RAIB

Rail Accident Investigation Branch

Rail Accident Report

Freight train derailment at Angerstein Junction, 3 June 2015

Report 10/2016
June 2016

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
The Wharf
Stores Road
Derby UK
DE21 4BA

Email: enquiries@raib.gov.uk
Telephone: 01332 253300
Fax: 01332 253301
Website: www.gov.uk/raib

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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 Angerstein Junction, 3 June 2015

Contents

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Summary

At about 12:10 hrs on Wednesday 3 June 2015, one wagon of an empty freight train derailed on the approach to Angerstein Junction, near Charlton in south-east London. The train continued over the junction, derailing two further wagons, before it stopped on the Blackheath to Charlton line. The three derailed wagons were partly obstructing the line used by trains travelling in the opposite direction. No other trains were involved in the accident and no-one was injured, but there was significant damage to the railway infrastructure.

The wagons derailed because the leading right-hand wheel on one of them was carrying insufficient load to prevent the wheel climbing up and over the outer rail on a curved section of track. The insufficient load was due to a combination of the suspension on that wheel being locked in one position, a twisted bogie frame and an intended twist in the track.

The RAIB has made three recommendations. The first, addressed to VTG Rail UK (the wagon owner), seeks improvements to its wagon maintenance processes. The second, also addressed to VTG Rail UK, seeks liaison with industry to improve understanding of how wagon suspension wear characteristics relate to maintenance processes. The third, addressed to Network Rail, seeks a review of infrastructure arrangements at the accident location.

The report also includes a learning point reinforcing a previous recommendation intended to encourage use of currently available wheel load data, to enable identification of wagons with defects or uneven loads that are running on Network Rail's infrastructure.

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 All mileages are measured from London Charing Cross Station.

3 The report uses 'left' and 'right', and 'leading' and 'trailing', with reference to the direction of train movement at the time of derailment.

4 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B. Sources of evidence used in the investigation are listed in appendix C.

The accident

Summary of the accident

5 At about 12:10 hrs on Wednesday 3 June 2015, three wagons of an empty freight train derailed as the train was leaving sidings to run onto the North Kent lines at Angerstein Junction, near Charlton in south east London (figure 1). The train came to a stand with the three wagons partly obstructing the opposite line, which was open to traffic (figure 2). No-one was injured in the accident, but there was significant damage to the railway infrastructure.

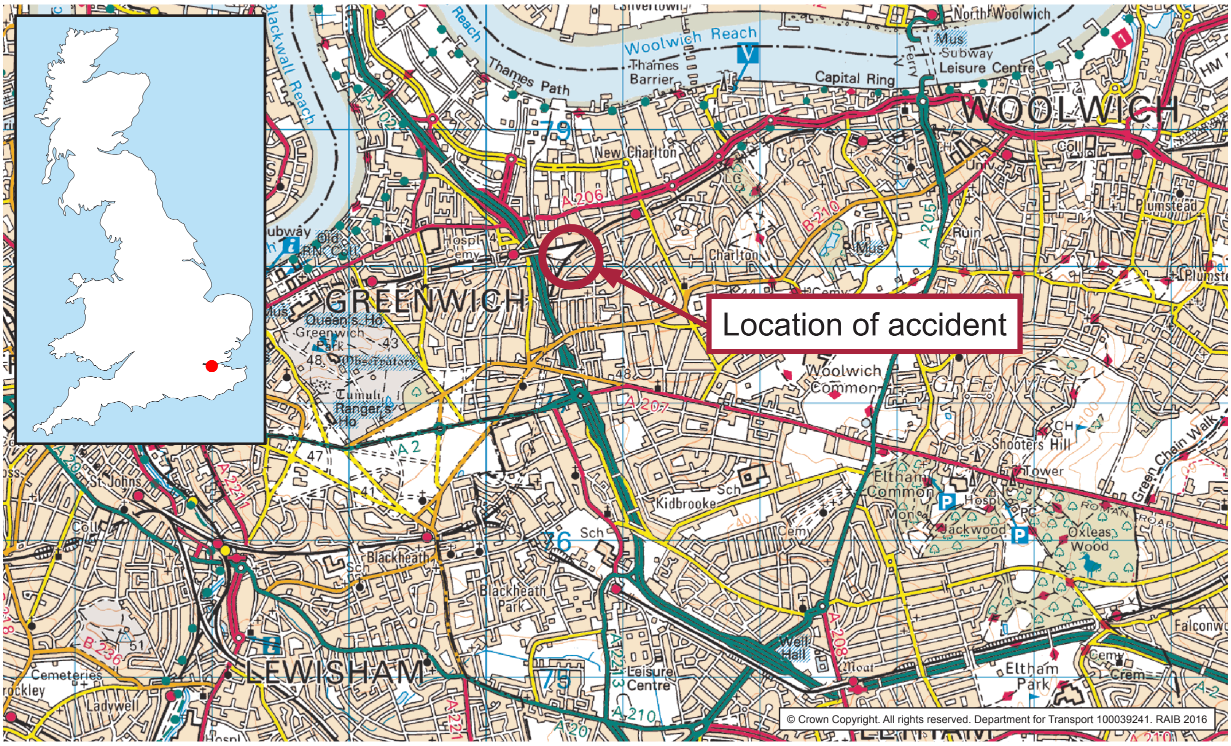


Figure 1: Extract from Ordnance Survey map showing location of accident

Context

Location

6 The derailment occurred within the length of a set of curved *trap points*, approximately 50 metres before the line from Angerstein Wharf sidings joins the North Kent lines at Angerstein Junction[1]. The train stopped approximately 160 metres after the initial derailment occurred, with three derailed wagons on the North Kent lines.

7 Angerstein Junction is located at 8 miles 46 *chains* on the North Kent lines, which connect Blackheath and Charlton (figure 3). At Charlton Junction, at 8 miles 63 chains, the North Kent lines join with the Greenwich lines.

[1] A similar derailment occurred at the same location on Wednesday 2 April 2014 (paragraph 102).

Figure 2: Derailed portion of the train (courtesy of Network Rail)

8 The North Kent and Greenwich lines are primarily used by trains between London and Woolwich. The Aggregate Industries terminal at Angerstein Wharf sidings is used by freight trains that arrive loaded with *aggregate*, unload, and then depart empty. Some trains that use an adjacent terminal arrive at Angerstein Wharf sidings empty and depart loaded.

9 The permitted speed limit for trains departing from Angerstein Wharf sidings is 15 mph (24 km/h), increasing to 50 mph (80 km/h) after Angerstein Junction.

10 Trains departing from Angerstein Wharf sidings start to descend a 1 in 211 gradient approximately 200 metres before the junction, and this gradient increases to 1 in 168 after trains join the North Kent lines.

11 Signal L425 protects the North Kent lines from trains leaving the Angerstein Wharf sidings. Signal L429 protects the Greenwich lines from eastbound trains on the North Kent lines.

12 The line from the sidings is single track and not electrified, while the North Kent and Greenwich lines are both double track with *third rail DC electrification*. The signalling is controlled from London Bridge Signalling Centre, and the electrification is controlled from Lewisham Electrical Control Office.

Figure 3: Google Earth image showing track layout and selected signals (showing train location after stopping)

Organisations involved

13 Network Rail owns and operates the railway infrastructure in the area where the train derailed, which is on Network Rail's Kent Route. It was also the employer of the staff responsible for the maintenance of the track.

14 GB Railfreight was the operator of the train that derailed, and the employer of the driver.

15 Aggregate Industries owns and operates the terminal at Angerstein Wharf, where the train was unloaded.

16 VTG Rail UK (subsequently referred to in this report as VTG) owned the wagons that derailed, and leased these to Aggregate Industries. VTG was the *entity in charge of maintenance* (ECM) for the wagons and was responsible for ensuring that maintenance activities were correctly carried out, including those involving subcontractors.

17 All of the above organisations freely co-operated with the investigation.

Train involved

18 The train involved in the accident was 6V43, the 11:56 hrs service from Angerstein Wharf sidings to Pengam sidings, near Cardiff. It consisted of a Class 66 locomotive hauling 22 type JGA aggregate *hopper wagons* (figure 4). The wagons that derailed were part of two batches that had been built in the UK between 1986 and 1988.

19 JGA wagons consist of a three compartment hopper supported on an underframe. The underframe is supported on two Y25 type *bogies*, each of which is supported on two *wheelsets* (figure 4). The suspension design is almost identical to that described for the JRA wagons in RAIB report 11/2015 (paragraph 102) and is summarised in paragraph 36.

Figure 4: JGA Hopper wagon

External circumstances

20 The weather was dry and bright at the time of the derailment, with scattered clouds. There is no evidence to suggest that unusual external circumstances influenced the accident.

The sequence of events

Events preceding the accident

21 The train had brought various grades of aggregate from Neath Abbey Wharf, in South Wales, to the Aggregate Industries terminal at Angerstein Wharf, arriving shortly after 05:30 hrs on 3 June.

22 After unloading, the train departed from Angerstein Wharf sidings at 11:07 hrs, towards Pengam sidings, near Cardiff.

Events during the accident

23 On approaching Angerstein Junction, the train was stopped by a *red aspect* at signal L425 (figure 3) at 11:16 hrs, to await its timetabled *path*. This signal is positioned before trap points 851A, and controls entry from the sidings on to the North Kent lines.

24 The train waited at this signal until 12:05 hrs. Signal L425 then changed to show a *yellow aspect*, and the train proceeded onto the North Kent *down line*, reaching a maximum speed of 5 mph (8 km/h). It was travelling towards signal L429, which was showing a red aspect and controls entry from the North Kent lines onto the Greenwich lines.

25 At 12:07 hrs, as the train was slowing in order to stop at signal L429, a wheelset on the 11th wagon (number BHQ 17121) derailed to the outside of the fixed outer rail on the curve at trap points 851A. This occurred very close to the moment when the train stopped at signal L429.

26 When signal L429 changed to a yellow aspect, the driver applied power and the train started to move, derailing a second wheelset at the same location and dragging the derailed wheelsets over Angerstein Junction. This resulted in derailment of the remaining wheelsets on the wagon (number BHQ 17121), all the wheelsets on both *bogies* of the preceding wagon (number BHQ 17149) and both the wheelsets on the leading bogie of the following wagon (number BHQ 17109).

27 After starting from signal L429, the train travelled for approximately 160 metres before stopping due to an automatic emergency brake application triggered by separation of a *brake pipe* linking the front two derailed wagons. The train stopped with the locomotive on Charlton Junction and the third wagon from the rear of the train standing at the point of the derailment.

Events following the accident

28 The signaller received a warning indication relating to the *points* at Angerstein Junction as the train was passing, and contacted the driver by radio, who advised the signaller that the train had derailed. The signaller stopped train movements on the North Kent and Greenwich lines. The electrical control room operator noted that the third rail had become short circuited to earth, and arranged for the power to be switched off.

29 The front eight wagons were later detached from the rest of the train and removed from the site, allowing the Greenwich lines to reopen by 16:30 hrs on the same day.

30 The three derailed wagons were rerailed and these three wagons, along with the rear part of the train, were pushed back into Angerstein Wharf sidings by 16:30 hrs on 4 June 2015. This allowed repairs to the track and associated infrastructure to be completed for reopening of the North Kent lines the following morning.

Key facts and analysis

Background information

Track twist

31 *Track twist* is a measurement of the rate of change in the relative heights (or *cant*) of the two *running rails* between two positions along the track. It can be expressed as an absolute measure of the difference in cant between the two measuring points. It can also be expressed as an average gradient, where the difference in cant is related to the distance between the two measuring locations. As an example, a change of cant from 20 mm to 30 mm over a base distance of three metres (the normal base used by Network Rail) is expressed as either a track twist of 10 mm or as a twist gradient of 1 in 300 (10 mm in 3000 mm).

