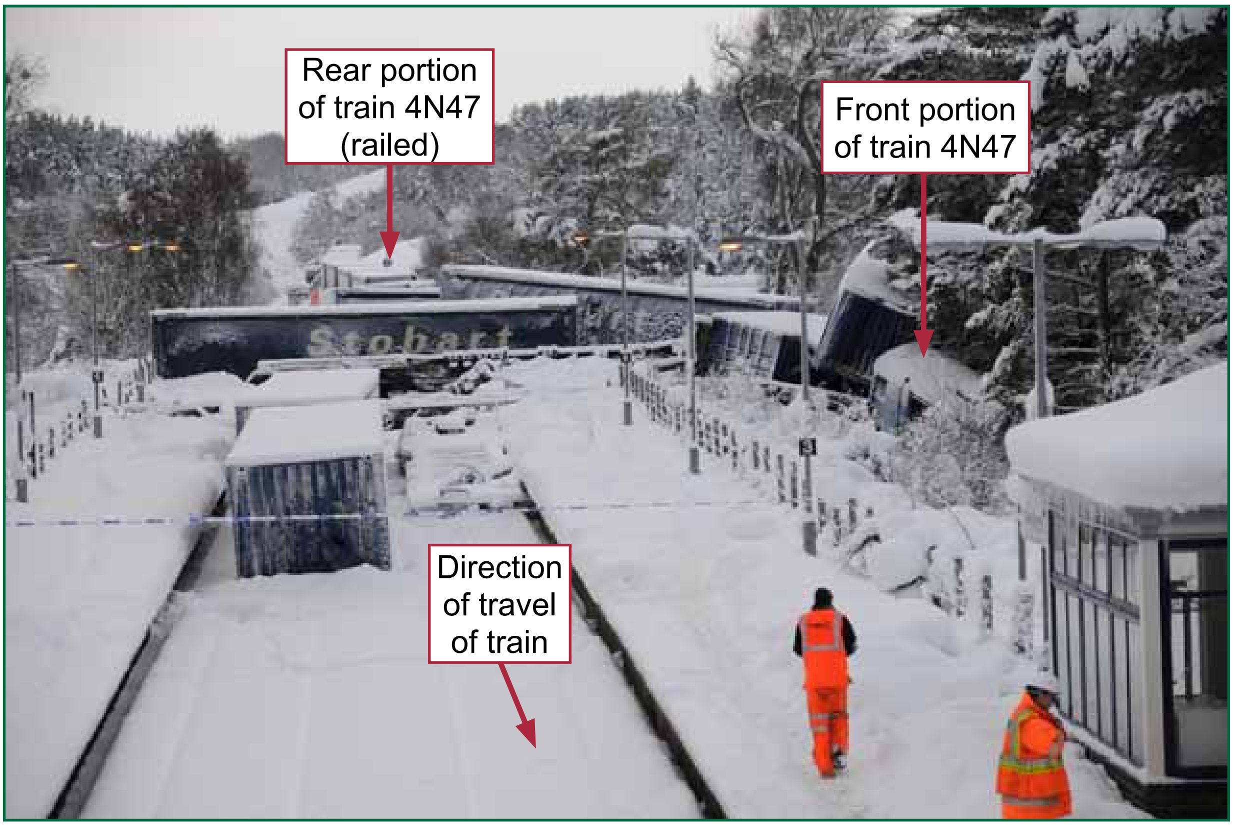

Figure 11: Train 4N47 on the morning of 5 January 2010 (image courtesy of the British Transport Police)

62 Both staff onboard 4N47 received minor injuries as a result of the derailment.

63 Locomotive 66048 was damaged during the derailment and remained out of service for some months. All six wagons which derailed were damaged, as were their container loads; some of these wagons and containers were damaged beyond economic repair.

64 There was damage to the infrastructure including the destruction of signalling equipment and points, damage to the track and damage to the platform at Carrbridge station. There was also damage to the gardens of the houses affected.

65 The line through Carrbridge station remained closed until 11 January 2010.

Events following the accident

66 Following the accident the driver undertook *emergency protection* of the line and contacted Network Rail in order to report the accident. Nearby residents telephoned the emergency services.

Figure 12: Final resting position of locomotive 66048

67 The main line re-opened under an ESR on 11 January 2010. The passing loop at Carrbridge was fully repaired by 12 February 2010.

68 On 25 February 2010, train reporting number 4H47 passed through Carrbridge and ascended Slochd summit in the direction of Inverness. This train consisted of the same rolling stock types to those found on train 4N47 on 4 January 2010 and was carrying laden containers.

69 The train ascended Slochd summit in weather conditions a little worse than those found on 4 January. Lying snow was slightly deeper and was thawing slowly, with a light to moderate snow fall keeping the depth of snow constant. Winds were gentle, although there were reports of snow drifts of five to six feet, and humidity was high.

70 Once the train reached the summit and started to descend towards Inverness, the driver of 4H47 tried to bring his train to a stand. The train's brakes did not perform as the driver expected and it took much longer to stop the train than normal. On this occasion, the train did not pass a signal at danger or place other trains at any risk of a conflicting movement. This incident is discussed in more detail in paragraphs 156 to 160.

The Investigation

Sources of evidence

71 The following sources of evidence were used:

- TOPS, *train running system on TOPS* (TRUST) and signalling records relating to the accident;
- examination and testing of the locomotive and wagons involved in the accident and of braking system components;
- design, certification and maintenance records relating to the train;
- OTDR data from the incident train and from other trains running over the same route;
- photographs of train 4N47 at Inverness and during its journey to Carrbridge;
- records of relevant route risk assessments, driver route learning documents, traction bulletins and special operating instructions; and
- information from braking system component manufacturers.

72 The RAIB commissioned a forensic meteorologist to determine the likely weather conditions present:

a. at Aviemore between 1 December 2009 and 3 January 2010;

b. during preparation of train 4N47 at Inverness Millburn Yard and at key points along its journey to Carrbridge on 4 January 2010;

c. at Carrbridge during the hours following the accident of 4 January 2010; and

d. during the passage of train 4H47 through Carrbridge and over the Slochd summit towards Inverness on 25 February 2010.

73 The RAIB reviewed the best practice of other countries for mitigating the effects of snow, ice and extreme cold on the braking performance of freight trains and also into any previous incidents in the UK or internationally where cold weather was thought to have affected braking performance. This review was conducted jointly for this investigation and that into a near miss at Carstairs on 22 December 2010 (RAIB report 02/2011[13]).

74 The RAIB, in conjunction with the freight operators and owners of the vehicles involved in these incidents, undertook an analysis of possible failures of freight train braking which could be caused by low temperatures, snow and ice and the effects that such failures might have on brake system and freight vehicle performance. During the analysis, evidence from the investigations into the Carstairs and Carrbridge incidents was compared to the potential failures and effects identified in order to identify possible causal or contributory factors to these incidents.

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[13] RAIB reports are available at www.raib.gov.uk

Key facts and analysis

Identification of the immediate cause[14]

75 **The immediate cause of the derailment was train 4N47 passing over 116 trap points while they were set for the run-out.**

Identification of causal factors[15]

76 **Train 4N47 derailed because:**

- **118 points had been set to direct trains into the loop whilst simultaneously 116 points had been set to direct trains entering the loop over the run-out; and**
- **the train passed signal AC336 at danger.**

The setting of 118 and 116 points to the run-out

77 **At the point that train 4N47 passed signal AC336 at danger 118 points had been set to direct trains into the loop (their normal position) and 116 points had been set to direct trains entering the loop into the run-out (also their normal position).**

78 As has been previously stated (see paragraph 36) both sets of points were set to the normal position automatically by the signalling system following the passage of the preceding train, passenger service 1T99. They stayed in the normal position because AC336 signal was being maintained at danger by the signaller (ie a route had not been set across them).

79 This configuration of the points to direct trains into the loop and over the run-out is intended to ensure that any train or vehicle which enters the section without a route having been set (eg a vehicle which has run away down the steep slope) is directed away from any other trains which may be occupying the main line or loop. This is in accordance with normal railway design principles.

80 The setting of 118 and 116 points to direct trains over the run-out, whilst a causal factor to the accident, was the intended configuration of the railway infrastructure. The suitability of the trap points at Carrbridge as risk mitigation for a train overrunning signal AC336 is discussed more fully in paragraphs 187 to 209.

Train 4N47 passing signal AC336 at danger

81 **Train 4N47 passed signal AC336 at danger because:**

- **the train had a much reduced braking force available from that expected; and**
- **the driver of train 4N47 did not have a correct understanding of the braking forces available to the train and braked as he would normally do on seeing that signal AC336R was at caution.**

[14] The condition, event or behaviour that directly resulted in the occurrence.

[15] Any condition, event or behaviour that was necessary for the occurrence. Avoiding or eliminating any one of these factors would have prevented it happening.

The train's reduced braking performance

82 **The loss of braking performance was caused by an absence or reduction in braking force at the brake block to wheel tread interface on some or all of the vehicles that made up train 4N47.**

83 Although there was a light covering of snow on the rail head during the descent of train 4N47 from the Slochd summit, evidence from witnesses, from OTDR data and from post-incident examination of the vehicles involved showed that low adhesion at the wheel-rail interface was not the cause of the reduced mean retardation of the train.

84 *Railway Group Standard* GM/RT 2043[16] requires that the minimum average mean retardation for a freight train is approximately 4.6 *%g*[17] when braking on the flat on a line signalled for 75 mph (121 km/h) maximum line speeds. This minimum figure relates to the performance of the whole train and as such includes an allowance for delays, such as those caused by the time required for air pressure changes to propagate along the length of the brake pipe[18].

85 By comparison, train 4N47's speed did not reduce at all during the first stages of braking. Once the train's speed did start to decrease, it achieved an average mean retardation of around 0.7 %g. The train was at that time on a 1 in 60 descending slope; mean retardation would have been around 2.4 %g if the effect of the gradient is removed.

86 The mean retardation achieved by the train increased during the braking application, particularly during its final stages. Immediately prior to the train traversing 118 points, the train, now on a 1 in 100 descending slope, achieved an average mean retardation of around 3.2 %g, or around 4.2 %g if the effect of the gradient is removed.

87 As was discussed earlier (see paragraph 23) TOPS calculated that train 4N47 had a large surplus of braking force available. Despite this, the brakes on train 4N47 were initially only able to produce a retardation equating to just over half of the minimum required by Railway Group Standards. That which was produced was almost entirely overcome by the effect of the 1 in 60 descending slope.

88 This reduction in braking force must also have included the loss of at least a portion of that provided by the wagons as the train would have remained compliant (in terms of TOPS equivalent brake force requirements) even with the loss of the locomotive's entire brake force.

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[16] Railway Group Standard GM/RT 2043 Issue 1 *Braking System and Performance for Freight Trains*.

[17] Braking forces are expressed in this report in the form of %g. This is the value of an acceleration (or deceleration) expressed as a percentage of that achieved by a freely falling object, which is taken to be 9.81 m/s².

[18] Vehicles may achieve much greater retardations when tested individually; for example, during acceptance testing an individual unladen FKA wagon was able to achieve around 8 %g mean retardation when emergency braking from 79 mph in dry conditions.

Probable causes of reduced braking forces on train 4N47

89 **The absence or reduction in braking forces on train 4N47 was caused by a combination of the following factors:**

a. a reduction in the braking force being generated by the brake blocks due to the ingress of snow and ice between the block and wheel tread surfaces (probable causal factor); and/or

b. snow and ice ingress restricting the movement of the brake rigging and thus reducing partially or completely the force exerted by the block on the wheel tread surface (possible causal factor).

The ingress of snow and ice between the brake block and wheel tread surfaces

90 **Snow and ice ingress between the brake block and the wheel tread can reduce the effective coefficient of friction for the portion of the block affected when it is applied to the wheel tread. This would in turn reduce the total braking force being generated to retard the wheel.**

91 Photographs of the train taken in the hours following the derailment show that, on some of the wagons which did not derail, the brake blocks, brake heads, suspension springs and underframe were coated in a layer of snow, ice and slush. In some cases a thin layer of ice and snow could also be seen between the lower portion of the brake block and the wheel tread (see figures 13, 14 and 15).

