Rail Accident Investigation Branch

Rail Accident Report

Derailment of a freight train near Langworth, Lincolnshire
30 June 2015

Report 11/2016
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.

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

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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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Derailment of a freight train near Langworth, Lincolnshire, 30 June 2015

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Summary

At about 14:15 hrs on Tuesday 30 June 2015, a freight train, conveying 22 empty diesel fuel tank wagons, derailed on a track buckle near Langworth, Lincolnshire. The locomotive and the first ten wagons successfully ran over the buckle before the eleventh and the following nine wagons derailed. Four of these wagons overturned and one came to rest across the adjacent track. There were no other trains in the area at the time. No-one was injured and there was no diesel fuel spillage. However, extensive damage was caused to the train and to the infrastructure.

The investigation found that the track buckled on the hottest day of the year to date because the forces in the rails resulting from thermal expansion exceeded the ability of the ballast to restrain the track. The buckle initiated at a point where there was a pre-existing misalignment in the track; a feature which reduced its resistance to buckling. The amplitude of the buckle increased under the train because its permitted speed was too fast for the vulnerable condition of the track and the rail temperature on the day.

Underlying the accident was a lack of appreciation of the vulnerability of the track to buckling. The under-resourcing of the maintenance team, leading to the continual reprioritisation of maintenance tasks, was also a possible underlying factor.

The RAIB has made four recommendations to Network Rail. Two recommendations relate to a review of its company standards and guidance, firstly to enable improved assessments of the vulnerability of track to buckling on the basis of more accurate data about its ability to withstand thermal expansion, and secondly to ensure a more consistent interpretation of risk factors to be included in the calculation of rail temperatures at which mitigation measures, such as speed restrictions, should be applied. There are also two recommendations relating to local resourcing for track maintenance and managerial oversight of the process of reprioritising or cancelling maintenance tasks.

The report has identified two learning points. The first reinforces the importance of completing records of maintenance interventions that could affect the buckling strength of the rail and investigating any anomalous behaviour of the rail during those interventions. The second relates to checking the security of bolts on a type of switch assembly.

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 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

3 At around 14:15 hrs on Tuesday 30 June 2015, a freight train derailed on a track buckle near Langworth, north-east of Lincoln (figure 1). The train was the 10:39 hrs DB Schenker service from Kingsbury Oil Terminal to Humberside Oil Refinery and consisted of a locomotive and 22 empty, diesel fuel tank wagons.

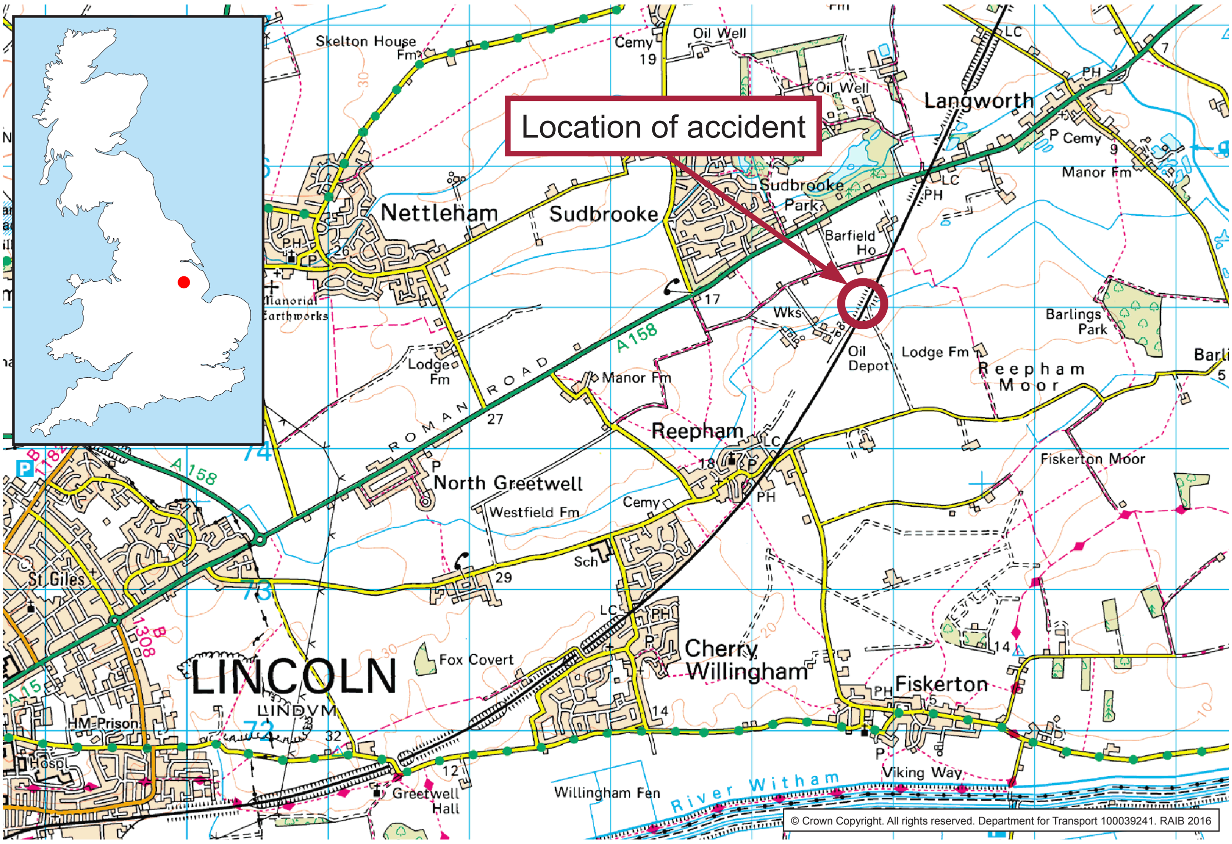


Figure 1: Extract from Ordnance Survey map showing location of accident

4 As the train was passing through a section of *switches* and *crossings* at approximately 46 mph (74 km/h), the driver reported encountering a 'bulge' (track buckle) in the track. The locomotive and the first ten wagons successfully passed over the buckle before the derailment commenced.

5 Wagons 11, 12 and 13 (from the leading end) derailed but remained upright. The train then separated between wagons 13 and 14, which caused the train's brakes to apply. The front part of the train came to rest about 250 metres from the rest of the train. Wagons 14 to 20 left the track with four wagons rolling over and one slewing across both tracks (figure 2). Wagons 21 and 22 did not derail.

6 Although no-one was injured, substantial damage was caused to the train and to the infrastructure over approximately 400 metres. Wagons 14 to 19 had to be recovered by crane which required the building of a temporary road. The remaining derailed wagons were rerailed and recovered by rail. There were no reports of any leakage of diesel fuel residue from the tanks.

7 The track in both directions remained closed for repairs until 9 July.

Figure 2: Overview of the accident site (image courtesy of Network Rail)

Context

Location

8 The accident occurred near the village of Langworth, on the *up main* line, immediately beyond the junction with the disused Welton Oil Terminal sidings, at 35 miles 1686 yards[1] (figure 3). The railway at this location comprises two tracks and has a maximum line speed of 75 mph (120 km/h) for passenger trains and 50 mph (80 km/h) for freight trains. The track at the point of derailment is straight and level.

Figure 3: Google earth image showing location of derailment

9 The signalling in the area is controlled from the signal box at Langworth.

Organisations involved

10 Network Rail owns the infrastructure which is maintained by its Derby Delivery Unit from the Lincoln depot.

11 DB Schenker Rail (UK) Limited (now known as DB Cargo (UK) Limited) operated and maintained the locomotive and tank wagons. It also employed the train driver.

12 VTG Rail UK owned the tank wagons.

13 Network Rail, DB Schenker and VTG freely co-operated with the investigation.

[1] Measured from a zero datum at New Holland.

Train involved

14 The train, reporting number 6E54[2], was hauled by a class 60 diesel-electric locomotive, number 60054. The locomotive had previously undergone routine heavy maintenance examinations in February and March 2015, and a lighter scheduled maintenance examination on 27 June 2015. The RAIB found no evidence that the operation and maintenance of the locomotive had any bearing on the accident.

15 The tank wagons were TEA type, bogied wagons used for conveying diesel fuel. The wagons were fitted with conventional buffers and screw couplers. The vehicle ends were fitted with an 'override beam', which is a horizontal beam above the buffers to protect the tanks from impact by the buffers of an adjacent vehicle in an accident.

16 All the wagons involved in the derailment were within date for their periodic maintenance examinations. The wheel profile measurements recorded for all the wagons at their last maintenance examinations were within specification and the wheel profiles of the first wagons to derail were confirmed to be compliant. The RAIB found no evidence that the operation and maintenance of the vehicles involved in the derailment had any bearing on the accident.

Infrastructure involved

17 The derailment occurred within an area known as the Welton switches and crossings, associated with directing traffic to and from the Welton Oil Terminal[3]. The switch and crossing assemblies make up numbered sets of *points*, and if there are two point ends in a set, they are identified as the 'A' and 'B' ends. Train movements to and from the Welton Oil Terminal were controlled by 102A points (figure 4). These points were installed on wooden bearers (*sleepers*) and operated by means of a point motor controlled from the signal box at Langworth.

18 Beyond 102A points in the up direction there was a 14 metre section of *plain line* (figure 4) to 101B points where the derailment occurred. The two sets of points are described as 'closely abutting' because of the short distance between them. Train movements from 101B points could either go straight ahead on the up main line or be directed over the crossover to 101A points on the *down main* line. Points 101A and 101B were installed on concrete bearers and also operated by point motors controlled from the signal box at Langworth.

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

[3] Rail traffic to Welton Oil Terminal ceased in about 2011.