32 Track twist can be present as part of the designed track configuration to accommodate changes in cant between curved and straight track, or can be the unintentional result of track movement. It can cause uneven loading of the wheels on a wagon, and so increases the risk of derailment for wheels that become more lightly loaded.

33 If one rail can be deflected downwards more than the other when a train passes, due to *voids*, or gaps under the track, it is possible for the amount of track twist to change. The twist without the effect of the weight of a train is known as *static twist*, while that with the effect of the weight of a train is known as *dynamic twist*.

Wheel unloading

34 The derailment mechanism considered in this report is known as *flange climb* and occurs when the vertical load on a wheel is insufficient to prevent lateral forces pushing the wheel up the sloping interface between the *wheel flange* and the rail (figure 5). The likelihood of derailment increases as the ratio between the lateral force and the vertical load increases. Consequently, the probability of a given wheel derailing increases as the vertical load on it decreases (ie the *wheel unloading* increases) and/or the lateral force increases. In some circumstances, such as an unevenly distributed payload, wheels on the same axle can carry differing loads. The level of friction and the *contact angle* at the rail wheel interface can also affect the probability of derailment.

35 A flange climb derailment depends on both the track geometry at the point of derailment and the geometry on the approach to this point. This is because the rail wheel has to travel sufficient distance along the track (typically up to two metres[2]) for it to be able to climb fully onto the rail head.

[2] Paragraph C2 in Appendix C of Railway Group Standard GM/RT2141 (Resistance of Railway Vehicles to Derailment and Roll-Over) refers to use of a two metre length.

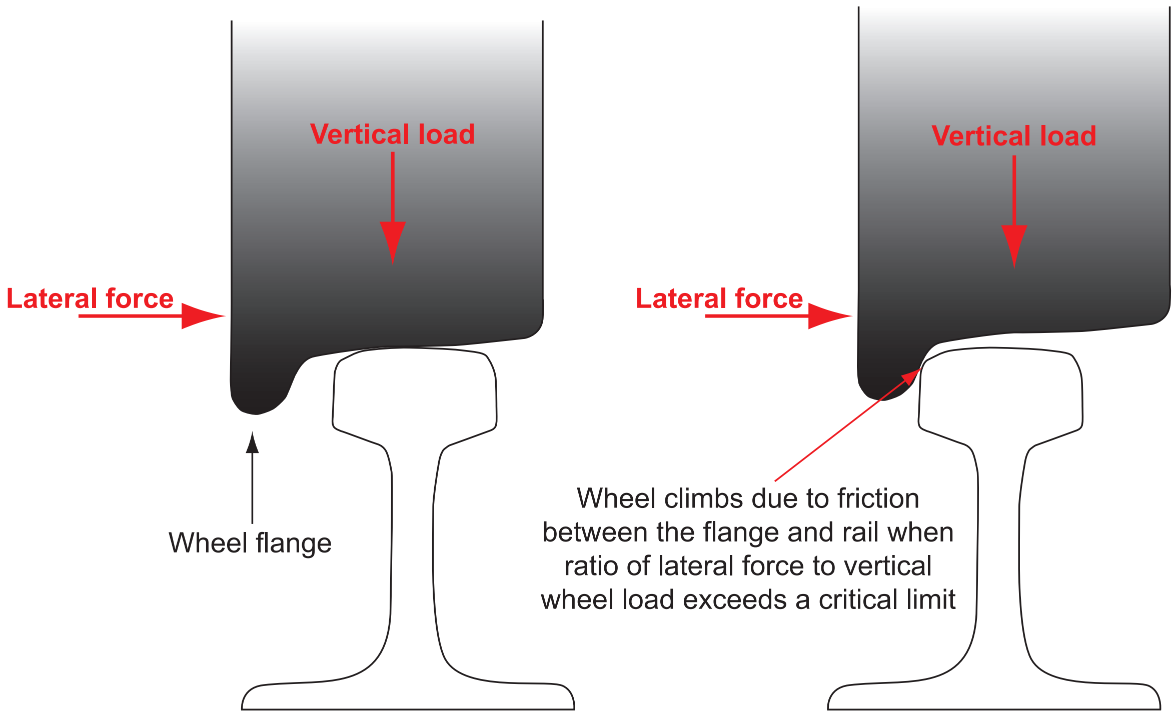


Figure 5: Flange climb

Wagon suspension

36 The JGA wagons are carried on two Y25 type bogies, each of which has two wheelsets. These bogies have a *primary suspension* consisting of *nested* pairs of coil springs, in which the outer spring of the pair (the 'tare' spring) is in use through all loading conditions and the inner spring (the 'laden' spring) engages as the load on the wagon is increased, making the suspension of the vehicle stiffer. In addition, part of the vertical force is applied via an inclined link (known as the 'Lenoir' link) causing the spring cap to push a damper onto a wear plate on the axle-box (figure 6). This provides vertical and lateral damping of the primary suspension, with a greater lateral force applied to the dampers, leading to increased damping, when the wagon is loaded.

Wheel weight data

37 *Gotcha* is a type of Wheel Impact Load Detector (WILD) system that is installed at key locations on Network Rail's infrastructure, and replaced an earlier system known as *Wheelchex*. Both rails on a section of straight and level track are instrumented to measure the load imparted by moving wheels. The primary function of Gotcha is to identify vehicles that are generating excessive dynamic loads on the rail head, such as wheels that have flat spots or are out-of-round, so that these vehicles can be stopped before they damage the infrastructure. Gotcha can also provide data that indicates the weights of individual wheels on passing trains, an issue considered by previous RAIB reports, including that relating to the previous derailment at Angerstein Junction (paragraph 102).

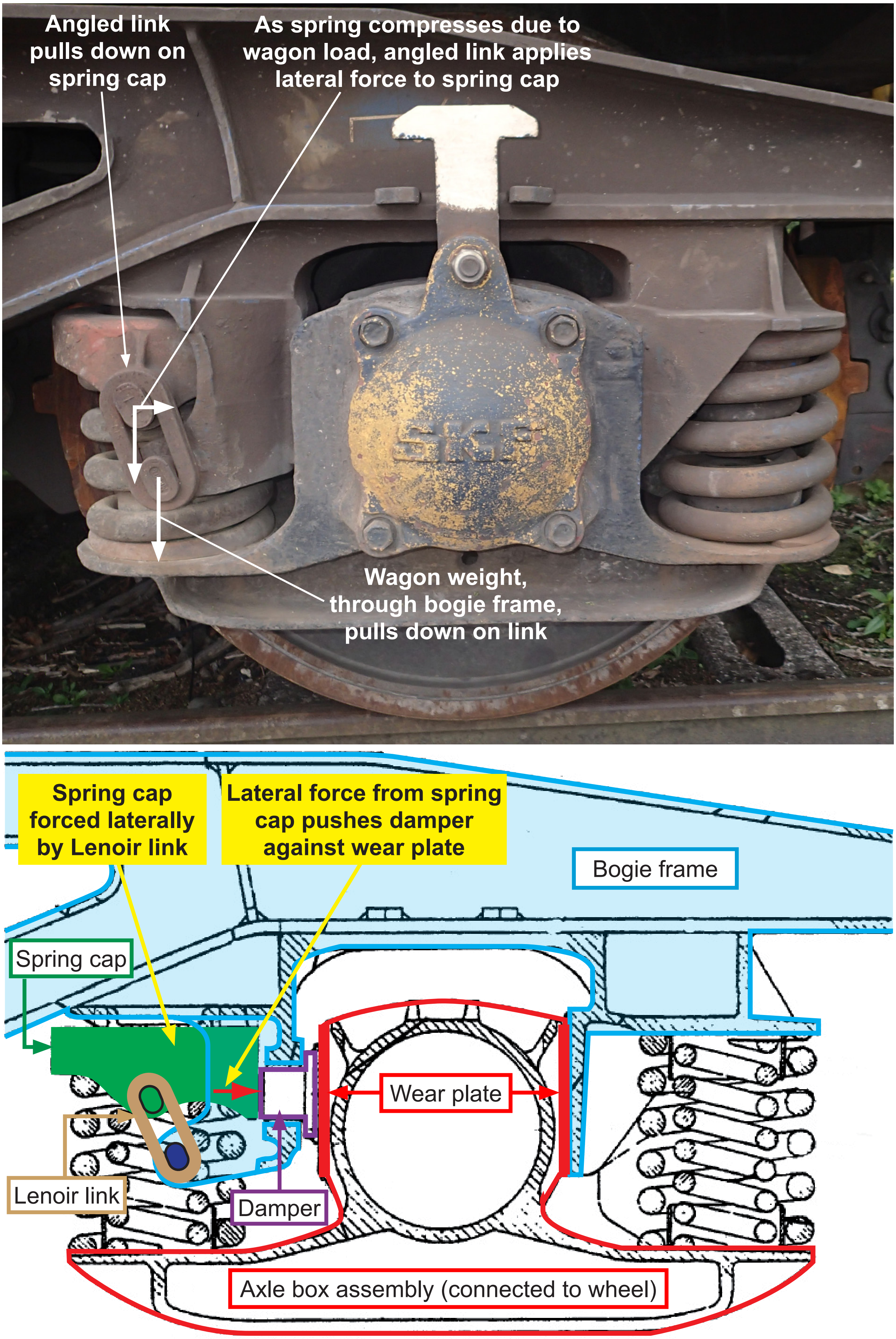


Figure 6: Suspension mechanism

Identification of the immediate cause

38 **There was insufficient load on the front right-hand wheel of the leading bogie on wagon BHQ 17121 to counteract the lateral forces at the wheel-rail interface, and thus to prevent the flange climbing over the rail head in the vicinity of trap points 851A.**

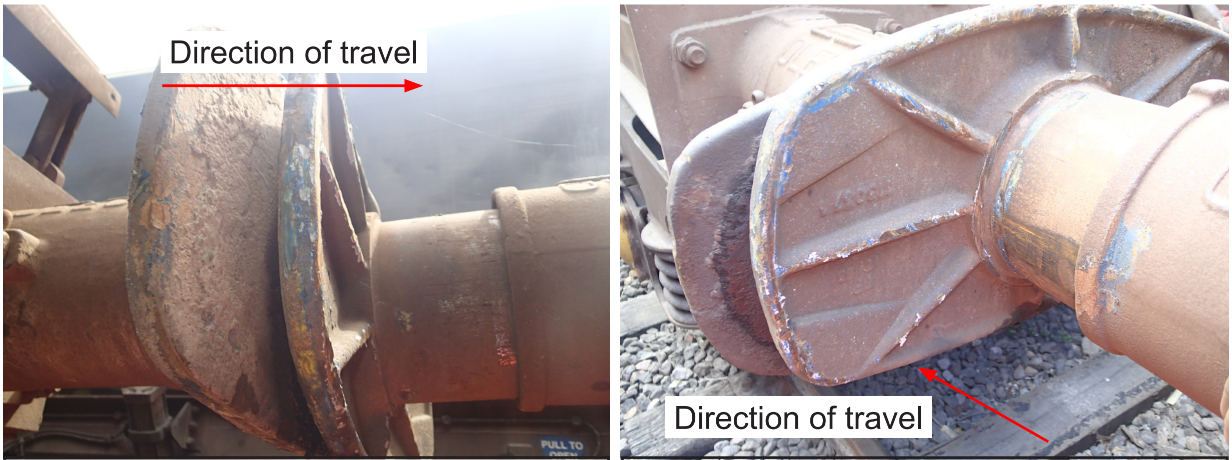
39 The marks on the rails at the point of derailment indicate that two wheel flanges climbed onto the head of the outer rail before derailing to the outside of the curve. This is supported by two sets of impact marks to the chairs supporting the outer rail (figure 7).

