Rail Accident Investigation Branch

Rail Accident Report

Loss of brake control on a sleeper train approaching Edinburgh 1 August 2019

Report 05/2020
May 2020

This investigation was carried out in accordance with:

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

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This report is published by the Rail Accident Investigation Branch, Department for Transport.

Cover image courtesy of Peter Fitton

Preface

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RAIB's findings are based on its own evaluation of the evidence that was available at the time of the investigation and are intended to explain what happened, and why, in a fair and unbiased manner.

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

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

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

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

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

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

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

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Loss of brake control on a sleeper train approaching Edinburgh, 1 August 2019

Contents

Summary

At about 07:25 hrs on Thursday 1 August 2019, the driver of the Edinburgh portion of the Lowlander sleeper service from London Euston was unable to control the train's speed on the approach to Edinburgh. He was unable to comply with the maximum permitted speed at Haymarket East Junction, and would have been unable to stop the train before the junction if there had been a conflicting train movement. The driver was also unable to stop the train at Edinburgh Waverley station. The train came to a stop approximately 650 metres beyond its intended stopping point at Edinburgh Waverley platform 11, after the train manager operated an emergency button in a coach.

The train crew subsequently identified that an air isolation cock between the locomotive and the coaches was closed when it should have been open. After identifying this and obtaining permission from the signaller, they reversed the train back into the platform where the passengers alighted. There were no injuries and no damage occurred.

The driver was unable to stop the train because the brake pipe isolating cock on the leading end of the leading coach was closed. This prevented the brakes on all the coaches from operating when demanded by the driver, although the driver still had control of the brake systems on the locomotive.

The isolating cock became closed during coupling operations when the Edinburgh train was split from the Glasgow train at Carstairs station; this happened after the mandated brake continuity test had been completed. The closure of the valve was therefore undetected prior to the train's departure from Carstairs. The effectiveness of the brake systems on the locomotive also masked the absence of the coach brakes until the train was approaching Slateford, on the approach to Edinburgh.

RAIB has made two recommendations. One is addressed to RSSB to change the wording of the railway rule book to make it clear that the brake continuity test should be undertaken after all coupling-related activities have been completed. The second is addressed to Caledonian Sleeper to review the vulnerability of the isolating cocks on its rolling stock, to prevent inadvertent operation by persons or objects.

RAIB has also identified six learning points, relating to procedures for coupling and uncoupling trains, incorporating risk mitigations into operational procedures, risk assessing the running brake test, using the 'train in distress' signal, application of standards to rolling stock, and access to recorded train data.

Introduction

Definitions

1 Metric units are used in this report, except when it is normal railway practice to give speeds and locations in imperial units. Where appropriate the equivalent metric value is also given.

2 The report contains abbreviations and acronyms explained in Appendix A. Sources of evidence used in the investigation are listed in Appendix B.

The incident

Summary of the incident

3 At about 07:25 hrs on Thursday 1 August 2019, the driver of the Edinburgh portion of the Lowlander sleeper service from London Euston, was unable to control the train's speed on the approach to Edinburgh. The train exceeded the maximum permitted speed at Haymarket East Junction, and would have been unable to stop before the junction if there had been a conflicting train movement. The train failed to stop as scheduled at platform 11 at Edinburgh Waverley station, and was brought to a stand approximately 650 metres beyond its intended stopping point.

4 The train comprised eight Mark 5 coaches hauled by a Class 92 electric locomotive that had been attached at Carstairs. On the approach to Edinburgh the driver discovered that his train's braking performance was well below normal. The driver had no control of the brakes on the coaches because a brake pipe isolating cock (BPIC) was in the closed position when the train left Carstairs station. This meant that the only effective brakes on the train as it approached Edinburgh were those on the locomotive, which were insufficient to maintain control of the train. The train manager brought the train to a stand by operating an emergency device in one of the coaches, which caused the coach brakes to apply.

5 There was no damage, nor any injuries, as a consequence of the incident. However, the outcome could potentially have been much worse, had it led to a collision with another train, either at Haymarket East Junction or at Edinburgh Waverley station.

Context

Location

6 The incident was initiated at Carstairs station, and the train then travelled 29 miles (46.6 km) along the double track electrified railway from Carstairs to Edinburgh Waverley station before coming to a stand in Calton South tunnel (figures 1 and 2). The first six miles (10 km) of the route were controlled by Motherwell signalling centre, with the rest being controlled by Edinburgh signalling centre. Since the incident, control of the Carstairs area has transferred to the West of Scotland signalling centre. The electrical supply on the whole route is controlled from the electrical control room at Cathcart.

7 From Carstairs Station Junction to Haymarket East Junction the down direction is towards Edinburgh. At Haymarket East Junction, where the line from Carstairs converges with the line from Glasgow Queen Street station, the up direction is towards Edinburgh and Calton South tunnel. Table 1 shows the cumulative mileage of the route taken by the train.

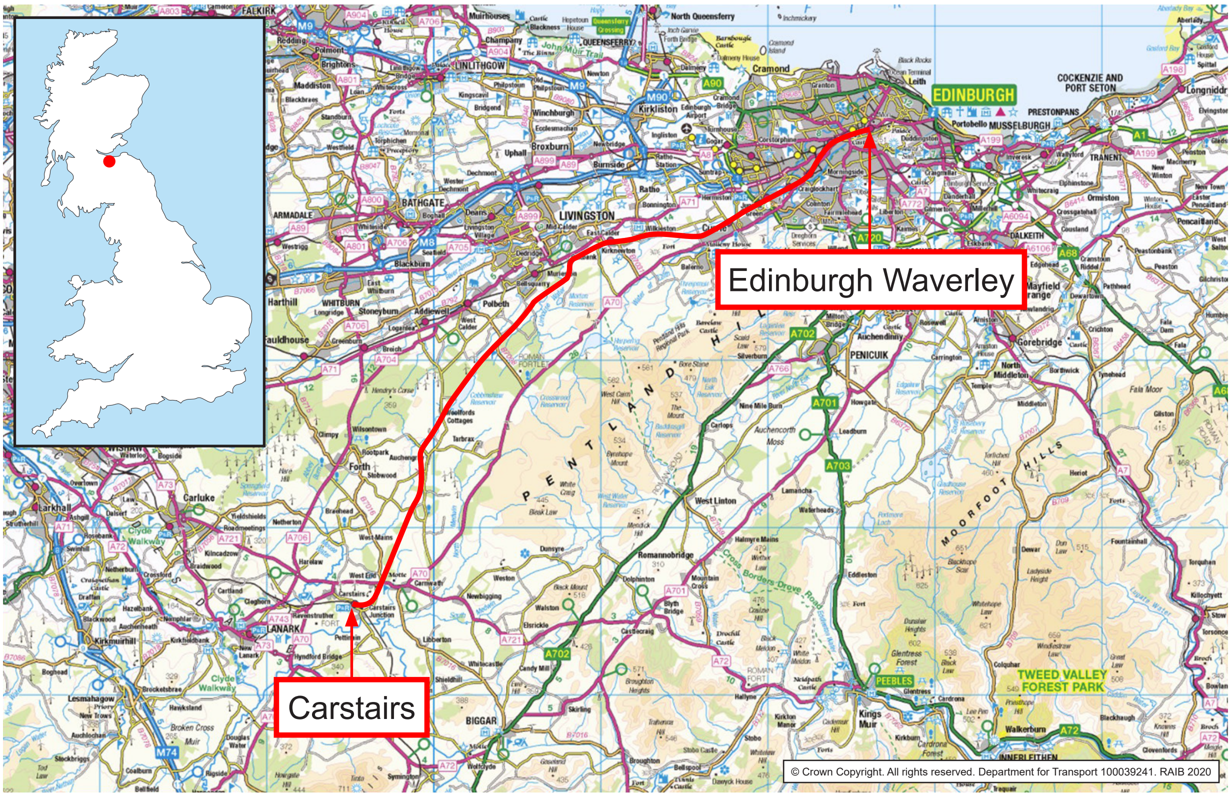

Figure 1: Extract from Ordnance Survey map showing route of the train from Carstairs to Edinburgh

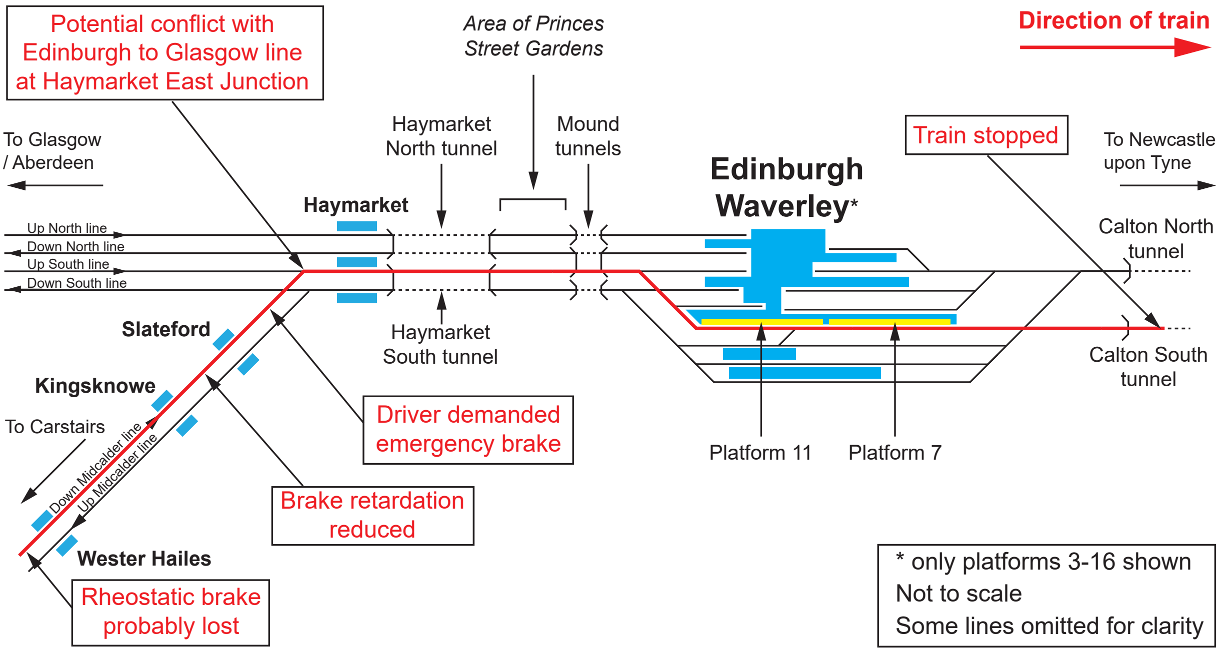

Figure 2: Track layout on the approach to Edinburgh

Location	Miles from Carstairs	Km from Carstairs
Carstairs Station	0	0
Carstairs Station Jn	0.1	0.2
Carstairs East Jn	0.8	1.3
Cobbinshaw Summit	9.4	15.2
Midcalder Jn	16.6	26.8
Kirknewton	17.6	28.3
Curriehill	22.2	35.7
Wester Hailes	23.9	38.5
Kingsknowe	24.7	39.8
Slateford	25.6	41.2
Haymarket East Jn	27.2	43.8
Haymarket	27.3	44.0
Princes St Gardens	28.1	45.3
Edinburgh Waverley	28.6	46.0
Train stop position	29.0	46.6

Table 1: Cumulative distance for the route taken by train

8 The majority of the route from Carstairs to Edinburgh has a maximum permitted speed of 95 mph (153 km/h), which reduces in steps to 20 mph (32 km/h) on the approach to Edinburgh Waverley station. Most of the first 10 miles (16 km) is uphill, with a maximum gradient of 1 in 100. After Cobbinshaw summit, the line is then mainly downhill to Haymarket East Junction, with a maximum gradient of 1 in 95 between Slateford station and Haymarket station. The detail of the permitted speeds and the gradient profile is shown in figure 3.

