Rail Accident Report

Freight train derailment at Ely West Junction
14 August 2017

Report 09/2018
August 2018

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.

Any enquiries about this publication should be sent to:

RAIB	Email: enquiries@raib.gov.uk
The Wharf	Telephone: 01332 253300
Stores Road	Website: www.gov.uk/raib
Derby UK	
DE21 4BA	

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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.

The 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 the RAIB has described a factor as being linked to cause and the term is unqualified, this means that the RAIB has satisfied itself that the evidence supports both the presence of the factor and its direct relevance to the causation of the accident. However, where the RAIB is less confident about the existence of a factor, or its role in the causation of the accident, the RAIB will qualify its findings by use of the words 'probable' or 'possible', as appropriate. Where there is more than one potential explanation the 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 but are associated with the underlying management arrangements or organisational issues (such as working culture). Where necessary, the words '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 event 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 the RAIB, expressed with the sole purpose of improving railway safety.

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

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Freight train derailment at Ely West Junction, 14 August 2017

Contents

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Summary

At 14:21 hrs on Monday 14 August 2017, the rear 12 wagons of a freight train carrying containers derailed at Ely West Junction on the line between Ely and March. The train was travelling at 41 mph (66 km/h) at the time of the derailment. It ran derailed for approximately 350 metres, causing significant damage to the infrastructure.

The first wagon to derail was an FEA-A wagon fitted with Y33 bogies. The derailment occurred because the damping on the bogies of this wagon was ineffective. The damping had become ineffective because the damping components, which had been on the wagon since it was built in 2003, had been managed to incorrect maintenance limits. The limits did not account for future wear in the period before the next maintenance intervention and were also not compatible with the design intent of the damping system. In addition, the maintenance interventions since a General Repair in 2010 (the last time when these components had been measured) were ineffective in identifying the worn state of the components. It is also probable that the company responsible for the maintenance of the wagon did not appropriately validate the General Repair maintenance specification used in 2010 to confirm that it would ensure continued safe operation up to the next planned General Repair due in 2017.

The fleet of wagons has since gone through General Repair and all of the damping components have been replaced.

The RAIB has made one recommendation to the company responsible for the maintenance of the wagons to review its maintenance documentation to ensure that the bogies on its freight wagons remain adequately damped at all times. In addition, the RAIB has identified three learning points. The first reminds those responsible for updating maintenance instructions that repair limits quoted in guidelines or by manufacturers should not be used as maintenance limits as this provides no future operational life. The second learning point reminds Entities in Charge of Maintenance that they should have a validated system of maintenance that ensures that the vehicles for which they are in charge remain safe for operation. The final learning point reminds maintainers of this type of bogie that some of them are fitted with an inspection window to allow the damping system components to be visually examined.

Introduction

Key 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. These are explained in appendix A.

The accident

Summary of the accident

3 At 14:21 hrs on Monday 14 August 2017, the rear 12 wagons of train 4Z33, the 11:18 hrs Felixstowe to Doncaster Railport freight service operated by GB Railfreight, derailed at Ely West Junction on the line between Ely and March (figure 1). The train was travelling at 41 mph (66 km/h) at the time of the derailment.

4 The train ran derailed for approximately 350 metres, damaging the infrastructure in the process. The driver was alerted to something being amiss when the train came to a stop as a result of a brake application following a loss of brake pipe pressure. Having spoken to the signaller, the driver examined his train and discovered that it had derailed (figure 2). No one was injured in the accident. However, there was considerable damage to the railway infrastructure resulting in the closure of the line for a week.

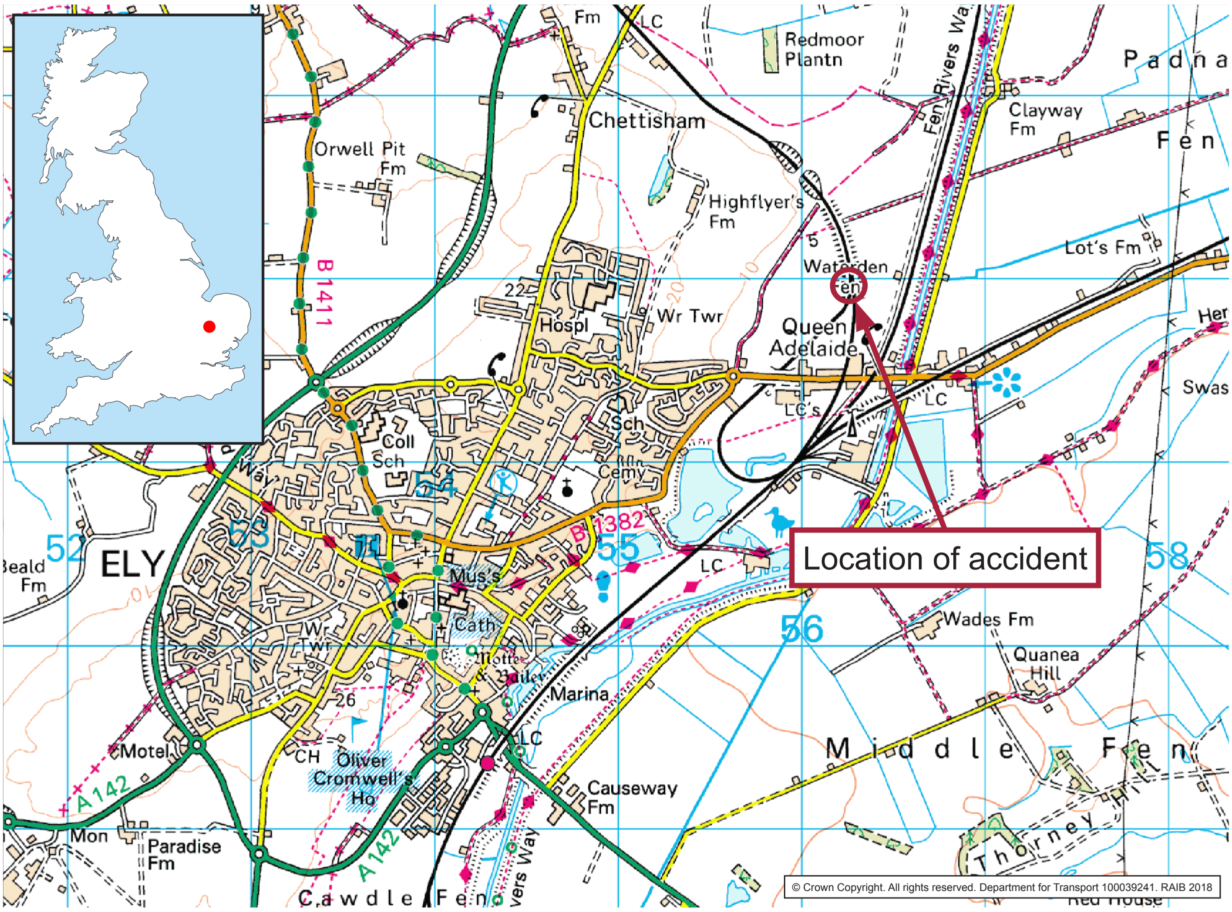


Figure 1: Extract from Ordnance Survey map showing location of accident

Figure 2: Derailed wagons on site

Context

Location

5 Ely West Junction is located at 72 miles 39 chains from London (Liverpool Street) on the line between Ely and Peterborough. The railway at this location consists of two tracks: the Up and Down Peterborough lines. The derailment occurred on the down Peterborough line (figure 3).

6 Ely West Junction is the location where a third line, known as the Ely West Curve, joins the Down Peterborough line using points 1160. Approximately 23.4 metres beyond the toe[1] of 1160 points along the Down Peterborough line is the toe of a second set of points, 1161A, part of a crossover between the Up and Down Peterborough lines.

7 The derailment took place on the plain line between the toe of 1161A points and its crossing nose (located 43 metres beyond the toe). The first visible derailment marks on the railhead were approximately 24 metres after the toe (figure 3).

8 The line speed at this location is 60 mph (96 km/h). The track is level and follows a gentle left-hand curve with a radius of approximately 1250 metres. The track has a designed cant[2] of 70 mm.

[1] The toe of a set of points is the end of the movable part of the switch rail.

[2] Cant is the amount by which the outer rail of a curved track is raised above the inner rail. The installed cant was also nominally 70 mm.

