Rail Accident Investigation Branch

Rail Accident Report

Near miss involving a freight train and two passenger trains, Carstairs 22 December 2009

Department for Transport

Report 02/2011
January 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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This report is published by the Rail Accident Investigation Branch, Department for Transport.

Near miss involving a freight train and two passenger trains, Carstairs, 22 December 2009

Contents

Summary

On 22 December 2009, a freight train travelling south on the West Coast Main Line, in freezing temperatures and snowy conditions, passed two red signals in succession at Carstairs. After it started braking, the freight train took almost two and a half miles to stop. It finally came to a stand over Carstairs Station junction, shortly after the passage of a passenger train. Actions taken by the signaller stopped the freight train from travelling towards a second passenger train that was also approaching Carstairs. Nobody was injured and there was no damage to trains or infrastructure. However, under slightly different circumstances, the incident may have led to either a collision between trains or a derailment.

The freight train's braking performance was very poor for a train of its type and was caused by snow and ice ingress stopping the brake equipment on its wagons from working properly. A combination of factors led to this situation occurring:

- the way that the driver applied the rules for operating trains in snowy conditions;
- the speed of the train, and as a result the amount of lying snow that it then disturbed; and
- the train entering into service with snow and ice already on its brake equipment.

The RAIB has made three recommendations. Two of the recommendations made are to freight operating companies in conjunction with the Rail Safety & Standards Board (RSSB) and relate to changes to the rules for operating trains in snowy conditions. The third recommendation is made to the freight operating companies and calls for a review of the safety impact of operating freight trains in snowy conditions, so that specific risk control measures can be identified and imposed when justified by the conditions.

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 units, in accordance with normal railway practice. In these cases the equivalent metric value is also given.

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

The Incident

Summary of the incident

5 At 20:26 hrs on 22 December 2009, a freight train travelling south on the West Coast Main Line (WCML) passed two red signals in succession at Carstairs (figure 1); one just to the north-west of the station and the other at its south-eastern end. In total the train took almost two and a half miles to stop after it had started braking and came to a stand over Carstairs Station junction (figure 2). This braking performance was below that expected of a train of its type.

6 As the freight train approached Carstairs, a London Kings Cross to Glasgow Central passenger train was passing across its path at Carstairs Station junction. This train cleared the junction about 75 seconds before the freight train arrived there.

7 A signaller noticed that the freight train had not stopped and changed the position of two *sets of points* ahead of it. The signaller's actions averted the potential for a derailment at the junction and stopped the freight train from travelling towards a North Berwick to Glasgow Central passenger train that was also approaching Carstairs, from the direction of Edinburgh.

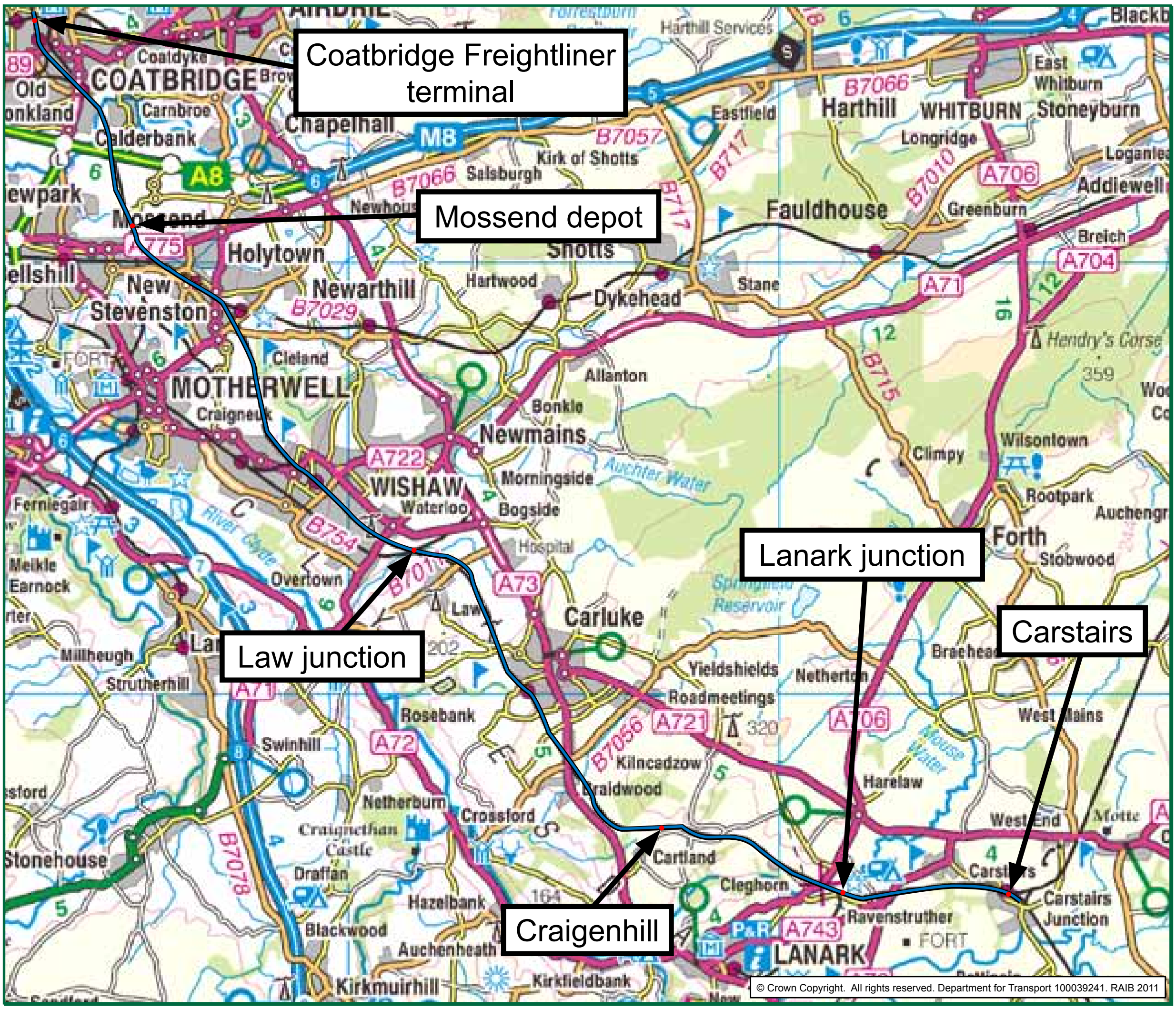

Figure 1: Extract from Ordnance Survey map showing route taken by the freight train from Coatbridge to Carstairs

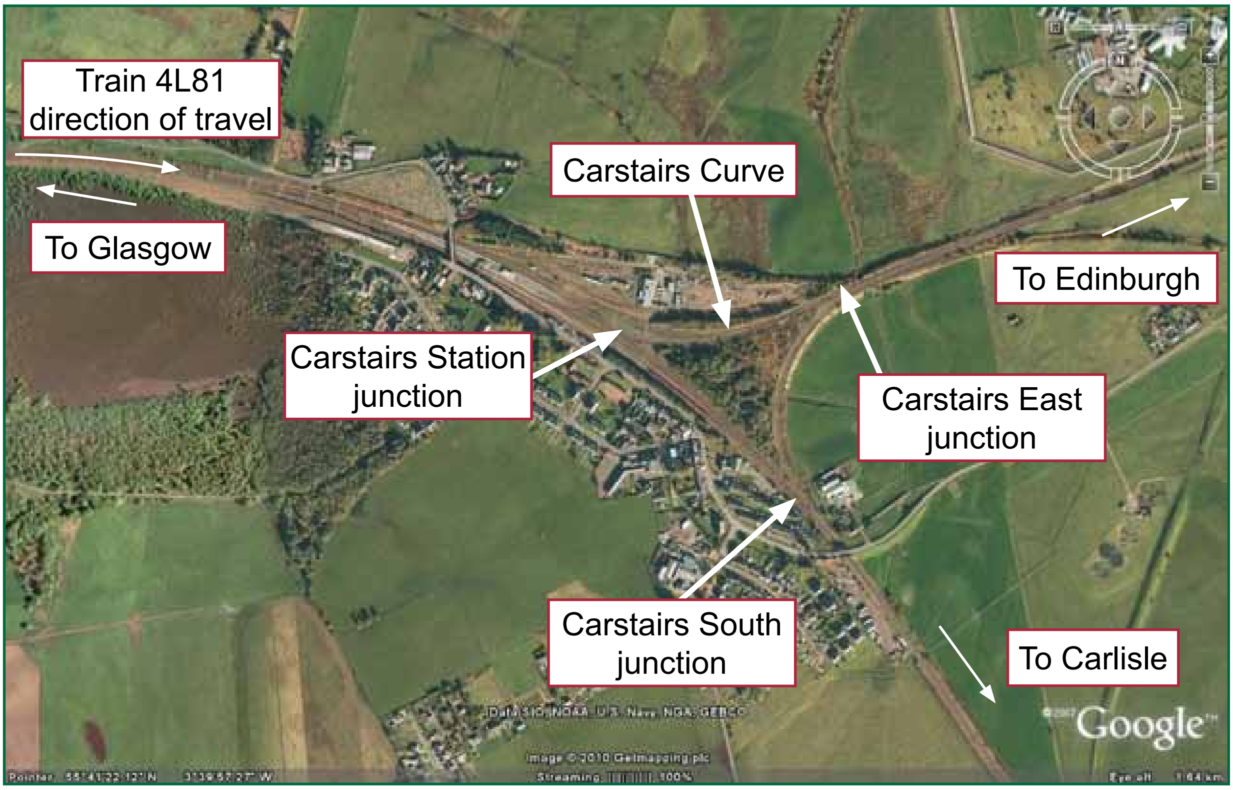

Figure 2: Overview of Carstairs showing railway junctions

8 Nobody was injured but the freight train's driver was badly shaken. There was no damage to trains or infrastructure. However, under slightly different circumstances the incident might have led to either a collision between trains or a derailment.

9 The railway at Carstairs Station junction remained closed until about 05:00 hrs the following day. It was reopened after the freight train was moved back into a *loop* at Carstairs.

Organisations involved

10 The freight train was operated by Freightliner Ltd, who also employed the driver and owned and maintained the locomotives and wagons. The London Kings Cross to Glasgow Central train was operated by East Coast and the North Berwick to Glasgow Central train was operated by First ScotRail.

11 Network Rail own the infrastructure and employed the signaller. Staff employed by DB Schenker and Davis Wagon Services examined parts of the train afterwards.

12 Freightliner Ltd, Network Rail and Davis Wagon Services freely co-operated with the investigation. East Coast, First ScotRail and DB Schenker have not had any significant involvement in the investigation.

Location

13 The key locations are shown in figure 3. The incident began on the north-western approach to Carstairs, on the *Up* Main line of the WCML, at around *milepost* 76. It ended at Carstairs Station junction near to milepost 73½. This section of railway is on a falling gradient throughout. The freight train had joined this line at Law junction (near to milepost 84), with the summit between Law junction and Carstairs being Craigenhill at around milepost 78¼.

14 The railway consists of a double track main line, with 25 kV AC overhead electrification. It is signalled using *track circuit block* and *four aspect colour light signals* and is controlled from Motherwell signalling centre. The *permissible speed* for trains on the Up Main line is 100 mph (161 km/h), reducing to 95 mph (153 km/h) on the approach to Carstairs and reducing further to 90 mph (145 km/h) through Carstairs station. However, the freight train had a maximum permitted speed of 75 mph (121 km/h). At Carstairs Station junction, there is a divergence with a permissible speed of 15 mph (24 km/h) onto a short section of single line called the Carstairs Curve.

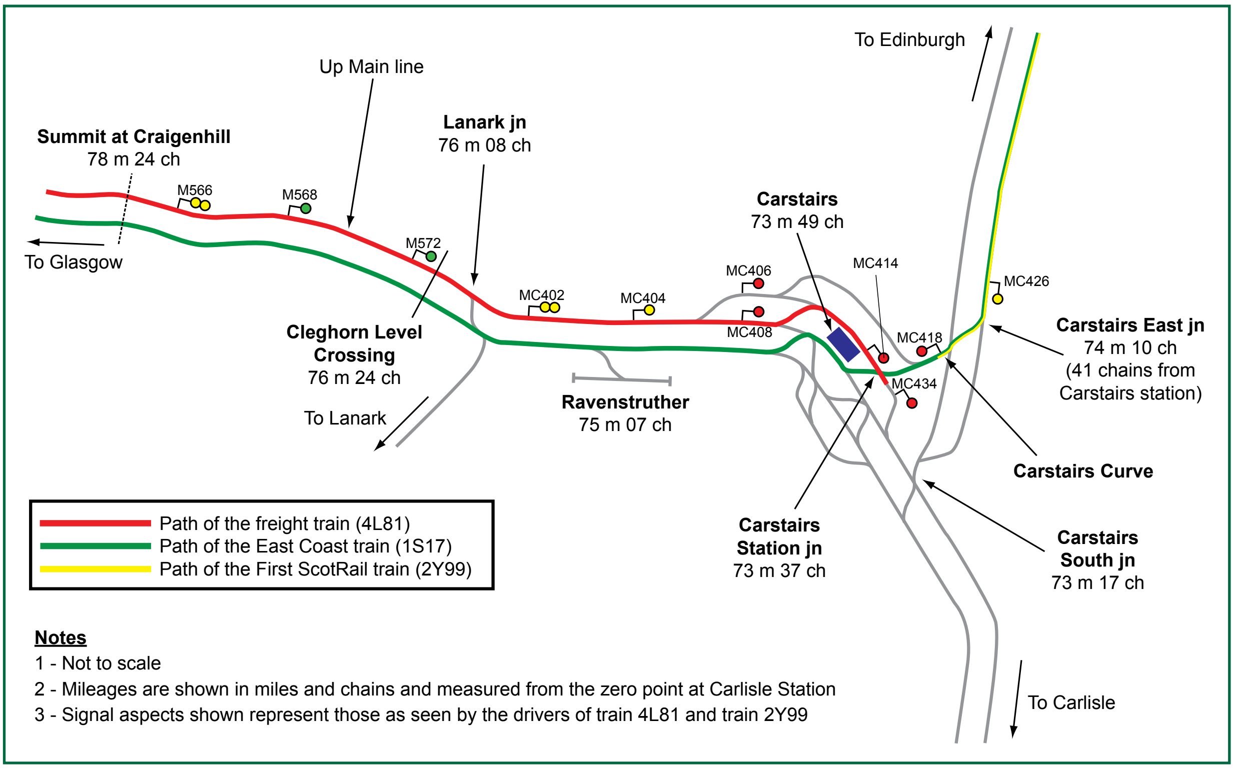

Figure 3: Track layout between Craigenhill and Carstairs showing movements of trains 4L81, 1S17 and 2Y99

External circumstances

15 The weather conditions throughout the day were poor with temperatures at or below freezing. There were light snow showers during the afternoon. At the time of the incident, it was dark and the temperature at Carstairs had fallen to -2°C. There was also a light snow shower in the area at around this time. Snow was lying to about the level of the *rail head*. On those lines on which trains were still running, the rail heads were clear of lying snow but were wet. Figure 4 shows the weather conditions about one hour after the incident.

Figure 4: Weather conditions about one hour after the incident - train 4L81 can be seen on the left (courtesy of Network Rail)

Trains involved

16 The freight train was train 4L81, the 19:21 hrs service from Coatbridge to Tilbury, and was running about 30 minutes late. It consisted of two class 86/6 AC electric locomotives (figure 5) hauling 22 *bogie container flat wagons*, types FSA, FTA and FEA-B. The train was 488 metres long with a trailing weight of 1275 metric tonnes. All of the wagons except for one were loaded.

17 The East Coast passenger train was train 1S17, the 13:00 hrs service from London Kings Cross to Glasgow Central. This train was running very late and had been held at Carstairs East junction for over 80 minutes because of snow causing points to fail in the Carstairs area. The First ScotRail train that was approaching Carstairs was train 2Y99, the 17:52 hrs service from North Berwick to Glasgow Central. The RAIB has found no evidence that the operation of these two passenger trains contributed in any way to the incident.