Figure 7: Derailment marks on the rail head and on the subsequent chairs

40 The RAIB considers that it was the right-hand leading wheel on the leading bogie of the eleventh wagon (BHQ 17121) that derailed first. RAIB experience of flange climb derailments and derailment theory[3] indicates that the leading wheel on a bogie is much more likely to climb the outer rail on a curve than the trailing wheel, because the *angle of attack* between the wheel flange and the rail will be larger and because it is likely to run closer to the outer rail. Gotcha wheel weight data from before the derailment showed that the leading wheel on this wagon was also significantly lighter than it should have been (paragraph 46). The wheels on both the 10th and 12th wagons had close to the normal load, making them less susceptible to derailment. It is likely that the trailing wheelset on the same bogie was the second to derail, with its flange climb assisted by the increased angle of attack due to the leading wheelset being turned towards the outside of the curve after it derailed.

[3] 'A theoretical manual of railway vehicle dynamics' (BM Eickhoff, British Railways Board 1989).

41 The marks on the *buffers* of the 10th and 11th wagons (figure 8) are consistent with this derailment sequence, because they indicate that the front bogie of the 11th wagon derailed to the right-hand side of the train and dropped off the rails while the 10th wagon was still on the rails. This is evidenced by the buffer face marks being concentrated on the top left-hand corner of the front left buffer of the 11th wagon and on the bottom right corner of the rear left buffer on the 10th wagon.



Wagon 10 rear left buffer – marks concentrated on bottom right, showing it was higher and to the left of wagon 11 front left buffer	Wagon 11 front left buffer – marks concentrated on top left, showing buffer was lower and to the right of wagon 10 rear left buffer

Figure 8: Buffer marks (shown after wagons had been rerailed)

42 The RAIB has concluded that the rest of the wheels on the 11th wagon were dragged into derailment, along with those on the 10th wagon and the lead bogie of the 12th wagon, as the derailed wheelsets were pulled across Angerstein Junction. This is because the wheels that were already derailed would have been pulled over the rails at the *pointwork*, and this would have dragged the other wheels off the rails.

Identification of causal factors

43 The accident occurred due to a combination of the following causal factors:

a. Wagon BHQ 17121 had a significant unloading of the leading right-hand wheel (paragraph 44), because:

i. the suspension on the front right-hand wheel of wagon BHQ 17121 was locked in the loaded position (paragraph 50); and

ii. wagon BHQ 17121 had a bogie frame twist acting to unload the leading right-hand wheel (paragraph 63).

b. Maintenance of wagon BHQ 17121 neither identified the presence of, nor prevented the development of, a *bogie frame twist* and a suspension defect causing uneven wheel loading (paragraph 67).

c. The infrastructure configuration at the point of derailment presented a derailment risk to wagons that had abnormal wheel load distributions (paragraph 78).

Each of these factors is now considered in turn.

Condition of the wagon

44 **Wagon BHQ 17121 had a significant unloading of the leading right-hand wheel.**

45 The RAIB obtained Gotcha wheel weight data for Wagon BHQ 17121 recorded on 1 June 2015, during its last empty journey prior to the derailment. This data is based on the average of the wheel loads recorded at three separate Gotcha sites, and is presented in table 1.

	Left wheel (tonnes)	Right wheel (tonnes)
Wheelset 1 (Leading bogie)	4.2	1.3
Wheelset 2	1.9	3.8
Wheelset 3 (Trailing bogie)	3.1	2.6
Wheelset 4	2.6	3.3
Note: Weights are the average of data from Gotcha sites at Waltham, Cholsey and Alderton		

Table 1: Wagon BHQ 17121 wheel weights on 1 June 2015

46 When the wagon is empty and on level track, and so with the wagon weight evenly distributed, each wheel should carry approximately 2.9 tonnes. The Gotcha data shows that the average weight of the leading right-hand wheel on the previous day was only approximately 1.3 tonnes, indicating that it was unloaded by 1.6 tonnes.

47 After the derailment, wagon BHQ 17121 was recovered to Long Marston, where the RAIB undertook a detailed inspection and carried out testing, including weighing the wheels. One of the suspension springs on the left wheel of wheelset 2 was found to be displaced from its normal position. The RAIB concluded that this spring had become displaced as a consequence of the derailment. This conclusion was demonstrated by testing, summarised in table 2, which showed that a wheel loading distribution in the bogie similar to that seen pre-derailment (summarised in table 1) was only seen after the displaced spring was replaced in its correct position. Small differences between the loads recorded in table 1 (before derailment) and those in table 2 (after reseating the spring) are probably due to disturbance of the bogie and suspension during the derailment (and possibly during rerailing and transport to Long Marston), and the different measuring equipment used.

	Nominal tare wheel load (tonnes)	Before reseating displaced spring		After reseating displaced spring	
		Left wheel (tonnes)	Right wheel (tonnes)	Left wheel (tonnes)	Right wheel (tonnes)
Wheelset 1 (Leading bogie)	2.9	2.4	3.3	3.7	1.7
Wheelset 2	2.9	3.2	1.9	1.9	3.7
Wheelset 3 (Trailing bogie)	2.9	2.7	3.3	2.4	3.3
Wheelset 4	2.9	2.9	2.9	2.9	2.7

Table 2: Wagon BHQ 17121 wheel weights during post-derailment testing

48 The effect of the track twist that was present at the point of derailment on wagon BHQ 17121 was simulated with the displaced spring replaced in its correct position and the wheels packed off the rails to simulate the track profile that was present when the wagon was at the point of derailment (the site track twist is discussed in detail from paragraph 86). With this track twist applied, the front right wheel was found to be lifted approximately 2 mm off the rail head, indicating that it was carrying no load and so the simulated track twist had caused an unloading of 1.7 tonnes.

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

a. the suspension on the front right-hand wheel of wagon BHQ 17121 was locked in the loaded position (paragraph 50); and

b. wagon BHQ 17121 had a bogie frame twist acting to unload the leading right-hand wheel (paragraph 63).

Each of these factors is now considered in turn.

50 The suspension on the front right-hand wheel of wagon BHQ 17121 was locked in the loaded position.

51 RAIB analysis of the Gotcha wheel weight data (paragraph 61) suggested that the suspension on the front bogie of wagon BHQ 17121 was not operating correctly. The RAIB observed, during testing of the wagon (paragraph 48), that the suspension on the front right wheel of wagon BHQ 17121 was locked, and not moving vertically. The effect of the locked suspension was demonstrated by jacking up the right side of the bogie (figure 9), and observing the front right wheel lifting off the rail while the other three wheels were still carrying load. Further wheel unloading testing of wagon BHQ 17121 provided evidence that the rest of the wagon's suspension was operating correctly.

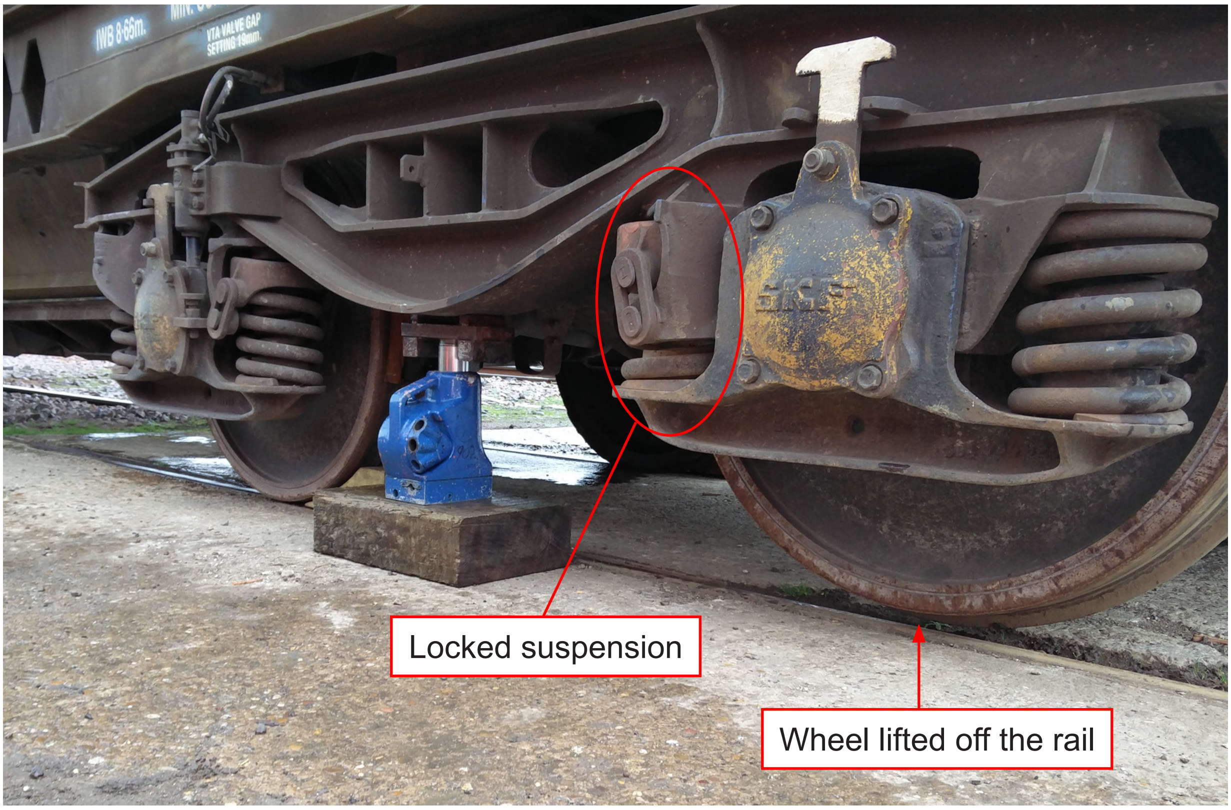


Figure 9: Effect of locked suspension when bogie side is jacked up

52 The effect of the locked suspension on the front right wheel was to prevent it from retaining its share of the load as the wagon load was reduced and the other suspension springs lengthened (figure 10). A consequence of this was that the diagonally opposite rear left wheel also became lighter than should have been the case, as its suspension springs extended further to keep the front right wheel, whose springs were not extending, on the rail. The front left and rear right wheels then carried a greater load than would have been the case if the suspension had been fully working, as they took up the remaining load (table 1).

53 The RAIB observed the stripping down of the leading bogie of wagon BHQ 17121 to identify the cause of the locked suspension. The longitudinal wear plate (paragraph 36) on the front right-hand wheel's axle box had become worn such that there was a step change in profile of approximately 1 mm just above the position where the damper contacted it when the suspension was in the laden condition. The wear pattern and recess are shown in figure 11. The relatively unworn wear face of the damper is shown in figure 12.

54 This change in profile meant that the damper entered a recess that was approximately 1 mm deep when the wagon was laden, and was then unable to slide out of the recess onto the less worn surface that it would normally contact when the wagon was unloaded.

