RAIB

Rail Accident Investigation Branch

Rail Accident Report

Derailment at Ely Dock junction
22 June 2007

Department for Transport

Report 02/2009
January 2009

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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Contents

Introduction

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents and improve railway safety.

2 The RAIB does not establish blame, liability or carry out prosecutions.

3 Access was freely given by Network Rail, Wabtec, Lafarge and English Welsh and Scottish Railways to their staff, data and records in connection with the investigation.

4 There are appendices at the rear of this report which contain the following:

- acronyms and abbreviations are explained in Appendix A;
- technical terms (shown in italics the first time they appear in the report) are explained in Appendix B;
- key standards at the time of the incident and reference material are listed in Appendix C;
- diagrams of the Gloucester *pedestal* suspension are included in Appendix D;
- aerial images of the derailment site are included in Appendix E;
- an explanation of the '*wheelchex*' system is contained in Appendix F;
- text from *national incident report*s relevant to this incident is reproduced in Appendix G; and
- historical incidents relating to *PHA* wagons from 1990 to 2008 are included in Appendix H.

5 All references to left and right are made facing the direction of travel of the derailed train.

Summary of the report

Key facts about the accident

6 At 02:00 hrs on 22 June 2007 wagon REDA16002, the 15th wagon in train 6L58, the 21:19 hrs Mountsorrel to Chelmsford, derailed on the approach to underbridge 2235 near Ely (Figure 1). The derailed wagon was dragged onto the bridge, where it, and other wagons that subsequently derailed, caused considerable damage to the structure. The railway was closed for six months, and the River Great Ouse for three months, which caused significant disruption to the local community and tourism in the area. There were no casualties in the derailment.

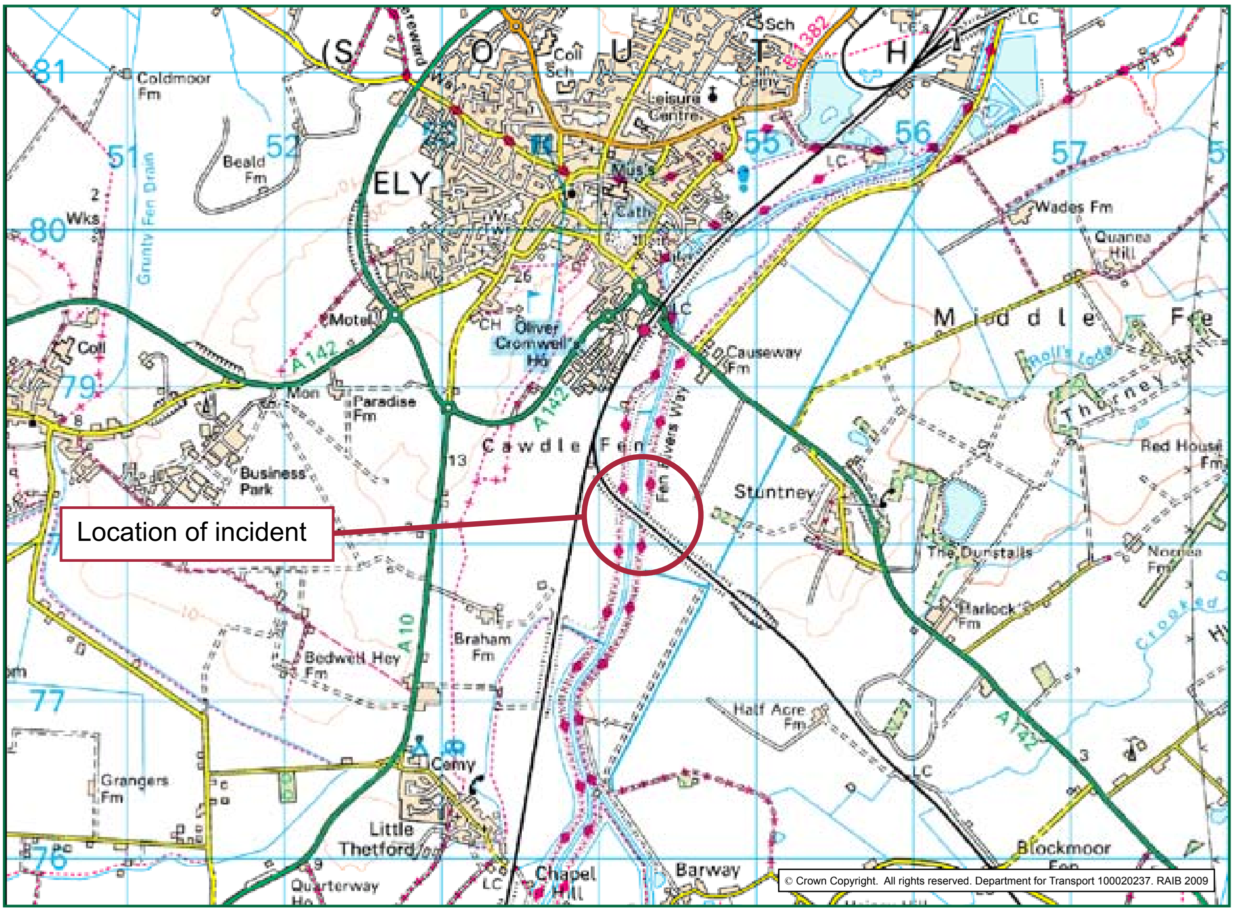


Figure 1: Location of incident shown on bridge 2235 near Ely, Cambridgeshire

Immediate cause, causal and contributory factors, underlying causes

7 The immediate cause of the incident was the right hand leading wheel *flange* on wagon REDA 16002 running over the rail head in the vicinity of Hawks *user worked crossing*. Due to the suspension locking up the guiding forces from this flange were insufficient to keep the wagon on the track as it rounded the curve. The low vertical load from the wheel resulted in very light marks on the rail head as the wheel flange ran across it.

8 Causal factors were:

- The frictional characteristics of the GFA suspension caused irregular wear and a misalignment to take place between the friction liners and lateral guides of the axle pedestal and the suspension *saddle*. This generated a frictional lock-up of the right leading suspension.
- The frame of wagon REDA 16002 had a twist of approximately 20 mm before the derailment, and wrongly placed compensatory *packing* present above the leading left and trailing right *axle boxes*. The wrongly placed packing compounded the twist effect, creating an effective twist of 40 mm, significantly greater than the 6 mm prescribed limit for twist.
- A *track twist* of 1 in 222 existed immediately before the *point of derailment*. This is outside the maintenance limits and within intervention limits but not so severe as to require attention within 14 days (see paragraph 109 for further explanation).
- *Tamping* that had been intended for the week before the derailment did not take place.
- English Welsh & Scottish Railway, Wabtec, Lafarge, and Network Rail did not identify *frame twist* features and a lack of corrective maintenance during an investigation into a previous derailment involving the wagons that were subsequently involved in the Ely incident.

9 The underlying causes were:

- Network Rail and the Freight operators did not recognise the ability of the Wheelchex system to be capable of preventative or reactive data processing in identifying wagon deficiencies relating to diagonally imbalanced wheel loads;
- British Rail (BR), English Welsh & Scottish Railway and later other companies within the Freight Industry had not regularly monitored vehicles for frame twist since 1992;
- Improvement options from a research report relating to the effects of contamination on the pedestal suspension assemblies were neither published nor implemented within the *Private Wagon Registration Agreement*; and
- The omission of a mandatory requirement to complete a measured frame twist check within PPM and BR 11188 is an underlying cause of the incident.

Severity of consequences

10 The closure of the railway line, and of the river Great Ouse, caused environmental, social and economic problems to the surrounding area and for local businesses. The land surrounding the river was contaminated with oil and grease residues from the damaged and derailed wagons. Bridge debris was removed from the river bed and embankments.

Recommendations

11 Recommendations can be found in paragraph 395. They relate to the following areas:

- the assessment of frame twist as a component of the maintenance of two axle wagons;
- the use of existing Wheelchex installations to reduce the operational risk to the rail network; and
- further research to fully understand the frictional characteristics of Gloucester Floating Axle (GFA) pedestal suspension.

The Accident

Summary of the accident

12 On 21 June 2007 the 21:19 hrs 6L58 Mountsorrel to Chelmsford freight train comprising a locomotive and 36 wagons left the Lafarge Quarry Railhead, near Mountsorrel, at 23:07 hrs. The delay was caused by staff having to deal with another train before they could load train 6L58.

13 Shortly after 01:55 hrs on 22 June 2007 the train ran through Ely station and onto the single track Soham branch line at Ely Dock Junction. The train was travelling at 16 - 17 mph (25 - 27 km/h) as the locomotive approached bridge No. 2235 over the River Great Ouse (Figure 2), with the rear part of the train still on a left-hand curve. At this point the right hand leading wheel flange of wagon REDA16002, the 15th wagon in the train, climbed the outer *high rail*, causing the wagon to derail. The derailment occurred on *plain line*.

14 At around 01:59 hrs, according to the locomotive's On Train Data Recorder (OTDR), the train lost *brake pipe* pressure caused by a breakage in the train air brake pipe. This caused the train's brakes to apply automatically and the train stopped. The locomotive was then a short distance to the east of the bridge and the front part of the train had crossed the bridge over the River Great Ouse. The driver investigated and discovered that the locomotive and first twelve wagons were all correct, but that a number of wagons had derailed on and around the bridge and the rear of the train appeared to be unaffected.

15 The line was blocked in both directions, and remained closed for all trains until the bridge was reconstructed. Services resumed on 21 December 2007.

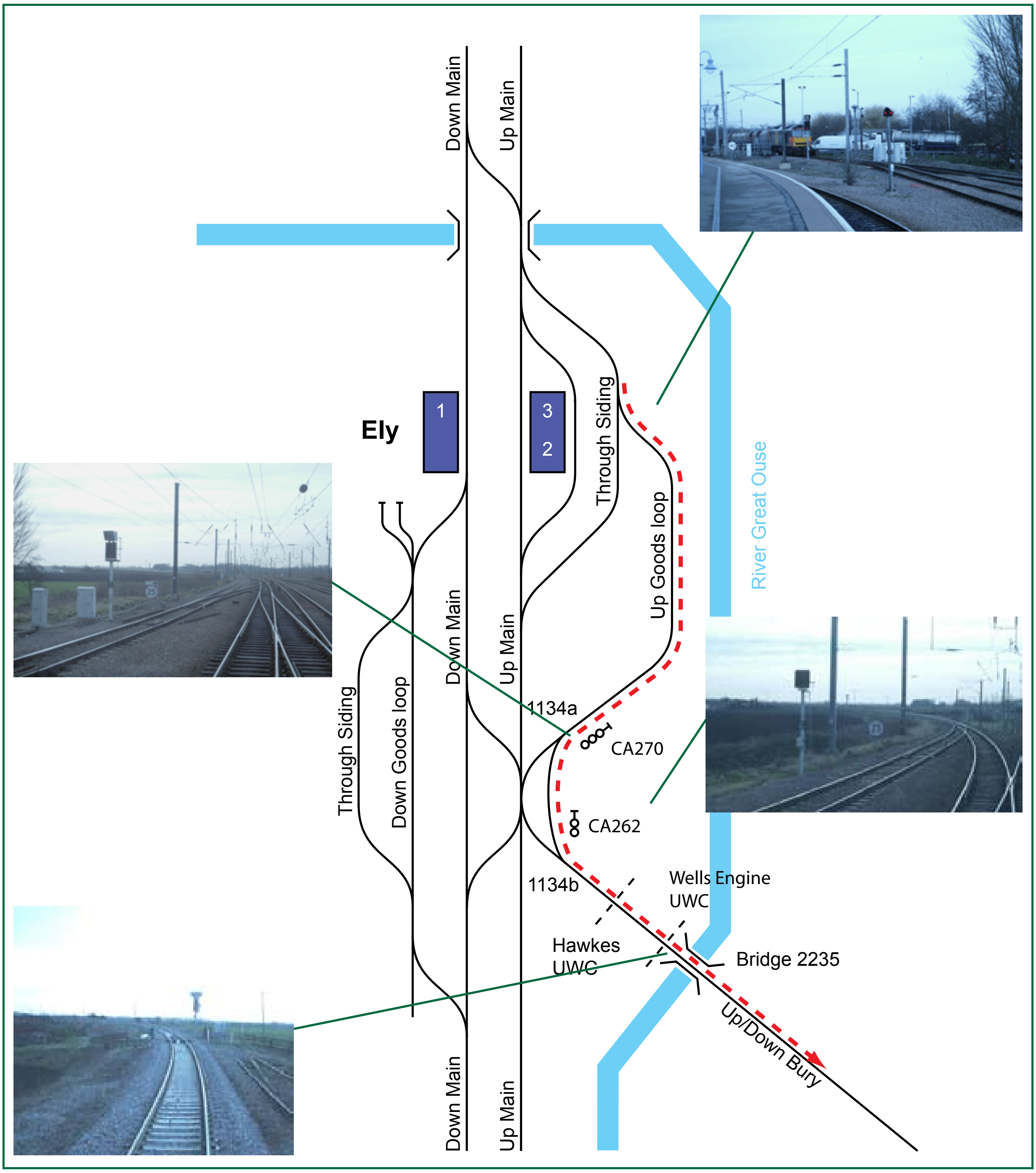


Figure 2. Plan showing signals passed by the train in the Ely area, and incorporating images of the route

The parties involved

16 The locomotive is owned and operated by English Welsh & Scottish Railway (now trading as D B Schenker).

17 The infrastructure is owned, operated, and maintained by Network Rail.

18 Lafarge Aggregates Limited own and operate the quarry and loading point at Mountsorrel, Leicestershire, from where train 6L58 started its journey. They also own the KJA *self-discharge* unit and the PHA wagons in the train (Figures 3 to 5).

19 The KJA self-discharge unit and PHA wagons were maintained jointly by Marcroft and Rail Freight Services (now Wabtec) between 1988 and 1998 and solely by Wabtec after 1998.

Location

20 Ely Station in Cambridgeshire is located on the London Liverpool Street to Kings Lynn route, some 70 miles (112 km) from London Liverpool Street. Ely Dock Junction is located south of Ely Station where the branch line diverges in a south easterly direction to Soham and Bury St Edmunds. A diagram of the track is shown in Figure 2. Mileages on this route are measured from a datum at the site of Snailwell Junction, on the outskirts of Newmarket.

21 The initial point of derailment was at 12 miles 19 *chains*. This was a short distance from Hawks user worked crossing (12 miles 17 chains), and between Ely Dock Junction (12 miles 33 chains) and bridge 2235 (11 miles 76 chains).

External circumstances

22 The loading of the wagons on 21 June at Mountsorrel took place during the hours of darkness and in heavy rain, which may have affected the extent to which it was possible to undertake visual inspection of the load distribution within the wagons.

23 The weather at the time of derailment, in the early hours of 22 June, was damp from the previous evening's rain fall. It had no bearing on the vehicle dynamics, the incident itself or the response to the incident.

24 The area around bridge 2235 is rural with no ambient artificial light.

The Infrastructure

25 The track from Ely Dock Junction towards bridge 2235 is on a left-hand canted curve with a minimum radius of 329 metres. The line rises from the junction on a 1 in 128 gradient to the 12 mile post and then descends on a 1 in 118 gradient towards bridge 2235. The line is built on a low embankment, which sits on a flood plain.

26 The permitted line speed for the branch line is 50 mph (80 km/h) for passenger trains and 40 mph (64 km/h) for freight trains. However, there was a 20 mph (32 km/h) speed restriction for heavy axle-weight vehicles over bridge 2235, which applied to train 6L58.

27 The method of signalling is *track circuit block* controlled by Cambridge Power Signal Box (PSB).

28 The track at the point of derailment was laid in 1999 - 2000 with 113 lb/yd flat-bottomed continuous welded rail (CWR) manufactured in 1999. The track is canted by 86 mm to 109 mm with the right hand side rail high.

29 The bridge consisted of five spans with the main *span* crossing the river and two side spans on each side crossing the flood plain. The side spans each consisted of three wrought iron main girders with wrought iron and steel cross girders. The main span across the river consisted of a pair of wrought iron truss main girders supporting steel cross girders of double track width. The rails across all spans were directly fastened to timber way beams which were supported by the cross girders. Timber *transoms* were used to space the way beams and maintain track *gauge*. The bridge was built for double track but only a single track was installed.

30 A wheel monitoring system known as Wheelchex (see Appendix F) is located at Eastrea, between Peterborough and Ely. This was approximately 23 miles from Ely Dock Junction on the route used by train 6L58.

The Train

31 Train 6L58 was formed of a Class 60 diesel-electric locomotive, number 60068, hauling a KJA bogie self-discharge vehicle followed by 35 PHA *hopper* wagons in three ten-wagon sets and one five-wagon set.

32 The authorised maximum weight of train 6L58 was 2430 tonnes, and the total weight recorded on the *Total Operations Processing System* (TOPS) was 1941 tonnes, including the payload of 1287.6 tonnes. This figure was also recorded on the train's '*order to move*' slip which is used to input data onto the TOPS system. (paragraph 48).