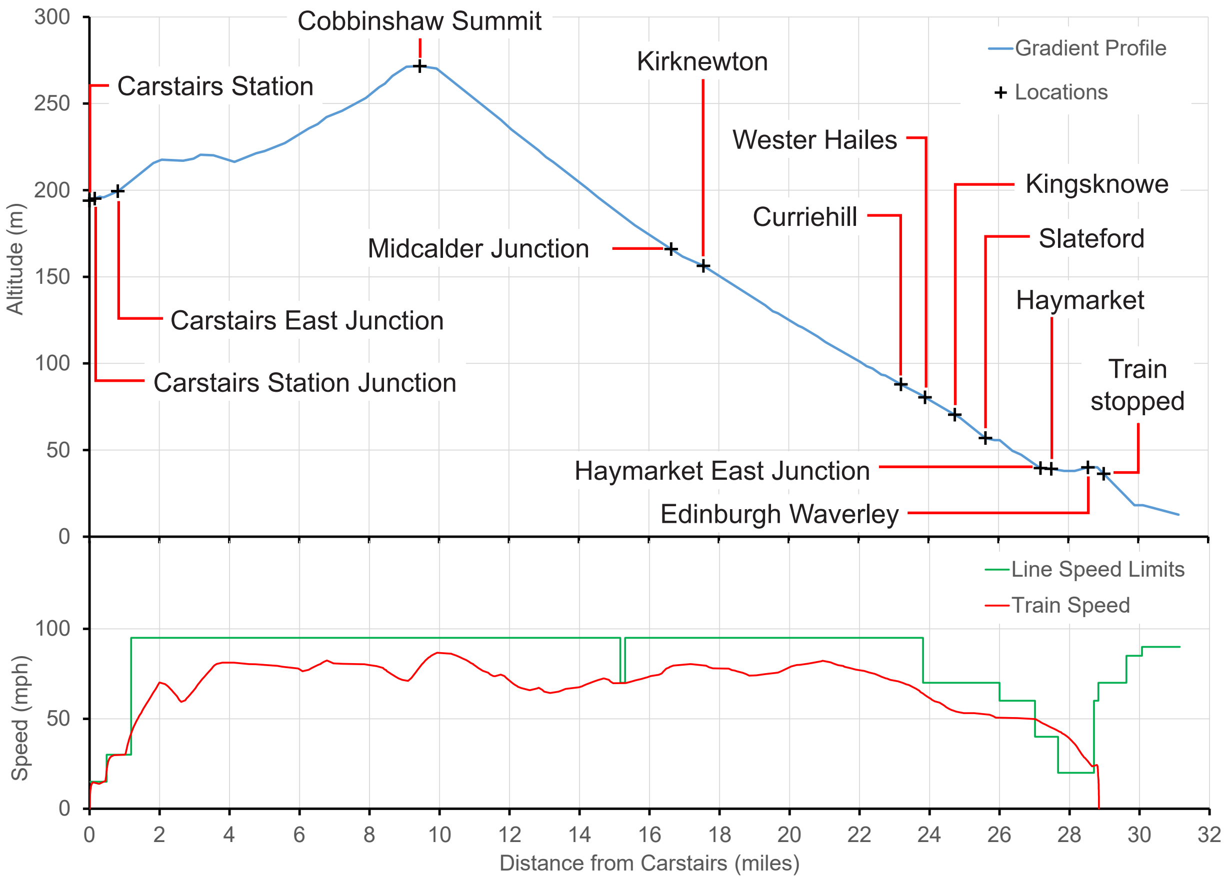

Figure 3: Gradient and speed profiles for the route between Carstairs and Edinburgh

Organisations involved

9 Serco Caledonian Sleepers Limited (trading as Caledonian Sleeper) was the operator of the train and employer of the on-train staff.

10 GB Railfreight Limited was the operator of the locomotive and employer of the train driver. GB Railfreight was contracted to Caledonian Sleeper to provide locomotive haulage for its trains.

11 Victa Railfreight Limited was the employer of the shunter at Carstairs. Although Caledonian Sleeper had its own shunting staff, Victa Railfreight was contracted to provide additional shunting staff when required.

12 Construcciones y Auxiliar de Ferrocarriles S.A. (CAF) manufactured the Mark 5 Sleeper coaches. CAF is a Spanish train manufacturer, and the Mark 5 coaches were built at its factories in Spain. CAF was the design authority for Caledonian Sleeper's Mark 5 coaches, exercising custody of the design specification for them and controlling and recording any changes to that design specification.

13 Network Rail is the owner and maintainer of the railway infrastructure, and employed the signallers involved in the incident.

14 Caledonian Sleeper, GB Railfreight, Victa Railfreight, CAF and Network Rail all freely co-operated with the investigation.

Train involved

15 The sleeper train had started its journey from London Euston at 23:36 hrs the previous evening, as train 1S26.[1] This was the 'Lowlander' sleeper service from London to Glasgow Central, which also included a portion for Edinburgh Waverley. Train 1S26 consisted of two eight-coach portions. At Carstairs, the rear portion was detached, with the assistance of a shunter, to run to Edinburgh, with the front portion continuing to Glasgow. The Carstairs to Edinburgh portion operated as train 1B26, and was scheduled to depart from Carstairs at 06:40 hrs.

The coaches

16 The coaches in the train were designated Mark 5, and were built by CAF, in Spain (figure 4). They first entered passenger service in April 2019. Each eight-coach portion of the train consisted of six sleeper coaches, a club coach and a seating coach.

17 The coaches are coupled together, and to the locomotives, using a Dellner coupler, which incorporates both the mechanical and the pneumatic connections (figure 5). There are also two electric train supply (ETS) connections on each coach end, to provide power for heating, ventilation, lighting and other services. The two ETS connections to the first coach consist of a cable from the locomotive, fitted with a plug which fits into a receptacle on the coach, and a similar cable from the coach which fits into a receptacle mounted on the locomotive. There is also a 61-way connection for a detachable jumper cable to allow transmission of communications and data between the coaches and the locomotive. Between the coaches there are also several other control and communications connectors.

[1] An alphanumeric code, known as a 'train reporting number', is allocated to every train operating on Network Rail infrastructure.

Figure 4: Mark 5 sleeper coach

Figure 5: Mark 5 sleeper coach end, showing Dellner coupler and other connections

18 The original design intent for the 61-way jumper was for it to be able to be fitted at any time. During testing and trial operations it was found that when two 61-way jumper cables were connected to a train, such as when there was a locomotive at each end of the train, there was a risk of damaging components in the locomotives. As a result, a limitation was introduced that prohibited the simultaneous connection of two 61-way jumper cables to the same set of coaches.

The class 92 locomotive

19 Between London and Glasgow/Edinburgh, the sleeper trains are hauled by class 92 electric locomotives operated by GB Railfreight (figure 6). The class 92 locomotives were originally built for British Rail in the mid-1990s and were intended to operate freight and sleeper services through the Channel Tunnel. They are capable of operating on either 25kV AC overhead or 750V DC third rail supplies. The cancellation of Channel Tunnel sleeper services and a shortage of freight work led to several locomotives being sold and others being stored for an extended period.

Figure 6: Class 92 locomotive

20 GB Railfreight started providing locomotives for Caledonian Sleeper in 2015, and ten class 92 locomotives were refurbished and modified for use with the Mark 5 coaches. Locomotive 92020, which operated the Edinburgh portion of the sleeper on the morning of the incident, was returned to service in December 2018, following refurbishment, after 17 years in storage.

21 Modifications to the class 92s included significant structural alterations to accommodate fitment of a Dellner coupler capable of coupling to the Mark 5 coaches. This coupler is suspended from the locomotive drawbar and needs to be manually lifted into position, with the locomotive air hoses having to be connected to it, every time it is used. Other modifications included modifying the control interface with the coaches, replacing the ETS connections and returning the ETS supply from 900V to 1500V, its original as-built condition.

Staff involved

22 The driver of the train was employed by GB Railfreight and had worked on the railway for 41 years. Most of this time was spent driving freight services, but he had been driving sleeper services for the last 10 years. He was trained in operating the Mark 5 coaches in March 2019. He had regularly coupled and uncoupled Mark 5 coaches at Glasgow Central, where drivers have been responsible for shunting activities since their introduction into service in April 2019. GB Railfreight stated that there were no safety-related incidents on the driver's record.

23 The train manager was employed by Caledonian Sleeper and had worked on the railway for 37 years. Most of this time was spent as a guard, initially on freight services, but primarily on passenger trains, with the last seven years being on sleeper services. He was trained in operating the Mark 5 coaches during February and March 2019 and had been working on them regularly since April 2019. Caledonian Sleeper stated that there were no safety-related incidents on the train manager's record.

24 The shunter was employed by Victa Railfreight and had worked on the railway for 40 years. He started out driving freight services and progressed to become a traction inspector and train crew leader. After changing roles several times, he became a mobile shunter, and had worked in that role at many locations around the UK for 4 years. He was trained in operating the Mark 5 coaches at Inverness in June 2019. He was also trained to shunt at Carstairs and had been last assessed in March 2019. He had shunted sleeper trains at Carstairs several times since then, although most of these were formed of the older Mark 2 and Mark 3 sleeper coaching stock. The day of the incident was his second shift working with the Mark 5 coaches in service. Victa Railfreight stated that there were no safety-related incidents on the shunter's record.

External circumstances

25 At the time the train was being split at Carstairs, it was daylight and the weather was dry with very little wind. However, by the time the train reached Edinburgh, it had started to rain.

26 At Carstairs there was no noise in the vicinity of the coupling activities, other than that coming from the cooling fans on the locomotive. There were no other external influences that affected the incident.

Background information

Brake systems on the train

27 Figure 7 shows a simplified diagram of the brake systems on the locomotive and the Mark 5 sleeper coaches. The locomotive controls the brakes on all the coaches using a conventional two pipe air system. A ‘main reservoir pipe’ and a ‘brake pipe’ run the length of the train, with the air connections passing through the couplers between each vehicle. Main reservoir and brake pipe isolating cocks (MRPIC and BPIC) are provided on the vehicle sides of every coupler. The main reservoir pipe keeps the auxiliary reservoirs on each vehicle topped up, using air from the locomotive main reservoir and compressor. The air in the auxiliary reservoirs provides the energy to apply the brakes on each vehicle. The driver’s train brake control adjusts the air pressure in the brake pipe, with 5 bar pressure commanding brake release and a reduction from 5 bar commanding a proportionate brake application.

