Rail Accident Report

Runaway locomotive at Beddgelert, North Wales
16 April 2019

Report 02/2020
February 2020

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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Preface

The purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences. It is not the purpose of such an investigation to establish blame or liability. Accordingly, it is inappropriate that RAIB reports should be used to assign fault or blame, or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

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

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

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

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

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

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

Any information about casualties is based on figures provided to the 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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Contents

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Summary

At around 09:17 hrs on 16 April 2019, a diesel locomotive was unable to stop as it descended a steep gradient into Beddgelert station on the Welsh Highland Railway, Gwynedd. After passing through the station at around 10 mph (16 km/h), the locomotive passed a signal at danger and then entered a single line section without authority. The driver tried various ways of applying more braking effort but was unable to slow the locomotive down. After travelling for around 1.7 km, the locomotive came to a halt when the gradient levelled out. The driver was uninjured, and no other train was on the line at the time.

The incident occurred because the locomotive's brakes had been modified in a way that limited the movement of the brake blocks. This, the state of the adjustment of the brakes and the wet conditions on the day prevented the brakes applying the necessary brake force to slow the locomotive down. The issue with the brake system modification had remained undetected during the 18 years since the modification was made. The RAIB investigation found that the change to the locomotive's brakes had not been adequately documented or controlled. RAIB observed that, although not causal to the incident, the locomotive did not have a documented brake inspection procedure, and the 'deadman' safety system was not enabled on the locomotive when the runaway occurred. RAIB also observed that the railway's investigations of its incidents could be improved to better understand underlying systemic issues.

As a result of its investigation, RAIB has made three recommendations addressed to the Festiniog Railway Company that relate to:

- improving its management of engineering change;
- ensuring its maintenance processes are documented and controlled; and
- the use of the 'deadman' safety system.

A fourth recommendation is addressed to the Heritage Railway Association to promote the distribution of this report's findings to other heritage railways.

RAIB has also identified three learning points, reminding heritage railways of the importance of:

- carefully assessing, checking and documenting safety critical modifications;
- understanding the risks associated with all safety critical systems and assessing existing control measures and dependence on human performance; and
- thorough investigation of safety incidents, which can help to ensure that risk mitigation measures are appropriate and proportionate.

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 around 09:17 hrs on 16 April 2019, the diesel locomotive 'Vale of Ffestiniog' was unable to stop as it descended a 1 in 40 gradient on the narrow-gauge Welsh Highland Railway (WHR). The locomotive passed through Beddgelert station (figure 1) at around 10 mph (16 km/h), passed a signal at danger and entered a single line section without authority.

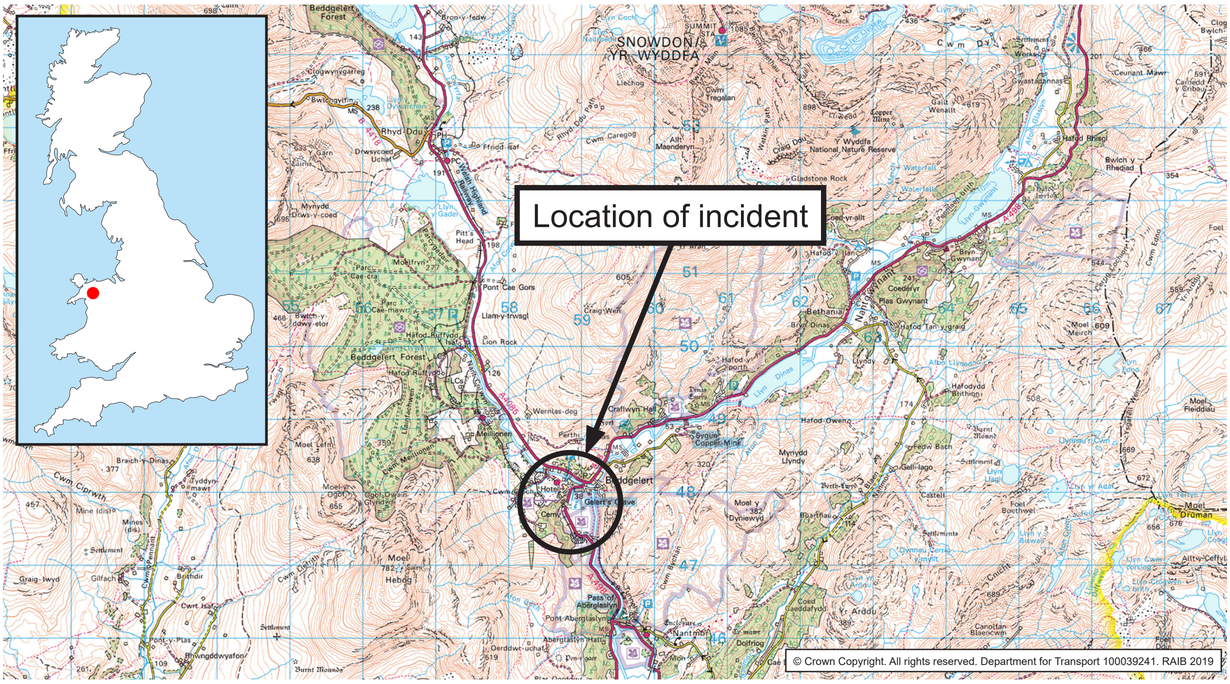

Figure 1: Extract from Ordnance Survey map showing location of incident

4 The driver of the train operated the brakes, but this did not result in sufficient brake force being applied to the wheels to slow the locomotive. The locomotive ran for around 1.7 km before coming to a stop when the gradient flattened out.

5 Nobody was injured and there were no other trains on the line at the time of the incident.

Context

Location

6 The WHR is a single-line, 600 mm (1'11½") gauge railway that runs for 40 km between Caernarfon and Porthmadog, both in Gwynedd, Wales (figure 2). The route ascends continuously for 20 km through Waunfawr and Rhyd Ddu, passing to the south-west of Yr Wyddfa (Snowdon). Shortly after Rhyd Ddu, the railway crests a summit at Pitt's Head, and then descends an average 1 in 43 gradient for 10 km, passing through Beddgelert and the Aberglasyn Pass (figure 3). The final 10 km is almost level, and runs over the Traeth Mawr polder and into Porthmadog (figure 2 and 3).