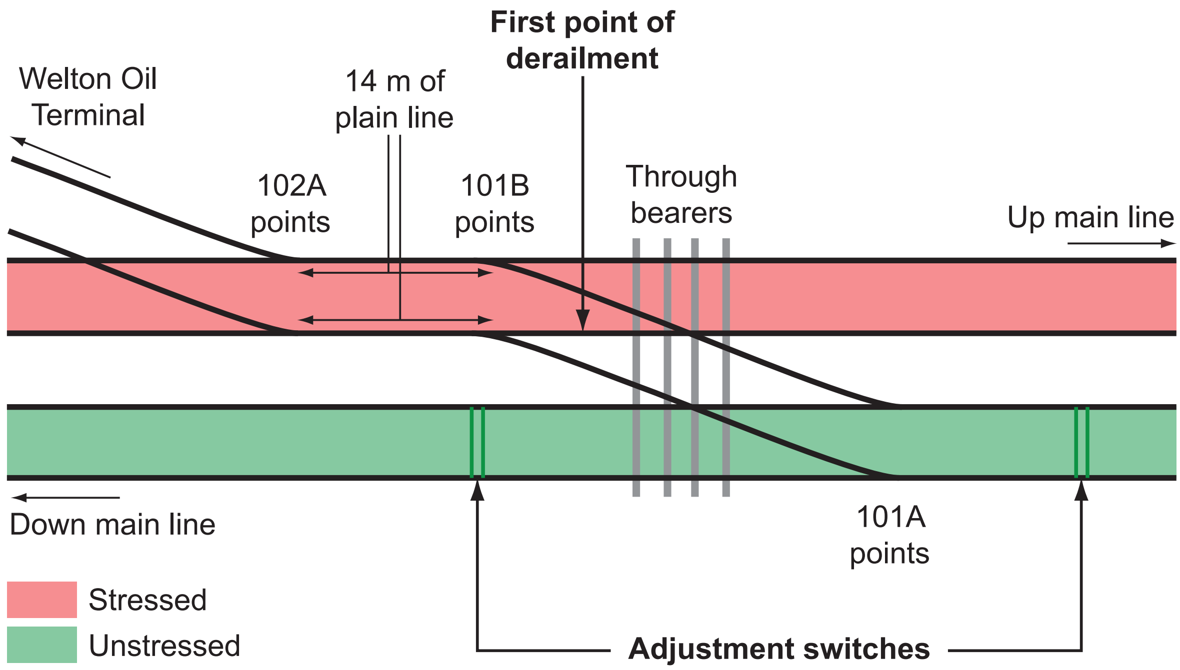


Figure 4: Layout of Welton switches and crossings (not to scale)

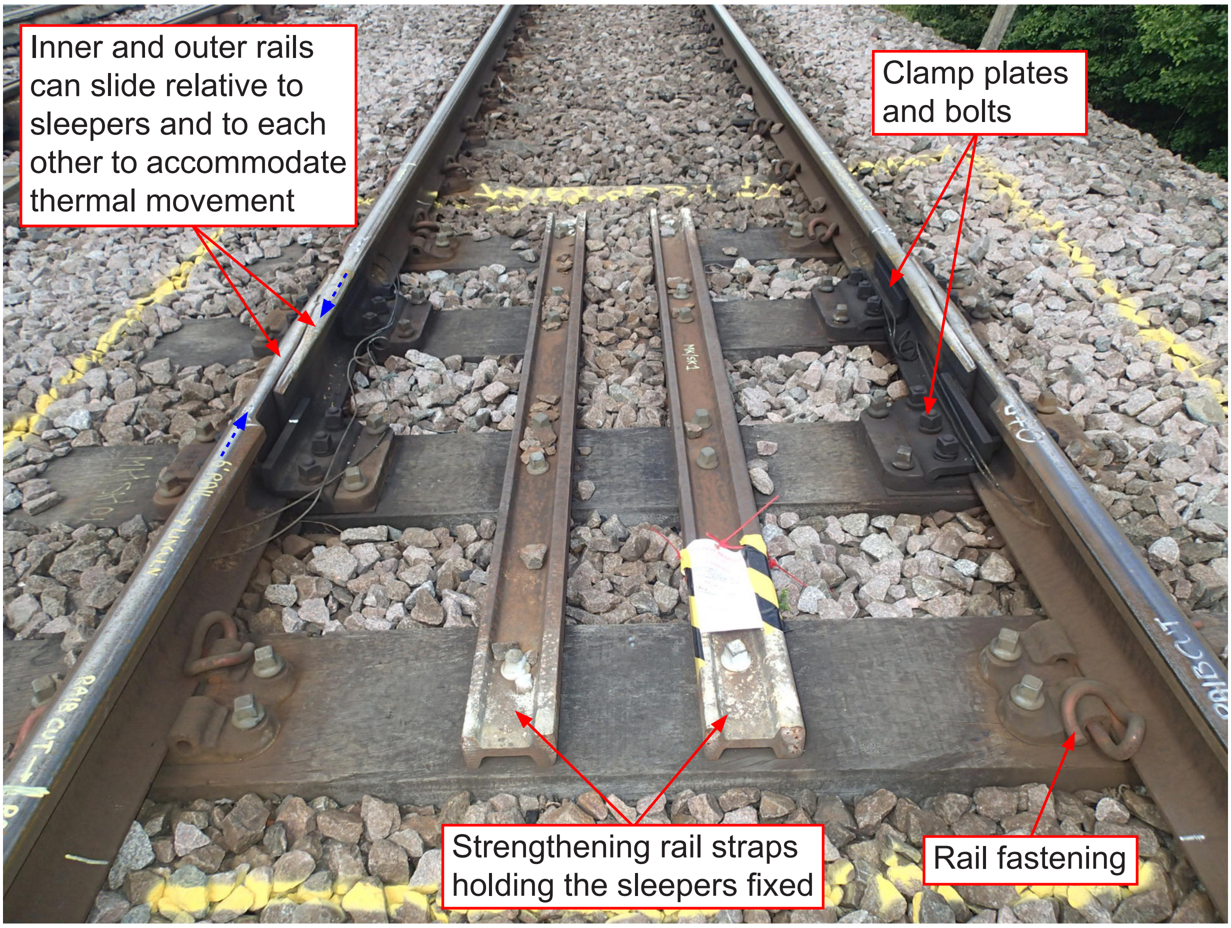


Figure 5: Adjustment switch on the down main line at the Lincoln end of 101A points

19 The rails on the up and down main lines were formed of *continuous welded rail* (CWR). The up main line was stressed, meaning that the rails had previously been pulled by *rail tensors* to the length they would naturally be at an air temperature of 27°C and then secured in place (paragraph 35). The down main line, however, was unstressed, meaning that it was installed without any additional stress applied before it was secured in place[4]. Any expansion or contraction of the rails on that line as a result of changing temperatures was isolated from 101A points on either side by means of adjustment switches (figures 4 and 5). Adjustment switches have overlapping rails which allow the rail to lengthen or shorten in response to longitudinal movements and prevent thermal forces from reaching the points.

Staff involved

20 The driver of train 6E54 had been driving trains since 2007. He was familiar with the route, having driven it regularly at least once a fortnight since he began driving. The driver was subject to an on-going competence management system by his employer, DB Schenker, who had assessed him as competent to drive trains.

21 Network Rail personnel from the Lincoln depot were involved in maintenance of the track:

- The *track maintenance engineer* (TME) had held the post in Lincoln for eight years and had 25 years' railway experience. He had line management responsibility for the *Section Manager (Track)* (SM(T)) and for the technical team. He had been assessed as competent by Network Rail in a number of maintenance disciplines, including the inspection of track. The TME last inspected the track in the area of the derailment as part of a cab-riding inspection on 30 March 2015.
- The SM(T) had 34 years' experience of maintaining track and had been a section manager for 1½ years. He had line management responsibility for both the track inspection and the track production (maintenance) teams and was responsible for the management and prioritisation of maintenance tasks in Network Rail's *Ellipse* database. The SM(T) had been assessed as competent by Network Rail to inspect track, including switches and crossings. He last carried out an inspection of the track in the area of the Welton switches and crossings on foot, on 13 May 2015.
- The Principal Technical Officer (PTO) had 15 years of railway experience and had been in the technical department at Lincoln depot for three years. His responsibilities included stressing of rails, the planning and overseeing of replacements of track components, and the inspection of switches and crossings. The PTO held several in-date certificates of competency, including those relating to inspection of switches and crossings and the stressing of rails. The PTO last carried out an inspection of the switches and crossings on foot at Welton on 1 May 2015.

[4] Network Rail was unable to explain why there were stressed and unstressed rails at this location as the original rationale had been lost over time.

External circumstances

22 The weather was hot on the day of the derailment, the air temperature reaching 21°C before 09:00 hrs and climbing steadily to a peak of 28.4°C at 16:30 hrs[5]. Throughout the day there was a light wind with scattered or no cloud. The Welton switches and crossings are located on an embankment in flat farmland and have some shade from trees on either side of the track. The weather was a significant factor in causing the track to buckle (paragraph 44).

[5] Temperatures recorded by Weather Underground just over 3 km away at Cherry Willingham.

The sequence of events

Events preceding the accident

23 Train 6E54 discharged its load of diesel fuel at Kingsbury Oil Terminal and departed on its return journey to Humber Oil Refinery at 10:25 hrs. The driver reported an uneventful journey up to the derailment.

24 At 12:44 hrs an East Midlands Trains (EMT) passenger service from Lincoln to Grimsby, formed of a single vehicle, passed over the site. Although the driver reported that he did not see or feel anything amiss with the track, images from the forward and rearward facing CCTV cameras show there was a track buckle starting to develop around the *toe* of 101B points (figure 6). It is possible that the size of the buckle developed further under the train.