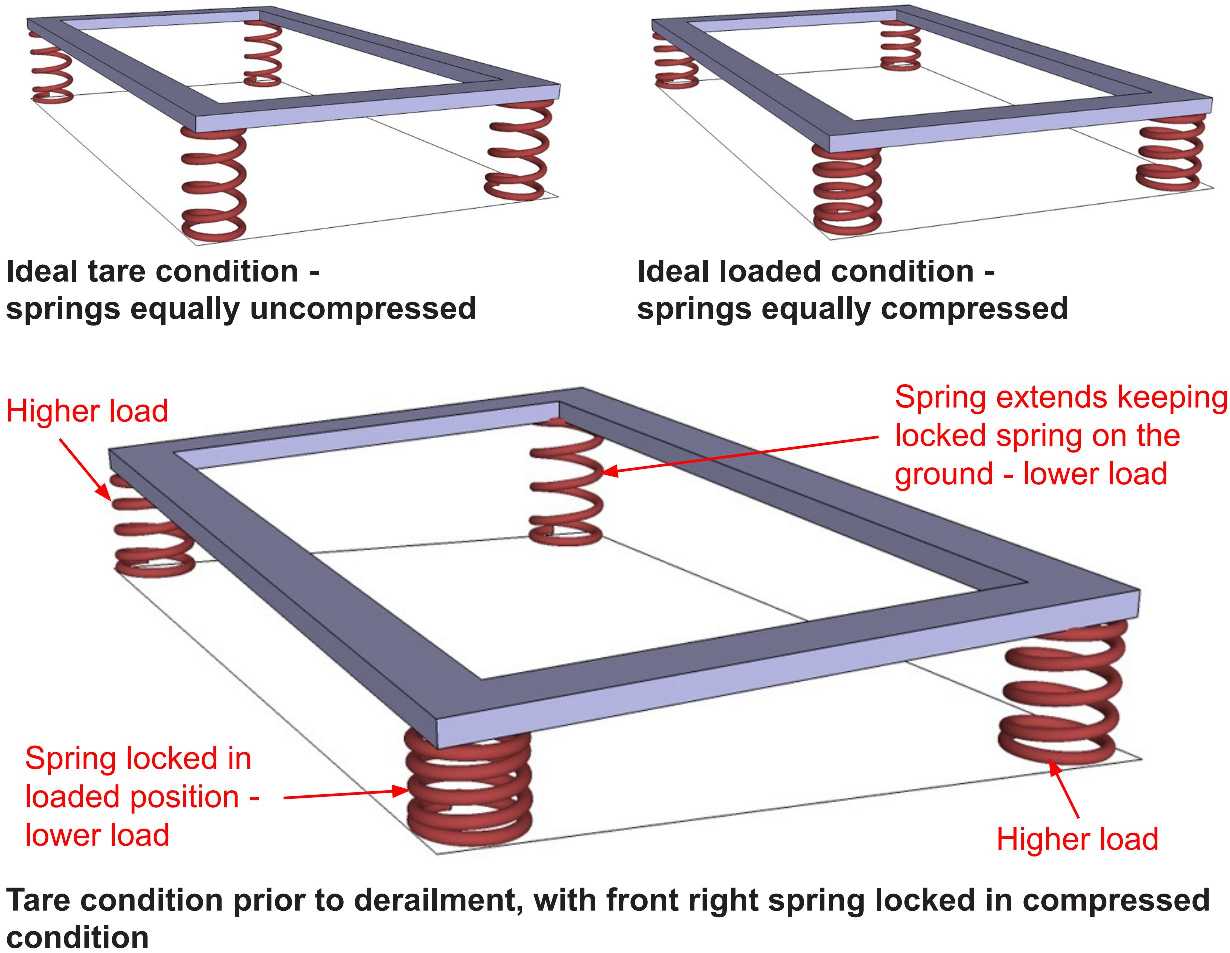


Figure 10: Representation of the effect of locked suspension on wheel loads

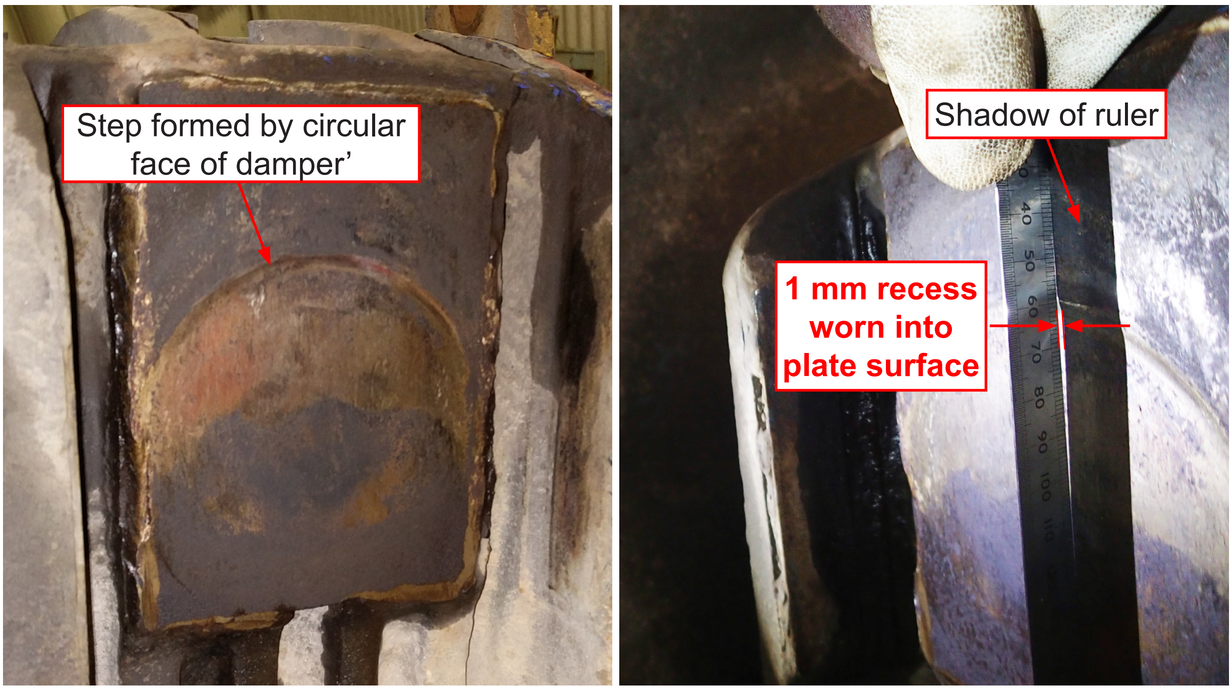


Figure 11: Worn axle box longitudinal wear plate

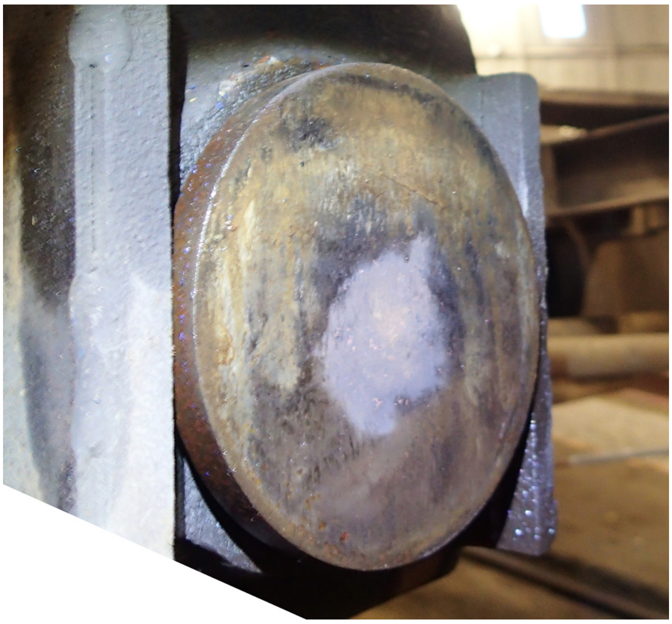


Figure 12: Damper wear face

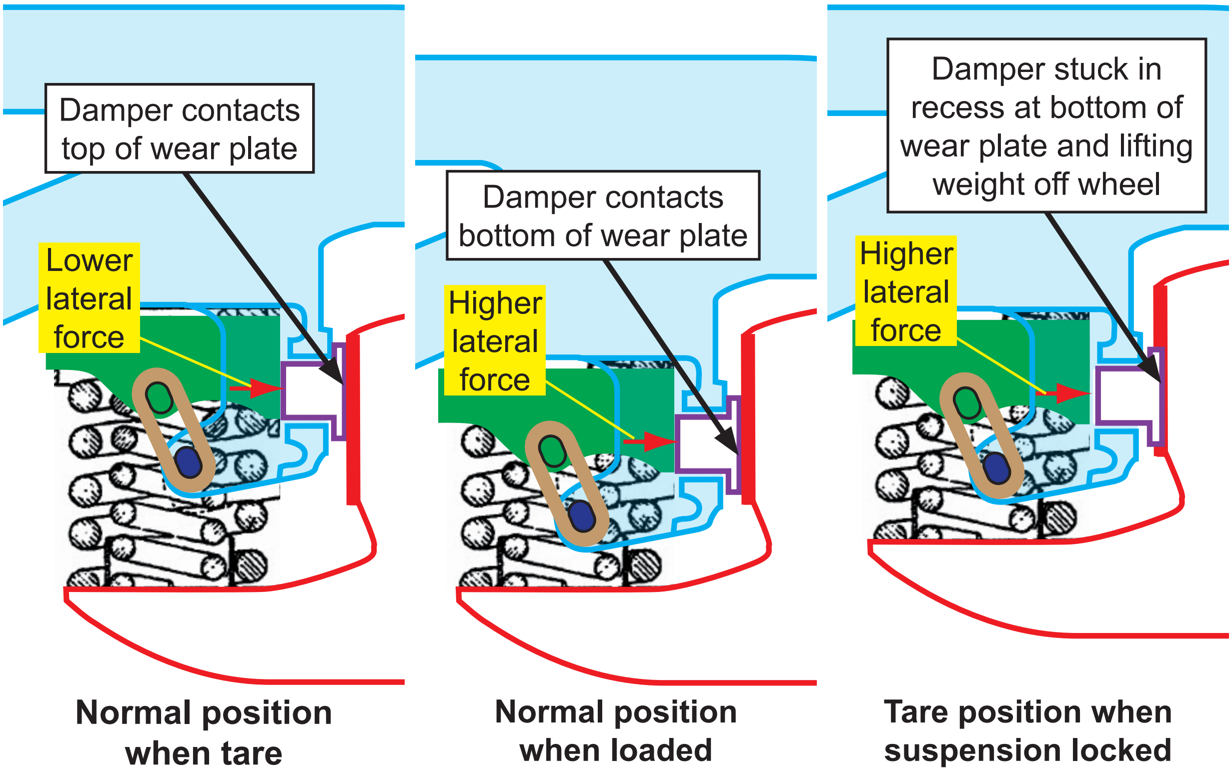


Figure 13: Suspension locking mechanism

55 Because the wagon normally operates either empty or heavily laden, the damper normally contacts the wear plate in one of two positions (figure 13). When the wagon is empty, the damper contacts the wear plate at the top, with a relatively low contact force. When laden, it contacts it nearer the bottom, with a larger force (paragraph 36). This means that the bottom of the wear plate is likely to be subject to more wear than the top, thus promoting the observed wear profile. Figure 13 shows the mechanism by which the change in wear plate profile, combined with the suspension and damper forces, prevented the suspension from moving to the correct unladen position.

56 The equivalent wear plate on the opposite wheel on the same axle had a similar wear pattern, but the change in profile was much smaller, measuring only 0.3 mm. This indicated that both wear plates had been subject to a similar wear mechanism, but the wear with the damper in the loaded position was much higher on the right-hand wheel. A possible explanation for this increased wear is that the right-hand wear plate had developed a sufficient step in its profile for the damper to become locked, and remained so for a considerable period of time (supported by Gotcha data – paragraph 72). In this case, the wear on the right-hand wear plate would have been continuously at the loaded position with its higher damper force. The opposite wheel would have had wear more evenly distributed across the loaded and tare positions, as the suspension on this side was still freely moving.