33 The *route availability* of the train was RA 10, and its maximum permitted speed was 60 mph (96 km/h).

34 The PHA wagons were introduced in the 1980s to facilitate the transfer of ballast and other aggregates to other railheads and from wagon to wagon or wagon to track. The KJA wagon dates from the same time, and is designed to make the transfers by a conveyor arm. Prior to the derailment there were 120 PHA vehicles and 4 KJA discharge vehicles operating on Network Rail infrastructure (Figures 3 to 5).

Figure 3: PHA/REDA type wagon

35 The PHA wagon is a rigid two axle vehicle with a conveyer belt running the length of the wagon set (paragraph 37) below the hopper of each vehicle. The design gives the vehicle a higher than usual centre of gravity for an aggregate hopper wagon

Figure 4: REDA coupling arrangement

Figure 5: Self-discharge train incorporating the off-load wagon showing the conveyer belt arrangement

36 Powell Duffryn & Standard Wagon Company built the PHA type wagons for the self-discharge train (SDT). The SDT is predominantly used for the transfer of aggregate between Lafarge sites, track renewal, track replacement and earthworks, as the aggregate can be unloaded at any site immediately adjacent to the track. English Welsh & Scottish Railway currently owns the design rights to the wagon. The wagons were supplied to Redlands Aggregate Limited in 1988, which was purchased by Lafarge in 1997. The PHA wagon's suspension system was manufactured by the Gloucester Railway Carriage and Wagon Company in 1987 and is known as a Mark 4 Floating Axle Suspension.

37 PHA wagons have a rigid frame with two sole bars, additional longitudinal beams and *cross members*. Each has a wheelbase of 4775 mm and can operate on a minimum curve radius of 170 metres (the curve on the approach to the bridge had a radius of 329 metres). Each wagon has a *tare* weight of approximately 12 or up to 16.25 tonnes if the wagon incorporates a drive motor for the discharge belt. The permitted *gross-laden weight* of the wagon is 51 tonnes (25.5 Tonnes on each axle). This allows a 38 or 39 tonne payload depending on the wagon type. The wagons are semi-permanently coupled in sets of five or ten wagons, using bar couplings. Each set measures approximately 42 or 82 metres in length respectively. The sets are fitted with side buffers to the outer wagons, and can be coupled to other sets or locomotives by screw and link couplings.

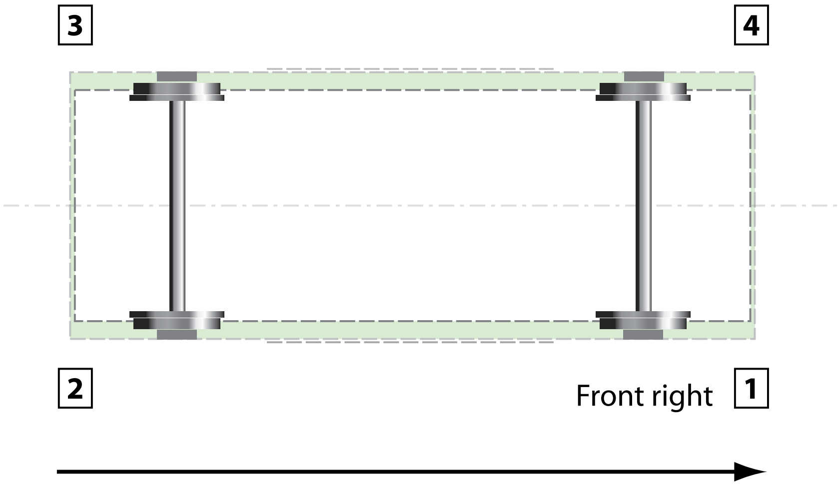


Figure 6: Plan view of PHA wagon with front right and left axle 1 - 4 and rear axle 2 - 3

38 The wagons are marked in accordance with the British Rail (BR) standards at the time of manufacture and which are still currently used (POCL 564, POCL 484 version 1 and BR 11888 'Regulations for repairing privately owned wagons running on British Railways). This includes:

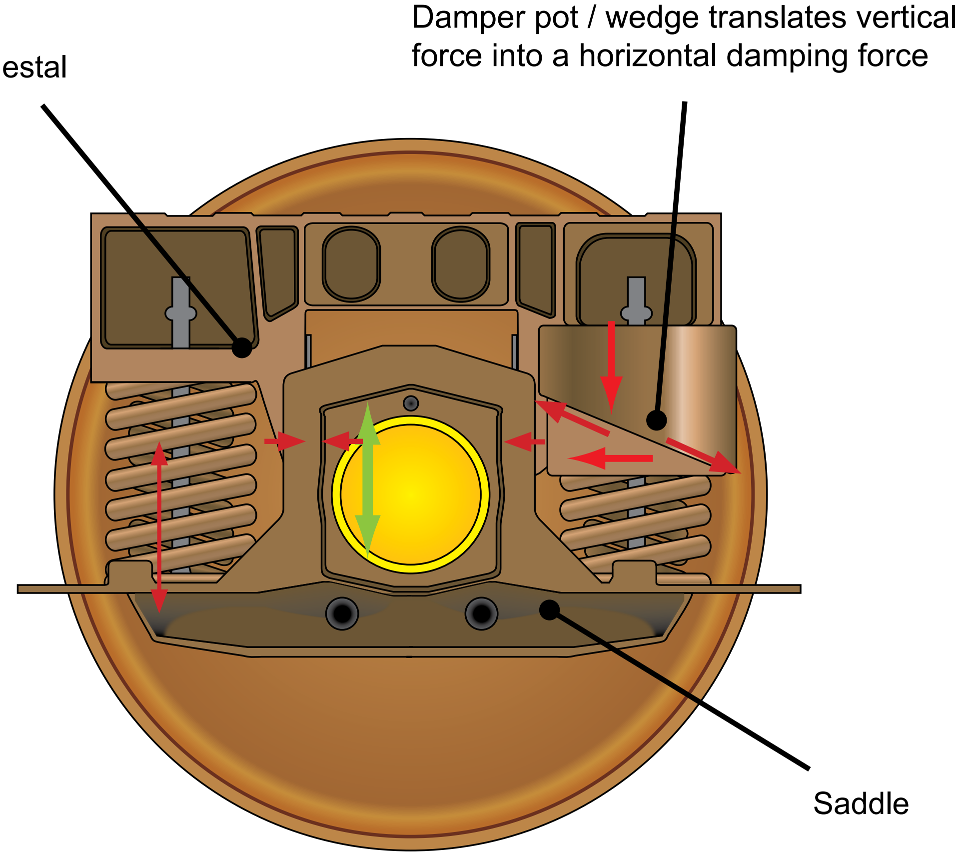
- dependant on the direction of travel, the corners are marked from 1 to 4 (front leading right corner in a clockwise direction around to corner 4 at the front left side);
- vehicle livery markings including the company name;
- latest *vehicle inspection* date, maintenance location and date;
- laden and unladen weights; and
- packing dimensions from any frame twist remedial work.

Gloucester Suspension

39 The Mark 4 pedestal suspension unit has an *axle horn guide* (also known as a pedestal) bolted to the underside of the frame. A saddle sits on the axle bearing.

40 The saddle supports primary, secondary and inner top hat or 'cup' springs. The spring arrangement is fixed with a retaining pin commonly known as an '*anti separation pin*' running through the centre.

41 The weight from the payload acts upon a pair of wedges between the pedestal and saddle damper pot which converts the downwards force into a horizontal force. The horizontal force pushes the damper pad between the pedestal and the saddle friction liners. The *damping* force thus changes according to the load (as shown in Figures 7, 40 and Appendix D).



Figures 7: GFA suspension showing damping forces of pedestal and saddle

Events preceding the accident

42 Soham branch line had been used by numerous freight and passenger services on the 21 June 2007; previous two trains were the 22:05 hrs Peterborough – Colchester passenger train, which passed Ely Dock Junction at 22:40 hrs, and the 15:45 hrs Wilton - Felixstowe freight train, which passed at 23:05 hrs. No irregular or relevant incidents were reported on this section of track by any train drivers on 21 June 2007.

43 On the night of 21 June 2007, English Welsh & Scottish Railway *ground staff* at Mountsorrel met the driver working 6L58 and advised him the train was not ready as the wagons had not been loaded. Lafarge staff were not able to start the loading of the train until a previous train had departed.

44 After the preceding train had left, Lafarge staff loaded 6L58 through No. 2 siding with mixed aggregate consisting of stone, ballast and dust. Neither Lafarge nor English Welsh & Scottish Railway staff checked whether there was any residual ballast in each wagon before loading train 6L58, nor was the load distribution checked after loading. The overhead gantry walkway is the only location where this can be checked as there is no ladder on the PHA wagons to permit examination of the wagon contents

45 The operator of the loading plant entered the details of the wagon loads onto the 'order to move' slip which is used to input details of the train and loads onto TOPS. The details were written onto the form as the computer system had failed. The figures that he entered were mainly a constant 37.5 tonnes based upon the average maximum load, excluding the weight of the wagon. He handed the list to English Welsh & Scottish Railway ground staff to prepare the train for dispatch.

46 The English Welsh & Scottish Railway ground staff completed a functional brake test, and checked that there were no problems with the handbrakes, buffers, springs, and suspension or discharge doors on the wagons. They confirmed that all was in order to the driver, and handed him the order to move slip. They then told him to draw up to the signal controlling the outlet to the main line, and to contact the signaller for authority to leave the depot. The English Welsh & Scottish Railway ground staff observed each wagon as the train passed to ensure all appeared in order in accordance with the English Welsh & Scottish Railway company procedures (paragraph 234).

47 Train 6L58 left Mountsorrel depot almost two hours late, at 23:07 hrs. The train made its way to Peterborough via Nottingham without incident. On arrival at Peterborough there was a change of driver, and the train departed at 00:05 hrs on 22 June 2007, 100 minutes behind schedule.

48 Train 6L58 passed through Eastrea wheelchex site at 01:16 hrs and March at 01:29 hrs.

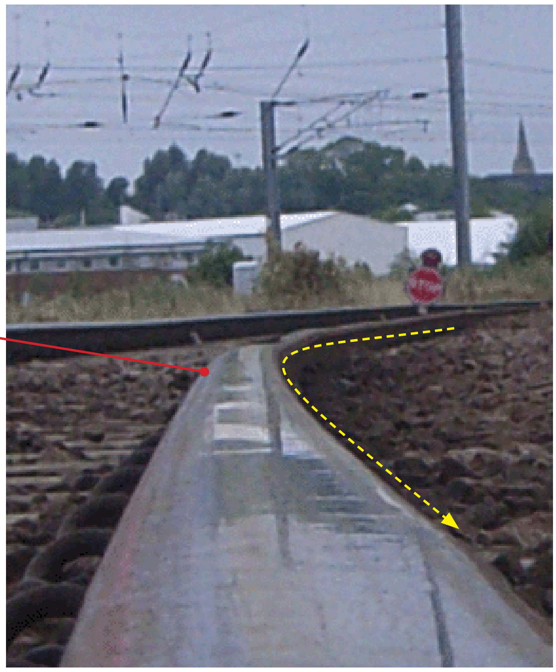
49 Just after 01:55 hrs the train passed through Ely Station via the goods *loop* as there was tamping work in progress on the main line. The train passed over the *automatic warning system* (AWS) magnet for signal CA270, which controls the exit from the goods loop, at approximately 8 -10 mph (12-16 km/h). As the train approached signal CA 262, the signal aspect changed from red to green with the *route indicator* for Soham displayed.

50 The train driver maintained a speed of 8 - 10 mph (12 - 16 km/h) until the train had diverged onto the Soham and Ipswich branch and he then overcharged the brake system to ensure the brakes were released, slowly increasing the speed of the train for the uphill gradient to bridge 2235.

51 The train was running at approximately 16 - 17 mph (25 - 27 km/h) as it rounded the curve to bridge 2235, which had a speed limit of 20 mph for train 6L58 (paragraph 26).

Events during the accident

52 As the train climbed the gradient the leading right hand wheel of the 15th wagon, REDA 16002, derailed by climbing over the right hand (high) rail at 12 miles 19 chains. This took place shortly before 01:59 hrs. The reasons why it is clear that wagon REDA 16002 was first to derail are explained in paragraph 146.



Figures 8 (left) showing view of track towards Ely with right high rail on left and low left rail on right. Figure 9 (right) view of track towards Ely showing low left rail (foreground) and high right rail (background) at the point of derailment

53 The wagon ran in a derailed condition through Hawks UWC and towards bridge 2235, a distance of approximately 460 metres.

54 The KJA discharge vehicle and the first 13 PHA wagons passed over bridge 2235 onto the Soham side and were undamaged, although the rear *wheelset* of wagon 16000, the 13th wagon, was derailed (paragraph 57).

55 As the derailed wagon REDA 16002 ran onto the first span of the bridge, travelling at 18 - 19 mph (28 - 30 km/h), the leading right pedestal and saddle of the wagon collided with the right hand longitudinal girder and deformed the central main girder on the bridge. The front wheels smashed through the way beam and decking, dropping onto the first pier of the bridge. This caused the leading left and right suspension saddles of REDA 16002 to become detached from the wheelset as the wagon continued across the bridge. The wheelset continued to travel a short distance finally coming to rest on the bridge decking.

56 The right hand suspension saddle of wagon REDA 16002 became lodged in the lattice framework of the right hand longitudinal girder. The left hand saddle was forced through the timber way beam and decking and onto the first masonry span. Wagon REDA 16002 veered onto its left side, the wagon body sliding along and destroying the main left girder of the bridge.

57 The weight of the 15th wagon running derailed caused the 14th wagon, REDA 16001, to topple onto its left side and the 13th wagon to derail its trailing wheel set. The 16th to 21st wagons also toppled over onto their left side in the same direction as wagon REDA 16002 as they reached the damaged bridge. They continued to slide, losing their payload, wheel sets and suspension components in the process. The derailment and wagon trajectories resulted in the bridge being catastrophically damaged.

58 The 22nd to 25th wagons derailed and remained upright, having come to a stand on the Ely side of the bridge. These wagons only suffered superficial damage. Suspension components, wagon payload (aggregate), timber and bridge debris dropped into the River Great Ouse.

59 The 26th to 35th wagons had not reached the bridge area and remained upright, undamaged and on the rails.

60 The driver had the cab window open, but did not hear or see anything unusual as the locomotive crossed bridge 2235. After crossing bridge 2235, he observed an initial flicker on the brake pipe pressure gauge, which at the time registered 5 bar pressure. When the locomotive was approximately 9 - 12 metres beyond the bridge the driver again observed a flicker of movement on the gauge. The brake pipe pressure then instantly fell from 5.0 bar pressure to zero causing an immediate brake application. This was recorded on the OTDR at approximately 01:59 hrs. At this time the train was travelling at 15.2 mph (24 km/h) (Figure 10).

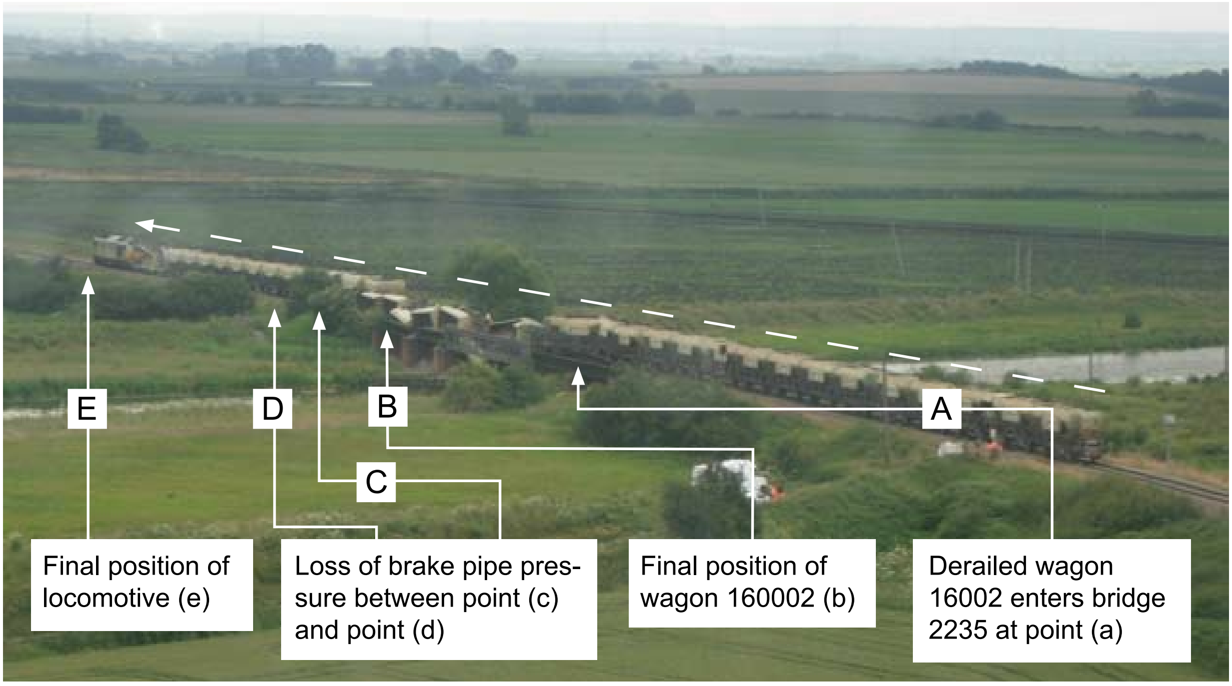


Figure 10: Image showing final position of train 6L58 on bridge 2235 (aerial images are shown at appendix E)

61 The driver applied the hand brake and straight air brake, and left the cab to inspect the train.

Events following the accident

62 The train driver walked back along the train to investigate. He intended to telephone the signaller to advise him of the situation when he had found out what had happened to the train. The driver passed under the coupling between the 13th and 14th wagons so as to inspect the incident from the other side of the train.