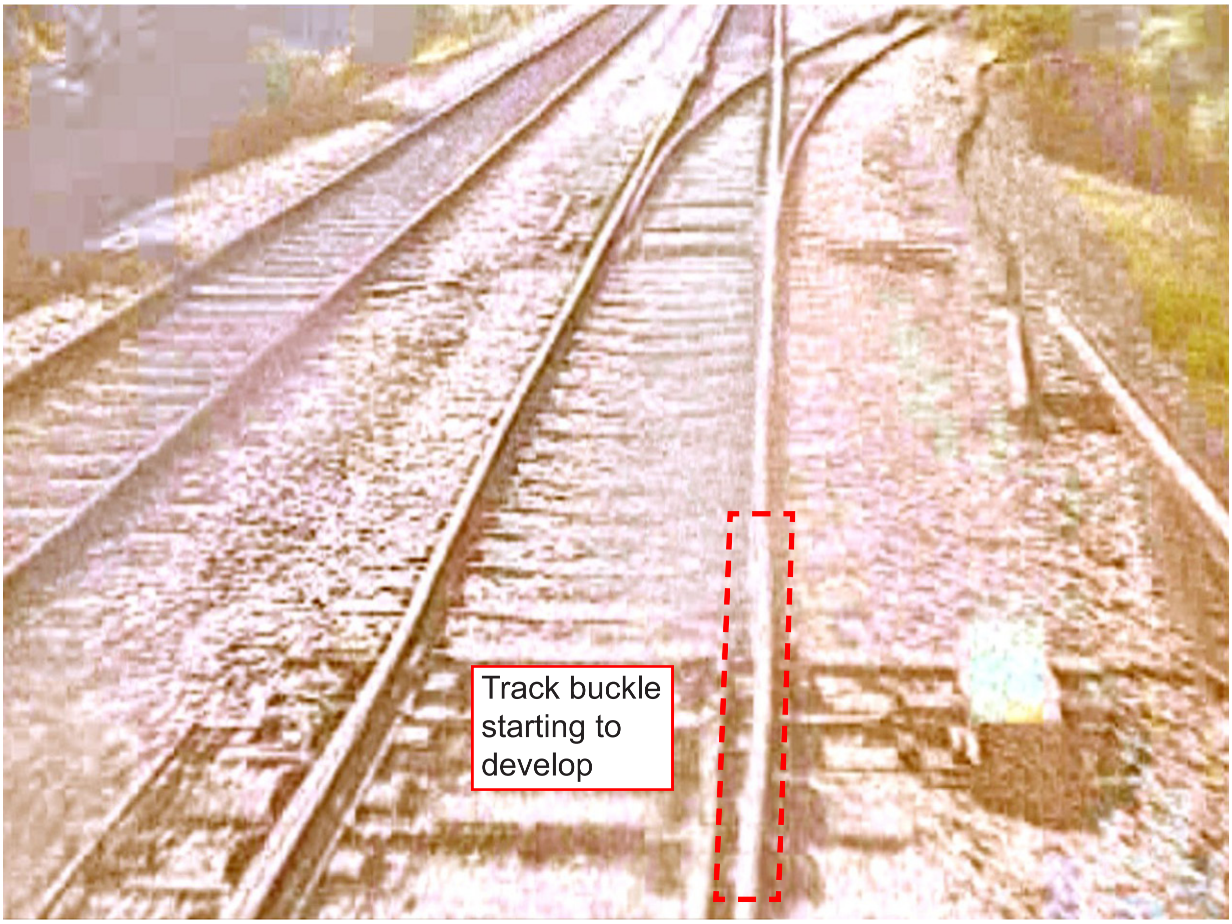


Figure 6: Image from rear facing CCTV camera on previous train at 12:44 hrs (image courtesy of East Midlands Trains)

25 Train 6E54 was the next train to pass over the line. At 14:15 hrs, it rounded the curve on the approach to the Welton switches and crossings travelling at 46 mph (74 km/h). When almost at the points, and too late to stop or slow the train, the driver saw what he described as a bulge in the left-hand rail at the toe of 101B points and felt the locomotive sway as it passed over it. The driver stated that he was concerned about this and intended to stop and report it to the signaller at the next signal. The on-train data recorder indicates that he shut off traction power immediately after the locomotive passed over 101B points.

Events during the accident

26 The locomotive and the first ten wagons had passed over the track buckle before the leading bogie of wagon 11 derailed to the *six-foot*, ie to the right, followed similarly by wagon 12. Wagon 13, however, derailed by both bogies to the *cess*, ie to the left (figure 7).

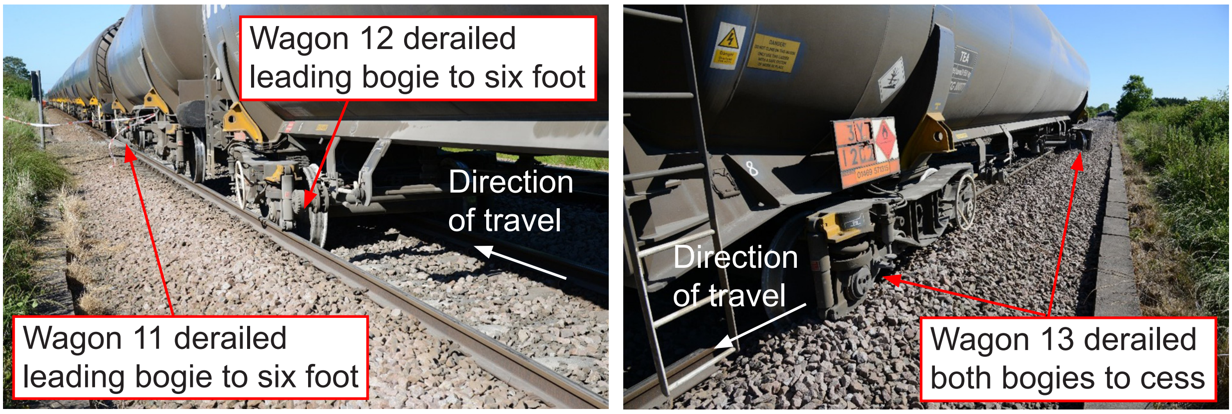


Figure 7: Wagons 11, 12 and 13

27 The train divided between wagons 13 and 14 which severed the continuous brake pipe and caused the train's brakes to apply automatically. The leading part of the train was brought to a stand with the locomotive about 615 metres beyond 101B points. The three derailed wagons in the leading part remained upright and broadly in line with the train. The RAIB estimates that the train divided when the trailing end of wagon 13 was about 50 metres beyond the toe of 101B points.

28 From the stopping position of wagon 13 there was a gap of approximately 250 metres to the rest of the train. The derailment marks suggest that wagons 14 and 15 (following the path of wagon 13) derailed to the cess and overturned, most likely when wagon 14 collided with a cabinet containing signalling equipment (figure 8). The leading bogie of wagon 16 also derailed to the cess but the trailing bogie moved towards the six foot with the result that wagons 16 and 17 jack-knifed and wagon 17 came to rest across both tracks. Wagons 18 to 20 derailed to the cess with wagon 18 overturning. Wagons 21 and 22 passed over the buckle without derailing, probably because of the slow train speed at this point, and came to rest with the rear of the train just beyond the toe of 101B points.

29 When the train came to a stand, the driver contacted the signaller at Langworth to report that he had had an unexplained brake application and requested permission to inspect the train. The signaller was already aware that something untoward had occurred because of the number of alarm indications received from damaged signalling equipment, and stopped rail movements in both directions. The driver reported that he did not initially associate the brake application with the track buckle and had not felt any unusual sensations from the train to indicate that it had derailed. On walking back along the train the driver realised that the train had divided and saw the derailed vehicles in the distance. He made a second call to the signaller who arranged for the fire service and police to attend.

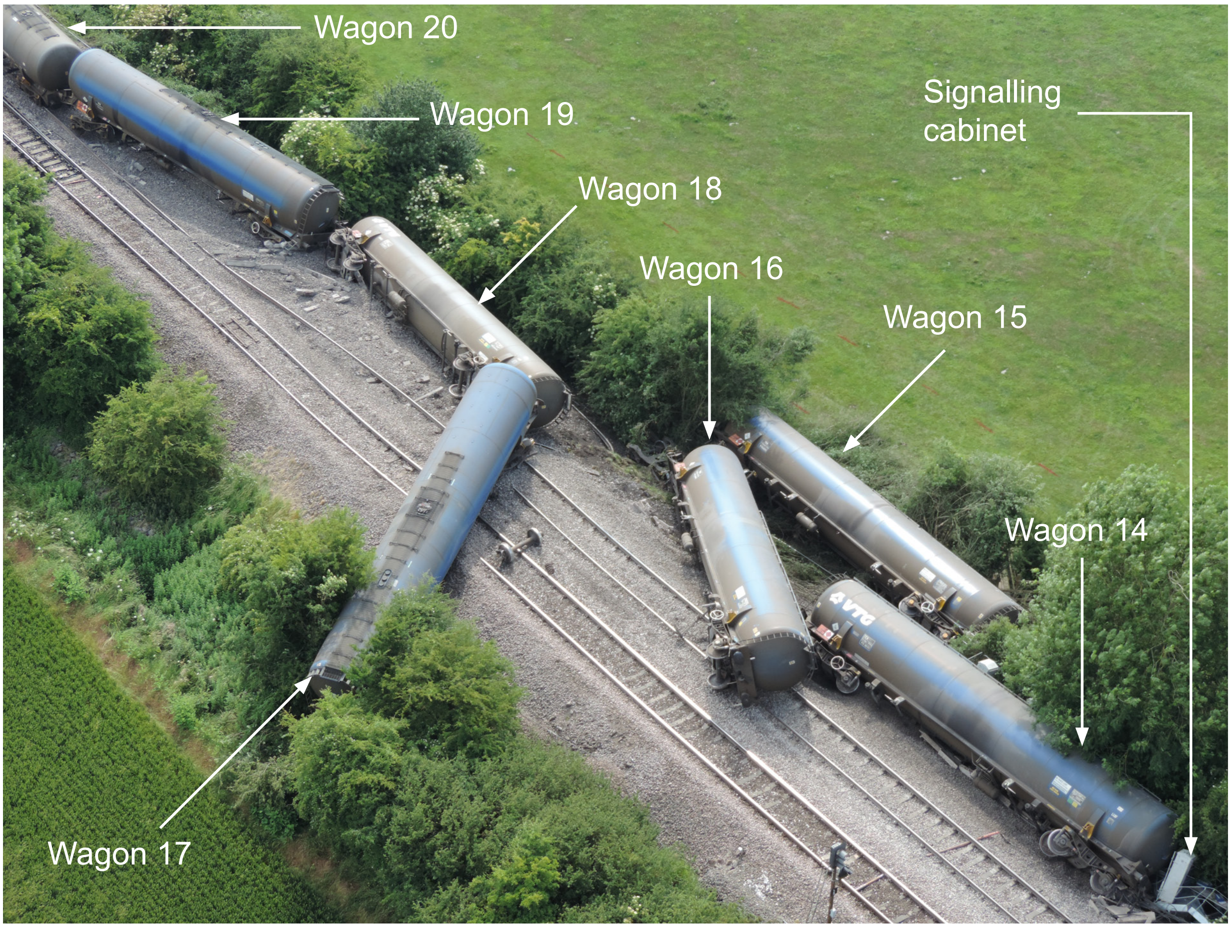


Figure 8: Wagons 14 to 20 (image courtesy of Network Rail)

Events following the accident

30 On 1 July, wagons 11, 12 and 13 were re-railed and the leading section of the train was recovered to DB Schenker's Immingham depot.