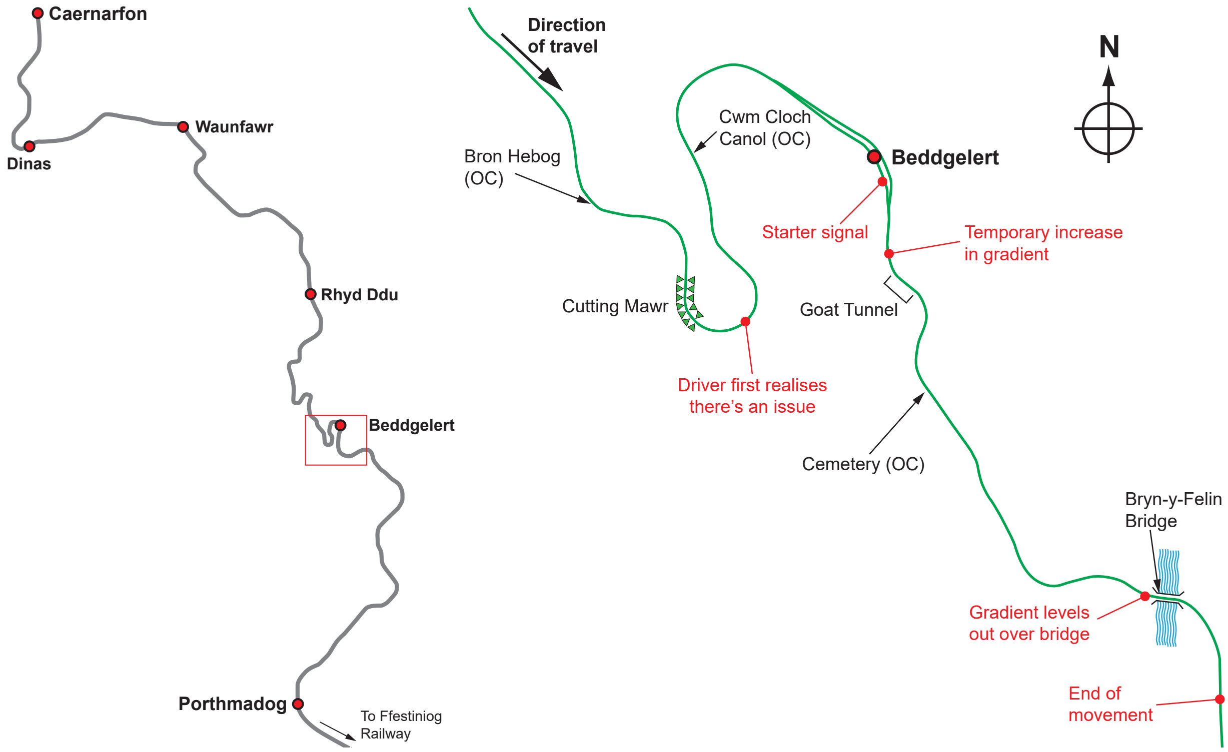

Figure 2: Geographical overview of the Welsh Highland Railway route, and (right) detail of the area in which the runaway occurred.

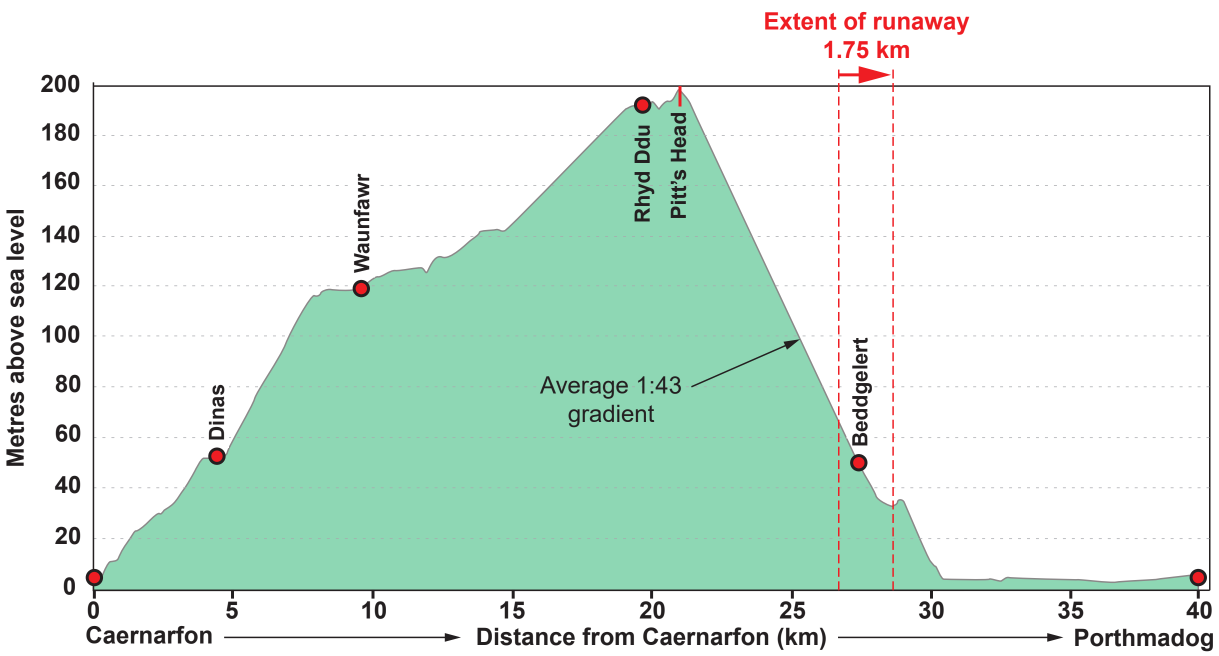

Figure 3: Gradient profile of the Welsh Highland Railway route.

7 At Harbour station, Porthmadog, the WHR connects to the Ffestiniog Railway (FfR), which continues a further 21 km to Blaenau Ffestiniog. Immediately after leaving Harbour station the FfR runs over the Cob, a 1.5 km artificial embankment constructed in the early 19th century to reclaim the land of Traeth Mawr from the sea. Boston Lodge engineering works is located at the eastern end of the Cob.

8 The railway approaches Beddgelert station from the north-west, down a 1 in 40 gradient in a heavily wooded area. One kilometre before the station, the railway passes over Bron Hebog open level crossing (figure 2). It then enters Cutting Mawr, a 200 metre long steep sided rock cutting, and passes over two further open crossings.

9 Beddgelert station has one platform with two faces, with sprung points automatically sending trains into the correct platform for their direction of travel. There is also a siding which can be entered by drivers manually changing a further set of points.

10 As the railway leaves Beddgelert to the south-east, there is a short section of track on a steeper gradient before entering the 35 metre long Goat Tunnel. Another open crossing is passed and the railway levels out as it crosses the Bryn-y-Felin bridge over Afon Glaslyn. The railway then descends another 1 in 40 gradient, through three more tunnels, down to Nantmor and Traeth Mawr.

Organisations involved

11 Both the WHR and FfR are operated and maintained by the Festiniog[1] Railway Company (FRC). The majority shareholder in this company is the Ffestiniog and Welsh Highland Railways Trust, and the railway trades under the title of the Ffestiniog and Welsh Highland Railways.

12 FRC freely co-operated with the investigation.

Locomotive involved

13 'Vale of Ffestiniog' (figure 4) was originally built in South Africa in the 1960s by CH Funkey & Co (Pty) Ltd to operate in diamond mines in Namibia. The locomotive was purchased by FRC and arrived at the railway in October 1993 together with another similar locomotive, 'Castell Caernarfon'.

Figure 4: Locomotive 'Vale of Ffestiniog'

[1] For historical reasons, the official title of the company spells Festiniog with a single 'f'.

14 To operate within the loading gauge[2] of the FfR, 'Vale of Ffestiniog' had a new body shell fitted which included a second cab. The electrical control systems were also replaced by a pneumatic system. This work was almost entirely undertaken by one FRC engineer who has since died.

15 The locomotive is arranged in a 'B-B' configuration, with two bogies, each with two wheelsets. All the wheelsets are driven from a centrally mounted transmission through cardan shafts, such that all eight wheels are mechanically linked and rotate at exactly the same speed. The locomotive has two forward gears, second and third, and one reverse gear. FRC decided to remove first gear when the locomotive was introduced, because it would apply too much torque to the wheels, which could damage the track. It was decided that second gear would be sufficient to handle the steep gradients on the WHR.

16 The locomotive can be driven in either 'shunt' or 'passenger' mode, for shunting in yards or for hauling passenger carriages respectively. In 'passenger' mode, the locomotive can operate the vacuum brakes fitted to hauled vehicles, and a driver's vigilance system, known by the railway as a 'deadman', is operational. In 'shunt' mode, both of these systems are inoperative. The 'deadman' safety system is intended to stop the train in the event that the driver should become incapacitated.

17 The locomotive has a compressed air brake system with four independent pneumatic brake cylinders, one on each corner. Each cylinder displaces a piston when the brakes are applied. This displacement is transferred through a series of links, resulting in a brake block being forced against each wheel. All four cylinders are simultaneously operated by a single common brake demand from the driver. The same cylinders can alternatively be operated by the application of a parking brake.

Staff involved

18 The locomotive was being driven by a senior manager from FRC. He was an experienced driver and had been assessed by the railway as competent to drive the locomotive on the WHR.