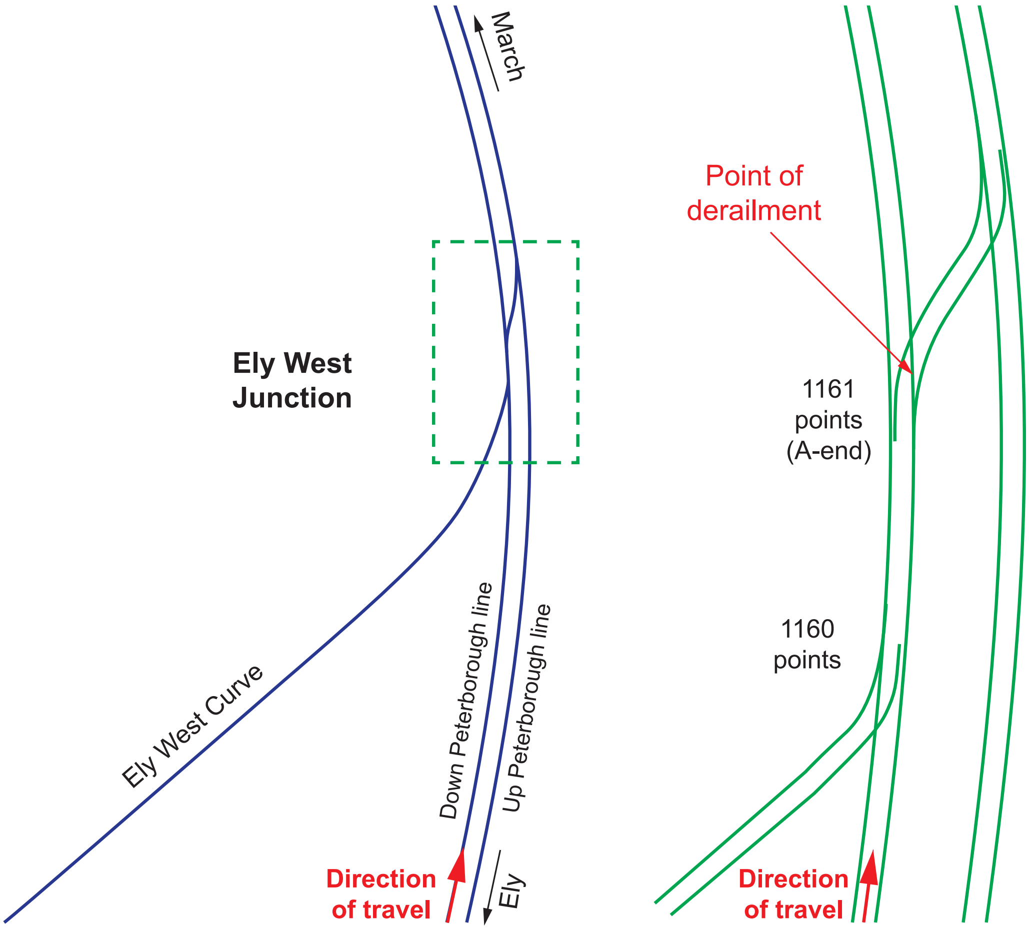


Figure 3: Track layout at Ely West Junction

Train involved

9 The train consisted of diesel-electric locomotive number 66713 and 30 container-carrying wagons of various types (FEA-S, IKA, FWA and FEA-A).

10 The first wagon to derail was the nineteenth from the front, wagon number 630034. This is an FEA-A wagon, part of a twin set with wagon number 630033 (they are permanently coupled with a rigid bar). Wagon 630034 was leading wagon 630033 in the direction of travel. The following eleven wagons (including wagon 630033) derailed as a consequence of wagon 630034 derailing and the damage that it caused to the track. The investigation focused on why wagon 630034 derailed.

11 Wagon 630034 carried a 40 foot container in the leading position and a 20 foot container in the trailing position. Examination of these containers after the accident showed that the 40 foot container was packed with office furniture (figure 4) and the 20 foot container with pallets of floor tiles (figure 5). The mass of the 40 foot container was measured as 11.2 t and the 20 foot as 27.6 t. The payload in the 20 foot container was such that the centre of gravity of this container was offset both longitudinally and laterally. Photographic evidence showing the content of the container as it was packed in Izmir (Turkey) before coming to the UK demonstrated that the payload had moved marginally longitudinally and laterally, likely as a result of the derailment, between packing and post-accident inspection. The load position as recorded in Izmir was used during the investigation.

Figure 4: 40 foot container opened post-accident

Figure 5: 20 foot container opened post-accident

Organisations involved

12 Network Rail owns and maintains the track on which the derailment happened.

13 GB Railfreight (GBRf) operated the train, employed the driver and was the Entity in Charge of Maintenance[3] for the wagons.

14 Wabtec maintained the FEA-A wagon fleet under contract with GBRf.

[3] A person or organisation responsible for the maintenance of rail vehicles (the terminology 'Entity in Charge of Maintenance' is defined in the Railways and Other Guided Transport Systems (Safety) Regulations).

15 Marcroft Engineering (now part of DB Cargo) designed and manufactured the FEA-A wagons in Stoke in around 2002.

16 Techni-industrie (France) manufactured the bogies fitted to the FEA-A wagons.

17 Vereinigung der Privatgüterwagen-Interessenten (VPI) is a private wagon owner association in Germany which defines maintenance requirements for freight wagons in a set of maintenance guidelines.

18 All these organisations freely co-operated with the investigation.

Rail equipment/systems involved

19 The bogies fitted to the FEA-A wagons were Y33 bogies (figure 6). They are a derivative of the Y-series family of bogies, widely used across the UK and in Europe for the past 50 years.

Figure 6: Y33 bogie (leading bogie on wagon 630034)

External circumstances

20 The weather was dry and clear with a light southerly wind and a temperature of 23°C, recorded at a nearby weather station in Ely.

21 There was no other train in the immediate vicinity at the time of the derailment.

The sequence of events

Events preceding the accident

22 At 11:18 hrs on Monday 14 August 2017, train 4Z33 departed from the container terminal at Felixstowe bound for Doncaster via Ely. The journey to Ely was uneventful. At approximately 14:18 hrs, train 4Z33 passed through Ely station platform 2 on the up main line. It crossed over onto the down main line outside Ely station. The line speed for freight trains at that location reduces to 20 mph (32 km/h) as the line passes over the river Great Ouse on two bridges; the driver observed this speed limit.

23 Having passed the second bridge on the down main line, train 4Z33 started accelerating as the line speed increased to 60 mph (96 km/h) for all trains. The down main line becomes the Down Peterborough line on its approach to Ely West Junction.

Events during the accident

24 At 14:21 hrs, locomotive 66713 passed over 1161A points at Ely West Junction. Shortly afterwards, when the leading right-hand wheel of wagon 630034 was 24 metres beyond the toe of 1161A points, it climbed onto the railhead and travelled along it for about 12 metres before dropping into the six-foot[4] (figure 3).

25 As wagon 630034 passed over the crossing nose of 1161A points, its leading wheelset veered further to the right away from the track centreline as its right-hand wheel was guided by the diverging crossing rail. This led to the derailment of the trailing wheelset of this bogie. Eventually the leading left-hand wheel came up against the six-foot rail and caused the crossing rail and six-foot rail to be squeezed together causing significant infrastructure damage. The damage caused the trailing bogie and all of the following wagons to derail. At 14:21:56 hrs, train 4Z33 came to a stop having run derailed for approximately 350 metres.

Events following the accident

26 The driver of train 4Z33 observed his train unexpectedly coming to a stand due to an automatic brake application. As he was about to contact the signaller controlling the movements of trains in the area, the signaller contacted him asking if he was on the move as the signaller had noticed a track circuit problem which was likely a result of the derailment. The driver left the cab to go and examine his train and discovered that the rear 12 wagons had derailed.

27 During this conversation with the driver, the signaller took actions to stop any trains from approaching on the adjacent line. He then alerted the emergency services[5]. The line re-opened at 03:09 hrs on 21 August 2017 with points 1161 partly dismantled and not able to be used for the crossover route.

[4] A term used for the space between two adjacent tracks.