63 The driver observed that a number of wagons were lying on their sides over the bridge and that a large area of the bridge had been destroyed. He also noticed three detached wheel sets (Figures 11, 12 & 13).

Figure 11: View in direction of Ely showing 6L58 on bridge 2235

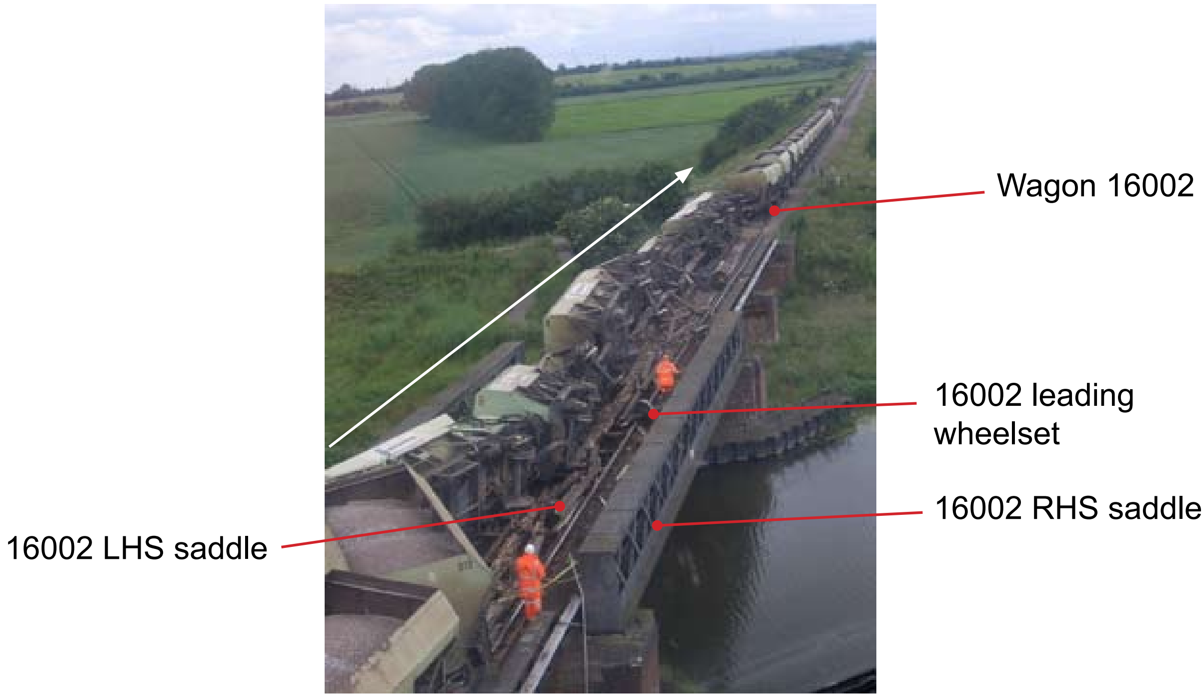


Figure 12: View of derailed wagons on bridge 2235

Figure 13: View of 6L58 on bridge 2235. Leading wheelset of 16002 can be seen on right with wagon REDA 16002 in background

64 Because of the unsafe condition of the site, the driver did not inspect the area further and contacted the English Welsh & Scottish Railway Control desk by mobile phone to ask for assistance. He returned to the locomotive cab and contacted the signaller at Cambridge PSB via the radio to ask for all emergency services to attend. He advised the signaller that he could not place protection at the back of the train as he was not able to safely cross the bridge. The Cambridge PSB had not been aware of any incident before the driver's phone call.

65 The local mobile operations manager (MOM) from Network Rail attended the site. The driver took photographs of the cab for the MOM. The driver at this time was suffering from shock and was given support by the MOM. Both went back to the Network Rail offices at Ely where the driver was interviewed and screened for drugs and alcohol in line with normal industry practice. No evidence of either substance was found.

Consequences of the accident

66 The driver was not physically injured.

67 Damage was caused to the infrastructure from the point of derailment and through Hawks and Wells Engine UWCs. Bridge 2235 was damaged beyond repair. The bridge and route was closed to rail traffic for 6 months.

68 As a result of the damage to bridge 2235 the River Great Ouse was closed to navigation for three months and only fully opened in December 2007.

The Investigation

Sources of evidence

69 The investigation obtained evidence from:

a. a detailed examination of the site and wagons;
b. the OTDR;
c. TOPS data;
d. wagon maintenance records;
e. a survey of the track and identification of the point of initial derailment;
f. a survey and weighing of the wagons in train 6L58 and subsequent vehicle modelling analysis;
g. a comparison of data obtained from the train with wheel imbalance data from the wheelchex system;
h. historical wheelchex data and wheelchex processes;
i. Lafarge processes for and records of loading at Mountsorrel Quarry;
j. Network Rail procedures and records for the inspection and maintenance of the track;
k. Network Rail procedures for investigating incidents;
l. Network Rail vehicle acceptance and strategy documents;
m. relevant records from Network Rail *track recording vehicles*;
n. British Rail Research Laboratory archive documents relating to ground borne vibration and contamination of GFA suspension assemblies;
o. Wabtec and Marcroft maintenance procedures and records for the wagons in train 6L58;
p. the Private Wagon Registration Agreement, and associated maintenance procedures;
q. interviews with witnesses;
r. English Welsh & Scottish Railway wagon maintenance procedures; and
s. English Welsh & Scottish Railway safety management documentation.

Key Facts

Mountsorrel Railhead

Computer system

70 The transfer of aggregate via a conveyer system from the quarry to the railhead terminal was introduced in 1984. A computer controlled delivery and loading system was introduced in 2004. There are two methods of loading wagons at Mountsorrel Railhead. One route is to load direct from the quarry onto a conveyor belt, via a weigh belt and a chute, to the wagon; the second sends the aggregate from the quarry via another belt to storage bins before the loading of the wagons. Train 6L58 was loaded directly by the conveyor belt from the quarry.

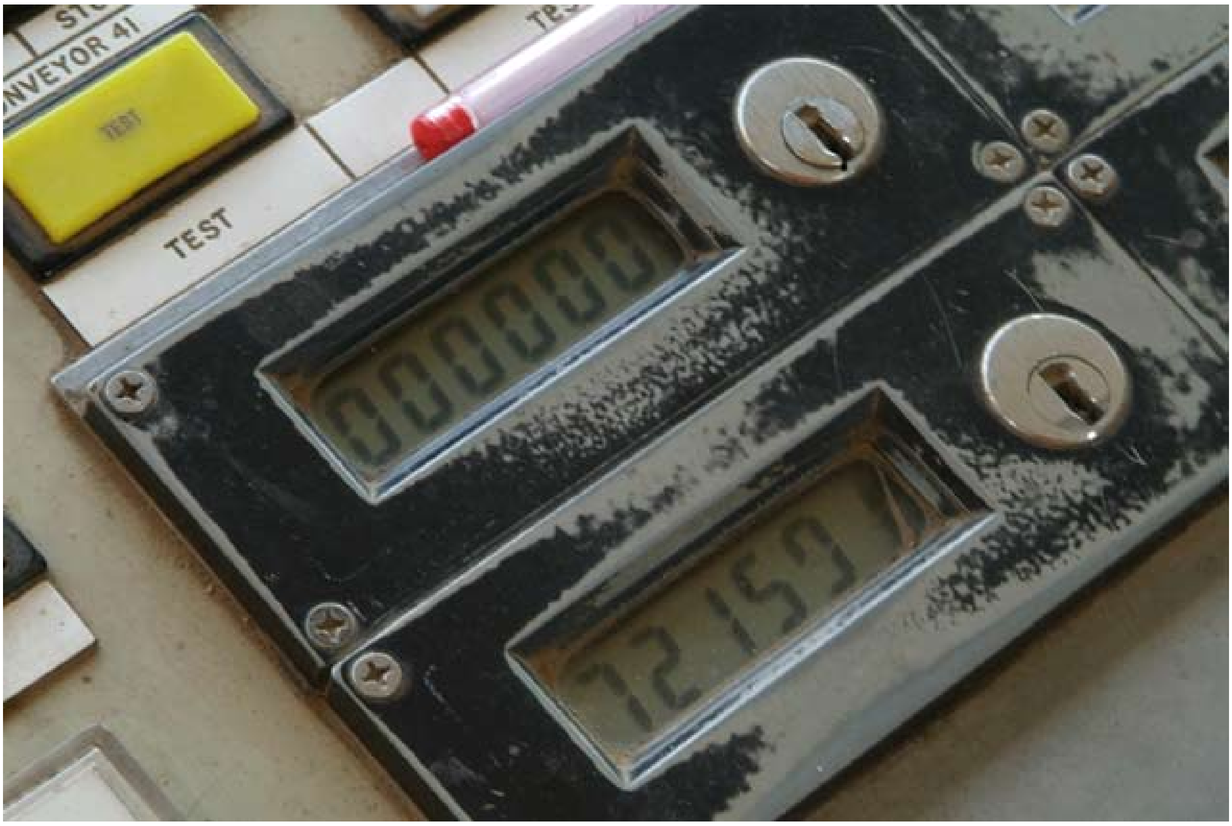


Figure 14: Digital counter as used at Mountsorrel

71 All material is requested in the form of tonnage, also known as a 'slug' of material. (e.g. 38 tonnes = 3 slugs).

72 Before the load is dropped into the wagons the weigh belt system records the batch weight requested for each wagon. The recorded data for each wagon is then printed for the English Welsh & Scottish Railway ground staff to enter the details onto TOPS.

73 The computer programme normally records the load data and produces a hard copy 'order to move' form. However, it had failed before the loading of train 6L58, so a manual method of using a digital counter (Figure 14) and writing the wagon weights on to the 'order to move' slip was used instead.

Figure 15: Control cabin at Mountsorrel

Figure 16: Loading system computer screen at Mountsorrel

74 The digital counter records the weight of the material on the weigh belt. It resets to zero to enable the next batch of material, or 'slug', to be weighed. The system operator writes the weight of stone deposited into each wagon onto the 'order to move form'.

75 The manual method required the operator to undertake several tasks at the same time or in quick succession (Figures 15 & 16). This included: manually entering the details onto the hardcopy TOPS paperwork; using a joystick to control the loading of the material into the wagon; and controlling the train's movement through the loading bay.

Figure 17: Image of loading bays at Mountsorrel

Loading

76 The material is discharged from the conveyer belt into the hopper, while the loading doors are closed (Figures 17 & 18). Due to different material flow rates and speed of door closing, the weight discharged may not be exactly what is requested. Lafarge state the variation should be within + /- 2.5% of the weight requested (0.9 tonnes). A request for 38.0 tonnes by the operator using the computer system should result in a load no greater than 38.9 tonnes going into the hopper.

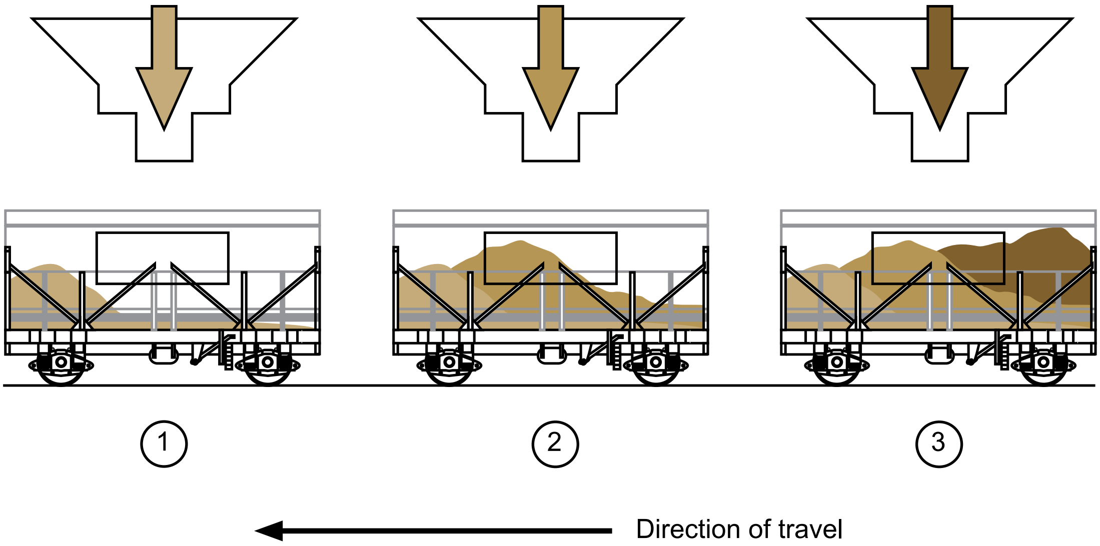


Figure 18: Diagram showing loading procedure and propensity to load wagons rear-axle-heavy

77 The loading of the wagon via the hopper doors is automatically triggered by the movement of the train. The loads are dropped into each wagon in three stages as the wagon slowly travels forward, hauled by a remote controlled locomotive under the control of the system operator.

78 As the wagon travels, the third load is deposited at the rear of the wagon. The dividers within the wagon are only partially effective as their purpose is to provide framework rigidity, so when the third slug enters the wagon part of the first and second slug has already spread towards the rear (Figure 18). This makes the wagon rear-axle-heavy unless the operator compensates for this as the load is dropped into the wagon or the peak loads are moved by hand by the English Welsh & Scottish Railway ground staff during their formal train preparation duties. There is no means of adjusting the position of the discharge to the left or right of the wagon, hence a load bias can exist to either side of the wagon (paragraphs 270 to 276).

79 At the time of the incident there were 10 second intervals between the loading of each slug.

80 Lafarge managers stated that staff were required to examine the wagons for residual load before loading. A 5% safety factor was included in the wagon payload to ensure the wagons were not above the maximum laden weight of 51 tonnes. However, no member of Lafarge operations staff was aware of this requirement.

81 During the investigation, the RAIB observed a wagon being sent for loading despite a residual load of 2 - 3 tonnes which was adhering to the rear wall of the wagon (Figure 19). This had not been checked before loading.

82 There was a weighbridge at the depot but it was not in use when train 6L58 was being prepared for departure on 21 June 2007.

Figure 19: Residual ballast in wagon REDA 16021

Knowledge and competency

83 Lafarge have stated that all of the loading operations team were verbally briefed on all system changes. Lafarge have also stated that they continually assess staff on their train loading capabilities, although these training processes were not formally documented and briefings were not recorded.

Maintenance and calibration of wagon loading

84 The load figures on the 'order to move' slip did not correspond to the loads found in the wagons that were weighed after the derailment.

85 Because of safety concerns on site at Ely the wagons which had retained their payload were not weighed in situ, but transferred to Peterborough and later to Mountsorrel. Tests were conducted at both locations. The incident and subsequent movement from the site may have affected the distribution of the aggregate payload within the wagon. Therefore any weight data for individual axle loads or differences in axle load may not fully reflect the load distribution before the incident, but the total weight is accurate.

86 Subject to the comments above, the tests confirmed that the trailing axle of each wagon carried a greater load. As an example, the total weight of wagon REDA 16055 was 53.7 tonnes; 29.4 tonnes were on the rear axle and 24.3 tonnes on the front, a difference of 5.1 tonnes. The total weight initially recorded by the Lafarge operator on the order to move slip was 48.4 tonnes. He subsequently amended this to 50.4 tonnes after the load had been dropped into the wagon (paragraph 275).

87 The total weight of wagon REDA 16056 was 51.4 tonnes; there were 29.7 tonnes on the rear axle and 21.7 tonnes on the front, a difference of 8.0 tonnes. The total weight initially recorded by the Lafarge operator on the order to move slip was 48.4 tonnes; this was amended to what was thought to be a correct 50.4 tonnes. Other wagons showed a similar pattern of load distribution.

88 Wagons that had been damaged and lost their payload could not be weighed. Details of known axle weights from the locomotive and KJA discharge vehicle were used as a reference to calculate the weights and axle loads of the whole train and to analyse the data from the Eastrea wheelchex site (paragraphs 128 to 133).