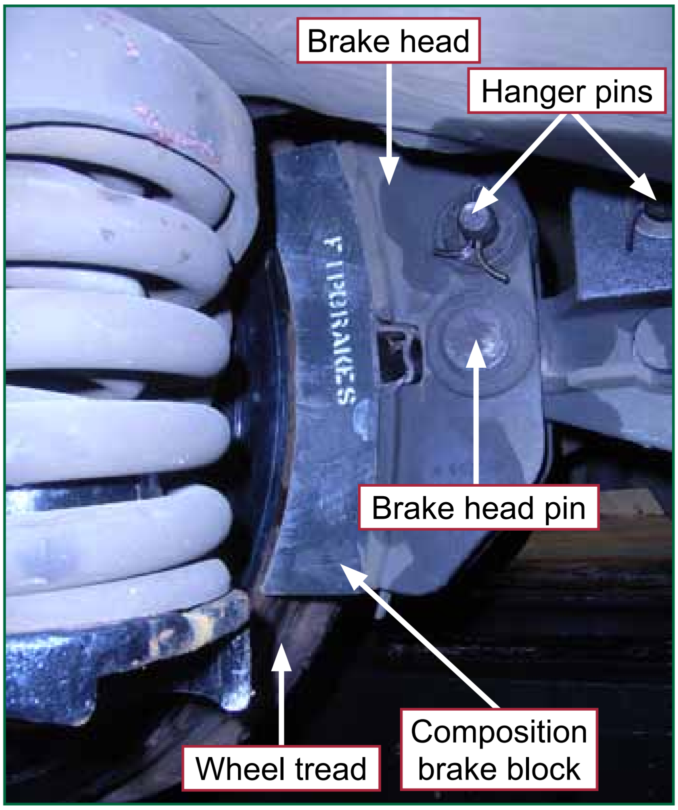

Figure 13: Photograph of the brake block, brake head, suspension springs and underframe of an FKA wagon without a coating of ice or snow

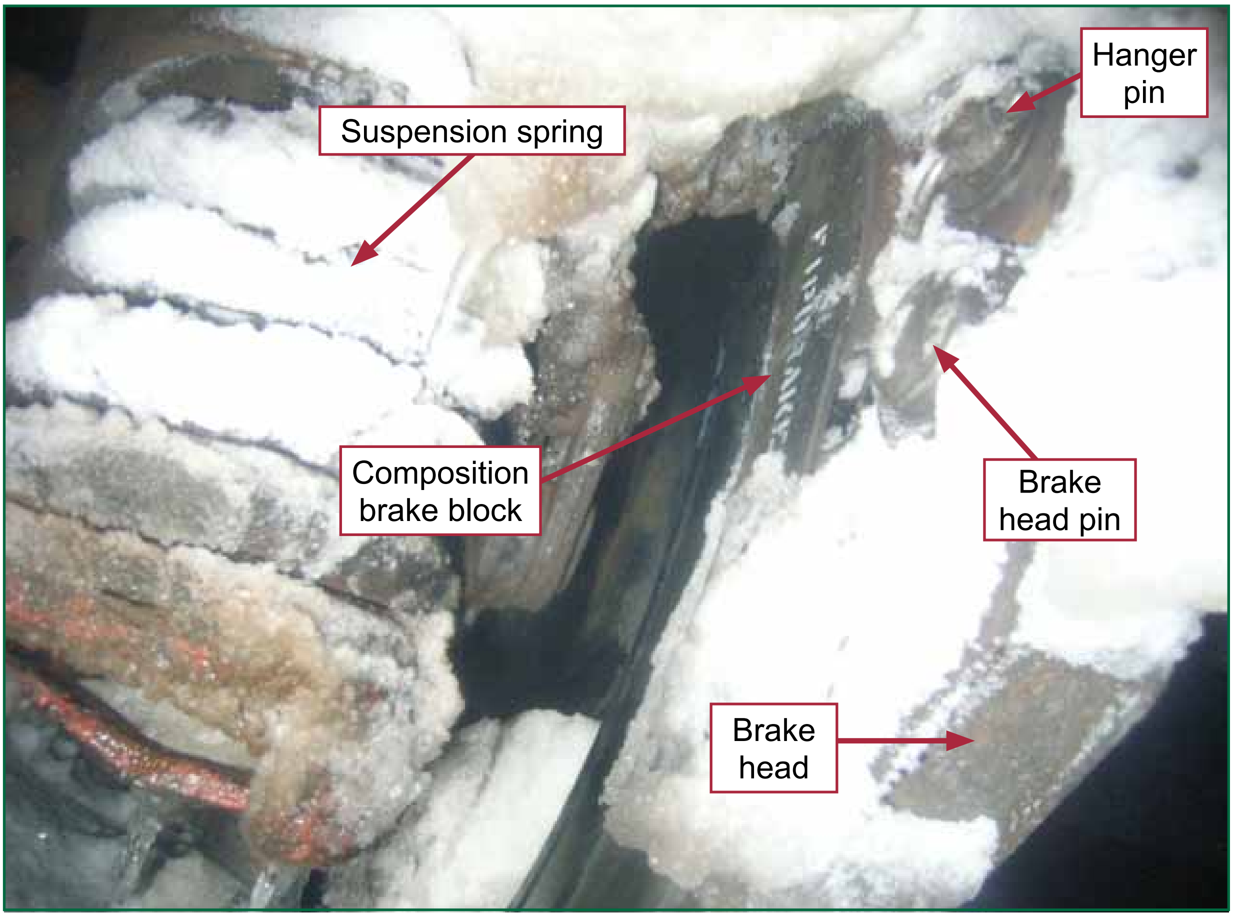

Figure 14: Photograph taken on the night of the accident showing snow, ice and slush coating the brake block, brake head and suspension springs of one of the FKA wagons which did not derail

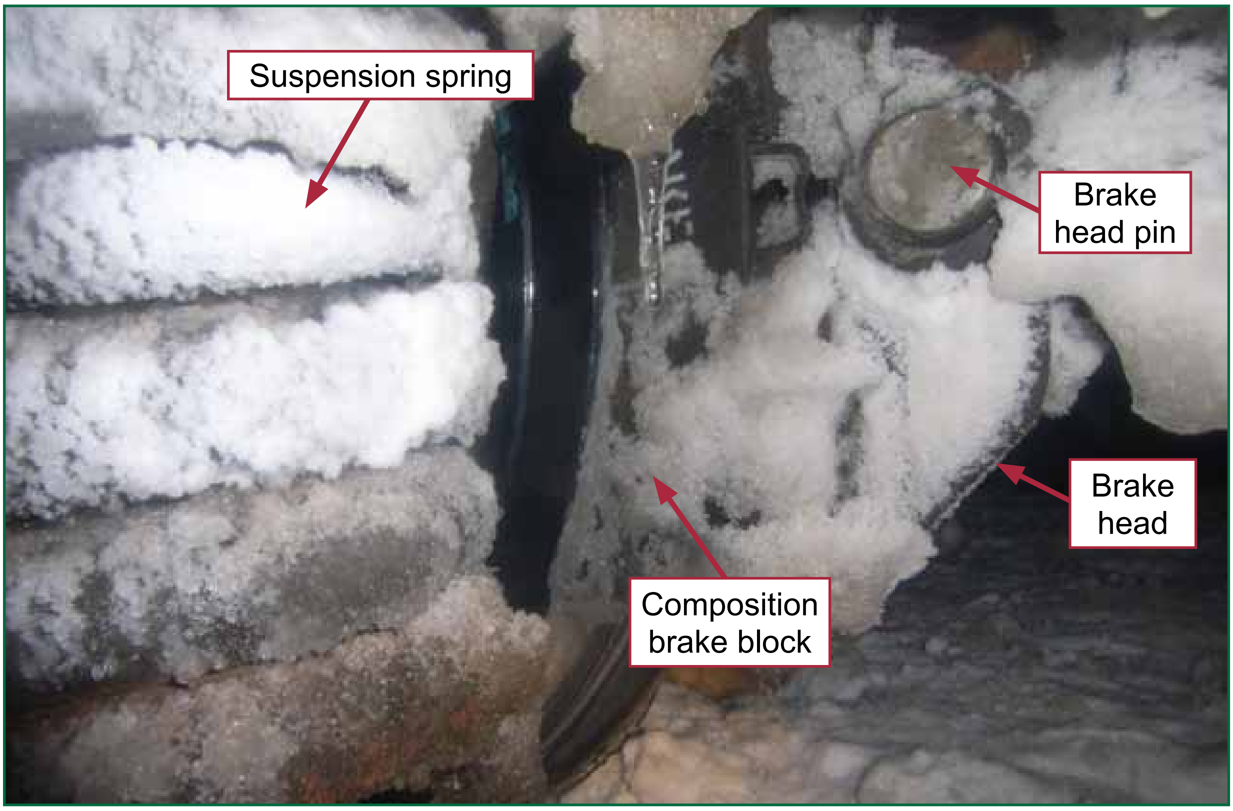

Figure 15: Photograph taken on the night of the accident showing snow, ice and slush coating the brake block, brake head, suspension springs and underframe of one of the FKA wagons which did not derail

92 Snow and ice ingress between the face of the brake block and the wheel tread would have the effect of reducing the effective coefficient of friction for the portion of the block face affected when it was applied to the wheel tread. This would in turn reduce the total braking force being generated by the block to retard the wheel. If the entire face of the block were to be covered with ice and snow, this would remove almost entirely any retardation of its associated wheel.

93 The brake heads (which hold the brake blocks) on FKA wagons are connected to the brake beam via a mounting pin (see figure 13). This arrangement gives the brake block a limited ability to pivot so that it can apply a uniform contact to the face of the wheel tread during normal braking applications[19]. Analysis undertaken by the RAIB has showed that, if the lower portion of the brake block is prevented from moving towards the wheel tread by an obstruction (such as a significant build up of ice or snow), then the block will pivot to apply the upper edge of the brake block face to the wheel tread[20].

94 The use of friction brakes produces substantial amounts of heat. In trains fitted with composite brake blocks a very high percentage of this heat is generated within the wheel being retarded and only a very low percentage within the associated brake block. This means that if part of the brake block face was not covered in ice or snow and was still able to make direct contact with the wheel tread during a brake application, it would start to generate heat within the wheel. This heat would be generated at a lower rate than when the full surface of a brake block face was applied to the wheel tread in normal conditions[21].

95 Heat generated in the wheel in this way would act to melt any ice or snow present. This would reduce contamination between the brake block face and the wheel tread and expose further areas to direct contact, thus increasing the braking force produced and retarding the wheel further. This would also increase the rate at which heat is generated in the wheel, making the process more effective as it continued.

96 The progressive melting of ice and snow by generated heat would explain the increase in mean retardation from 2.4 %g to 4.2 %g seen during train 4N47's brake application on the approach to signal AC336 (see paragraph 86). This suggests that the ingress of snow and ice between the brake block and wheel tread was probably a causal factor to the accident.

97 The potential problems which can be caused by ice and snow ingress into the friction interfaces of a train braking system have been a feature in past incidents in both the UK and abroad and are well understood within the rail industry[22].

98 Within the UK and in other countries, the main defence against such ingress causing a loss of braking is the undertaking of periodic *running brake tests* (see paragraph 134) in order to generate heat and to dislodge any ice or snow.

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[19] The brake block material used on FKA wagons is of a 'highly conformable' type. This means that it is able to distort itself to a limited degree when subjected to force (ie when the brakes are applied) in order to match the profile of the wheel tread.

[20] Post-incident inspection of the vehicles involved in the accident did not show any signs of accelerated or non-uniform wear on the upper portion of the wagon brake blocks.

[21] It is possible that the rate at which the temperature of both the wheels and the blocks rose (and thus at which ice and snow was melted) may have been reduced due to contact with cold rails, which would act as a heat-sink.

[22] Further information regarding other incidents of a similar nature are discussed in the RAIB's report into the near miss at Carstairs on 22 December 2009, RAIB report 02/2011, published January 2011.

Snow and ice ingress restricting the movement of the brake rigging

99 **Snow and ice build-up on brake rigging has the potential to restrict the movement of the brake cylinder, push-rod, slack adjuster and brake hangers and thus reduce partially or completely the load exerted by a brake block on a wheel tread surface. This could in turn reduce the braking force being generated by the block.**

100 It was not possible to determine exactly the extent to which the brake rigging of the FKA wagons on train 4N47 were covered by ice or snow. Very little of the rigging (other than the lower portion of the brake hangers) is visible when standing at the side of the vehicle and access underneath the wagons which had not derailed was restricted immediately following the accident by the deteriorating weather conditions and safety considerations. Although the rigging on some of the wagons which had derailed was visible, any ice or snow which might have been present would have probably been removed due to the impact following the derailment.

101 Testing on a comparable wagon demonstrated that an obstruction of the rigging at any one wheel on a bogie would not affect the application of the other brake blocks on that bogie. This means that for a widespread loss of braking to occur, blockages would have to have occurred either concurrently at multiple wheel locations or at a point which could have a common effect on all wheels on a bogie simultaneously (for example at the brake cylinder or cylinder transfer lever, as shown in figure 16).

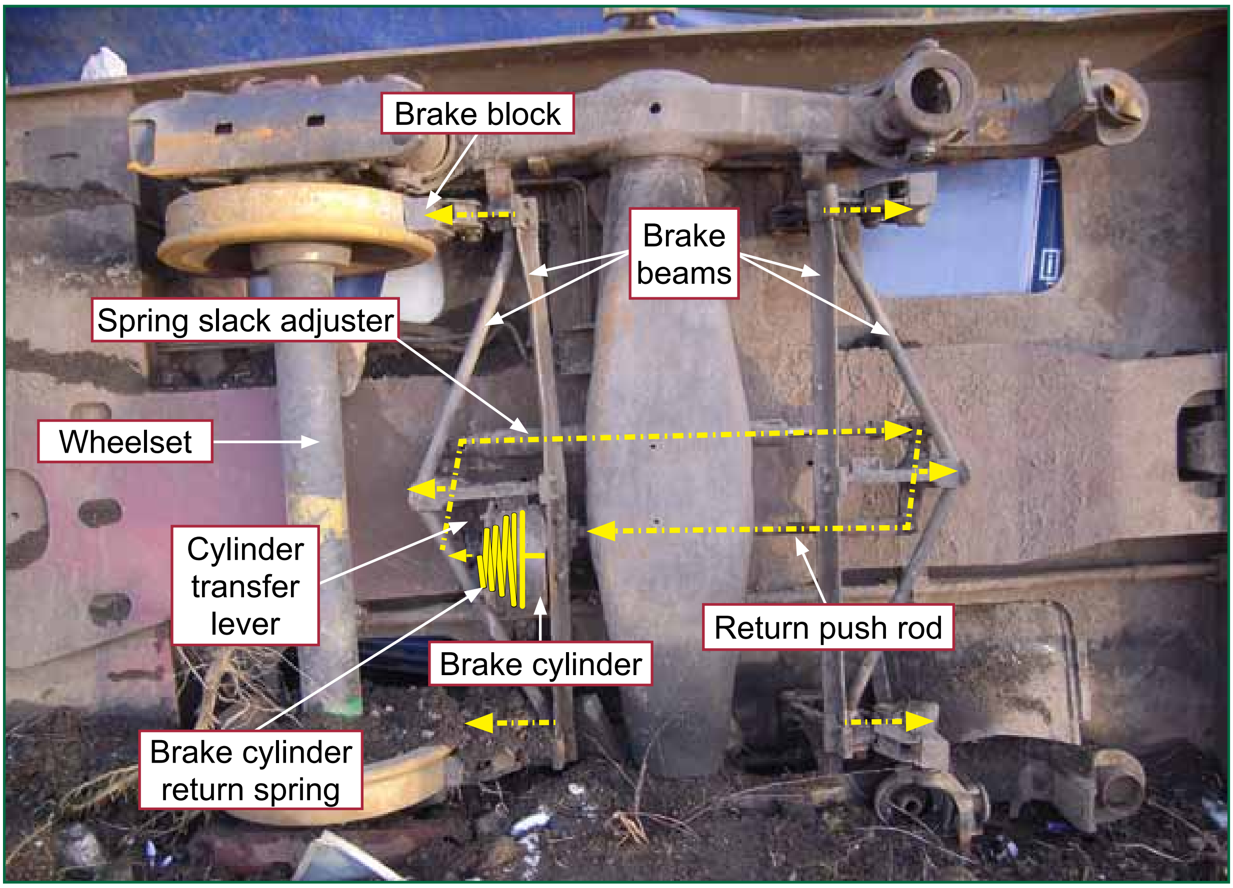

Figure 16: A photograph taken post-accident of the brake rigging of a derailed FKA wagon - note that the right-most wheelset is missing from this bogie. Direction of movement of the brake rigging and brake blocks on application are shown by the dotted yellow lines.