31 Network Rail arranged for a temporary road to be built across the adjacent field to provide access for a large crane. On 3 and 4 July wagons 14 to 19 were hoisted on to road vehicles and were taken to VTG's site at Long Marston.

32 Work to repair the line commenced on 6 July. The track was 'plain-lined', meaning that the switches and crossings and associated equipment were completely removed. Both lines were reopened with a temporary speed restriction on 9 July 2015 and restored to full line speed on 29 July 2015.

Key facts and analysis

Background information

33 The following explanation of relevant railway engineering terms is provided to assist an understanding of the causal factors in this accident.

Track buckle and buckling temperature

34 Rail will naturally expand when heated, but if restrained such that it cannot expand, there will be a build-up of compressive forces in the rail. Should the compressive forces become excessive, the rail will tend to buckle (move sideways) to relieve the stress. This tendency is mainly opposed by the lateral resistance of the *ballast* around the sleepers supporting the track. If this resistance is insufficient, because of an inadequate quantity of ballast or because the ballast has been recently disturbed, the ballast will be unable to prevent the track from buckling. The rail temperature at which this occurs is the buckling temperature. The track's resistance to buckling and the buckling temperature are decreased if there are lateral misalignments. The additional lateral loading of the track that can occur at such misalignments when trains pass, can trigger the formation of a track buckle or exacerbate an existing buckle.

Stress free temperature

35 The stress free temperature (SFT) is the rail temperature at which installed rails are in a neutral state, being neither in compression nor tension. Network Rail standards require that rail is installed to be stress free at 27°C. This is achieved by pulling (stressing) the rail using rail tensors to the length it would naturally be at 27°C (allowing for welding the rails together) and then securing it in place by rail fastenings (figure 5). At temperatures below 27°C such rail is in tension and above 27°C it is in compression. The SFT is chosen by Network Rail to be the best compromise between adequate resistance to buckling in hot weather and resistance to breaking in cold weather, when the rails are in tension.

36 Rail that has lost some or all of its installed stress will have an actual SFT of less than 27°C. Rail stress may be lost, for example, when it is cut for a repair and not reinstated to the correct stressed condition. Such rail will go into compression when the rail temperature reaches this lower actual temperature, thus making it more vulnerable to buckling in hot weather. The minimum acceptable SFT for rails on Network Rail infrastructure is 21°C.

Critical rail temperature (CRT)

37 The critical rail temperature (CRT) is the temperature to which rail is allowed to rise before Network Rail standards dictate that actions are needed to protect rail traffic. The CRT is dependent on the SFT and the quality and consolidation of the ballast in the track. The CRT can be adversely affected by a loss of stress in the rail, by maintenance works that temporarily disturb the consolidation of the ballast or by insufficient ballast support for sleepers. Such sites are recorded in Network Rail's *CRT register* and a calculation is made of the reduced CRT to be applied until the ballast has been reconsolidated, normally by the passage of rail traffic.

38 There are three levels of CRT specified in Network Rail's company standard NR/L2/TRK/001/mod14 'Managing track in hot weather', 01 December 2012, each with an associated action to protect traffic (in ascending order):

- CRT(W) = temperature at which a *watchman* is deployed to monitor the track concerned.
- CRT(30/60) = temperature at which speed restrictions of 30 mph or 60 mph (48 km/h or 97 km/h) are imposed for freight and passenger traffic respectively.
- CRT(20) = temperature at which a 20 mph (32 km/h) speed restriction is applied for all traffic.

39 The CRT is not a threshold between safe and unsafe conditions, more a gradual transition from conditions in which a track is unlikely to buckle to conditions in which it is likely to buckle. The speed limits are intended both to reduce any lateral loading from vehicles (freight trains normally being heavier, give rise to higher lateral loads at increasing speeds) which can promote the development of a track buckle, and to mitigate the consequences of a derailment.

Identification of the immediate cause

40 **Train 6E54 encountered a track buckle which derailed wagons 11 to 20.**

41 The recording from the rear facing CCTV camera on the previous train at 12:44 hrs showed that the track around the toe of 101B points had started to buckle towards the cess (figure 6). The driver of train 6E54 subsequently confirmed that the bulge in the rail he saw was in the same place and judged it to be as bad as, or worse than, that shown in figure 6.

42 Witness marks on the right-hand rail from the first wheels to derail were consistent with wheel *flanges* climbing over the head of the rail as a result of encountering the buckled track.

Identification of causal factors

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

a. the track started to buckle when the rail temperature in the vicinity of 101B points exceeded its buckling temperature; and subsequently

b. a long freight train ran over the developing buckle at too high a speed for the vulnerable condition of the track.

Each of these factors is now considered in turn.

Rail buckling temperature

44 The track started to buckle when the rail temperature in the vicinity of 101B points exceeded its buckling temperature.

45 A rail temperature of 38°C was measured in the vicinity of the track buckle after the derailment at 17:20 hrs. The air temperature at this time was around 27°C which was slightly higher than at the time of the derailment (26.8°C) and when the previous EMT passenger train passed the site (26.3°C). Rail temperatures on 1 and 2 July were measured by RAIB and using a comparable ratio of air to rail temperature from around 14:00 hrs on subsequent days (about 1:1.4), the RAIB has estimated that the rail temperatures at the time of the derailment and when the previous train passed were around 37°C.

46 According to Network Rail company standard NR/L2/TRK/001/mod14, the CRT(W) for standard track with a SFT of 27°C and which is undisturbed, fully ballasted and consolidated, should be a minimum of 59°C. The track buckled at a buckling temperature of about 22°C lower than the expected minimum CRT(W) for standard track.

47 The rail temperature in the vicinity of 101B points exceeded the buckling temperature due to a combination of the following:

- it was the hottest day of the year to date;
- there was insufficient ballast at 101B points to laterally restrain the track from buckling;
- there was a pre-existing lateral misalignment in the area of 101B points which promoted the formation of the track buckle; and
- the SFT of the rails was probably less than the 27°C recorded in Network Rail's stressing database.

These factors are discussed in the following paragraphs.

Rail temperature

48 It was the hottest day of the year to date.

49 The Met Office summary of United Kingdom weather for Tuesday, 30 June 2015 stated that it was the hottest day of the year so far across the whole country. The previous peak for the year measured at nearby Cherry Willingham (figure 1) had been 24.8°C, three weeks earlier. On 30 June 2015 this temperature had been reached just after 11:00 hrs and by 12:44 hrs, when the buckle had already started, it had risen a further 1.5°C, and a further 0.5°C by the time of the derailment.

50 The Network Rail log for 30 June 2015 recorded three other track buckle incidents, in Cardiff, Worcester and Stowmarket, suggesting that the new peak in temperature for the year experienced on that day was a relevant factor. There is some evidence[6] that track buckles are more likely to occur when there has been a step rise in temperature from the previous peak that year, subject to a threshold temperature being exceeded. The threshold air temperature in NR/L2/TRK/001/mod14 'Managing track in hot weather' at which poorly supported track becomes vulnerable to buckling is about 25°C and research has found that the majority of severe track buckles occur when the maximum daily air temperature is over 27°C[7].

51 The rail at 101B points had been subject to higher air temperatures the previous year without buckling. In July 2014 the local air temperature had reached 28°C, rising from 25°C in three 1°C steps over a period of two weeks. Although the air temperature on the day of the derailment was lower than temperatures seen in 2014, the step change from the previous peak was bigger, and this combined with other factors to reduce the buckling temperature of the track and cause it to buckle. These factors are examined below.

Lateral restraint

52 **There was insufficient ballast at the toe of 101B points to laterally restrain the track from buckling.**

53 After the accident the RAIB observed that there was an absence of ballast in the cess at the ends of the bearers for 101B points on which the point motor was mounted (figure 9). The bearers for 102A points were similarly exposed. There was also a minimal *ballast shoulder* on the cess-side ends of the sleepers between the closely abutting toes of 102A and 101B points (figure 10) and the ends of the sleepers adjacent to the toe of 101B points were above the level of the ballast (figure 11). However, the spaces between sleepers within the rails (known as 'cribs') were mainly full of ballast.

54 According to standard NR/L2/TRK/001/mod14, the ballast shoulder should be 450 mm wide and 125 mm above the sleeper top and extend not less than 10 sleepers either side of abutting switch toes. The standard regards abutting switch toes as a discontinuity in the track and the plain line between them as more vulnerable to buckling than normal plain line.

55 This ballast deficiency had existed for some time. A recording made by the forward facing CCTV on Network Rail's track recording train (which measures track geometry) in August 2014 showed that the ballast profile on the cess-side of the track was very similar to that at the time of the derailment with little or no ballast shoulder, and some sleeper ends and sides exposed (figure 12).