28 Each vehicle has a brake distributor that controls the flow of air from its own auxiliary reservoir to the brake cylinders on that vehicle when the brake pipe pressure falls below 5 bar. A reduction in the brake pipe pressure results in an increase in the pressure to the brake cylinders on all the vehicles, and thus the amount of friction braking applied. A brake pipe pressure reduction to 3.5 bar or lower causes a full application of the brakes on all vehicles. Gauges in the cab show the driver the air pressures in the brake pipe and the main reservoir pipe, as measured on the locomotive, and in the locomotive brake cylinders.

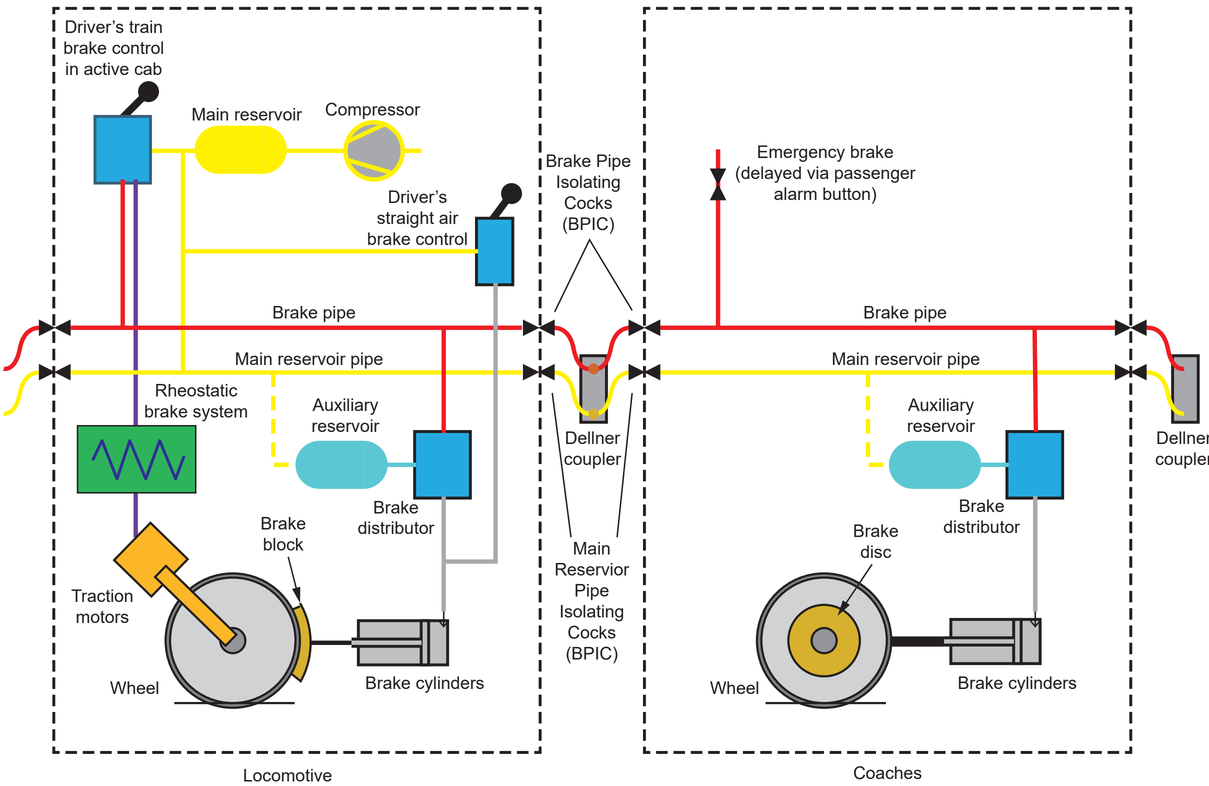

Figure 7: Simplified diagram of train brake systems (omitting other air-related systems)

29 In an emergency brake application, the brake pipe is vented to atmosphere, so that all the pressure is released, and the brakes apply. An emergency brake application can also be initiated by operating the passenger alarm buttons in the coaches, although this is delayed by ten seconds to allow the driver the opportunity to override it. This override function is provided so that the train is not brought to a stand in a hazardous location, such as within a tunnel or on a viaduct.

30 In addition to the train braking system, locomotives are also provided with a separate ‘straight air braking system’ that applies air directly to the friction brake cylinders on the locomotive only. The operation of the straight air brake has no effect on the pressure within the train brake pipe, and so does not apply the brakes in the rest of the train.

31 The class 92 locomotives are also fitted with a dynamic brake system that uses the locomotive’s traction motors to slow down the train and dissipates the energy, via the electrical converters, in a bank of electrical resistors. This is known as the rheostatic brake system. Class 92 locomotive dynamic brakes do not regenerate power to the overhead line on Network Rail infrastructure. The rheostatic brake is powerful and results in greatly reduced wear to the friction brake on the locomotive. It is designed to operate under the driver’s control, via the train brake controller, and effectively replaces the locomotive’s friction brake when it is travelling at above 3 mph (5 km/h). When the rheostatic brake is in full operation, there is no air in the locomotive brake cylinders, and therefore the cab brake cylinder gauges do not register any pressure.

The sequence of events

Events preceding the incident

32 Train 1S26 left London Euston on time at 23:36 hrs on 31 July 2019. This was earlier than the normal 23:50 hrs departure time, to accommodate a planned diversion via Manchester.

33 The shunter left Edinburgh at 23:40 hrs, travelling on the southbound Edinburgh to London sleeper, arriving at Carstairs at 00:13 hrs. He carried out the duties required to couple the southbound Edinburgh portion to the Glasgow to Euston service, which departed at 00:44 hrs. He then went to the shunter's 'bothy', located in the Carstairs station building, for some rest before the arrival of the northbound service in the morning.

34 The driver for the northbound Edinburgh portion started his shift at Polmadie depot in Glasgow before travelling by road to Carstairs. He powered up the locomotive that had been stabled on the west side of the main line at Carstairs station (figure 8). At 05:38 hrs, the driver moved the locomotive from the stabling point. After proceeding via the north end of Carstairs station, the locomotive waited on the curve between Carstairs Station Junction and Carstairs East Junction at 06:10 hrs.

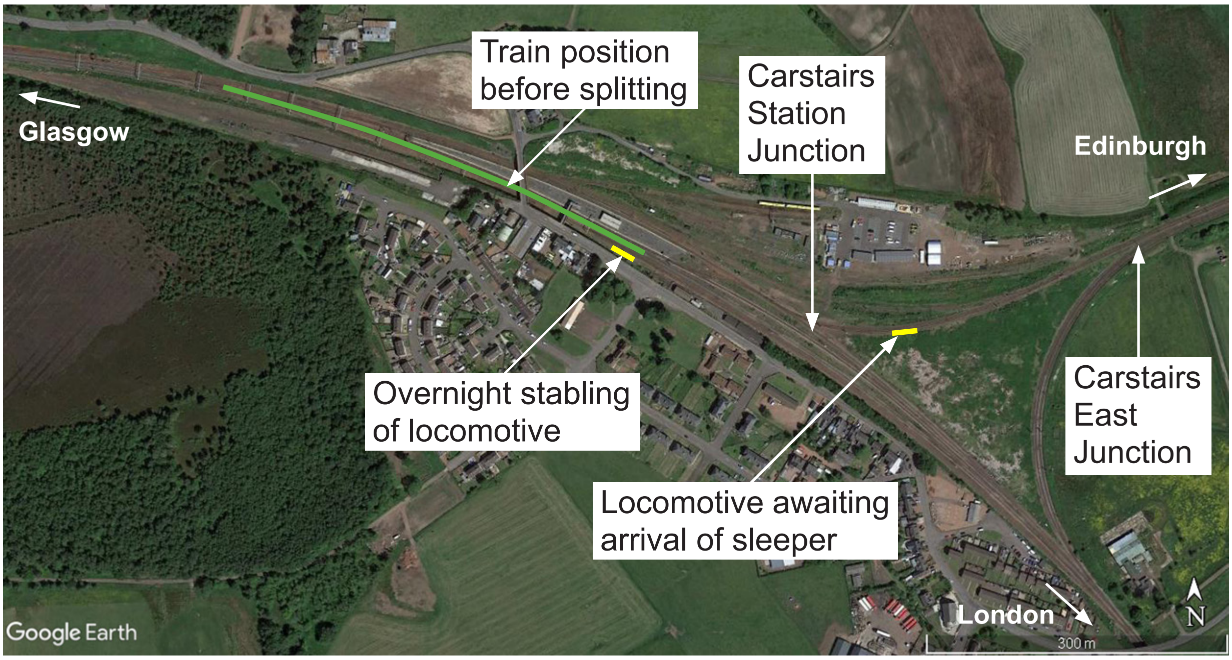

Figure 8: Detailed layout at Carstairs station

35 At 06:24 hrs, train 1S26 from London arrived in the platform at Carstairs. The train stopped with the rear ten coaches in the platform, and the locomotive and the front six coaches beyond the north end of the platform. As soon as train 1S26 stopped, the locomotive for the Edinburgh portion was signalled towards the platform and started its move from the curve towards the rear of the train.

36 The locomotive stopped short of the train, before the shunter went on to the track. The driver took the 61-way jumper cable from the cab and placed it on the platform ready for it to be connected up. The shunter opened the BPIC at the rear of train 1S26 to vent its brake pipe, ensuring that it could not move. Assisted by the driver, the shunter lifted the locomotive's Dellner coupler into the horizontal position and then connected the locomotive's brake pipes to it, so that it was ready for coupling to the train. The shunter then went back onto the platform, and the driver returned to the locomotive cab.

37 At 06:31 hrs, the driver moved the locomotive slightly forward to contact the rear of train 1S26, and the locomotive and coach couplers engaged automatically. The driver then carried out a pull test to ensure that the couplers had mechanically engaged. The shunter went back onto the track and visually checked that the couplers were fully engaged before connecting the ETS connector on the platform side of the coach to the locomotive. The shunter then started to move towards the second ETS connector on the non-platform side of the locomotive, with the intention of connecting it to the coach. However, he saw a freight train arriving alongside train 1S26 and decided to delay connection of the second ETS jumper cable until later (paragraph 75).

38 The shunter then climbed back onto the platform and walked alongside the train to the mid-point where the Edinburgh and Glasgow portions were to be separated. He then went onto the track and separated the electrical connections between the eighth and ninth coaches and closed the BPICs on both coaches to seal the brake pipe. After checking that the tail lamps on both portions had illuminated, he used the radio to contact the driver of the Edinburgh portion, who was in the cab. At 06:43 hrs, the driver drew the Edinburgh portion of the train away from the Glasgow portion, after the shunter had released the mechanical coupling between them.