102 Around 24 hours after the accident, the brakes on the wagons which did not derail were tested. The brakes were found to have become jammed in the applied position and could only be released once an external force was applied. It was found that these wagons, which had been left standing in freezing conditions during this period, had ice and snow on their brake rigging. This ice and snow had stopped the rigging from moving and releasing the brakes.

103 When releasing from the applied position, the ice and snow in the rigging is only resisting the force of the brake cylinder return spring. This is considerably less than the force exerted by the pressurised air which is admitted into the brake cylinder when a brake application is commanded. This means that, whilst snow and ice was able to prevent the movement of the rigging with the brakes in the applied position, it does not necessarily follow that the brakes were able to become jammed in the same way in the released position during train 4N47's journey to Carrbridge.

104 During the final braking application, train 4N47's speed first started to reduce 18 seconds after the increase in braking from an initial application to close to full service was commanded by the driver (see paragraph 57). This was 10 seconds after the brake pipe had reached the 3.6 bar pressure resulting from this command. It is very likely that there was sufficient time by this point for the brake cylinders on the vehicles to have become pressurised to close to their maximum air pressures[23] and for the cylinders to be applying close to maximum force into the brake rigging. This is because the drop to 3.6 bar was not the first brake application made (ie the brake pipe pressure had already been partly lowered for the initial application) and because the train was operating in passenger brake timings.

105 The train's speed started to reduce one second after the locomotive's straight air brake was applied; it is not likely that this was a sufficiently long period for there to have been any connection between the two events. The train's speed also started to reduce before the driver operated the emergency brake plunger.

106 It is possible that speed started to reduce when it did because the increased level of force applied to the brake rigging by the climbing brake cylinder pressures was able to overcome any obstruction caused by snow and ice and thus apply a higher force to the brake blocks. It is also possible that the increased brake cylinder pressures in brake equipment unaffected by snow produced a rise in braking force that was sufficient to start retarding the train.

107 The pressure in the wagons' brake cylinders would have subsequently increased slightly to the maximum (full service) level as the brake pipe was vented to atmosphere, following the driver's use of the emergency brake plunger. As the brake cylinders were close to maximum pressure before this occurred, and given the rapid drop in pressure in the brake pipe which follows an emergency brake application, this increase would have taken place very quickly after the emergency brake plunger was used. Brake cylinder pressure would have been constant once at this maximum pressure[24].

[23] A brake pipe pressure of 3.6 bar would lead to a brake cylinder pressure in the connected vehicles of at least 93% of the maximum full service value.

[24] There is no significant increase in brake cylinder pressure when the brake pipe pressure drops from its maximum full service value (ie brake pipe at 3.35 bar) to its emergency pressure (ie brake pipe completely vented).

108 Although brake cylinder pressure would have remained constant from this point, there were subsequently to be significant increases in the mean retardation of the train, particularly in the latter stages of braking as the train approached 118 points at Carrbridge (see paragraph 85). This suggests that, although the increase in brake cylinder pressure may have been sufficient to have started retarding the train, the subsequent increases in braking forces were independent of it.

109 As was stated in paragraph 94, during friction braking, only a low percentage of the heat generated passes into the brake blocks themselves. This means that there was not an effective mechanism to conduct heat into the brake rigging from the wheels as they heated up. Photographs taken post-accident (see figures 13, 14 and 15) also show that snow and ice surrounded the brake block and brake head. This indicates that there was not sufficient heat radiated or convected from the wheel to have melted ice or snow from the rigging, which is located further away from the wheel than these components. This lack of a mechanism to input heat into the brake rigging suggests that, once the maximum brake cylinder pressure had been reached, the increase in retardation during the train's final brake application was probably not the result of further brake rigging movement being permitted by the melting of snow and ice.

110 As with snow and ice ingress at the friction face, the principal defence against snow and ice reducing brake rigging mobility is the undertaking of periodic running brake tests (see paragraph 134).

111 As a cause of reduced braking forces, the ingress of snow and ice into the brake rigging does not exclude snow and ice being present between the brake block and the wheel tread. In the case of train 4N47, it is probable that the reduction in braking forces was due to a combination of both causes.

Causes of snow and ice ingress

112 **The ingress of snow and ice between the brake blocks and wheel treads, and around the brake rigging, were both probably caused by the passage of train 4N47 between Inverness and Carrbridge ploughing into, and/or disturbing, lying or falling snow.**

113 **The ingress of ice or snow could have been caused by two mechanisms;**

a. direct contact between lying snow and components on the FKA wagons' bogies; and/or

b. the disturbance of lying snow by the passage of the train.

114 Although the snow and ice ingress which affected the brakes may have feasibly occurred prior to train 4N47's arrival at Inverness, there was no known issue with the braking of the train during the incoming journey[25] or, once it had arrived, any obvious evidence of snow or ice on the brake blocks or brake rigging during shunting or train preparation (see paragraph 42). Photographs of train 4H47 taken on arrival and of train 4N47 taken during shunting also show no obvious sign of ice or snow around braking equipment. The train underwent a successful brake continuity test at Inverness and stopped from 9 mph (14 km/h) on exiting the yard. This would indicate that any ice and snow ingress sufficient to cause a reduction in braking forces probably took place after the departure of train 4N47 from Inverness.

[25] The weather conditions in the area around Slochd summit during the incoming journey of 4H47 were similar, although a few degrees colder, to those present when 4N47 undertook the outbound journey some hours later.

115 It is unlikely that other environmental factors played a role in the ingress of ice or snow. Although it is possible that, given the exposed nature of some sections of the line on the ascent towards Slochd summit, wind alone could have disturbed lying snow, windspeeds during train preparation and on the journey were generally only gentle to fresh (see paragraph 15). The disturbance of lying snow by the wind has therefore been discounted as a casual factor.

Direct contact between lying snow and components on the FKA wagons' bogies

116 **It is possible that lying snow had accumulated to a level where it could have directly contacted the lower part of the axleboxes and suspension springs on the bogies of the FKA wagons which formed train 4N47. Such direct contact could have led to snow and ice being thrown up in between the brake blocks and wheel treads or around the brake rigging.**

117 Lying snow had been present on the line for several weeks prior to the accident (see paragraph 16). During this period the track was being cleared of snow by line proving locomotives, equipped with miniature snow ploughs (MSP). Prior to the derailment on 4 January, MSP equipped locomotives ran over the line between Inverness and Carrbridge several times, including one running over the line 45 minutes before the passage of 4N47 (see paragraph 47). The line was also being run-over by a variety of other freight and passenger stock types, including the passenger service running directly ahead of 4N47.

118 DB Schenker produced a diagram (see figure 17) which shows the combined 'ploughing' profile that the MSP equipped line proving locomotives and the other freight and passenger stock types running on the line would produce in lying snow. This shows that the combined 'ploughing' profile left snow lying close to the line. When compared to the profile of an FKA wagon, it could also be seen that the lower portion of the bogies' axleboxes and suspension springs were not covered by this combined 'ploughing' profile, meaning that they could potentially have run through lying snow.

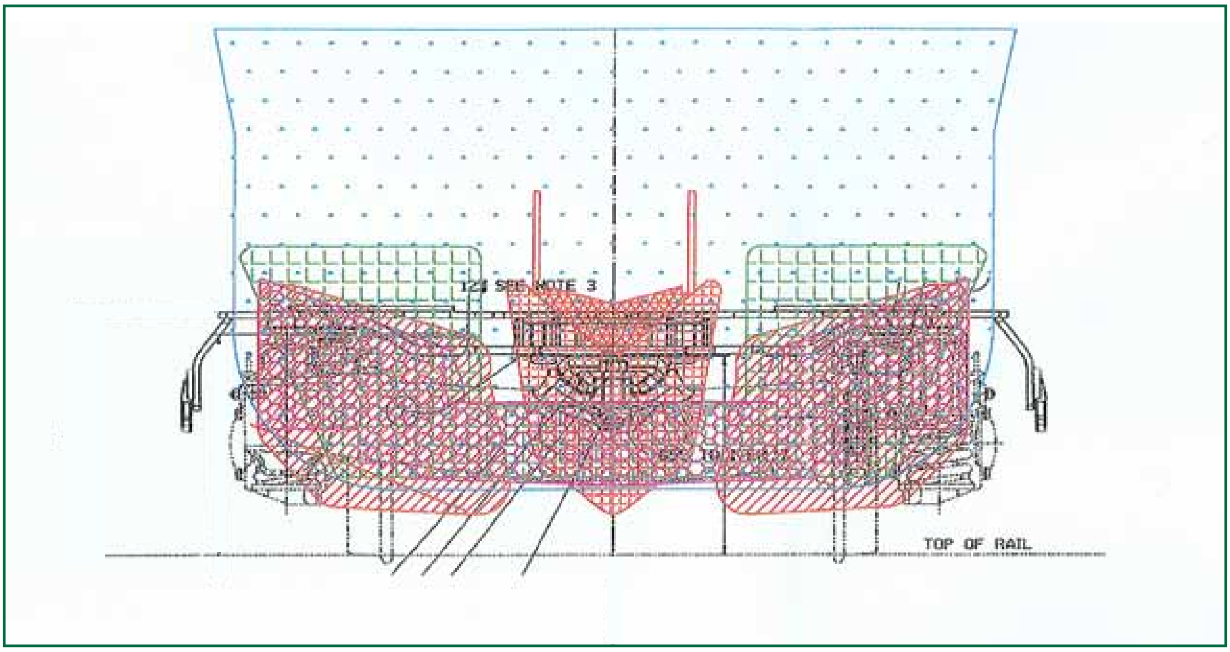

Figure 17: Profile of an FKA wagon element compared with the combined ploughing profiles of MSP-equipped stock and other trains running between Inverness and Carrbridge (coloured sections) (image courtesy of DB Schenker)

119 As these wagons had travelled over the same route in reverse only around six hours prior to the passage of train 4N47 any lying snow which could have been directly contacted by these components would have probably been pushed aside at this point. However, as snow was continuing to fall periodically throughout the day it is possible that, by the mid-afternoon, the lying snow had again reached a level where it could be contacted by components on the FKA wagons.

The disturbance of lying snow by the passage of the train

120 **Snow was being disturbed by the passage of trains, including train 4N47, on 4 January. It is probable that train 4N47 disturbed snow throughout its ascent towards Slochd summit and that this led to snow and ice ingress inbetween the brake blocks and wheel treads or around the brake rigging.**

121 The profile cut in lying snow by the passage of trains, including MSP equipped locomotives, had left snow close to the track. As clearance with MSP equipped locomotives had continued over a period of weeks by this date, there was a significant accumulation of snow lying near to the line where loose snow could be easily picked up by the passage of trains.

122 Lying snow being disturbed by the passage of trains and accumulating on bogie and brake components is understood, both in the UK and internationally, as having the potential to cause a reduction in braking effectiveness. This disturbance can take the form of a passing train throwing up loose snow flakes from the ground (sometimes described as ‘snow smoke’, see figure 18) or in snow which is coating the rail head being picked up by a train’s wheels. This can result in the wheels spraying out a snow-water mix as they roll and in an accumulation of wet snow around brake block edges. Falling snow can also form a coating on the braking equipment components on some types of rail vehicle.

Figure 18: A Class 66 locomotive and FKA wagons disturbing lying snow on 6 January 2010 (image courtesy of Trevor Roots)

123 A photograph taken of train 4N47 (see figure 19) on 4 January as it left the Culloden Viaduct clearly shows snow being disturbed by the passage of the train. At this point the train's speed was around 30 mph (48 km/h). During the ascent towards Slochd summit, the speed of train 4N47 only occasionally dipped below 25 mph (40 km/h), and reached a high point of 54 mph (87 km/h). It seems probable therefore that the train's speed was high enough to have generated a similar disturbance through much of the 39 minute-long ascent of the summit. The disturbance of lying snow by train 4N47, due to the speed at which it ascended Slochd summit, was therefore probably causal to the accident.

Figure 19: Train 4N47 exiting Culloden Viaduct on 4 January 2010 (image courtesy of Phillip Watt)

124 During the descent from Slochd summit the train's speed reached a high point of 69 mph (111 km/h). Although this would have led to further disturbance of lying snow, it is likely that the brakes had already been adversely affected by the ingress of snow by the start of the descent (see paragraph 144).

125 Witness evidence confirms that there was a light covering of snow on the rail head at some locations on the line between Inverness and Carrbridge. It is therefore also possible that the wheels of 4N47 were able to pick up snow and to spray it as a wet snow/ice mixture onto underframe components.