57 VTG sent the wear plate and damper from the leading right-hand wheel for metallurgical analysis. This reported that the materials were of the correct type for the application, and that the wear mechanism observed was typical of that for the metals involved.

58 Examination of the wear plates on the opposite faces of the axle boxes on that wheelset also showed a similar damper wear pattern, despite there not being dampers associated with them (figure 6). The step change in the wear surface, although visible, was small, measuring less than 0.2 mm. This indicated that the axleboxes fitted to that wheelset had been previously fitted in a bogie with those faces facing the damper mechanism. VTG reported that axle boxes are not permanently associated with a given wheelset, and can be changed from one wheelset to another when the wheelset is replaced, so long as the wear plates are within specification (paragraph 75).

59 In ideal circumstances the load on a bogie is shared equally between the four wheels. Uneven wheel unloading can be separated into a lateral offset[4] (left/right), a longitudinal offset[5] (front/back) and a *diagonal wheel unloading*[6]. These are independent of each other and add together to indicate the total difference in wheel load for each wheel from the bogie average. The lateral and longitudinal offsets generally represent the effects of the wagon payload. However, the diagonal wheel unloading generally indicates an irregularity in the bogie (or wagon) structure or suspension and can represent a twist in the bogie frame, a restriction in suspension movement, or some other defect.

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[4] Calculated as 0.25 x (front left weight + rear left weight - front right weight - rear right weight).

[5] Calculated as 0.25 x (front left weight + front right weight - rear left weight - rear right weight).

[6] Calculated as 0.25 x (front left weight + rear right weight - front right weight - rear left weight).

60 RAIB report 11/2015 on the April 2014 derailment at Angerstein Junction highlighted that diagonal wheel unloadings were not unusual on some freight wagons operating on Network Rail infrastructure, and that bogie frame twist is an explanation in many cases. A twist in the bogie frame means that two diagonally opposite wheels carry more load than the wheels on the other diagonal[7]. As long as the suspension is operating correctly, the magnitude of the diagonal wheel unloading is generally proportional to the amount of bogie frame twist, and depends on the stiffness of the suspension springs. Because the suspension on the Y25 bogie is stiffer when loaded (paragraph 36), any diagonal wheel unloading resulting from a given twist in the bogie frame will be greater when the wagon is loaded than when it is tare (although the derailment risk will probably be lower than when tare, due to the higher average wheel load).

61 The RAIB compared mean Gotcha wheel weight data for wagon BHQ 17121 when tare on 1 June 2015 with similar data when loaded on 2-3 June 2015. This showed a diagonal wheel unloading within the bogie that derailed of 1.23 tonnes when tare, compared to 0.76 tonnes when loaded. This was the opposite characteristic to that expected for a bogie frame twist alone. This suggested that the bogie had a defect that was restricting movement of the suspension.

62 The RAIB obtained the journey history of wagon BHQ 17121 and either Wheelchex or Gotcha data for some of these journeys from Network Rail. The likely diagonal wheel unloadings recorded for the leading bogie on wagon BHQ 17121 on selected dates, when both empty and loaded, are recorded in table 3. From 1 October 2014 until the time of derailment, the sample data analysed shows the diagonal wheel unloading when tare to be higher than the equivalent value when loaded, indicating that the suspension was probably locked for this period. Data for 4-5 June 2014 shows the tare diagonal wheel unloading to be lower than on the later dates reviewed, and also lower than the equivalent loaded value, as is normal (paragraph 60). This indicates that the suspension was not locked at that time. This means that it is likely that the suspension became locked between 5 June 2014 and 1 October 2014, and probably remained locked until the date of the derailment (it is possible that the suspension locked intermittently before becoming continuously locked).

Date	**Diagonal Wheel Unloading (tonnes)**		
	Tare	**Loaded**	**Tare: Loaded relationship (paragraph 60)**
4-5 June 2014	0.33	0.66	Loaded > Tare
1 October 2014	0.88	0.59	Tare > Loaded – suspension probably locked
12-14 January 2015	1.29	0.60	Tare > Loaded – suspension probably locked
1-3 June 2015	1.23	0.76	Tare > Loaded – suspension probably locked
Note: Rail industry data on train formations for 12-14 January 2015, 1 October 2014 and 4-5 June 2014 was incomplete, so the position of wagon BHQ 17121 has been inferred from certainty of its presence in the train, measured diagonal unloadings at several Gotcha sites and available formation data.			

Table 3: Historic diagonal wheel unloadings for lead bogie on wagon BHQ 17121

[7] The effect of bogie twist without a locked suspension is discussed at paragraphs 63 to 66.

63 **Wagon BHQ 17121 had a bogie frame twist acting to unload the leading right-hand wheel.**

64 The effect of a twist in the frame of a wagon bogie is described in RAIB report 11/2015 (paragraph 102). In summary, bogie frame twist introduces an uneven diagonal distribution of the wheel loads within the bogie which will reduce the load on a diagonal pair of wheels and increase the load on the other two.

65 After testing of the wagon, the lead bogie was removed and a bogie frame twist of 16 mm was measured, with this oriented so as to unload the leading right-hand wheel. This twist was slightly larger than that which was identified in the same type of bogie on the wagon that derailed at the same location on 2 April 2014. RAIB report 11/2015 indicates that bogie frame twists of this magnitude, although not common, appear to exist in some wagons currently operating on Network Rail's infrastructure.

66 The RAIB used the observed effect of the 13 mm bogie frame twist seen in the wagon that derailed on 2 April 2014 to estimate that the 16 mm bogie frame twist on wagon BHQ 17121 would have given rise to a wheel unloading of approximately 0.4 tonnes, if the suspension had been operating freely. Because the suspension was not operating freely (paragraph 51), it has not been possible to separate the contribution of the bogie frame twist towards wheel unloading, from that resulting from the locked suspension. However, the effect of the bogie frame twist alone would have been relatively small compared to the 1.6 tonnes of unloading due to the combined effect of bogie frame twist and the locked suspension.

Wagon maintenance

67 **Maintenance of wagon BHQ 17121 neither identified the presence of, nor prevented the development of, a bogie frame twist and a suspension defect causing uneven wheel loading.**

68 This wagon had been routinely maintained in accordance with the specification defined in VTG document VTG MAINT-0011 'Maintenance & Overhaul Specification – Bogie Hopper Wagon'. The maintenance regime includes a 4-monthly Planned Preventative Maintenance (PPM), an annual Visual Inspection & Brake Test (VIBT), together with maintenance actions required as a result of these. There is also a weekly In Service Inspection (ISI), as described in VTG document VTG-TI/PPM/VIBT/001 'Master Maintenance Specification - Section 1 - In Service Inspection'. Records show that the last ISIs before the derailment took place on 31 and 26 May 2015, with the last PPM inspection on 14 April 2015, and the last VIBT on 28 July 2014. Intermediate ISIs and PPMs were in line with the weekly and 4-monthly requirements.

69 Both PPM and VIBT involve a wagon inspection in accordance with checklists in document VTG MAINT-0011 'Maintenance & Overhaul Specification – Bogie Hopper Wagon', with the VIBT including a more detailed test of the braking system. VTG reported that the 119 point checklist for the PPM would normally take approximately 1.5 hrs to complete for a single wagon, with the 137 point checklist for the VIBT taking approximately 3 hours. The ISI also involves a brief wagon inspection in line with a much less detailed 22 point checklist. VTG reported that the ISI would normally take 7 minutes to complete for a single wagon.

70 The maintenance records show that the wheelsets on the leading bogie of wagon BHQ 17121 were replaced on 29 May 2014, following an inspection on 23 April 2014. However, the wheelsets and axleboxes were transferred directly from another wagon without having being overhauled, meaning that it is possible that the wear plates had some wear at that time. Such wear would not have been identified by the thickness check required in the maintenance specification (paragraph 75). One of the wheelsets on the trailing bogie was replaced later, on 23 April 2015, as a result of the PPM inspection on 14 April 2015.

71 Table 4 shows how the maintenance and inspection timeline relates to the likely presence of the locked suspension on the leading wheelset of wagon BHQ 17121.

Date	**Activity**	**Suspension locked? (from table 3)**
29 May 2014	Leading wheelset replaced	No
4-5 June 2014	Wheel weights recorded in service, passing Wheelchex/Gotcha sites	No
28 July 2014	VIBT inspection	Uncertain (see paragraph 72)
1 October 2014	Wheel weights recorded in service, passing Wheelchex/Gotcha sites	Probably Yes
14 November 2014	PPM inspection	
12-14 January 2015	Wheel weights recorded in service, passing Wheelchex/Gotcha sites	Probably Yes
14 April 2015	PPM inspection	
1-3 June 2015	Wheel weights recorded in service, passing Wheelchex/Gotcha sites	Yes

Table 4: Maintenance timeline (omits weekly in-service inspections)

72 Table 4 shows that it is unlikely that the suspension was locked immediately after the leading wheelset was fitted in May 2014. However, by the start of October 2014, the Gotcha/Wheelchex data indicates that it is likely that the suspension had become locked (paragraph 59). This means that it is likely that the suspension was locked when it underwent PPM inspections in November 2014 and in April 2015. It is also possible that it could have been locked at the time of the VIBT inspection in July 2014, but the RAIB has been unable to confirm this due to limitations in the available Gotcha/Wheelchex data.

73 None of the ISI or PPM inspections between October 2014 and the derailment on 3 June 2015 identified that the suspension was locked. The specifications for the PPM and VIBT both require a visual check for damage or displacement of the bogie frame and springs as part of the extensive checklists (paragraph 69). The VIBT also requires a visual examination of all suspension components. The ISI focuses on a visual check for obvious damage and structural integrity.

74 Figure 14 shows the right-hand side of the leading bogie, with the wheel with the locked suspension on the right. Visually it is not obvious that the springs in the leading wheel are locked in the compressed position, as they do not appear to be significantly different in position from those on the trailing wheel. This demonstrates that it is probable that the locked suspension would not be identified by the visual inspections included in PPM and VIBT. The locking could be identified by measurement of, or observing the position of, appropriate components in the suspension, but this was not a specified part of PPM or VIBT.

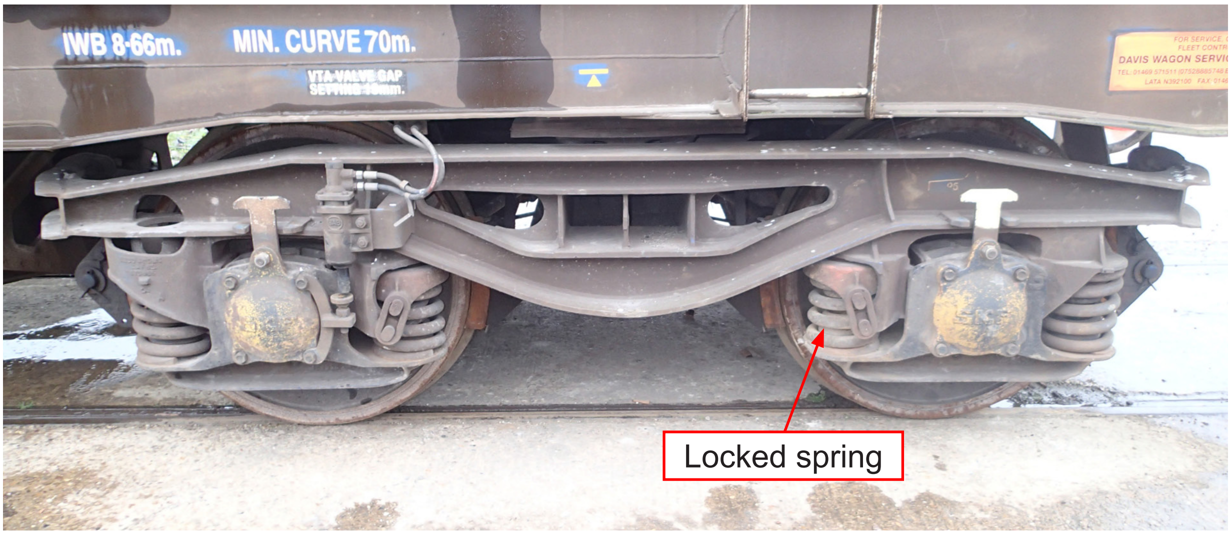


Figure 14: Wagon BHQ 17121 leading bogie – wheel with locked suspension on the right

75 The PPM and VIBT checklists also include a requirement to check the axlebox longitudinal wear plates for condition. This wear plate is the part that was found to be worn (paragraph 53). The maintenance specification states that this should include a check for cracks, and that the thickness should nominally be 5 mm, and no less than 4 mm. The specification only states the minimum allowed pad thickness and there is no specified criterion for surface flatness.