56 Following a routine visual track inspection by a track patroller, a work order to remedy the lack of ballast at 101B and 102A points was raised in Network Rail's maintenance database, Ellipse, on 25 March 2015. The work order stated that the points were 'very low on ballast' and action was needed within one month to 'box in' the points, meaning that the areas between, and at the ends of, the bearers required additional ballast to restore a compliant profile.

[6] BR Research RR TM 013 'An analysis of track buckling risk', Hunt GA, March 1994.

[7] Dobney K, C J Baker, A D Quinn and L Chapman (2009) 'Quantifying the effects of high summer temperatures due to climate change on buckling and rail related delays in the UK', Meteorological Applications, 16, 245-51.

Figure 9: Ballast support at the ends of 101B point motor bearers and in the 'cribs' at the toe of the points

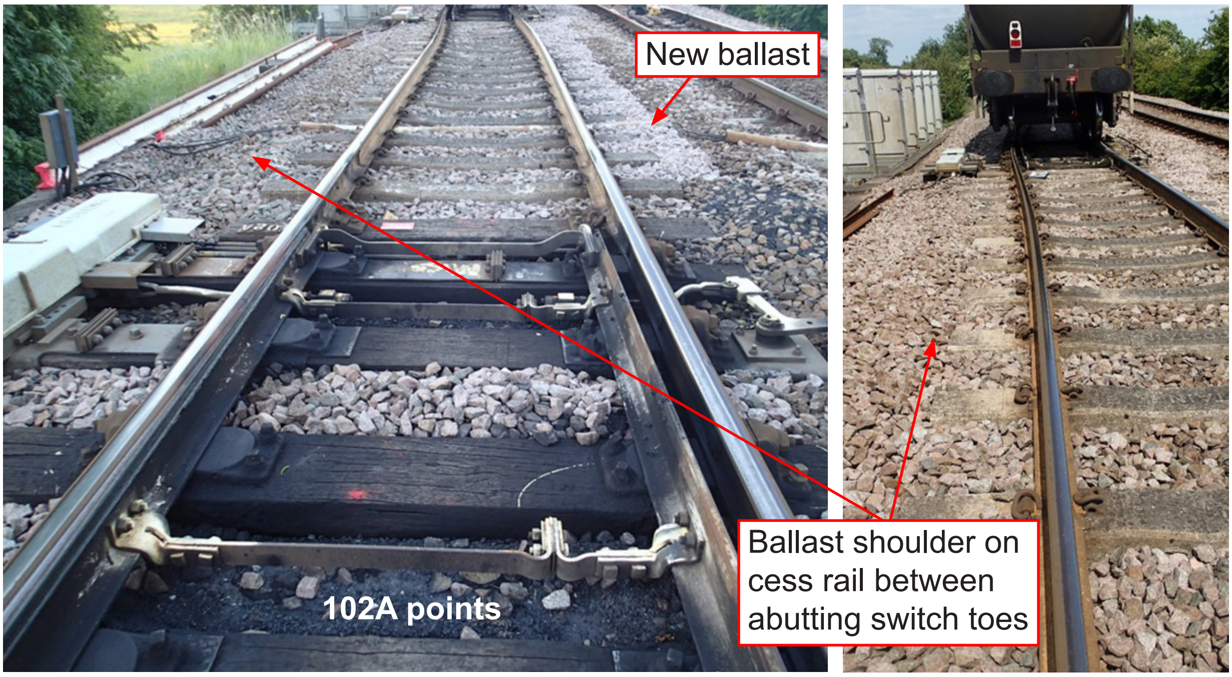


Figure 10: Ballast shoulder in plain line section between 102A and 101B points

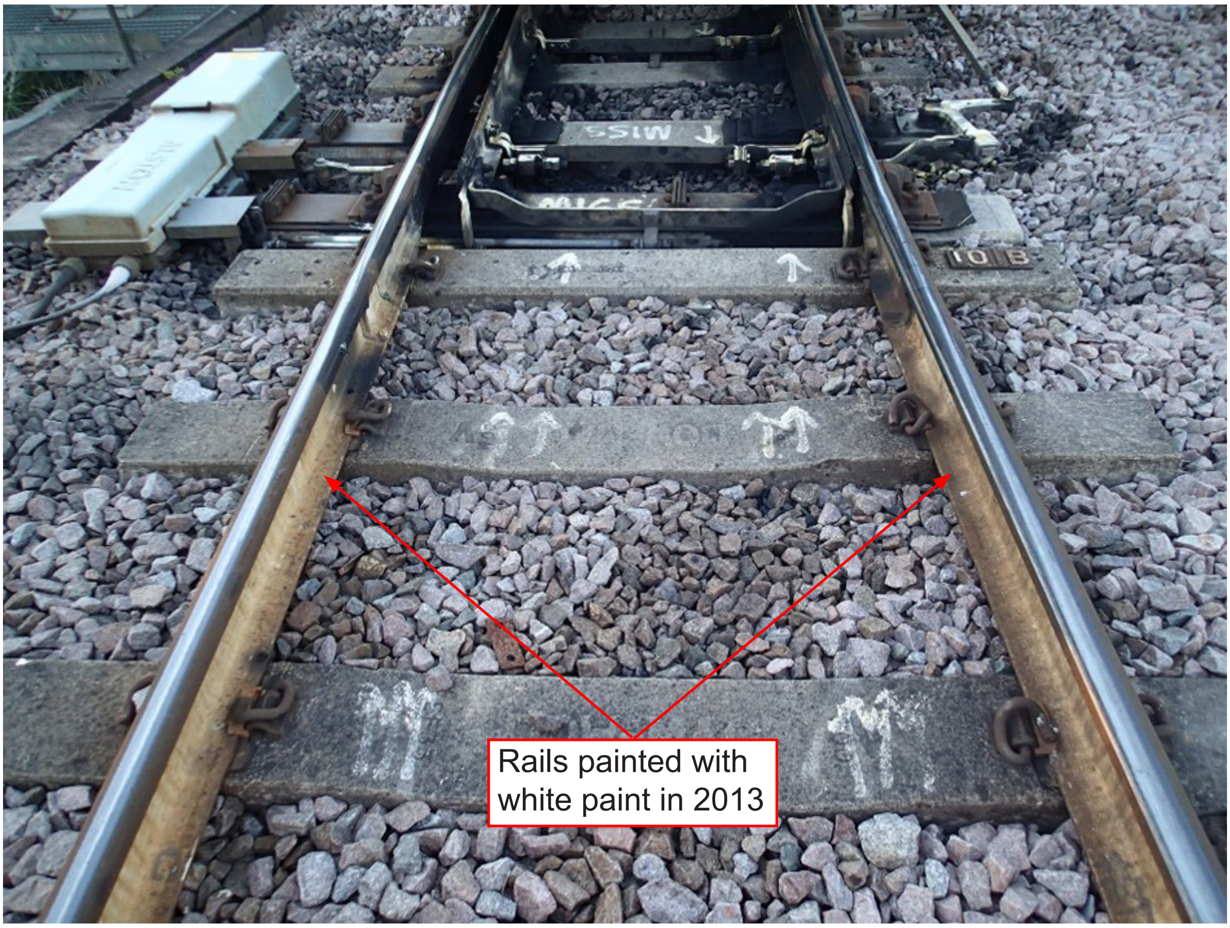


Figure 11: Sleeper tops above ballast at toe of 101B points

Figure 12: Ballast shoulder in plain line section between 102A and 101B points, captured by the forward facing CCTV camera on Network Rail's track recording train, August 2014 (image courtesy of Network Rail)

57 On 08 April 2015 the work order was cancelled by the SM(T). The SM(T) thought he might have cancelled it because he believed that new ballast had recently been dropped at the site. A comparison with the ballast profile recorded in August 2014 shows that there had been some dressing of the ballast on the six-foot (right-hand) shoulder on the approach to 101B points (figure 13).

58 The investigation found that the ballast deficiency at the toe of 101B points was not considered by local track maintenance staff to be severe enough to merit the inclusion of the site on the CRT register and the calculation of a critical rail temperature (paragraph 37). Neither the SM(T) nor the PTO, who had both visited the area in the weeks before the derailment (paragraph 21), considered the level of ballast at 101B and 102A points met the descriptors of severe shortage set out in NR/L2/TRK/001/mod14. Their explanation for this view was that there was generally plenty of ballast around the track providing a reasonable standard of lateral support with only localised areas of shortage at the toe of the points where, in any event, it is permissible for ballast height to be restricted to avoid interfering with movements of the points mechanism[8].

[8] Network Rail standard NR/L2/TRK/2102 'Design and construction of track' iss 7, permits ballast between bearers containing equipment associated with the movement of points to be kept 100mm below the top of the bearer.

Figure 13: Area of ballast dressing in the six-foot between 102A and 101B points

Misalignment of the track

59 **There was a pre-existing lateral misalignment in the area of 101B points which promoted the formation of a track buckle.**

60 The track buckle that formed coincided with a lateral misalignment on the cess rail which was present in August 2014. Images from the forward facing camera on the track recording unit taken in August 2014 showed an apparent deviation in the rail at the toe of 101B points in the same place as the buckle occurred (figure 14).

61 Further evidence of a long-standing misalignment at the toe of 101B points was found in a Network Rail fault report from 30 June 2009. This records that a 20 mph (32 km/h) emergency speed restriction was imposed because of a 'buckle/poor line' at the toe of 101B points due to extreme heat (the air temperature on that day reached 27°C, ie similar to the day of the derailment). There are no other records relating to this incident but local recollection was that a precautionary speed restriction was imposed for around an hour until a comparison could be made with photographs taken of the points in winter which apparently showed the same degree of misalignment. However, the toe of the points was reported to be low on ballast and a CRT(W) of 44°C was imposed until this was remedied and the track restabilised.