Discounted causes of reduced braking forces on train 4N47

126 **Analysis of evidence by the RAIB has shown that certain potential causes of reduced braking forces on train 4N47 can be discounted.**

127 There was no evidence during post-incident testing and examination of the train that braking components had failed on either the locomotive or the wagons. There was also no evidence that the maintenance or preparation of the train was causal to the accident.

128 There have been previous occurrences in the UK on other types of rail vehicle where control devices (eg wagon distributor releases, brake pipe cocks) have changed state due to an accumulation of snow or ice causing them to move. During post-incident examination and testing of the vehicles involved in the accident on 4 January, there was no evidence that a sufficient number of control devices could have changed state in this way to produce the loss of braking force seen prior to the derailment.

129 The presence of water in a braking system can form ice and the direct ingress of ice or snow into the system can also be considered. Either could result in blockages in locomotive brake pipe control units, train brake pipes, or wagon distributors, variable load control valves or variable load valves. In the case of train 4N47 this type of blockage was discounted as a possible cause for the following reasons:

- The train passed a successful brake continuity test at Inverness Millburn Yard immediately prior to departure, indicating that flow of air in the brake pipe was continuous to the end of the train.
- When the rear portion of the train (ie the four wagons which did not derail) was tested for brake continuity on the day following the accident there was no evidence of the presence of ice or snow in the brake pipe, despite the weather conditions having deteriorated following the accident.
- Once the train had left Inverness, brake pipe pressure remained higher than 4.5 bar until the final braking application on the approach to AC336 signal. This greatly limited the opportunity for the ingress of snow or ice via hose couplings.
- Throughout 4 January the air dryer was working within the range of environmental conditions for which it had been designed and there was evidence during post-incident examination and testing of the locomotive that water had not been carried-over through the air dryer into the braking system. Analysis following the accident concluded that the air dryer would have been producing air with a dew point at atmospheric pressure which was close to the ambient air temperatures present. This meant that relatively little moisture would have been produced when the brake pipe pressure was vented to atmosphere[26].
- There was no evidence that air system water drain valves on either the locomotive or wagons had malfunctioned due to ice or snow.
- Had the air systems on the locomotive been frozen then this would have meant a complete loss of functionality of its own braking system. Data from the OTDR shows that the braking system on the locomotive was functioning at least to the degree that air pressure was entering the locomotive's brake cylinders and that the brake pipe control unit pressure was being varied.

[26] Independent of the action of the air dryer, the higher air pressure present when the brake pipe was pressurised would also have prevented any precipitation of water.

- The wagons were loaded with empty containers. Their gross laden weight of around 57 tonnes remained closer to the specified tare weight of 48 tonnes than to the specified part-laden weight of 112 tonnes. This would limit the effect of any reduction in brake force which could have potentially been caused by ice or snow affecting the operation of variable load control valves or variable load valves.
- There have been relatively few recorded incidents both in the UK and in other railway systems where cold weather conditions are present, where ice or snow blockages in the brake pipe have been in evidence. Those which have occurred have taken place on other types of rolling stock to those involved in the derailment at Carrbridge and have taken place during weather colder than that found on 4 January 2010.

130 Research conducted by British Rail in 1987[27] found that windchill was not a significant factor in decreasing the surface temperature of rolling stock below ambient. This research determined that approximately 2 ºC would be the maximum reduction found and that any effect dropped off rapidly below freezing. For this reason windchill has been discounted as a casual factor.

The driver of train 4N47 did not have a correct understanding of the braking forces available to the train

131 **The driver of train 4N47 on 4 January was unaware that the brake forces available to the train were significantly reduced. Had he been able to detect the reduction he could possibly have taken action, such as applying his brakes earlier on the descent, which would have prevented the train from passing signal AC336 at danger.**

132 A driver would normally establish an understanding of the brake forces available to them from a variety of sources including:

- the undertaking of a running brake test whilst the train is moving;
- the train document produced by TOPS, which will confirm (for freight services) that there is sufficient equivalent brake force available for the weight of the train;
- the undertaking of a brake continuity test before departure, which will confirm that braking is continuous to the rear of the train;
- their training and experience of the rolling stock which form their train;
- their route knowledge of the line over which the train is to travel eg its topography, the location of signals at risk of being overrun, and any points known to suffer with low-adhesion; and
- their training and experience relating to the environmental conditions relevant to his journey.

[27] P. J. Williams, *Windchill and Air Minimum Temperatures in Great Britain*, Scientific Services Branch, BR Research Division, October 1987

133 Drivers are required by the Rule Book[28] to undertake a running brake test at the first opportunity after beginning a journey in order to confirm that the brakes are operating effectively and that the speed of the train is being reduced. The effectiveness of the brakes may vary due to factors such as train length and weight, the type of braking systems in use, their state of repair and the level of wheel-rail adhesion present.

134 In certain cases a driver, having undertaken a running brake test after beginning a journey, may need to make further such tests during a journey. Module TW3 of the Rule Book[29], for example, requires that drivers if possible undertake a running brake test before approaching a steep-falling gradient. In addition, when a train is travelling in conditions where snow is falling or being disturbed by the passage of trains Module TW1[30] of the Rule Book requires drivers to ensure that additional running brake tests are undertaken every 3 to 5 minutes. The module requires that these 'snow' running brake tests:

- should be a full service brake application; and
- should result in a retardation of train speed of at least 10 mph (16 km/h).

135 Module TW1 allows drivers of locomotive-hauled trains such as 4N47 the discretion to extend the interval between running brake tests where they are on steep upwards gradients if the train may be brought to a stand by the application of the brakes.

136 The intent of the requirement to conduct frequent running brake tests in snow is to both test the brakes to ensure that they have not been rendered ineffective by snow (detection) and to work the brakes frequently in order to avoid the ingress of snow and ice affecting their function (prevention).

137 DB Schenker's internal publication 'Working with low adhesion' states that:

> *'Certain weather conditions are particularly challenging to drive in such as … frost/ice. Take into [account] the prevailing weather when operating power or brake control… weather conditions vary from location to location and can be dependant on elevation…If operating in falling or disturbed snow remember the specific running brake test instructions. When braking you must also take into account the train weight and formation…Your interpretation of your running brake test is vital when making your judgement on the effectiveness of your train brake'.*

138 'Working with low adhesion' was briefed to DB Schenker drivers in the autumn of 2008, with reminder posters being distributed during 2009.

139 Following the incident at Carstairs on 22 December 2009, DB Schenker issued Traction Digest 174 which reminded drivers of the requirements of Module TW1 in respect of undertaking running brake tests in snow. This was not issued to drivers on an individual basis but was posted into the *late notice case* at depots; in the case of Inverness Millburn Yard it was posted on 31 December 2009. In addition to this notice, DB Schenker also asked its controllers to remind drivers of the need to conduct these tests.

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[28] Railway Group Standard GE/RT8000 Rule Book, Module TW3 *Preparation and movement of locomotive-hauled trains*.

[29] Railway Group Standard GE/RT8000 Rule Book, Module TW3 *Preparation and movement of locomotive-hauled trains*.

[30] Railway Group Standard GE/RT8000 Rule Book, Module TW1 *Preparation and movement of trains*.

The driver of train 4N47's application of running brake tests not detecting the loss of brake force

140 **Had the driver detected a loss of braking sufficiently early in the descent, it is likely that he would have made a brake application at this point to try to slow or stop the train. Had the train achieved a similar mean average retardation as was achieved on the approach to AC336R then the train would have been able to stop prior to entering the run-out and the derailment would have been avoided.**

141 Once the train started its ascent towards Slochd summit on 4 January 2010, the driver of train 4N47 did not make any snow running brake tests which met the requirements of Module TW1 (see paragraphs 48 to 52). This was because the driver was concerned that making a running brake test of this type would bring the train to a stand during the ascent, where the topography lacked a suitably long portion of descending or level gradient in which to make such an application. As was discussed in paragraph 135, Module TW1 allows drivers the discretion to extend the interval between running brake tests in these circumstances.

142 The driver was aware that one of the purposes of the running brake test in snow was to prevent ingress of snow and ice from causing the brakes to become ineffective. For this reason, although the driver did not want to make a full service brake application during the ascent, he instead made several initial applications of the automatic brake with the throttle set high in order to generate heat in the brakes and to melt any ice or snow which may be present. There were long intervals between some of these initial applications, including one of 28 minutes between the train brakes being released after it had come to a stand outside Inverness and the brake application made on the approach to Culloden Moor.

143 The driver was also aware that the running brake test in snow was intended to detect a loss of braking forces. As was described in paragraph 50, the driver thought that he had retarded the train successfully just before reaching the summit; it was this and other incorrectly perceived retardations during the ascent that gave him confidence that he had no loss of available braking force.

144 Having reached the summit, and with the train starting the descent towards Carrbridge, the driver made a further initial application of the automatic brake, this time with the throttle closed (see paragraph 53). This application was again made with the intent of heating up the brake equipment. Although the train speed increased during this application, the driver was not concerned by this, as he felt that the brakes had been proven to be working correctly on the ascent. Given that this braking application occurred only around 2½ minutes prior to that made on the approach to AC336R signal, it is probable that the braking forces available to the train had already been adversely affected at this point.

145 Had the driver detected a loss of braking at this point on the descent, he would probably have decided to apply the train's brakes in order to slow or stop the train. Had the train then attained a similar mean average retardation as it actually achieved on the approach to AC336R, then it would have been able to stop before entering the run-out and the derailment would have been avoided. The driver's application of running brake tests not detecting the loss of brake force was therefore a casual factor in the derailment.

146 There is no evidence to suggest that there was any deficiency in the driver's training, or his knowledge and experience of the train and the route between Inverness and Carrbridge. These have therefore been discounted as causal factors.

Identification of contributory factors[31]

147 A reduction in the coefficient of friction of composition brake block material may have contributed to the derailment of train 4N47.

A reduction in the coefficient of friction of composition brake block material

148 The coefficient of friction of brake blocks made of composition material is not constant and will vary with the force applied to the block, the speed and temperature of the wheel tread and the temperature of the brake block material, with the coefficient of friction reducing very slightly when the blocks are cold. Whilst the blocks will quickly heat up and recover this loss once applied, it is possible, although unlikely, that the cold weather on 4 January reduced slightly the effectiveness of train 4N47's brakes via this mechanism.

149 Research by British Rail in 1994[32] determined that brake pads made of composition material may absorb water in certain circumstances. This water absorption is caused by applying the brake pad to a brake disc which is wet due to ice and snow ingress but doing so in a way (ie repeated light brake applications) that does not generate sufficient friction (and therefore heat) to purge the disc's surface or the brake pad material of water. Having absorbed the water instead of removing it, the pad material then has a reduced coefficient of friction on its next application, thus reducing braking effectiveness.

150 Whilst this research applied to rolling stock equipped with brake pads and discs and not that equipped with brake blocks (as with train 4N47), it is possible that the repeated initial brake applications made on the journey between Inverness and Carrbridge may have led to water being absorbed into the brake blocks, thus reducing their coefficient friction and capacity to retard the wheels.

Identification of underlying causes[33]

Effectiveness of the running brake test requirements of Module TW1

151 The existing requirements contained in Module TW1 for running brake tests to be undertaken in snow (see paragraph 134) are neither an effective detection of loss of braking force in snowy conditions nor an effective preventative measure against the ingress of snow and ice into brake equipment when trains are traversing steep gradients.

[31] Any condition, event or behaviour that affected or sustained the occurrence, or exacerbated the outcome. Eliminating one or more of these factors would not have prevented the occurrence but their presence made it more likely, or changed the outcome.

[32] A.C. Wayte, *Braking Under Winter Conditions*, British Rail Research, January 1994

[33] Any factors associated with the overall management systems, organisational arrangements or the regulatory structure.

152 The current requirements of Module TW1 allow the interval between running brake tests to be extended on locomotive-hauled trains when they are ascending steep gradients at the driver's discretion, in order to prevent trains being brought to a stand (see paragraph 135). This is necessary as, once a freight train has stopped on a steep ascending gradient, the train can take considerable time, and sometimes require assistance from another locomotive, before it is able to restart, potentially causing disruption to the running of the railway.

153 Witness evidence indicates that some drivers will, for this reason, use their discretion to increase the interval between running brake tests in snow substantially or indefinitely. The interval used will ultimately rely on the driver's judgement of factors including the length and weight of the train, and the steepness of the gradient.

154 Some drivers, also in order to prevent their trains coming to a stand on ascending gradients, will undertake a running brake test in snow by making a brief initial brake application which is released as soon as any retardation is felt. Depending on the length of the brake application made, this form of test may not prove that a train's brakes are functioning throughout the length of the train and could potentially lead to water being absorbed into braking equipment friction components (see paragraph 149).

155 This means that, whilst the Rule Book requires drivers to undertake a running brake test before descending a steep-falling gradient if possible (see paragraph 133), locomotive-hauled trains may be undergoing irregular running brake tests during snowy conditions whilst ascending steep gradients.

Incident on 25 February 2010

156 On 25 February 2010 train 4H47 also suffered a loss of braking, this time when ascending towards the Slochd summit in the opposite direction to that of train 4N47 during the accident on 4 January (paragraphs 68 to 70). Analysis of the OTDR from this train shows that the driver on this occasion made regular running brake tests using full service brake applications at a maximum interval of 6 minutes during the ascent of Slochd. The train's speed reduced during each of these running brake tests. During the ascent the driver was also making initial applications of the automatic brake under full throttle (as occurred on 4 January) between some of these running brake tests.

157 Once the train had reached the summit and started to descend towards Inverness, the driver tried to bring the train to a stop from 35 mph (56 km/h) in order to comply with a recent Special Operating Advice issued by his company (see paragraph 221). This brake application took place at just over half the speed of that made by train 4N47 on 4 January immediately prior to the derailment. During this brake application, which included both an emergency brake application and the use of the locomotive's straight air brake, the train was able to achieve a mean retardation of around 0.5 %g. The train was at that time on a 1 in 60 descending slope; mean retardation would have been around 2.1 %g if the effect of this gradient is removed.