Signalling system

19 The WHR uses a token and ticket block system to control access to each of its single line sections. For a driver to enter a single line section, they must obtain permission from the control office and be in possession of the relevant token. The signal authorising the train to enter the single line section is operated by inserting the correct token for the section into a key switch located at the station at the entrance to the section. Alternatively, if instructed, a train driver can be issued with a ticket from a locked box, opened by a key attached to the relevant token. The driver must have sight of the relevant token before accepting a ticket. There is only one token for any section, so it must be positioned at the correct end of each single line section for each planned train movement.

External circumstances

20 The incident occurred on a rainy morning, which had been preceded by a long dry period.

[2] The maximum size that a railway vehicle can be to operate safely on a given railway.

21 The rails throughout the area of the incident were wet. There were leaves around the rails, particularly in the areas around Cutting Mawr and Goat Tunnel (figure 5). Some wheelburns, which can occur if train wheels spin on the rails, were noted in the area, indicating the presence of low adhesion conditions. However, it was clear from the spacing and arrangement of the wheelburn marks that they had not been caused by 'Vale of Ffestiniog'.

Figure 5: Photographs showing the general aspect and track conditions a) looking south into Cutting Mawr; and b) looking north into Goat Tunnel

The sequence of events

Events preceding the incident

22 At the end of service on 15 April 2019, the day before the incident, a fault was identified with one of the railway's steam locomotives which prevented its use for passenger services on 16 April. In order to cover that locomotive's duties, two of FRC's managers decided to utilise another smaller steam locomotive to be coupled with 'Vale of Ffestiniog'. Since 'Vale of Ffestiniog' was stabled at Dinas (figure 2), and the service started at Porthmadog, it was necessary to reposition the locomotive. The managers decided that this would be done as a light engine movement (ie. with the locomotive not hauling any other vehicles).

23 On the morning of 16 April 2019, one of the managers (hereafter referred to as the driver) decided that he would undertake the movement himself. He made the necessary operational arrangements, informed another manager of the proposed move and arranged for a fitter at Dinas to prepare the locomotive for departure.

24 At around 07:00 hrs the driver left home and drove his car to Boston Lodge works to collect his driving bag, and then departed for Dinas.

25 The light engine move was additional to the timetabled train movements for that day, and in the opposite direction to the first regular service. This meant that some of the tokens (paragraph 19) were positioned at the wrong end of the single line sections for the planned move. Therefore, on his way to Dinas, the driver stopped at the stations at the end of each single line section to reposition the tokens as required, as allowed by the railway's rules.

26 At approximately 08:00 hrs, the driver arrived at Dinas to find that the locomotive had been prepared by the fitter and left with its brakes on, and the engine running. The fitter had left the log book on the driver's seat, an unofficial but well understood indication on this railway that the locomotive was ready for departure. The driver enabled 'shunt' mode (paragraph 16) and departed from the yard at Dinas. As he left he saw the fitter and they each offered a 'thumbs up' gesture to the other.

27 The driver reported that while undertaking the move to depart from Dinas yard, he did a running brake test[3] to confirm that the brakes were functioning correctly. He noted that he needed to apply a higher brake demand than normal and concluded that the brakes might need some adjustment. He did not consider this to be unusual and decided that he would mention it to the staff at Boston Lodge works at the end of the journey.

28 The locomotive left Dinas shortly after 08:15 hrs, proceeding to Waunfawr and then onto Rhyd Ddu. At both stations the driver stopped to exchange a token or take a ticket, and gain authority to enter the next single line section. He noted that the locomotive required a heavier than normal brake application at these stations. Before leaving Rhyd Ddu, the driver sent a text message to a member of the works management team to report the need to adjust the brakes.

[3] A driver undertakes a running brake test by applying a moving train's brakes to ensure they are slowing the train down correctly.

29 At approximately 09:00 hrs the locomotive crested the summit of the line at Pitt's Head and began to descend the prolonged gradient of 1 in 43 (paragraph 6). The driver put the locomotive into third gear, and with minimal throttle or braking, this kept the locomotive at a steady speed of 15 mph (24 km/h) which is the permitted speed for this section.

30 As the locomotive progressed down the gradient, it crossed several open[4] and user worked[5] level crossings, for which the driver successfully reduced speed to comply with permitted speed restrictions of either 5 mph (8 km/h) or 10 mph (16 km/h). He noted again that the brakes required a greater than normal application but did not believe this to be a significant problem.

Events during the incident

31 At approximately 09:17 hrs, the locomotive crossed Bron Hebog open crossing (figure 2) while travelling at the permitted speed of 10 mph (16 km/h). The driver applied the brakes lightly to maintain this speed through Cutting Mawr.

32 As the driver exited Cutting Mawr (figure 5a), he realised that the locomotive would not reduce speed any further, even when he applied the full service brake.

33 The locomotive continued at a steady speed of around 10 mph (16 km/h) over another open crossing. The driver reported that he tried releasing and reapplying the brakes, dropping the locomotive into second gear and applying both the hand and parking brakes. He noted no additional braking effect from any of these actions and returned the locomotive to third gear. The driver reported there was no drop in the speedometer reading. Had the locomotive's wheels been sliding, the speedometer would have been fluctuating or reading zero.

34 At 09:20 hrs, the locomotive entered Beddgelert station limits and passed through the platform. It then entered the next single line section without the token or authority, passing the starting signal at danger. The driver had placed the token in Beddgelert station earlier (paragraph 25), so he was confident that there was no train approaching in the other direction.

35 Between Beddgelert station and Goat Tunnel, there is a short section at a steeper gradient. The driver reported that the locomotive's speed temporarily increased over this section to around 13 mph (21 km/h) and then returned to 10 mph (16 km/h) as the gradient reduced to 1 in 40.

36 After passing through Goat Tunnel (figure 5b), the track continues to descend towards Cemetery open crossing. The driver reported that he considered putting the locomotive into reverse gear and selected neutral in preparation for this. He then considered that doing this might cause a catastrophic failure of the gearbox, which could result in severe damage to the locomotive and potentially cause injury to himself. Because of these perceived risks he took no further action, but then noted that the speed of the locomotive was slowly decreasing.

[4] An open level crossing has no barriers or warning lights. Road traffic is required to give way to rail traffic.

[5] A user worked level crossing is gated and requires road users to manually open the gates and contact the railway control room to obtain permission to cross.

37 After crossing Cemetery open crossing (figure 2), the track passes under the A498 road and then over the Afon Glaslyn on Bryn-y-Felin bridge, where the gradient begins to level out. Shortly after crossing the river, the locomotive came to a stop. The total distance travelled from the point the driver first realised there was a problem was approximately 1.75 km.

Events following the incident

38 The final stopping position of the locomotive was in an area with insufficient mobile telephone reception to enable the driver to call the control room. The driver decided not to continue his journey to Porthmadog as that would have involved descending another 1 in 40 gradient (figure 3), including three tunnels. He chose instead to drive the locomotive back to Beddgelert, where he stopped in the platform, chocked the wheels to secure the locomotive and called the control room.

39 Another manager from the railway attended Beddgelert station and secured the locomotive in the siding, enabling the day's passenger services to proceed as planned. The railway tested the driver for drugs and alcohol and all results were clear.

Analysis

Background information – brake testing

40 To assess the effect of the various factors involved in the reduction of brake force, RAIB and FRC undertook braking distance tests on the Cob (paragraph 7) on 17 April and 15 May 2019. A series of tests were carried out in which the locomotive was driven at a steady speed to a fixed point, at which point the test driver applied full service braking. The distance to stop was then measured and the locomotive's average deceleration calculated.

41 The base case test was carried out with the locomotive unadjusted from the incident and driven over a dry rail head at 20 mph (32 km/h), the permitted speed for the test site. Four further tests were then conducted to examine the effect on deceleration of: initial speed, the adjustment of the brakes and the presence of water on the rail heads. Table 1 summarises the tests undertaken.