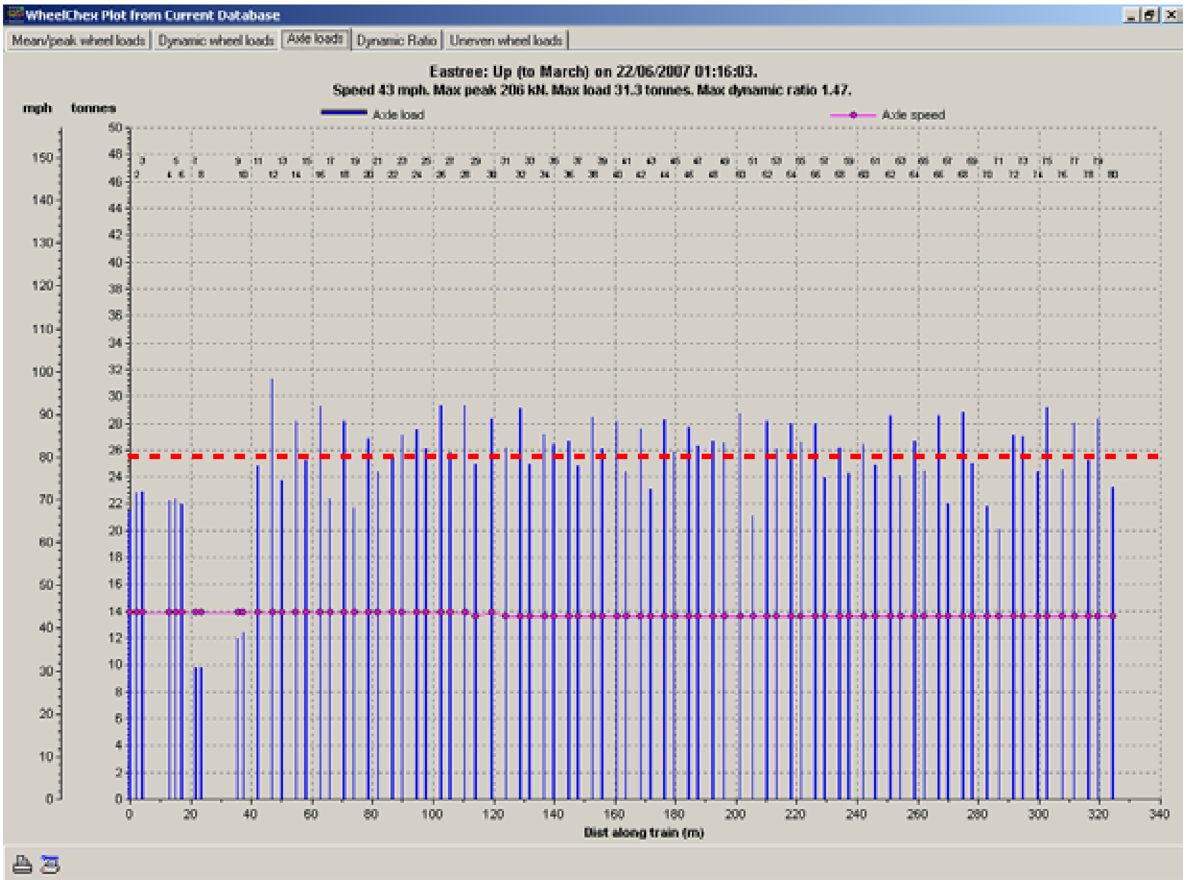


Figure 20: Data from Eastrea Wheelchex site showing axle load of 6L58. Data shows axle loads against datum line of maximum permitted tonnage on each axle (25.5 tonnes)

89 The weighing tests on the non-derailed wagons, and the data from Eastrea, showed that:

- most of the wagons were rear axle heavy;
- 55% of the wagons were between 0.29 and 4.84 tonnes above the data recorded on TOPS and 52% of the wagons which retained their load were above the 51.0 tonnes permitted;
- wagon weights on the written order to move documentation were not the same as the actual weights in the wagons (Figure 20).

90 The weigh belt had been calibrated in March 2007, and was shown as recording an average of +0.43% material weight over the three load requests recorded; this was within the permitted 2.5% tolerance.

Frictional lock-up during loading

91 Previous incidents and visual observations indicate that frictional lock-up of the GFA suspension can occur in a laden and unladen condition. The characteristic can also occur during loading, or in normal traffic or after the discharge of the payload.

92 The payload of the wagon produces a vertical downward force on the GFA suspension which is transmitted into a horizontal force by the damper pot and wedge on one side of the suspension acting on the mating surfaces of the axle and pedestal. The downward and horizontal force on the wedge and mating surfaces can be affected either individually or by a combination of payload distribution, contamination or condition of the track causing the suspension to momentarily stick or lock during service. A frictional lock-up prevents the suspension damping performing as designed and can generate a risk of derailment if the lock-up occurs whilst the springs within the suspension are in compression, causing the wheel to become unloaded (Figure 40).

93 Frictional lock-up can also occur after the discharge of the payload. The SDT method of unloading is unlike that for other wagons with the Gloucester Mark 4 suspension, which release their payload via side or end doors in one movement. The SDT discharges payload slowly through the clam shell doors onto a conveyor belt. The compression of the springs from the original payload can remain after the discharge of the load. The subsequent movement of the train can then cause the friction to be released between the pedestal and saddle friction liners, causing the springs within the suspension to 'jerk' and the wheelset to derail. This is believed to have been the cause of the Peterborough incident on 10 December 2007 (paragraph 264).

94 Research conducted by British Rail Research during the 1990's (paragraphs 101 & 102) and observations made by RAIB during this investigation have highlighted that the GFA suspension still suffers from this frictional characteristic.

95 In August 2007, testing of two non derailed wagons' load and frames was undertaken to assist in computer simulated analysis. During the tests, the suspension of one wagon's suspension assembly frictionally locked and could not be released, although the pedestal and guide wear measurements were both within specification.

96 Observations made at the Mountsorrel loading point showed that the frictional lock-up and break-out on the wagon suspension occurs as the load fills the wagon. This is unpredictable and can be on the first, second or third slug.

97 Wagons have been observed to frictionally break-out at any combination of front, rear and left and right. Frictional break-out could occur at any time up to and after the point of discharge.

Mountsorrel environment

98 The Mountsorrel loading area is a dusty environment with a cement works adjacent to the Wabtec maintenance bays. Water sprays are employed in the area to reduce airborne contamination.

99 British Rail Research had carried out research for Railtrack on the effects of contamination on frictional break-out problems on the GFA pedestal suspension units in 1996 - 1997. This research provided improvement options for:

- the long term phasing out of the pedestal suspension in favour of other less damaging suspension types, but it was also highlighted that this may not be cost effective;
- speed and load restrictions instigated for this type of wagon;
- redesigning the suspension components to ensure friction levels are close to the design values;
- a review or modification of the loading and unloading procedures and the introduction of some type of shield to prevent contamination of the suspension components to reduce the 'stiction' effect and friction levels; and
- a review of loading and unloading procedures to reduce contamination effects.

100 Railtrack did not publish the improvement options from the research and consequently Lafarge, its predecessor company Redland, the maintainer Wabtec, other railway maintainers and English Welsh & Scottish Railway had no knowledge of any improvement option relating to the fitment of physical guards to prevent contamination and reduce the likelihood of frictional breakout characteristics on the wagons. This may have been due to the subject matter being focused on ground borne vibration and track access charges and therefore the safety issue of the frictional breakout was never considered

The Derailment

The track

101 The point of derailment was at 12 miles 19 chains, 50 *sleepers* on the Ely side of Hawks UWC. Witnesses on site described what appeared to be a flange climb mark as a 'dobbing' mark on the rail head and not an expected characteristic flange climb mark. Derailment marks were identified on the right hand *gauge corner* indicating the flange of the right wheel had climbed onto the rail head in a condition that showed a reduced wheel load. The derailment mark was 250 - 300 mm in length, extremely light, and barely visible to the eye. It was intermittent in contact with the rail which corroborated the initial witness (paragraph 280).

102 The point of derailment was identified as sleeper zero (0), with positively numbered sleepers preceding it (in the direction of travel), and negatively numbered ones in the area where the train had derailed (Figures 21-24 inclusive).

103 A track survey was completed from sleepers +100 through the point of derailment to sleeper -30. Track profile and gauge measurements were recorded up to sleeper -19. The track had sustained damage as a result of the derailment beyond that point.

104 *Void* measurements for the vertical deflection of the track were taken to sleeper -3 using *void meters* and a locomotive. There was no significant evidence of voiding in the area of the derailment. The *cant* on the track varied between 80 mm and 120 mm.

105 The leading right hand wheel of wagon REDA 16002 made contact with the surface of the sleepers causing them to fracture. Impact marks on the foot of the rail, damaged *Pandrol clips* and base plates started at the point of derailment and continued to Hawks UWC. Damage to the longitudinal timbers at Hawks UWC indicated that the derailed wagon moved to the right and that the wheelset ran parallel to the rails.

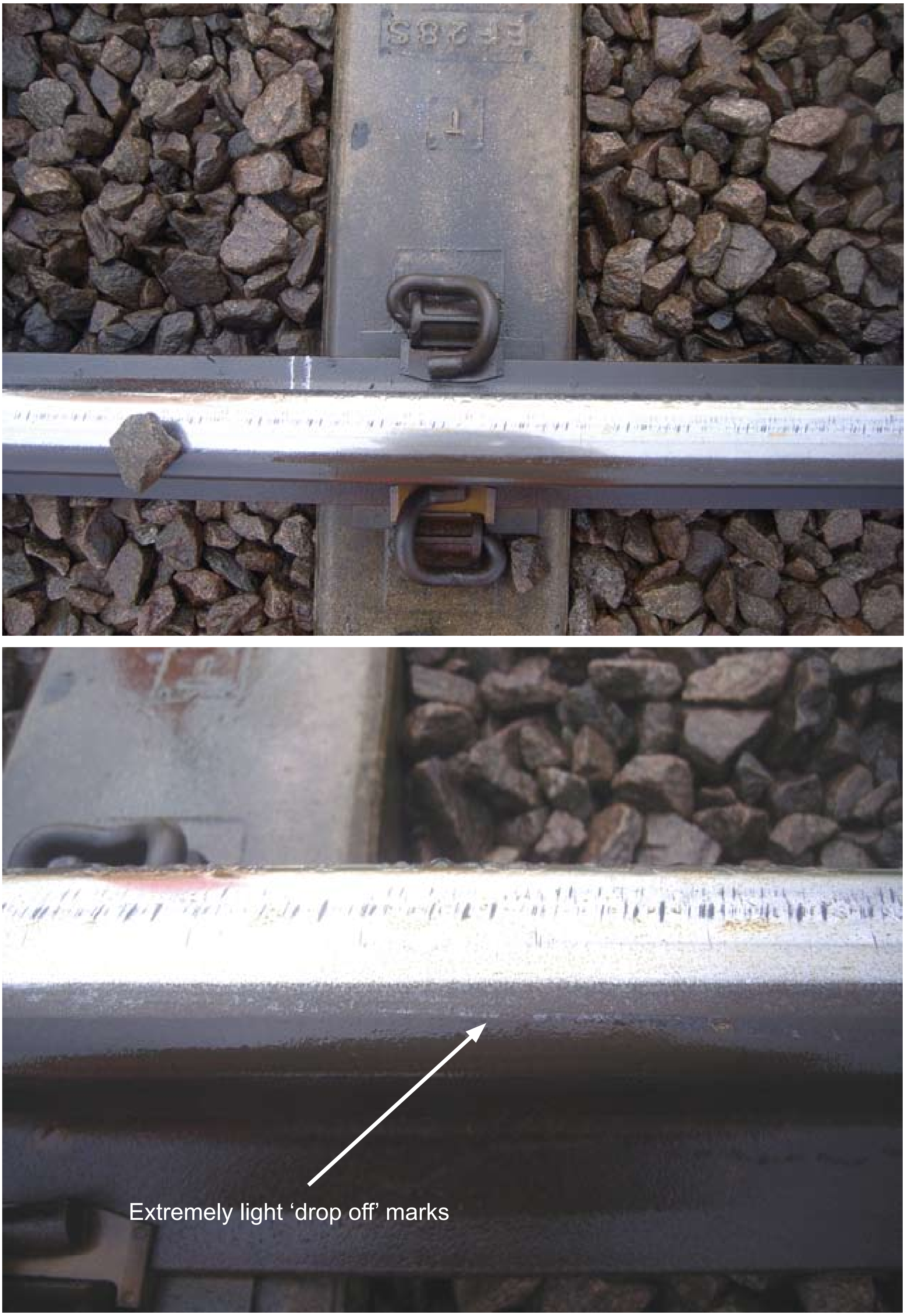


Figure 21a & b: Derailment drop-off mark on high right-hand rail

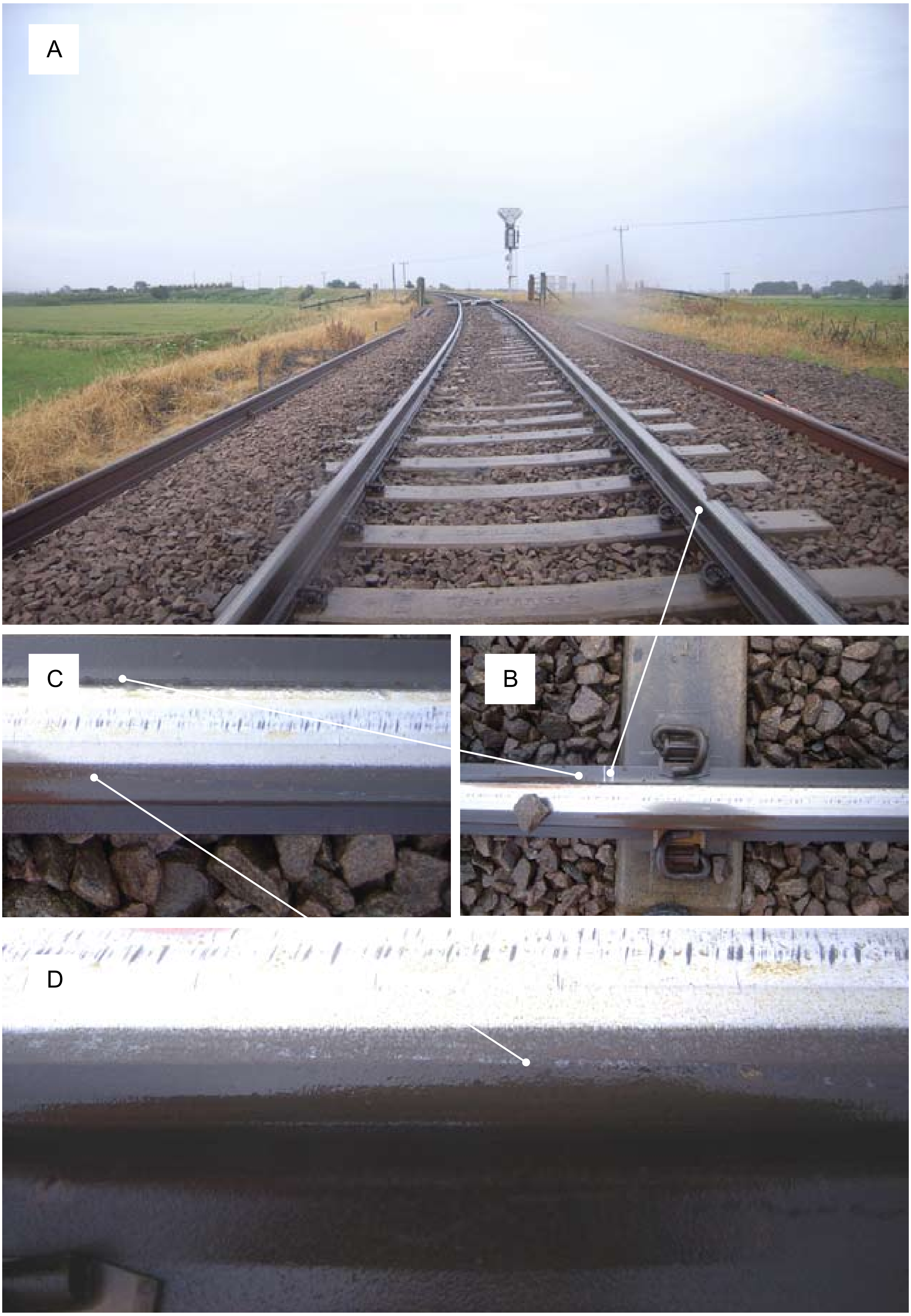


Figure 22: Sequence of images showing the area of flange climb (a), from the gauge corner onto the crown of the high right-hand rail (b & c) and the drop off mark (d)