Staff involved

18 The driver of train 4L81 was based at Freightliner's train crew depot at Mossend. He had 30 years experience of driving and was very familiar with the route and this type of locomotive. The driver's competency records showed that he had passed his most recent practical and knowledge based assessments and the last operational incident on the driver's records was in 1991.

Figure 5: The leading class 86 locomotive of train 4L81 after the incident (courtesy of Network Rail)

19 On the day before the incident the driver had been on duty at the depot but he did not drive any trains; he was there as a spare driver and to work trains if the need arose. He was rostered not to be at work the two days before that.

20 The signaller was based at Motherwell signalling centre. He had over 19 years experience working as a signaller and over 11 years experience working at Motherwell. The RAIB has found no evidence that the actions or performance of the signaller contributed to the incident. His quick perception of the problem and response to it reduced the potential consequences (paragraph 139).

Events preceding the incident

21 The wagons that formed train 4L81 arrived at Coatbridge Freightliner terminal early that morning on an overnight service from Felixstowe. As this train arrived, Freightliner's ground staff carried out a *roll-by check* in accordance with procedure MIE 0727 (Freightliner Examination and Attention to Freightliner Intermodal and Heavyhaul Trains) and did not report any problems with it. After arriving in the terminal, the ground staff reported they pulled the cord attached to the bottom of the *brake distributor* on each wagon to remove all of the air from the *brake actuators* and release the brakes. This is a standard procedure that is followed so that the wagons' brake equipment is not damaged when containers are unloaded and loaded. Unloading and loading then took place through the day.

22 At 17:42 hrs that evening, the ferry driver[1] arrived from Mossend with two class 86/6 locomotives, 86610 and 86612, and these were coupled to the wagons. The locomotives charged the air systems on the wagons via the *brake pipe*. At 18:32 hrs the ferry driver and ground staff carried out a *brake continuity test*; both reported that the test was successful. The ferry driver then *overcharged* the brake pipe to make sure that the brakes on the wagons were all fully released.

23 At 19:17 hrs, the driver who was taking train 4L81 forward to Crewe booked on for his duty at Mossend. He read the *notices*, including a weather forecast that told him that snow may be falling during parts of his journey.

24 At 19:53 hrs, train 4L81 departed from Coatbridge. At 19:57 hrs the train reached a maximum speed of 37 mph (60 km/h) and at 19:59 hrs the ferry driver made several *initial brake applications* on the approach to Mossend. At 20:03 hrs, the ferry driver made a *full service brake application* and train 4L81 stopped on the main line at Mossend, rather than on one of the loop lines, as it was running late. The ferry driver handed the train over to the new driver, saying that it had been prepared and that there were no problems with the train. The train departed from Mossend at 20:04 hrs.

25 After leaving Mossend, the train climbed through Holytown on a rising gradient for almost two miles as can be seen in figure 6. The gradient then levelled out and fell for about half a mile until the Calder viaduct. The driver kept traction applied throughout this section to maintain the train's speed as the train soon began climbing again on a rising gradient for the next four miles to Law junction. Here it joined the WCML and headed south towards Carstairs.

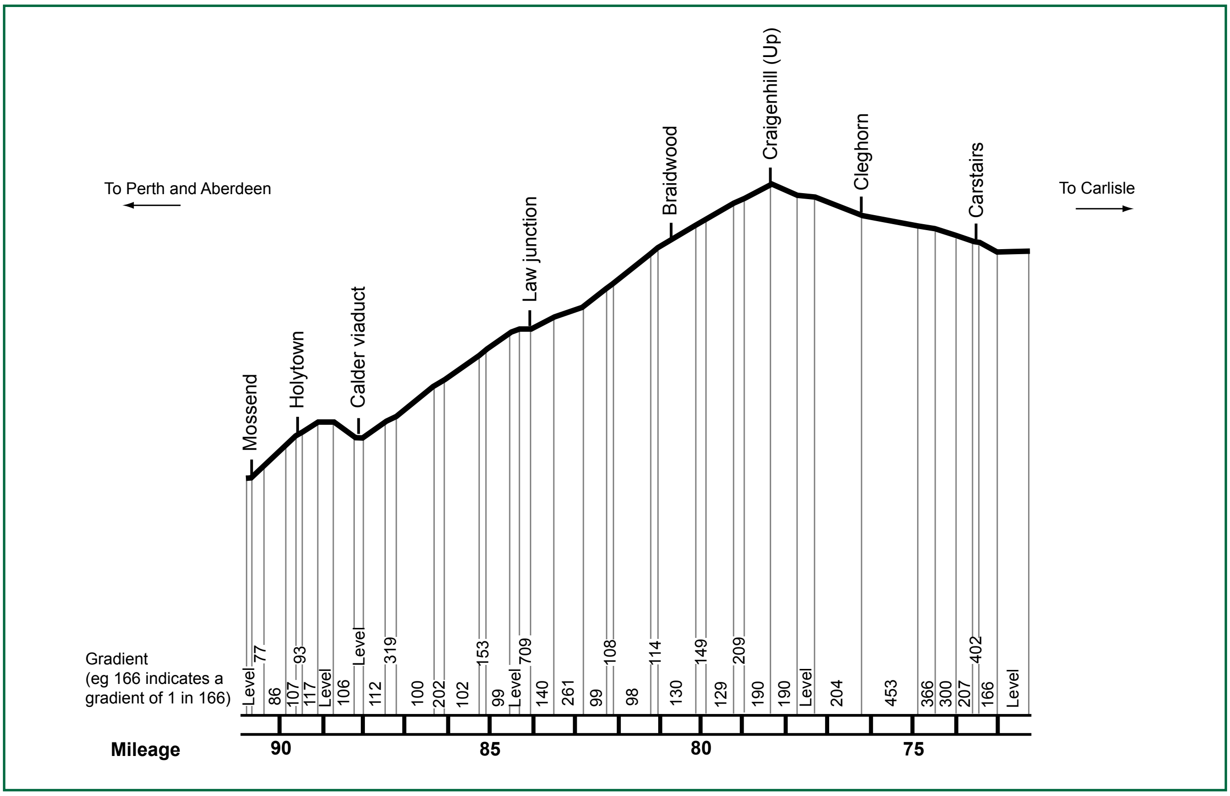

Figure 6: Gradient profile from Mossend to Carstairs

[1] The ferry driver is a term used locally at Mossend. It refers to a driver whose duty is to take locomotives from the sidings at Mossend up to Coatbridge, prepare the train they are attached to and then bring the train as far as Mossend. Another driver then takes the train forward.

Events during the incident

26 The train continued to climb a rising gradient on the WCML as can be seen in figure 6. At 20:22:05 hrs while travelling at 66 mph (106 km/h), the driver made a full service brake application in response to a double yellow aspect at signal M566, which is located about 580 metres after the summit at Craigenhill (figure 3). The driver reported that he felt the train starting to slow down. He released the brakes one minute later when he sighted the next signal showing a green aspect. By this time, the train's speed had reduced to 60 mph (97 km/h).

27 The driver took traction again and accelerated on the falling gradient to a speed of 74 mph (119 km/h). At 20:24:12 hrs, the driver responded to signal MC402 showing a double yellow aspect by making a full service brake application. About 33 seconds later, the driver sighted the next signal, MC404, showing a single yellow aspect. He then made an *emergency brake application* as the train's speed had only fallen by 7 mph (11 km/h) since he first applied the brakes.

28 At 20:25:00 hrs, train 4L81 passed signal MC404 at 63 mph (101 km/h). About 1.4 miles (2.3 km) away, train 1S17 was crossing in front of it at Carstairs Station junction. About thirty seconds later and with train 4L81 just under one mile (1.6 km) away, train 1S17 had moved clear of its path.

29 At 20:25:47 hrs, the *Train Protection and Warning System* (TPWS) equipment on train 4L81's leading locomotive triggered an emergency brake application, as the train's speed was too high approaching signal MC408 that was showing a red aspect. The TPWS intervention had no further effect as the brakes were already commanded to be fully applied. The train passed this signal at 44 mph (71 km/h) at 20:26:06 hrs. At the same time, the signaller operated the controls on his panel so that signal MC426 displayed a single yellow aspect. This permitted train 2Y99 to move onto the Carstairs Curve as far as signal MC418 (figure 3) and about 25 seconds later it began moving.

30 Figure 7 shows the conditions on the approach to signal MC408 on the night.

Figure 7: Approach to signal MC408 on night of the incident (courtesy of Network Rail)

31 Motherwell signalling centre was not fitted with an alarm to alert signallers when a train has passed a signal at danger. However, the signaller noticed that train 4L81 had not stopped at signal MC408. He immediately commanded two sets of points, P311 and P312 at Carstairs Station junction, to move; this was to stop train 4L81 from going on the Carstairs Curve and to keep it on the WCML instead. At 20:26:40 hrs the points were in their commanded positions. The signaller also asked his supervisor to arrange with Network Rail's route controller for an *emergency call* to be made to the driver of train 4L81.

32 Five seconds later, train 4L81 passed signal MC414 at danger while still travelling at 25 mph (40 km/h). At 20:26:52 hrs train 4L81 passed over the points at Carstairs Station junction at 20 mph (32 km/h). Figure 8 shows signal MC414 at the southern end of the station and the junction beyond. This is the place where train 1S17 had been crossing over about 75 seconds before.

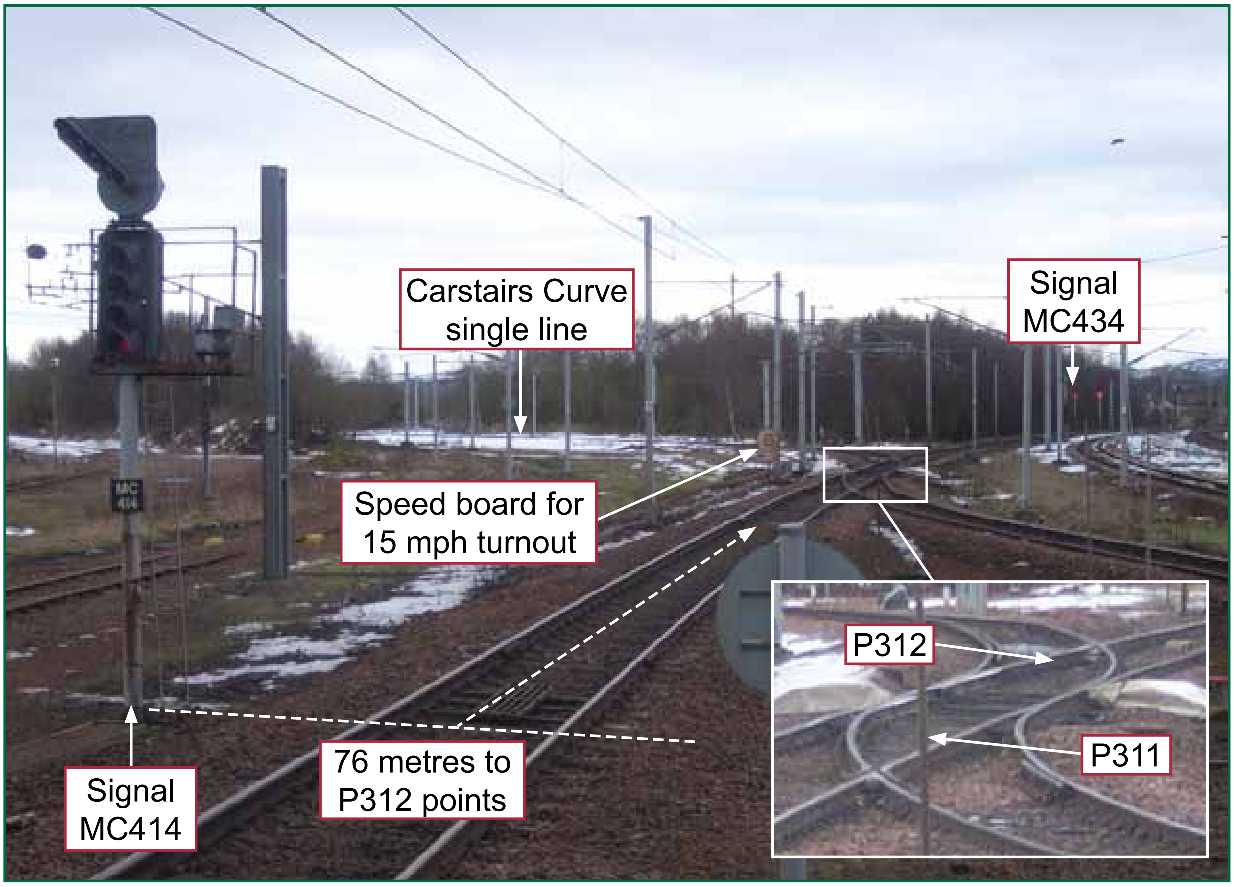

Figure 8: Signal MC414 and Carstairs Station junction

33 At 20:27:16 hrs, train 4L81 stopped 210 metres after signal MC414 and 73 metres before signal MC434. Shortly afterwards, train 2Y99 stopped at signal MC418, 444 metres from train 4L81 which was now blocking the junction ahead of it.

Events following the incident

34 Just as train 4L81 stopped, the driver received the emergency call from Network Rail route control asking him to bring his train to a stand. He reported back that he was now at a stand and Network Rail route control asked him to call the signaller at Motherwell.

35 The driver then spoke to the signaller. The signaller filled out the forms that are used when a train has passed a signal at danger, and when asked the driver stated the cause was "no brakes". The signaller stopped all other train movements in the area while the driver applied the handbrakes on the first ten wagons to secure the train. As train 4L81 was blocking its path, train 2Y99 returned to Edinburgh.

36 Network Rail and Freightliner arranged for staff to travel to Carstairs. A rolling stock technician employed by DB Schenker attended on behalf of Freightliner and carried out a functional brake test on the locomotives, which was successful. The technician did not examine the wagons as he was not qualified to test them. By midnight, the temperature had fallen to -8°C and when a relief driver attempted to reverse the train into a loop at Carstairs, this could not be done as several of the handbrakes had frozen on. All of the handbrakes were finally released at 04:55 hrs and the train was moved into the loop and then secured. The railway line was reopened just after 05:00 hrs.

37 On 23 December, about 15 hours after the incident, a wagon fitter from Davis Wagons Services attended on behalf of Freightliner. He examined the wagons and reported to Freightliner that the train needed to be de-iced. On the next day, 24 December 2009, staff from Freightliner attended. They removed the ice and snow from underneath the wagons, visually checked that their brakes applied and released, and declared that the train was now fit to be moved.

38 The train ran to Crewe as the 4Z81 service from Carstairs to Crewe, departing at 17:05 hrs. One of the Freightliner staff who de-iced the train rode with it to Carlisle in case of further problems. The driver tested the operation of the brakes throughout the journey. He reported that the train's braking performance was substandard for the first few tests after leaving Carstairs but soon improved and the brakes responded as expected after that.

The Investigation

Sources of evidence

39 The following sources of evidence were used:

- witness statements;
- the *data recorders* on both locomotives;
- data logged by the signalling system;
- Closed Circuit Television (CCTV) recordings taken from Carstairs station;
- site photographs, measurements and cab ride video footage;
- photographs, reports and documentation provided by Freightliner;
- photographs, information and documentation provided by Network Rail;
- a meteorological report and weather observations provided by those at the site;
- failure mode analysis exercise involving industry parties and consultants;
- a review of previous reported occurrences involving freight trains with poor braking performance in snowy conditions;
- information from Scandinavia, Germany, Switzerland and North America about similar incidents and operating procedures followed during severe weather; and
- a review of RAIB investigations that had relevance to this incident.