Test Case	Nominal Speed	Brake Adjustment	Rail Condition
1 (Base Case)	20 mph	As incident	Dry
2	20 mph	Adjusted	Dry
3	20 mph	As incident	Wet
4	10 mph	As incident	Wet
5	10 mph	Adjusted	Wet

Table 1: Summary of braking tests 1-5

43 The speedometer in the locomotive was checked by measuring the time taken to travel a fixed distance, and it was found to be reading approximately 10% over the actual speed. The test results were adjusted to take this into account.

44 After testing the base case, the brakes were adjusted so that the blocks were just clear of the wheel tread, which required an average extension of 18 mm to each slack adjustment turnbuckle (paragraph 56). This is a link of adjustable length, used to maintain the gap between the brake blocks and wheels as they both wear. To simulate the wet conditions involved in the incident, water was discharged ahead of the leading wheels using water containers and hoses carried on the locomotive.

45 The resulting decelerations, expressed as a percentage of the acceleration due to gravity[6] are shown in figure 6, in each of five different test cases. There was some scatter in the results due to imprecision of the speedometer, and the differing temperatures of the brake blocks as the tests were repeated.

[6] The industry's standard method of expressing deceleration rates is as a percentage of the acceleration due to gravity, or 'g', which is nominally 9.81ms^{-2}. For example, 10%g would equal 0.981ms^{-2}.

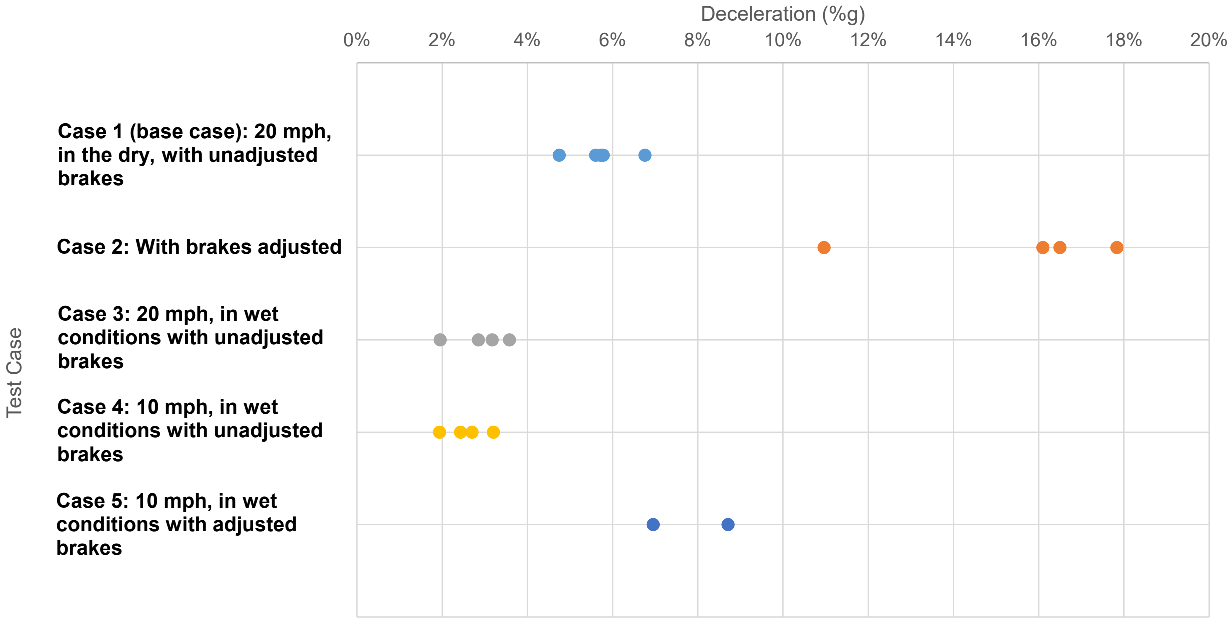

Figure 6: Graph showing the decelerations achieved by 'Vale of Ffestiniog' in the five different test cases

46 The tests showed that, regardless of speed, when the brakes are adjusted as they were on the day of the incident and the rail is wet, the locomotive achieves a deceleration of between 2%g and 4%g. In the incident, this low level of braking would have been more or less balanced by the accelerating effect of the downhill gradient of 1 in 40 (which would cause an acceleration of around 2.5%g), and the idling tractive effect of the locomotive being left in gear. The braking would have been assisted by a small amount of rolling resistance from the wheels. The tests also showed that adjusting the brakes resulted in much higher deceleration, regardless of the speed or conditions.

Identification of the immediate cause

47 **The locomotive's brakes could not apply sufficient brake force to stop on a 1 in 40 gradient.**

48 Despite the driver applying full service brake and trying a variety of in-cab controls (paragraph 33), the locomotive did not reduce speed as it descended the gradient into and through Beddgelert station.

Identification of causal factors

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

a) there was a mechanical foul in all four brake mechanisms which limited the movement of the brake blocks and thus the force between the brake blocks and the wheels when the brakes were applied (paragraph 50);

b) the locomotive was being driven light and therefore was reliant solely on the capability of its own brakes (paragraph 72); and

c) there was lowered friction between the brake blocks and wheels due to the wet conditions (paragraph 69).

Each of these factors is now considered in turn.

Fouling within the brake system

50 **There was a mechanical foul in all four brake mechanisms which limited the movement of the brake blocks and thus the force between the brake blocks and the wheels when the brakes were applied.**

51 Following the incident, the locomotive was hauled to Boston Lodge works for a detailed inspection by FRC and RAIB. This inspection identified that the four sets of brake equipment, one in each corner of the locomotive, which operate independently of each other, had the same mechanical fouling problem. As the brakes were applied, a link in the brake mechanism was found to foul on the associated brake hanger[7]. With the brakes released, witness marks on both components were evident (figure 7).

52 The foul meant that the movement of the brake linkage, and hence the brake blocks, was obstructed, preventing full brake force being applied to the wheels.

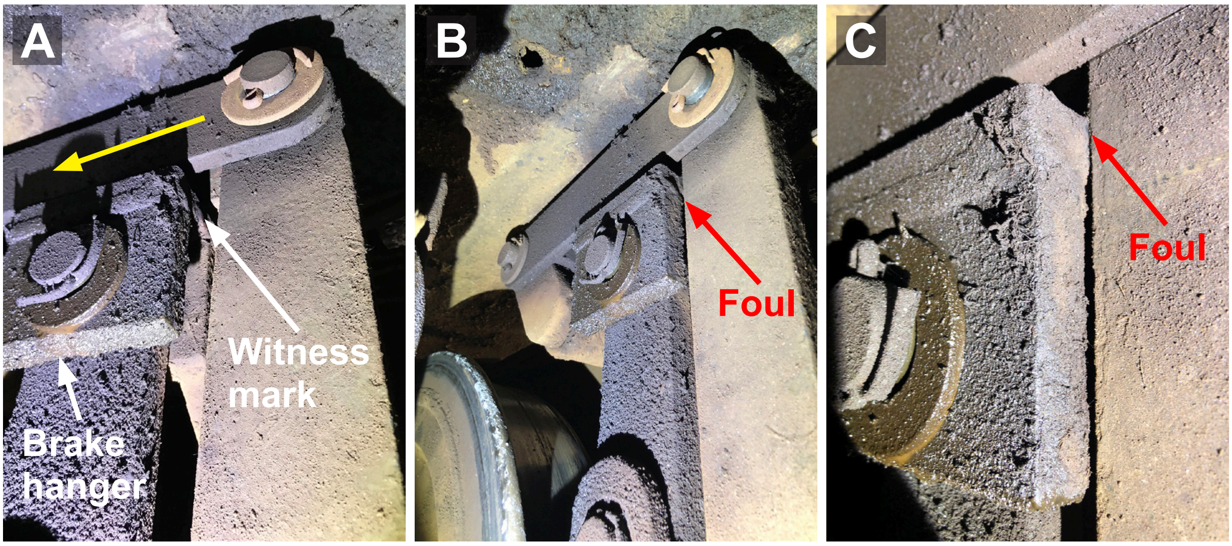

Figure 7: Photographs showing the location of the foul in the brake linkage (red arrows), (a) with brakes off; (b) with brakes on and (c) close-up view with brakes on. The yellow arrow in (a) indicates the movement of the link when the brakes apply.