39 At 06:44 hrs, the shunter and driver communicated by radio to undertake a brake continuity test on the Edinburgh portion, now identified as train 1B26. This involved the shunter opening the BPIC at the rear of the train and the driver confirming that the brake pipe pressure displayed in the cab had dropped towards zero. The test then involved the shunter closing the BPIC and the driver recharging the brake pipe to ensure that the brake pipe pressure was re-established to 5 bar ready for overcharge (paragraph 61). This test was successfully completed and demonstrated that the brake pipe was continuous from the locomotive to the rear of the train.

40 The Glasgow portion (train 1S26) departed Carstairs at 06:46 hrs, approximately 8 minutes behind schedule. This portion did not require a brake continuity test because, other than dropping off coaches from the rear, no changes had been made to its formation.

41 After completing the brake continuity test, the shunter, with the train manager, started to walk along the platform towards the locomotive. Around this time, the driver noticed that the shunter had only connected one ETS connector and used the radio to remind him. The shunter said that he would connect it up when he reached the front of the train. At 06:47 hrs, the train manager used the emergency access device to enter the passenger door at the Edinburgh end of train 1B26, to access his office. The shunter picked up the 61-way jumper cable from the platform and went onto the track to connect the jumper cable between the locomotive and the coaches. By this time, the driver was already on the track by the non-platform side ETS receptacle, where he was having difficulty attempting to insert the second ETS plug. Having connected the 61-way jumper cable, the shunter moved across to assist the driver with the second ETS connection. The two of them struggled with this for about four minutes, during which time the driver went to collect some spray oil from the shunter's bag in the rear cab. At 06:52 hrs, the shunter and the driver had succeeded in inserting the second ETS plug, and both left the track. The driver went to the front cab and contacted the signaller to let him know the train was ready to depart, while the shunter went to the platform via the rear cab.

42 At 06:59 hrs, after a southbound train had passed on the opposite platform, train 1B26 departed from Carstairs, 19 minutes late.

Events during the incident

43 At 07:04 hrs, the driver used the train brake control to carry out a running brake test, after having travelled two miles (3.2 km). This brought the train's speed down from 70 mph (113 km/h) to 59 mph (95 km/h).

44 On the initial descent after passing Cobbinshaw summit at 07:10 hrs, the train reached 87 mph (140 km/h). The driver then made the first of many short service brake applications to control the train's speed on the gradient. This successfully controlled the speed to comply with the short 70 mph (113 km/h) speed restriction near to Midcalder Junction. After this, and because the train was running on green signals, the driver allowed the speed to increase again on the downhill gradient. Shortly before Curriehill station, at 07:19 hrs, the driver started to apply the service brake for the approach to the sequentially reducing speed restrictions at Wester Hailes, Slateford and Haymarket. At the neutral section[2] just after Curriehill station, the pantograph unintendedly dropped and it is very likely that the rheostatic brake stopped working (paragraph 88). A continuous, varying brake application successfully brought the speed down to 50 mph (80 km/h) by Slateford. Just before Slateford station, at 07:24 hrs, the train stopped decelerating on the gradient (which at this point is approximately 1 in 100), with the service brake fully applied. At this point the driver realised that the train brakes were not performing as expected. Fortunately, the train had clear signals ahead of it, with the route set through Haymarket East Junction.

[2] The overhead line supplying the train is broken up into sections that are energised separately. A neutral section is a short non-conducting length of overhead line used to keep these sections electrically separate.

45 Shortly before the train reached Haymarket East Junction, at 07:25 hrs, the driver operated the emergency brake plunger. This had no immediate effect, and the train continued at the same speed until the track levelled out at the junction, after which the speed slowly reduced as the train passed through Haymarket station and entered Haymarket tunnel. The driver tried to call the train manager to advise him of the brake problem but was unable to make contact. The train left Haymarket tunnel and was still travelling at 41 mph (66 km/h) as it entered the 20 mph (32 km/h) speed restriction at Princes Street Gardens. Around this time, the driver made a GSM-R[3] call to the signaller to advise that the train had a brake problem and to request a clear route through Edinburgh Waverley station. The signaller alerted his colleagues and set a clear route through Platforms 11 and 7, which are continuous, and on through Calton South tunnel.

46 The speed had reduced to 30 mph (48 km/h) by the time the train entered platform 11 (figure 9), and to 23 mph (37 km/h) by the time it passed the east end of platform 7. As the train was passing through platform 11, the train manager realised that there was a problem and operated the passenger alarm button in his office to try to stop the train. The passenger alarm button alerts the train driver to an emergency and applies the train brakes after a ten second delay (paragraph 29). When nothing seemed to be happening, because of the ten second delay, the train manager operated a second passenger alarm button in the passenger area outside his office, and he then felt the brakes apply sharply, bringing the train to a stop at 07:28 hrs. By this time the front of the train was in Calton South tunnel, with the rear between platform 7 and the tunnel (figure 10).

Figure 9: The train entering platform 11 during the incident (Courtesy of Peter Fitton)

[3] A radio in the cab of a train based on a digital railway communication system that allows communication between drivers and signallers.

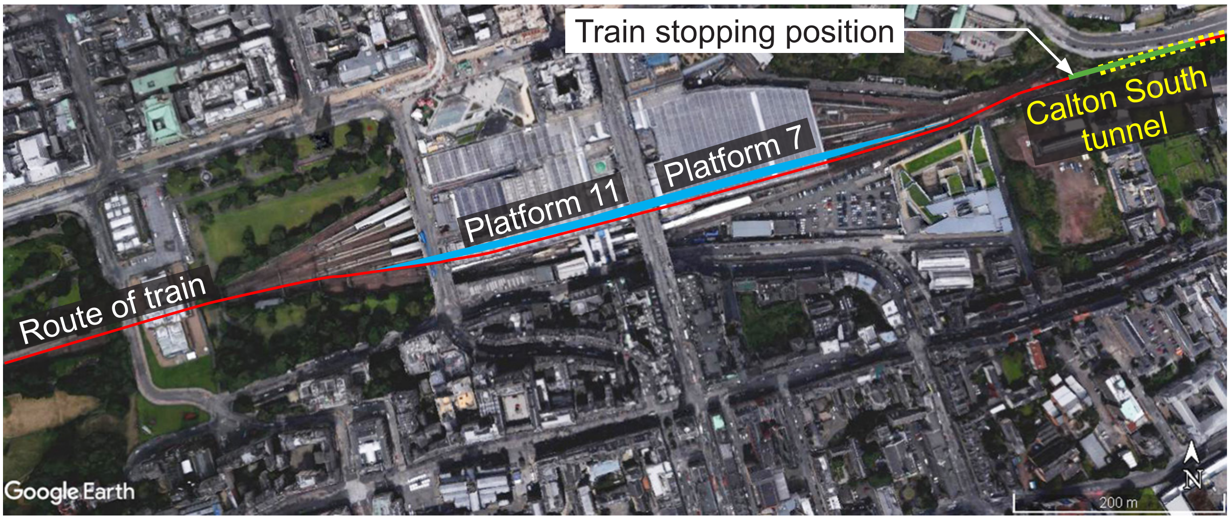

Figure 10: Route of the train through Edinburgh Waverley station

Events following the incident

47 When it stopped, the train was fully protected from other train movements by the signalling system. The train driver, the shunter and the train manager got off the train and met near the back of the locomotive. They quickly identified that the BPIC on the locomotive end of the leading coach was closed. They then advised the signaller, who sought advice on recovery of the train from Caledonian Sleeper and GB Railfreight's control offices. Network Rail informed RAIB of the incident at 07:47 hrs, and RAIB gave permission for the train to be recovered after evidence photographs had been taken. The signaller authorised the train crew to open the BPIC and to carry out a brake test before propelling the train back into the platform. The train arrived back into platform 11 at 08:44 hrs, and the passengers detrained.

48 The train staff were tested for drugs and alcohol after the train arrived in Edinburgh, and all were shown to be clear.

49 The locomotive was allowed to run round the empty sleeper coaches, and then to depart to the maintenance depot at Polmadie at 11:44 hrs. RAIB witnessed testing of the train after it had arrived at Polmadie.

50 The eastern approach to Edinburgh Waverley station was partially blocked to trains while train 1B26 was stopped in Calton tunnel. This led to some disruption to services.

Analysis

Identification of the immediate cause

51 **The driver did not have control over sufficient brake force to fully control the speed of the train on the approach to Edinburgh.**

52 The BPIC on the leading end of the leading coach was found to be closed when the train came to a stop (paragraph 47). The effect of this was to disable control of the brakes on the coaches from the locomotive. The braking performance of the train, as recorded by the on-train data recorders (OTDR) on both the locomotive and the coaches, was consistent with the BPIC being closed for the entire journey from Carstairs to Edinburgh. This meant that the driver only had control of the friction and rheostatic brakes on the locomotive. The rheostatic brake shut down towards the end of the journey, and only the friction brakes on the locomotive remained available to stop the train (paragraph 88).

Identification of causal factors

53 The incident occurred due to a combination of the following causal factors:

- The brake pipe isolation cock was closed, removing control of the coach brakes from the driver (paragraph 54)
- The train driver did not recognise that the train's braking performance was compromised until the final approach to Haymarket East Junction (paragraph 69)
- The train manager was not alerted to the brake problem until the train was passing through Edinburgh Waverley station (paragraph 92).

Each of these factors is now considered in turn.

Brake Pipe Isolation Cock

54 **The brake pipe isolation cock was closed, removing control of the coach brakes from the driver.**

55 The BPIC was closed when the brake pipe pressure was 5 bar (paragraph 59), meaning that the coach brakes were released. Closure of the BPIC sealed that pressure into the brake pipe which connected all the coaches, meaning that any subsequent brake application by the driver would have no effect on the brakes on the coaches, although the locomotive brakes would continue to operate.

Operation of the BPIC

56 After the shunter and the driver had carried out the brake continuity test, the shunter returned to the front of the Edinburgh portion of the train (paragraph 41). When he arrived at the locomotive, the driver was already on the track attempting to insert the second, non-platform side, ETS plug into the coach receptacle. The shunter went onto the track and connected the 61-way jumper cable before moving over to assist the driver with the second ETS connection.

57 The two of them struggled with the ETS plug for several minutes, before eventually fully connecting it with the assistance of some spray oil. They then left the track and prepared for departure of the train. Table 2 shows the detailed sequence of activities, with known timings, during the period when the shunter and the driver were on track struggling with the ETS plug.