Key facts and analysis

Identification of the immediate cause[2]

40 **The immediate cause of the near miss incident was that train 4L81 had a significantly reduced braking performance and therefore passed both signals MC408 and MC414 at danger.**

41 The driver was not aware of any performance problems with the train's brakes, so he approached Carstairs at around the maximum permitted speed for his train and only began to brake when he saw signal MC402 showing a double yellow aspect. Evidence from the train's data recorder, supported by the account given by the driver, shows that the train's speed did not reduce as expected after this brake application was made.

42 The braking performance of train 4L81 was calculated using the data from the leading locomotive's data recorder, and can be seen in figure 9. The train took just under 3900 metres to stop from a speed of 74 mph (119 km/h), giving an average deceleration of 1.4%*g*. When the effect of the falling gradient is taken into account, the equivalent deceleration on level track would be 1.7%g. This is much less than the deceleration required by Railway Group Standard GM/RT2043 which sets out the braking requirements for freight trains. This requires a minimum average deceleration on level track of 4.6%g from a speed of 75 mph (121 km/h). However brake test reports[3] show that the brakes on the locomotives and wagons that formed this train would have been expected to give an average deceleration of about 6%g on level track.

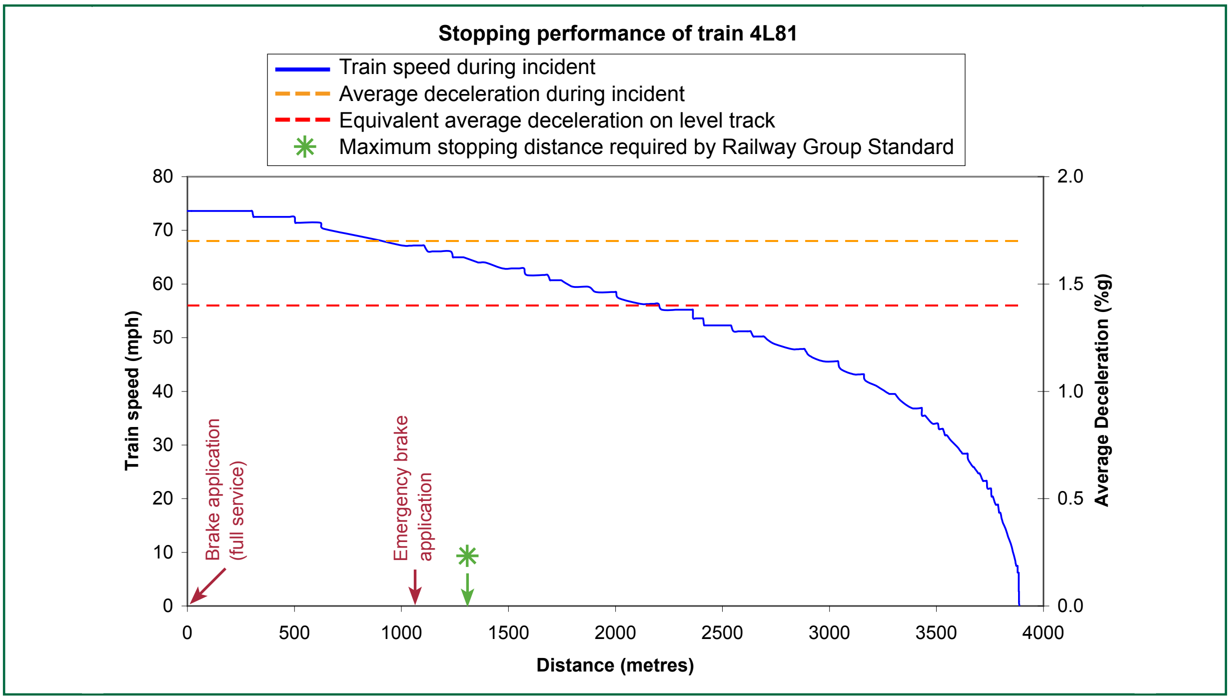

Figure 9: Graph showing stopping performance of train 4L81 (speed taken directly from the train's data recorder)

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

[3] Class 86/4 braking with reduced rheostatic brake, British Rail Testing Section report no. 1009A, December 1987 and RFD container carrying wagon (Arbel) brake acceptance tests, British Rail Testing Section report no. 1274B, October 1991.

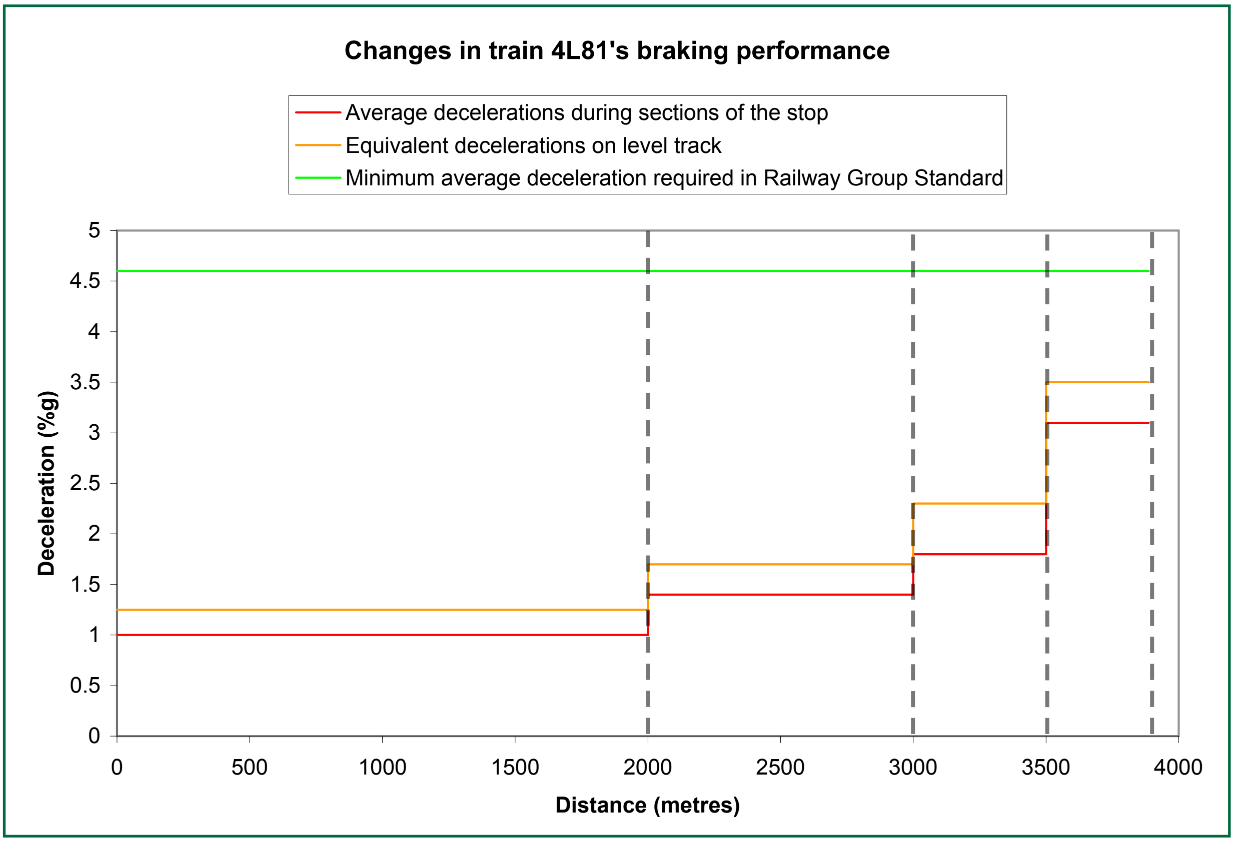


Figure 10: Graph showing changes in train 4L81's braking performance

43 Figure 10 shows that train 4L81's braking performance progressively got better during the stop. It was very low during the first 2000 metres but was starting to approach the minimum requirement over the final 350 metres. The CCTV footage from Carstairs station confirms that the train decelerated quite quickly in the final stage of its stop.

Identification of causal[4] factors and contributory factors[5]

The train's reduced braking performance

44 Railway Group Standard GO/RM3056, the Working Manual for Rail Staff Freight Train Operations (also known as the 'White Pages'), defines what a train's minimum *equivalent brake force* must be. This value, which is measured in *tonnes*, is set by the train's total weight (locomotives and wagons) and its maximum speed. For train 4L81's weight and speed, its minimum equivalent brake force was 600 tonnes.

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

[5] 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.

45 The train's actual equivalent brake force is automatically calculated by the Total Operations Processing System (TOPS), which is a mainframe based computer system that contains information on train services and vehicles. After details about the train's consist and loading have been entered by the train preparer, TOPS automatically checks that limits for weight etc have not been exceeded and then calculates what the train's equivalent brake force is. The train preparer then uses TOPS to produce the train document. This is a series of printed sheets that record details about the train's consist including its minimum and actual equivalent brake force. The train document for train 4L81 showed that TOPS had calculated it had an actual equivalent brake force of 912 tonnes. Therefore the vehicles that formed the train should have been more than capable of stopping it.

46 Of the 22 wagons in the train's formation, 20 of them were types FSA and FTA. The train document showed that these wagons should have provided about 87.5% of the train's equivalent brake force. Based on the load they were carrying, the FSA and FTA wagons had individual equivalent brake forces ranging from 28 to 51 tonnes.

47 The other two wagons in train 4L81 were type FEA-B. On 18 December 2009 the brakes had been isolated on one of these FEA-B wagons because its brake blocks were worn. Consequently this wagon had no containers loaded on it. The remaining FEA-B wagon was laden and the train document showed that this wagon should have had an equivalent brake force of 34 tonnes. As this was only a very small percentage of the train's total equivalent brake force (less than 4%), the RAIB did not investigate whether the FEA-B wagon type contributed to the train's poor braking performance.

48 The FSA and FTA wagons were built by Arbel Fauvet and commissioned into service between October 1991 and December 1993. Figure 11 shows that the mechanical difference between the FSA and FTA types of the wagon is that the buffer height differs at one end, but the rest of wagon design, including air and braking systems, is identical on both types.

49 Their braking equipment was specified to operate in a wide range of environmental conditions, including an ambient temperature range of -30°C to +40°C, a relative humidity range of 0 to 100%, and snow and ice. Their braking performance was specified to meet the requirements of two *International Union of Railways* (UIC) leaflets: UIC-543 (Brake Regulations) and UIC-544 (Brake, Braking Power).

50 Between April and June 1991, British Rail carried out braking performance acceptance tests on the wagons in their laden and tare conditions. From these test results, the RAIB calculated that the brakes gave an average deceleration of 6.1%g in its laden condition.

51 From the braking performance seen during the incident, the RAIB calculated that there must have been either a complete absence of braking on some wagons or a reduced braking force on some or all of the wagons, even after the effect of the falling gradient is taken into account. This was confirmed by calculations which showed that even if the braking effort provided by the two locomotives is removed, the remaining braking effort provided by the FSA and FTA wagons should still have been sufficient to stop the train before signal MC408.

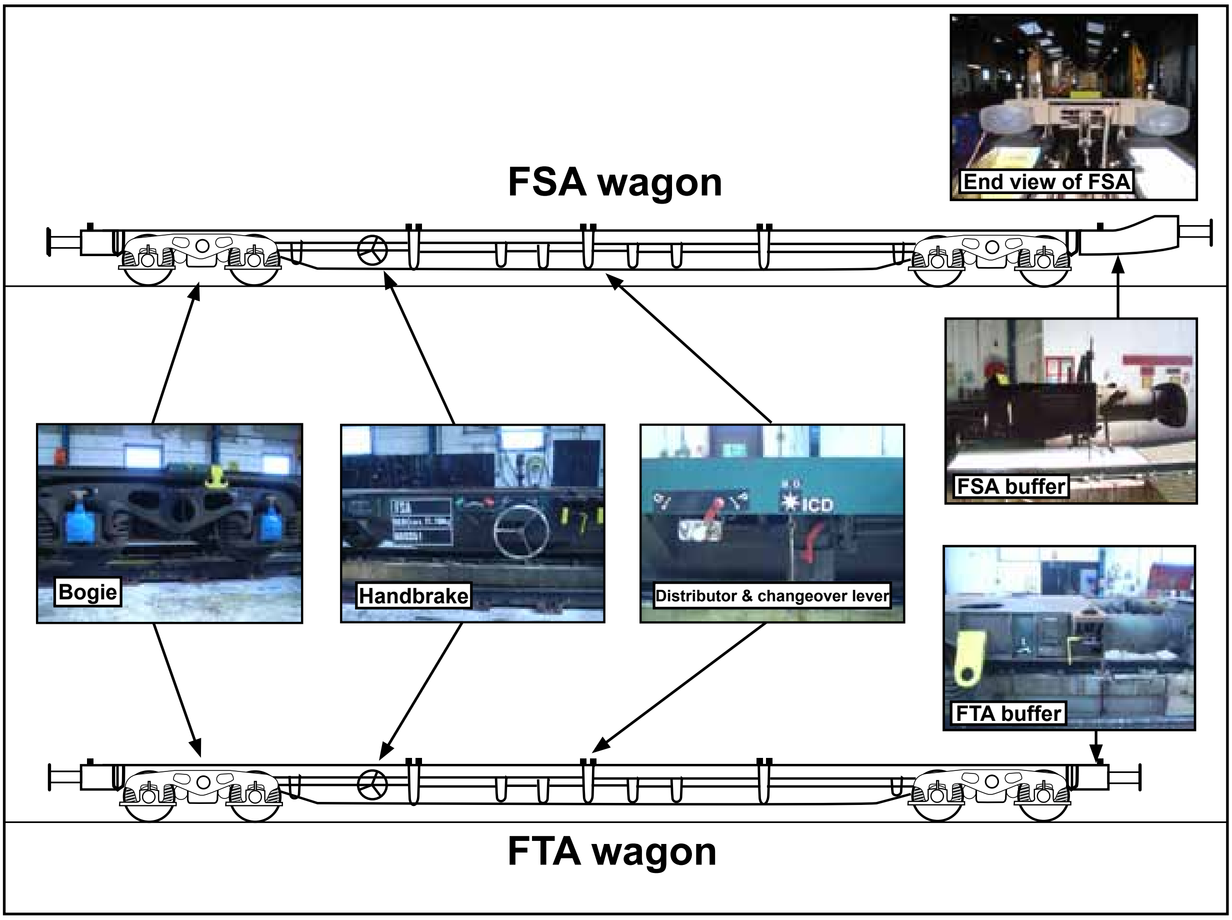


Figure 11: Side view of FSA and FTA wagons

52 The RAIB looked for previous similar events of poor braking performance involving this type of wagon but none were found.

Reasons for the absence or reduction in the train's braking forces

53 The absence or reduction in braking forces on the FSA and FTA wagons was caused by a combination of the following factors:

- **snow and ice ingress restricting movement of *brake rigging* and reducing the force that the brake pad applies to its brake disc (a probable causal factor); and**
- **a reduction in the coefficient of friction between the brake pads and the brake disc due to the ingress of snow/ice and water between them (a possible causal factor).**

Snow and ice restricting movement of the brake rigging

54 Each FSA / FTA wagon has eight independent sets of brake actuators, pads, discs and rigging, with two sets per axle, giving four sets per bogie. The failure of one set of brake rigging will have no effect on the other seven. Figure 12 shows the axle mounted discs and figure 13 shows the arrangement for one set of brake equipment.