76 During PPM and VIBT, this check is undertaken with the suspension fully assembled, and so it is not possible to see all of the surface of the wear plates, particularly the part being hidden by the damper. Figure 15 shows that only the top edge of the wear plate is visible when viewed from above, while the view from below is even more restricted. This makes it impossible to check for wear over the part of the wear plate that is being contacted by the damper, and hence the part that is being worn. Inspection of this area would require the suspension to be dismantled, which is not specified as part of the PPM/VIBT. The difficulty in seeing most parts of the wear plate surface means that the plate thickness can only be measured at the top edge, where the wear is not present, unless the suspension is dismantled.

Figure 15: Visibility of the wear plate with the suspension fully assembled

77 The maintenance specifications for VIBT and PPM require the bogie frame to be visually checked for mechanical damage, such as fractures and visible defects. This does not include a measurement of bogie frame twist, which can only be practically achieved with the bogie disassembled. RAIB report 11/2015, describing the previous derailment at Angerstein Junction in April 2014, identified that wagon owners only normally measure bogie frame twist after an incident such as a collision or derailment, and not as part of routine maintenance. The RAIB observes that, although bogie frame twist is difficult to measure, diagonal wheel unloading derived from Gotcha wheel weight data can provide an indicator of possible bogie defects, such as the presence of significant frame twist.

Infrastructure configuration

78 **The infrastructure configuration at the point of derailment presented a derailment risk to wagons that had abnormal wheel load distributions.**

79 During the derailment, a number of features of the track configuration at the derailment location, together with effects due to the train's braking, affected the risk of derailment due to flange climb (paragraph 34). There is no evidence to suggest that these were abnormal, but their combined effect is illustrated in figure 16. This shows one of the right-hand (outer) wheels on the third wagon from the rear of the train, after it had stopped at the derailment location, while attempting to flange climb. Other similar wagons in this train, and in other trains, would routinely have been affected by these features and had passed over the incident location without derailment. The main features of the track, and of the train operating characteristics, affecting the derailment are briefly discussed below.

Figure 16: Wheel with working suspension starting to flange climb at the point of derailment

Features affecting lateral forces

80 Lateral forces were necessary to allow the front right-hand wheel of wagon BHQ 17121 to climb over the rail. The main causes of these lateral forces are discussed in the following paragraphs.

81 The track at the point of derailment was on a tight curve of approximately 130 metres radius, introducing lateral forces on the wheels towards the outer rail. This was within the 70 metres minimum negotiable curve radius of the wagon. This was a normal operational condition.

82 There was no *check rail* fitted at the point of derailment at trap points 851A. *Railway Group Standard* GC/RT5021 (Track System Requirements)[8] did not require a check rail at this location because the inside rail was located in the movable section of the trap points. Installation of a movable check rail would be technically complex and, although isolated examples have been used on other rail networks, Network Rail has never used this solution on its infrastructure. As a result, this was considered to be a normal operational condition. A continuous check rail was provided on the rest of the curve, both before and after the trap points, and would have been provided at the point of derailment if it had been on a section of plain line. Provision of a check rail would very probably have prevented the derailment, as it would have resisted the lateral forces on the wheels.

83 The train was braking gently on a left-hand curve with the front 19 wagons on a downhill gradient (figure 17), at the time of derailment, and this could have affected the lateral forces between the wheels and the outer rail. This was a normal operational condition for any train that was required to stop at signal L429.

84 This scenario, where the signal positions and aspects meant that the train was required to brake with part of it on tightly curved downhill track, a portion of which had no check rail, was also present in the previous derailment that occurred at the same location on 2 April 2014 (paragraph 102).

[8] Section 3.2.11.1 states – 'All passenger lines, and freight only lines adjacent to passenger lines, with a horizontal radius of 200 metres or less shall be fitted with a continuous check rail to the inside rail of the curve, except where the design of S&C prevents this from being provided.'

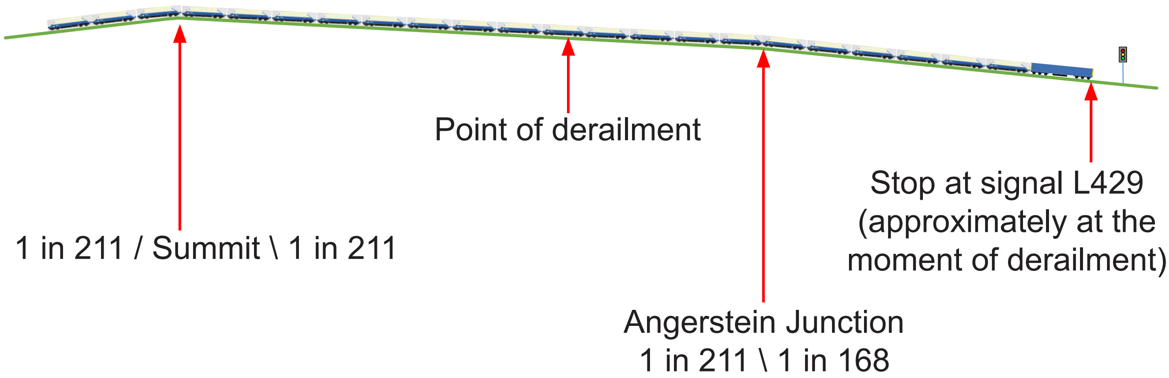


Figure 17: Gradient profile relative to the train position at derailment

Features affecting vertical load

85 The load on the front right-hand wheel of wagon BHQ 17121 was lower than designed when on level track (paragraph 46), due to the locked suspension and bogie twist, thus increasing its derailment risk. At the point of derailment a track twist (paragraph 31) further unloaded this wheel, increasing the derailment risk further.

86 Network Rail undertook a track survey after the derailment, with the rear of the train stationary over the trap points, thus ensuring that the survey recorded the dynamic twist (paragraph 33) encountered by the wagon. Figure 18 shows the dynamic track twist measured by Network Rail and that present during the previous derailment at almost the same location on 2 April 2014 (the point of derailment during the 2015 derailment was approximately 1.25 metres before that for the 2014 derailment).

87 Part of this track twist was designed in to the track layout, as the canted track on the curve transitioned towards the uncanted track at Angerstein Junction. Over the 25 metres centred around the point of derailment, the average *cant gradient* was 1 in 500, which was within the maximum design limit of 1 in 400 (7.5 mm change in cant every 3 metres) that is allowed by Railway Group Standard GC/RT5021 ‘Track System Requirements’ for new track.

88 Network Rail standard NR/L2/TRK/001 ‘Inspection and maintenance of permanent way’ places limits on the amount of track twist that is allowed to be present on the network, and defines timescales within which track twists that exceed those limits should be corrected. The three metre dynamic track twist limits, and the actions required, for track with the curvature and speed limit present at the derailment location are annotated on figure 18.

89 The 3 metre dynamic twist at the point of derailment was well within these limits, measuring 6 mm, or an average gradient of 1 in 500. This was much less than the 22 mm that was present at the point of derailment on 2 April 2014.

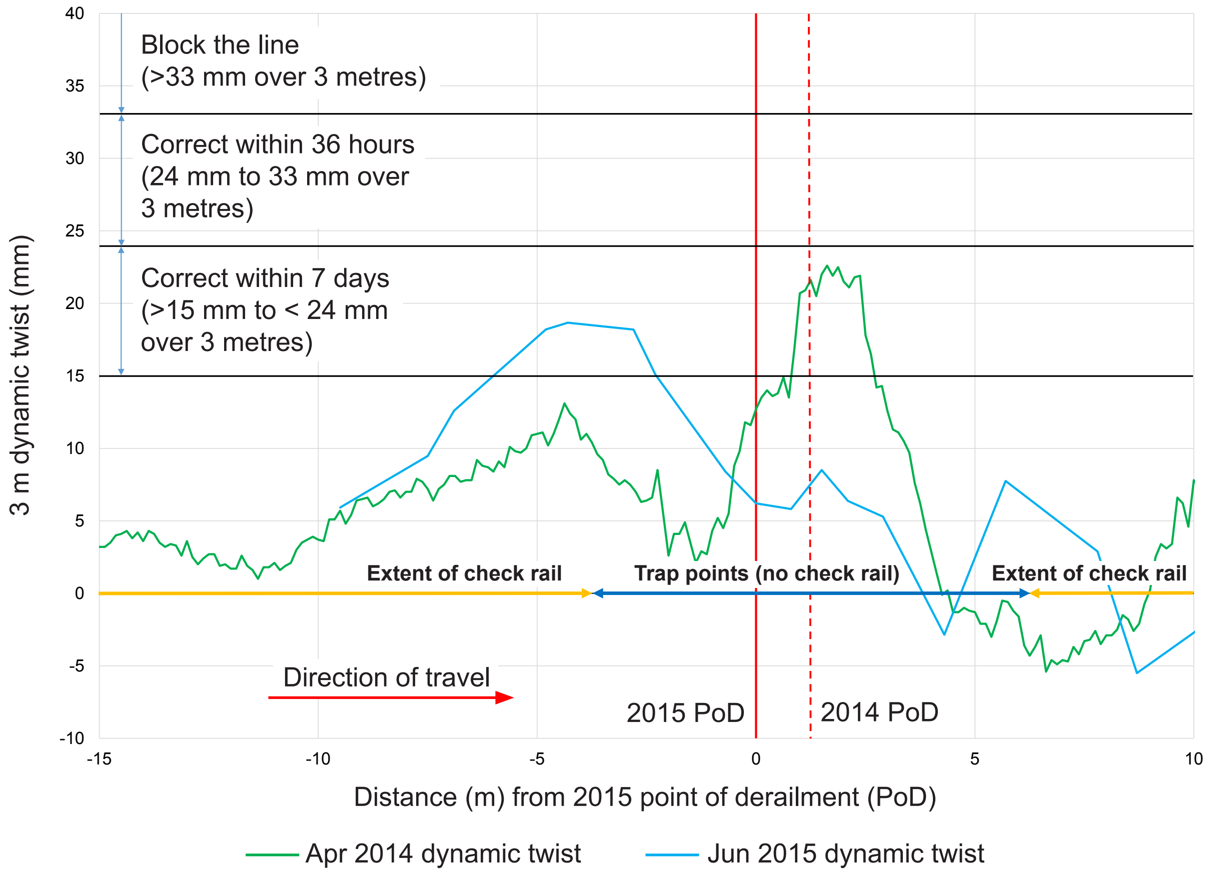


Figure 18: Track twist in the vicinity of the derailment location

90 However, the June 2015 survey found twist reaching a maximum of 18 mm on the approach to the point of derailment. This exceeded the first maintenance action limit of 15 mm for a distance of approximately 4 metres until 2.5 metres before the point of derailment. The first 3 metres of track that exceeded the first maintenance intervention limit was within the section of line that had a check rail, and so had additional derailment risk mitigation when compared to the last metre. There were no marks on the rail head to indicate that the derailed wheel had climbed onto the rail head in the 4 metre length that exceeded the first maintenance intervention limit.