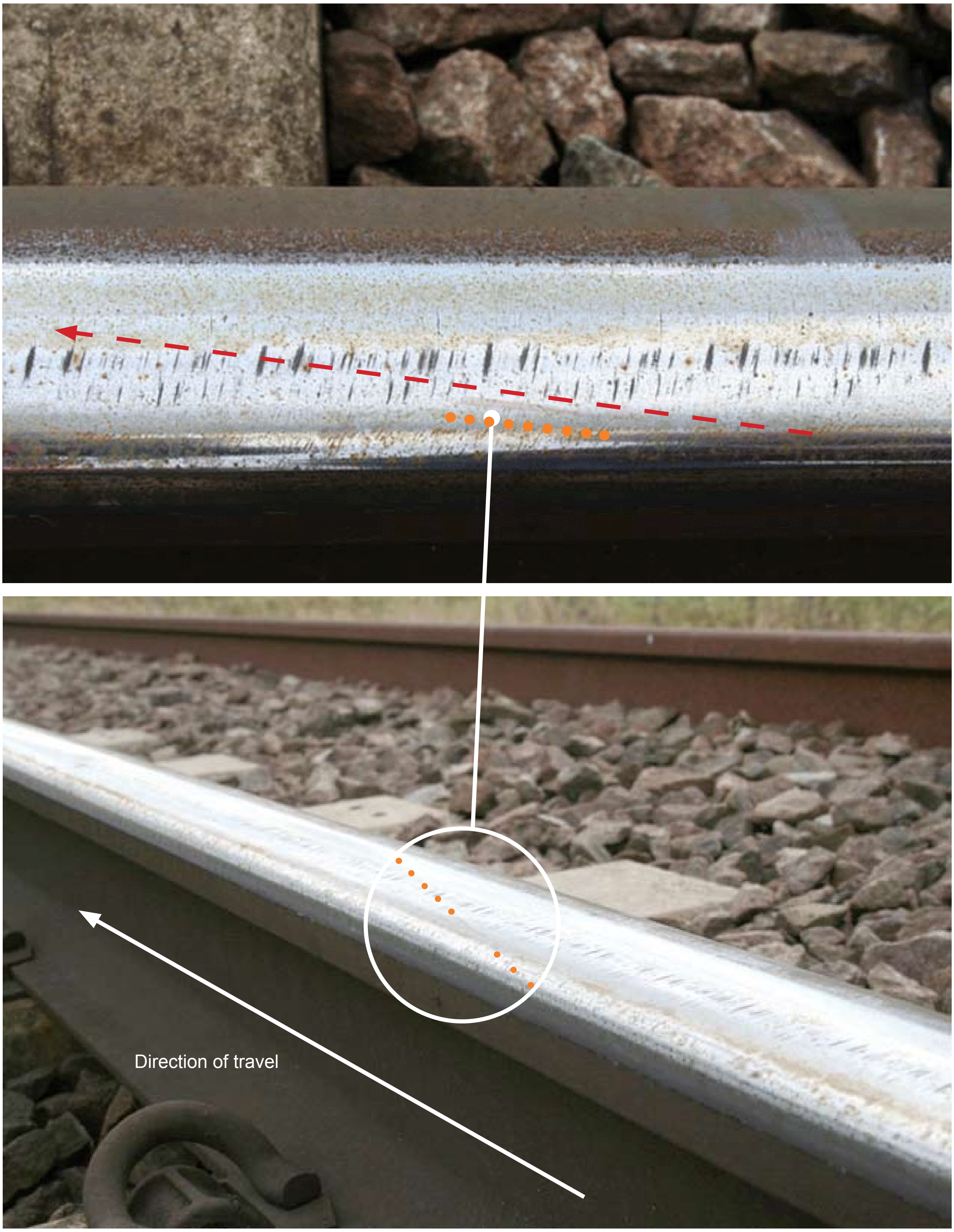


Figure 23a (top) and b (bottom): High right-hand rail showing view of derailment mark on railhead from the four-foot in direction of travel

Figure 24a: Lower left-hand rail (drop off)

Figure 24b: Close-up image of lower left-hand rail (drop off)

106 The leading left wheel rode heavily in the *four-foot* on the ballast and concrete sleepers next to the low (left) rail and cut through some of the steel reinforcing strands in the sleepers.

107 The leading right hand wheel of the leading right hand suspension generated slight impact marks on the sleepers on the high (right) side of the track. The right wheel only skimmed the top of some concrete sleepers with visible damage from the wheel flange of 1 - 2 mm in depth. The depth of the impact marks from the right hand wheel increased with time and distance from the point of derailment. There was no evidence of the suspension breakout from sleeper number (0) to bridge 2235.

Track twist

108 The track was also surveyed to obtain the vertical geometry of the left and right rails approaching, and at, the initial point of derailment. From this data it was possible to derive the *cross-level* of the track and to calculate the track twist over a 3 metre base, as prescribed in Network Rail company standard NR/SP/RK/001, Inspection and Maintenance of Permanent Way.

109 The change in cant over 3 metres was 13.5 mm at sleeper +28 to +24, giving it a track twist of 1 in 222. This is worse than the 1 in 300 maintenance limit and requires the Track Maintenance Engineer to monitor the track conditions to prevent deterioration to the point where the track reaches intervention limits mandated by NR/SP/TRK/001. Those intervention limits include the requirement for action within 14 days of detection for twists below 1 in 200 and on a curve radius of 400 metres (paragraph 114). There was also an opposing track twist of 1 in 236 over 3 metres at sleeper +13. Calculated over 5 metres (225 mm more than the wagon wheelbase of 4775 mm), the greatest track twists occurred at sleeper +22 (1 in 268), and at sleeper +12 (1 in 250) (Figure 25).

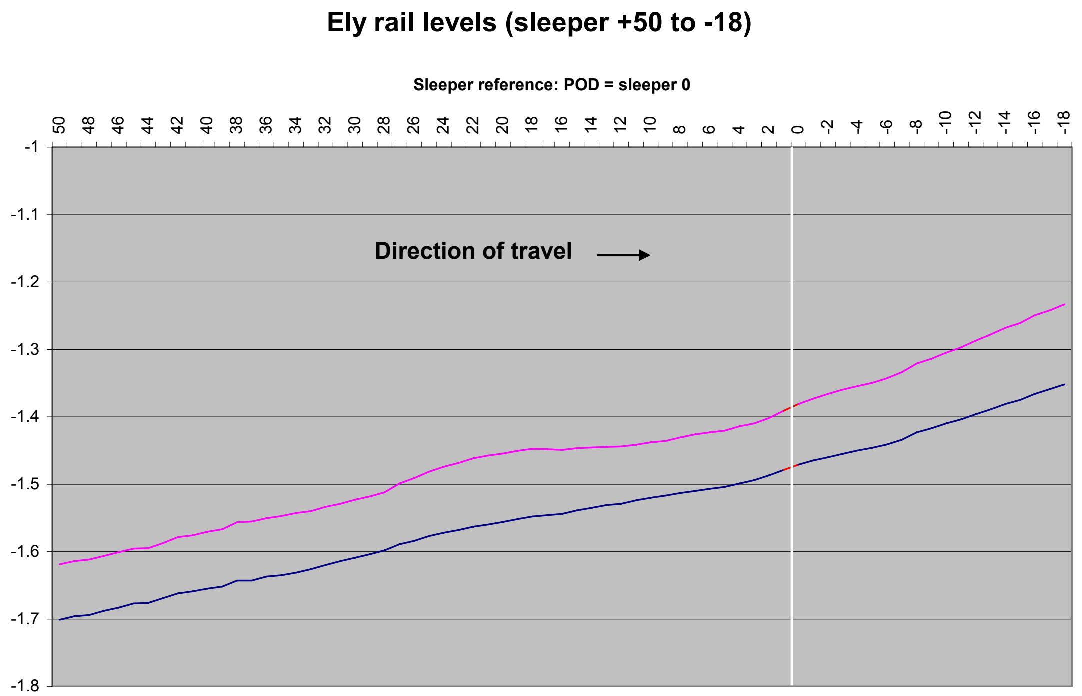


Figure 25: Diagram showing the twist features in track geometry from +50 sleepers to -19. High right-hand rail (magenta) and low left-hand rail (blue). Point of derailment marked at zero (paragraph 277)

110 There was no evidence of any flange climb marks at the location of either track twist fault, indicating that the derailment did not occur at these locations.

Track gauge and alignment

111 NR/SP/TRK/001 specifies a standard gauge of 1435 mm with maximum gauge limit at 1446 mm and minimum at 1424 mm. Although there were variations of track gauge in the area of the derailment none were outside the requirements of NR/SP/TRK/001. However, in the three metres approaching the point of derailment a small number (@ 5%) of the insulators between the Pandrol shoulders and the rails on the outside of the low rail had been crushed. This coincided with an area of wide gauge up to 1443 mm.

112 The average curve radius was 450 metres, with the tightest curve being 329 metres between sleeper +12 to +2, just before the point of derailment. The alignment was as designed, and it was permissible for the wagons to negotiate a curve of this radius (paragraph 37) (Figure 26).

Rail profiles

113 The rails were BS 113A flat bottom type manufactured in 1999. There was no sign of wear on the rails that could have contributed to the derailment.

Figure 26: Aerial image showing the area from the point of derailment to bridge 2235

Track Recording vehicle

114 Network Rail's *track recording vehicle* (TRV) was scheduled to run over the track every six months and ran over the Soham branch on 12 June 2007, ten days before the derailment. The Track Maintenance Engineer (TME) considered the track to be in satisfactory condition based upon his evaluation of inspection records, and the propagation of faults was in line with his preventative maintenance plan.

115 The TRV recorded a twist fault of 1 in 222 within the curve leading to bridge 2235 in February 2006, but it was not highlighted until after 12 June 2007 when the new TRV trace was reviewed and the fault fell within the maintenance limits of NR/SP/TRK/001 (Figure 27).

116 Tamping is carried out on an as required basis normally in response to the output from the track recording; however the section of track at the point of derailment had not been tamped since 2004.

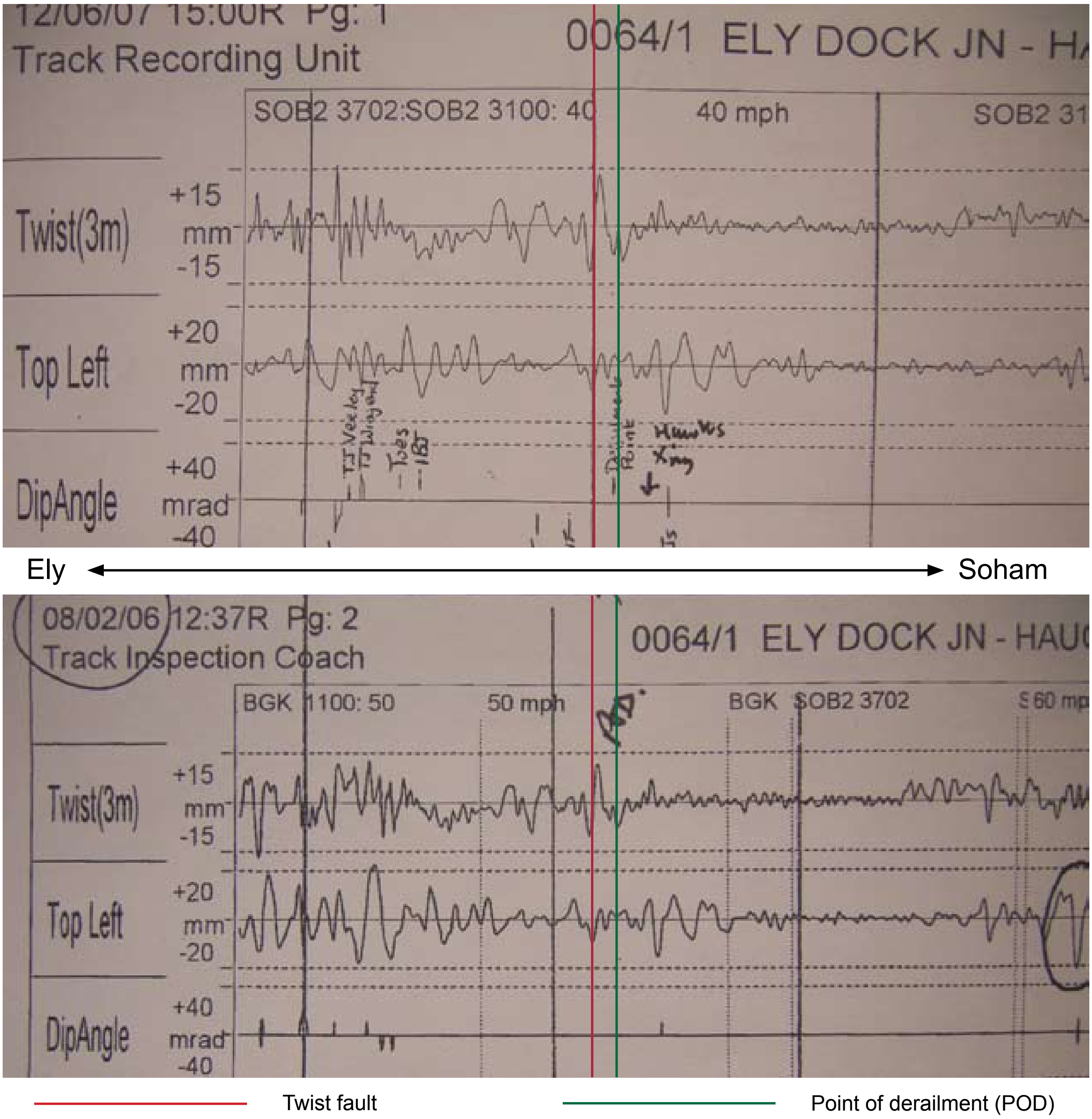


Figure 27: Track recording vehicle data trace from 8 February 2006 (bottom) and 12 June 2007 (top). The horizontal dotted line indicates the intervention limit. The track twist and POD are also shown

117 The Track Maintenance Engineer had identified and marked up a mileage / chainage discrepancy on the hardcopy trace from the TRV on 12 June 2007 which showed the track in the very poor alignment category. The discrepancy was due to the way the TRV recorded each 1/8 mile section of track at 40 mph when the section of track actually changed from 40 mph to 25 mph within the 1/8 mile section, as shown in Figure 27.

118 The Track Maintenance Engineer had intended the track at Ely Dock Junction to be tamped on the night of 15 June 2007 and planned to extend the tamping work to include the Soham branch and the area of track twist. This work was cancelled due to other engineering possession activities finishing late. The work was published in the Weekly Operating Notice (WON 13/2007) to take place during the night of 24 to 25 June 2007, two days after the incident (paragraph 297).

Traffic levels

119 NR/SP/TRK/001 divides routes into categories based upon speed and train-borne tonnage on the route. The category influences the frequency of the inspection regime. The section of track leading to Ely Dock Junction is classified as category 3 and Soham branch line as category 2 (category 1 routes carry the heaviest and fastest traffic). Category 2 track should be visually inspected by *patroller*s on a weekly basis, with a supervisor's inspection every six months and annual inspection by the Track Maintenance Engineer.

120 Rail traffic on the Soham route had increased since 2004 with the re-opening of the depot at Whitemoor yard near March. The section of track on the branch line and junction had been subject to a route category review but this had not altered the route availability or the tonnage category of the line.

121 The Track Maintenance Engineer had not perceived the increase in rail traffic to have had an adverse effect on the track condition, although he had identified that heavy freight trains had contributed to a general widening of the rail gauge. Insulators between the rails and Pandrol clips had moved and been damaged but neither was considered by the Track Maintenance Engineer to be a route safety issue.

122 However, the increase in freight traffic did have an effect in reducing the time available for maintenance (paragraphs 118 and 372).

Track management

123 The Track Maintenance Engineer had 6 years experience in his present role. Maintenance records were correct and show he had a practical and realistic approach to managing the track in his area.

124 The patrollers', supervisor's and Track Maintenance Engineer's track inspection records were all completed in accordance with the requirements of NR/SP/RK/001 (paragraph 119).

Bridge 2235

125 The structure of the bridge and maintenance and inspection records were examined by the RAIB. At an early stage, it was identified that the bridge structure was neither causal nor contributory to the derailment and it was therefore not investigated further by the RAIB.

126 Network Rail assessed the damaged bridge. The foundations were found to be intact but with damage to the masonry piers, main longitudinal girders, cross members and total destruction of the timbers the bridge needed to be completely replaced (paragraph 303).

Wheelchex

127 Network Rail operates 24 sites located around the network which measure wheel loading and wheel impact data from passing trains. Alarms are raised when preset levels are exceeded indicating that suspension or wheel faults might be present. The system also records wheel impact data for all trains. Both sets of data are brought to the attention of operators so that maintenance can be carried out, thus preventing damage to the infrastructure. The system also records overloaded axles (Appendix F).

Wheelchex data

128 The system measures the average, peak, *dynamic ratio* and uneven diagonal wheel load on each axle (Figure 28). Prior to the Ely incident the data was received, but uneven diagonal wheel loads were not analysed and processed by Network Rail's Private Wagon Registration Agreement department.

129 This system was capable of, but not configured at the time of the incident to trigger an alert when there was an imbalance of load between wheelsets or between wheels on the same axle beyond a predefined level. The identification of the wheelchex software capability to operate in this way was not recognised until after the Ely incident (paragraph 305 and Appendix F).