Time	Activity
06:46:29	The shunter arrives at the locomotive and the driver is already on the track struggling to insert the ETS plug into the coach receptacle.
06:46:57	The shunter goes on to the track to connect the 61-way jumper cable, while the driver is struggling to insert the ETS plug
06:48 (approx.)	The shunter moves across to help the driver with the ETS plug
Uncertain	The shunter and driver continue to struggle with the ETS plug, and the driver goes to collect spray oil from the rear cab of the locomotive
06:50:57	Brake pipe disturbance recorded on the OTDR, indicating likely closure of the BPIC
06:52:00	The train manager observes both the shunter and driver still on track, having just completed the ETS connection
06:52:28	The driver resets an alarm in the front cab (resulting from the 61-way jumper cable having been connected)
06:52:38	The shunter exits the rear cab onto platform

Table 2: Sequence of activities when connecting the second ETS plug

58 At 06:50:57 hrs, the locomotive's OTDR shows a small dip in the locomotive brake pipe pressure, which then recovers very quickly. This is consistent with the dip in pressure expected when the BPIC on the coach is closed, with that on the locomotive remaining open. The coaches' BPIC has a small vent on the non-coach side, which opens to atmosphere when the valve is in the closed position. The purpose of this is to release pressure in inter-vehicle connections ready for uncoupling.

59 The effect of closing only the coach BPIC was to seal 5 bar pressure in the brake pipe linking the coaches, and to vent the locomotive side. However, because the locomotive was still coupled with its BPIC open, the locomotive quickly detected the fall in brake pipe pressure and charged the brake pipe back to 5 bar. The rate of recharging was much faster than the vent could release the pressure, and so the brake pipe quickly returned to 5 bar. Figure 11 shows the brake pipe pressure record from the locomotive's OTDR, showing the short dip in the brake pipe pressure. It also shows a similar dip resulting from a post incident test operation of the coach BPIC at Polmadie depot. RAIB has concluded from this testing that it is almost certain that the brake pipe pressure dip seen at Carstairs indicates when the BPIC on the coach was closed.

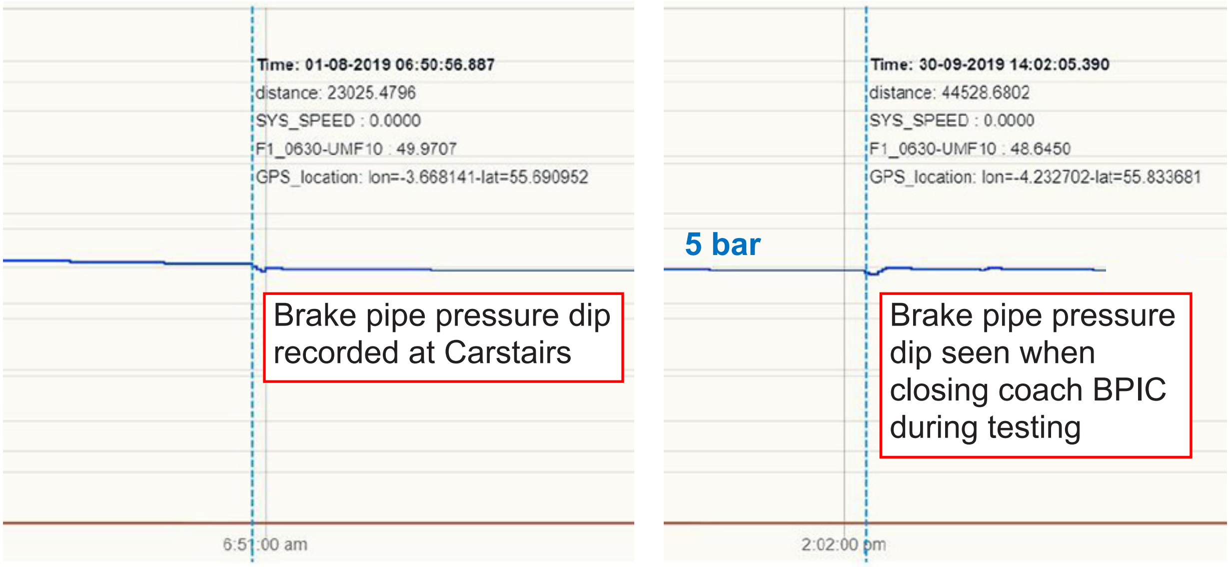

Figure 11: Comparison of brake pipe pressure dip at Carstairs and during BPIC operation testing

60 The timing of the brake pipe pressure dip indicates that the BPIC was almost certainly operated part way through the period when both the driver and the shunter were struggling with the second ETS plug. This was at least one minute before they finally connected it and started to leave the track. This means that it is very unlikely that either the driver or the shunter operated the BPIC deliberately to provide some personal protection to prevent the train from moving when accessing the track, or to remove such protection when leaving the track. Neither the driver nor the shunter recall operating the BPIC when on track, and neither recalls seeing the other operate it. The absence of a reason to interact with the BPIC at the time indicated by the OTDR, combined with the lack of awareness of it being operated, leads RAIB to conclude that, although the possibility of it being turned by hand cannot be totally discounted, it was almost certainly operated inadvertently by either the shunter or the driver.

Status of the train brake when the BPIC was closed

61 When the train driver went on track to help connect the second ETS plug, the train was being held using only the locomotive straight air brake (paragraph 30). The train brake pipe was charged to above 5 bar, as the driver had initiated the overcharge[4] process required at the end of the brake continuity test. This meant that the coach brakes were still released when the BPIC was closed.

62 Closure of the BPIC also meant that the coaches' brake pipe was not being kept charged by the locomotive, and so any leakage would tend to start to apply the coach brakes. However, because the coaches were new, and the air systems were well sealed, there was virtually no leakage and the pressure remained at 5 bar throughout the journey, keeping the brakes released.

[4] Brake pipe overcharge is undertaken to reset all the brake distributors on the train after the brake pipe has been vented, such as during the brake continuity test. The brake pipe pressure is raised to approximately 5.5 bar and allowed to return slowly back to 5 bar.

63 GB Railfreight's General Operating Appendix Module A4 'Automatic air brake testing' specifies that the driver should use the straight air brake on the locomotive, and not the coach brakes, to secure the train when a shunter is working on the track during the brake continuity test. This is consistent with Module SS2 'Shunting' of the railway Rule Book (GERT8000),[5] which states:

- *You must never go between vehicles unless you are sure they will not move. If you have to go between vehicles, you must:*
  - *wait until the vehicles have stopped completely*
  - *display a hand danger signal to the driver or instruct the driver not to move.*

64 GB Railfreight has general operating instructions requiring the driver to apply full service train brake and secure the cab when leaving it. If the driver had applied the train brake before accessing the track, closing the BPIC would have locked the 3.5 bar pressure in the coaches' brake pipe, keeping the coach brakes applied, and the train would then have been unable to depart. Although connecting the ETS and 61-way cable at Carstairs is supposed to be undertaken by the shunter, the driver tried to assist him by going to connect the second ETS plug while the brake pipe was in overcharge, and did not expect this to take the time that it did.

Vulnerability of the BPIC

65 The BPIC is positioned immediately below the ETS receptacle into which the shunter and the driver were trying to insert the plug (figures 12 and 13). It is operated by a handle that points horizontally across the coach, in line with the brake pipework, when open and downwards when closed. The handle is fitted with a latch mechanism that secures the handle when it is in either the fully open or the fully closed position. When the BPIC is not fully open or closed, the latch mechanism does not secure the handle, and it is free to turn without releasing the latch. The latch mechanism can be released by leaning on it or brushing past it, and if the valve is turned slightly, the latch will not re-engage.

66 When the shunter first went to help the driver, he was between the running rails, in a position similar to that shown in figure 12.[6] The driver was attempting to connect the ETS plug while crouching outside the rails facing towards it, in a position similar to that recommended in the rolling stock ergonomic assessments. The shunter later moved out from between the rails to a position crouching beside the driver and close to the steps. The work with the ETS plug was being undertaken above and very close to the BPIC. It is very likely that the BPIC was either leaned on or brushed against by either the driver or the shunter, caught on clothing, or knocked by the loose ETS plug. Although the BPIC was open, it is possible that its handle might not have been turned sufficiently for the latch to have engaged prior to coupling the locomotive, thus making the valve more susceptible to inadvertent closure.

[5] The railway Rule Book is maintained and published by RSSB on behalf of its members. RSSB is a not-for-profit body whose members are the companies making up the railway industry, and is registered as Rail Safety and Standards Board Ltd, but trades as RSSB.

[6] Note that at Carstairs, the train was on ballasted track, rather than the illustrated concrete surface, and so there would have been a little more vertical space for the shunter to move onto his knees.

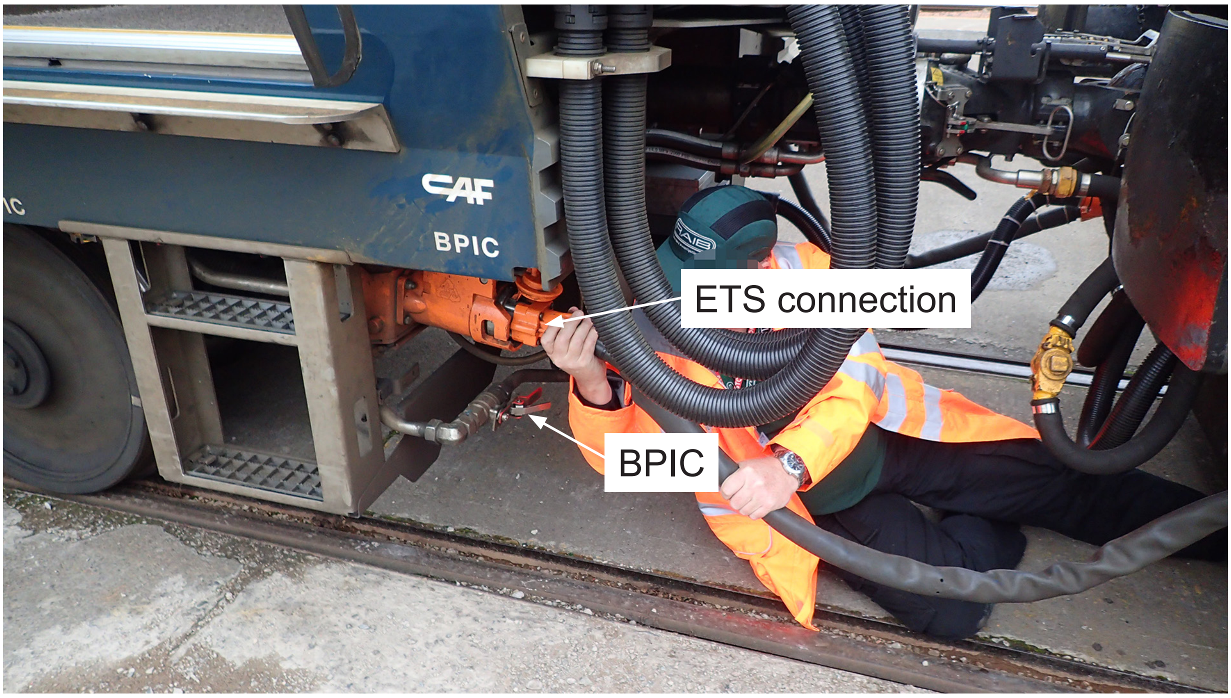

Figure 12: Location of the BPIC, showing proximity to ETS connection

67 Venting through the closed BPIC would have been accompanied by the sound of escaping air. However, the vent on the coach BPIC is much smaller than that on the locomotive BPIC, and also smaller than that fitted to Mark 2 and 3 coaches, the previous vehicles used on the sleeper service. As a result, the Mark 5 BPIC vent makes much less noise than the staff would normally have experienced with other coaches and locomotives. Neither the driver nor the shunter recalled hearing the BPIC vent, over the sound of the adjacent locomotive, and so were not alerted to the BPIC being closed.