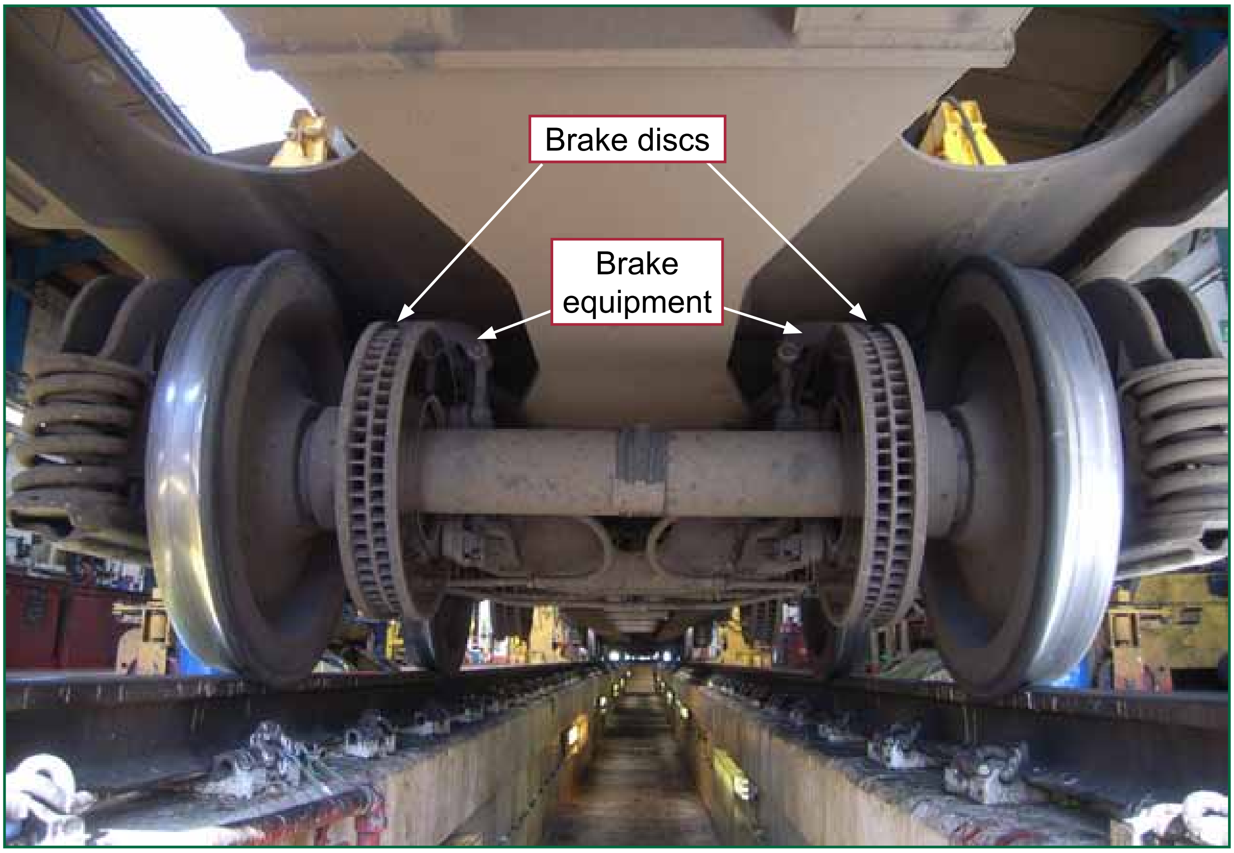


Figure 12: Brake discs mounted on one axle of an FSA/FTA wagon

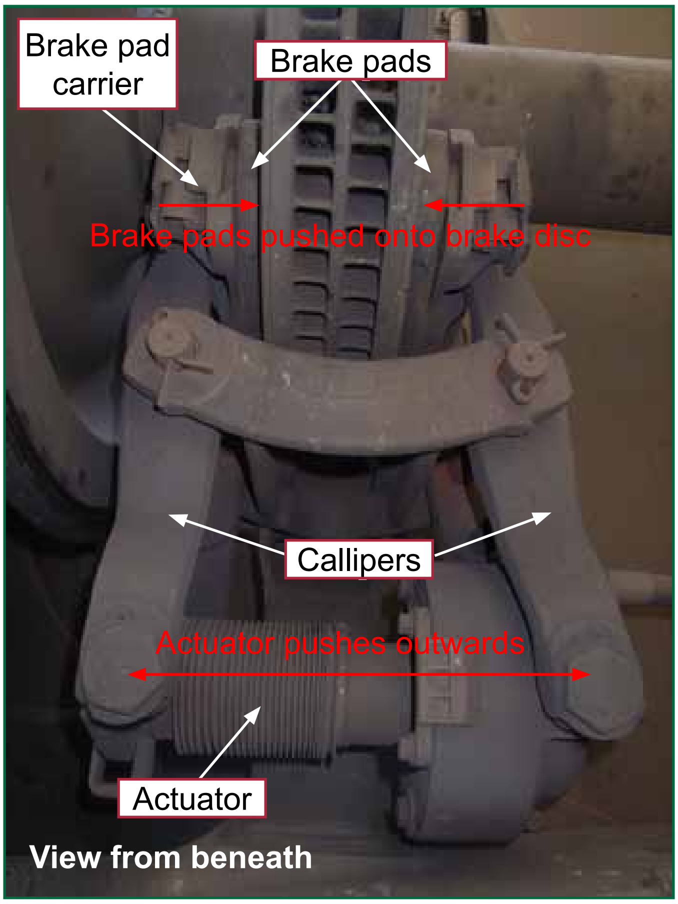


Figure 13: One set of brake equipment on an FSA/FTA wagon

55 When the brakes are to be applied, air is supplied to the brake actuator and it pushes a piston outwards. This outward force is transferred via a brake calliper assembly to push a pair of brake pads inwards and onto the axle mounted brake disc. Examination and measurements on two FSA and FTA wagons showed there was only a small amount of movement between the brake pads being in their released position, and in contact with the brake disc. The measured brake pad movement, ie the clearance between the brake pad and brake disc, was in accordance with Freightliner's maintenance standard MIE 07/FSA/01 (Vehicle Maintenance Instructions, FSA/FTA "Arbel" Container Wagons). A slack adjuster is also fitted to each brake actuator. This device automatically maintains the right amount of clearance by taking up any slack caused by the wearing of the brake pads. On the wagons that were examined, the outwards movement by the actuator piston was about 5 mm and this gave about 2 mm movement at the brake pads. If the movement of the brake callipers is restricted or limited, the amount of force that each brake pad then exerts on the brake disc is reduced, or in a worst case, the brake pad is held off completely.

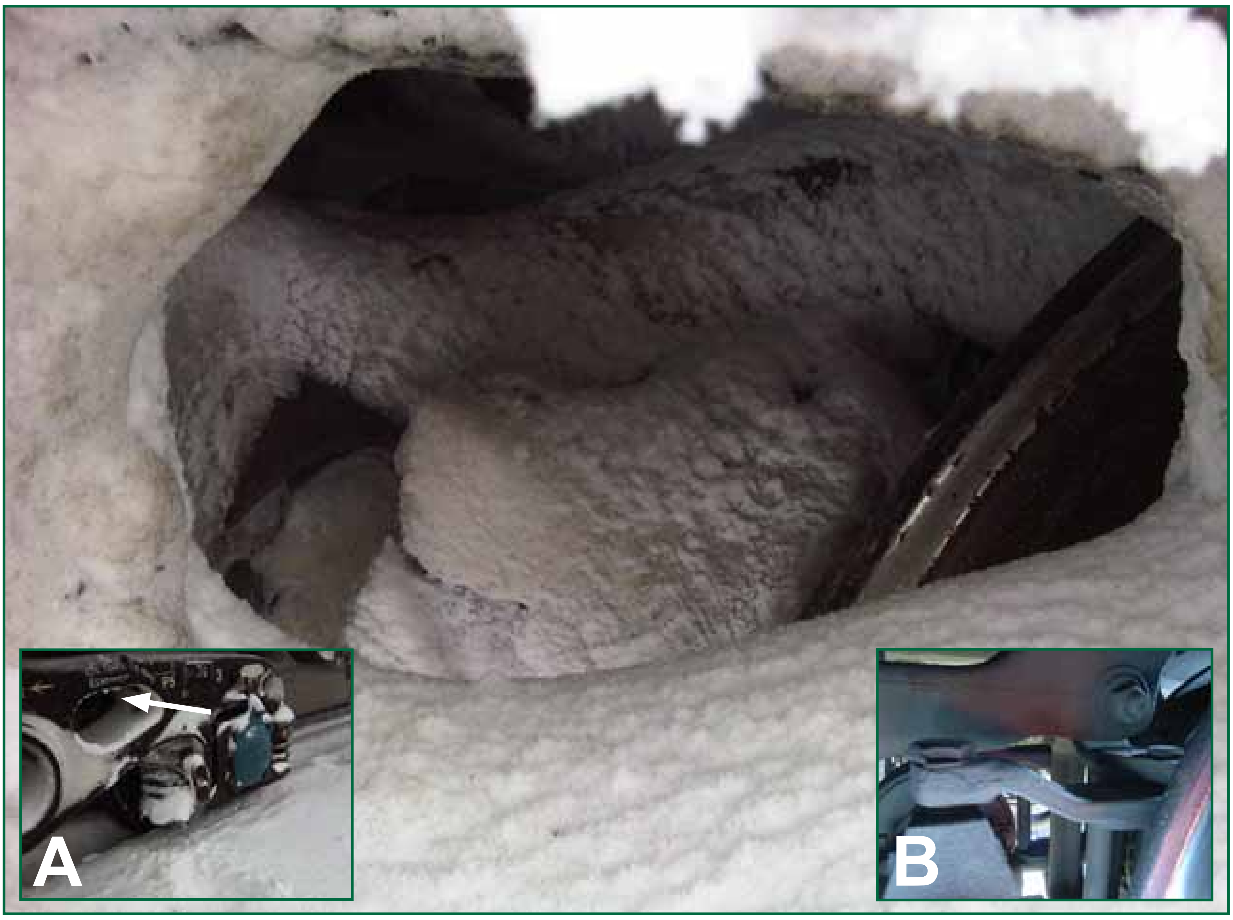


Figure 14: Snow and ice built up around the brake calliper assembly of a FSA/FTA wagon on train 4L81: inset image A shows an inspection opening in the side the bogie frame; the main image shows the view through this opening; and inset image B is the same view without snow and ice present (main image and inset image A courtesy of Davis Wagon Services)

56 The RAIB obtained accounts from the staff who examined the wagons 15 hours after the incident. These accounts and photographs indicate that there was a significant build up of ice and snow covering all brake callipers, pads and discs under each wagon. On about half of the brake sets there was compacted snow and ice within the frame of the brake calliper assembly. The remaining sets were not covered as much, so parts of the brake callipers and actuator were still visible. An example of this build up of ice and snow is shown in figure 14.

57 As these staff arrived some time later, what they saw may not have necessarily reflected the state of the brake equipment at the time of the incident. While the train had been standing at Carstairs, there had been occasional snow showers with light winds. However, the brake rigging is sheltered underneath the wagon frame, the bogie frame and behind the wheels, so it is unlikely that very much new snow would have blown under the wagons and collected on it after the incident. Therefore the condition of the brake rigging as seen afterwards was probably representative of its condition during the incident.

58 The staff that arrived about 36 hours after the incident to de-ice the wagons found that all of the brake pad and brake calliper assemblies were covered in varying amounts of ice and snow. Staff visually checked the application and release of the brakes on each wagon before and after de-icing them. Before de-icing, the movement of each set of brake rigging was reported as restricted and slow. Once the rigging had been freed from ice and snow, the brakes released and applied quickly and there was an audible ‘clunk’ when the brake pads made contact with the brake disc. This indicates that the iced up brake rigging was preventing the wagons’ brakes from working correctly.

59 Given the accounts and photographic evidence obtained by the RAIB, it is probable that compacted snow and/or ice were restricting the movement of the brake callipers.

60 It is also possible that the iced up brake rigging prevented the handbrakes on the FSA and FTA wagons from working properly. When the handbrake is applied, two of the brake calliper assemblies on the wagon are mechanically moved to push their brake pads onto their brake discs. As movement of the brake rigging was restricted, it is unlikely that staff applying the handbrakes after the incident would have generated enough force to fully push the brake pads against the brake discs. However, while the wagons were at Carstairs, the locomotives remained attached and it is likely that their *tread brakes* held the train in place.

61 The RAIB’s analysis of the train’s stopping performance showed that the train’s brake force progressively increased during the stop (see figures 9 & 10), which supports the hypothesis that the brake rigging movement was restricted. Heat would be generated by those sets of brake rigging where the brake pads were being pushed against the brake disc, albeit with a reduced amount of force. The brake disc is designed to expel this heat through its vents so snow and ice that had collected very close to it would be melted by a flow of warm air. Heat would also be directly radiated from the disc to melt snow and ice that had built up on the parts of the brake rigging mounted very close to it. As this snow and ice melts, it would allow further movement in the brake rigging. This in turn would increase the force with which the brake pad is pushed against the brake disc, with a corresponding increase in the brake force generated.

62 The balance of evidence suggests it is most likely that the movement of the brake rigging was restricted by snow and/or ice, and is therefore a probable causal factor.

Snow, ice and water between brake pads and brake discs

63 The accounts given to the RAIB state that there was snow and ice between the brake pads and discs on some of the wagons. Although these observations were made after the incident, as explained in paragraph 57, the amount of snow on and around the brake pads and disc was likely to be similar to that at the time of the incident. However, the amount of ice on the brake disc is unlikely to be similar, as the temperature remained below freezing all of this time so it is likely that fresh ice formed on the brake disc while the wagons were standing at Carstairs.

64 British Rail Research produced a report[6] in 1994 that considered the likely causes of incidents of poor braking performance by class 158 *diesel multiple units* in snowy conditions (paragraph 135). It concluded that their poor braking performance was primarily caused by water on the surface of the brake disc which reduced the coefficient of friction between the brake pad and disc. The report identified the source of this water as melted snow. Snow is able to enter various parts of the train to a greater degree than rain or water spray; snow flakes are much lighter than water droplets so can be carried much further on the air flows around the train. The effect of this water was made worse by the low pressure exerted by the brake pads on the brake discs. The FSA & FTA wagons are fitted with the same type of brake pad as used on the class 158 units but not the same type of actuator or calliper.

65 At different points during train 4L81's approach to Carstairs, snow, ice and water were all likely to have been present between brake pads and brake discs on the FSA and FTA wagons. As on the class 158 units, their presence could have reduced the coefficient of friction between the brake pad and the brake disc and caused poor braking performance. Also, the effect of this reduced coefficient of friction would have been more significant because of the restricted force being exerted by the wagons' brake pads on the brake discs, due to the build-up of snow and ice on the brake rigging (paragraphs 54 to 62), despite the driver making full service and emergency brake applications that should have resulted in the brake pad being fully pushed against the disc.

66 The train's brake force increased as the speed decreased as it approached Carstairs (figures 9 & 10). This suggests that something was changing during the brake application, to cause this increase in brake force. When train 4L81 began braking, it is likely that there would have been ice and possibly some snow between the brake pads and brake disc. These would have been melted by the pressure exerted by the pad on the disc and the heat generated by the brake pad rubbing against the brake disc. The findings in the British Rail Research report show that the initial rate of melting would have been slow due to the low brake pad to brake disc force (paragraphs 54 to 62) and the brake disc's very low starting temperature, but would have increased as more heat was generated.

[6] Braking under Winter Conditions, BR Research report LR-MEP-012, dated January 1994.

67 As the snow and ice melted, it is likely that it would have formed a thin layer of water on the brake disc. The British Rail Research report identified that a brake pad can ride on top of a film of water, thus giving a low coefficient of friction; this phenomenon is commonly referred to as aquaplaning. The report also identified that the rate at which this water is removed from between the brake pad and brake disc is slowed by several factors: the low pad to disc force, the low temperature of the brake discs and the water, and the reduced levels of natural evaporation in the cold conditions. All of these factors were present when the brakes on train 4L81 were applied. The report also states that slowly over time, the increasing heat and force generated will reduce the amount of water between the brake pad and the disc and the brakes will become more and more effective. This behaviour matches that of train 4L81.

68 The evidence suggests snow and ice, and consequently water, was likely to have been present between the brake pads and the brake discs on the wagons, which reduced the coefficient of friction between them, and therefore is a possible causal factor. This factor is consistent with the probable cause of ingress of snow and ice restricting the movement of the brake rigging. In reality, the cause of the train's poor braking performance was a combination of both factors.