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

i. FRC had modified the locomotive's brake system, unintentionally reducing the clearance between the outboard brake linkages and brake hangers (paragraph 54);

ii. the brakes and wheels were partly worn (paragraph 60); and

iii. the issue of the reduced clearance has not been previously detected by the railway (paragraph 64).

Each of these factors is considered in turn below.

[7] The brake hanger is a bracket fixed to the underside of the locomotive and the associated mechanical link that supports the brake block.

Modification of the brake system

54 FRC had modified the locomotive's brake system, unintentionally reducing the clearance between the outboard brake linkages and brake hangers.

55 Around 2001, after operating the locomotive for a few years, FRC found it was experiencing an issue with leaking seals on the locomotive's brake cylinders. FRC was unable to source replacement seals, so the engineer who had originally rebuilt the locomotive (paragraph 14) proposed to increase the cylinder air pressure to alleviate the issue. The associated increase in the locomotive's braking force would lead to undesirable differential braking between the locomotive and any hauled carriages, causing a jerky ride for passengers. To prevent this, the engineer decided to reduce the leverage applied by the brake cylinder, which would return the brake force to the 'pre-modification' level, despite the increased air pressure. He achieved this by reducing the distance between the brake cylinder attachment point and the first pivot in the linkage (figure 8). To prevent a clash with the original attachment hole, he welded a metal lug onto the side of each of the first links, with a new attachment hole.

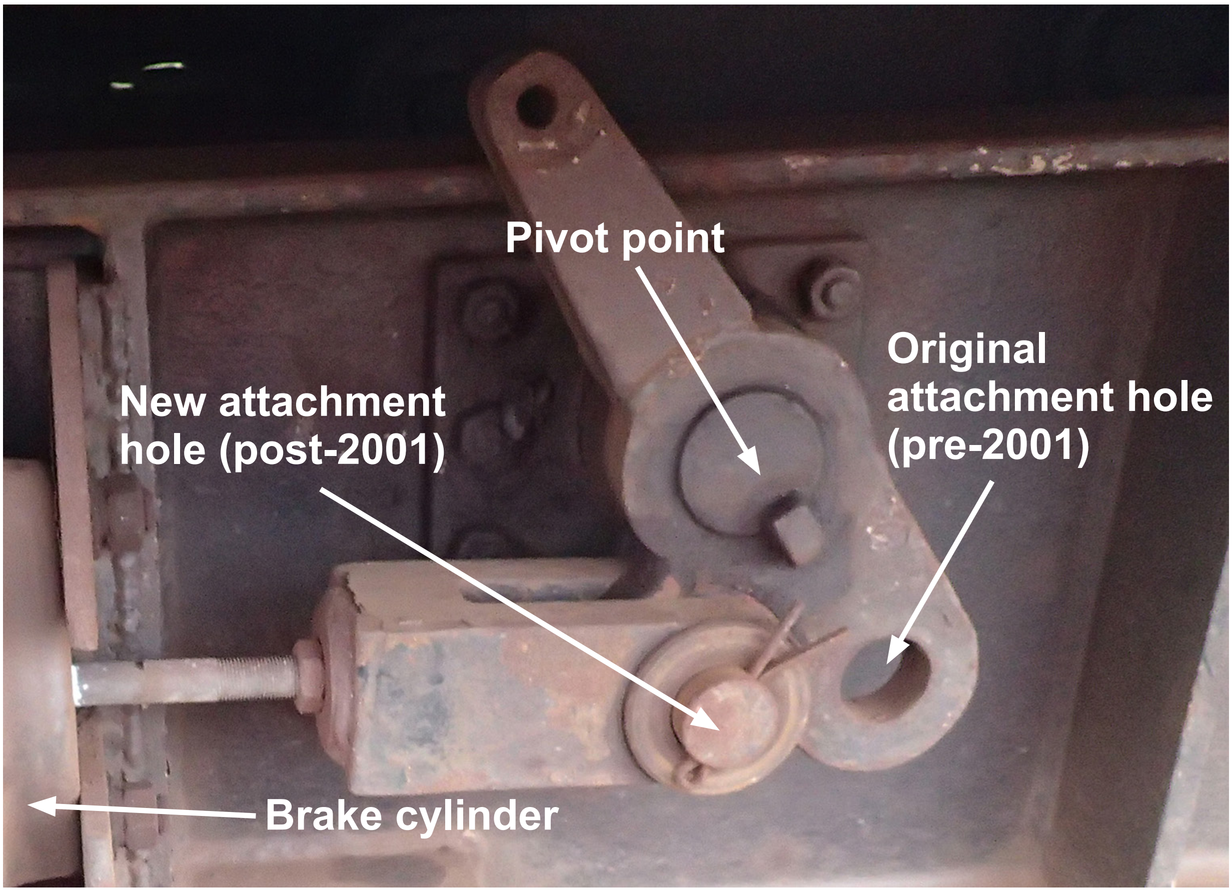

Figure 8: The original and new (2001) brake cylinder attachment positions

56 The change in the attachment position altered the angle of the first link in the brake mechanism. This resulted in a change to the geometry of the remainder of the linkage, which was compensated for using a turnbuckle slack adjuster (shown in red in figure 9) within the mechanism.