68 RAIB notes that, although a flying ballast protection plate is provided, this only protects the BPIC on one side and the valve's position means that it is exposed to impact from objects approaching from the other side, such as fallen vegetation or flying ballast. The handle and its latch appear to be less robust than the latched type handles normally used on UK rolling stock (figure 13), and therefore may be more susceptible to inadvertent operation. Latched BPIC handles were recommended by the Railway Inspectorate report on a collision at Darlington on 16 February 1977, which was caused by a BPIC being knocked closed by debris on the track.

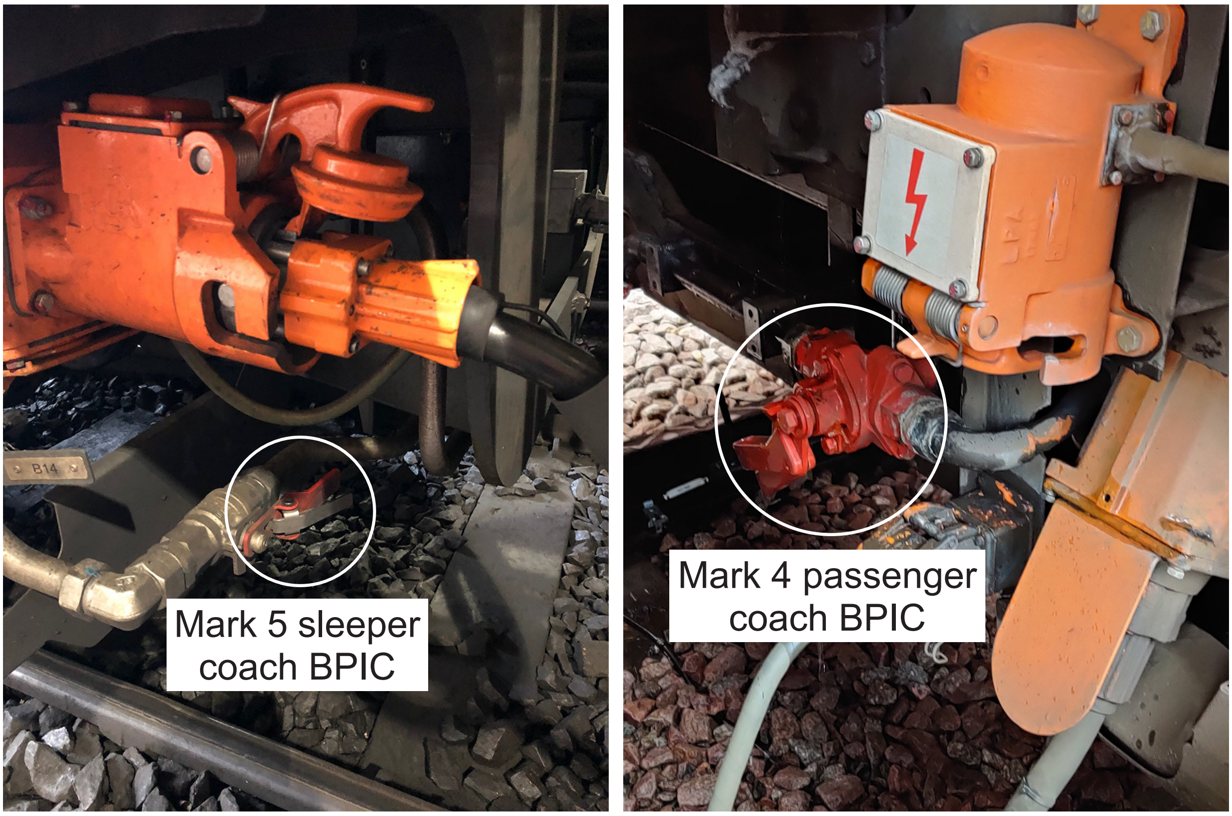

Figure 13: Mark 5 sleeper coach BPIC compared with Mark 4 passenger coach BPIC (Left image courtesy of GB Railfreight)

Driver's awareness of brake performance

69 **The train driver did not recognise that the train's braking performance was compromised until the final approach to Haymarket East Junction.**

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

- The brake continuity test was undertaken at Carstairs before the BPIC valve was closed (paragraph 71)
- The running brake test undertaken after leaving Carstairs did not reveal the compromised braking to the driver (paragraph 80)
- The service braking performance of the train did not reveal the compromised braking to the driver until after the rheostatic brake had shut down, as the train was approaching the 60 mph (96 km/h) speed restriction near to Slateford (paragraph 85).

Each of these factors is now considered in turn.

71 The brake continuity test was undertaken at Carstairs before the BPIC valve was closed.

72 The procedure for shunting the northbound sleeper at Carstairs is defined in the Caledonian Sleeper document 'Local Operations Manual – Carstairs'. At the time of the incident, the relevant document number was 'LOM SCGB 003 – Issue 9', dated 9 March 2019. This document was finalised on 25 April 2019 and was circulated to Caledonian Sleeper staff, and to GB Railfreight, that day. In light of the issues with damaged components (paragraph 18), an email was sent to operational staff on 26 April emphasising the importance of the new procedural requirement to only connect the 61-way jumper cable after the train has been split and the brake test completed. For the northbound sleeper, which splits at Carstairs, the key steps in the process are shown in table 3.

Step	North Bound Sleeper Shunting Moves
1	The Northbound Lowlander (1S26) arrives into Carstairs Station
	…
4	The Edinburgh locomotive is shunted on the rear of the train by the Caledonian Sleeper shunter. The 61 Jumper must not be connected at this point …
5	The Shunter then uncouples the Edinburgh and Glasgow sets and draws the two sets apart.
	…
10	1S26 Glasgow Section then departs with the Train Manager at rear of train in seated coach.
11	Brake test is then carried out on the Edinburgh portion.
12	The Shunter will confirm to Train Manager on 1B26 Edinburgh section that a satisfactory brake test has been undertaken. They will then connect the 61 Jumper …
	…
16	The Train Manager will close the local door and give the 'ready to start' signal to the Driver.

Table 3: Key steps in the train splitting process at Carstairs, reproduced from the 'Local Operations Manual – Carstairs'

73 After train 1S26 arrived at Carstairs, the driver and shunter prepared the locomotive for coupling and the shunter opened the BPIC on the coach they were about to couple to (paragraph 36). They then mechanically coupled the locomotive to the coaches, as required by step 4. As specified, the shunter did not connect the 61-way jumper cable, but did start to connect the ETS supply to the coaches.

74 After connecting the first ETS connector, on the platform side, the shunter observed that a northbound freight train was slowly passing on an adjacent track and coming to a stand at a red signal. This signal was red because the train's route ahead was blocked by train 1S26, the front end of which extended well past Carstairs station (paragraph 35). Although the presence of the freight train would not have prevented the shunter from moving to the non-platform side to connect the second ETS cable, it did prompt him to consider the steps that he still had to take and the order in which he would carry them out.

75 The shunter recognised that he still had to make the second ETS and the 61-way connections between the locomotive and the coaches. He was also aware that the 61-way jumper cable could not be connected before the two portions of the train were separated (paragraph 72). As a result, he decided that the second ETS connection could wait until he returned to the locomotive, and he proceeded to split the train and allow the Glasgow portion to depart without any additional delay.

76 The shunter had separated the two portions of the train, as required by step 5. He then, in communication with the driver of the Edinburgh portion, carried out the brake continuity test that was required by step 11 (paragraph 39). This verified that there was a continuous brake pipe between the locomotive and the rear of the Edinburgh portion of the train. The Glasgow portion then departed (step 10). The brake continuity test is mandated by Module TW1 'Preparation and movement of trains' of the Rule Book, which states *'You must carry out a brake continuity test … when a locomotive is coupled to the train'*. When they carried out the brake continuity test, the locomotive was coupled to the train, but some electrical connections still had to be made.

77 The shunter then returned to the Edinburgh locomotive, with the train manager, and proceeded to fit the 61-way jumper cable (step 12). He then assisted the driver with the second ETS plug, during which time it is almost certain that the BPIC was moved to the closed position (paragraph 60).

78 The Local Operations Manual, which included instructions to complete the brake continuity test before connecting the 61-way jumper cable, was an evolution of a previous version. This had related to the Mark 2 and 3 coaching stock that was used on the Lowlander Sleeper up until the introduction of the Mark 5 coaches in April 2019 (paragraph 16). There was no 61-way connection on the previous coaches and locomotives, although there were other system connections that were not sequence constrained. This meant that the Edinburgh locomotive could be fully coupled before the train was split and the brake continuity test carried out. There was no need for staff to go back on to the track after the brake continuity test had been completed.

79 The shunter was largely compliant with the documented operational procedure in that it required him to access the track between the locomotive and the coaches after the brake continuity test had been completed. It was implicit in the procedure that this was intended to be to used to fit the 61-way jumper cable, but the shunter took advantage of this opportunity to delay making the second ETS connection. The procedure had an inherent vulnerability in that it placed staff on track, in a position where they could either consciously or inadvertently affect the position of valves in the brake system and thus compromise the integrity of the brake continuity test. The absence of a subsequent brake continuity test led to the closure of the BPIC being undetected prior to departure from Carstairs.

80 **The running brake test undertaken after leaving Carstairs did not reveal the compromised braking to the driver.**

81 The running brake test is mandated by Module TW1 of the Rule Book and is intended to give the driver feedback to indicate that the brake system on the train is operational. The Rule Book states that:

- *You must test that the automatic brake is working properly by carrying out a running brake test.*
- *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*
  - *the speed of the train is being reduced.*
- *You must carry out the running brake test at the first opportunity after beginning the journey*.

82 The driver carried out the brake test as soon as the train was on relatively level track, when it had reached 70 mph (113 km/h) (paragraph 43). This was the normal location for carrying out the running brake test after leaving Carstairs for Edinburgh. The driver applied the train brake and reduced the speed by 11 mph (18 km/h). The rate of speed reduction achieved was similar to that obtained by a different driver on the previous day, but the level of brake application required to achieve this was higher this time. Because of the effect on passenger comfort on the sleeper service, the driver was not intending to achieve a rapid deceleration; he achieved what he perceived to be a normal deceleration rate, and so did not identify that there was reduced available braking.

83 Although the coach brakes were isolated by the closed BPIC, the brakes on the locomotive were fully operational and under the driver's control. The locomotive braking is designed to primarily be provided by the rheostatic brake, to reduce brake block wear. The rheostatic brake is intended to replicate the retardation available from the locomotive's friction brake during normal operation, so that if the rheostatic brake is unavailable for any reason, the friction brake takes over. This means that the entire train of eight coaches was being retarded by the locomotive's rheostatic brake. The effectiveness of the rheostatic brake masked the non-operational coach brakes during the running brake test, so the driver did not perceive a problem.