158 As discussed in paragraph 84, Railway Group Standard GM/RT 2043[34] requires the minimum average mean retardation of the train to be approximately 4.6 %g The retardation achieved by train 4H47 on 25 February was just under half of this minimum and what was produced was again almost entirely overcome by the effect of gradient. The driver had no previous indication of a loss of brake force and felt that he had been successfully retarding his train during the immediately preceding ascent.

159 The likely reason for this failure to prevent or detect loss of braking force is that the retardation of the train on the ascent was partially or entirely due to the effect of gravity and not to the braking force produced by the train. This meant that there was reduced heat generated in the wheels available to melt ice or snow and also that the driver was incorrectly interpreting the retardations achieved as a sign that the brakes were working correctly.

160 This incident suggests that, when undertaken on steep climbing gradients, running brake tests in snow made regularly with full service brake applications will not always detect a loss of braking effectiveness, nor prevent such a loss from occurring.

161 Following the incident on 25 February, DB Schenker diverted subsequent trains formed of FKA wagons from the Highland Main Line to an alternative route which avoided steep gradients. This diversion was put in place based on an assessment by DB Schenker of the depth and position of snow lying on or near the line, the forecast weather and the temperature. The diversion remained in place until 15 March 2010.

162 The limitations of the running brake test in snow in respect of steep gradients were already recognised within the rail industry prior to the accident at Carrbridge on 4 January. Certain types of disc-braked passenger rolling stock had been specified as being potentially vulnerable to snow ingress, and were already required by Network Rail's Scotland Route Sectional Appendix to stop by making a full service brake application on the approach at designated locations[35], including Slochd summit (see paragraph 32).

163 Following the derailment of train 4N47, DB Schenker and the wider rail freight industry issued further procedures and guidance relating to the operation of services in winter conditions (see paragraphs 221 and 224 respectively).

The design of the FKA wagon braking system

164 **It cannot be clearly determined if wagons with a 1Bg braking arrangement are more or less vulnerable to the ingress of snow and ice relative to other common arrangements of wagon brake blocks.**

165 FKA wagons have a 1Bg braking arrangement (see paragraph 24). This applies a brake block to only one side of the wheel. In contrast, 'clasp' type arrangements, such as the 2Bg and 2Bgu (see figure 20), where brake blocks are applied to both sides of the wheel, may have more redundancy when dealing with the ingress of snow and ice. This is because if one side becomes affected by snow and ice ingress, then the other side may remain clear.

[34] Railway Group Standard GM/RT 2043 Issue 1 *Braking System and Performance for Freight Trains*.

[35] Other locations in Scotland with similar requirements include the Beattock and Druimuachdar summits.

166 The 1Bgu, 2Bg and 2Bgu type block arrangements also have a larger brake block face surface area than the 1Bg arrangement and so may require a greater degree of snow ingress to reduce their effectiveness. The 2Bg and 2Bgu arrangements additionally also have twice the number of brake block edges available to pivot and apply to the wheel if the lower portions of the blocks are prevented from moving towards the wheel tread by an obstruction.

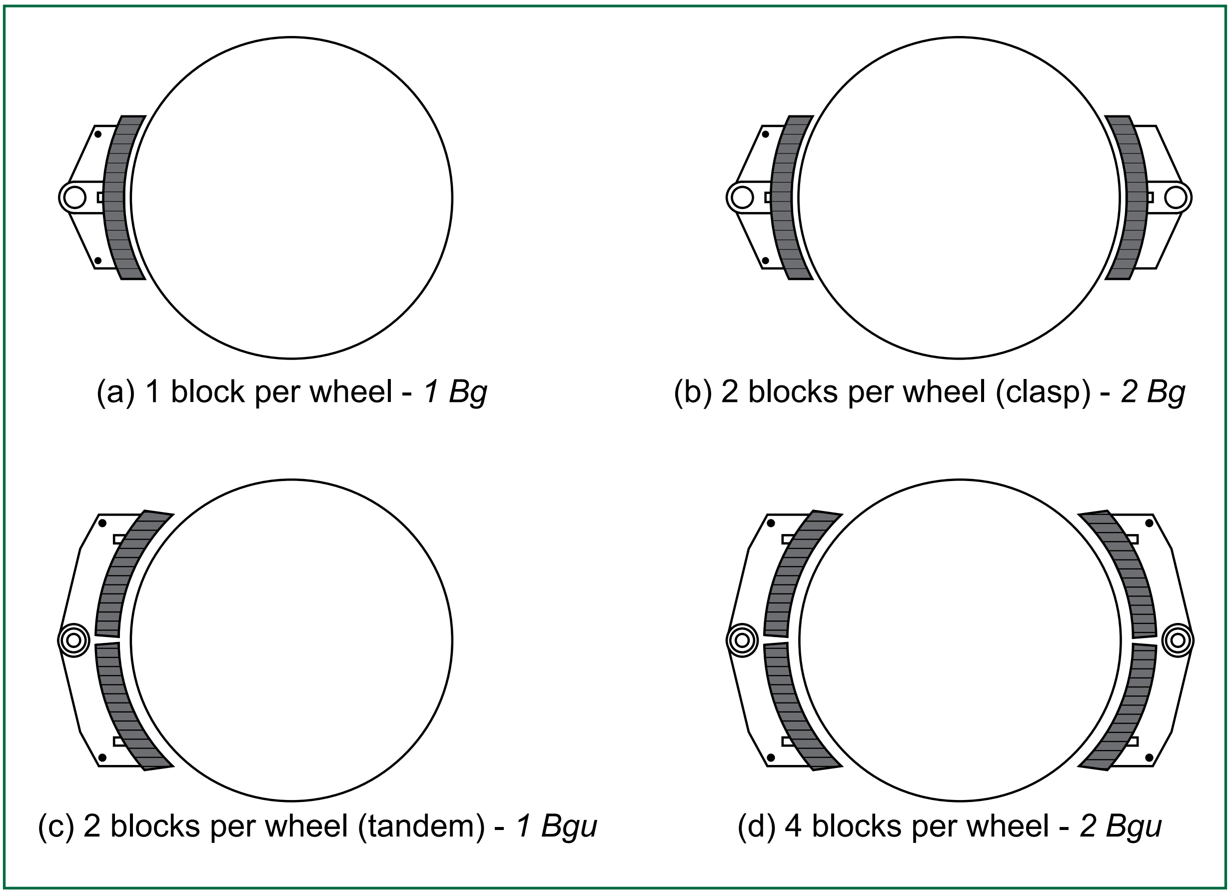

Figure 20: Four common arrangements of brake blocks. Blocks can be used in either a clasp or tandem arrangement

167 The 1Bg braking arrangement may however have certain advantages compared to other arrangements when used in ice and snow. Assuming that the overall force applied by the brake rigging in each arrangement is similar, the pressure exerted by a single brake block would be higher than in the other arrangements. Whilst increased pressure will not result in greater brake forces being generated in dry conditions, greater block pressure more effectively purges water (such as that resulting from the melting of ice and snow) from the tread surface and so may improve overall braking effectiveness.

168 Vehicles with a 1Bg braking arrangement may also have a simpler design of brake rigging equipment than those using other arrangements. This may make them relatively less vulnerable to blockages in the brake rigging due to snow and ice ingress.

169 In summary, when compared to other common arrangements of wagon brake blocks, the 1Bg braking arrangement has both potential disadvantages and advantages when exposed to ice and snow. For this reason, it cannot be clearly established by the RAIB if the design of the braking system of the FKA wagon was an underlying cause of the accident or not.

Network Rail's understanding of the risks presented by the prolonged use of miniature snow ploughs

170 **Network Rail did not recognise the risk that the prolonged use of miniature snow ploughs might leave an accumulation of snow lying near the line. Had they done so, then it is possible that this may have made trains less likely to have had ice and snow ingress in their braking equipment.**

171 The use of trains equipped with miniature snow ploughs is covered by Module M4 of the Rule Book[36]. This states that once lying snow has reached a depth that is between 200 to 300 mm above rail height then rolling stock equipped with miniature snow ploughs may run normally. They may, if authorised, continue to run if snow depths increase to between 300 to 450 mm above rail height. The intent of this rule is to allow rolling stock equipped with miniature snow ploughs (such as line proving locomotives) to clear the line of snow depths up to 450 mm above rail height.

172 In Scotland, the requirements of Module M4 are supplemented by Network Rail's Scotland winter working arrangements[37]. These also state that rolling stock equipped with miniature snow ploughs can be used to clear the line of snow up to 450 mm above rail height.

173 As is described in paragraph 120, by 4 January 2010 the continued use over a period of weeks of locomotives equipped with miniature snow ploughs to clear the line had left an accumulation of snow lying near the line where it was at risk of being ploughed into by some trains or of being disturbed by their passage. The use of line proving locomotives equipped with miniature snow ploughs over this prolonged period was, however, compliant to both the requirements of Module M4 and Network Rail's Scotland winter working arrangements.

174 It is possible that, had Network Rail recognised the potential risk of leaving an accumulation of lying snow near to the line, then the Scotland winter working arrangements could have included a warning or prompt to mitigate this risk. This may have resulted in the use of alternative snow clearance resources on the Highland Main Line (such as an independent snow plough, one of which was available on-call at Inverness) which could have pushed the snow further away from the line and thus reduced the risk of the ingress of ice and snow into train braking equipment.

175 The lack of recognition of the risks of the prolonged use of miniature snow ploughs within the Scotland winter working arrangements document is therefore possibly an underlying factor to the derailment.

Discounted underlying causes

176 **Analysis of evidence by the RAIB has shown that certain potential causes of reduced braking forces on train 4N47 can be discounted.**

Applicability of the speed restrictions in snowy conditions within Module TW1

177 **The speed restriction rules within Module TW1 did not require train 4N47 to reduce its speed by 10 mph below that permitted when snow was falling or being disturbed by the passage of trains. However this was not an underlying cause to the accident.**

[36] Railway Group Standard GE/RT8000 Rule Book, Module M4, *Floods and snow.*

[37] Network Rail, *Scotland Route Winter Working Arrangements November 2009 - April 2010*, published 2009.

178 Where snow is falling or being disturbed by the passage of trains, Module TW1 contains a requirement for certain trains to reduce speed. The module states:

'If you are working a train permitted to run at more than 100 mph, you must make sure that the speed of the train does not exceed 100 mph, or is restricted to 10 mph below the permitted speed for the train concerned over each portion of the line, whichever is lower. However, you do not need to reduce the speed below 50 mph'.

179 The wording of Module TW1 is such that trains not normally permitted to run at more than 100 mph (160 km/h), such as train 4N47, are not required to reduce speed in snowy conditions, even though they may equally be affected by the disturbance of snow.

180 The speed of the train during the ascent to the Slochd summit has been identified as a causal factor to the accident (see paragraph 123). Once train 4N47 had started its ascent of Slochd Summit, its speed was at least 10 mph (16 km/h) below the maximum permitted line speed until it reached the summit. This means that during the ascent, any requirement of Module TW1 to reduce train speed by 10 mph would not have had any effect in reducing snow and ice ingress or have caused the train's driver to have applied the brakes and thus possibly have detected the reduction in brake force which had occurred.

181 During the train's descent from the Slochd Summit towards Carrbridge, the speed of train 4N47 was also at least 10 mph (16 km/h) below the maximum permitted line speed until just prior to the approach to AC336R signal. This means that any requirement of Module TW1 to reduce train speed by 10 mph below line speed would not have reduced snow and ice ingress during the ascent or have caused the driver to have applied the brakes earlier in the descent.

182 At the point where the train braked on the approach to AC336R signal its speed of 67 mph (107 km/h) was 8 mph (13 km/h) below the maximum permitted line speed. In the opinion of the RAIB a further reduction of 2 mph (3 km/h) in the train speed (to produce the 10 mph reduction required by Module TW1 in snowy conditions) would not have avoided the accident or reduced the severity of its consequences.

183 For this reason the application of the snow speed restriction rules within Module TW1 not requiring train 4N47 to reduce speed has been discounted as an underlying factor to the accident.

Certification of the FKA wagons

184 **As was described in paragraph 25, evidence was provided by the wagon manufacturer to a vehicle acceptance body (VAB) during the engineering acceptance of the FKA wagons that their braking system would continue to operate in environmental conditions worse than those encountered by train 4N47 on 4 January 2010. However the certification of the wagons was not an underlying factor to the derailment.**

185 Evidence submitted detailed the results of the on-track testing of individual wagons, the cyclic testing of the brake rigging, the testing of the brake blocks and the approval status and previous successful use of the distributor. In terms of performance in snowy and icy conditions, the previous successful operation of similar brake rigging designs in North America was taken as evidence of performance in a comparable environment which would support a conclusion that the braking system would not encounter problems when used in similar conditions in the UK.

186 The RAIB has not identified any omission in the certification process on the part of the VAB which could have prevented the accident on 4 January from occurring. The certification of the wagons has therefore been discounted as a possible underlying factor to the accident.

Other factors for consideration

The risks presented by the use of trap-points at Carrbridge station loop

187 The derailment on 4 January destroyed the loop, trap points and run-out at Carrbridge station. All were restored to operational use by Network Rail following the accident (see figure 21).

188 As described in paragraph 33, the run-out at Carrbridge station at the time of the accident was 27 metres long. A train braking on entering it would have been able to stop within this length only if its speed was no higher than around 11 mph[38] (17 km/h). If a train was unable to stop before reaching the end of the run-out and derailing, then it would descend an embankment and be directed into a copse of trees lying to the east of the line. It was these trees that arrested the forward travel of train 4N47[39]. Adjacent to this copse is a residential property and beyond it lies the access road to the station.