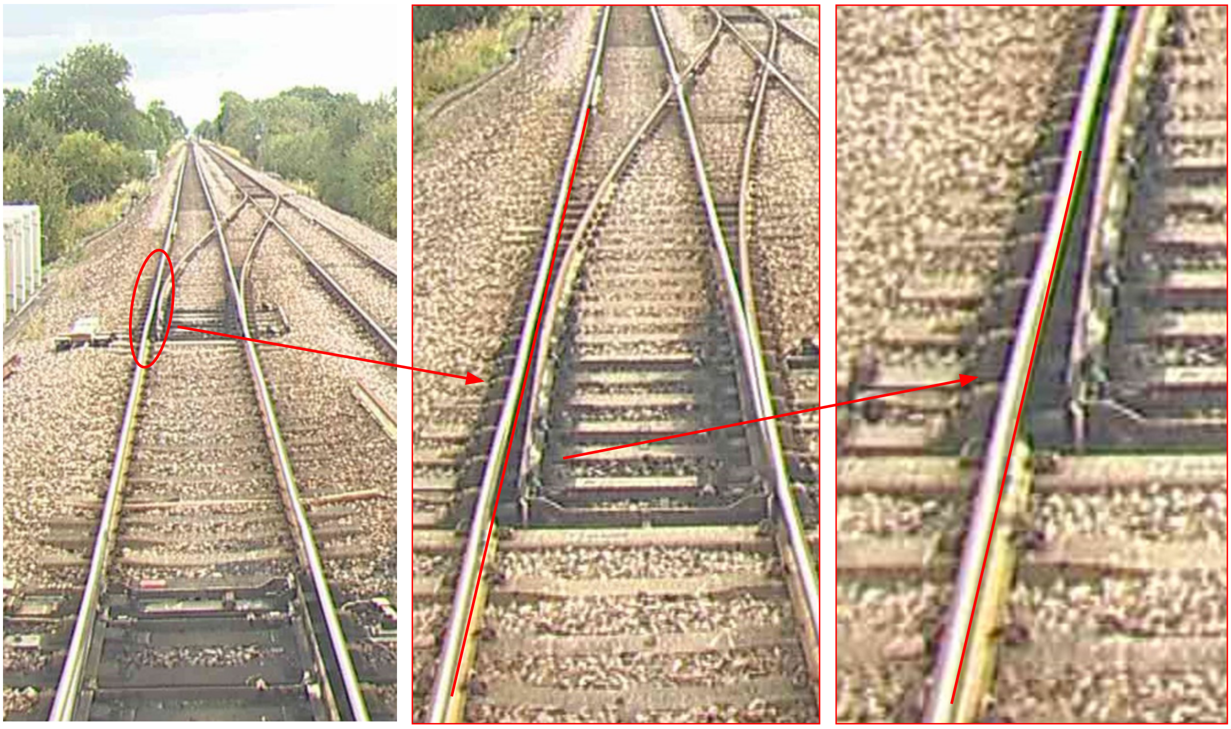


Figure 14: Pre-existing misalignment on LH rail at 101B toes, captured by the forward facing CCTV camera on the Network Rail's track recording train, August 2014 (image courtesy of Network Rail)

62 The switches and crossings at this location (Welton Oil Terminal) have had a history of problems with the horizontal and vertical alignment of the track, generally referred to as 'line' and 'top' respectively. Recordings of track geometry from Network Rail's track recording train going back to 2006 show that there were persistent problems with top in the area of the switches and crossings and, from about 2009 onwards, there were increasing issues with line (figure 15).

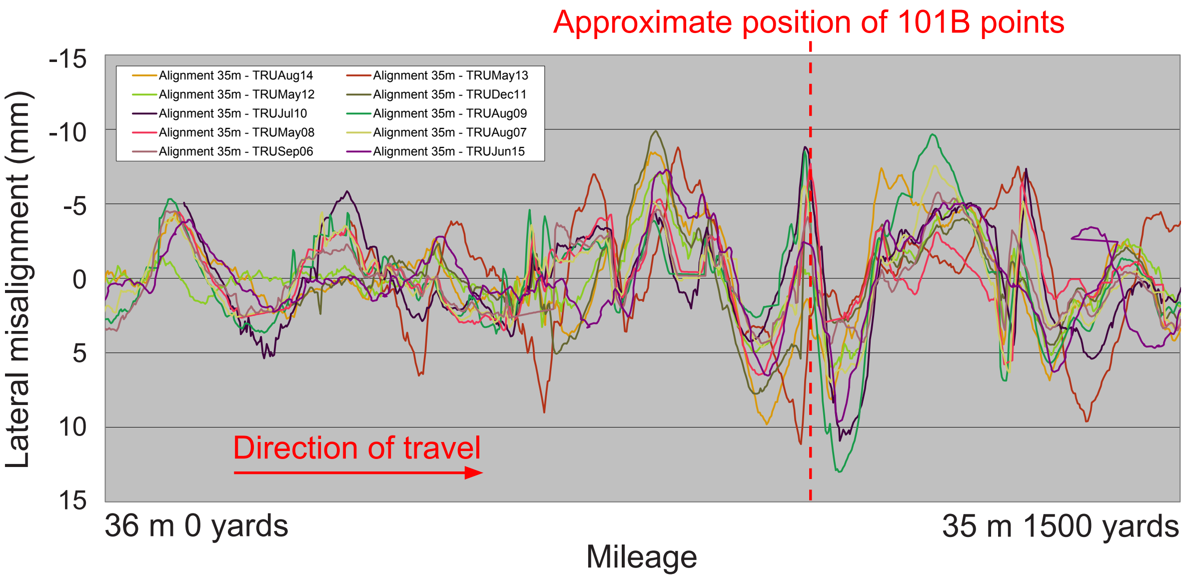


Figure 15: Traces of track alignment 2006 to 2014 for up line at 35 miles 1500 yards to 36 miles 0 yards

63 The track geometry trace from the last run of the track recording train on 8 June 2015 found that the track quality in the eighth of a mile section containing the Welton switches and crossings was poor. It had previously been very poor. There had been some *tamping* of the switches and crossings in the interim which could explain the improvement. However, any discrete geometry defects were below mandatory intervention levels.

64 The British Rail research report from 1994[9] suggested that the probability of buckling is greater in track with poor alignment quality and reports early findings that the highest risk defects are those that have short wavelengths (ie significant deviation over a short length of track). An *RSSB* report[10] which reviewed worldwide literature on SFT and stability of CWR also identified alignment quality as a salient parameter of track buckling. Other studies[11] have similarly reinforced the finding that lateral alignment defects can act as a trigger for buckles.

Stress free temperature (SFT)

65 **The stress free temperature of the rails was probably less than the 27°C recorded in Network Rail's stressing database.**

66 The Network Rail rail stressing database recorded that both rails of the up main line for the mileages containing the Welton switches and crossings were stressed and there were no areas recorded as 'stress unknown' or which were awaiting re-stressing. The records indicate that the plain line between the abutting toes of 102A and 101B points was re-stressed to 27°C in May 2012 using the prescribed method in Network Rail's company standard (paragraph 35).

67 Since May 2012 there had been a number of maintenance interventions around the points that could have adversely affected the SFT of the rails in the area of the track buckle. In July 2012 there were two repairs carried out as a result of the repeated failure of a weld associated with the re-stressing of the rails in May 2012. The records suggest that the tensor forces used to restore the stress in the rail as part of the repair work were not as expected. On the first occasion (when the failed weld was re-welded) the amount of force required to close the rails and to restore the stress to the same level, was more than predicted by calculation. On the second occasion (when a five metre length of rail was inserted in the plain line section between points 102A and 101B to eliminate the failed weld) the amount of force recorded as required was less than predicted by calculation. However, Network Rail has reported that these apparent anomalies were not investigated further to understand the reasons for the unexpected stressing behaviour of the rails.

68 In March 2015 the *crossing nose* on the approach to 102A points was replaced and in May 2015 a set of *fishplates* was changed, also on the approach to 102A points. In both cases, no stressing records were completed, in contravention of Network Rail standard procedures. It is not possible to verify, therefore, whether the SFT of the rails was likely to have been affected.

[9] BR Research RR TM 013 'An analysis of track buckling risk', Hunt GA, March 1994.

[10] 'Stress free temperature and stability of continuous welded rail', RSSB Research Programme Engineering, February 2005.

[11] A Shah, N K Mandral and G Chattopadhyay 'Track stability management – Part 1 Literature review: Theories and practice', Project R3112, CRC for Rail Innovation, 2009.

Development of the track buckle leading to the derailment

69 **A long freight train ran over the track buckle at too high a speed for the vulnerable condition of the track.**

70 The locomotive and ten wagons ran over the buckle without derailing before the size of the buckle increased to a point where the wheels were unable to steer through it and the right-hand wheels of the leading bogie of wagon 11 climbed over the head of the rail into derailment.

71 After the derailment the amplitude of the buckle was measured to be approximately 300 mm. Research into track buckling[12] identifies a mechanism in which track misalignments grow progressively under the passage of trains. As a train passes, the forces imparted to the track create a dynamic movement of the sleepers (both down and up). Dynamic uplift of the sleepers reduces the restraint provided by the ballast. If the lateral force on the sleeper exceeds the ballast restraint, the sleeper makes a small sideways movement and sheds load on to the adjacent sleepers. This creates a progressive wave effect which gradually makes a buckle worse and which, in turn, causes the dynamic lateral forces exerted by each successive wheelset to increase rapidly until derailment occurs. The magnitude of the dynamic forces exerted onto the track by the passage of trains depends on several factors such as lateral track alignment, axle load and suspension design, but for a given type of vehicle it is affected largely by speed.