[5] A member of the public had also reported to the emergency services that the train was on fire (he had confused dust created by the derailment with smoke as there was no fire).

Key facts and analysis

Background information

Y33 bogie damping arrangement

28 Almost all road and rail vehicles incorporate some damping to minimise the amount of bouncing they experience following external inputs, eg unevenness in the road or track. Y33 bogies use a friction-damping arrangement where the vertical movement of the axlebox within the bogie frame horn guides is damped by friction. The key components of the damping arrangements are the Lenoir links, the spring cap and its wear plate, the plunger and the axlebox. Figures 7 and 8 show how these individual components are arranged.

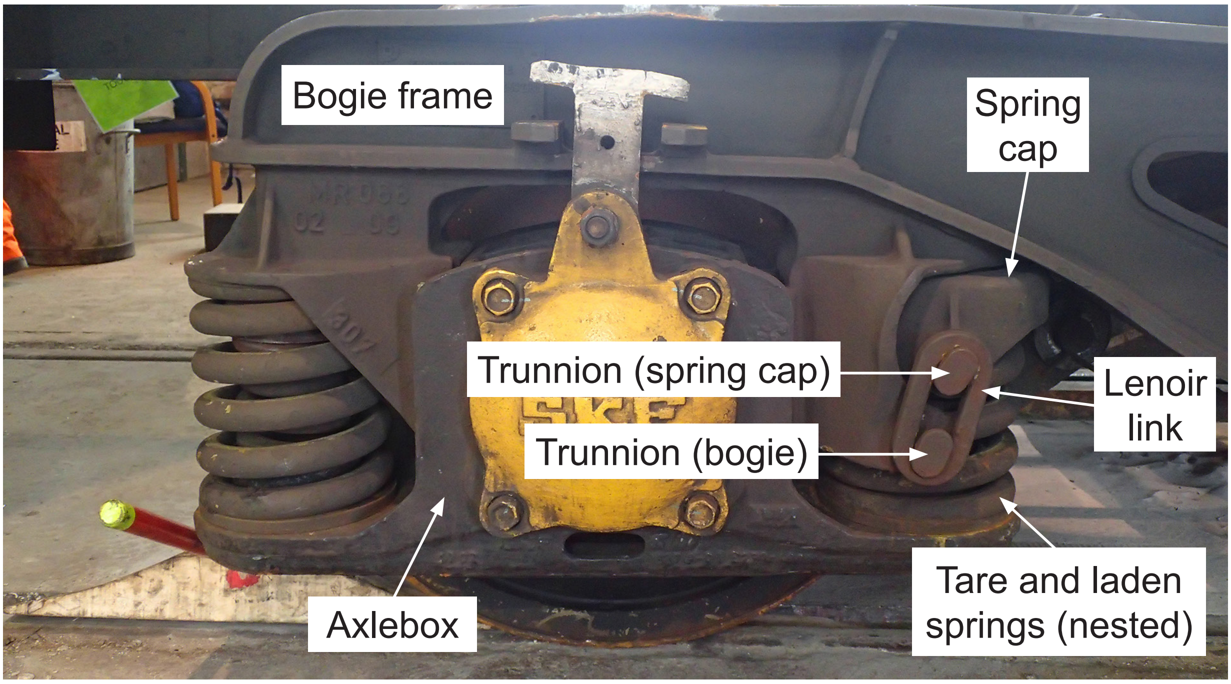


Figure 7: Components of damping system on Y33 bogies

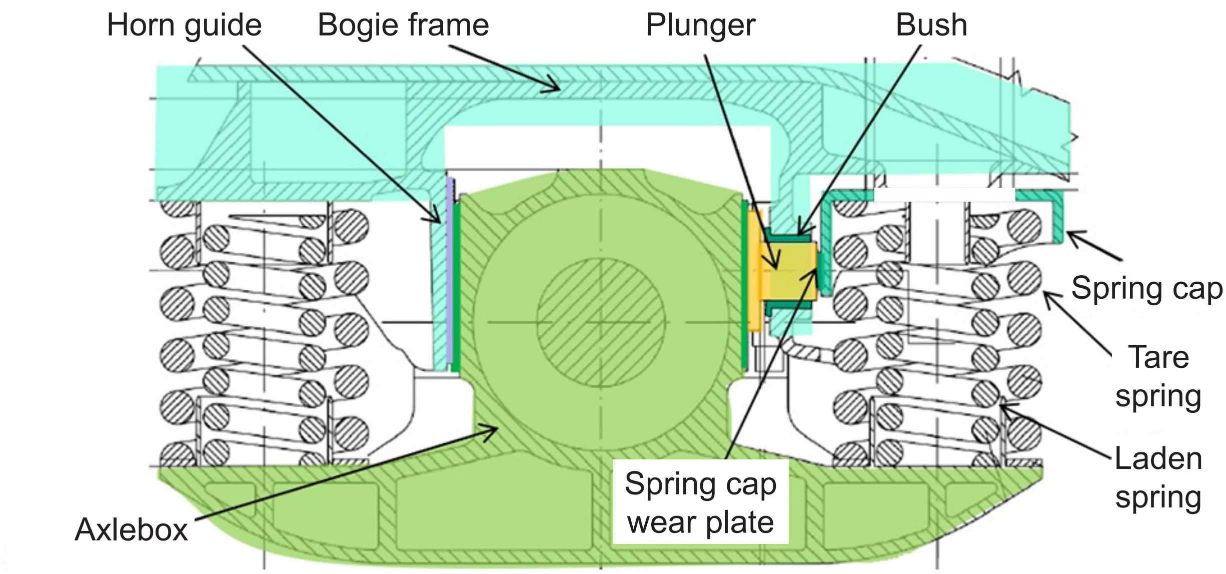


Figure 8: Components of damping system on Y33 bogies

29 The spring cap restrains the top of the tare spring on one side of the axlebox. The spring cap itself is restrained by the Lenoir links which attach it back to the bogie frame. The links are set at an angle and can only carry a load along the axis defined by that angle. When the tare spring carries a load, it pushes against the spring cap which creates a load in the links. Because of the angle of the Lenoir links, the load in the links has a vertical component (which equates to the spring load) and a horizontal component which pulls the spring cap towards the axlebox.

30 Under the horizontal component of the load in the links, the spring cap wear plate pushes against the plunger which is free to move inside a bush (figure 8). The plunger pushes against the axlebox which in turn pushes against the bogie frame horn guide wear plate. If the axlebox slides up or down inside the horn guides, the axlebox has to overcome the frictional force provided by the horizontal load which pushes the components against one another, hence the name 'friction-damping'.

31 As the load on the tare spring increases (for example as the vehicle is loaded with containers), the load in the Lenoir links increases and hence so does the amount of damping.

Inspection of bogie damping components

32 Wagon 630034 was examined at March depot after the derailment. The wagon underframe was lifted which enabled the bogies and their components to be examined. Of particular note was an unusual wear pattern on the spring cap wear plates (figure 9). This wear pattern suggested that:

a. the spring cap wear plate had been sitting higher than the bush (figure 10); and

b. the spring cap wear plate had been pushing against the top of the bush instead of the plunger which suggests that the plunger was recessed inside the bush, instead of passing through and protruding from it (as shown on figure 11).