Ingress of snow and ice

Snow and ice on the train while running

69 The ingress of snow and ice between the brake pads and brake discs or around the brake rigging has a probable common cause – the passage of train 4L81 between Mossend and Carstairs disturbing lying snow.

70 The ingress of snow and ice was most likely to have been caused by the disturbance of lying snow without direct contact by the train, ie turbulence. Studies[7,8] have shown that train shape affects how air flows form around the outside of a moving train. Freight trains, including container flat wagons such as the FSA and FTA wagons, create a lot of air turbulence as they do not have an aerodynamic shape. The amount of air turbulence also increases as the train's speed increases. A study[9] of higher speed train operations in snowy conditions states that at higher speeds, and with dry snow, clouds of snow will be created around the lower half of the train.

71 Due to the low air temperatures in the region, it is likely that the snow that fell that afternoon was dry and powdery with low moisture content. The turbulence caused by the passage of the train is likely to have easily disturbed this dry snow, which was lying to the height of the rail head, and entrained snow that was airborne: this cloud of snow around the train is able to enter various parts of it to a greater degree than rain or water spray (see paragraph 64). Through this mechanism, ice and snow build up can be considerable as seen in figure 14. This is also the experience of railways elsewhere, such as in Scandinavia.

[7] A study of the slipstreams of high-speed passenger trains and freight trains, M Sterling, C J Baker, S C Jordan and T Johnson, Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, Volume 222, Number 2 / 2008.

[8] Effective management of risk from slipstream effects at trackside and platforms, Rail Safety & Standards Board Research Programme - Engineering, Project 425, November 2007.

[9] High-speed train operation in winter climate, A study on winter related problems and solutions applied in Sweden, Norway and Finland, L Kloow & M Jenstav, Transrail - Sweden, July 2006.

72 The train's data recorder shows that after it departed from Coatbridge, it travelled at a relatively low speed for 9 minutes on its journey to Mossend, reaching a maximum speed of 37 mph (60 km/h). However, once it left Mossend, it reached much greater speeds. Therefore it is likely that the majority of ice and snow ingress probably took place after departure from Mossend. This is supported by the train stopping at Mossend without the ferry driver detecting any problems with the braking performance.

73 Just before the incident the train's speed reached 74 mph (119 km/h). The train was a class 4 freight train which was permitted to travel at speeds of up to 75 mph (121 km/h) on this part of the line. There was no restriction on the speed of this train in the snowy conditions.

74 The experience of rail operators in Scandinavia is that their faster services have much greater problems with snow and ice ingress, due to the increased amount of snow disturbance when running at higher speeds. Experience in North America indicates that snow and ice ingress is less of a problem for operators as their freight trains tend to travel at lower speeds and consequently disturb less snow.

75 Train 4L81 was likely to have disturbed a lot of lying snow that night due to the amount of turbulence the wagons would have created (paragraph 70), the snow conditions (paragraph 71) and the train's speed (paragraph 73).

76 The direct ingress of snow and ice onto the braking equipment was very unlikely. This is because the brakes are sheltered (paragraph 57) and the train had not been ploughing through the lying snow. Witness accounts indicate that the snow along the route was not deep enough for this to have occurred.

Snow and ice on the train before departure

77 A possible contributory factor was that there was snow and ice on or around the brake equipment before train 4L81 departed from Coatbridge.

78 The cold weather started in this area of Scotland on Friday 18 December and some snow had already fallen during the days before the incident. When the wagons that formed train 4L81 arrived in Coatbridge at about 06:30 hrs on the morning of 22 December, it is likely that some snow and ice had collected on their underframes during their inbound journey. There is no requirement to remove this snow or ice from under the wagons unless a problem has been reported with their operation. Neither the driver of the incoming service nor the ground staff who conducted the roll-by check as it arrived reported a problem. Temperatures were at or below freezing all day at Coatbridge so any snow and ice that was present would not have melted.

79 When train 4L81 was prepared, both the ground staff and ferry driver saw snow already underneath the wagons but they were unable to give an estimate as to how much there was. Any snow and ice around the brake pads, brake discs and brake rigging would not have been easily visible to them.

80 The driver and ground staff successfully carried out a brake continuity test and the train stopped without difficulty at Mossend. The ferry driver stated that he felt there was no problem with the train's brakes when he drove it. The RAIB's analysis of the train's performance for the stop at Mossend shows that, from the way the train's speed was controlled, the brakes were performing as expected.

81 It is likely that the snow and ice that was already on the brake equipment did not directly affect its operation during the first part of the journey. As explained in paragraph 72, the majority of ice and snow ingress almost certainly occurred between Mossend and Carstairs. However, the existing snow probably contributed to the incident as it required less new snow to cause a problem and the existing layer of snow and ice provided an ideal surface for fresh snow to stick to.

Discounted factors relating to the loss of braking

82 The analysis of the evidence discounted the following factors as having caused or contributed to the loss of braking. Further details of each factor are given in appendix D:

- the braking effort being provided by the class 86 locomotives being reduced;
- water in the braking system formed ice which led to a blockage restricting air flow;
- a loss of air from within the braking system;
- a low level of adhesion between the train's wheels and the rails; and
- snow and ice building up and its weight activating the cords attached to the bottom of the brake distributors.

Train speed

83 **The speed that train 4L81 approached Carstairs was a contributory factor, even though it was travelling below its maximum permitted speed.**

84 Train 4L81 was approaching Carstairs at 74 mph (119 km/h) when the driver began braking. If the train had been travelling at 68 mph (109 km/h) when it started braking, with the same braking performance it would not have passed signal MC414 at danger. Similarly, if the train had been travelling at 57 mph (92 km/h), it would have stopped before it reached signal MC408.

85 Also train 4L81's speed affected the amount of turbulence that it created, which in turn affected the amount of lying snow that it disturbed as it travelled along (paragraph 70).

The driver's understanding of the braking forces available to the train

86 **A causal factor was the way the driver applied the *running brake test* rules which meant he did not have a correct understanding of the brake forces available.**

87 In order to judge the braking performance of their train, drivers carry out a running brake test. In the Rule Book (Railway Group Standard GE/RT8000), section 3.16[10] of module TW3 sets out the running brake test requirements for drivers of locomotive-hauled trains. It states:

'You must test that the automatic brake is working properly. You must do this by carrying out a running brake test at the first opportunity after beginning the journey. You must, if possible, also carry out a running brake test in good time before approaching:

- *the first stopping place*

[10] At the time of the incident, section 3.16 of module TW3 was published in Rule Book module AM which contains amendments to other Rule Book modules in the GE/RT8000 series.

- *a crossing place on a single line where the train has to stop*
- *a steep-falling gradient*
- *a terminus or dead-end platform line.*

When you carry out a running brake test, you must do so from a speed that is high enough for you to be sure that:

- *the brake is operating effectively, and*
- *the speed of the train is being reduced.'*

88 The Rule Book also requires drivers to carry out additional running brake tests in snowy conditions so that they can regularly judge how their train's brakes are performing (see paragraphs 89 to 96). If the driver had regularly applied these rules and become aware that the available braking force was very low, it is likely that he would have applied his brakes earlier and slowed down on his approach to Carstairs. This factor is therefore considered to be causal.

Background on running brake tests in snowy conditions

89 Section 18 of Rule Book module TW1 explains what the driver is required to do when working trains during snow conditions. These instructions apply when 'snow is falling or fallen snow is being disturbed by the passage of trains'. Specifically, section 18.2 states:

'You must make a full service application of the automatic brake every three to five minutes and make sure that the speed of your train is reduced by at least 10 mph as a result of the application.

If driving a locomotive-hauled train, you can extend this interval when:

- *the train is climbing a steep-rising gradient, and*
- *the train might be brought to a complete stand as a result of using the brake.'*

90 The intent of this rule is to provide the driver with a way of detecting any loss of braking performance by regularly testing the brakes to ensure that they have not been rendered ineffective by snow or ice. Its application also helps to prevent any loss of braking in snow by frequently moving brake equipment (eg rigging) and generating heat at the interface between the brake pad and disc or between the brake block and wheel tread.

91 The rules for working trains in snowy conditions were introduced in the late 1980's after a number of incidents during the winter of 1986/1987 when trains experienced poor braking. The original rule asked drivers to make a brake application. A change was introduced in 1992 after further problems were experienced and tests showed that a full service brake application was needed to clear snow and ice from between the brake pads and brake discs. Following comments from the drivers of heavy freight trains about the practicalities of applying this rule, a further change was introduced in 1994. This allowed the drivers of locomotive-hauled trains to extend the interval between tests when on a steep rising gradient, if there was a chance that their train might be brought to a stand by carrying out the test at that location.

92 The current rule is open to interpretation by drivers. It relies on their judgement of what is a steep rising gradient, and there is also some ambiguity as to whether the disturbance of snow by trains includes the train that they are driving.

93 Freight train operations staff, at various grades which ranged from senior operations managers to drivers, felt that full implementation of the rule is not practical, especially for freight trains that run at speeds of 60 mph (97 km/h) or less and those that include wagons with long brake application and release times. As well as the risk of being brought to a stand, the rule has a big impact on a driver's ability to keep to time, as it may take some time for a freight train to regain 10 mph (16 km/h).

94 Class 86 locomotive design also makes the rule difficult to implement. The process of cutting traction, applying the brakes, observing a reduction in speed, releasing the brakes and then taking traction again can easily take over a minute to complete. Modern electric locomotives that are fitted with electronic control systems respond more quickly when the driver cuts or takes traction. Other types of locomotive also allow the driver to continue to take traction while a running brake test is carried out. Tests carried out by Freightliner have shown that if a class 86 locomotive-hauled train is on a rising gradient, its speed could be reduced by as much as 30 mph (48 km/h) instead of 10 mph (16 km/h) (paragraph 149).

95 Freight train driver managers indicated to the RAIB that there were likely to be low levels of compliance with the rule. While operators may test their drivers' knowledge of this rule, they do not carry out any monitoring or checks to see if it is being applied.

96 The RAIB found out that similar rules exist in other countries that operate trains in snowy conditions. In both Scandinavia and North America, it is common practice for drivers to carry out frequent running brake tests. However, the rules in these countries are not as prescriptive about the type and frequency of brake application as it is left to the judgement of the driver to satisfy himself that the train's brakes are still working correctly.

Long period without applying the brakes

97 A causal factor was that the driver went for a long period without applying the train's brakes.

98 Had the driver regularly made full service brake applications, he could have detected when the brakes were no longer operating efficiently. It is also likely that he would have generated heat in the brake pads and brake discs, so promoting the melting of ice and snow, and helping to keep the brake rigging free of ice and snow through regular movement.

99 The train's data recorder showed that after the train left Mossend at 20:04 hrs, the driver did not apply the train's brakes again until 20:22 hrs, which was when he saw a double yellow aspect on the signal close to the summit at Craigenhill.

100 Rule Book module TW3 section 3.16 (paragraph 87) did not require the driver to carry out a running brake test after taking the train forward from Mossend, as the ferry driver had carried out the train's post departure running brake test when he brought it into Mossend from Coatbridge. Some train operators have a driving policy that does require their drivers to carry out a running brake test after they take a train forward. They consider it good practice for the new driver to gain an understanding of how the train's brakes are performing. Freightliner does not have such a policy.

101 After leaving Mossend, the driver was required to carry out the additional running brake tests in accordance with module TW1 section 18 of the Rule Book (paragraph 89), as there were places where snow was falling, and his train was disturbing lying snow. However, the driver extended the interval between tests because the train was on a rising gradient throughout this part of the journey and he stated he did not want to risk it being brought to a stand. The railway climbs from Mossend via Law junction to Craigenhill with no long plateaux or downhill slopes, apart from a section about one mile long on the approach to Calder viaduct. Here there is a 40 mph (64 km/h) permanent speed restriction which continues over the viaduct. When the train reached the start of this section, the driver did not carry out a test as the train had accelerated slowly after leaving Mossend and its speed was only 30 mph (48 km/h). By the time the train reached the viaduct, it had accelerated to a speed of 40 mph (64 km/h) but the driver did not want to carry out a running brake test at this location as he would lose too much speed just as he was starting the climb up to Law junction.

102 The driver was also concerned about the wet rail head conditions (paragraph 15) which, if he took too much power, could cause *wheel spin*. Excessive wheel spin could cause a loss of traction on one of the locomotives, which would take him some time to regain. He would then lose a significant amount of speed on the rising gradient.

103 When the driver did apply the brakes for the first time, he felt the train slow down. The train's data recorder shows that the speed fell from 66 mph (106 km/h) to 60 mph (97 km/h). However, the train at this point was passing over the summit at Craigenhill, with its rear third still on a rising gradient of 1 in 190. By the time the driver released the brakes and took traction again, all of the train was over the summit and on a falling gradient. The RAIB calculated that most of this reduction in speed was due to a combination of the rising gradient acting on the rear third of the train and the brake force provided by the electric locomotives, with the wagons' brakes contributing very little to slowing the train.

104 This deceleration may have given the driver false confidence that his train's brakes were working and explains why the driver then accelerated to 74 mph (119 km/h) when he saw the next signal showing a green aspect.

The driver's understanding of the rule

105 **The driver knew the rule for carrying out running brake tests in snowy conditions and he understood the purpose of the rule. However, a probable causal factor was his interpretation of parts of the rule, which meant the likelihood of him carrying out these running brake tests was reduced.**

106 The driver's interpretation of the rule was that:

- He did not have to do a running brake test if the train was on any rising gradient and he needed to take traction in order to maintain the train's speed.
- It only needed to be applied when it was snowing or he was passing other trains that were disturbing snow that would be thrown up onto his train. He did not consider that snow 'being disturbed by trains' included snow disturbed by his own train.

107 As stated earlier (paragraph 92), the rule is open to interpretation. However, by interpreting the rule in this way, the likelihood of the driver doing these running brake tests was reduced and the risk of an incident happening increased. It is therefore most likely that a different understanding by the driver would have avoided the passing of signals MC408 and MC414 at danger. This factor is therefore considered to be probably causal.

108 Freightliner may test its drivers' knowledge of the rule as part of their rules assessment but it is not a mandatory question. Freightliner do remind drivers about what the rule for carrying out running brake tests in snowy conditions is as part of their pre-winter briefing. The driver received this briefing on 4 November 2009.

109 However, the driver's interpretation of the rule is not assessed. Other operations staff from within Freightliner interpreted the rule in a similar way when braking long freight trains on a rising gradient. They knew they had to be careful as there would be significant loss of speed, especially with class 86 locomotives (paragraph 94), and they may come to a stand and be unable to restart their train. Their interpretation of snow being disturbed by trains differed, as they considered that it did include snow disturbed by their own train.

110 Driving in snowy conditions is not specifically covered in Freightliner's driver training. The driver had driven in snow before but he had not experienced conditions similar to those on the night for a long time. Therefore he was not familiar with performing frequent running brake tests.

Discounted factors relating to the staff involved in the operation of the train

111 Train preparation, the driver's route and traction experience, and risk assessment for the train's route were discounted as factors that caused or contributed to the incident. Further details are provided in appendix D.

Identification of underlying factors[11]

The effectiveness of the Rule Book

Existing running brake test in snowy conditions

112 **The existing requirements for carrying out running brake tests in snowy conditions are not an effective preventive measure.**

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

113 As explained in paragraph 91, the rule relating to snowy conditions was relaxed in 1994 so that the drivers of locomotive-hauled trains, especially freight trains, could avoid stopping their trains on rising gradients. The RAIB has not found any guidance to assist these drivers in deciding when or where to carry out these tests or when to extend the interval between them. It is therefore left to individual drivers to interpret the rule for themselves. This means that some drivers can interpret it in a way that makes it no longer effective.

114 The RAIB has witness evidence indicating that some drivers increase the interval between tests substantially while climbing gradients, or do not carry them out at all, for fear of bringing their train to a stand or substantially slowing its progress.