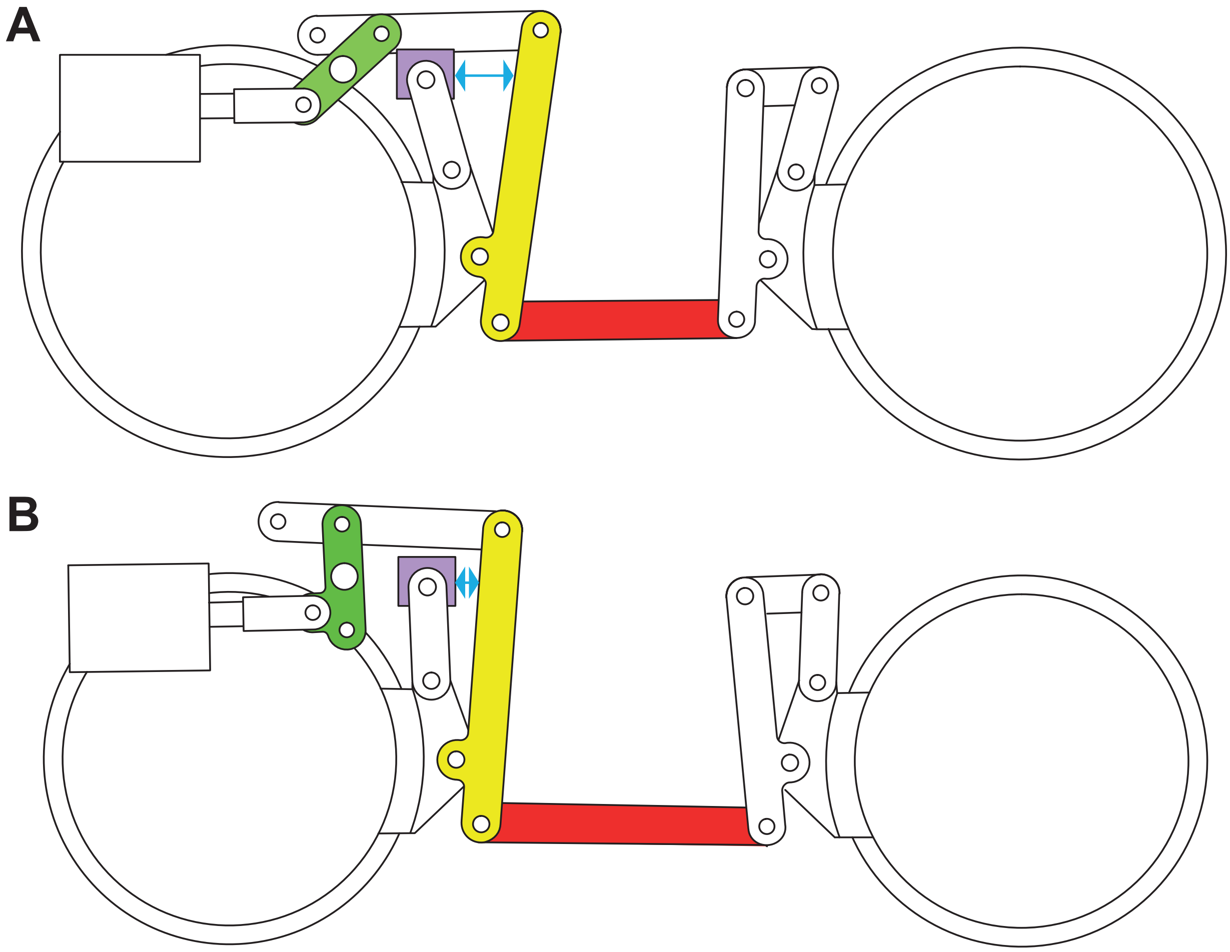

Figure 9: Diagram of the geometry of the brake mechanism when a) built to the original design; and b) the brake cylinder attachment position had been altered and the wheels have worn. The link altered by the railway is highlighted in green, the adjustable turnbuckle link in red and the clearance by the blue arrow.

57 A result of this modification was a reduction in clearance (shown by the blue arrow in figure 9) between the outboard brake hanger (shown in purple) and the long vertical link (shown in yellow) on the outboard side of the slack adjuster. Although initially there would be a clearance when the brake block positions were adjusted to be closer to the wheels with the brakes off, as the wheels and brake blocks wore, the brake blocks would have further to travel. Because of this, when the brakes were applied, the clearance (shown in blue) would reduce.

58 At some point during the operation of the locomotive, the clearance within each brake mechanism, indicated by the blue arrow in figure 9, reduced to zero, resulting in the fouling noted in figure 7. Once the foul occurred, any further force applied by the brake cylinder would not translate to additional movement of the brake blocks against the wheel, hence limiting the brake force applied.

59 RAIB noted during the inspection of the brake blocks after the incident that one brake assembly was poorly aligned. However, given the foul occurring in this brake mechanism, it is not considered that this additional factor significantly influenced the lack of brake force.

Wheel and brake block wear

60 **The brake blocks and wheels were partly worn.**

61 For the foul to have occurred, the brakes and/or wheels would need to have been worn since the previous brake adjustment. Records provided to RAIB indicate that the last brake block change occurred in February 2018. The railway was unable to provide records of what changes were made to brake adjustment on this date, or whether any adjustment has been carried out since this date. The inspection form used by the fitters did not have a specific place to record the adjustment made to turnbuckles, or the associated brake block positions. If anything was adjusted, it was left to the fitter to record it in the 'Observations' section (paragraph 82).

62 Following the incident, the adjustable turnbuckle links required an average of 18 mm of adjustment to reset the brake blocks to a position where they are just clear of the wheels. Post incident testing showed that, if the brakes had been adjusted to be just clear of the wheels, the locomotive brakes would have been able to generate sufficient brake force to avert the runaway (paragraph 46).

63 Since the locomotive was originally built, the diameter of its wheels had reduced by an average of 80 mm. FRC measured the wheels on the locomotive following the incident and determined that the wheels were within defined wear limits.

Detection of the mechanical fouling

64 **The issue of the reduced clearance has not been previously detected by the railway.**

65 The locomotive is normally used for either yard shunting or passenger services. When shunting, speeds are typically low and the track within yards is relatively flat, so only moderate brake effort is required to stop the locomotive. When operating in passenger service, the vacuum brake system is enabled (paragraph 16) and the carriages being hauled assist in the braking of the entire train. This would have masked any issues with the locomotive brakes. Light engine moves over the significant gradients of the WHR, as happened on the day of the incident, are rare.

66 Before the incident, the railway was unaware of the potential for mechanical fouling of the brake mechanism, as described at paragraph 49. If a reduction in the braking capability of the locomotive was noted by drivers, the brakes would be adjusted to alleviate the issue. The witness marks (figure 7a) and fouling components had not been spotted by maintenance staff.

67 RAIB considers that the location of the foul (figure 7) was such that it is unreasonable to have expected the railway to have spotted the issue during maintenance activities on the locomotive. Space underneath a narrow-gauge locomotive such as 'Vale of Ffestiniog' is limited, so staff have restricted access to some parts of the underframe. This includes the brake hanger area, which is in a small space between the axles on the bogies, in an position that is difficult to access.

68 Unless working on the brakes, most maintenance activities undertaken on the underframe of the locomotive would be done with the brakes applied, when the view of any foul that may be occurring or of any resulting contact marks would be difficult to see unless a fitter was specifically looking for it (figure 7c).

Friction between the brake blocks and wheels

69 **There was lowered friction between the brake blocks and wheels due to the wet conditions.**

70 The weather on the morning of the incident resulted in wet rails (paragraphs 20 and 21). The area in which the runaway occurred was also heavily wooded, with leaves on and near the rails (figure 5). Water from the rail, and possibly some leaf contamination, was able to transfer onto the wheel treads and affect the friction between the wheels and the brake blocks.

71 The post incident braking tests on the locomotive (paragraph 40) showed that the addition of water to the rail ahead of the wheels reduced the brake effort to levels that, when combined with the engine braking, would be insufficient to stop the locomotive on the 1 in 40 gradient with the brakes adjusted as they were.

Light locomotive

72 **The locomotive was being driven light, so was reliant solely on the capability of its own brakes.**

73 FRC's operating procedures allow the use of light locomotives with no special restrictions on their use. They are treated in all respects as a normal train.

74 Since the locomotive was not hauling carriages, the only brakes available were its own air brakes. Had the locomotive been hauling vehicles fitted with an operational vacuum braking system they would have been able to assist with stopping the train (paragraph 65). Locomotive hauled unbraked wagons are not normally permitted on the WHR, and can only be used with the written authorisation of FRC's Chief Mechanical Engineer.

Identification of underlying factors

Management of engineering change

75 **FRC did not have a robust engineering change management process in place when modifications to the braking system were made.**

76 While some staff at FRC remembered the modifications carried out to the locomotive, the railway was unable to provide documentation for the changes made to the brake system (paragraph 54), or evidence of how these changes were managed, risk assessed and checked. At the time of the modification, FRC was not required to notify the safety authority of the change[8]. RAIB also noted that the railway could not provide documentation detailing changes made to the locomotive in more recent years, or evidence that these changes were risk assessed.

77 Had FRC had a process in place for the management of engineering change, that was compatible with good industry practice, when the brakes were modified, that process would have required a risk assessment of likely hazards arising and an independent assessment of the modified design. Application of such a process should have identified potential risks in areas such as uncompensated brake block wear or brake rigging faults, and led to an appropriate brake inspection procedure and checks to mitigate any identified risks.

[8] At the time of the change, The Railways and Other Transport Systems (Approval of Works, Plant and Equipment) Regulations (1994) applied.

78 Since 2009, FRC has managed change in its organisation using policy document SM POL 035, 'Safety Verification and Management of Change'. The main part of this document details when and how the railway will undertake 'safety verification' (SV). This is a process mandated on non-mainline operators by the 'Railways and Other Guided Transport Systems (Safety) Regulations 2006' (ROGS). Safety verification is required when a new or significantly different asset (for instance, a rail vehicle) is being introduced, which introduces or increases the risk to safety[9]. It is rare for FRC to need to use the SV process, as almost none of its changes satisfy the ROGS condition of being new or significantly different.

79 The management of changes which are not subject to SV are intended to be covered by the final section of SM POL 35 which states that: '*The Board and the General Manager are responsible for managing change when new or altered procedures are put in place, including changes in management structure*'. RAIB observes that this section does not contain any specific statement of how engineering change should be managed, documented or risk assessed. There is no separate engineering change process to manage changes made to locomotives or rolling stock.