Figure 9: Wear pattern on incident spring cap wear plate

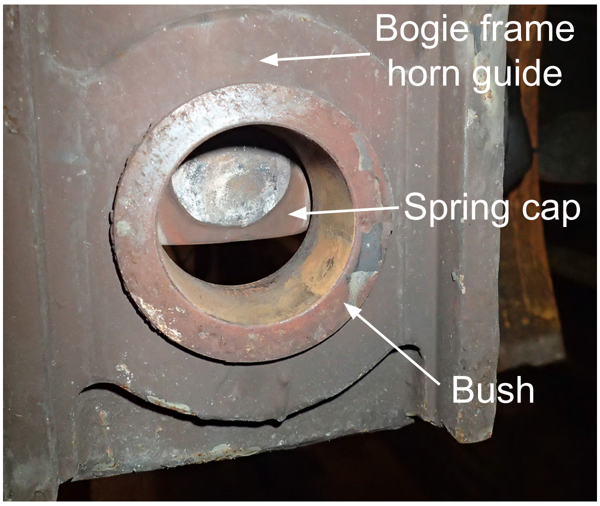


Figure 10: Position of spring cap wear plate relative to bush reconstructed on trailing axle of incident wagon (for illustrative purposes only)

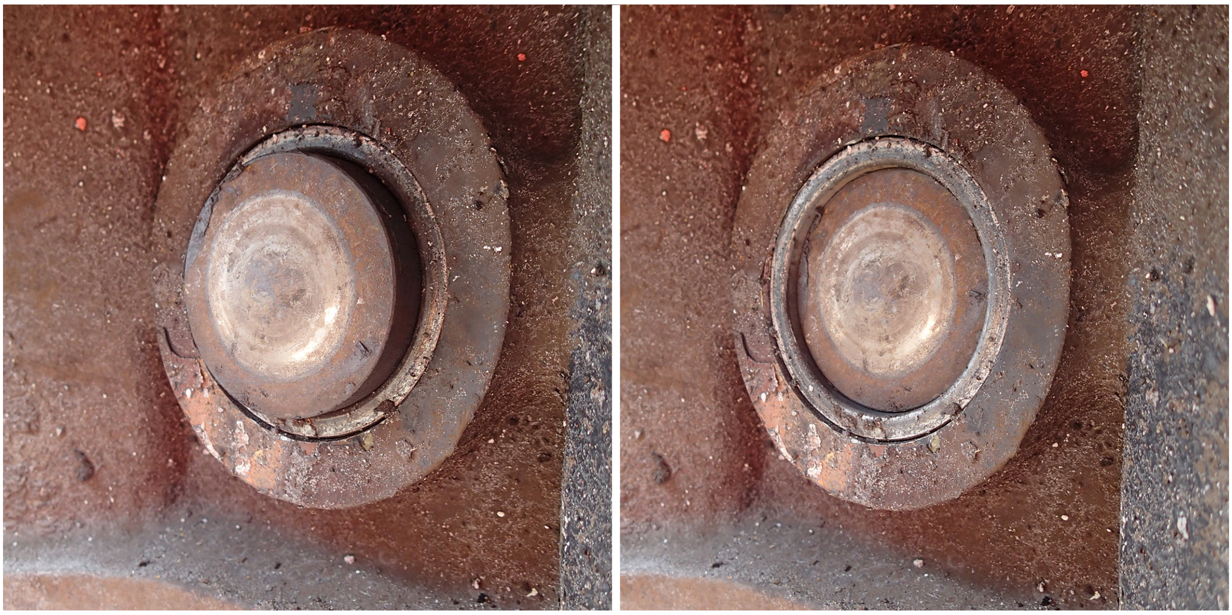
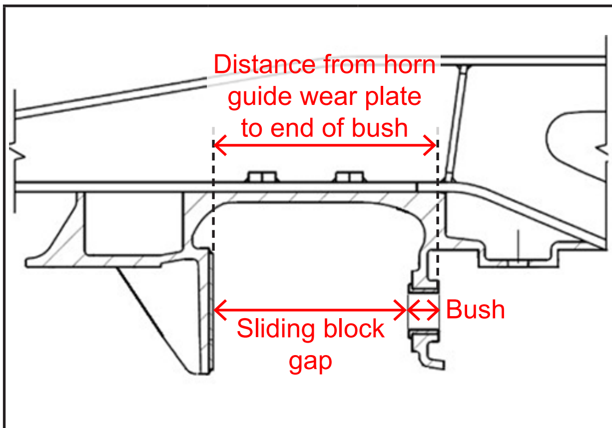
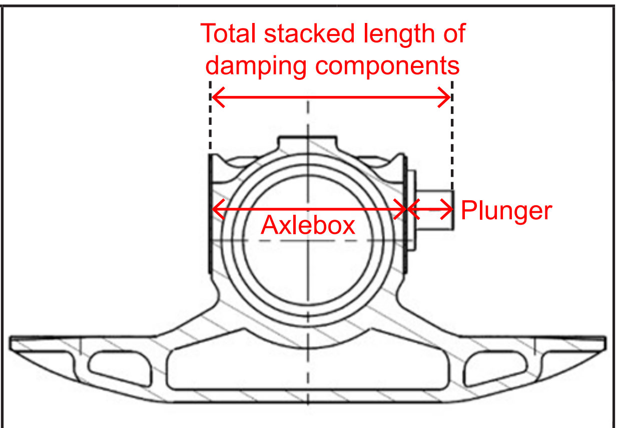


Figure 11: A plunger in normal position and in a recessed position - reconstructed on a different wagon for illustrative purposes

33 The fact that the spring cap wear plate was sitting higher than the bush is demonstrated by the physical evidence. In order to establish whether the plunger had been sat recessed inside the bush, the RAIB took detailed measurements of the leading right-hand axlebox, the one associated with the wheel which first derailed, and its plunger. This enabled a comparison of the stacked length of these components with the measured distance between the bush and the horn guide wear plate. Table 1 shows the results.





Sliding block gap (mm)		Bush (mm)		Distance from horn guide wear plate to end of bush (mm)	Axlebox (mm)		Plunger (mm)		Total stacked length of damping components (mm)
290.9*	+	44	=	334.9	271**	+	63.2	=	334.2

* The accuracy of this measurement is +/-1.5mm because of derailment damage to the horn guide carrying the bush.

** The accuracy of this measurement is +/-1mm because of the method used to do the measurements. The maintenance records for the axlebox showed that this dimension had been checked in February 2016 at 273 mm

Table 1: Measured bogie dimensions and damping stack length

34 This comparison showed that the damping stack made up of the axlebox and plunger was likely to be shorter than the distance between the horn guide wear plate and the end of the bush. This suggested that the plunger was recessed inside the bush and the spring cap was unable to apply any significant load to it, as confirmed by the wear pattern on the spring cap wear plate (figure 9). In essence, the damping arrangement was ineffective due to excessive wear of the damping components. This was the case on all four axleboxes of the leading bogie of wagon 630034 when measured after the derailment.

Maintenance of bogie damping components

35 Since introduction into service, the wagons have been subject to a regular regime of Planned Preventative Maintenance (PPM) and Vehicle Inspection and Brake Test (VIBT). The periodicity of these has varied over the years, but since 2010 each has been undertaken annually. Additionally, the wagons are subject to General Repair every seven years – carried out once before the accident at Wabtec in Doncaster in 2010.

36 It is inevitable that, because the surfaces within the friction damping arrangement slide against each other under load, they will wear. The wearing elements of these components are the Lenoir links and associated trunnions, the spring cap wear plate, the plunger, the wear plates welded on either side of the axlebox and the wear plate welded on the bogie frame horn guide.

37 GBRf provided the RAIB with a copy of the General Repair specification that had been used in 2010. It had been drafted in 2009 in preparation for the General Repair. Table 2 shows the maintenance limits quoted in the 2009 General Repair specification for the wearing components.

Component	Nominal dimension in 2009 General Repair specification	Maintenance limit[6] in 2009 General Repair specification	Measured dimensions post-accident
Spring cap wear plate thickness[7]	3 mm	2 mm	1.5 mm
Plunger length	66 mm	63 mm	63.2 mm
Axlebox width (including wear plates)	274 mm	272 mm	271 mm
Horn guide wear plate thickness	7 mm	5 mm	4.2 mm
Lenoir link (inside length)	103 mm	106 mm	106.4 mm
Trunnion diameter (bogie)	30 mm	28 mm	29.8 mm
Trunnion diameter (spring cap)	30 mm	28 mm	29.2 mm

Table 2: Maintenance limits in 2009 General Repair specification

[6] During maintenance activities components are assessed against maintenance limits to determine whether they can remain in service. This is different from repair limits which determine when components need to be replaced.

[7] As the spring cap wear plate wears, its effective diameter increases due to the wear of the fillet weld attaching it to the spring cap. The resultant effective diameter will be dependent on the size of the weld that has been deposited during manufacture.

38 With the assistance of the bogie manufacturer, the origin of the maintenance limits used in the 2009 General Repair specification was traced to a set of guidelines managed by VPI (Germany). VPI maintenance guidelines quote limits for many bogie components including the Y-series bogies[8]. These limits are widely referred to in Europe and in the UK. For example, VPI 02 'Maintenance of Freight Wagons Underframes, bogies' and VPI 03 'Maintenance of Freight Wagons, Wheelsets' describe the dimensions for the spring cap wear plate, plunger, axlebox, Lenoir links and trunnions reported in table 2.