189 The trap-points and run-out appear to have been fitted at Carrbridge station as a result of a fatal accident in March 1940. This involved a freight train dividing at the top of the Slochd summit following which the rear portion ran away down the gradient. This rear portion subsequently collided with a second freight service around 2 miles north of Aviemore, killing its driver and fireman. The report into the accident[40] stated that the railway company which owned the line[41] intended to fit electrically operated catch points '…*sufficiently far north of Carrbridge station to ensure that any derailment effected by them would not involve risk to the users of the public roadway immediately north of the station'.*

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[38] Assuming the train was braking in order to produce a mean retardation of 4.5%g.

[39] Some of the trees originally lying in the direct path of a derailing train were cut down during post-accident recovery.

[40] Ministry of Transport, *Report into accident which occurred at about 8.36 p.m. on the 5th March 1940, between Aviemore and Carrbridge Stations*, August 1940, available from http://www.railwaysarchive.co.uk/documents/MoT_Aviemore1940.pdf

[41] In 1940 the owner and operator of the railway was the London Midland and Scottish Railway.

190 Four houses are located east of the loop at Carrbridge station (see figure 2). Three of these houses were formerly railway properties built around the time of the construction and opening of the railway in 1898. A fourth house was built in the early 2000's[42]. Some of these houses lie close to the potential path of a train derailing from the run-out at Carrbridge. Derailed wagons and containers from 4N47 came to rest within the gardens of two of them, including the newest property, on 4 January 2010.

191 The rail industry's own formal investigation into the derailment found that, given the speed of train 4N47 when it passed over 116 points, the *drag length* required to stop a train following a similar derailment occurring would be approximately 600 metres. In the opinion of Network Rail, topography and landscape meant that such a drag length could not be achieved in practice.

Figure 21: The run-out at 116 points as restored post-accident (image courtesy of Peter Carson).

The assessment of risk at signal AC336 prior to 4 January 2010

192 Railway Group Standard GI/RT 7006[43] lays down requirements for the design and operational use of track and signalling equipment to be reviewed in order to control the risks associated with a train exceeding the end of its movement authority (such as when passing a signal at danger). This is known an assessment of *overrun* risk.

[42] The then operators of the railway, British Rail, were informed of the planned construction of the newest house in the mid-1990's. They raised no objection to construction of a house in this location.

[43] Railway Group Standard GI/RT 7006 Issue 1 *Prevention and Mitigation of Overruns – Risk Assessment*.

193 Guidance for assessing overrun risk is contained within Railway Group Guidance Note GI/GN 7606[44]. This states that, where trap points are mandated then they may not alone provide a sufficient control of overrun risk and that their use must be considered within the broader risk assessment process required under Railway Group Standard GI/RT 7006. When considering the use of trap points, GI/GN 7606 refers to criteria for their use contained within Railway Group Standard GK/RT 0064[45].

194 Railway Group Standard GK/RT 0064 states that trap points may be used as a risk reduction measure at the convergence of two running lines only if other risk reduction measures are not sufficient to control the risk and if the secondary risks of using trap points have been assessed as acceptably low. Secondary risks detailed in the standard are vehicles failing to remain upright or fouling other lines and the presence of deceleration rates that could cause injury to the occupants of a train which derails. The standard also mandates that trap points must guide derailing vehicles away from other lines, structures and any other hazards and that they must include a suitable arresting device (such as a sand-drag) if this is required to stop a derailing train safely.

195 The trap points in use at Carrbridge station loop do not meet many of the requirements of the group standards and guidance notes described. Vehicles derailing at anything other than very low speed will descend an embankment and will probably not remain upright. Also, if their forward travel is arrested by the trees (as with train 4N47) the subsequent deceleration rates may well cause injury to a train's occupants. In addition, the points do not direct a derailing train away from hazards (eg the trees).

196 These requirements however apply only to layouts of track and signalling being brought into service after the December 2000 issue date of the standards. For 'existing' layouts (ie those pre-dating the standard) where a signal protects a junction (such as AC336 at Carrbridge) the standard requires that:

'…A review of overrun risk…shall be conducted at least once by October 2005'.

197 Prior to the derailment on 4 January 2010, signal AC336 had been passed at danger on three previous occasions, the last previous occasion being on 28 October 2005. During the first recorded *Signal Passed at Danger* (SPAD) in January 1994, the passenger train involved (a Class 158 DMU) over-shot the end of the run-out by a few feet and derailed at very slow speed. It remained upright following the derailment.

198 Network Rail issued its own internal standard, NR/L2/SIG/14201[46], to specify how it will meet the requirements of GI/RT 7006. NR/L2/SIG/14201 also mandates that all signals that protect junctions, such as AC336, are subject to an overrun risk assessment. It additionally requires that the overrun risk at *multi-SPAD signals* (ie a signal which has been passed at danger two or more times in the previous five years) or any signal which has had more than three SPADs since 1985 is assessed using a process known as *detailed assessment* (DA).

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[44] Railway Group Guidance Note GI/GN 7606 Issue 1 *Guidance Note: Prevention and Mitigation of Overruns – Risk Assessment*.

[45] Railway Group Standard GK/RT 0064 Issue 1 *Provision of Overlaps, Flank Protection and Trapping*.

[46] Network Rail Standard NR/L2/SIG/14201 Issue 2 *Prevention and Mitigation of Overruns – Risk Assessment at Signals*.

199 DA is a qualitative risk assessment process which uses the judgement of experts within a formal workshop to develop an understanding of risks presented by an overrunning train at a particular signal. The DA workshop is able to consider potential secondary consequences (such as the risks presented by the use of trap points) and will consider if the risk presented by the overrun of a particular signal has been reduced so far as is reasonably practicable. The workshop will produce a report for further consideration within Network Rail detailing the risks and any mitigation options identified.

200 Signals, including those which protect junctions, are normally only subjected to DA if they are scored above a specified limit when initially assessed using a simplified quantitative risk assessment method known as the *signal assessment tool* (SAT). Signals which have multi-SPAD status, or three SPADs since 1985, are required by NR/L2/SIG/14201 to undergo a DA review regardless of their SAT score.

201 In April 2003 Network Rail issued a 'Certificate of Authorisation of Non-Compliance' which authorised their staff on a national basis not to automatically undertake DA of any signal which has had more than three SPADs since 1985. Any such signal still scoring a sufficiently high score on SAT would still be taken to DA, in the same manner as other signals, and provision was made for DA to be undertaken if there were any expressions of concern from within the railway industry about a signal. The requirement to automatically undertake DA for multi-SPAD signals was not altered by this certificate of authorisation.

202 This certificate of authorisation was granted because Network Rail judged that the time commitment for staff needed to DA all signals with three or more SPADs since 1985 was too high. Network Rail stated that any residual risk would be mitigated by the ongoing requirement for all signals with a high SAT score to be progressed to DA.

203 In summary, as a signal protecting a junction, signal AC336 was required by both Railway Group Standards and Network Rail's own standards to have its overrun risk reviewed. In addition, as a signal which has had more than three SPADs since 1985, Network Rail's own standard initially required this risk assessment to automatically take the form of a DA, although this specific requirement was later superseded and an assessment using DA would subsequently only be called for if the SAT score was sufficiently high.

204 Signal AC336 did not have its overrun risk assessed in any format prior to the derailment on 4 January 2010. Because of the certificate of authorisation granted by Network Rail (see paragraph 201) such an assessment would have involved only the use of SAT and would not have used the DA methodology. A post-accident assessment of the signal using SAT gave the signal an extremely low risk score (see paragraph 208) and it is likely that a similar assessment prior to the accident would have resulted in the same finding.

205 As the score achieved was too low to lead to the signal being assessed using the DA methodology, and as SAT is not capable of assessing the risks of a derailment due to the use of trap points (see paragraph 208), it is very unlikely that, had a SAT assessment been conducted prior to the accident, that this would have led to any action being taken which might have avoided the derailment. For this reason the absence of an assessment of overrun risk at signal AC336 prior to 4 January 2010 is not a casual or underlying factor to the accident.

The assessment of risk at signal AC336 following the accident of 4 January 2010

206 The derailment on 4 January 2010 was the second time that signal AC336 had been passed at danger within five years. Because of this, it was designated by Network Rail as a multi-SPAD signal following the accident. As such NR/L2/SIG/14201 requires it to automatically undergo an assessment of overrun risk using the DA method, regardless of its SAT score (see paragraph 201).

207 NR/L2/SIG/14201 is supported by Network Rail guidance note NR/GN/SIG/14202[47]. This gives non-mandatory guidance to Network Rail staff concerning the prevention and mitigation of overruns at signals. This guidance states that;

> '*There is a legal obligation under the Health and Safety at Work Act…for Network Rail to carry out risk assessments. Potential hazards need to be identified and consideration given to their removal whenever possible or to the application of control measures that will reduce risks to a level that is as low as is reasonably practicable. This applies to current operations (Existing Layouts)…*'

208 In December 2010, Network Rail undertook a SAT assessment of signal AC336. This resulted in a risk score of 2, which represents a very low assessed risk[48]. However an assessment using SAT is, and is intended to be, a simplified process. It considers only the risks caused by a train overrunning a signal and colliding with another train in the section ahead or another train at a junction or a vehicle on a public level crossing. Although it calculates a risk connected to the possible derailment of a train following a collision caused by an overrun, it does not consider the risk of a derailment on trap points[49].

209 Network Rail has not at the time of writing (February 2011) undertaken an assessment of overrun risk of signal AC336 using the DA method, as is required by NR/L2/SIG/14201. It has stated to the RAIB that its intention is to undertake such an assessment before the end of February 2011.

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[47] Network Rail Standard NR/GN/SIG/14202 Issue 2 *Prevention and Mitigation of Overruns – Risk Assessment at Signals*.

[48] A signal would normally need to achieve a risk score of 150 or higher to be progressed towards an assessment using the DA method.

[49] Staff using SAT are also trained not to consider trap-points as mitigation against overrun risk.

Conclusions

Immediate cause

210 Train 4N47 passed over 116 trap points, while they were set for the run-out (**paragraph 75**).

Causal factors

211 The absence or reduction in braking forces in some or all of the vehicles making up train 4N47 was caused by a combination of the following factors:

a. A reduction in the coefficient of friction between the brake blocks and the wheel tread surface due to the ingress of snow, ice and water between them (a probable causal factor) (**paragraph 89a, Recommendations 1 and 2**); and

b. Snow and ice ingress restricting movement of brake rigging and reducing the force that the brake block applies to the wheel surface (a possible causal factor) (**paragraph 89b, Recommendations 1 and 2**).

212 Other casual factors were:

a. 118 points at Carrbridge had been set to direct trains into the loop whilst simultaneously 116 points had been set to direct trains entering the loop over the run-out (**paragraph 77, no recommendation**);

b. Train 4N47 passed signal AC336 at danger (**paragraph 81, no recommendation**); and

c. The way the driver applied the running brake test rules meant he did not have a correct understanding of the brake forces available (**paragraph 145, Recommendations 1 and 2**).

213 It is probable that the following factor was causal;

a. The disturbance of snow lying close to the line by train 4N47 due to the speed at which it ascended the Slochd summit (**paragraph 123, Recommendation 3**).

214 It is possible that the following factor was causal;

a. Snow accumulating to a level where it could directly contact components on the bogies of the wagons (**paragraph 119, Recommendation 3**).

Contributory factors

215 It is possible that the following factor was contributory;

a. The composition brake block material on train 4N47 may have had its coefficient of friction slightly reduced (paragraph 147, no recommendation).

Underlying factors

216 An underlying factors was:

a. The requirement for running brake tests to be undertaken in snow contained in Module TW1 were neither an effective detection of loss of braking force in snow nor an effective preventative measure against the ingress of snow into braking equipment when trains are climbing steep gradients (**paragraph 151, Recommendations 1 and 2**).

217 It is possible that the following factor was underlying:

a. Network Rail's Scotland winter working arrangements did not contain a suitable warning that the prolonged use of miniature snow ploughs might leave an accumulation of snow lying near the line (**paragraph 174, Recommendation 3**).

218 It cannot be clearly established if the following factor was underlying or not:

a. The design of the braking arrangement of the FKA wagon (**paragraph 164, no recommendation**).

Other factors for consideration

219 Network Rail has not yet assessed the level of overrun risk at signal AC336 using the Detailed Assessment (DA) as is required by Network Rail standard NR/L2/SIG/14201 Issue 2 (**paragraph 209, Recommendation 4**).

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

220 Immediately following the accident on 4 January 2010 Network Rail issued an Urgent Operating Advice asking all train and freight operating companies to remind their drivers of the provisions of Module TW1 in respect of making running brake tests when snow is falling or being disturbed.

221 Between 5 and 16 January 2010, DB Schenker issued several special operating advice notices to its staff concerning working in extreme weather conditions. These notices detailed extra measures to be taken when preparing trains and testing brake continuity in snowy or icy conditions. A reminder to drivers about the requirements of Module TW1 in respect of conducting running brake tests in snow was also included.

222 In these notices DB Schenker additionally advised its drivers of the following general requirements when driving trains during the winter period:

> *'…Working on rising inclines; Often when ascending gradients it is impractical to carry out running brake tests which means that there is a possibility of brake equipment becoming inoperative.*
>
> *Except at locations where special instructions are issued as soon as you reach the summit of the incline and your speed begins to increase you must make a brake application and observe a positive reduction in speed of at least 10 mph…*
>
> *…When working on falling inclines; Even if you are satisfied that the running brake test is satisfactory you should reduce speed approaching falling inclines, and maintain a lower speed whilst descending. It may be necessary to maintain at least an initial brake application in order to do this. Remember if the brakes are applied they are generating heat which will assist in keeping the brakes working correctly…*
>
> *…Speeds; The faster a train goes the greater the likelihood of snow building up on the brake rigging… During snow conditions running at reduced speed is permitted, where the snow is heavy or there is significant movement of lying snow'*

223 Special instructions were also issued for drivers of trains travelling over either the Slochd or Druimuachdar Summits:

> *'…When ascending… to either of these summits in either direction you must;*
>
> *Make an Initial brake application every three to five minutes. You may make this application whilst the locomotive is taking power.*
>
> *You must observe a positive reduction in speed. You must release the brake once you have seen the reduction in speed.*
>
> *Before descending from either of these summits in either direction as soon as the speed begins to rise make a Full Service brake application and allow the train to come to a stand.*
>
> *Once the train has come to a stand recreate the brake and continue. You must then continue to undertake running brake tests…'.*

224 In October 2010 the Rail Freight Operations Group issued a code of practice[50] relating to the preparation and operation of rail freight services during adverse winter weather.