91 The track survey data was used to determine the track cant at each of the wheelsets of wagon BHQ 17121, when its leading wheelset was at the point of derailment. This is summarised in table 5. These measured values were used during testing to evaluate the wheel unloading that would have resulted at the time of derailment.

Wheelset	**1st (Leading)**	**2nd**	**3rd**	**4th**
Dynamic cant (positive is right rail high)	14 mm	17 mm	56 mm	59 mm
Relative cant (Leading wheelset level)	0 mm	3 mm	43 mm	46 mm

Table 5: Track cant at wagon BHQ 17121 wheelsets, when at the derailment location

92 The RAIB applied these cant values to the wagon suspension model that was used in the investigation of the derailment at the same location on 2 April 2014, adapting some of the parameters to suit the JGA wagon involved in the June 2015 derailment. This calculated that a fully empty JGA wagon with freely operating suspension would experience a wheel unloading of approximately 0.65 tonnes as a result of the track twist measured at the point of derailment. This wheel unloading would have posed a much lower risk of the wagon derailing than the 1.7 tonnes of unloading measured with the suspension locked (paragraph 48).

Factors that were unlikely to be causal to the accident

Other possible contributors to the derailment

93 The RAIB has also considered the possible presence and significance of several other factors which can affect derailment risk. Although these factors cannot be entirely discounted, the RAIB has found no evidence to suggest that they were significant to the causation of the accident.

94 There was no visible evidence of overly high rail/wheel friction, such as the presence of metallic particles that had been worn from the rail, at the point of derailment. The curve was fitted with several lubricators intended to provide lubricating grease on the wheel-rail interface of both the outer and check rails[9], and grease was seen to be distributed on the outer rail through the length of the trap points. Network Rail's maintenance documentation indicated that the lubricators had undergone a two-monthly inspection, which showed that they contained sufficient grease and were operational, about 6 weeks before the derailment, with no outstanding faults recorded.

95 The RAIB measured the wheel flange height and thickness on all the wheels of wagon BHQ 17121 and found these to be compliant with the requirements of Railway Group Standard GM/RT2466 (Railway Wheelsets). Network Rail measured the right-hand rail profile at the derailment location immediately after the derailment and this showed that the rail was not excessively worn. There was no evidence to indicate that the contact angle between the front right wheel of wagon BHQ 17121 and the right-hand rail at the point of derailment would have adversely affected the derailment risk.

96 The *cant excess* when the leading wheel was at the point of derailment, with the train travelling at 5 mph (8 km/h) was calculated to be 8 mm. This was very small compared to the limit of 110 mm permitted in Network Rail standard NR/L2/TRK/2049 (Track Design Handbook). The RAIB considered this to be a normal operational condition.

97 The evidence from the buffer marks (paragraph 41) indicates that the buffers between the 10th and 11th wagons did not lock together until after the first wheelset had derailed.

98 There was no evidence of any abnormal *buffing forces* between the wagons at the buffers. The buffer faces were well lubricated and there were no marks on the central area to indicate any high contact forces.

[9] Network Rail states that the primary purpose of rail lubrication is infrastructure asset protection (ie reduction of wear at the rail/wheel interface) and not mitigation of derailment risk (See RAIB report 07/2014 – March 2014: Locomotive derailment at Ordsall Lane Junction, Salford, on 23 January 2013)

99 Examination of the bogie rotation friction components on Wagon BHQ 17121 showed that these were still within the wear specification, although the *pivot liner* on the leading bogie was slightly displaced. The RAIB was unable to determine if this was a consequence of the derailment, or if it had been present before this. If present before the derailment, this could have affected the rotational resistance of the bogie, thus affecting the lateral forces at the wheel-rail interface. However, the RAIB considered the effect of this on the derailment to be relatively insignificant when compared to the simultaneous, large wheel unloadings resulting from the locked up suspension (paragraph 46) and from the track twist (paragraph 48).

Previous occurrences of a similar character

Derailment at Ely Dock junction on 22 June 2007, RAIB report 02/2009

100 At 02:00 hrs on 22 June 2007, thirteen four-wheeled PHA wagons derailed near Ely Dock Junction, causing considerable damage to an underbridge. The derailment was a result of the suspension in one wheel of one of the PHA wagons locking up, thus reducing its vertical load. A relevant recommendation from the RAIB investigation is reproduced in paragraph 108.

Derailment at Bordesley Junction on 26 August 2011, RAIB report 19/2012

101 At about 00:44 hrs on 26 August 2011, four four-wheeled PHA wagons derailed just before Bordesley Junction, in Birmingham, before rerailing at a crossover. The derailment was probably a result of the suspension in one wheel of one of the PHA wagons locking up, thus reducing its vertical load, combined with a track twist.

Freight train derailment at Angerstein Junction on 2 April 2014, RAIB report 11/2015

102 At about 12:15 hrs on Wednesday 2 April 2014, two wagons of a nominally empty freight train derailed on the approach to Angerstein Junction, at approximately the same location as the June 2015 derailment. The April 2014 derailment was caused by a combination of an uneven retained load in a nominally empty JRA bogie hopper wagon, combined with a twist in one of its bogie frames and a twist in the track. A common feature in both derailments was that the train was braking to a red signal when the derailments occurred. Two relevant recommendations from the RAIB investigation are reproduced from paragraph 111 onwards.

Derailment at Angerstein Junction in January/February 2015, No associated RAIB report

103 On 4 February 2015, Network Rail staff identified some track damage on the approach to Angerstein Junction, at the same general location as both the April 2014 and June 2015 derailments. The February 2015 damage indicated that at least one wheelset of a railway vehicle had derailed since the previous track patrol on 27 January 2015. Marks on the track also showed that the wheelset had rerailed itself as it passed Angerstein Junction. Network Rail was unable to identify the train that had derailed. The derailment occurred after trap points 851A had been relaid in January 2015. No dynamic track survey data was recorded immediately after the derailment, but a static survey undertaken immediately after the damage was identified showed a static 3 metre track twist of 25 mm, which exceeded the 18 mm static twist recorded after the April 2014 derailment. The track twist was subsequently repaired. The RAIB did not investigate this derailment.

Summary of conclusions

Immediate cause

104 There was insufficient load on the front right-hand wheel of the leading bogie on wagon BHQ17121 to counteract the lateral forces at the wheel-rail interface, and thus to prevent the flange climbing over the rail head in the vicinity of trap points 851A (**paragraph 38**).

Causal factors

105 The causal factors were:

a. Wagon BHQ 17121 had a significant unloading of the leading right-hand wheel (**paragraph 44, Recommendation 1**). This causal factor arose due to a combination of the following:

   i. The suspension on the front right-hand wheel of wagon BHQ 17121 was locked in the loaded position (**paragraph 50, Recommendation 1**); and

   ii. Wagon BHQ 17121 had a bogie frame twist acting to unload the leading right-hand wheel (**paragraph 63, Recommendation 1**).

b. Maintenance of wagon BHQ 17121 neither identified the presence of, nor prevented the development of, a bogie frame twist and a suspension defect causing uneven wheel loading (**paragraph 67, Learning point 1, Recommendations 1 and 2**); and

c. The infrastructure configuration at the point of derailment presented a derailment risk to wagons that had abnormal wheel load distributions (**paragraph 78, Recommendation 3**).

Previous RAIB recommendations relevant to this investigation

106 The following recommendations, which were made by the RAIB as a result of its previous investigations, have relevance to this investigation.

Derailment at Ely Dock junction on 22 June 2007, RAIB report 02/2009, Recommendation 2

107 The RAIB considers that adoption of measures similar to that identified in recommendation 2 in RAIB report 02/2009, which was targeted at a different wagon owner, could have allowed identification of the locking of the wagon suspension which was a factor in this accident (paragraph 67).

108 This recommendation reads as follows:

Recommendation 2

Lafarge should as a short term measure, evaluate the use of, and if practical fit, visual markers on PHA wagon suspension, to enable train preparation staff to identify if a frictional lock-up has occurred, after discharge and before the train movement from the depot.

109 The Office of Rail and Road (ORR) has reported that such markers were trialled, but found to be impracticable for use on PHA wagons, and so the recommendation was recorded as 'implemented'.

110 The suspension on the Y25 type bogies fitted to the JGA hopper wagons differs from that on the four wheel PHA wagons. The RAIB considers that such markers could have had the potential to allow early identification and correction of frictional lock ups in the suspension on Y25 bogies.

Freight train derailment at Angerstein Junction on 2 April 2014, RAIB report 11/2015, Recommendations 2 and 5

111 The following recommendations made recently, and being considered by the rail industry, address factors identified in this investigation. So as to avoid duplication, they are not remade in this report, but their wording and an account of their current status is given below.

112 Control of derailment risk (paragraph 85) is addressed by:

Recommendation 2

RSSB, in conjunction with freight wagon operators, freight operating companies and entities in charge of maintenance for freight wagons, should review the extent to which diagonal wheel unloadings are present within freight wagon bogies that are operating on Network Rail infrastructure, and the contribution that this makes to derailment risk. This review should consider:

- *identifying the magnitude and prevalence of diagonal wheel unloadings caused by bogie frame twist (and other possible causes);*
- *proposing criteria for acceptable levels of diagonal wheel unloading, or for bogie frame twist; and*
- *proposing proportionate measures for identifying, and then managing, unacceptable diagonal wheel unloadings.*

113 The ORR has not yet reported to the RAIB how this recommendation is being addressed. However, the RAIB is aware that the rail industry is considering how it can be implemented.

114 Potential use of wheel impact load detection equipment (eg Gotcha) to detect wagon defects (paragraph 72) is addressed by:

Recommendation 5

Network Rail should review the potential to use wheel impact load detection system data to provide information about possible defects, such as uneven wheel loading or uneven load distribution, relating to specific wagons. The review should include consideration of how this information could be used to improve control of overall derailment risk (such as identifying the need for entities in charge of maintenance to check the condition of suspect wagons and take appropriate remedial action). Network Rail should seek inputs from relevant entities in charge of maintenance as part of the review. If justified by the review, Network Rail should implement track side and reporting processes needed for collecting and disseminating this information.

115 The ORR has not yet reported to the RAIB how this recommendation is being addressed. However, the RAIB is aware that the rail industry is considering how it can be implemented.

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

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

116 After the derailment, Network Rail introduced an operational restriction to prevent unladen trains departing from Angerstein Wharf sidings onto the North Kent lines unless the second signal (L429) was showing a *proceed aspect* (indicated by a *green aspect* at signal L425 - figure 3). The intention of this restriction is to reduce the probability of departing trains having to brake while the rear wagons are still on the unchecked curve through the trap points 851A (paragraph 83).

117 Network Rail carried out its own investigation into the derailment, and this recommended that the efficacy of the layout of track and signalling through the derailment location should be reviewed in the light of this derailment and those of January/February 2015 (paragraph 103) and 2 April 2014 (paragraph 102).

Other reported actions

118 After the wagon had been tested by the RAIB, VTG replaced all the wheelsets and both bogies on the wagon, in preparation for further inspection before returning it to service.