39 The limit for the horn guide wear plate is not directly quoted in the VPI maintenance guidelines which instead defines a sliding block gap (as defined in table 1) with its own limit (table 3). As the only surface that wears in the sliding block gap is the horn guide wear plate, the limit for the sliding block gap is really a limit for the horn guide wear plate. Interestingly, the sliding block gap is allowed to wear by up to 2.5 mm, which would in this case suggest a worn limit for the horn guide wear plate of 4.5 mm. This is only marginally different from the dimension quoted in the 2009 General Repair specification of 5 mm.

40 A review of the PPM and VIBT instructions applicable before the derailment showed that these maintenance interventions did not require the measurement of any of the damping components. As such, their dimensions were never checked against maintenance limits during these interventions. The only time when the dimensions of the damping components were checked was during the General Repair at Wabtec in 2010.

41 Wabtec provided the RAIB with the records of the 2010 General Repair intervention on wagon 630034. This shows that, in accordance with the specification which was in place at the time, the damping components had been measured and re-used, as they were found to be within the maintenance limits quoted in the specification. The damping components on wagon 630034 had therefore been part of the wagon since the day it was first put into service, 14 years before the accident[9].

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[8] The VPI maintenance guidelines list the bogie types to which the guidelines apply. The Y33 bogie design developed by Techni-industrie is not listed. Techni-industrie is not a member of VPI (and neither are GBRf or Wabtec). VPI stated to the RAIB that its maintenance guidelines are likely to be a suitable reference for Y33 bogies but that the suitability of the maintenance limits and arrangements would have to be validated by the organisations involved.

[9] The axleboxes get replaced every time the wheelsets are replaced, on average every 3 years according to GBRf, with the last replacement on wagon 630034 taking place in March 2016.

Identification of the immediate cause

42 **There was insufficient wheel load on the leading right-hand wheel of wagon 630034 to prevent the wheel lifting onto the railhead as it traversed Ely West Junction.**

43 Following the derailment, GBRf commissioned a simulation of the derailment by computer modelling. The simulation used an FEA-A wagon model which was validated against static test results undertaken during the original approvals of the wagon type. The wagon model included a representation of the containers and took account of the ineffective damping in the bogies as well as the actual wheel profiles. The track characteristics used in the model were directly based on the track geometry recorded by the Track Recording Unit (TRU) during its last run before the derailment (21 July 2017).

44 This simulation predicted that the leading right-hand wheel of wagon 630034 would fully unload at the point of derailment[10]. The leading right-hand wheel was predicted to lose contact with the railhead and to rise 6 mm (described as wheel flight) before re-contacting the rail in a partially climbed state (figure 12). At that point, the ratio of lateral load to vertical load applied to the wheel was also predicted to be high enough to continue to promote a derailment.

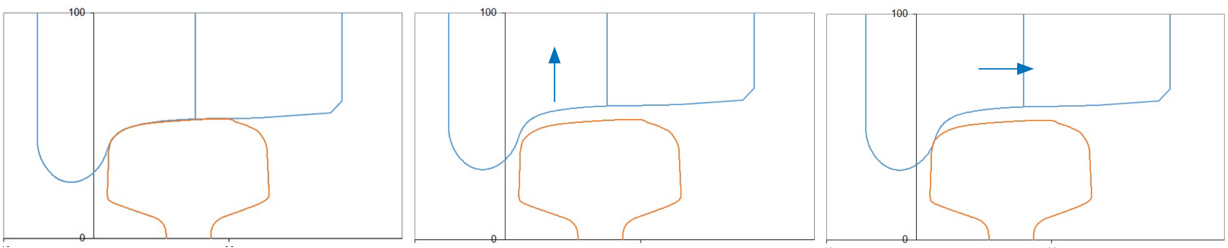

Figure 12: Wheel in contact with rail – normal condition (left), wheel in flight (middle), wheel landing in partially climbed state (right)

45 The level of partial climb predicted in the simulation (approximately 6 mm) is at a position at which the contact angle between the wheel flange and the rail starts to reduce. If the ratio of lateral load to vertical load is unfavourable, as was the case in the simulation[11], the wheel will likely continue to climb and eventually lead to a derailment. The RAIB therefore concluded that the simulation predicted a high risk of derailment at the point at which the leading right-hand wheel actually derailed.

[10] The dynamic simulations carried out during the investigation showed that the derailment at Ely West Junction was as a result of a complex relationship between the dynamic response of the wagon and the track geometry.

[11] The track curve will introduce a lateral force as the train negotiates it.

Identification of causal factors

46 **The derailment occurred because the damping on the bogies of wagon 630034 was ineffective.**

47 The RAIB commissioned a sensitivity study to understand which of the input parameters to the simulation had a significant effect on the likelihood of a derailment. A number of wagon-related factors were reviewed to determine whether to include them in the sensitivity study. These included damping, longitudinal and lateral offset of the payload, bogie rotational resistance, bogie twist, underframe twist and wheel profile.

48 As damping had already been found to be ineffective, reinstating damping was included in the sensitivity study; full damping and 60% of full damping representing the operating limit were both modelled. The ratio of bogie vertical loads, accounting for the difference in mass of the containers and the longitudinal offset of the payload in the 20 foot container, was within the guidelines provided by the UIC in its 'Code of practice for the loading and securing of goods on railway wagons' and hence this was not included in the study. However, the lateral offset on the 20 foot container payload was such that the wheel load ratio at the leading wheelset exceeded the guideline provided by the UIC (wheel load ratio limit of 1.25 to 1 with an actual value of 1.38 to 1). As a result, it was included in the study. All the other wagon parameters were found to be within maintenance limits and hence were not included in the study.

49 A number of track-related factors were also reviewed to determine whether to include them in the sensitivity study. These included vertical and lateral track alignment, track twist, cyclic top[12], gauge variation, cant excess and rail sidewear.

50 The last TRU run showed that the vertical and lateral track alignments were both within the intervention limits quoted in Network Rail's standard NR/L2/TRK/001. As such, no discrete alignment issue needed to be addressed. However, the TRU run had classified the eighth of a mile where the derailment took place as 'poor' in terms of vertical track quality and 'very poor' in terms of lateral track quality, in accordance with the same standard[13].

51 A 'poor' rating does not trigger any required action by Network Rail whereas a 'very poor' rating requires the people in charge of track maintenance to review what might be driving this rating and, where necessary, to take corrective actions. As such, the level of lateral irregularity was included in the sensitivity study. All other track factors were found to be within alert limits and hence were not included in the study. Figure 13 shows the input parameters and compares their values against the limits.

52 The sensitivity study demonstrated that reinstating the damping on the bogies, either fully or at a level of 60%, would have prevented the derailment. The main derailment indicators (wheel flight/climb and the ratio of lateral load to vertical load) were reduced to acceptable values. The only derailment indicator which remained high was the amount of wheel unloading (see paragraph 96). The RAIB concluded that the lack of damping was a causal factor to this derailment.

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[12] A regular series of high and low spots in a track.

[13] Network Rail assesses the quality of its track geometry using a statistical value called the standard deviation which quantifies by how much the track irregularities differ from the mean value over one-eighth of a mile.