Observations

Inspection and adjustment of the brake system

80 **FRC did not have a documented brake inspection and adjustment process for the locomotive.**

81 The locomotive receives routine inspections at three different intervals:

a. a daily check by the driver;

b. an inspection by a fitter after fifteen days in traffic; and

c. a further inspection by a fitter after thirty days in traffic, which additionally checks the vacuum brake system.

82 During any fitter's inspection, the fitter is required to work through a checklist. This list includes a section on the braking system, in which the fitters are asked to check fixings and rigging, air brake fittings and adjustment, hand brake fittings and adjustment, and test the vacuum brake system. Once the inspections are complete, the fitter ticks the relevant box on the inspection form. There is a blank section titled 'Observations' on the rear of the form, which a fitter can use to record any comments.

83 FRC does not mandate how the brake inspection checks should be carried out and relies on the competence of its fitters. The checklist does not include specific dimensions for the clearances between the brake blocks and wheels or the angular position of the brake actuation lever. There is no easy way of checking during inspection whether or not the brake blocks are fully engaged when the brakes are applied.

[9] Further details are available from the Office of Rail and Road (ORR), https://orr.gov.uk/rail/health-and-safety/health-and-safety-laws/rogs.

Use of the 'deadman' system

84 **The driver did not enable the 'deadman' safety system on the locomotive while working alone.**

85 In addition to the vacuum brake system, selecting the locomotive's 'passenger' mode of operation enables the 'deadman' safety system (paragraph 16). When the safety system is operational, an alarm sounds in the cab every forty seconds. The driver must respond to this within five seconds by pressing a button mounted near the throttle. Failure to do this automatically applies the brakes and disengages the gearbox. This system is installed to stop the locomotive should a driver become incapacitated without anyone else to assist, to prevent a runaway. The system is isolated when the park brake is engaged.

86 FRC's procedure LC POL 100, 'Locomotive and train operations', section J6.2 states the following:

> *'Diesel Locomotives fitted with a "Deadmans" may operate on a Running Line with just a Driver on board provided that the system has been tried and proved to be working. If the system fails, then a secondman must be requested when in service on a passenger train.*
>
> *Where no "Deadmans" is fitted (or it is not operational), then a locomotive may operate a works train provided that the Person In Charge is made aware that this is the case and clear understanding is reached with regards to ensuring all is well.'*

87 Additionally, the railway's rulebook, rule H2 'Out of hours trains', states that '*single manning of out-of-hours trains should be avoided*'. It states that an emergency contact should be in place should the single-person movement be required.

88 On the day of the incident, while alone, the driver operated the locomotive in 'shunt' mode. There was nothing to prevent him using 'passenger' mode, even without carriages attached. The managers involved on the day of the incident did not consider that having a second person in the locomotive was necessary or proportionate for the risk of the movement. They established an emergency contact as required by rule H2.

89 RAIB observes that in accordance with procedure LC POL 100 J6.2, paragraph 1, the 'deadman' should have been used as it was fitted to the locomotive and the procedure makes no distinction between a passenger train and a works train (ie. a non-passenger train). However, the driver believed he was compliant with FRC's rules since the second paragraph of procedure LC POL 100 J6.2 allows a locomotive with a non-operational deadman to be used as a works train. In FRC's fleet of ten operational diesel locomotives, only 'Vale of Ffestiniog' is currently fitted with a 'deadman' system.

Lone working

90 FRC's risk assessment for lone working document, SM RAS 021, identifies a specific hazard with the single person operation of engineering trains, and the risk of a runaway leading to a potentially fatal scenario. To reduce this risk, the railway identifies its control measures as regular medical examination of staff and the application of rulebook rule H2 (paragraph 87). It considers that these measures reduce the likelihood of the hazard occurring from a 4 to a 1, on a scale of 1 to 5[10]. RAIB considers that these control measures alone do not offer sufficient protection from the risk to justify such a reduction in the likelihood of occurrence. The risk assessment does not include the use of the 'deadman' system, which (when available) would normally be the primary control to prevent a runaway in the event of the driver becoming incapacitated. FRC has reported to RAIB that it has not had such an incident in over fifty years of operating locomotives in this manner.

91 RAIB also noted that the control measures selected in many of FRC's other risk assessments for safety critical systems were generally reliant on human performance rather engineered safeguards.

Learning from incidents and accidents

92 **FRC could improve its investigation of incidents and accidents to better understand underlying systemic issues on its railway.**

93 An important aspect of a positive organisational safety culture is the ability to learn from incidents and accidents, and to use all available information to improve understanding of risk and to select the most appropriate controls for the future.

94 As part of its investigation, RAIB reviewed sections of FRC's Safety Management System relating to the incident, and its accident and incident investigation procedures and practice. It was apparent that FRC has a strong culture of reporting incidents and accidents, and FRC managers considered how to respond to each event. RAIB observed that:

- investigations often established 'human error' as being the main cause, and did not establish the underlying reasons for that error; and
- while FRC undertakes analysis of incident trends, it does not always use this to understand the critical safety risks to its organisation.

[10] The scale ranges from 1 (Not likely, less than once per ten years), to 5 (Very likely, almost certain in normal operating conditions).

Summary of conclusions

Immediate cause

95 The locomotive's brakes could not apply sufficient brake force to stop on a 1 in 40 gradient (paragraph 47).

Causal factors

96 The causal factors were:

a) there was a mechanical foul in all four brake mechanisms which limited the movement of the brake blocks and thus the force between the brake blocks and the wheels when the brakes were applied (paragraph 50), which occurred due to a combination of the following factors;

  i. FRC had modified the locomotive's brake system, unintentionally reducing the clearance between the outboard brake linkages and brake hangers (paragraph 54, **Recommendation 1, Learning point 1**);

  ii. the brake blocks and wheels were partly worn (paragraph 60); and

  iii. the issue of the reduced clearance has not been previously detected by the railway (paragraph 64).

b) the locomotive was being driven light and therefore was reliant solely on the capability of its own brakes (paragraph 72); and

c) there was lowered friction between the brake blocks and wheels due to the wet conditions (paragraph 69).

Underlying factor

97 FRC did not have a robust engineering change management process in place when modifications to the braking system were made (paragraph 75, **Recommendations 1 and 4, Learning points 1 and 2**).

Additional observations

98 Although not causal to the runaway incident, RAIB observes that:

a) FRC did not have a documented brake inspection and adjustment process for the locomotive (paragraph 80, **Recommendations 2 and 4**);

b) The driver did not enable the 'deadman' safety system on the locomotive while working alone (paragraph 84, **Recommendation 3**); and

c) FRC could improve its investigation of incidents and accidents to better understand underlying systemic issues on its railway. (paragraph 92, **Learning point 3**).

Previous RAIB recommendations relevant to this investigation

99 RAIB has previously made recommendations to the heritage railway industry about the management of change and the importance of controlling safety critical maintenance activities.

Runaway and collision on the Great Central Railway, RAIB report 04/2015, Recommendation 4

100 Recommendation 4 read as follows:

'The Great Central Railway should review the arrangements currently in place by which it ensures that diesel locomotives operating on its infrastructure are being maintained in a way which adequately addresses the risks posed by the potential failure or reduced reliability of components and systems. This review should specifically consider the maintenance of braking systems.

The Great Central Railway should implement any changes identified as being necessary as a result of this review.'

ORR reported to RAIB on 9 May 2016 that the Great Central Railway had completed its actions in response to this recommendation and that the recommendation had been implemented.