130 Delta Rail, formerly AEA Technology Rail (who were successors to British Rail Research), is responsible for the supply of all parts, software support, on track maintenance and calibration of the sites. It is the responsibility of Network Rail to request calibration as and when required.

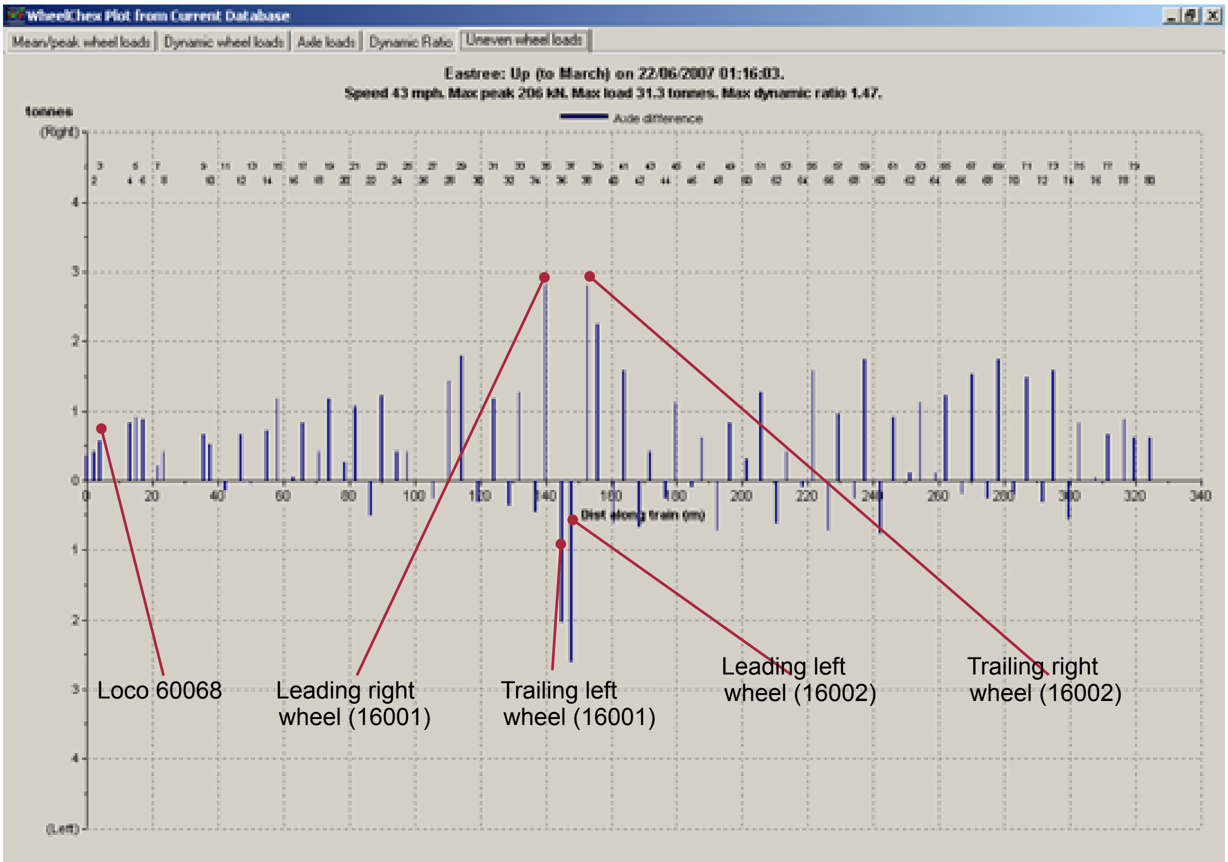


Figure 28: Wheelchex graphs showing uneven wheel loads REDA 16001 and REDA 16002

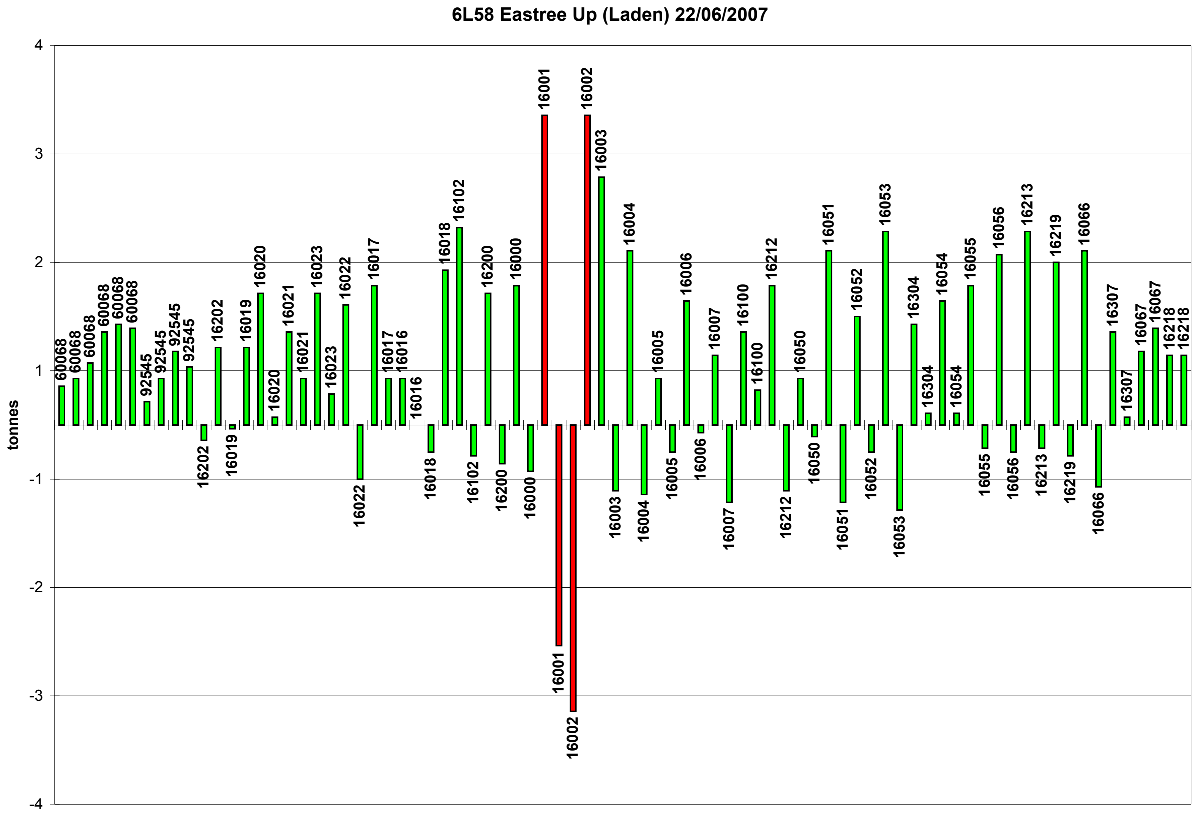


Figure 29: Train consist diagram from the Eastrea Wheelchex site showing incident wagons REDA 16001 and REDA 16002 (both shown in red) and non incident wagons (green)

131 Train 6L58 passed over the Eastrea wheelchex site. The system recorded high diagonal wheel imbalance loads on wagon REDA 16001 and REDA 16002 (Figures 28 - 29) but did not highlight this data or trigger an alarm.

132 The maintenance schedule specifies that each site must be calibrated and maintained every six months, and following any repairs or nearby track maintenance. Eastrea was calibrated in January 2006 and was scheduled for further calibration in June 2006 (and January and June 2007). This was not done, and neither was the omission identified by Network Rail or its sub contractor.

133 The post accident calibration of the system at Eastrea showed that it was still within specification and working correctly.

Vehicles

Locomotive 60068

134 The RAIB examined the cab controls and the locomotive. No irregularities were observed.

135 The OTDR showed:

- that no sand had been applied by the train driver;
- that during the journey from Mountsorrel the train had reached a maximum speed of 56 mph (90 km/h), within the permitted 60 mph (96 km/h);
- the speed of the train as it ran through Ely and up to the derailment did not exceed any speed limit (Figure 30); and
- that no irregularities in brake pressure were recorded during the journey from Mountsorrel.

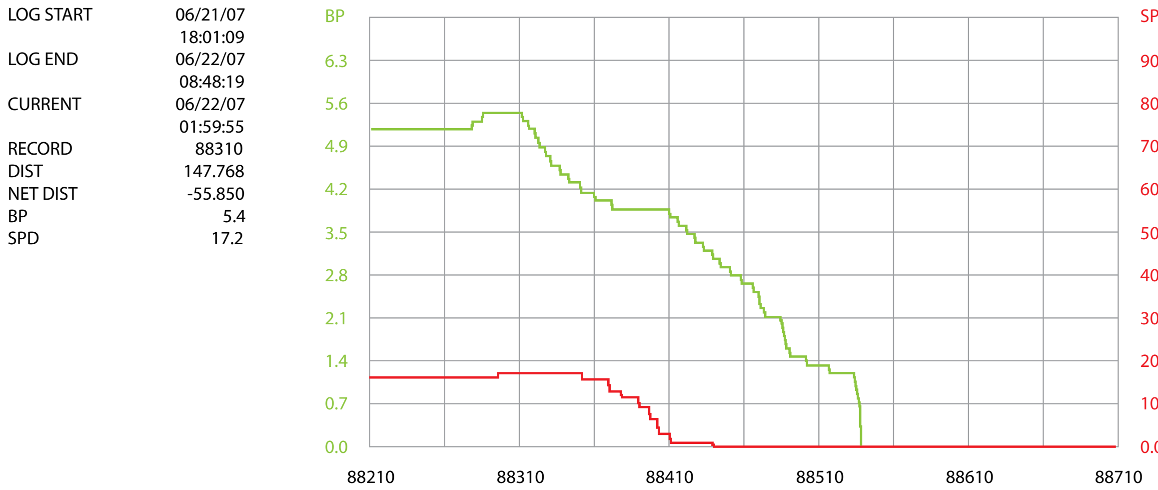


Figure 30: Locomotive 60068 OTDR reading of speed (red trace) and brakepipe pressure (green trace) at 01:59:55 seconds 22 June 2007

The Wagons in train 6L58

136 Train 6L58 passed over a set of hot axle box detector (HABD) equipment at Manea, five miles north of Ely Dock Junction. There was no indication that there were any overheated axle boxes in the train at that time.

137 There was no evidence and no visible sign of incident-related damage to the KJA discharge vehicle, the 2nd to 12th wagons and the 26th to 35th wagons, which had not derailed. All brake components and systems were found to be correct. The 13th wagon had partially derailed on its rear wheel set with the right trailing wheel off the rail and left wheel still in contact with the railhead. The bar coupling between the 13th and 14th wagons was damaged, but there was no visible evidence that any damage had occurred before the accident, or that there was any effect on the running of the adjacent wagons.

138 Wagon REDA 16001, the 14th wagon, was lying on its left side on the Soham side of the river. The wagon had lost its payload onto the *cess*. The hopper was superficially damaged through impact; however the framework, wheel sets and suspension components were relatively undamaged.

139 The other wagons that had derailed on the bridge (paragraph 57 to 59) had received significant damage, with framework twisted and wheelsets and brake components detached and missing.

140 The RAIB examined all the derailed wagons in situ. Particular attention was paid to visual inspection of the coupling arrangements, wheel sets, *wheel profile*s, axle bearings, and suspension assemblies. All the axle horn guides and suspension saddles on the derailed wagons were examined (Figures 32 & 33).

141 The RAIB examined all the wheel profiles of the wagons that had derailed on site, and found the flange heights and thickness compliant with their design specification. The leading wheelset of wagon REDA 16002, the 15th wagon in the train, was the only wheelset that showed signs of impact damage and concrete debris, commensurate with running derailed for a distance, indicating that this was the first wheelset to have derailed.

142 Several primary, secondary and cup springs were lost during the incident and were not recovered. These were likely to have been lost in the river although the river bed was searched to recover evidence.

143 Springs that were recovered were compliant with the manufacturer's material and dimensional specifications, and free of corrosion.

144 In close proximity to the derailment site and on the Soham side of Hawks UWC a single green painted anti rattle or 'cup' spring was recovered (Figures 26 and 40). This spring is housed inside the 'top hat' which sits within the primary and secondary spring assembly as shown in Figure 31. The spring was found on the left-hand embankment in the vegetation (paragraph 328).

Figure 31: Spring assembly showing primary, secondary and inner 'cup' spring sitting within the 'top hat' component. Inner cup spring is identical that found at Hawks user worked crossing

Wagon tests

145 After recovery, static stiffness and *torsional stiffness* tests were completed on two undamaged PHA wagons REDA 16055 (28th wagon) and REDA 16056 (29th wagon) to obtain the static load of each suspension unit and to assess any effect that transfer of payload might have on the suspension. High torsional stiffness along the length of the wagon frame can heighten a non bogie two axle wagon's sensitivity to a twist fault. This was completed for the vehicle dynamic computer analysis which is based upon a PGA type wagon (see paragraph 289 for further explanation).

Wagon 16002

146 Wagon REDA 16002 had travelled approximately 19,000 miles (31,000 km) in service between a previous derailment at Northampton (paragraph 249) and the Ely site.

147 The front wheel set of wagon REDA 16002 remained on the wreckage of the bridge, some 25 - 30 metres from the final position of the wagon. It has not been possible to determine which primary, secondary, *cup spring* or retaining pins came from which pedestal assembly.

148 The frame of the wagon had suffered substantial damage as it slid along the bridge on its side. The wagon lost its payload onto the bridge and into the river.

Figures 32 (left) with inset. Front portion of inner aspect of the right-hand pedestal showing heat damage. Figure 33 (right). Heat damage to rear portion of inner aspect of pedestal guide.

149 The wagon had 10 mm *shims* fitted on the front left axle guide (corner no. 4), and at the rear right (corner no. 2), indicating an attempt to correct a frame twist of 20 mm. A marker (also known as a Q marker) or date is then required to be painted on the frame; however, there was no evidence to suggest this had been completed and no evidence to support that this had been identified during maintenance checks.

150 The bolts and fastenings between the shims and the pedestal / frame on corners 2 and 4 were of a different type and visually different to the un-shimmed corners 1 and 3 which may indicate that the shims were fitted post manufacture or at different times. The damage sustained as a result of the incident prevented any accurate physical frame twist examination being completed on wagon REDA 16002 (Figure 34).

Figure 34: Left side of wagon REDA 16002 showing severe damage and frame twist caused by incident

151 Historical modifications to the design were visible with additional side bearers fabricated onto the frame. The main hopper body also showed signs of pre-incident damage. Several areas of welded repair work to the container were visible. Maintenance and repair records for the wagon do not identify when this occurred. This was the only wagon in train 6L58 to display any evidence of significant pre-incident repair work to its body work (paragraph 240).

152 The undamaged brake mechanisms were adjusted within the limits specified by the Wabtec maintenance specification.

153 The pedestals were later removed from corners 1 and 4 of wagon REDA 16002. The suspension saddles were recovered on site. In addition to this evidence, the right hand pedestals / horn guides were also removed from the 14th wagon (REDA 16001) and from wagon REDA 16011 (not involved in the derailment, but with identified frame twist features, paragraph 244) both of which had been identified as having frame twist. These samples were used as a reference for comparison with the parts from wagon REDA 16002.

154 The specification for the width of the inner surfaces of the saddle friction liners is 204 mm with a maximum wear limit of 208 mm (Appendix D). The specification for the pedestal outer surfaces is 186 mm with maximum permitted reduced wear limit of 182 mm. The lateral tolerances are recorded on the PPM sheet.

155 The right and left saddles of wagon REDA 16002 were both within specification. However, the right hand side saddle and guide at their upper extremes were both on their maximum limits of wear, as seen below. Any further wear would have occurred between the parent material of the saddle and guide. The reference sample taken from REDA 16011 was within specification.

REDA 16002 Right hand side

16002 RHS Saddle: Upper 207 mm, Lower: **208 mm**

16002 RHS Guide: Upper 185 mm, Lower: **182 mm**

REDA 16002 Left hand side

16002 LHS Saddle: Upper 206 mm, Lower: 207 mm

16002 LHS Guide: Upper 183 mm, Lower 185 mm

REDA 16011 Right hand side (Reference sample)

16011 RHS Saddle: Upper 205 mm, Lower: 205 mm

16011 RHS Guide: Upper 186 mm, Lower: 188 mm

156 The frictional behaviour of the wagon suspension is explored further from paragraphs 281 onwards.

157 The embossed markings on the axle found on the bridge confirmed the wheel set originated from wagon REDA 16002. Although the flanges of the wheel set were damaged, the back to back measurements, flange thickness and height were within specification.

158 The correct bearings and axles had been fitted to wagon REDA 16002. The bearing housing and bearings on axle E616740 had been damaged as a result of the detachment from the suspension saddle and wagon frame. The axle bearings and lubrication showed no sign of heat damage or bearing seizure. The damper pad was deformed and the damper pot was missing and has not been recovered (paragraph 325, Figure 7).