84 Although the Rule Book requires drivers to carry out an additional running brake test '*before approaching a steep falling gradient*', the driver did not consider this necessary before passing Cobbinshaw summit. He did not consider the gradient of approximately 1 in 100 to be sufficiently steep, and he had just undertaken a running brake test about five minutes earlier. However, even if he had carried out an additional running brake test on the uphill gradient before Cobbinshaw summit, the rheostatic brake would still have masked the non-operational state of the coach brakes.

85 The service braking performance of the train did not reveal the compromised braking to the driver until after the rheostatic brake had shut down, as the train was approaching the 60 mph (96 km/h) speed restriction near to Slateford.

86 The service brake application shortly after the train had passed Cobbinshaw summit brought the speed down to 64 mph (103 km/h), to comply with the short 70 mph (113 km/h) speed restriction at Linhouse Water viaduct, near to Midcalder Junction (paragraph 44). Comparison of the braking used at this location with that from the same service on different dates shows that more braking demand was required to achieve the deceleration than was normal, although the actual deceleration achieved was similar. The driver stated that the brake performance during this period did not feel unusual at the time, and that it was within, although at the lower end of, the normal limits that he would expect for this type of train. As a result, he did not perceive a problem with the train brakes.

87 Figure 14 shows that the driver made two short applications of the locomotive's straight air brake during this initial period of service braking. Although this might suggest that the driver had some concern about his brakes, he stated that this was because the cab gauges were showing no brake cylinder pressure during braking, and he applied the straight air brake to get reassurance that the friction braking was working. The brake cylinder pressure gauges (paragraph 31) were not showing any friction brake application at the time because the rheostatic braking was providing the required braking. The driver allowed the train speed to rise after this, showing that he was not particularly concerned about the operation of the brakes.

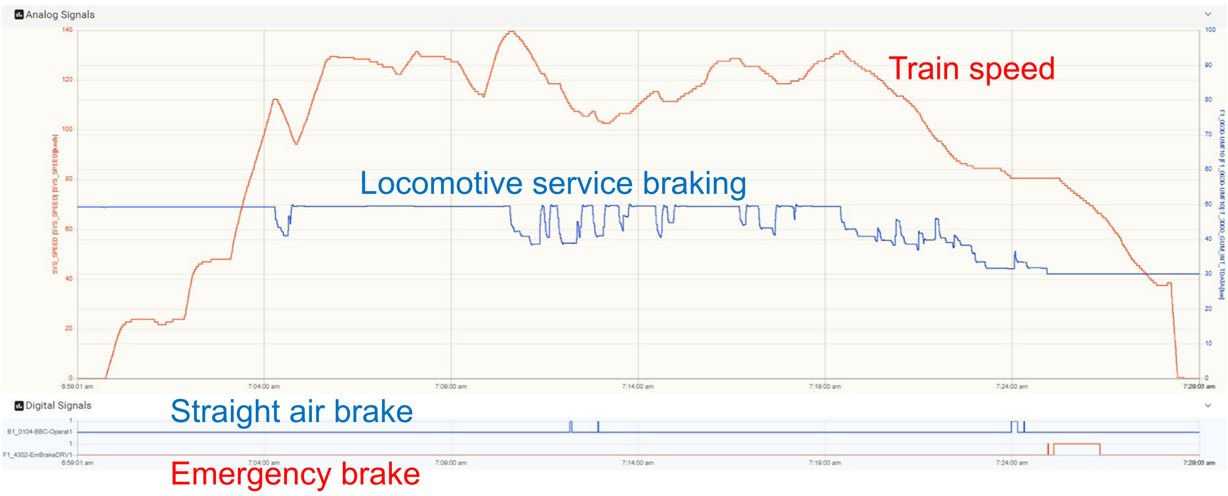

Figure 14: Speed and braking data from the locomotive OTDR

88 At the overhead line neutral section near Curriehill station (paragraph 44), the main circuit breaker on the locomotive opened automatically as intended, but did not reclose, and the pantograph dropped about 25 seconds later. The OTDR data does not include the detail required to explain why this happened, or the detail of subsequent events within the locomotive's control system. However, it is likely that the locomotive's electrical converters shut down during this event, and consequently the rheostatic brake stopped working. That would have resulted in the locomotive's friction brake becoming active, thus continuing to retard the train.

89 Just before Slateford station, the train stopped decelerating (paragraph 44), although the brakes were still effective in preventing the train speed from increasing on the gradient. It is likely that the cast iron brake blocks used on the locomotive's friction brake had become very hot while braking the total weight of the locomotive and the coaches from Curriehill. British Railways Board Technical Note TNMS9[7] shows that the coefficient of friction of cast iron brake blocks applied at speed reduces as they heat up, thus reducing their effectiveness.

90 On sensing the reduced deceleration, the driver applied maximum service train braking, but this had no additional effect. The train then entered a short, almost level, section of track through Slateford station and the train started to decelerate. This lasted until the gradient resumed after the station, when the train stopped decelerating at a speed of 50 mph (80 km/h). At this point the driver applied the straight air brake, but this also had no effect because the locomotive friction brake was already fully applied due to the maximum service brake application.

91 About halfway between Slateford and Haymarket East Junction, with the train not decelerating under a full service train brake application and a full straight air brake application, the driver, recognising that there was a serious problem with the train braking, applied the emergency brake. This vented the brake pipe on the locomotive to apply full brake. However, the brakes on the locomotive were already fully applied. The brake pipe on the coaches did not vent, because the BPIC was closed, and so the coaches' brakes remained released. As a result, the emergency brake application had no effect on the train braking.

'Train in distress'

92 The train manager was not alerted to the brake problem until the train was passing through Edinburgh Waverley station.

93 The 61-way jumper cable provides a telephone link between the driver in the locomotive cab, and the train manager in their office in the seated coach. These calls can also be answered at communications points in each coach and are indicated on the in-coach information displays. The train manager also normally has a radio in the office, but a change of coach in the train meant that there was no radio available on the day of the incident.

94 During the journey from Carstairs, the train manager was not in his office, and was moving between coaches undertaking his duties and responding to faults with the on-board toilets. Because he was not in his office and did not have a radio, the driver was unable to contact him after recognising the brake problem. The presence of toilet fault indications also distracted the train manager from any visible call alert on the in-coach information displays. Caledonian Sleeper stated that it did not expect train managers to always be in the office, nor for them to always carry a radio, and that they should regularly move through the train to check all is in order during the journey. As a result, it did not expect the driver to always be able to talk to the train manager immediately.

[7] Titled 'Cast Iron Brake Blocks – Part 1 – The friction and wear characteristics of very high phosphorus (VHP) and standard cast iron using a simulated carriage axleload'.

95 Module TW1 of the Rule Book states that '*if you cannot control the speed of your train or you need to alert anyone about some other emergency, you must … sound the 'train in distress' warning (a continuous series of long blasts on the high/loud tone of the horn)*'. The driver did not do this, despite being unable to stop the train. Had he done so, it is possible that the train manager would have heard it and either called the driver or used the passenger alarm button to apply the coaches' brakes earlier.

96 The driver was focused on trying to regain control of the brakes and on contacting the signaller to ensure that his route ahead was clear of other trains. To do this, he made a GSM-R call to the signaller on the approach to Princes Street Gardens to alert him that the train's brakes were not working and to request a clear route through Edinburgh Waverley station. The driver did not press the emergency button on his GSM-R unit, as he was aware that this would stop all trains in the station and possibly prevent the signallers from being able to set a clear route.

Identification of underlying factor

Operational changes

97 Caledonian Sleeper did not fully assess the operational consequences of changes in the evolving sleeper rolling stock design.

98 The design of the Mark 5 coaches went through a number of iterations, which had an impact on how they would be operated. In April 2016, the design intent was for the coaches to use a fully automatic coupler, which would avoid the need for operational staff to access the track during coupling and uncoupling. The BPIC was to be located in a cupboard in the end vestibules, so that the shunter could operate it from on board the train. However, the intention to avoid needing to go on track proved to be impractical because of the difficulty in making the high-power ETS connections between coaches without using a manual plug and receptacle.

99 In October 2016 the BPIC was repositioned on the end of the coach underframe, due to the manufacturer's concerns about the possibility that the complexity of the brake pipe layout would result in excessive brake propagation[8] times along a 16-coach train. The repositioned Mk5 BPIC was installed below the ETS socket (figures 5, 12 and 13). This change also required staff to access the track during coupling and uncoupling.

100 As a result, the coupling and uncoupling operations for the new coaches and the previous Mark 2 and 3 rolling stock were similar, in that access to the track was required to make mechanical and electrical connections, and to operate isolating cocks. The existing procedure in the Local Operations Manual was adapted for the new coaches after the design was finalised, and again later to include lessons learned during test running. As a result, it was only finalised in the week that the new coaches entered service, in April 2019, and remained unchanged until the date of the incident.

[8] Brake propagation is the rate at which the pressure in the brake pipe changes along the length of a train.

101 Undertaking the brake continuity test after the completion of all coupling and uncoupling operations had been identified as a key mitigation measure in design and operational risk assessments that were undertaken, with Caledonian Sleeper participation, throughout the design process. Despite this, that mitigation measure was not embodied within the procedure for operations at Carstairs when it was revised by Caledonian Sleeper. Furthermore, there was no risk assessment of the operation as defined by the Local Operations Manual, which could also have highlighted the vulnerability in the procedure. Alternatively, the impact on the operability of the coupling operation resulting from the need to delay fitting the 61-way jumper cable could have been considered and possibly designed out, or alternative operational controls introduced. The positive implications of such measures were not identified.

Factor affecting the severity of consequences

102 **The train was running under green signals and so did not have to stop at the conflict point at Haymarket East Junction.**

103 As the train approached Haymarket East Junction on 1 August 2019, the signalling system had already set a route through Haymarket platform 3 and into Princes Street Gardens. Two trains in each direction on the Edinburgh and Glasgow lines, which the train joined at Haymarket East Junction, were held at signals to allow the sleeper train a route through Haymarket station. In addition, there was no train ahead of it in Haymarket station. Sleeper operating staff stated that it was unusual for the train to get a clear route through Haymarket East Junction, without encountering adverse signals. Had the route not been clear, it is possible that a collision between passenger trains at significant speed could have occurred at the junction or in Haymarket station. The train passed through Haymarket East Junction at 50 mph (80 km/h). Although this was above the 40 mph (64 km/h) maximum permitted speed, it was well below that required to pose a significant risk of derailment.

Observations

Design of the BPIC valve

104 **The BPIC valve on the Mark 5 sleeper coaches does not comply with the most appropriate standard for such equipment.**

105 The valve that was selected for use as the BPIC was not designed or certified against the requirements of British and European standard BS:EN14601:2005+A1:2010 ‘Railway applications - Straight and angled end cocks for brake pipe and main reservoir pipe’. This is the normal standard for the design of the BPICs on railway rolling stock in both the UK and Europe.