72 There was no speed restriction in place at the time of the derailment because the site was not included on the CRT register (paragraphs 37 and 38). If it had been, the air temperature would have been monitored and if it was considered likely that the rail temperature could reach the calculated CRT for that section of track, then prompt action would have been taken to deploy a watchman or to impose a speed restriction. There was witness evidence that the Welton switches and crossings had previously been included in the CRT register prior to 2013 and the area had been patrolled in hot weather. However, the RAIB understands that the site was removed from the register in 2013 when the switches and crossings were painted with white paint as part of an initiative to reduce the number of sites on the CRT register (figure 11, paragraph 86). A coating of white paint can reduce the rail temperature by up to 5^{o}C to mitigate the risk of buckling in hot weather (although it is not included in any calculation of CRT). It is not clear why the area originally merited inclusion on the CRT register but a loss of understanding of the vulnerability of the site to hot weather may have led to its removal without a continuing plan to maintain some level of risk mitigation.

[12] This phenomenon was observed in a paper ‘Track Buckling’ by C O Frederick, Group Manager, Track, British Railways Board, Railway Technical Centre, Derby, 1980.

73 It is possible that even if the site had been on the CRT register, the calculated CRT(W) rail temperature (paragraph 38) may not have prompted intervention in time to have averted the accident. Network Rail standard NR/L2/TRK/001/mod14 contains guidelines for calculating the CRT where the track has been degraded either by a reduction in SFT or a reduction in ballast support around the sleepers. Assuming an SFT of 27°C, the CRT at the time of the derailment could have been as low as 32°C or as high as 40°C, depending on judgements made about the shortage of ballast. If the worst case CRT(W) of 32°C had been calculated a watchman should have been deployed when the air temperature was around 21°C (which, using the Network Rail 'rule of thumb' multiplier of 1.5, would have equated to a rail temperature of 32°C). If this had happened, the watchman should have observed the track buckle forming earlier in the day and taken preventive action (to close the line to rail traffic or impose a speed restriction appropriate to the size of the buckle) before the passage of train 6E54. However, the RAIB found that the descriptors of ballast shortage severity in NR/L2/TRK/001/mod14 were open to interpretation and, depending on the factors included in the calculation, a watchman (or speed restriction) may only have been deployed when the air temperature was approaching 27°C, which was the temperature at the time of the derailment.

Discounted factors

Instability of the track formation

74 The RAIB considered whether there had been any movement of the embankment which could have caused the rails to buckle.

- It was noted that the south side of the embankment was reinforced with *gabions* and that there had possibly been some movement there in the past. However, there were no signs of any movement on the north side and maintenance staff confirmed that there was no history of a loss of ballast down the bank.
- There is a culvert running under the embankment, almost directly below the area of the track buckle. The culvert appeared to be in good repair, free flowing and with no sign of debris in the bottom.

Track instability from recent disturbance

75 Sites where the ballast has recently been disturbed, especially where on-track (engineering) machines have been working, are known to be particularly vulnerable to track buckles. Following any disturbance the track has a reduced CRT and mitigation measures have to be taken in hot weather until the ballast is reconsolidated by the passage of trains.

76 The track in the Welton switches and crossings had been tamped using an on-track machine in March 2015, sixteen weeks before the derailment. The job was only partially completed and records and witness evidence are unclear about what was tamped and what was not. However, the period of time following the tamping in which a reduced CRT would have applied would have expired before the derailment.

77 The investigation also considered the possibility that the lift applied to the sleepers by the tamper exposed the tops and sides by lifting them above the level of the ballast. However, the design plan for the tamping exercise, which affected the level of the top only, did not apply an unduly high level of lift compared with a routine maintenance tamp and there is no evidence that the design was not followed.

78 There are no records in the Ellipse database of any other recent maintenance in the area which could have disturbed the ballast.

Rail creep

79 Over a period of time there can be a gradual tendency for rails to move through the fastenings, usually in the direction of traffic. This phenomenon, known as rail creep, increases the load at fixed points in the rails, such as switches, and can cause misalignments. Rail creep is influenced by factors such as shortage of ballast, worn or missing rail fastenings, gradient and the braking of trains. The TME confirmed that the area had no history of rail creep and the RAIB did not observe signs of rail creep on site.

Thermal stresses from seized adjustment switches on the down line

80 A track layout comprising a crossover between stressed and unstressed rails (figure 4) is unusual on Network Rail infrastructure. It is theoretically possible that, had the adjustment switches protecting 101A points on the down main line been seized or had reached the end of their travel, thermal stresses could have been transferred via the crossover to 101B points. The RAIB arranged for both sets of adjustment switches to be forensically examined and both were found to be in working order with capacity for further movement.

Identification of underlying factors

Lack of understanding about the factors affecting the buckling temperature of the site

81 **There was insufficient appreciation of the factors affecting the CRT of the site and its vulnerability to hot weather. This was an underlying factor.**

82 The decision to cancel the work order to remedy the ballast deficiency at 101B points was made without a full understanding of the risk of buckling (paragraphs 57 and 58). Apart from the shortage of ballast, which local staff did not consider met the descriptors of ‘severe deficiency’, the site was vulnerable to hot weather from other risk factors. These factors were not required by NR/L2/TRK/001/mod14 to be assessed as part of a wider view of the risk. However, they are known to adversely affect the buckling resistance of the track and, in this instance, are likely to have combined to cause the track to buckle. These factors were:

- the known difficulty of maintaining stressed rail in a short section of plain line between abutting switch toes, and therefore the likelihood that the assumed SFT of 27°C could not be relied upon at that location;
- the general history of poor line and top in the area around 101B points and the misalignment around the toe of 101B points which, although below the level at which intervention was required, could have reduced the buckling temperature; and

- the added risk from a localised shortage of ballast around the bearers at point motors and at the toe of points, because of the high incidence of track buckles close to switches and crossings[13].

Reprioritisation of maintenance work

83 **Maintenance work was continually reprioritised or cancelled because the Lincoln maintenance depot was under-resourced. This was a possible underlying factor.**

84 The investigation found that the work bank of maintenance tasks in the Ellipse database was too large to be delivered by the maintenance staff available at Lincoln depot. Witnesses described a process of continual 'juggling' of tasks in which planned work was frequently reprioritised, sometimes several times, and then sometimes cancelled. The Ellipse database contains multiple examples of work given an initial priority of, for example, 'M3', ie to be completed within three months, which was not done within three months. One explanation given by witnesses was that staff were being overly conservative in their initial assessment of urgency and more experienced staff reprioritised it with a more realistic timeframe. However, work was also reprioritised because there were not enough resources to deliver it.

85 The repainting of the Welton switches and crossings with white paint in preparation for hot weather was listed as a required task in the Ellipse database. Network Rail's standardised task work sheet on painting of switches and crossings identifies short sections of plain line between abutting switch toes as vulnerable to track buckles and suitable for painting to mitigate the risk. It also states that repainting must be done annually to remain effective.

86 In 2013 the TME made a successful bid for capital expenditure to repaint them from a special budget to increase reliability (figure 11). The work was completed in July 2013 and a work order was raised in the Ellipse database for repainting the rails in 2014. This work order was reprioritised in 2014 and again in 2015, before being cancelled by the SM(T) in May 2015.

87 The RAIB notes that the high priority work order to correct the ballast shortage (paragraph 56), which would have entailed a delivery of ballast to the site using a hired-in specialised vehicle, was cancelled without any measures being taken to mitigate the potential risk.

88 In April 2011 Network Rail undertook a major restructuring, known as 'Phase 2BC' to standardise its maintenance function. This gave each section manager a template organisation to match the workload in their section. The Lincoln SM(T) was allocated a staff of 22, including an inspection team of six people, and a total of 14 maintenance staff in two teams. The RAIB was told that at no time since the restructuring exercise had the delivery unit had sufficient resources to fill all of these posts. The inspection team was kept fully staffed because the inspection of track is mandatory. However, this was at the expense of the maintenance team which carried the vacancies. At the time of the derailment, the maintenance team was five short of its complement of 14 staff.

[13] Network Rail's analysis of the 96 track buckles that occurred in 2006/2007 found that 60% occurred either in switches and crossings or within 100 metres of a switch and crossing.

89 The SM(T) reported that his workload was particularly heavy in the months leading up to the derailment because the section planner was on long-term sick leave and he and other staff within the section were having to take up the planning of work. There were also additional pressures on his time from the introduction of a new way of working for managing safety of staff, known as the 'Planning and delivering safe work' programme. These pressures may have led to certain remedial work being overlooked or not being planned. Other staff reported similar workload pressures.

90 The TME has stated that the maintenance team delivers what they can with the resources they have and always have to plan to do the most important things. He felt, however, that the workload was under control.

Factors affecting the severity of consequences

91 The wagons were nominally empty (usually taken to mean containing less than 50 litres) of diesel fuel. There was no evidence of spillage from any damaged tank fittings.

92 During the derailment, some wagons tried to override other wagons as vertical offsets arose. The override beams fitted to the wagons appeared to have successfully prevented any direct holing of the tanks arising from this. However, the tank of wagon 16 was holed when it collided with a buffer from the overturned wagon 14. This occurred high on the side of the tank and again there was no evidence of spillage.

93 There were no passenger trains passing on the adjacent line at the time of the accident; a collision with wagon 17 which slewed across the track could have resulted in serious consequences.

Observations

Security of clamp plate bolts in adjustment switches

94 **The process specified in Network Rail's company standard on adjustment switches for achieving a consistent bolt clamping force was found to be unreliable.**

95 One of the checks made during the forensic examination of the adjustment switches (figure 5) was the torque tightness of the bolts in the clamp plate. Clamp plate bolts secure the adjustment switch rails to the baseplates and are required to be tightened on to a spring washer, leaving a 1 mm gap in the spring washer. Achieving this gap consistently on all the bolts should provide the requisite level of clamping load in the bolt. This is in preference to torque tightening the bolts and reliance on a consistent level of friction between the components of the bolted assembly to achieve the required clamping force.

96 The forensic examination found that the 1 mm gap in the spring washer bore little correlation to the measured torque and therefore to the likely clamping force. This was because some of the spring washers had become broken or distorted and therefore achieving the requisite gap did not provide any confirmation that a sufficient and uniform clamping load had been achieved.