159 The front right hand horn guide of the wagon provided the only visual evidence of heat damage (Figures 32 - 33).

160 The Eastrea Wheelchex data for wagon REDA 16002 on the night of 21 June 2006 recorded axles 37 (front) and 38 (rear) with a total axle load of 24.81 tonnes and 28.39 tonnes respectively, a difference of 3.58 tonnes (Figure 35).

16002	LEFT WHEEL (kN) (Tonnes)		RIGHT WHEEL (kN) (Tonnes)	
LEADING AXLE	157.2 kN	15.00 T	96.2 kN	9.81 T
TRAILING AXLE	111.7 kN	11.39 T	156.8 kN	17.0 T

Fig 35: Wheelchex data relating to wagon 16002

161 Historic Wheelchex data showed an ongoing diagonal imbalance of wheel loads between the left leading wheel and trailing right wheel of 2.510 tonnes on wagon REDA 16002 since at least March 2005 for every time it passed this installation (Figure 37). This has been calculated from the mean of the averages of the total leading axle weight (Appendix F). This imbalance was on the other diagonal on the preceding wagon REDA 16001 (paragraph 164).

Combined diagonal imbalance wheel load data for 16002	Date recorded	Line
-11.0	**22/06/2007**	**Eastree Up**
-10.5	16/06/2007	Eastree Up
-13.5	15/06/2007	Thurmaston Up Relief
-12.8	06/06/2007	Thurmaston Up Main
-12.4	**25/05/2007**	**Eastree Up**
-11.8	**19/05/2007**	**Eastree Up**
-9.6	**17/05/2007**	**Eastree Up**
-10.1	**14/05/2007**	**Eastree Up**
-10.1	**04/05/2007**	**Eastree Up**
-12.1	31/03/2005	Thurmaston Up Main

Figure 36: Table showing historical Wheelchex data. The wheel load (minus) relates to the leading left wheel load imbalance on wagon **REDA***16002. The highlighted data (red) shows wagon* **REDA** *16002 passing over the Eastrea site and travelling through the Ely to Soham section. The data for* **REDA** *16002 passing over the Eastrea and Thurmaston Wheelchex site and* ***not*** *travelling through the incident area is also shown in black (Appendix F)*

162 Ely Dock Junction was on the route normally used by SDT trains such as train 6L58. Wagon 16002 had travelled over the section of track at Ely Dock Junction on the Soham branch in a loaded condition on at least five occasions in May 2007 (Figure 36).

163 The track twist fault was also present when the train previously travelled over the same section of track (Figure 36). There had been no derailment at this location before 22 June 2007.

	REDA 16515	REDA 16782	REDA 16795	REDA 16822	**REDA 16001**	**REDA 16002**	**REDA 16011**	REDA 16024	BCC 11042	ESSO 61930
Mean diagonally imbalance load (tonnes) =	1.58	4.58	4.32	5.03	**8.6**	**11.4**	**9.2**	2.3	6.1	6.5
Measured Twist (mm) =	6	9	8	15	**27**		**36**		15	27
Calculated Twist (mm) =						**40**				

REDA 16822 has 12mm packers already fitted
REDA 16024 identified as 16011 due to TOPS error.

Fig 37: Table comparing Wheelchex data from the incident and non-incident wagon

Reference wagons

Wagon REDA 16001

164 Wagon REDA 16001, which was also involved in the Northampton derailment, had travelled approximately 19,000 miles in service between the Northampton and Ely incidents.

165 Wagon REDA 16001 travelled immediately in front of wagon REDA 16002 in train 6L58, and was semi-permanently coupled to it. Wheelchex data showed that it had a wheel imbalance in the opposite (leading right wheel to trailing left wheel) orientation to wagon REDA 16002. The wheel load showed that it had a diagonal wheel imbalance of approximately 2.8 tonnes difference from the mean value of the axle load of the wagon.

166 The wagon had a frame twist of 27 mm which had neither been identified during maintenance, nor after the Northampton derailment in 2006 (Figure 37).

Wagon REDA 16011

167 Wagon REDA 16011 was not involved in the Ely incident but was identified by Wheelchex as displaying uneven wheel loads. It was used as a reference sample to compare its physical features to wagons REDA 16001 and REDA 16002 and establish pre and post wheel imbalance comparison over the Wheelchex system after frame compensation packing had been added to remedy the frame twist. It is likely that the frame twist originated from the Small Heath derailment on 10 December 2005 (paragraph 246) (Figure 37).

168 Wagon REDA 16011 was optically measured with the following results:

- There was a 36 mm frame twist.
- The friction liners on the wagon displayed a variety of wear patterns with one being highly polished. However they did not show any sign of abnormal wear or heat damage resulting from a frame misalignment (Figure 38).
- The pedestals and saddles on corners 1 - 4 were within tolerance.

169 Following the fitment of 18 mm frame twist compensation shims in diagonally opposite corners, Network Rail's Private Wagons Registration Agreement department authorised Lafarge to return the wagon to operational use (Figure 39).

Fig 38: Wear to leading right pedestal guide on REDA 16011 showing polished surfaces but no evidence of heat damage

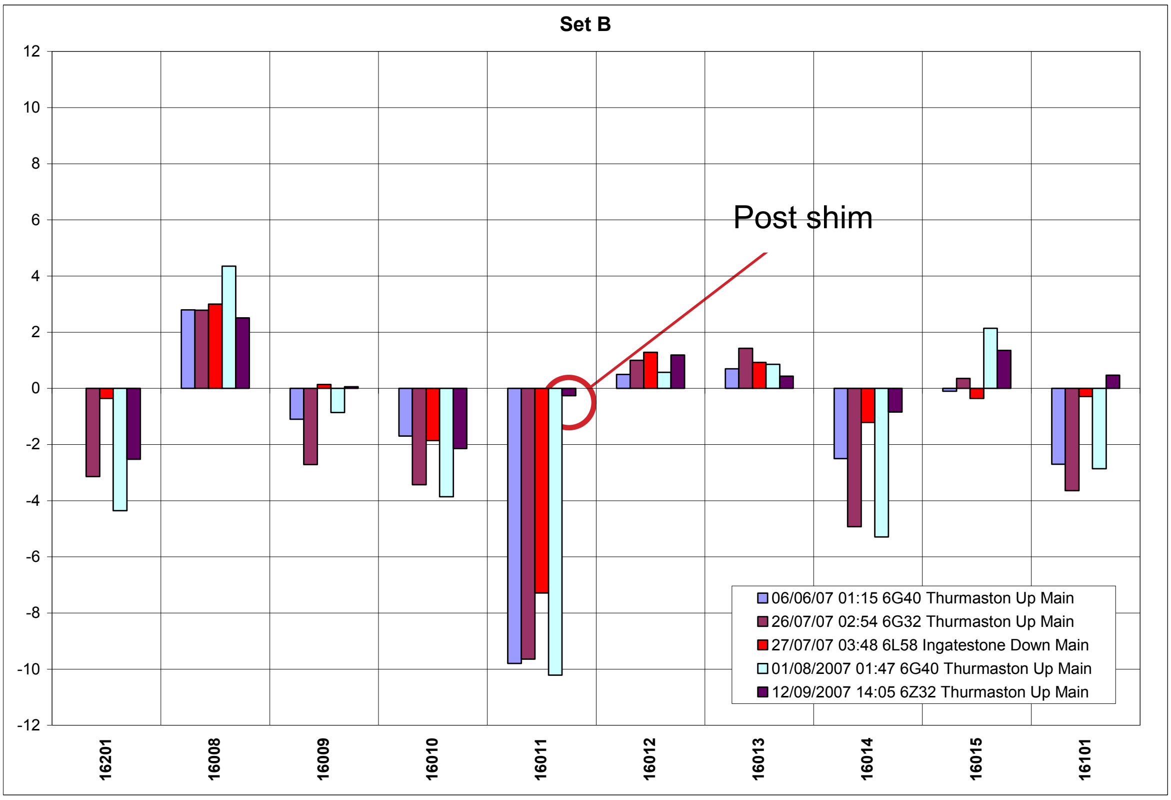


Figure 39: Graph showing analysis of raw Wheelchex data of pre and post frame twist on REDA 16011

170 The wagon was then monitored to establish if the required packing had corrected the frame twist and to determine its new 'footprint' on the same Wheelchex site. The data from the first journey showed the uneven loading on the wheels on wagon REDA 16011 had been effectively corrected. This check was repeated to confirm the results (Figure 39).

171 The fitment of two 18 mm shims was greater than the maximum total of 30 mm (2 x 15 mm) permitted by British Rail in 1981. Network Rail authorised this after a subjective assessment of the additional risk to wagon, gauge and suspension alignment.

Railway Group Standards and other documents affecting maintenance

172 A critical parameter in rail vehicle operation is suspension behaviour and the ability to maintain adequate vertical wheel loads while traversing irregular track geometry. For a four-wheeled vehicle the relevant *Railway Group Standard*, GM/RT2141 Resistance of rail vehicles to Derailment and Roll-over, stipulates that the most unloaded wheel must retain at least 40% of its nominal wheel load when subjected to a 1 in 150 twist over the wheelbase of the wagon.

173 Lafarge's PHA wagons and suspension performance specification predate the current acceptance regime (GM/RT2141) and consequently use *Grandfather Rights* for their ongoing operation. The original design specification for the wagons is not known but the wagon specification is reported by Network Rail to have met the British Rail standards applicable in 1994.

General Repair

174 Before 1992 PHA wagon types and similar wagons were subjected to *General Repair*s at wagon workshops on a seven-yearly cycle. During this work, wagons were normally dismantled to individual components, which were examined, repaired, refurbished or replaced as appropriate and the wagons reassembled. In certain circumstances wagons received new bodies during these activities.

175 A key feature of the chassis refurbishment was a dimensional check of the wagon frame for any twist. At the time it was considered that there was a risk of some frame twist being induced during the general repair activities. Any frame twist greater than 6 mm was compensated by packing above the axle boxes on the diagonally opposite 'high' corners. A small plate was also affixed to the sole bar above the high corner wheels to indicate the requirement for, and magnitude of, this additional packing. A maximum of 30 mm (2 x 15 mm shims) was permitted per wagon frame. The Network Rail's Private Wagon Registration Agreement section has not been able to establish how the maximum permitted limit of 30 mm was originally set.

176 The procedure for checking and rectifying frame twist was originally laid down in BR Instruction document WF/81 Measurement and Compensation of Frame Twist as a requirement for any post-incident (e.g. derailment) investigation.

177 The criteria to check for frame twist were based upon the requirement to check the frame after fabrication work had been completed and a similar requirement to examine wheel sets after a derailment, the criteria of which were dependent on the speed and distance of a derailed wagon or train. The recognised procedure was to use a 'Tilers' or 'Tyle' water gauge on level track.

178 The general repair programme was changed by British Rail in 1992 and was introduced during Railtrack's management of the Private Wagon Registration Agreement after 1994. This was largely replaced by Planned Preventative Maintenance (PPM) (also known as the 'balanced' maintenance process) which was completed at local maintenance facilities with an increased frequency. One of the principal requirements for maintenance was adherence to BR's document BR11888 which still contained the General Repair elements. Section 7 required that the maintainer must carry out a frame twist check after a derailment but referred the maintainer to the POCL document which specified the frame twist examination was only carried out if twist was suspected (paragraphs 230, 347 and 360).

179 At the same time the annual cyclic maintenance process, which included a Vehicle Inspection and Brake Test (VIBT), was enhanced and introduced. General repairs were then only carried out on an 'as-required' basis. The requirement for frame twist measurement remained in the general repair programme but was not incorporated and mandated in the VIBT annual maintenance regime or the PPM. It is not known why or how this occurred (paragraph 347). The VIBT check list includes a visual frame twist check and requires a pass or fail box to be endorsed with a tick. This implies a subjective element of inspection. However, all wagon records examined by the RAIB, including for REDA 16001, REDA 16002 and REDA 16011, were ticked as a pass.

Network Rail Safety Case (RSC) version 8.1 January 2006

180 The Network *Rail Safety Case* outlined how the company discharged its duty as the infrastructure controller. Sections 4.1.39 to 4.1.43 described the company's responsibility for the Private Wagon Registration Agreement, *Private Owner Circulation Letters*, TOPS and the use of the Wheelchex system to ensure that wagons owned by rolling stock companies complied with its instructions.

Safety Management System (SMS) version 2.2007

181 The Network Rail *Safety Management System* provides the means to control health and safety risk on the rail infrastructure through a hierarchy of procedures and rules. While operational and engineering activities are mentioned in detail, no reference is made to the Private Wagon Registration Agreement department and its safety responsibilities (paragraph 371).

Planned Preventative Maintenance (PPM)

182 PPM is completed every four months within the 12 month VIBT period. The PPM which is used by English Welsh & Scottish Railway and Wabtec incorporates all aspects of the British Rail maintenance specification. Each parameter is recorded as a pass or fail. The frame twist check is a subjective assessment by the fitter and is only measured if the fitter identifies a fault. There is no requirement to record the actual measurements of the frame to ensure compliance.

Private Owner Circulation Letter 484 version 1. Issued 19 October 1981

183 Private Owner Circulation Letter (POCL) 484 (paragraph 217) is the recognised reference guide for private wagon owners if frame twist is suspected; the document lays down a specific procedure to compensate for frame twist using compensatory shims placed between the frame and pedestal.

184 Because the VIBT tests were being marked as a pass the POCL 484 assessment at the time of the incident was not applied by Wabtec. Audits undertaken by several other PWRA members also highlighted a lack of understanding of the 'hierarchal' status between the POCL 484 process and the historical requirements of section 7 of BR 11888. No evidence was found that British Rail, Railtrack or Network Rail had fully reviewed whether the general repair tasks were fully addressed by the Private Wagon Registration Agreement companies and their respective PPM maintenance organisations (paragraph 336).

British Rail Manuals & standards

185 Maintenance manuals issued by British Rail before 1994 and POCLs still form the basis of the VIBT and PPM. The manuals are maintenance based documents dealing with specific suspension and wagon maintenance procedures. Version 1 of POCL 484, issued circa 1981, was in force at the time of the incident.

186 BR Standard TFT/T/10007, Examination and Lubrication of British Rail and Private Owners Freight Trains, issued January 1996, incorporate the repair, testing and labelling of wagons within PPM regimes. Section G3.12 outlines procedures for frame compensation and the requirement for owners to retain records when frame compensation was undertaken.

187 Section G3.13.3 requires special identification plates to be attached above the corners where a wagon had been shimmed showing the thickness of the shim (e.g. 10 mm). This document has been replaced by GM/RT 2004 Requirement for Rail Vehicle Maintenance, but is still used as a reference source by maintainers of wagons.

188 British Rail manual 11888 The Regulations for Repairing Private Owner Wagons, referred to as the 'Green Book', was issued in 1982. Schedule C outlines the procedure for the Gloucester Pedestal Suspension Mark 1,1a and 2 but not the later Mark 4. Section 7 Underframes outlines:

"*Whenever vehicles come under notice, all underframe members must be* [the word visually is then hand written and inserted into the text] *examined for loose rivets, defective welds, excessive corrosion, distorted or defective members and corrected as necessary.*

When wagons are undergoing G.R. plating repairs, or after re bodying, or receiving attention following a derailment, the underframe must be checked for frame twist in accordance with PO/CL [484 is then hand written]. *In cases where it is deemed necessary to strengthen any frame member, the proposed method of doing this must be submitted for official approval to the C.M & E.E (B.R.B.).*"

189 The requirement is that frame twist checks must be visually examined and reference is made to the procedure in POCL 484 version 1, (circa 1981) where the requirements for the frame twist check is only to be undertaken if 'suspected' (paragraph 230 and 347).

190 The VIBT procedure is incorporated within the manual. Section 1 specifies that checks on the underframe are completed and shims or packing checked.

191 British Rail manual (BR 11889) Planned Preventative Maintenance for Freight Stock and Departmental Vehicles was issued in June 1987 and is referred to as the 'Blue Book'. The manual is only applicable to BR wagons but is used by non BR wagon maintainers as a reference source. Section 1.1 incorporates the requirement to examine the wagon underframe and compensation packing during the maintenance check, directing the reader to procedure WF/81 Measurement and Compensation for Frame Twist using the 'Tyle' gauge.

192 Section 11 outlines the requirement for painting and labelling of wagons. This includes the requirement to label wagons that have frame twist and where packing or shims have been fitted. Section 11 specifies that details of such work should be recorded for future reference. The document does not contain any requirement to transfer or retain records on the sale or transfer of the wagons. BR 11889 is still used as a reference source by maintainers even though it is outside the scope of the PWRA as it relates to British Rail wagons.

193 The manuals contain useful information for current maintenance procedures. However, documents BR 11888, 11889 and TFT/T/10007 contain duplicated processes, refer to historical frame twist processes and do not reflect current POCL 484 procedures (paragraph 364).