119 VTG is considering introduction of a spring length comparison check into the maintenance regime, so that locked suspension can be identified. This would achieve the aim of Recommendation 2 of the RAIB report on the derailment at Ely Dock Junction (paragraph 108).

120 VTG has surveyed 46 wear plates on Y25 wheelsets that were awaiting overhaul, to understand the extent and magnitude of wear patterns similar to that found on wagon BHQ 17121 (paragraph 53). This data is being used to develop an Engineering Instruction (VTG-EI-043 'Y25 axlebox wear plate condition checks') for checking the wear plate condition every time that the wheels are removed. This instruction describes the risk arising from worn wear plates and provides inspection pass/fail criteria for wear plate surface flatness.

121 VTG is developing a new Engineering Instruction (VTG-EI-045 'Y25 wear plate and damper pad checks') to check for signs of locked suspension. This instruction describes the risk arising from worn wear plates and outlines possible indicators of a suspension that is possibly locked, and the required actions. This instruction will be incorporated into the maintenance plan for wagons with Y25 bogies, and is to be carried out at ISI, PPM and VIBT inspections.

122 VTG has reviewed the Gotcha data obtained by the RAIB for this investigation and the investigation into the April 2014 derailment at the same location. This review identified six wagons as having a bogie frame that was suspected to be twisted and VTG reports that it has replaced these bogies.

Learning point

123 The RAIB has identified the following key learning point[10] which is linked to Recommendation 5 of RAIB report 11/2015 (paragraph 114):

1 Network Rail, and the wider rail industry, should note that, in addition to its current primary use for identifying impact loadings (eg those associated with wheel flats), Gotcha wheel weight data for freight wagons can be analysed to identify the following:

- Wagons with excessively light, or uneven wheel loadings that could present an increased derailment risk requiring immediate action;
- The presence of uneven loads within wagons, leading to lateral or longitudinal wheel load offsets; and
- The presence of wagon or bogie defects, such as frame twist or suspension locking, which may not require immediate action but could trigger maintenance activities (paragraph 105b).

[10] '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.

Recommendations

122 The following recommendations are made[11]:

1 *The intent of this recommendation is to manage the derailment risk arising from locked up wagon suspensions by ensuring that wagon maintenance regimes facilitate the prevention of defects. This recommendation seeks completion of work that VTG has already initiated in response to the derailment. It may also be applicable to other entities in charge of maintenance for freight wagons, as the circumstances leading to suspension lock up of the type identified in this derailment may not be limited to VTG.*

VTG Rail UK should review and improve the inspection and maintenance regimes for its wagons with Y25 type bogies to ensure that these adequately manage the risk arising from suspension locking up. This review should include, but not be limited to:

- understanding which friction surfaces in the suspension systems of its wagons with Y25 type bogies can be subject to excessive or uneven wear that could lead to suspension locking up;
- understanding the prevalence of such wear to these friction surfaces;
- amending inspection processes to allow identification of uneven wear patterns on friction surfaces;
- consideration of methods, such as measurements or physical markers, to allow identification of suspension lock up problems; and
- consideration of the use of wheel weight data sources, such as Gotcha, to identify wagon defects that can increase derailment risk (paragraphs 105a and 105b).

This recommendation may also be applicable to other entities in charge of maintenance for freight wagons.

continued

[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.

2 *The intent of this recommendation is to develop industry understanding of the potential wear mechanisms that can lead to suspension lock up, so that wagon maintenance regimes adequately manage the associated risks.*

VTG Rail UK should liaise with other entities in charge of maintenance for freight wagons to review and, if appropriate, amend its inspection and maintenance regimes for wagons with Y25 type bogies to ensure that friction surface inspection and/or replacement frequencies are compatible with foreseeable wear rates. This review should include, but not be restricted to:

- understanding the mechanisms that lead to friction surface wear in Y25 bogie suspension;
- understanding the wear rates that are experienced in service; and
- understanding the limits of wear that can lead to suspension locking (paragraph 105b).

This recommendation may also be applicable to other entities in charge of maintenance for freight wagons.

3 *The intent of this recommendation is to ensure that the derailment risk at Angerstein Junction is adequately controlled.*

Network Rail should review and, if appropriate, alter the infrastructure configuration on the line between Angerstein Junction and Angerstein Wharf sidings to reduce its contribution to the derailment risk in the immediate vicinity of the 851A trap points. This review should include, but not be limited to, consideration of:

- the wagon types and loads normally using the line;
- the layout of the check rail;
- the speed and braking profiles of trains using the line;
- the locations and operation of signalling equipment; and
- the location of the trap points, or the provision of alternative risk mitigation measures (paragraph 105c).

Appendices

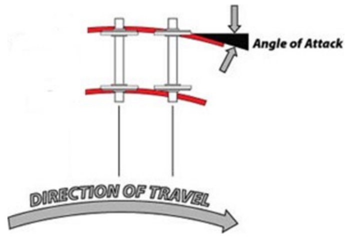
Appendix A - Glossary of abbreviations and acroyms

DC	Direct Current
ECM	Entity in Charge of Maintenance
ISI	In-Service Inspection
JGA	A type of hopper wagon
JRA	A type of hopper wagon
ORR	Office of Rail and Road
OTDR	On-Train Data Recorder
PPM	Planned Preventative Maintenance
RAIB	Rail Accident Investigation Branch
TOPS	Total Operations Processing System
VIBT	Vehicle Inspection and Brake Test
WILD	Wheel Impact Load Detector

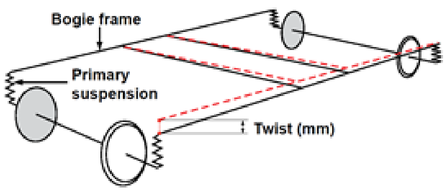
Appendix B - Glossary of terms

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

Aggregate	Pieces of broken or crushed stone or gravel.
Angle of attack	The angle between the running edge of the rail and the plane of the wheel flange.*



Bogie	An assembly of two wheelsets in a frame which is pivoted at the end of a long vehicle to enable the vehicle to go round curves.
Bogie frame twist	Distortion of the structural frame on a bogie that results in the one of the primary suspension connection points being out of plane with the others.



	Measured at the top of the suspension springs and sometimes corrected by inserting packing pieces above these springs.
Brake pipe	A pipe running the length of a train that controls, and sometimes supplies, the train's air brakes. A reduction in brake pipe air pressure, as happens when the pipe is separated or ruptured, applies the brakes.
Buffers	Impact absorbing devices fitted to rail vehicles to accommodate changes in alignment between adjacent vehicles and to prevent them from colliding heavily during braking.*
Buffing forces	The dynamic loads imposed on rail vehicles through buffer contact with adjacent vehicles.*
Cant	The amount by which one rail is raised higher than the other rail on the same track.
Cant excess	The amount that the track cant needs to decrease in order to balance the centrifugal force acting on a rail vehicle when running at speed on a curve.
Cant gradient	The rate at which cant changes in a specific length. This is equivalent to twist, but can refer to an intentional feature of the track design.
Chain	An imperial unit of length measurement that is equivalent to 22 yards (approximately 20 metres).
Check rail	A rail or other special section provided alongside a running rail to give guidance to flanged wheels by restricting lateral movement of the wheels.*

Contact angle	The angle between the tangential plane at which the wheel makes contact with the rail and that of the track.
Diagonal wheel unloading	The unloading on the wheels of a bogie due to distortion or other conditions affecting the frame or suspension, manifesting itself as an uneven sharing of the load between the wheels on the leading and trailing wheelsets.
Down line	A track on which the normal passage of trains is in the down direction, ie away from London, the capital, the original railway company's headquarters or towards the highest mileage.*
Dynamic twist	The change of cant along a track measured over a specific distance, while the track is under load from a train. This differs from static twist, which is the measure when the track is not loaded.
Entity in charge of maintenance	A person or organisation responsible for the maintenance of rail vehicles, as required by The Railways and Other Guided Transport Systems (Safety) Regulations 2006 (as amended).
Flange climb	A situation where the flange of a rail wheel rides up the inside (gauge) face of the rail head while rotating. If the wheel flange reaches the top of the rail head, the wheelset is no longer laterally constrained and this usually leads to derailment.
Gotcha	A track-mounted monitoring system designed to measure the vertical wheel loads of passing trains and identify those with the potential to cause excessive damage to the infrastructure. This is a replacement for Wheelchex.
Green aspect	The green light on a colour light signal that indicates to the driver that the next signal is showing a proceed aspect.
Hopper wagon	A wagon which discharges its load through doors in the bottom area of the wagon.
Nested springs	A spring arrangement where two springs of different stiffness and of different diameter and length are arranged one inside the other, so that the overall stiffness increases when the applied load is sufficient to compress the longer spring to the length of the inner spring.
On-train data recorder	A data recorder fitted to a train that records information on the status of train equipment, including speed and brake applications.
Path	A route between two points built into a timetable.*
Pivot liner	A replaceable component that forms the load bearing surface between a wagon body and its bogie.
Pointwork	Sections of track with moveable rails and fixed crossings that can direct a train from one track to another.

Primary suspension	Those components of a suspension system that are connected to the axles.*
Proceed aspect	Any light, or combination of lights, on a signal, other than a red stop aspect, which indicates that the train can proceed to at least the next signal.
Railway group standard	A document which defines technical standards, for use by the UK railway industry.
Red aspect	The red light on a colour light signal that means stop.
Running rails	Rails that support and guide the flanged steel rail wheels of a rail vehicle.*
Static twist	The change of cant along a track measured over a specific distance, while the track is not under load from a train. This differs from dynamic twist, which is the measure when the track is loaded.
Third rail dc electrification	A general term used to cover the type of electrification that involves the supply of DC traction current to trains by means of a conductor rail laid along one side of the track, known as the third rail.*
TOPS (Total Operations Processing System)	A computer system used to track rail vehicles. It deals with destination, load, location and maintenance information for all vehicles on the network. Vehicle data is entered for every movement, allowing virtually real time updates.*
Track twist	The change in cant, along the track, measured over a specific distance. This is equivalent to 'cant gradient', but is normally referring to unintentional track features.
Trap points	An assembly of switches or points intended to derail rail vehicles in the event of their unauthorised movement, such as conflicting movements onto passenger lines.*
Voids	A track fault consisting of spaces or soft ground under sleepers, that results in vertical displacement of the track when trains pass over.
Wheel flange	The extended portion of a rail wheel that contacts the rail head and thus provides the wheelset with directional guidance.
Wheel unloading	A reduction in the downward force exerted by a rail wheel. This reduced force can be a factor that permits a rail wheel to derail.
Wheelchex	A historic track-mounted monitoring system designed to measure the vertical wheel loads of passing trains and identify those with the potential to cause excessive damage to the infrastructure. This has been replaced by Gotcha.
Wheelset	Two rail wheels mounted on their joining axle.

Yellow aspect	The single yellow light on a colour light signal that indicates to the driver that the next signal may be displaying a red stop aspect.

Appendix C - Investigation details

The RAIB used the following sources of evidence in this investigation:

- track surveys carried out by Network Rail after the derailment;
- track maintenance records;
- site photographs taken by Network Rail;
- data from the *on-train data recorder* (OTDR);
- wagon surveys carried out by the RAIB;
- results from wagon wheel unloading tests undertaken at Long Marston;
- wagon maintenance records;
- Wheelchex and Gotcha data;
- *TOPS* data for the trains included in the above Wheelchex data;
- wagon weight data from Aggregate Industries;
- weather data; and
- a review of previous RAIB investigations that had relevance to this accident.

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Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby UK
DE21 4BA

Telephone: 01332 253300
Fax: 01332 253301
Email: enquiries@raib.gov.uk
Website: www.gov.uk/raib