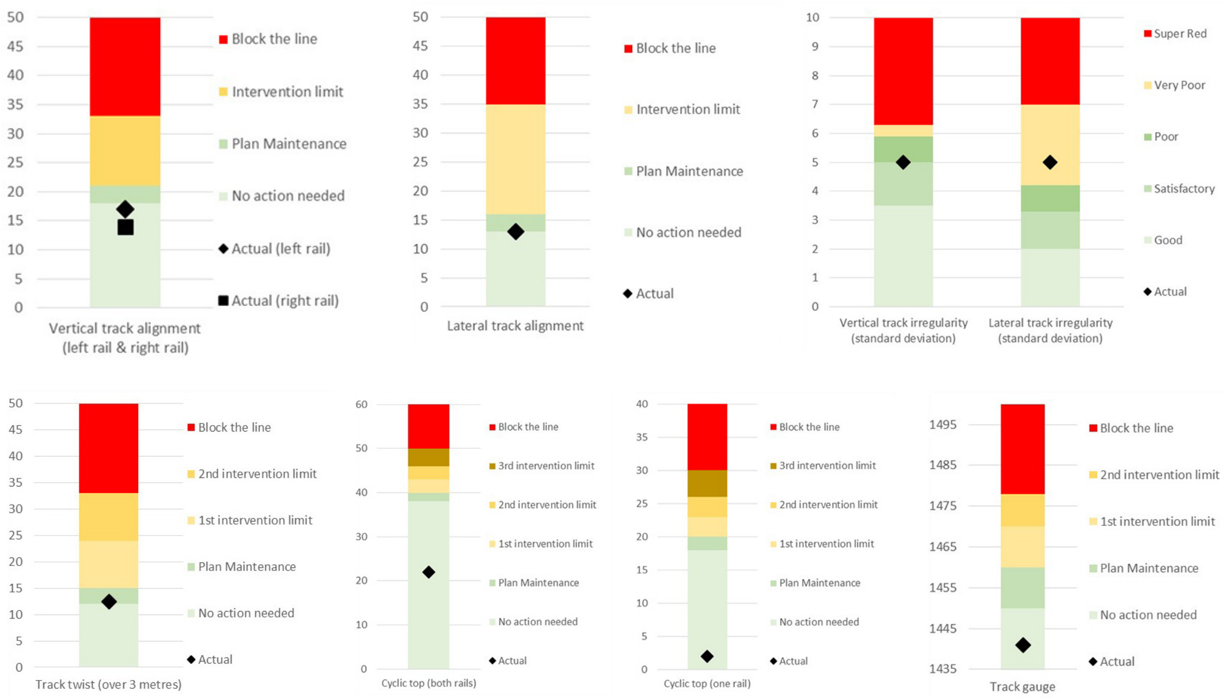


Figure 13: Track input parameters

53 The sensitivity study also demonstrated that adjusting the payload lateral offset of the 20 foot container such that the wheel load ratio at the leading wheelset was just within the UIC guideline made little difference to the prediction. The RAIB concluded that the lateral offset of the payload of the 20 foot container was not causal to this derailment.

54 Finally, the sensitivity study demonstrated that improving the lateral track geometry from a 'very poor' to a 'poor' rating reduced the amount of wheel flight that had been predicted[14] but increased the amount of wheel climb and also increased the ratio of lateral to vertical wheel loads. Hence the risk of the derailment remained high. The RAIB concluded that the lateral track irregularity was not causal to this derailment.

55 The damping on the bogies of wagon 630034 was ineffective because:

a. The damping components were managed to maintenance limits which did not account for future wear before the next maintenance intervention (paragraph 56);

b. The maintenance interventions between General Repairs did not identify that the damping system had become ineffective (paragraph 60); and

c. The damping components were managed to maintenance limits that were not compatible with the design intent of the damping system (paragraph 65).

Each of these factors is now considered in turn.

[14] The simulations suggested that the irregularities in the lateral track alignment contributed to the excitation of the wagon lower sway mode. And this excitation contributed to the sustained unloading of the leading right-hand wheel which resulted in wheel flight. By reducing the lateral track input, the dynamic response reduced accordingly to the point where wheel unloading (while remaining very high) was not sustained anymore. As a result, wheel flight was not predicted.

Maintenance limits in 2009 General Repair specification

56 **During the General Repair in 2010, the damping components were managed to maintenance limits which did not account for future wear before the next maintenance intervention.**

57 The only time the damping components were measured was during the 2010 General Repair at Wabtec (paragraph 40). The measured dimensions were checked against the maintenance limits quoted in the General Repair specification, which were based on the values quoted in the VPI maintenance guidelines.

58 However, the dimensions defined in the VPI maintenance guidelines (paragraph 38) are described as 'repair limits'. VPI clarified that this means dimensions beyond which the components need to be removed from service for repairs as they have no further useful life. Therefore, these dimensions are not 'maintenance limits' to use during maintenance interventions as they provide no allowance for future wear before the next intervention. Maintenance limits should be more restrictive in order to allow for future wear.

59 Using the 'repair limits' quoted in the VPI maintenance guidelines in the 2009 General Repair specification as 'maintenance limits' allowed worn damping components to remain in service, with insufficient wear life left to reach the next scheduled maintenance intervention. By the time of the accident, this had occurred and the damping had become ineffective.

Ineffective maintenance interventions

60 **The maintenance interventions between General Repairs did not identify that the damping system had become ineffective.**

61 After the General Repair in 2010 and prior to the derailment, wagon 630034 was maintained using a regime of PPM and VIBT interventions (paragraph 35). The maintenance documentation defining the activities to be undertaken during PPM and VIBT interventions required the maintainer to visually confirm that the axlebox was in contact with the horn guide wear plate and that the plunger was in contact with the axlebox. Crucially, it did not require confirmation that the spring cap wear plate was in contact with the plunger; the design of these Y33 bogies is such that this contact is not visible (see paragraph 75). Examination of wagon 630034 post-accident showed that it is feasible for the gaps between the axlebox and horn guide wear plate and plunger to look closed despite there being a gap between the plunger and the spring cap wear plate.

62 Although the maintenance documentation also required the gap between the top of the spring cap and the underside of the bogie frame to be checked, this does not ensure that the vertical position of the spring cap wear plate is within the diameter of the bush. Examination of wagon 630034 post-accident showed that it is feasible for the spring cap clearance to be greater than the limit of 3 mm despite the top of the spring cap wear plate sitting higher than the bush. The relative position of the spring cap wear plate and bush cannot be confirmed visually as this area is not visible from the outside (see paragraph 75).

63 The only means to establish whether the damping components were overly worn would have been to measure them. This would require the axlebox to be removed so that the components could be accessed. Between General Repairs, this only happened during wheelset replacement, and the related instructions did not require any such measurements to be taken. The wheelset replacement instructions were updated in April 2016 to introduce a new requirement for the damping components to be measured. However, the last wheelset replacement on wagon 630034 took place in March 2016, before this requirement was introduced. As such, the damping components had not been measured since the General Repair in 2010.

64 There is no means to establish how long the damping system of wagon 630034 had been ineffective. However, little assurance can be taken from the fact that neither the last PPM intervention in April 2017 nor the last VIBT intervention in September 2016 had raised any concerns with the effectiveness of the damping system on the wagon.

Compatibility with the design intent

65 **The damping components were managed to maintenance limits which were not compatible with the design intent of the damping system.**

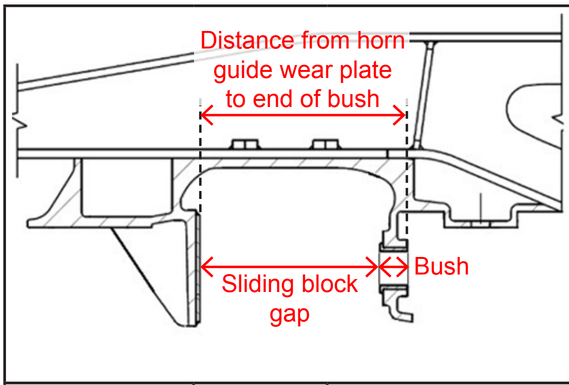
66 The maintenance limits used in the 2009 General Repair specification were based on the VPI maintenance guidelines (paragraph 38). VPI stated that the design intent is for the spring cap wear plate to be able to reach a plunger sat recessed inside the bush by up to 1.5 mm. For that to happen, the top of the spring cap wear plate must stay lower than the top of the bush for all conditions.

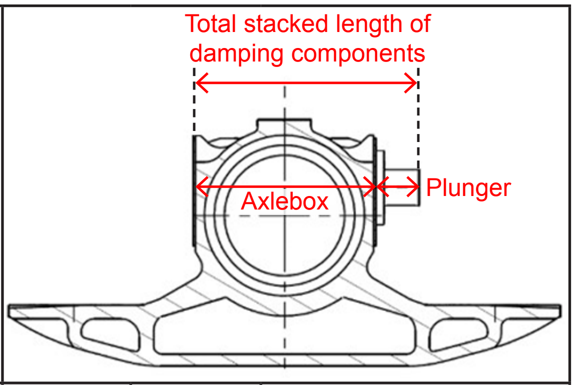
67 Table 3 shows the new and repair dimensions defined in the VPI maintenance guidelines for the damping components that controls the relative position of the plunger and the bush. The only dimension that is not declared in the VPI maintenance guidelines is the bush length. VPI advised that this bush is a standard component and that its length is 44 mm. Table 3 summarises the relative length of the damping stack (axlebox and plunger) against the distance between the horn guide wear plate and the end of the bush, both in new and repair conditions.