An alternative approach

115 As a rising gradient is quite often followed by a descending gradient, it is evident that one of the most important places to carry out such a test is before starting the descent. If running brake tests have not been carried out while climbing, the condition of the brake equipment may have deteriorated because of snow and ice ingress. In such circumstances the driver will not be aware of a problem until the brakes are applied. By applying the brakes at the summit, a driver can detect if there is a problem before the train's speed starts to increase and will have more time to stop.

Speed restrictions in snowy conditions

116 **There are currently no general speed restrictions in module TW1 of the Rule Book, for freight trains operating in snowy conditions, that might reduce snow disturbance or mitigate loss of braking capability.**

117 Section 18 of Rule Book module TW1 states the instructions for working trains when snow is falling or fallen snow is being disturbed by the passage of trains. Section 18.3 only applies to trains that are normally permitted to run at speeds greater than 100 mph (161 km/h) and 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.'*

118 The application of this rule means that if the permissible line speed is 75 mph (121 km/h), then passenger trains that normally run at speeds of more than 100 mph (161 km/h) will be restricted to a speed of 65 mph (105 km/h). However, there is an anomaly in that other trains, such as freight trains with a maximum permitted speed of 75 mph (121 km/h), will still be permitted to run at 75 mph (121 km/h) over the same section of railway. As a result this rule does not apply any speed restrictions to freight trains in snowy conditions.

119 In Network Rail's Scotland Route *sectional appendix*, speed restrictions are applied to one type of rolling stock in freezing conditions, when snow is falling or when snow is being disturbed by wind or the passage of trains. Following previous problems with class 158 diesel multiple units having difficulty stopping in freezing or snowy conditions (paragraph 135), drivers of these trains are required to limit their speed in such conditions. They must drive at a maximum of 75 mph (121 km/h) or 10 mph (16 km/h) below the permissible speed on the section of line, whichever is lower. There is no need to reduce the speed below 50 mph (80 km/h). A similar rule in section 7 of Rule Book module TW2 is applied during snow conditions by the drivers of multiple unit passenger trains conveying disc-braked vehicles. Again the driver must restrict the train's speed to 10 mph (16 km/h) below the permissible speed for the train over each portion of the line, but there is no need to reduce the speed below 50 mph (80 km/h). There are no similar restrictions that apply to freight trains.

120 During adverse weather, Network Rail can implement blanket speed restrictions on parts of its network. The process for managing extreme weather events is documented in Network Rail's company standard NR/L2/OPS/021, Weather – Managing the Operational Risks. Any such speed restrictions would apply to all trains.

121 Train operating companies can also decide to place a speed restriction on their own trains. The RAIB are aware of one train operator which, on one day during the winter of 2009/2010, placed a unilateral speed restriction of 100 mph (161 km/h) on its trains on some Scottish routes due to snow and ice. However, this type of unilateral decision is entirely at the discretion of the operator and it is very unusual for an operator to do this. The RAIB are not aware of any train operating companies applying any restrictions to the speed of their trains on 22 December 2009.

122 The RAIB found there were no rules or procedures in place to limit the speed of freight trains such as train 4L81 in snowy conditions. If train 4L81 had been travelling at a lower speed, evidence suggests that it would have disturbed less snow, reducing the likelihood of snow ingress. Also in the event of a loss of braking performance, the train would be at less risk.

Trains entering into service with snow and ice on them

123 **Trains can enter into service with snow and ice already on or around their brake equipment.**

124 Freight operating companies in the United Kingdom do not take any specific measures to mitigate the effects of cold weather, although those measures mentioned above that relate to speed of operation (paragraphs 120 and 121) could be applied.

125 The RAIB found that Freightliner does not require its staff to check the amount of snow or ice that has built up on a wagon, either upon arrival or departure from a terminal, or while in service. The RAIB looked at practices followed in other European countries and in North America. None of these countries prescribe set limits for the amount of snow that can be allowed to build up. In some countries such as Sweden, it is left to train staff to assess the amount of snow and ice and then make a judgement as to what effect it might have and whether any action needs to be taken.

126 Freightliner staff will take action to remove snow or ice from a wagon but only after a problem has been reported with its operation. Staff will not routinely de-ice wagons as there is no requirement to do it as part of Freightliner's daily examination instruction or as part of a train's preparation. However, the staff must be able to see the components that are being examined and the train preparer must be able to check the applied and released positions of the brakes on the rear wagon when a brake continuity test is carried out.

127 Train operators in some European countries de-ice their vehicles periodically. These operators tend to maintain their vehicles more frequently in the winter months as certain components can be adversely affected by cold and although de-icing is not regarded as a normal maintenance activity, it is considered to be important since it allows maintenance checks to be carried out. Some have facilities to de-ice vehicles by blowing warm air on them or by spraying the underside with warm water or de-icing agents. At the time of the incident there were no such facilities in the United Kingdom to de-ice trains. However, during the winter of 2010/2011, First ScotRail has been using polythene sheet tunnels with warm air blowers to de-ice their passenger trains and has also been applying a de-icing agent to the underneath of their trains. When the train was de-iced at Carstairs, staff manually applied a de-icing agent and then used tools to remove the remaining snow and ice. Experience shows that the mechanical removal of ice is time-consuming, expensive and has the potential to cause damage to the vehicle, so its use tends to be very limited. However, recent guidance does suggest that freight operators should make an effort to remove snow and ice from the brake equipment on wagons before they enter service (paragraphs 151 and 152).

128 Based on the evidence found, wagons will enter into service with snow and ice already on them, and some of this snow and ice will be on or around the brake equipment. Freightliner's approach is not only consistent with the norm for operating in the United Kingdom, as it also matches that of railways which operate in winter conditions that are far more severe.

Other occurrences of a similar character

129 The RAIB searched for similar incidents in the United Kingdom but none were found that involved freight trains. The primary sources that were searched were national rail industry systems, including one for recording safety related events and another for reporting rolling stock equipment failures and issues. There is anecdotal evidence of previous events where drivers have had a poor or delayed response from their train's brakes in snowy conditions, but these events resulted in little or no consequence so went unreported. However, since this incident, there have been two similar occurrences on the railway line between Aviemore and Inverness.

130 An accident occurred on 4 January 2010, involving a freight train from Inverness to Mossend yard, formed by a class 66 locomotive and ten *twin wagons* carrying containers. It passed a red signal on the single line while approaching Carrbridge station on a steep falling gradient. It continued for another 500 metres before running into a loop and onto a short length of track designed to divert trains away from the station (this is known as a 'run out'). When still travelling at about 60 mph (97 km/h) the locomotive and the first wagon overshot the end of the run out and came to rest down an embankment, with the next five vehicles coming to rest at various angles across the loop and the main line. The driver, and a technician who was travelling with the train, both received minor injuries. Major damage was caused to the railway infrastructure. The weather at the time was poor, with a layer of snow over the head of the rail, heavy falling snow and temperatures around freezing. This accident is the subject of a RAIB investigation which is shortly to be published. It too has identified issues relating to snow and ice ingress affecting the operation of brake equipment and the driver's application of the rules for running brake tests in snowy conditions.

131 On 25 February 2010, a second incident occurred involving a freight train with poor braking performance. This train was a service from Mossend yard to Inverness and again was formed by a class 66 locomotive and twin wagons carrying containers. As the train passed over Slochd summit on the single line between Carrbridge and Inverness and began its descent, the driver carried out a running brake test but the train did not slow down and stop as expected. It ran for about 2.5 kilometres, under green signals, before coming to a stand. Again the weather was poor, with heavy falling snow and temperatures around freezing.

132 On 22 December 2010, a further incident occurred at Stafford in snowy conditions when a freight train passed a red signal by about 180 metres. This train was a Freightliner service from Trafford Park to Felixstowe and was formed by 20 FSA and FTA wagons plus 2 FEA wagons. As the train approached Stafford, the driver made an initial brake application but the train did not slow down as expected. When the driver made an emergency brake application, the train's braking performance improved but not in time for it to stop before the signal. Initial investigations by Freightliner found that the driver had carried out running brake tests by making initial brake applications, rather than the full service brake applications as required by the Rule Book. This had allowed snow and ice to accumulate on the brake callipers, pads and discs which then led to a loss of braking performance.

133 Previous incidents involving passenger trains with poor braking performance in snowy and freezing conditions were found. In 1986, a passenger train formed of coaches with disc brakes overran Carlisle station. An investigation of this incident by British Rail concluded that the brake discs had been coated with ice and that this had prevented the pads from contacting the discs when a brake application was first made. After this incident, the rule book was changed so that drivers were required to carry out additional running brake tests in snowy conditions.

134 In 1987, during the same winter, a locomotive-hauled passenger train with tread braked coaches overran Burton-on-Trent station. The underframes on the coaches were heavily contaminated with compacted ice and snow. It had departed from Birmingham New Street station and ran without braking for about 25 minutes prior to the incident.

135 During the winter of 1990/1991, a series of station overruns occurred in Scotland involving class 158 diesel multiple units. A British Rail investigation report[12] stated that the poor braking performance was due to snow on and around the brake mechanism. The brake performance was much worse when there had been no recent applications so the brakes were cold. It also reported on tests that assessed the effect of carrying out running brake tests at intervals of two minutes. These tests showed that full service brake applications kept the brakes working when the time came to stop the train, whereas initial brake applications did not. The report recommended that the Rule Book be changed so drivers make a full service brake application when carrying out a running brake test in snowy conditions. It also led to entries being made in the Scottish sectional appendix for this type of unit (paragraph 119).

136 More recently, on 20 December 2010, an incident occurred in snowy conditions at Uphill junction, near to Weston-super-Mare when a passenger train passed a red signal by about 375 metres and ran through a set of *trailing points*, causing damage to them. This train was a service from Newton Abbot to London Paddington and was formed by a High Speed Train (HST) which has coaches that are fitted with brake pads and discs. The train's data recorder showed that the driver did not correctly carry out the instructions in Section 18 of module TW1 of the Rule Book relating to braking in snow conditions. While the driver did carry out running brake tests at the required frequency, he did not make a full service brake application and reduce the train's speed by at least 10 mph (16 km/h). After this incident the train operating company reissued a notice to its drivers which mandated them to comply with the full requirements of the rules in Section 18 of module TW1 whenever there was snow lying on the ground. This was in addition to the requirement for drivers to apply these rules when snow is falling or fallen snow is being disturbed by the passage of trains. This notice was later withdrawn when the weather conditions improved.

137 The RAIB also searched for events that have happened in Europe and North America involving poor braking performance in snowy and icy conditions. Information was sought from the European Rail Agency, national railway authorities and consultants based in Europe and North America. The following events were found:

- Grande Cache subdivision, Alberta, Canada, January 1994 – a freight train began to run away as it travelled on a falling gradient towards a 10 mph (16 km/h) permanent speed restriction area. All attempts by the driver to slow the train failed and when the train reached a speed of approximately 28 mph (45 km/h), the train crew abandoned the train. The unmanned train negotiated the 10 mph (16 km/h) speed-restricted area and eventually came to a stop several miles later. The weather was very cold and a snow storm had just passed through the area. The loss of control occurred because running brake tests had not been carried out periodically to nullify the effects of snow and ice build-up on the brake shoes, and because the *dynamic braking* system was inoperative.

[12] Class 158 Braking Performance in Winter, TME 170-430-17(MDW), 8 May 1991.

- Jasper, Alberta, Canada, January 1999 – a freight train ran away on a falling gradient on the approach to Jasper yard. It collided with a stationary locomotive in the yard. The driver was unaware that the dynamic brake was not operational on one of the locomotives. The train had passed through deep blowing snow on the approach to Jasper but the driver did not make repeated initial brake applications to clear snow and ice from between the wagons' brake blocks and wheels.
- Lillestrøm station, Norway, April 2000 – a freight train with poor braking passed a number of signals at danger and collided with another train. Ice obstructing the brake pipe was ruled out as a cause and instead it was concluded the cause was a driver error that reduced the train's braking performance to very low levels. However, the accident led to a number of recommendations being made about how drivers should test their brakes when in service.
- Kiruna, Sweden, 2000 – a freight train was being shunted out of a mine when its brakes failed to stop it. It passed a signal at danger and collided with another train entering the mine. It was snowing at the time of the accident and had been snowing previously. Snow on the wagons melted when they entered the mine and then froze to ice when the wagons left the mine and met the colder air. Immediately after the accident, staff observed a thin ice layer on virtually all of the brake blocks which was not present when the brake test was carried out.
- Ope, Jämtland, Sweden, October 2002 – a passenger train, which consisted of a locomotive and two tread braked coaches, passed a signal at danger which led to a near miss with another train. When the train began braking, its wheels slid on slippery rails that were covered in ice. This is an example of snowy and icy conditions causing poor adhesion between the train's wheels and the rails.
- Dietlikon, Switzerland, January 2004 – a freight train with poor braking, caused by ice, passed a signal at danger and collided with a passenger train. Tests found that when the brakes were frozen in ice, they gave no braking effort when initial brake applications were made. To overcome the effects of the ice, brake applications that produced a higher brake actuator pressure were required, as these freed the brake rigging and applied the brakes.
- Gårdsjö, Sweden, February 2005 – a passenger train passed a signal at danger because two ice plugs in the brake hose between the locomotive and the first of the train's carriages had drastically reduced its braking performance. It then became worse as the outside temperature fell. The driver's driving style contributed as he made early and gradual brake applications which meant the extent of the problem was detected much later than it could have been. This incident led to a recommendation relating to carrying out regular brake tests and how they are done.

Severity of consequences

Other train movements

138 The poor braking performance of train 4L81 caused an operating incident: two signals were passed at danger. Under slightly different circumstances, it could have led to a collision between trains. Train 1S17 crossed in front of train 4L81 and moved clear of the point at which the trains would have collided just 75 seconds before train 4L81 arrived at it. Train 2Y99 was also approaching Carstairs and was to be allowed across the path of train 4L81. Fortunately the incident happened before train 2Y99 was signalled across Carstairs Station junction.

Actions of the signaller

139 The signaller took timely action and used the controls on his panel to change the position of two sets of points, P311 and P312, in front of train 4L81 (figure 15). His actions kept it on the WCML route, thereby preventing it from taking the low speed diverging route onto the Carstairs Curve. This had three effects on the consequences:

- Firstly, it stopped the train running through and damaging a set of trailing points, P311, which would have been in the wrong position.
- Secondly, it removed the risk of train 4L81 derailing on the *facing points*, P312. The divergence onto the Carstairs Curve has a maximum speed of 15 mph (24 km/h). The train's data recorder showed that it was travelling at 20 mph (32 km/h) when it reached this point. Therefore the risk of an actual derailment was very small but could have been much greater had the train reached the points at a higher speed.
- Thirdly, it removed the risk of train 4L81 running away towards train 2Y99 that was moving onto the Carstairs Curve from the opposite direction. Train 2Y99 had been signalled to travel as far as signal MC418 on the single line, which is located 444 metres from P312 points. Train 4L81 stopped about 135 metres after passing over the points. Therefore the risk of an actual collision was very small but could have been much greater under slightly different circumstances.