Locomotive failure at Winchfield, Hampshire, RAIB report 13/2014, Recommendation 4

101 Recommendation 4 read as follows:

'The Heritage Railway Association and the Main Line Steam Locomotive Operators Association should bring this report to the attention of their members and invite them to consider thoroughly evaluating and risk assessing changes to the design of steam locomotives that are made during restoration, overhaul or maintenance. The following should be considered:

- *whether the purpose and function of the original design, and the reasons for making the change are fully understood;*
- *whether any additional risk will be introduced by the change; and*
- *any measures that may be needed (during overhaul, operation or maintenance) to reduce the risk associated with the change, and to assess its impact.'*

ORR reported to RAIB on 11 August 2015 that the Heritage Railway Association had completed actions in response to this recommendation and that the recommendation had been implemented by alternative means.

Derailment at Fisherground, Ravenglass & Eskdale Railway, RAIB report 32/2007, Recommendation 2

102 Recommendation 2 read as follows:

'Ravenglass and Eskdale Railway should review their safety management system and operational procedures to identify if there are other areas where safety critical maintenance or design work is undertaken, or decisions are made, which should be subject to independent checking, and implement appropriate changes to procedures.'

ORR reported to RAIB on 4 November 2010 that the Ravenglass and Eskdale Railway had completed its actions in response to this recommendation and that the recommendation had been implemented.

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

103 Following the incident, FRC has modified the attachment point of the brake cylinder (figure 10a) to be in line with the hole in the original design, albeit with the hole closer to the pivot to maintain the reduced leverage (paragraph 54). This has had the effect of restoring the original brake linkage geometry, increasing the clearance between the brake hanger and vertical link (paragraph 56) such that the foul can no longer occur.

104 FRC has developed a documented adjustment procedure for the ‘Vale of Ffestiniog’, and its sister locomotive ‘Caernarfon Castle’. This includes a requirement to record the work undertaken in the locomotive log book.

105 FRC has added tell tales to all the brake systems to assist drivers in performing a daily check of the state of the adjustment of the locomotive’s brakes (figure 10b). This is now included as part of the driver’s checks undertaken before any locomotive is driven.

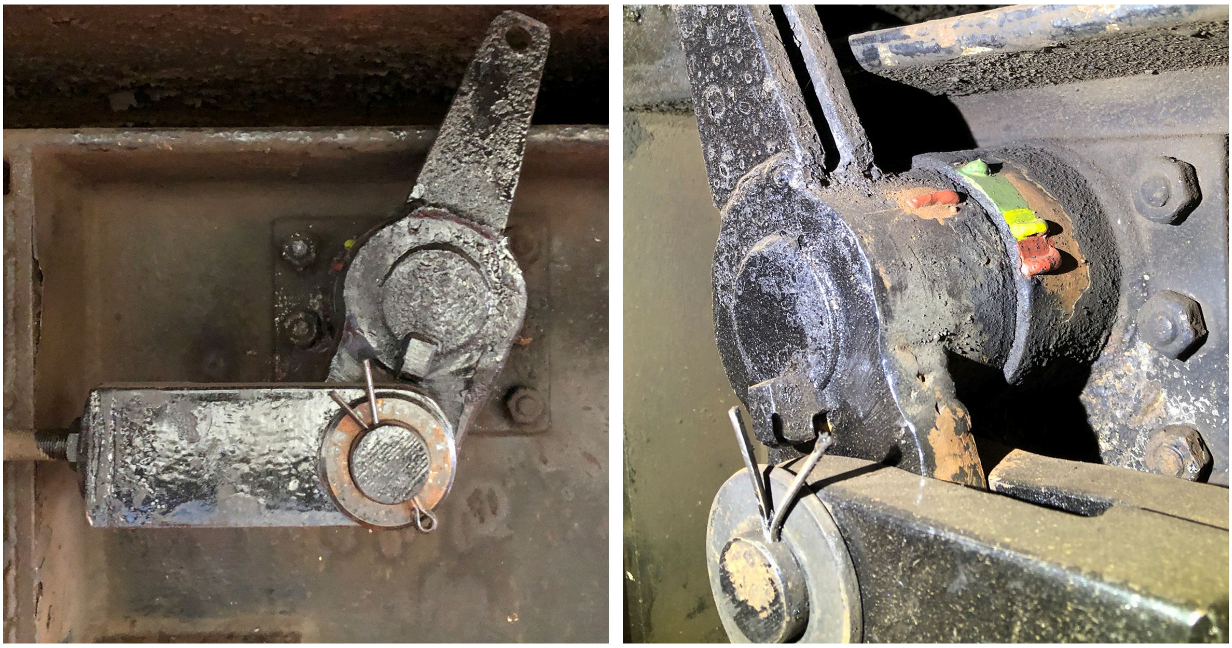

Figure 10: Photographs of the modifications made to the brake mechanism in response to the incident, showing a) the altered attachment point; and b) the tell tales used as a daily check.

106 FRC has begun to consider how to best control engineering change within its organisation.

107 FRC has arranged training in the fundamentals of accident investigation and human factors, and extended an invitation to other heritage railways in the area.

108 On 16 October 2019, ORR wrote to FRC with details of actions FRC should take following the incident. These actions related to the:

a) review of FRC’s change management arrangements;

b) production of a plan to review the current locomotive maintenance procedures;

c) provision of information, training and documentation of daily locomotive checks;

d) implementation of a competence management system and the competence of current drivers; and

e) use of the ‘deadman’ safety system.

Recommendations and learning points

Recommendations

109 The following recommendations are made[11]:

1 *The intent of this recommendation is that the Festiniog Railway Company should improve the way that it manages engineering changes to its assets, thoroughly consider the risks involved and preserve knowledge of any changes for the future of the railway.*

Festiniog Railway Company should develop and implement a robust engineering change management process encompassing all rolling stock and locomotives (paragraphs 96a and 97).

2 *The intent of this recommendation is that the maintenance of brakes and other safety critical systems on FRC's rolling stock is adequately controlled.*

Festiniog Railway Company should systematically review how it monitors, assures and records the inspection and maintenance of brakes and other safety critical systems on its rolling stock and locomotives, and implement measures to address any shortcomings found (paragraph 98a).

3 *The intent of this recommendation is that Festiniog Railway Company makes use of the 'deadman' systems on its locomotives, where fitted.*

Festiniog Railway Company should review its lone working arrangements, and its policy relating to the use of 'deadman' systems, where fitted, for situations where trains are being driven by an unaccompanied person. It should update its rulebook to take account of any changes (paragraph 98b).

[11] 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.

4 *The intent of this recommendation is that the safety learning identified in this report is thoroughly shared amongst the heritage railway industry.*

The Heritage Railway Association should bring the safety learning in this report to the attention of its members and the wider heritage railway industry, highlighting the importance of evaluating and risk assessing engineering changes made to assets, using suitable processes to maintain safety critical systems and thoroughly investigating the factors that underlie accidents and incidents (paragraphs 97 and 98a).

Learning points

110 The RAIB has identified the following key learning points[12] for heritage railways:

1 This incident demonstrates the importance of carefully assessing and checking any modifications to equipment that have the potential to affect its safety function, and adequately documenting the changes for the future (paragraphs 96a and 97).

2 It is important to fully understand the risk associated with the failure of all safety critical equipment, including those that have not been modified. This enhanced knowledge should be used to assess the adequacy of existing control measures, particularly where these are heavily reliant on human performance. In such cases the need for additional engineering safeguards should be considered (paragraph 97).

3 Thorough investigation of the factors underlying safety incidents will help to ensure that any risk control measures adopted (both human and engineering) are appropriate and proportionate (paragraph 98c).

[12] '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

FfR	Ffestiniog Railway
FRC	Festiniog Railway Company
ORR	Office of Rail and Road
ROGS	The Railways and Other Guided Transport Systems (Safety) Regulations 2006
SV	Safety Verification
WHR	Welsh Highland Railway

Appendix B - Investigation details

RAIB used the following sources of evidence in this investigation:

- information provided by witnesses;
- site examinations, photographs and measurements;
- engineering drawings;
- weather reports and observations at the site;
- brake testing of the locomotive involved;
- FRC’s safety management system and associated documentation;
- previous reported incidents; and
- previous RAIB investigations that had relevance to this incident.

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