68 Table 3 shows that when all components are new and of nominal dimensions, the plunger is expected to protrude out of the bush by 6 mm. When all components are at their repair limit, table 3 confirms VPI's understanding that the plunger may sit recessed inside the bush by up to 1.5 mm.

69 The RAIB ascertained the relative vertical position of the bush and spring cap wear plate centrelines using the dimensions contained in the VPI maintenance guidelines and standard bogie components drawings. As new, the centreline of the spring cap wear plate (diameter 36 mm) is aligned with the centreline of the bush (diameter 55 mm). As the damping components including the Lenoir links and trunnions wear, the spring cap moves up in relation to the bush position. The RAIB calculated that at the extreme of wear of the components[15], the top of the spring cap wear plate may sit higher than the top of the bush. The physical evidence showed this was 4 mm in the incident axlebox (figure 9).

[15] As the spring cap wear plate wears, the weld connecting the spring cap wear plate to the spring cap also wears which increases the effective diameter of the spring cap wear plate (the diameter on the incident wagon was approximately 44 mm).





	Sliding block gap (mm)		Bush (mm)		Distance from horn guide wear plate to end of bush (mm)	Axlebox (mm)		Plunger (mm)		Total stacked length of damping components (mm)
New	290	+	44	=	334	274	+	66	=	340
Repair limit	292.5	+	44	=	336.5	272	+	63	=	335

Table 3: Comparison of bogie dimensions and damping stack length using VPI values

70 In order to achieve damping, the intent of the design declared by VPI is for the spring cap wear plate to be able to reach the plunger recessed inside the bush. The maintenance limits quoted in the 2009 General Repair specification are not compatible with this intent. This arose because the repair limits quoted in the VPI maintenance guidelines, when combined with tolerances on standard components, are also incompatible with this intent. However, it is noted that the VPI maintenance guidelines state that owners and Entities in Charge of Maintenance must check the applicability of the values quoted in the guidelines when integrating them into maintenance programmes.

Identification of underlying factors

Validation of 2009 General Repair specification

71 **In 2009, GBRf did not appropriately validate its General Repair specification to ensure continued safe operation up to the next General Repair in 2017. It is probable that this factor was linked to the cause of the accident.**

72 The 2009 General Repair specification was based on a document, GBRF-MAINT-001, which had been certified by Network Rail's Vehicle Acceptance Body as part of the original certification of the fleet in 2002-2003. Neither GBRf nor Network Rail have been able to source a copy of GBRF-MAINT-001.

73 In 2009, GBRF-MAINT-001 was amalgamated with other documents into the 2009 General Repair specification. The 2009 General Repair specification describes the maintenance limits for the key components. These maintenance limits have been found deficient in this investigation, in respect of allowance for future wear before the next maintenance intervention and compatibility with the design intent of the damping system.

74 The approvals regime had changed in 2006 with the introduction of the Railways and Other Guided Transport Systems (Safety) Regulations which handed back the responsibility of validating changes to existing procedures and processes to the people proposing the changes. GBRf has been unable to provide evidence of how this validation was carried out. However, it is apparent that any validation that was undertaken was ineffective since the 2009 General Repair specification did not manage the damping components' wear correctly (paragraph 56).

Observations

Inspection window

75 **GBRf did not make use of the inspection window provided on other Y-series bogies.**

76 Some bogies of the Y-series family are equipped with a window allowing visibility of the plunger and the spring cap (figure 14). The origin of this window could not be traced, but its purpose is almost certainly to provide a means to inspect the position of the spring cap wear plate relative to the plunger and bush (paragraph 61).

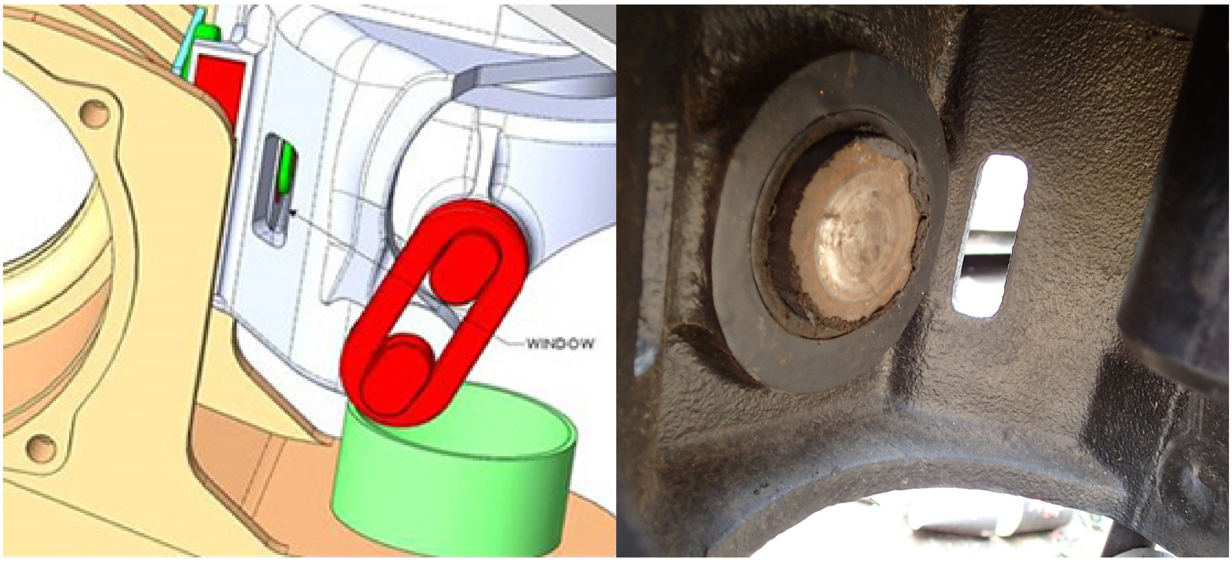


Figure 14: Inspection window on Y-series bogies (outside and inside view)

77 The bogies fitted to the FEA-A wagons are not provided with this inspection window. However, other Y-series bogies operated and maintained by GBRf, but supplied by different manufacturers, are equipped with the window. A review of the associated maintenance documentation shows that GBRf does not make use of the windows. It is therefore unlikely that it would have made any difference had a window been provided on the Techni-Industrie bogies.

Previous occurrences of a similar character

78 The RAIB has previously investigated the derailment of FEA wagons on Network Rail's infrastructure (at Duddeston (RAIB report 16/2008), Reading West Junction (RAIB report 02/2013) and Primrose Hill (RAIB report 21/2014)) but none of these derailments were associated with a deficiency in the maintenance of the damping system on the wagons. In addition, all these derailments concerned FEA wagons manufactured by another wagon builder with a different supplier of bogie equipment. As such, these previous occurrences are not directly relevant.

79 On 23 October 2014, a PCA wagon derailed after passing through Heworth station at 51 mph (82 km/h) (RAIB report 16/2015). The immediate cause of the derailment was a combination of a loss of damping due to an excessively worn plunger within the suspension and dips in the track at regular intervals (cyclic top). The wagon's maintenance regime had not identified the worn plunger. The RAIB recommended that Freightliner amend its vehicle maintenance instructions to ensure that the plunger is measured during VIBT examinations.

Summary of conclusions

Immediate cause

80 There was insufficient wheel load on the leading right-hand wheel of wagon 630034 to prevent the wheel lifting onto the railhead as it traversed Ely West Junction (paragraph 42).

Causal factors

81 The derailment occurred because the damping on the bogies of wagon 630034 was ineffective (paragraph 46, **Recommendation 1**). This causal factor arose due to a combination of the following:

a. the damping components were managed to maintenance limits which did not account for future wear before the next maintenance intervention (paragraph 56, **Learning point 1**);

b. the maintenance interventions between General Repairs did not identify that the damping system had become ineffective (paragraph 60); and

c. the damping components were managed to maintenance limits which were not compatible with the design intent of the damping system (paragraph 65).