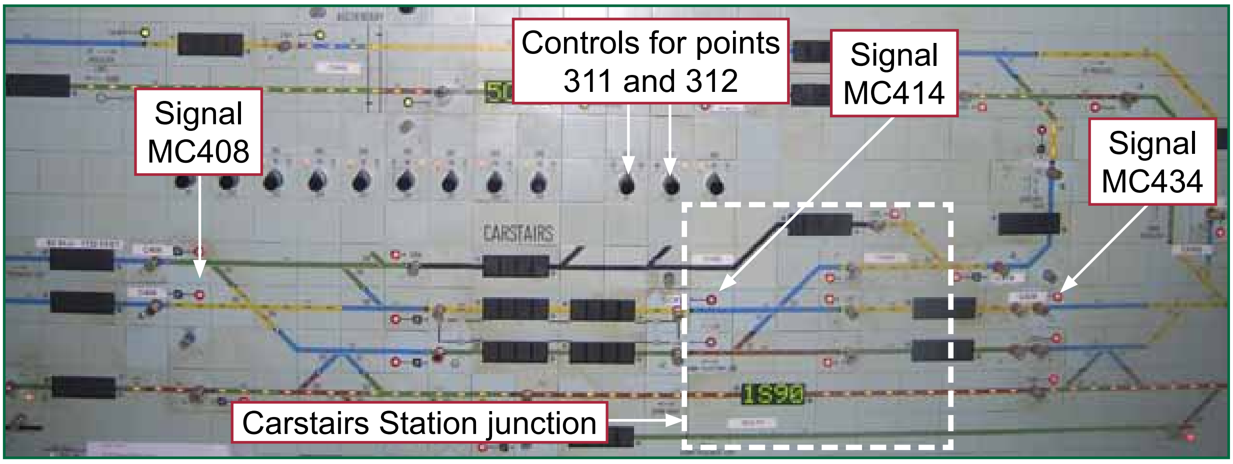


Figure 15: Carstairs area on the signaller's panel at Motherwell

Summary of Conclusions

Immediate cause

140 The immediate cause of the near-miss incident was that train 4L81 had a significantly reduced braking performance and therefore passed both signals MC408 and MC414 at danger (**paragraph 40**).

Causal factors

141 The absence or reduction in braking forces on the FSA and FTA wagons was caused by a combination of the following factors:

a. snow and ice ingress restricting movement of brake rigging and reducing the force that the brake pad applies to its brake disc (a probable causal factor) (**paragraphs 53 and 62, Recommendations 2 and 3**); and

b. a reduction in the coefficient of friction between the brake pads and the brake disc due to the ingress of snow/ice and water between them (a possible causal factor) (**paragraphs 53 and 68, Recommendations 2 and 3**).

142 The other causal factors were:

a. the way the driver applied the running brake test rules which meant he did not have a correct understanding of the brake forces available (**paragraph 86, Recommendation 1**); and

b. the driver went for a long period without applying the train's brakes (**paragraph 97, Recommendation 1**).

143 It is probable that the following factors were causal:

a. the passage of train 4L81 between Mossend and Carstairs disturbing lying snow (**paragraph 69, Recommendations 2 and 3**); and

b. the driver's interpretation of parts of the rule for carrying out running brake tests in snowy conditions meant the likelihood of him carrying out these running brake tests was reduced (**paragraph 105, Recommendation 1**).

Contributory factors

144 The contributory factor was:

a. the speed that train 4L81 approached Carstairs, even though it was travelling below its maximum permitted speed (**paragraph 83, Recommendations 2 and 3**).

145 It is possible that the following factor was contributory:

a. there was snow and ice on or around the brake equipment before train 4L81 departed from Coatbridge (**paragraph 77, no recommendation**).

Underlying factors

146 The underlying factors were:

a. the existing requirement for carrying out running brake tests in snowy conditions is not an effective preventive measure (**paragraph 112, Recommendation 1**);

b. there are currently no general speed restrictions in snowy conditions in module TW1 of the Rule Book, for freight trains operating in snowy conditions, that might reduce snow disturbance or mitigate loss of braking capability (**paragraph 116, Recommendations 2 and 3**); and

c. trains can enter into service with snow and ice already on or around their brake equipment (**paragraph 123, no recommendation, see paragraphs 151 to 152 for details of actions already taken**).

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

147 On 29 December 2009 Freightliner issued a notice to its drivers which reminded them about the rule for carrying out running brake tests in snowy conditions. All Freightliner drivers were briefed and signed that they had received the notice.

148 On 4 January 2010 Network Rail issued an urgent operating advice asking all train operators to remind their drivers of the instructions in module TW1 section 18 of the Rule Book. This was in response to the prolonged spell of extreme cold weather that was affecting the whole network, this incident at Carstairs, and a subsequent accident at Carrbridge (paragraph 130).

149 Freightliner carried out its own investigation and recommended that 'GE/RT8000 (Rule Book) clause TW1 18 is reviewed with regards to snow affecting vehicles'. Freightliner has also carried out trials to assess how practical it is to carry out running brake tests on class 86 hauled trains when on a rising gradient. These tests showed that the speed of these trains can be reduced by as much as 30 mph (48 km/h) after completing a running brake test. Large reductions in speed like these not only limit how often running brake tests can be done, but they can also reduce the train's speed to a point where a problem such as wheel spin can then cause the train to stall on the rising gradient.

150 Freightliner raised the issue of carrying out additional running brake tests in snowy conditions at the Rail Freight Operations Group meeting. The attendees at the group's meetings are senior operators representing all the freight operating companies, together with attendees from the Rail Safety and Standards Board and the Office of Rail Regulation. The group set up a small working party to formulate instructions to amplify the rules and provide guidance, with the aim of issuing a code of practice for freight operators to follow. In October 2010, the Rail Freight Operations Group issued this guidance as an approved code of practice[13]. It offers specific guidance for drivers about testing the operation of their train's brakes in snowy conditions and offers general guidance to freight train operators on how to minimise the risk associated with their operations in winter weather conditions.

[13] Operation of Freight Services in Winter Conditions, Rail Freight Operations Group Approved Code of Practice 001, RFOG ACoP 001, Issue 1, dated November 2010.

151 The Rail Freight Operations Group approved code of practice also includes general guidance on preparing for operation in winter conditions and includes a section on train preparation. In this section, it asks for freight operators to consider including the guidance within their company operating arrangements. Paragraph 3.3 states:

'Whilst preparing the train the train preparer must pay particular attention to any build up of snow or ice on vehicle brake:

- *rigging*
- *actuators or brake cylinders*
- *discs / pads*
- *distributor release mechanisms.*

Should any build [sic] of snow or ice be observed, every effort must be made to ensure that this is removed before the train enters service.'

152 The removal of snow and ice from around the brake equipment before departure as stated in this guidance reduces the likelihood of a problem being encountered when in service. This is because it increases the amount of time or amount of fresh snow ingress that is required for critical components to be affected (paragraphs 77 to 81).

Recommendations

153 The following recommendations are made:[14]

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[15]. 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 (paragraphs 142a, 142b, 143b and 146a).

continued

[14] 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 www.raib.gov.uk.

[15] The RAIB's investigation of the accident at Carrbridge (paragraph 130) will make recommendations about operating locomotive-hauled trains over steep gradients.

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.*

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 (paragraphs 141a, 141b, 143a, 144a and 146b).

3 *The intent of this recommendation is to address an anomaly in the Rule Book which requires trains that can travel at more than 100 mph (161 km/h) to reduce their speed by 10 mph (16 km/h) below the permissible line speed (down to a minimum of 50 mph (80 km/h)), which does not apply to other trains, including freight trains, that can run at speeds above 50 mph (80 km/h).*

Freight operating companies in conjunction with the Rail Safety and Standards Board should make a proposal to modify the existing arrangements in section 18.3 of module TW1 of the Rule Book, by making this rule applicable to all trains (paragraphs 141a, 141b, 143a, 144a and 146b).

Appendices

Appendix A - Glossary of abbreviations and acronyms

AC	Alternating Current
CCTV	Closed Circuit Television
HST	High Speed Train
RSSB	Rail Safety & Standards Board
TOPS	Total Operations Processing System
TPWS	Train Protection and Warning System
UIC	International Union of Railways (Union Internationale des Chemins de Fer)
WCML	West Coast Main Line

Appendix B - Glossary of terms

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

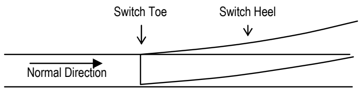
%g	The value of a deceleration expressed as a percentage of that achieved by a freely falling object, which is taken to be 9.81 m/s^2.
Bogie	An assembly of two wheelsets in a frame which is pivoted at the end of a long vehicle to enable the vehicle to go round curves.
Brake actuator	A device which converts an air pressure input into a mechanical force which is proportional to the air pressure applied. When air pressure is applied, a piston extends which is connected to the brake rigging and when air pressure is reduced a return spring retracts the piston.
Brake continuity test	A test to confirm the application and release of brakes on the locomotive and other rail vehicles in a train when demanded by the driver.*
Brake distributor	The pneumatic component of the train air braking system that responds to changes in brake pipe pressure and initiates charging of the brake actuators.
Brake pipe	A pipe running the length of a train that controls, and sometimes supplies, the train's air brakes. A reduction in brake pipe air pressure applies the brakes.
Brake rigging	Mechanical arrangement of links and levers connecting the brake actuators to the brake pads.
Container flat wagon	Long low ladder chassis fitted with bogies and equipment to secure standard shipping containers.*
Data recorder	Equipment fitted on-board the train which records the train's speed and the status of various controls and systems relating to its 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.
Diesel multiple unit	A train consisting of two or more vehicles, semi-permanently coupled together, with a driving cab at each end. Some or all vehicles are equipped with axles powered by one or more diesel engines.
Dynamic braking	Collective term for braking systems using the traction motors of the traction units to act as generators which provide the braking effort. The power generated during braking is dissipated either as heat through on-board resistors, called rheostatic braking, or by returning it to the traction supply, called regenerative braking.*

Emergency brake application
The (abnormal) full application of all available braking effort, sometimes using a more direct and separate part of the control system to signal the requirement for a brake application than that used for the full service application. On certain vehicles, the retardation rate may be specified to be higher than that of the full service braking application.*

Emergency call
A direct call, which is given a high priority, that can be made by a network controller to the driver of a specific train over a dedicated radio network operated and maintained by Network Rail.

Equivalent brake 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.

Facing points
A set of points installed so that two or more routes diverge in the direction of travel. Traffic travels from switch toe to switch heel in the normal direction of traffic.*



Four aspect colour light signal
Railway signal which uses four coloured lights to indicate whether the driver has to stop, needs to be prepared to stop or can proceed without restriction. The lights may show:

Green - proceed, the next signal may be displaying green or double yellow.

Double yellow - caution, there are two signal sections to the stop signal, the next signal may be displaying a single yellow.

Single yellow - caution, the next signal may be displaying a stop signal.

Red – stop.

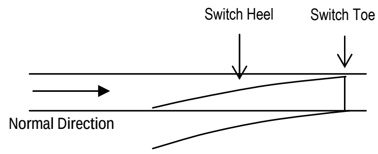
Full service brake application
A full (non-emergency) brake application.*

Initial brake application
A minimum brake application, when there is only a small reduction in the brake pipe pressure.

International Union of Railways (also known as Union Internationale des Chemins de Fer)
An international organisation formed in 1922 comprising a union of various railway companies and administrations. It agrees common standards and practices.*

Loop
A short length of track connected to another line at both ends.

Milepost
A coloured (generally yellow) post placed at one mile intervals along a railway. Intervening quarter-mile intervals (quarter, half and three quarter) are also similarly marked. Often, the quarter, half and three quarter are indicated by one, two or three symbols such as dots, triangles or lines.

Notices	A means of providing train drivers with information of a short-term or emergency nature at the time they commence their driving shift.*
Overcharge	Applying additional pressure through the air brake system to facilitate the release of all brakes.*
Permissible speed	The maximum speed at which trains may safely negotiate a section of track, as published in the sectional appendix.*
Rail head	The bulbous upper part of a rail section.*
Roll-by check	A check that is carried out by a nominated competent person when the train is being shunted into the terminal. Each wagon is monitored for audible as well as visual defects or irregularities which may not become apparent when the vehicles are at a stand eg skidding wheels, excessive flats, roller bearing faults, excessive heat etc.
Running brake test	A brake test performed by the driver whilst the train is in motion.*
Sectional appendix	An operating publication produced by Network Rail that includes details of running lines, permissible speeds, and local instructions.
Set of points	An assembly of two movable rails, the switch rails, and two fixed rails, the stock rails. Also known as a set of switches. Used to divert vehicles from one track to another.
Tonne	A standard unit of mass used as a non-standard unit of force, equivalent to about 9.8 kilonewtons. It is often called simply “tonne” or “metric ton” without identifying it as a unit of force.
Track circuit block	A signalling system where the line beyond each signal is automatically proved clear to the next signal, and sometimes beyond it, using track circuits. Track circuit block can also be implemented using any automatic train absence detector system.*
Trailing points	A set of points where two routes converge in the normal direction of traffic, eg traffic normally travels from switch heel to switch toe.* 
Train Protection and Warning System	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. It will also automatically apply a train’s brakes if it is travelling too fast on the approach to certain speed restrictions and buffer stops.
Tread brake	An arrangement in which a brake block bears on the tyre of the wheel.*

Twin wagons	Two wagons operated as a pair, with a semi-permanent bar coupling between them and conventional drawgear on raised headstocks at the outer ends.
Up	The name in the report given to lines used by trains travelling in the direction of London.
Wheelset	Two rail wheels mounted on their joining axle.
Wheel spin	The turning force applied to the wheel greatly exceeds the opposing friction force between the wheel and the surface of the rail, causing the wheel to turn but without being able to move the train forward. This can happen if the driver applies too much power to the wheels.

Appendix C - Key standards

Current at the time of the incident:

GE/RT8000/AM, Issue 9	Rule Book Module AM, Amendments module
GE/RT8000/TW1, Issue 8	Rule Book Module TW1, Preparation and movement of trains, General
GE/RT8000/TW3, Issue 2	Rule Book Module TW3, Preparation and movement of locomotive-hauled trains (including HSTs, push-pull, postal, parcels)
GM/RT2043, Issue 1	Railway Group Standard, Braking System and Performance for Freight Trains
GO/RM3056, Issue 2	Railway Group Standard, Working Manual for Rail Staff Freight Train Operations
MIE 07/FSA/01, Issue 1, Rev B	Vehicle Maintenance Instructions, FSA/FTA “Arbel” Container Wagons, dated February 2003
MIE 0718, Issue 1, Rev C	Freightliner Winterisation Procedure: Traction and Rolling Stock, dated 18/10/2007
MIE 0727, Issue 1, Rev G	Freightliner Examination and Attention to Freightliner Intermodal and Heavyhaul Trains, dated 17/06/2009
NR/L2/OPS/021, Issue 2	Network Rail’s company standard Weather – Managing the Operational Risks

Current at the time the FSA and FTA wagons were built:

UIC 543, 9th edition	International Union of Railways Leaflet, Brake Regulations Relative to the Equipment, published 01/07/1976 with amendments on 01/01/1977, 01/01/1978, 01/01/1979, 01/01/1981, 01/01/1982, 01/01/1984, 01/07/1984, 01/01/1986 and 01/01/1988
UIC 544-1, 3rd edition	International Union of Railways Leaflet, Brake, Braking Power, published 01/01/1966 with amendments on 01/01/1981, 01/07/1981, 01/01/1984 and 01/01/1985

Appendix D - Factors that were discounted

Train 4L81's loss of braking

1 An explanation of how the braking system on a train such as train 4L81 works is provided in appendix E.

2 **The braking effort being provided by the class 86 locomotives being reduced has been discounted as a factor.**

3 The braking effort provided by the class 86 locomotives is a combination of tread braking (brake blocks are pushed by air against the tread of the wheels) and rheostatic braking (a form of dynamic braking where the connections to the traction motors are reversed and the motors then slow the train down as they generate a current which is dissipated through a resistance). Above 7 mph (11 km/h), the locomotive's braking is primarily rheostatic.

4 The evidence from the data recorders on both locomotives, and the RAIB's analysis of it, indicates that the braking systems on both locomotives were operating as expected. The locomotives' data recorders show tread brakes being applied at low speed. They also show rheostatic braking being demanded at higher speeds, with the tread brakes applying initially and then being released as rheostatic braking is achieved. If rheostatic braking had not been achieved, the locomotives' tread brakes would have been applied throughout the stop. This braking behaviour matched that seen on a data recorder for another class 86 locomotive hauling a similar freight train.

5 The brakes on the locomotives were examined on the night of the incident by a rolling stock technician. He carried out a functional brake test that was successful. When the train was reversed into a loop after the incident, the driver used the air brakes on the locomotive to hold the train and did not find any problems with the operation of its brakes.