106 This arose primarily because the ‘Locomotives and Passenger Rolling Stock’ Technical Standard for Interoperability (TSI), does not define the Dellner coupler used on the Mark 5 sleeper coaches as a manual coupler. It defines a manual coupler as ‘buffers and screw coupling’ and, even though the Dellner coupler used on the Mark 5 sleeper coaches requires activity at track level to make mechanical and electrical connections and to operate isolation valves, it falls outside this definition. The design requirements for manual couplers direct the designer towards a suite of standards for underframe equipment, such as BS:EN14601:2005+A1:2010 for the BPIC and MRPIC. The TSI does not point the designer to any standards for BPICs for rolling stock fitted with other types of couplers.

107 None of the parties involved in specifying, designing or approving the coaches identified BS:EN14601:2005+A1:2010 as being appropriate for the BPIC. This meant that a valve was selected that was not certificated as compliant with the most appropriate standard for the intended application.

108 BS:EN14601:2005+A1:2010 specifies that cock handles should have a latch system, and one was fitted to the BPIC to help prevent unintended operation. However, it does not specify any requirements for the force required to release this latch. The EN standard also requires the BPIC to be installed with the handle pointing upwards when closed, but this would not necessarily have prevented inadvertent operation. As a result, the incident could still have happened with a BPIC design that was compliant with BS:EN14601:2005+A1:2010.

Locomotive OTDR

109 **GB Railfreight was unable to download the locomotive’s OTDR data to enable detailed analysis of the brake performance.**

110 The OTDR used on the class 92 locomotives communicates remotely with an internet-based data storage and analysis system. The OTDR uploads data to this system every few minutes and it is then available to view by anyone with a login using an internet-connected web browser.

111 After the incident, RAIB asked GB Railfreight to provide the OTDR data from the locomotive, to provide an evidential record of the locomotive status during the journey from Carstairs to Edinburgh. GB Railfreight was unable to download the data from the internet-based system. It did succeed in providing a data file that was downloaded directly from the locomotive, but this only covered a period of a few minutes after the train had come to a stop in Calton South tunnel.

112 GB Railfreight did provide RAIB with a login for the system and this allowed RAIB to view the locomotive data online throughout the investigation. However, RAIB was also unable to download the data from this system. This meant that RAIB was unable to carry out more detailed analysis or secure a copy of the OTDR data in its evidence management system.

Summary of conclusions

Immediate cause

113 The driver did not have control over sufficient brake force to fully control the speed of the train on the approach to Edinburgh (paragraph 51).

Causal factors

114 The causal factors were:

a The brake pipe isolation cock was closed, removing control of the coach brakes from the driver (paragraph 54, **Recommendations 1 and 2**).

b The train driver did not recognise that the train's braking performance was compromised until the final approach to Haymarket East Junction (paragraph 69). This causal factor arose due to a combination of the following:

i The brake continuity test was undertaken at Carstairs before the BPIC valve was closed (paragraph 71, **Recommendation 1**, **Learning points 1 and 2**).

ii The running brake test undertaken after leaving Carstairs did not reveal the compromised braking to the driver (paragraph 80, **Learning point 3**).

iii The service braking performance of the train did not reveal the compromised braking to the driver until after the rheostatic brake had shut down, as the train was approaching the 60 mph (96 km/h) speed restriction near to Slateford (paragraph 85, no recommendation).

c The train manager was not alerted to the brake problem until the train was passing through Edinburgh Waverley station (paragraph 92, **Learning point 4**).

Underlying factor

115 An underlying factor was that Caledonian Sleeper did not fully assess the operational consequences of changes in the evolving sleeper rolling stock design (paragraph 97, **Learning point 2**).

Factor affecting the severity of consequences

116 A factor affecting the severity of consequences was that the train was running under green signals and so did not have to stop at the conflict point at Haymarket East Junction (paragraph 102, no recommendation).

Additional observations

117 Although not linked to the incident, RAIB observes that:

a the BPIC valve on the Mark 5 sleeper coaches does not comply with the most appropriate standard for such equipment**.**(paragraph 104, **Learning point 5**)

b GB Railfreight was unable to download the locomotive's OTDR data to enable detailed analysis of the brake performance (paragraph 109, **Learning point 6**).

Previous RAIB recommendations relevant to this investigation

118 RAIB has previously investigated incidents where the brakes on trains have been isolated when in service. These include the runaway of a maintenance train near Markinch on 17 October 2017 (RAIB report 01/2018) and a signal passed at danger near Ketton on 24 March 2016 (RAIB safety digest 02/2016). Neither of these investigations resulted in recommendations that were directly relevant to this incident.

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

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

119 Immediately after the incident Caledonian Sleeper issued an internal safety alert to its staff, and to its contractors. This stated that it was now mandatory that the last operational task during coupling or uncoupling was to be the brake continuity test. It also stated that if any work was required between the locomotive and the coaches after the brake continuity test had been completed, then the brake continuity test had to be repeated. This instruction superseded the procedure detailed in the Local Operations Manual for Carstairs, pending its revision. A similar brief was issued by GB Railfreight to its staff.

120 Caledonian Sleeper also issued a safety alert to the industry on 5 August 2019 (Rail Notice NIR 3350/224) alerting railway staff to the risk of not carrying out a brake continuity test as the final action prior to a train being despatched.

121 Caledonian Sleeper, in conjunction with GB Railfreight, carried out a fresh risk assessment of the train operations at Carstairs. The procedure has since been revised to use the Glasgow-bound locomotive to split the train before the Edinburgh-bound locomotive is coupled to the Edinburgh portion. The effect of this is to allow the Edinburgh locomotive to be fully coupled up, including the two ETS connectors and the 61-way jumper cable, in one activity. This means that no coupling activity takes place after the brake continuity test has been completed. The Local Operations Manual for Carstairs has been revised to reflect these operational changes and briefed to staff.

Other reported actions

122 Caledonian Sleeper has updated its training material to include reference to the risks associated with operation of the BPIC. This is intended to highlight the need to carry out a brake continuity test as the last activity after coupling a locomotive, and explain the reasons why.

123 Caledonian Sleeper has reviewed the orientation of the BPIC handle and concluded that it should be inverted so that the handle points upwards when the valve is closed. This is so that it is consistent with the orientation of the BPIC on the class 92 locomotives, and so that it should vibrate to the safe (open) position in the event of being left unlatched. Caledonian Sleeper has had this modification independently assessed, taken it through the engineering change process with the manufacturer and has fully implemented it.

124 Caledonian Sleeper is also reviewing the vent arrangements on the BPIC. The intention is to make the vent larger, so that venting is more audible to staff. This review is also considering whether the vent capacity could be sufficient to prevent the locomotive from achieving sufficient pressure to release the brakes if a valve has been closed within the train. This review was ongoing at the time of publication of this report.

125 Caledonian Sleeper has introduced an additional check to the train despatch process after a locomotive has been coupled. The train manager undertakes a visual check of the BPIC position before departure and verifies that a final brake continuity check has been completed. This check is recorded on the train manager's shift report paperwork.

126 Caledonian Sleeper has taken steps to ensure that train managers always have access to a radio to allow communication with the driver or the shunter when required.

Recommendations and learning points

Recommendations

127 The following recommendations are made:[9]

1 *The intent of this recommendation is to ensure the integrity of the mandated brake continuity test when coupling a locomotive to a train.*

RSSB, in consultation with its members, should amend the wording of section 4.2 of Rule Book module TW1 (GERT8000-TW1 – 'Preparation and movement of trains') to make it clear that the brake continuity test should be carried out after all coupling-related activities have been completed (paragraphs 114a and 114b(i)).

2 *The intent of this recommendation is to reduce the probability of the driver losing control of the coach brakes on the Caledonian Sleeper trains.*

Serco Caledonian Sleepers Limited, in conjunction with its design authority, should review the design of the brake pipe isolating cock on its Mark 5 sleeper coaching stock, particularly in relation to its vulnerability to undetected, inadvertent operation by people during shunting or train preparation, or by objects (such as fallen trees, flying ballast, or other debris). If applicable, it should implement mitigation measures to reduce the risk (paragraph 114a).

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[9] Those identified in the recommendations have a general and ongoing obligation to comply with health and safety legislation, and need to take these recommendations into account in ensuring the safety of their employees and others.

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

(a) ensure that recommendations are duly considered and where appropriate acted upon; and

(b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

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

Learning points

128 RAIB has identified the following important learning points:[10]

1. Train and freight operating companies are reminded of the importance of ensuring that their procedures for coupling and uncoupling of trains do not require staff to access areas where they could undermine the integrity of the brake continuity test after it has been completed (paragraph 114b(i)).

2. Train and freight operating companies are reminded of the importance of ensuring that all mitigation measures identified during the design and commissioning of new or modified rolling stock are taken fully into account in associated operating procedures (paragraph 114b(i) and 115).

3. Train and freight operating companies are reminded that any risk assessments undertaken for the operation of trains should recognise that the running brake test mandated by the rule book may not reveal train brake defects, particularly when locomotives with rheostatic braking are being used (paragraph 114b(ii)).

4. Train drivers are reminded of the rule book requirement to sound the ‘train in distress’ signal on the train horn in circumstances where they are unable to control the speed of their train or need to alert anyone about some other emergency (paragraph 114c).

5. Specifiers, designers and manufacturers of railway vehicles, and relevant approval bodies, are reminded that safety-critical equipment, such as the brake pipe isolating cock, should comply with the most appropriate standards defined for such equipment, and that to achieve this, appropriate standards need to be identified at an early stage in the project lifecycle (paragraph 117a).

6. Train and freight operating companies are reminded of the importance of being able to download the relevant OTDR data from their trains in the event of an accident or incident, so that detailed analysis can be undertaken (paragraph 117b).

[10] ‘Learning points’ are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where RAIB has not identified management issues that justify a recommendation) and the consequences of failing to do so. They also record good practice and actions already taken by industry bodies that may have a wider application.

Appendices

Appendix A - Glossary of abbreviations and acronyms

AC	Alternating Current
BPIC	Brake Pipe Isolating Cock
CAF	Construcciones y Auxiliar de Ferrocarriles
DC	Direct Current
ETS	Electric Train Supply
GSM-R	Global System for Mobile Communications - Railway
MRPIC	Main Reservoir Pipe Isolating Cock
ORR	Office of Rail and Road
OTDR	On-Train Data Recorder
RAIB	Rail Accident Investigation Branch
TSI	Technical Standard for Interoperability

Appendix B - Investigation details

RAIB used the following sources of evidence in this investigation:

- information provided by witnesses
- documentation relating to operation of the sleeper trains
- design and approvals documentation and drawings
- information taken from the train's on-train data recorders (OTDR)
- closed circuit television recordings taken from Carstairs and Edinburgh Waverley stations
- site photographs and measurements
- weather reports and observations at the site
- testing of the train at Polmadie
- a review of previous RAIB investigations that had relevance to this incident.

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This report is published by the Rail Accident Investigation Branch,
Department for Transport.

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