Underlying factor

82 In 2009, GBRf did not appropriately validate its General Repair maintenance specification to ensure continued safe operation up to the next General Repair in 2017. It is probable that this factor was linked to the cause of the accident (paragraph 71, **Learning point 2**).

Additional observations

83 Although not linked to the accident on 14 August 2017, the RAIB observes that GBRf did not make use of the inspection window provided on other Y-series bogies (paragraph 75, **Learning Point 3**).

Previous RAIB recommendations relevant to this investigation

84 The recommendations which were made by the RAIB as a result of its previous investigations into the derailment of FEA wagons have no direct relevance to this investigation.

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

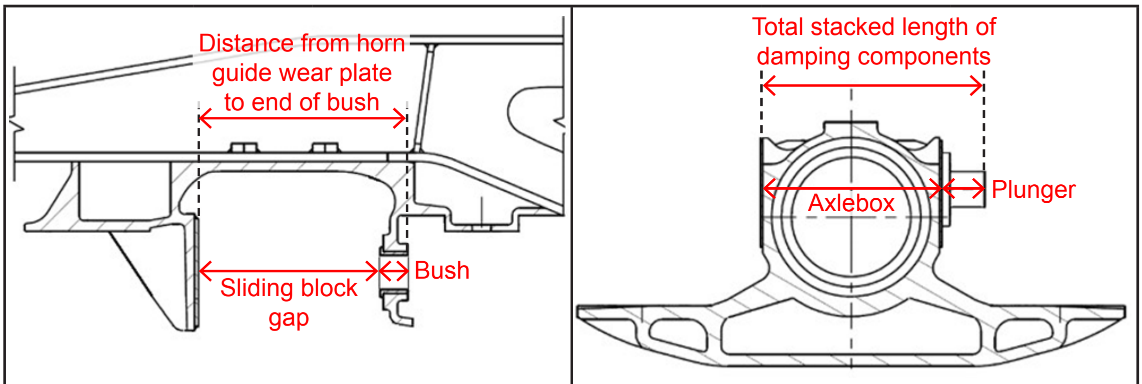
GBRf actions

85 In 2016 and in preparation for the upcoming General Repair planned for 2017, GBRf commissioned Ricardo Rail to undertake a review and update of the 2009 General Repair specification. GBRf contracted Ricardo Rail to carry out both the update to the documentation to bring it in line with industry best practice in the UK, and an independent verification of the changes being made.

86 Ricardo Rail reviewed the 2009 General Repair specification and changed some of its content. For example, the maintenance limit for the Lenoir links and trunnions were changed from 106 mm to 104.5 mm and from 28 mm to 29 mm respectively. The maintenance limit for the plunger was increased from 63 mm to 65 mm. The new maintenance limits came from various historical sources including a British Rail document, dated 1986, which defines the requirements for General Repairs on Y25 bogies (MT/277). In addition, Ricardo Rail changed the thickness of the horn guide wear plate from 7 mm (as designed by Techni-Industrie) to 5 mm. This change took place because Ricardo Rail believed that a 5 mm wear plate was the recommended best practice in the UK.

87 The reduction in allowable wear on the Lenoir links and trunnions equate to a reduction in maximum vertical movement of the spring cap in relation to the bush of up to 3.5 mm.

88 Table 4 shows the effect of the changes introduced in the 2016 General Repair specification on the stack length. By changing the thickness of the horn guide wear plate from 7 mm to 5 mm, the nominal sliding block gap has increased from 290 mm to 292 mm. As the new 5 mm wear plate has a fully worn limit of 4 mm, the repair limit for the sliding block gap dimension becomes 293 mm.



	Sliding block gap (mm)		Bush (mm)		Distance from horn guide wear plate to end of bush (mm)	Axlebox (mm)		Plunger (mm)		Total damping stack length (mm)
New	292	+	44	=	336	274	+	66	=	340
Repair limit	293	+	44	=	337	272	+	65	=	337

Table 4: Comparison of bogie dimensions and damping stack length using 2016 General Repair specification

89 Table 4 shows that when all components are new and of nominal dimensions, the plunger is now expected to protrude out of the bush by 4 mm (a reduction of 2 mm). However, when all components are at their repair limit, the plunger is now expected to sit flush with the bush.

90 In April 2017, GBRf decided, on economic grounds, to replace spring caps, plungers and Lenoir links during the upcoming General Repairs, regardless of their level of compliance with the maintenance limits in the 2016 General Repair specification.

91 In June 2017, Wabtec in Doncaster started undertaking General Repairs on the fleet of FEA-A wagons on behalf of GBRf. At the date of the derailment on 14 August 2017, the first twin set of wagons had just been completed. The programme was completed by July 2018.

92 In November 2017 and in response to the derailment, GBRf decided to carry out a fleet replacement of all the damping components that could be replaced (plunger, spring cap, Lenoir links) to reduce the risk of derailment on other wagons which had not yet gone through the General Repair programme.

93 On 2 May 2018, GBRf issued a National Incident Report[16] (NIR 3462) to share with the UK rail industry the concerns regarding the loss of damping on Y-series bogies when the components have reached their repair limits (paragraph 70).

VPI actions

94 On 13 July 2018, VPI issued a notification of change of the VPI maintenance guidelines which altered the repair limits for:

i. the plunger from 63 mm to 65 mm

ii. the Lenoir links from 106 mm to 105 mm

95 In addition, VPI advised the RAIB that it had commissioned an expert in the design of the Y-series bogies to review the compatibility of the design intent of the damping system and the associated repair limits in the VPI guidelines.

RAIB actions

96 In June 2018, the RAIB wrote to RSSB[17] to advise it of the findings of this investigation. In particular, it highlighted that the results of simulations indicated that:

a. significantly compliant track features (none of the parameters reaching intervention levels); in combination with

b. a wagon which was compliant to the wheel unloading requirement in GM/RT2141

could lead to very high levels of wheel unloading on the leading right-hand wheel, even when damping had been reinstated (paragraph 52). This could indicate a risk of a derailment in other circumstances.

[16] A reporting system in the UK to initiate, disseminate and manage urgent safety related defects in rail vehicles, plant and machinery.

[17] A not-for-profit company owned and funded by major stakeholders in the railway industry, and which provides support and facilitation for a wide range of cross-industry activities. The company is registered as 'Rail Safety and Standards Board', but trades as 'RSSB'.

Recommendation and learning points

Recommendation

97 The following recommendation is made[18]:

1 *The intent of this recommendation is to ensure that the Y-series bogies fitted to freight wagons are adequately damped at all times.*

GBRf should review and modify its current maintenance documentation to ensure that it prescribes maintenance limits on the damping components of its Y-series bogies that both account for future wear before the next maintenance intervention and are compatible with both the bogie manufacturing dimensions and design intent of the damping system. The revised maintenance documentation should also include effective inspection measures to provide assurance that the damping components are not worn beyond the maintenance limits (paragraph 81).

Note: this recommendation may also apply to other Entities in Charge of Maintenance.

Learning points

98 The RAIB has identified the following key learning points[19]:

1 People in charge of preparing and revising maintenance instructions are reminded that declared 'repair limits' should not be used as 'maintenance limits' for wearing components as this may provide no useful future life and does not guarantee safe operation to the next maintenance intervention.

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[18] Those identified in the recommendation have a general and ongoing obligation to comply with health and safety legislation, and need to take this recommendation 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, this recommendation is 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.

[19] 'Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when the RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where the 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.

2 Entities in Charge of Maintenance are reminded of their obligation to ensure that the vehicles for which they are in charge of maintenance are in a safe state of running by means of an appropriately validated system of maintenance.

3 Maintainers of Y-series bogies are reminded that some of the bogies are fitted with an inspection window which enables a visual assessment of the effectiveness of the damping system.

Appendices

Appendix A - Glossary of abbreviations and acronyms

GBRf	GB Railfreight
ORR	Office of Rail and Road
PPM	Planned Preventative Maintenance
TRU	Track Recording Unit
UIC	Union Internationale des Chemins de fer (International Union of Railways)
VIBT	Vehicle Inspection and Brake Test
VPI	Vereinigung der Privatgüterwagen-Interessenten

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Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby UK
DE21 4BA

Email: enquiries@raib.gov.uk
Telephone: 01332 253300
Website: www.gov.uk/raib