6 **Water in the braking system formed ice which led to a blockage restricting air flow has been discounted as a factor.**

7 In conjunction with industry experts the RAIB sought to identify possible single failures which could have caused the widespread loss of braking performance along the length of train 4L81.

8 The RAIB considered whether there was a problem with the control of the brake pipe by the leading locomotive. If water within the air systems on the locomotive had frozen and caused a blockage then it is very likely that there would have been a complete loss of braking functionality. The data recorders and tests carried out afterwards show that the control of the brake pipe was functioning normally (appendix D, paragraph 5).

9 The RAIB considered whether there was a blockage somewhere along the train's brake pipe. The brakes on those wagons ahead of the blockage would apply as normal but those behind it would not, so the amount of braking effort delivered by the train would be set by where the blockage was. The RAIB found evidence that made a blockage in the brake pipe unlikely:

- the train's data recorders both show the brake pipe pressure falling and rising at the expected rates for a train of its length during all of its journey;

- witness evidence indicates that the ferry driver and ground staff successfully conducted the train's brake continuity test at Coatbridge (and the data recorder confirms that it was carried out), which indicates that the brake pipe was not blocked before the train departed;
- the ferry driver carried out a running brake test after leaving Coatbridge and stopped the train at Mossend without detecting a problem, which indicates the brake pipe was not blocked during the first part of its journey;
- the brake pipe was continuous when the train reversed into the loop at Carstairs after the incident; and
- the brake pipe was continuous when all of the wagons were de-iced and tested on 24 December 2009, even though temperatures in the area had remained below freezing since the incident happened.

10 Class 86 locomotives are not fitted with air dryers to remove any moisture from the compressed air that they supply to the wagons via the brake pipe. This means the compressed air can contain moisture. Most of this will condense into the main reservoir air tanks on the locomotive but it is possible that a small amount of moisture can be passed out of the locomotive into the brake pipe. This could condense as water within the train's air pipes, which could cause a problem if frozen. To prevent this water from freezing, the locomotives are fitted with a dispenser that mixes an anti-freezing agent with the air intake to the compressor. The agent used was Kilfrost BTB, which is a low viscosity propylene glycol (double alcohol) based fluid that is used as a non-toxic antifreeze.

11 The RAIB examined the maintenance records for the two locomotives, 86610 and 86612. These show that Freightliner carried out the activities defined in their procedure (MIE 0718 Winterisation procedure: Traction and Rolling Stock) for preparing the locomotives for operating during the winter. They also showed that the dispensers were checked and filled up as required when maintenance examinations were carried out before the incident. There was also no evidence of water carry-over or malfunction of air system components on the locomotives afterwards.

12 The RAIB searched for previous incidents involving brake pipe blockages and found just one that occurred in Sweden. Snow was left in a locomotive's brake hoses when it was coupled to its train. This reduced the train's braking performance over time until the brakes no longer worked once the temperature had fallen to -7°C and the snow froze. The RAIB found no evidence that snow had entered train 4L81's brake pipe, and the outside temperature was only just below freezing at the time of the incident, suggesting that the likelihood of a pipe blockage in this case was very low.

13 **A loss of air from within the braking system has been discounted as a factor.**

14 A loss of air from within the train's braking system could be caused by a component failure such as a drain valve freezing in the open position. In the majority of cases, a loss of air will lead to the brakes being applied. However, there are some scenarios where a loss of air may leave the brakes released, especially after all of the air has been removed from the brake actuators to release the brakes as happened at Coatbridge. Analysis of the evidence did not identify any such failure.

15 None of the drivers reported a problem with low main reservoir pressure on the locomotives. The air compressor on each locomotive should have been able to supply enough air to maintain the brake pipe pressure with some small leakage. However, a major leak would mean that brake pipe pressure could not be maintained or recreated quickly after applications. The data recorder shows the drivers were able to restore pressure in the brake pipe and release the brakes without difficulties throughout. The train's data recorder also showed the brake pipe pressure:

- falling and rising at the expected rates when the brakes were applied and released by driver;
- holding at a steady value when the brakes were not being applied or released; and
- being successfully overcharged by the ferry driver prior to departure and also by the driver after leaving Mossend.

16 After the incident the staff who de-iced and tested the brakes on the whole of the train did not find any air leaks.

17 Maintenance staff recorded that the air system drain valve on each locomotive was working when it was checked during examinations both before and after the incident. The RAIB found no evidence afterwards that flexible components had deformed due to air leakage and the temperatures were not low enough to change the state of flexible components such as rubber seals.

18 **A low level of adhesion between the train's wheels and the rails has been discounted as a factor.**

19 The developed retarding force would have been low if the wheels had stopped rotating when the brakes were applied. This problem would occur if there was a low level of adhesion on the rail head. The locomotives were fitted with equipment which can be used to deposit a layer of sand onto the head of the rails to stop wheels sliding but the wagons were not fitted with any systems to prevent or stop sliding from happening.

20 The RAIB found no evidence that the train slid. The driver reported that the head of the rails was wet and Network Rail staff who attended at Carstairs found no signs of contamination when they examined the rails behind the train. The driver also stated that he had no indication that his train was sliding at any point.

21 When a train has slid for any distance, flat areas are sometimes worn into the tread of the wheels. Staff who examined the train saw no signs of wheel flats. Also Network Rail has sites throughout its network that monitor the forces that train wheels exert on the track to specifically look for wheels with flats on them. Before the incident, the train passed one of these sites at Braidwood, between Law junction and Carstairs. After the train left Carstairs, it passed over a second site at Dallam, near Warrington. The data from these sites show there were no wheel flats either before or after the incident.

22 **Snow and ice building up and its weight activating the brake distributor's pull cords has been discounted as a factor.**

23 The FSA and FTA wagons have pull cords running to the bottom of their brake distributor. When these cords are pulled, the air to the brake actuators is vented which releases the brakes. The RAIB is aware of a potential failure mechanism where snow and ice could collect on these cords, and its weight would be sufficient to pull the cord. For the loss of braking performance that train 4L81 experienced, this would have to occur on multiple cords down the train at the same time.

24 The RAIB found that an instance of this type of failure happened during the winter of 2009/2010. The driver of a DB Schenker freight train from Tees Yard to Margam reported that his train was not slowing down as quickly as he expected it to and he suspected that the brakes were not applying on some of the wagons. The train was recessed and its wagons (types BCA, BLA and BZA) were examined by DB Schenker staff. Underneath a number of wagons they found snow and ice had built up around the brake distributor pull cord as shown in figure 16. Its weight was sufficient to pull the cord which stopped the brakes applying.

Figure 16: Snow and ice built up around distributor pull cord (Courtesy of DB Schenker)

25 The RAIB determined that this was unlikely to happen on the FSA and FTA wagons. The pull cord located on the same side of the wagon as the brake distributor is very short and the pull cord from the far side is located very high up on the underframe. It does not hang down in the same way as cords on other stock and is routed across the wagon through holes in the underframe. Figure 17 shows the pull cords on one of train 4L81's wagons on the day after the incident, which are free of snow and ice.

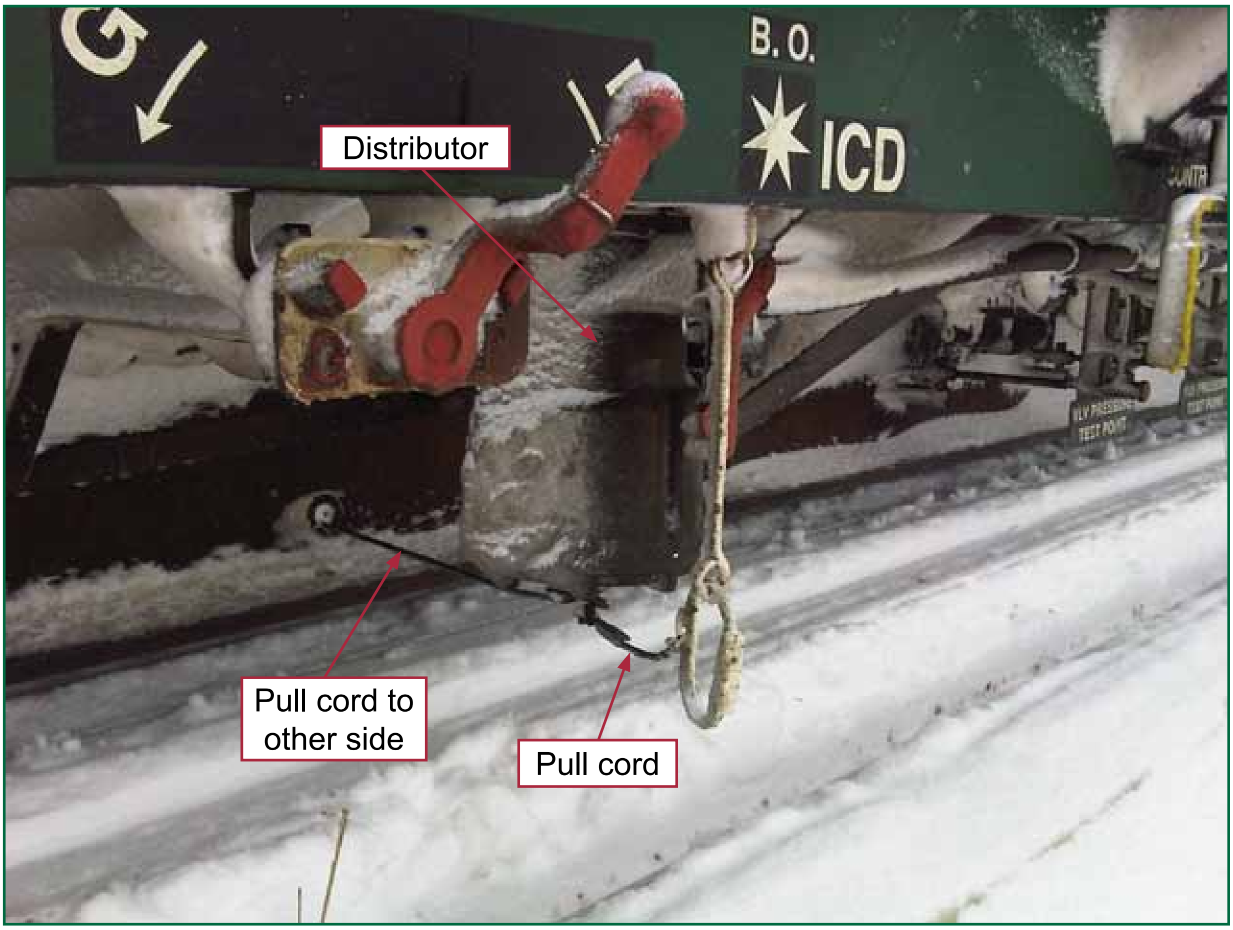


Figure 17: Photograph of distributor pull cord on train 4L81 (Courtesy of Davis Wagon Services)

Discounted factors relating to the staff involved in the operation of the train

26 **Train preparation has been discounted as a factor.**

27 The train was prepared at Coatbridge by the ferry driver and ground staff. After they coupled the locomotives to the wagons and charged the wagons' air systems, they successfully carried out a brake continuity test as required by section 3.8 of Rule Book module TW3. This test was done to check the brake pipe was continuous throughout the train. Prior to departure, the ferry driver overcharged the brake pipe to ensure that all of the brakes on the train released. He then carried out a post departure running brake test on the approach to Mossend as required by section 3.16 of Rule Book module TW3. The ferry driver found no faults with the train during preparation or the initial part of its journey, so no problems were reported at the handover.

28 **Driver route and traction experience has been discounted as a factor.**

29 The driver of train 4L81 was very experienced in driving this type of train over this route. He had passed his last rules assessment and all of his training and briefings were up to date.

30 **Risk assessment for the train's route has been discounted as a factor.**

31 Freightliner had risk assessed the route that the train took. The risk assessment included categories such as locations where signals could be approached on major falling gradients. Beattock was listed but Craigenhill was not as the gradients on either side of it are not especially steep. There was also a category for 'exceptional low rail adhesion areas, low rail adhesion areas and other locations which are affected by seasonal or climatic factors'. Craigenhill and Carstairs were not listed under this category as they were not areas known for having low rail adhesion.

32 For the part of the route from Mossend to Carstairs, Freightliner had not identified any risks that may have caused or contributed to this incident, so there were no corresponding mitigations in place that would have affected how the driver handled train 4L81. Freightliner had not specifically assessed the risk of operating over the route in snowy conditions, although it has since revised its assessment and included Craigenhill as a location which is affected by climatic factors. It has indicated that if it had done so prior to the incident, any risk would have been mitigated by applying the rules for additional running brake tests in snowy conditions. However, for this incident it is unlikely that this mitigation would have been effective, due to the driver's interpretation of the rule.

Appendix E - Simplified explanation of single pipe arrangement for train braking

1 An automatic air brake was fitted to train 4L81. 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 4L81 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 has 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 brake equipment on each vehicle.

3 A simplified schematic diagram showing the arrangement for a single pipe system is shown in figure 18.

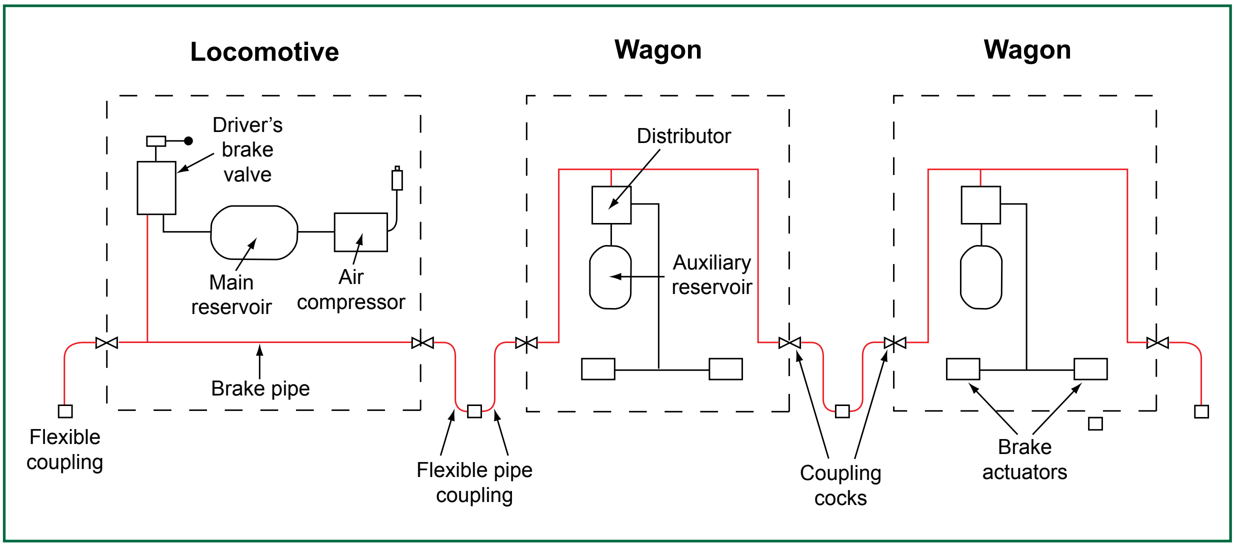


Figure 18: Simplified schematic diagram showing a single pipe system

4 The air compressor on the locomotive produces compressed air that is stored in a main reservoir 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 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 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 tank. 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 actuators. As the brake pipe pressure falls, there is a proportional increase in the brake actuators pressure. The brake actuator 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 zero (atmospheric) as it will be completely vented. The maximum brake actuator pressure is the same as for a full service brake application but it is attained more quickly. Under all braking conditions, the maximum brake actuator pressures, as controlled by the distributors, are attained as soon as the brake pipe pressure has fallen to around 3.4 bar.

10 The driver releases the brakes 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 5.3 bar. It will then slowly drop over several minutes back to 5.0 bar. The driver will normally do this after attaching the locomotive to the train for the first time. 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 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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This report is published by the Rail Accident Investigation Branch,
Department for Transport.

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