Previous occurrences of a similar character

Track buckle derailments

97 The RAIB investigated the derailment of a passenger train on a track buckle at Cummersdale in Cumbria on 1 June 2009 (RAIB report 06/2010). There were some similarities in that it occurred on a day with the highest air temperature of the year to date, the site was not designated as a 'hot weather' site and there were workload pressures on other remedial work which led to a loss of focus on preparing for the impending hot weather. However, the causes of the track buckle were different in that there had been recent track disturbance, the site had jointed track and the CRT was affected by rail creep. The recommendations from that investigation are therefore not relevant to this accident.

Staffing levels

98 In September 2014 the RAIB wrote to Network Rail about a recurring theme in its investigations relating to staffing levels in its maintenance organisation and high workload. The RAIB drew Network Rail's attention to the potential for these to be a causal factor in accidents in the future. The RAIB subsequently found in its investigation of a derailment at Heworth (RAIB report 16/2015) that unfilled vacancies in Network Rail's local maintenance function and associated high workloads were an underlying factor.

Summary of conclusions

Immediate cause

99 Train 6E54 encountered a track buckle which derailed wagons 11 to 20 (**paragraph 40**).

Causal factors

100 The causal factors were:

a. the track started to buckle when the rail temperature in the vicinity of 101B points exceeded its buckling temperature because:

i. it was the hottest day of the year to date (**paragraph 48, no recommendation**);

ii. there was insufficient ballast at the toe of 101B points to laterally restrain the track from buckling (**paragraph 52, Recommendations 2 and 4**;

iii. there was a pre-existing lateral misalignment in the area of 101B points which promoted the formation of a track buckle (**paragraph 59, Recommendation 2**;

iv. the stress free temperature of the rails was probably less than the 27°C recorded in Network Rail's stressing database (**paragraph 65, Recommendation 1**); and

b. a long freight train ran over the buckle at too high a speed for the vulnerable condition of the track (**paragraph 69, Recommendation 2**).

Underlying factors

101 The underlying factors were:

a. There was insufficient appreciation of the factors affecting the CRT of the site and its vulnerability to hot weather (**paragraph 81, Recommendations 2 and 4**).

b. Maintenance work was continually reprioritised or cancelled because the Lincoln maintenance depot was under-resourced (**paragraph 83, Recommendation 3**). This was a possible underlying factor.

Additional observations

102 Although not linked to the accident on 30 June 2015, the RAIB observes that the process specified in Network Rail's company standard on adjustment switches for achieving the requisite torque tightness of clamp plate bolts was unreliable in terms of achieving uniformity of bolt clamping load due to damage to the washers (**paragraph 94, Learning point 2**).

Actions already taken

103 The Welton switches and crossings, and the associated adjustment switches on the down main line, were removed as part of the reinstatement of the track. Network Rail is currently pursuing a proposal to make this a permanent arrangement.

Learning points

104 The RAIB has identified the following key learning points[14]:

1 it is important to complete accurate stressing records for all maintenance interventions with the potential to affect the CRT of the track and to investigate any unexpected or anomalous behaviour of the rails when restoring stress, so that sound decisions can be made about the vulnerability of the track to hot weather (paragraph 68); and

2 it is important to check the integrity of spring washers when maintaining adjustment switches to ensure that the clamp plate bolts are properly secured (paragraph 94).

[14] '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

105 The following recommendations are made[15]:

1 *The intent of this recommendation is for Network Rail to improve the reliability and accuracy of the stress free temperatures recorded in its database of rail stresses as a key element of its strategy for the prevention of track buckles.*

Network Rail should:

a. review its guidance to maintainers on the circumstances in which:
   - a re-measurement of stress free temperature; or
   - the re-stressing of rails to a stress free temperature of 27°C, is considered appropriate.

   The review should include an assessment of whether sufficient account is taken of factors not explicitly covered by the standard currently, such as the difficulty of maintaining stress in short sections of plain line between abutting switch toes or the nature of any maintenance work carried out, which can affect the buckling resistance of vulnerable track; and

b. develop a programme to deliver any actions arising from the review, including amendments to standards and early rebriefing of track maintenance staff, to meet the intent of the recommendation (paragraphs 100a.iv and 101a).

continued

[15] 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.govuk/raib.

2 *The intent of this recommendation is to reduce the risk of track buckles by enabling the consistent application of Network Rail's procedure for the calculation of critical rail temperatures, with sufficient account taken of all relevant factors.*

Network Rail should:

a. assess whether the descriptors of ballast shortage conditions in its current standards and guidance require further clarification to enable consistent calculation of critical rail temperatures. The review should also include an evaluation of whether additional allowances should be made for combinations of conditions, such as localised ballast shortage in switches and crossings (particularly around point motor bearers), sub-intervention level misalignments and any maintenance that could have affected the stress free temperature; and

b. develop a programme to deliver any actions arising from the review, including amendments to standards and rebriefing of track maintenance staff, to meet the intent of the recommendation (paragraphs 100a.ii, 100a.iii, 100b and 101a).

3 *The intent of this recommendation is to ensure that there are sufficient resources available to Lincoln depot to manage the risks from track buckling.*

Network Rail should review the Ellipse track maintenance workbank for the area covered by its Lincoln depot to ascertain the adequacy of resources to prepare the track for hot weather, taking account of the overall workload and the level of resources assessed as required in its 'Phase 2BC' reorganisation, and then implement a plan to manage any shortfall (paragraph 101b).

4 *The intent of this recommendation is to ensure that there is a robust process in place at Lincoln depot for reprioritising work orders relating to hot weather preparation so that the mitigation of any associated risks is appropriately managed.*

Network Rail should examine the process of managerial oversight of the reprioritisation and cancellation of work orders at its Lincoln depot assure itself that these are being undertaken in accordance with company procedures, that the decision-making processes are technically sound and risk based and, where necessary, any interim mitigation measures are put in place (paragraph 101b).

This recommendation may have wider application within Network Rail's maintenance functions.

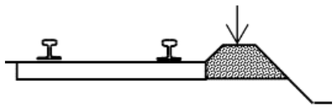
Appendices

Appendix A - Glossary of abbreviations and acronyms

CRT	Critical rail temperature
CRT(W)	Critical rail temperature (Watchman)
CWR	Continuous welded rail
EMT	East Midlands Trains
PTO	Principal technical officer
SFT	Stress free temperature
SM(T)	Section manager (track)
TME	Track maintenance engineer

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.

Ballast	Crushed stone that is used to provide lateral and longitudinal track stability, to maintain the track to line and level, to spread the load on the formation and to permit the dispersal of water.
Ballast shoulder	The ballast placed at the ends of the sleepers, timbers or bearers to give lateral stability to the track.* 
Cess	The area along the side of a railway track.
Continuous welded rail	A rail of length normally greater than 36.576 metres (120') produced by welding together standard rails or track constructed from such rails.
Crossing	An assembly that permits the passage of wheel flanges across other rails where tracks intersect.*
Crossing nose	A vee-shaped track component located where two rails intersect.
CRT register	A register of all sites that are vulnerable in hot weather and for which site-specific critical rail temperatures have been calculated.
Down main	The name given to a line when there is only one down line and one up line. A down line normally conveys trains away from London, or towards the highest mileage (ie towards Lincoln in this case).
Ellipse	A computer based asset management system used by Network Rail to record and prioritise what maintenance is work required to be done and when it needs to be done by.
Flange	The extended portion of a rail wheel that provides it with directional guidance.*
Fishplate	Specially cast or forged steel plates used in pairs to join two rails at a fishplated rail joint. Two, four or six fishbolts are used through the fishplates and rail ends to secure the fishplates to the rail ends.
Gabion	A wire mesh basket filled with broken stone or rubble, used as an efficient but plain reinforcing or retaining structure for earthworks*.
Plain line	Track without switches and crossings (S&C).*
Points	An assembly of switches and crossings (S&C) designed to divert trains from one line to another.* (See also switch and crossing.)

Rail tensors	An assembly consisting of a pair of hydraulic rams and special rail clamps that between them are capable of producing up to 690kN of tensile force across a gap in the rail. They are used to achieve the desired stress free temperature in the rail when the actual rail temperature is lower.*
RSSB	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'.
Section manager (Track)	The local Network Rail manager directly responsible for managing teams of track maintenance staff.
Six-foot	The area between the tracks of a double track railway line.
Sleeper (bearer)	A beam made of wood, pre- or post-tensioned reinforced concrete or steel placed at regular intervals at right angles to and under the rails. Their purpose is to support the rails and to ensure that the correct distance is maintained between the rails.*
Switch (may also be referred to as a set of switches or points)	An assembly of two movable rails (the switch rails) and two fixed rails (the stock rails) and other components (baseplates, bolts, soleplates, stress transfer blocks and stretcher bars) used to divert vehicles from one track to another.
Tamping	The operation of lifting the track and simultaneously consolidating the ballast beneath the sleepers.*
Toe (switch)	The movable end of a switch rail.*
Track maintenance engineer	The Network Rail manager responsible for the delivery of track maintenance, and the line management of the Track Section Managers, within a defined area.
Up main	The name given to a line when there is only one up line and one down line. An up line normally conveys trains towards London, or towards the lowest mileage (ie towards New Holland in this case).
Watchman	A person (male or female) appointed to monitor the track when the rail temperature exceeds the CRT(W). The person is equipped and competent to block the line in an emergency.

Appendix C - Investigation details

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

- information provided by witnesses;
- information taken from the train's on-train data recorder;
- CCTV recordings taken from the previous train and from the track recording train;
- site photographs and measurements;
- weather data from nearby weather station, weather reports and observations at the site;
- a forensic examination report of the adjustment switches commissioned by the RAIB;
- Network Rail maintenance, stressing and inspection records;
- Network Rail company standards;
- locomotive and vehicle maintenance records;
- survey of derailed vehicles and wheel measurements;
- voice recordings of contacts with the signaller; and
- a review of previous RAIB investigations relevant to this accident.

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

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