225 This code of practice advises that railway companies operating freight services should ensure that they have made winter preparedness arrangements. Suggested arrangements include advising staff of impending adverse weather, and ensuring that they are prepared for it and also making sure that staff involved in train preparation take steps to limit any possible ingress of snow into brake pipe connections, pay particular attention to any build up of snow on brake equipment and assist the drivers of trains in conducting additional tests of brake operation, if required.

226 The code of practice additionally discusses how train braking equipment may be affected by the ingress of ice and snow and how the use of running brake tests may prevent and detect any consequential loss in braking effectiveness. Advice is given also to reduce the running speed of trains where there is a heavy snow fall or if there is a significant disturbance of lying snow.

227 The code of practice also provides guidance for when trains are working on falling and rising gradients in adverse weather. This advice is very similar to the requirements made by DB Schenker on the same subject in its special operating instructions of January 2010 (see paragraph 221).

228 The code of practice defines certain rising gradients, including the Slochd and Druimuachdar Summits, as requiring special working instructions. When working trains over these locations, the code of practice states that:

'When ascending… drivers must:

- *make a brake application ensuring that the train is not brought to a stand as a consequence*
- *make this application whilst the locomotive is taking power and at frequent intervals not exceeding five minutes*
- *ensure the automatic brake is responding accordingly by monitoring for positive retardation caused by the braking effect of the train*
- *release the brake only when satisfied that the brake is functioning correctly.*

Before descending …drivers must:

- *bring the train to a stand at, or near to, the highest point*
- *move the train onto the falling gradient*
- *carry out a succession of running brake tests during the descent until the train is clear of the falling gradient'.*

50 Rail Freight Operations Group, Approved Code of Practice ACoP 001 Issue 1 *Operation of Freight Services in Winter*.

Previous recommendations relevant to this investigation

229 The following recommendations were made by the RAIB as a result of a previous investigation and address in part some of the causal and underlying factors identified in this report. These recommendations are not remade in this report, so as to avoid duplication.

Near miss at Carstairs, 22 December 2009[51]

230 On 22 December 2009 a freight train travelling south on the West Coast Main Line passed two red signals in succession at Carstairs and had a near miss with two passenger trains. The RAIB's investigation concluded that the train had reduced brake forces due to the ingress of snow and ice into braking equipment and that its driver did not have a correct understanding of the brake forces available. The RAIB made three safety recommendations as a result of their investigation into this incident, two of which are relevant to this report.

231 Recommendation 1 addresses in part the factors identified in paragraphs 212c and 216a.

Recommendation 1

The intent of this recommendation is to mitigate the effects of a driver extending the interval between running brake tests when their locomotive-hauled train is climbing a rising gradient. It aims to mitigate any potential reduction in braking performance caused by snow or ice ingress. It will also improve the effectiveness of the existing running brake test in snowy conditions by detecting any such reductions.

Freight operating companies in conjunction with the Rail Safety and Standards Board should make a proposal to review the existing arrangements in section 18.2 of module TW1 of the Rule Book for running brake tests in snowy conditions. The review should consider the practicalities of carrying out running brake tests when driving locomotive hauled trains on rising gradients and identify how these rules can be modified if drivers have not carried out a running brake test for more than five minutes. Options for consideration should include a requirement that drivers of locomotive-hauled trains should make a full service brake application and sufficiently retard their train as soon as they have passed over a summit and onto a descending gradient.

232 Recommendation 2 addresses in part the factors identified in paragraphs 211a, 211b, 213a and 214a and addresses fully the factor identified in paragraph 218b.

Recommendation 2

The intent of this recommendation is to ensure that any risks to the safety of the line resulting from falling or disturbed snow affecting different types of rolling stock are assessed and that rolling stock specific risk controls are considered in advance of adverse weather. For example, when snow is falling or is being disturbed by the passage of trains, there is less potential for snow and ice ingress when trains run at a reduced speed. A lower speed also allows the train to stop in a shorter distance than it would otherwise if it had a problem with its brakes due to snow or ice.

[51] RAIB report 02/2011, published January 2011

Freight operating companies should carry out a review of the safety impact of their freight trains operating in snowy conditions. The review should take into account the likelihood of different types of rolling stock disturbing lying snow and the consequent impact on the operation of their brake equipment. The findings should inform a consideration of the need for rolling stock specific risk control measures to be imposed when justified by the conditions. These could include reducing the maximum permitted speed of some types of train, additional actions by train staff and the re-routing of certain types of rolling stock away from adverse winter weather or from routes containing steep gradients.

Recommendations

233 The following safety recommendations are made[52]:

Recommendations to address causal, contributory, and underlying factors

1 *The purpose of this recommendation is to improve the effectiveness of the existing running brake test undertaken in snow in detecting or preventing any reduction in the brake forces available to a train when it is climbing steep gradients.*

Freight operating companies, in conjunction with the Rail Safety and Standards Board, should make a proposal to review module TW1 of the Rule Book in order to establish if additional measures (such as bringing trains to a stand when starting to descend from summits) are required for trains working on steep gradients when snow is falling or being disturbed. The requirements and guidance within DB Schenker's special operating advice notices for working in extreme weather conditions and the Rail Freight Operations Group's code of practice for operating freight services in winter should be examined for their suitability as a basis for these additional requirements (paragraphs 211a, 211b, 212c and 216a).

2 *The purpose of this recommendation is to ensure that risks to safety on steep gradients during periods of falling or disturbed snow are assessed and that appropriate control measures are considered in advance of adverse weather. It is also intended to extend the current use of line-side snow signs to other sites assessed as requiring such additional risk control measures.*

Network Rail, in consultation with train operators, should assess any lines which include steep gradients in order to establish if additional risk control measures (such as bringing trains to a stand prior to descending from summits) may be required during periods when snow is falling or being disturbed by the passage of trains. Any steep gradients assessed as requiring additional risk control measures in these conditions should be designated in the appropriate sectional appendix and marked by the use of lineside snow signs (paragraphs 211a, 211b, 212c and 216a).

continued

[52] 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 Regulation 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 167 to 171) can be found on RAIB's website at www.raib.gov.uk.

3 *The purpose of this recommendation is to ensure that the potential risks involved in the prolonged use of stock equipped with miniature snow ploughs to clear snow from lines are understood and that Network Rail staff involved in the management of extreme weather are made aware of any risk control measures identified.*

Network Rail, in consultation with train operators, should assess the risks of an accumulation of snow being left on or close to the line as a result of the prolonged use of miniature snow ploughs to clear lines of snow. Any appropriate risk control measures (such as additional instructions within route winter working arrangements) that are identified should be implemented (paragraphs 213a, 214a and 217a).

Recommendations to address other factors considered during the investigation

4 *The purpose of this recommendation is to ensure that the risk of an overrun of signal AC336 is reviewed in line with existing industry requirements to ensure that it is acceptably low. It is also intended to ensure that the secondary risk introduced by trap points at other similar locations is considered.*

Network Rail should consider if there are additional measures which could reduce the overrun risk at signal AC336 and implement those measures found to be reasonably practicable to introduce. This consideration should include the undertaking of a detailed assessment as required by Network Rail standard NR/L2/SIG/14201. Network Rail should have regard to the guidance and requirements regarding trap points within Railway Group Guidance Note GI/GN 7606 and Railway Group Standard GK/RT 0064 and should specifically consider the risks to the public of an overrun at this signal. Network Rail should also review where trap points have been used to control overrun risk at similar locations in order to establish that any secondary risks introduced by their use have been adequately assessed and mitigated (paragraph 219).

Appendices

Appendix A - Glossary of abbreviations and acronyms

AWS	Automatic Warning System
DA	Detailed Assessment
DMU	Diesel Multiple Unit
ESR	Emergency Speed Restriction
EWAT	Extreme Weather Action Team
GLW	Gross Laden Weight
MSP	Miniature Snow Plough
OSS	TPWS Overspeed Sensor System
OTDR	On Train Data Recorder
PSR	Permanent Speed Restriction
SAT	Signal Assessment Tool
SPAD	Signal Passed At Danger
TOPS	Total Operations Processing System
TPWS	Train Protection and Warning System
TRUST	Train Running System on TOPS
TSS	TPWS Train Stop Sensor System
VAB	Vehicle Acceptance Body

Appendix B - Glossary of terms

All definitions marked with an asterisk, thus (*), have been taken from Ellis's British Railway Engineering Encyclopedia © Iain Ellis. www.iainellis.com.

%g	The value of an acceleration (or deceleration) expressed as a percentage of that achieved by a freely falling object, which is taken to be 9.81 m/s².
Automatic (air) brake	A continuous brake which applies throughout a train and which will cause a brake application on all of its vehicles when air pressure in the brake pipe is reduced, either by the driver operating the brake controls or in the event of other circumstances such as a train division.
Automatic Warning System (AWS)	A track inductor based system linked to the aspects of fixed line side signals that provides audible and visual warnings to the driver on the approach to signals, certain level crossings and emergency, temporary and certain permanent speed restrictions.
Brake continuity test	A test to confirm the application and release of brakes in a train. For locomotive-hauled trains using the automatic air brake system, the test indicates that the flow of air in the brake pipe is continuous to the end rail vehicle.
Brake cylinder	A cylinder into which pressurised air is admitted or vented by the action of the distributor. The pressure of the air varies with the position of the distributor and the associated variable load valve. The admission of air extends a spring loaded piston connected to the brake rigging, producing a mechanical force proportional to the air pressure applied. When air pressure is reduced, this spring retracts the piston.
Brake pipe	A pipe running the length of a train that controls (and in the single brake pipe configuration also supplies) the air brakes on the rail vehicles forming the train. A reduction in brake pipe air pressure will apply the brakes.
Brake timings	The brake application and release timings on freight trains can usually be set to either 'passenger' or 'goods'. Passenger timings will give a quicker build up of brake force in the train.
Caution aspect	A signal aspect that indicates to the driver that the next signal may be displaying a stop (danger) aspect. This takes the form of a single yellow light on a colour light signal.*
Class 4	A freight train authorised to run at between 60 and 75 mph.*
Danger aspect	Universal term for a red (stop) signal aspect.*
Detailed Assessment (DA)	A qualitative risk assessment process which uses the judgement of experts within a formal workshop to develop an understanding of risks presented by an overrunning train at a particular signal.

Dew point	The temperature to which humid air must be cooled for water vapour to condense into water.
Diesel Multiple Unit (DMU)	A train consisting of two or more vehicles, semi-permanently coupled together, with a driving cab at each end. Some or all vehicles may be equipped with axles powered by one or more diesel engines.
Distant signal	A signal only capable of displaying a proceed aspect or caution aspect. When showing a caution aspect its purpose is to alert the driver that the next signal will be showing a stop aspect.*
Distributor	The pneumatic component of an air brake system which responds to changes in brake pipe pressure and initiates charging and venting of the brake cylinders.*
Down	In a direction away from London, the capital, the original railway company's headquarters or towards the highest mileage.*
Drag length	The length of the sand drag installed at certain trap points intended to decelerate a derailing train.
Driver's slip	A document signed by a train preparer stating that preparation procedures have been completed on a freight train. This document must be received by the driver of the train prior to its departure.
Emergency brake application	A commanded application of the automatic air brake which vents the brake pipe completely and at a quicker rate than for other braking applications. May use a more direct and separate part of the control system in order to signal this requirement.
Emergency brake plunger	A plunger within the driver's cab which vents the brake pipe in order to initiate an emergency brake application.
Emergency protection	The action of placing track circuit clips and detonators on the track to prevent a train running into a failed train, an obstruction, or a potential obstruction, on the track.
Emergency Speed Restriction (ESR)	A speed restriction imposed for a short time, at short notice, generally for safety reasons. Such restrictions are not published in engineering notices.*
Engineering acceptance	The process whereby conformance of railway vehicles to the requirements of railway group standards is scrutinised and certificated.*
Engineering notice	A document, published weekly and issued as required, giving details of possessions, temporary speed restrictions and alterations to the operational infrastructure of the railway.*
Equivalent braking force	A measure of braking capability that is directly related to the retarding force that all of the vehicles in the train should be providing at the interface between the wheel and the rail.

Extreme Weather Action Team (EWAT)	A team of senior managers drawn from the operations, engineering, communications and commercial functions within a Network Rail route which is activated when extreme weather conditions are forecast.
Full service brake application	A full brake application.*
Gross Laden Weight (GLW)	The weight of a rail vehicle including the weight of any load.*
Initial brake application	A minimum brake application, when there is only a small reduction in the brake pipe pressure.
Late notice case	A means of providing train drivers with information of a short-term or emergency nature at the time they commence their driving shift.*
Line proving locomotive	A locomotive sent out to patrol a line in order to look for obstructions and other hazards. In winter conditions, it may be equipped with a miniature snow plough in order to keep lines free of light snow.
Miniature Snow Plough (MSP)	A small snow plough attached to the front of a locomotive or multiple unit which can clear snow up to 450 mm above rail height.
Multi-SPAD signal	A signal which has had two or more SPADs in the preceding five years.
Movement authority	The authority (via signals or other means of communication) for a train to make a specified movement. A train is required to come to a stand at the end of its movement authority.
Normal	For a set of points this is the default position. The opposite is reverse.*
On Train Data Recorder (OTDR)	Equipment fitted on-board a traction unit which records train speed and the status of various controls and systems relating to the unit's operation. This data is recorded to a crash-proof memory and is used to analyse driver performance and train behaviour during normal operations or following an incident or accident. May also be known as an OTMR, black box or incident recorder.
Overspeed Sensor System (OSS)	Part of the train protection and warning system (TPWS), the over-speed sensor system is located on the approach to an associated signal. It is designed to trigger an emergency brake application if a train approaches a stop signal at an excessive speed.
Overrun	A train passing the end of its movement authority. On lines with lineside signals, an overrun is normally referred to as a Signal Passed At Danger (SPAD).

Part-Laden	The weight of a load carrying rail vehicle when it is loaded to a pre-defined point between its tare and laden weights.
Passing loop	A track onto which traffic may be diverted or held to allow other traffic to pass.*
Permanent Speed Restriction (PSR)	A speed restriction applied permanently to a length of track because it has a maximum permissible speed lower than the linespeed for that route.*
Permanent way	The track, complete with ancillary installations such as rails, sleepers, ballast, formation and track drains, as well as lineside fencing and lineside signs.*
Points	An assembly of two movable rails, the switch rails, and two fixed rails, the stock rails. Also known as a set of points or a set of switches. Used to divert rail vehicles from one track to another.
Protection	The use of a signal to prevent trains from entering a section where a conflicting movement could take place.*
Railway Group Standard	Standards issued by the Rail Safety and Standards Board that mandate measures in areas of interface between different rail companies.
Release	The state of vehicle brakes when the brakes are not acting to slow or hold the vehicle.*
Reversal	When applied to a set of points, placing them in the opposite position to their normal position.
Route indicator	An indicator associated with a signal that shows a driver which route is set where more than one route is available.*
Route	The signalled path from one signal to the next signal.*
Route setting	A signalling control system in which all the points, signals and indicators for a route are set by the operation of a few buttons and not individually.*
Running brake test	A brake test performed by the driver whilst the train is in motion.*
Run-out	A length of line onto which trains will be directed by trap points. In some locations the run-out may direct the train into a sand drag in order to decelerate it. Sometimes known as a run-off.
Section	A length of track bounded by signals or other similar control arrangements.*
Semi-permanently coupled	Two rail vehicles designed to operate normally as a fixed formation but which can be uncoupled and re-coupled.*
Solebar	Longitudinal beams which run along the sides of a rail vehicle at floor level and which form the joint between the floor and the sides of the bodywork.

Signal Assessment Tool (SAT)	A quantitative risk assessment methodology which provides a simplified assessment of overrun risk for a signal protecting a junction or section of plain line.
Signal Passed at Danger (SPAD)	A train failing to stop correctly at a signal displaying a stop aspect.*
Signal post telephone	A telephone located on or near a signal that allows a driver or other member of staff to communicate only with the controlling signal box.*
Spigot	A peg, in some cases retractable, used to retain containers laterally on a wagon deck.*
Straight air brake	On a locomotive hauled train, the air braking system that applies the brakes on the locomotive's wheels only. It does not apply the brakes of any rail vehicles connected to the locomotive via the automatic air brake system. Also known as a direct brake.
Stop aspect	A colour light signal displaying a red light.*
Stop signal	A signal capable of showing a stop aspect. Thus also applied to any signal actually showing a stop aspect at that time.*
Tare	The weight of a load carrying rail vehicle when it is not carrying any load.
Three aspect colour light signal	A colour light signal capable of displaying three aspects. These are red (a stop aspect), yellow (a caution aspect) and green (a proceed aspect).*
Total Operations Processing System (TOPS)	A mainframe based computer system used to track rail vehicles. It deals with destination, load, location and maintenance information for all vehicles on the rail network. It is able to calculate the required equivalent brake force for a given load and to compare this to that available from the rail vehicles which form a train.
Track circuit block system	A signalling system where the line beyond each signal is automatically proved clear to the end of the overlap beyond the next signal using track circuits.*
Train document	A series of sheets printed from TOPS giving information including the train's identification number; departure time; origin; destination points; maximum load; brake force type and tonnage; route availability; length limit and maximum speed. TOPS automatically checks whether the train formation conforms to prescribed criteria and standards when it produces the train document.*
Train examiner	A person appointed by a train operator and passed competent to undertake train examinations.

Train examination	An in-service inspection of rail freight vehicles which looks for the presence of defects which could jeopardise the safe running of the vehicle or of a train. The inspection includes examinations of wheels and axles, bearings, suspension, brake equipment, structural items and bodywork. Also known as a Freight Train Exam.
Train preparer	A person appointed by a train operator and passed competent to carry out train preparation before departure. Duties include checking the train for compliance with the train document and physically checking all vehicles to ensure that they are properly coupled (including brake pipe and electrical connections); the necessary lamps are provided on the train; all vehicles appear safe to travel and all handbrakes are released.*
Train Protection and Warning System (TPWS)	A system fitted to certain signals which will automatically apply a train's brakes if it approaches the signal at too high a speed, or fails to stop at it, when it is set at danger.
Train-stop Sensor System (TSS)	Part of the train protection and warning system (TPWS) the train-stop sensor system (TSS) is located adjacent to the associated signal and is designed to trigger an emergency brake application if a train passes over it when the associated signal is showing a stop aspect.
Trap points	Facing points provided to derail unauthorised movements and thus protect other trains.
Tread brakes/tread braking	A friction braking system where the brake force is applied directly to the wheel tread.
Train running system on TOPS (TRUST)	A computer system that processes reports of train running and compares it with the timetables*.
Two aspect colour light signal	A colour light signal capable of displaying two aspects. These are normally yellow and green at a distant signal.*
Up	In a direction towards London, the capital, the original railway company's headquarters or the lowest mileage.
Variable load control valve	The component of the braking system on a load-carrying rail vehicle which detects the weight of the load being carried and transmits a signal to the variable load valve to allow braking effort to be adjusted accordingly.
Variable load valve	The component of the braking system on a load-carrying rail vehicle which automatically adjusts the vehicle's braking effort to match the carried load.
Vehicle Acceptance Body (VAB)	A body given authority by the Railway Safety and Standards Board (RSSB) to undertake engineering acceptance for rail vehicles.*

Wheel tread	The part of a rail wheel that runs on the rail.
Wheelset	Two rail wheels mounted on their joining axle.*
Wheelslide protection equipment	A control system fitted to some locomotives and multiple unit trains which is intended to prevent wheelsets from locking and sliding during brake applications. Analogous to anti-lock braking in a car.
Wheelslip protection equipment	A control system fitted to some locomotives and multiple unit trains which is intended to prevent wheelsets from spinning in place when traction power is applied. Analogous to traction control in a car.

Appendix C - Key standards current at the time

Network Rail Standard COM/EWAT	'Scotland Route Winter Working Arrangements November 2009 - April 2010'
Network Rail Standard NR/L2/SIG/14201 Issue 2	'Prevention and Mitigation of Overruns – Risk Assessment at Signals'
Network Rail Standard NR/GN/SIG/14202 Issue 2	Prevention and Mitigation of Overruns – Risk Assessment at Signals
Network Rail Standard NR/L2/OPS/021 Issue 2	'Weather – Managing the operational risks'
Railway Group Standard GK/RT 0064 Issue 1	'Provision of Overlaps, Flank Protection and Trapping'
Railway Group Standard GI/RT 7006 Issue 1	'Prevention and Mitigation of Overruns – Risk Assessment'
Railway Group Standard GM/RT 2043 Issue 1	'Braking System and Performance for Freight Trains'
Railway Group Guidance Note of GI/GN 7606 Issue 1	'Guidance Note: Prevention and Mitigation Overruns – Risk Assessment'
Railway Group Standard GE/RT8000 Rule Book, Module M4, as amended by Issue 8 of Module AM	'Floods and snow'
Railway Group Standard GE/RT8000 Rule Book Module TS1, April 2009, as amended by Issue 8 of Module AM	'General signalling regulations'
Railway Group Standard GE/RT8000 Rule Book, Module TW1, October 2008, as amended by Issue 8 of Module AM	'Preparation and movement of trains'
Railway Group Standard GE/RT8000 Rule Book, Module TW3, November 2004, as amended by Issue 8 of Module AM	'Preparation and movement of locomotive-hauled trains'

Appendix D - Simplified explanation of the single pipe arrangement for train braking

1 An automatic air brake was fitted to train 4N47. This is a brake system which is operated by compressed air and which automatically applies the brakes if air pressure is lost.

2 The type of automatic air brake system that the wagons on train 4N47 were fitted with is commonly known as a single pipe system. One pipe, known as the brake pipe, runs along the length of the whole train and provides two purposes:

- it controls the application and release of the brakes along the length of the train; and
- it provides a supply of air to the auxiliary reservoir which feeds the brake equipment on each individual vehicle.

3 A simplified schematic diagram showing the arrangement for a single pipe system is shown in figure 22.

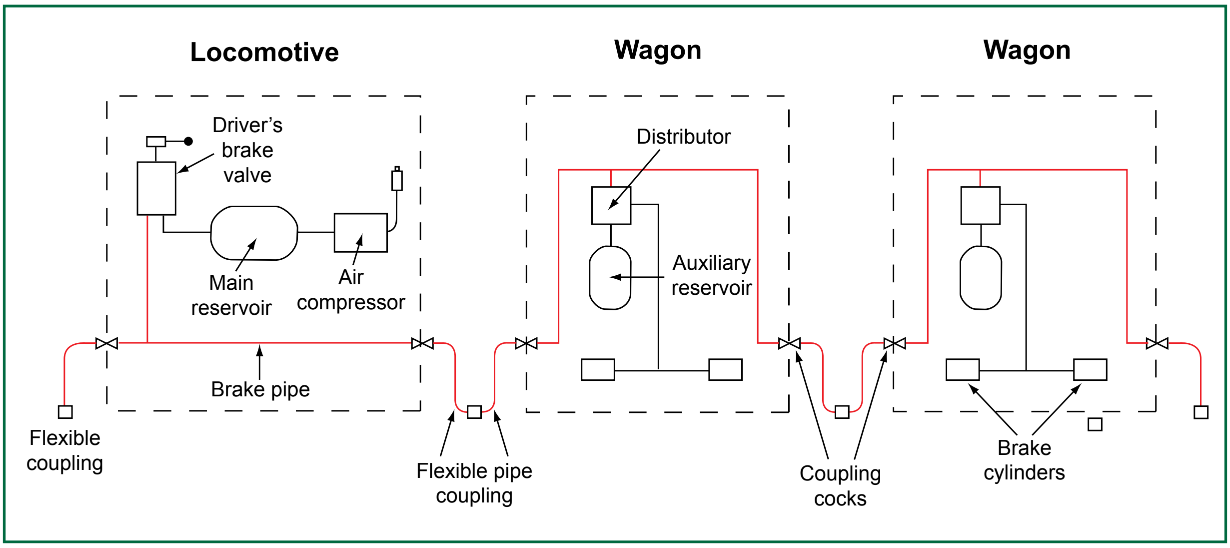

Figure 22: Simplified schematic diagram showing single pipe system

4 The air compressor on the locomotive produces compressed air that is stored in a main reservoir tank so a supply is readily available. The locomotive's main reservoir supplies air to all of the locomotive's air systems and to the wagons via the brake pipe. Flexible pipe couplings are used for the brake pipe connections between vehicles.

5 The driver controls the amount of air pressure in the brake pipe by moving a brake handle in the locomotive's cab that controls the driver's brake valve. This valve allows air from the main reservoir into the brake pipe or vents air out of the brake pipe. The amount of pressure in the brake pipe can range from 0 to 5 bar. A gauge in the cab tells the driver what the brake pipe pressure is.

6 When the locomotive is first coupled to the wagons, it may be that the wagons have little or no air in their systems. To charge their air systems, the driver will set the brake pipe pressure to 5 bar. As air passes down the brake pipe, the brake distributor on each wagon allows air into its auxiliary reservoir. Once each auxiliary reservoir is charged to 5 bar, the brake pipe pressure will settle at 5 bar. Throughout the subsequent journey, the auxiliary reservoirs will be replenished whenever the brake pipe pressure is at 5 bar.

7 During normal running, the train's brakes are in their released position when the brake pipe pressure is at 5 bar.

8 To apply the train's brakes, the driver moves the brake handle so that the driver's brake valve allows air to flow out of the brake pipe which reduces the pressure in the brake pipe. The distributor on each wagon detects this reduction in pressure and allows air to flow from the auxiliary reservoir to the brake cylinders. As the brake pipe pressure falls, there is a proportional increase in the brake cylinder pressure. The brake cylinder pressure reaches its maximum when the brake pipe pressure has fallen to around 3.4 bar. This is known as a full service brake application.

9 When an emergency brake application is made, or if the train divides and the brake pipe is broken, the brake pipe pressure will fall to atmospheric pressure as it will be completely vented. The maximum brake cylinder pressure is the same as for a full service brake application but it is attained at a faster rate. Under all braking conditions, the maximum brake cylinder pressures, as controlled by the distributors, are attained as soon as the brake pipe pressure has fallen by around 1.5 bar.

10 The driver then releases the brakes again by allowing the brake pipe pressure to rise back to 5 bar. One disadvantage of the single pipe arrangement is that the brakes may be slow to release because the auxiliary reservoirs are being refilled at the same time.

11 Locomotives are also fitted with a facility that allows the driver to overcharge the pressure in the brake pipe. This raises the pressure in the brake pipe to 5.4 bar. It will then slowly drop over several minutes back to 5 bar. The driver will normally do this after attaching the locomotive to the train for the first time or when changing ends. It is done because the driver's brake valve is not set up exactly the same on each locomotive and this action will make sure that all of the brakes along the train are released.

12 The length of the train also has an effect on braking. When the driver applies the brakes, it may take some time for the reduction in brake pipe pressure to propagate down the length of the train. Therefore the wagons at the back of the train may take longer to start braking than the wagons nearer the front. Similarly it takes longer for the brakes to release on the wagons towards the rear of the train.

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