British Rail Research

194 Research undertaken by British Rail Research (TM 037) in 1988 concluded only 10% of the vehicles were below designed friction levels and research in 1997 - 98 (TRS 097) concluded that that Gloucester type pedestal suspension causes track damage and ground borne vibration which results in high levels of track repair and maintenance. Wagon types using this suspension were thus given the highest category track access charge. Improvement options were sent to Railtrack for consideration. However, since 1998 very little current data is available on the dynamic and frictional characteristics of the suspension units (paragraphs 348 to 353).

195 From 1994 to 2004 the responsibility for historical documentation in relation to research and recommendations on the Gloucester pedestal suspension was transferred from British Rail to Railtrack and then from Railtrack to Network Rail. However, the knowledge and awareness of the issues was corporately lost through the transfer of design authority to a sequence of private companies and through staff wastage. British Rail Research improvement options were not published for the private wagon owners or their maintainers (paragraph 222 and 352). This may have been due to the research being focused on ground borne vibration and the implementation of track access charges rather than the frictional charteristics of the suspension and its derailment risk.

Wagon Maintenance

Gloucester Suspension

196 All PHA wagons have the Gloucester suspension. Dependent on the date of manufacture and repair the suspension versions could be the Mark 1, 2, 3 or 4. The Mark 4 cannot be interchanged with previous versions as it employs a different type of damper pot (Figure 40).

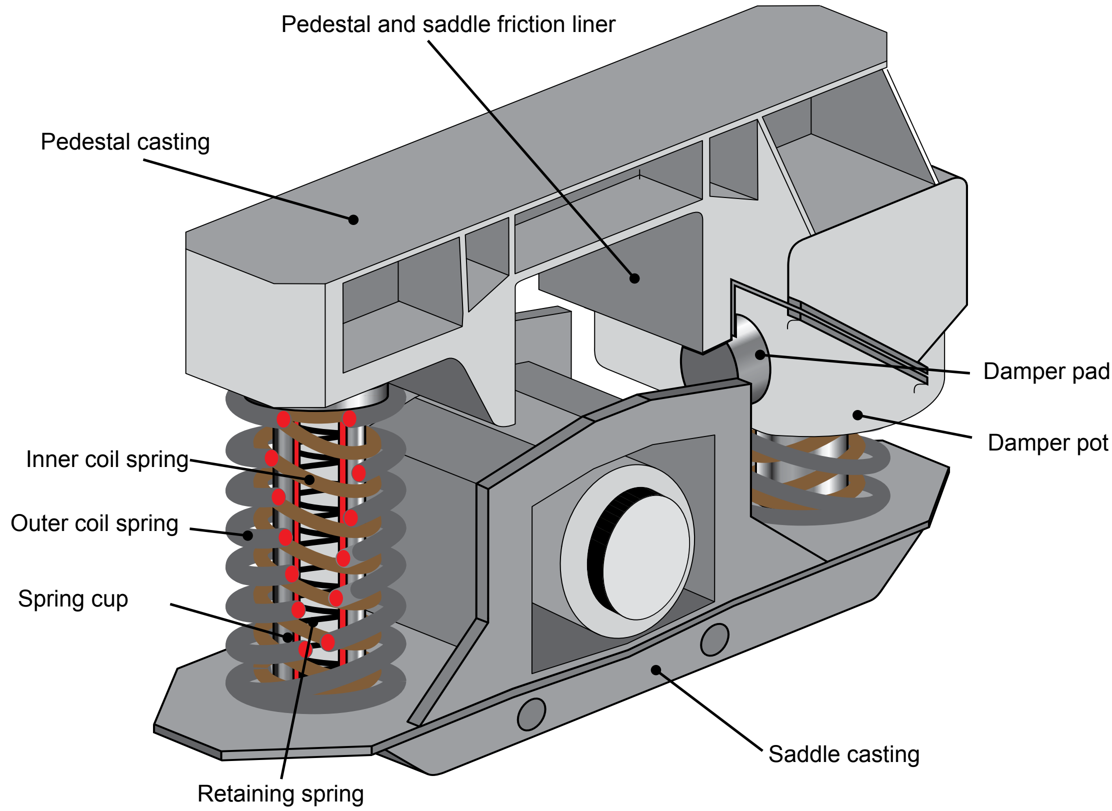


Figure 40: Diagram of GFA suspension and components

197 The current maintenance manual for the GFA is entitled Gloucester Floating Axle Mark 4. Extracts from the former British Rail maintenance manuals are contained within the certificated maintenance plans for the wagons.

198 The Mark 4 manual includes:

- the process for dismantling and reassembly;
- a replacement parts checklist;
- torque limits;
- minimum and maximum wear limits of the friction liners; and
- identification of those suspension components, the non-lubrication of which could affect damping (the periodic inspection of the damping is highlighted as a very important task).

199 The GFA mark 4 manual requires wear measurements to be recorded for the inner surfaces of the saddle and the outer surface and guides of the pedestal. Replacement parts must be fitted when maintenance limits are reached. A minimum gap of 8 mm between the damper pad and the saddle is permitted (Appendix D).

200 The friction liners are visually inspected and measured to ensure they are in tolerance. Friction liners and friction surfaces are replaced, welded and 'dressed back' onto the guide and saddle where necessary. The alignment of the weld plates is visually checked. The lateral tolerances are recorded on the PPM sheet (paragraph 154).

201 The PPM wagon repair specification does not mandate the replacement of both friction liners of the pedestal and guide, thus they may be replaced individually. The surface materials of the mating friction liners are identical. It is not known if the surface profiles wear at the same rate during service to produce an identical mating surface or if a newly fitted friction liner affects a previously worn surface that does not require replacement during PPM (paragraph 313).

National Incident Report No.838 / 2000

202 National Incident Report (NIR) 838 was issued on 9 February 2000 (Appendix G), relating to the Gloucester two axle friction damped suspension. Research had concluded that the suspension lock-up characteristics could result in high impact forces on an axle when frictional break-out occurred.

203 The NIR was issued across the rail industry to mandate that all axles would be metal particle inspection (MPI) tested before 1 January 2001. Network Rail did not consider derailment as a potential risk associated with the friction suspension characteristics, including the momentary frictional lock-up requiring management action. At the time of RAIB's investigation into the Ely derailment in late 2007 the NIR status report showed the work had not been completed.

Maintainer history and process

204 The wagons involved at Ely were maintained by Marcroft for Redlands Aggregate Limited between 1988 to 1998. The maintenance was then transferred to Rail Freight Services (RFS) which later became Wabtec. Wabtec has been responsible for the maintenance of PHA Lafarge wagons since 1998 - 1999. Neither Marcroft nor Wabtec now hold records relating to any maintenance or incident repair on these wagons before 1998.

205 Wabtec adopted balanced maintenance, incorporating the annual VIBT and PPM regime, after BR removed the regular general repair procedure. Their fitters use the Gloucester Floating Axle Mark 4 maintenance manual in conjunction with BR manuals 11888 and 11889 as part of their maintenance regime

206 Lafarge should, in parallel with Wabtec, retain maintenance records to comply with Railway Group Standard GM/RT 2004, 'Requirement for rail vehicle maintenance', and POCL 564, 'Maintenance and overhaul policies for Private Wagon Registration Agreement companies and maintainers', but have not done so. However,Wabtec retain the records of Lafarge's wagons at Mountsorrel and they are readily available to Lafarge if they require the documents.

Maintenance of wagon REDA 16002

207 The wagon had no frame compensation label at the time of the incident. The suspension units on wagon REDA16002 were manufactured in 1987.

208 From 1998 Wabtec records relating to the most recent VIBT and PPM for REDA 16002 did not accurately reflect the physical condition of the wagon as they did not record the frame packings, because frame twist had neither been suspected nor identified. There is no documentation relating to the fitment of shims since January 1998.

209 New wheel sets were fitted to the wagon on 21 October 2006, after the derailment of the wagon on 5 October 2006 at Northampton depot (paragraph 249). The replacement front wheel set was E616740 and the trailing set E616702 (MPI inspection in September 2006). In addition to wagon REDA 16002, wheel sets from wagons REDA 16003, REDA 16004, REDA 16005 and REDA 16006 were also replaced.

210 Routine maintenance work on the wagon took place on 15 December 2006. A coil spring, damper pot liner, plunger and anti separation pin (Appendix D) was replaced on corner 4 (leading left) and a *ferrobestos* liner to the damper pot on corner 3 (left hand trailing). The replacement of these parts was neither causal nor contributory to the incident.

211 The last VIBT test for wagon REDA 16002 occurred on 12 April 2007. Some components were replaced on corners 3 and 4. These did not have any bearing on the derailment

212 Available records do not show if the frame twist occurred at manufacture, as a result of an incident or from unequal loading during its service life. The damage sustained as a result of the incident prevented any accurate frame twist check being completed. The severe derailment of wagons REDA 16001, REDA 16002 and REDA 16003 at Baguley Fold Junction in 1997 (paragraph 240) may have been the occasion when the twist occurred, followed by the fitting of the compensatory packing. Photographs taken of the wagons immediately after the derailment show that no packing was then fitted. No records from Wabtec or Marcroft indicate any other damage or modification work; thus it is probable but not certain that the packing was fitted as a consequence of the Baguley Fold Junction derailment. There is no documentary or photographic evidence of subsequent identification of frame twist or packing, even when the wheelsets were changed after the Northampton derailment on 5 October 2006.

213 Wabtec reported that no significant heat damage to the friction liners on the incident wagons had been seen during PPM, although the lateral inner guide would have been obscured. Unless other factors had prompted attention, the lateral guides would not have been subject to closer inspection.

214 Subsequent investigations by Network Rail between January and March 2008 have highlighted that significant wear and heat can be generated on lateral guides of the PHA wagon pedestal suspension which are still within the limits of wear. This had not been previously identified by Wabtec, or by Private Wagon Registration Agreement checks (paragraph 382 - 383).

Maintenance of wagon REDA 16001

215 The last VIBT on the wagon was completed on 11 April 2007. Frame twist was not identified and a pass was recorded. The PPM sheets from the last 2 years indicated that frame twist had never been suspected; the records suggest that the frame was correctly set up.

216 The historical wheelchex data show that the frame twist in the region of 27 - 28 mm has been evident since at least March 2005. This wagon was also derailed at Baguley Fold Junction in 1997.

Private Wagons Registration Agreement

History

217 Privately owned wagons have been operated on Britain's main line railway network since the 1840's. The present agreements governing their use were implemented between 1992 and 1994 and remained in force through the changed ownership to Network Rail. All new wagons also operate under a freight operating company's safety case which requires new freight wagons to conform to Railway Group Standards.

218 The private wagon registration agreement evolved during the late 1980s to encourage use of the rail network and ensure all private wagon operators worked to a common standard. The agreements are legally binding contracts between Network Rail and the private owner that can only be terminated with the agreement of both parties.

219 The Private Wagon Registration Agreement identifies the legal responsibilities and duties of private wagon owners and Network Rail. It requires the private owner to comply with all appropriate railway legislation, codes of practice, Health and Safety legislation, POCLs and a maintenance plan which is approved by Network Rail. Regulations applicable to private wagon owners and POCL's were introduced in the 1920s and circulated to private companies to give guidance and establish standard rules for the railway operator.

220 The POCLs are distributed by the Private Wagons Registration Agreement department on a frequent basis to brief the private owners of any changes to POCL procedures, changes to Railway Group Standards affecting their rolling stock or recommendations from incidents or investigations. The Network Rail Private Wagon Registration Agreement department is responsible for the contents, issue and enforcement of the Board's Regulations including the procedures in the former British Rail Maintenance Manuals (paragraph 183).

221 There are currently 23 private wagon owner companies and approximately 5000 private wagons registered under PWRA agreements operating on the rail network. The Private Wagon Registration Agreement has continued throughout the privatisation of British Rail and Railtrack to Network Rail.

222 In October 2002, the maintenance and audit of Private Wagon Registration Agreement companies changed from a contractor acting on behalf of Railtrack to Network Rail. Historical records were handed to Network Rail. For a brief period until 2004, Network Rail subcontracted audit to another contractor, but since then has undertaken all Private Wagon Registration Agreement work internally (paragraph 195). The Private Wagon Registration Agreement department makes recommendations to the private wagon owners and maintainers as results of such audits.

223 Network Rail's Private Wagons Registration Agreement department currently undertakes the audit management and monitoring of the Private Wagons Registration Agreement companies and vehicles operating over its infrastructure.

224 The department audits safety data, such as compliance with wagon maintenance procedures and safety related topics, which is collected from all Private Wagon Registration Agreement companies on a monthly basis. Periodic owner liaison meetings are held with PWRA registered companies to discuss issues and recommendations from the audit.

225 The Private Wagon Registration Agreement department also deals with route availability issues for wagons covered by agreements at the time of registration. Any subsequent changes due to wagon modification are dealt with by the Private Wagon Registration Agreement department in consultation with the freight operator.

226 Safety management and Freight Technical forums are held regularly among Private Wagon Registration Agreement companies to discuss wagon data and incidents that have occurred, although at present there is no local or central Private Wagon Registration Agreement collation of derailment or engineering fault information that may affect other wagon owners or freight operating companies (paragraph 341 and 370).

227 Many of the freight vehicles were registered with British Rail for 20 - 25 year periods. Re-registration and permission for new maintenance regimes is only granted when the maintainer and wagons have been reviewed and assessed to ensure they meet Railway Group Standards. Re-registration is only granted when it can be demonstrated that the relevant wagons remain fit for further traffic, and permission for new maintenance regime is granted.

228 During the Private Wagon Registration Agreement department's inspection and audit of Lafarge PGA wagons in May 2007 'abnormal wear' on the friction liners of the Gloucester suspension was reported by Wabtec to Network Rail , although no action or further investigation was recommended to Wabtec (Figure 41). The last Private Wagon Registration Agreement department audit, inspection and re-registration of Lafarge PHA wagons was in September 2006 (paragraph 91 to 97 and 349 to 351). No relevant issues were identified for these wagons.

229 Records relating to previous incident damage on wagons REDA 16001 to REDA 16005 do not exist within the Private Wagon Registration Agreement department and the Safety Management Information System is used as the central data source for all historical data relating to wagons and incidents (paragraph 343 to 345). The Rail Safety and Standards Board are responsible for the management of the system and audit. Network Rail manages quality of the data through their Safety Delivery Team (paragraph 370 and Appendix H).

Figure 41: Abnormal wear pattern on friction liner of wagon 14503 identified during Network Rail's audit of Lafarge vehicles in May 2007

Private Owner Circulation Letters procedure

230 POCLs are reviewed to maintain the appropriateness of their technical content following an NIR or other safety incident. POCL's are reviewed annually to ensure they are accurate, current and are distributed and amended as required. Certain POCLs issued to PWRA agreement holders incorporate cross references to Railway Group Standards. The Railway Group Standards are reviewed by the PWRA section every 2 months and where necessary changes are incorporated directly into POCL's or referenced from POCL's as appropriate (paragraph 178 and 188 to 189).

English Welsh & Scottish Railway Maintenance & Inspection

231 Although English Welsh & Scottish Railway were not responsible for carrying out the maintenance of the wagons involved, they specify that the wagon owner and maintainer ensure maintenance and performance conform with the requirements of Railway Group Standards and POCLs.

232 The English Welsh & Scottish Railway maintenance manual specifies that the responsibility for maintenance of non English Welsh & Scottish Railway -owned Wagons is with the owner and maintainer. English Welsh & Scottish Railway specifies that private wagon owners are responsible for the audit of their sub contractors to ensure that they implement the appropriate maintenance procedures.

233 English Welsh & Scottish Railway procedures EWS/EP/0079 and EWS/EP/0091, 'Auditing of Private Owners and their Sub-Contractors', state that the company is responsible for ensuring that all wagons in trains that it operates comply with Railway Group Standards to ensure wagons are safe to operate on Network Rail infrastructure.

234 In order to minimise incidents involving wagons and traction units not owned and maintained by English Welsh & Scottish Railway, the company performs a number of checks that include:

- wagon examination at departure points;
- selective audits on the maintenance regime for non English Welsh & Scottish Railway owned wagons;
- reviews of audit reports performed by Network Rail who monitor the Private Wagons Registration Agreement & Private Locomotive Registration Agreements (PLRA); and
- reviews of incidents and accidents with Network Rail, Railway Safety & Standards Board and Private Wagon Registration Agreement & Private Locomotive Registration Agreement (PLRA) owners.

235 The requirements for annual VIBT maintenance are given in English Welsh & Scottish Railway engineering standard EWS/ES/0081, 'Maintenance Specification – MGR and Derivative wagons'. English Welsh & Scottish Railway specifies that frame twist is measured using BR standard WF/81, 'Measurement and compensation for frame twist' (paragraph 360).

236 The English Welsh & Scottish Railway Safety Management System, and previously Railway Safety Case, states that Network Rail is responsible for undertaking audits on wagons registered under a Private Wagon Registration Agreement. English Welsh & Scottish Railway will only undertake its own audit of owners and their vehicles in accordance with English Welsh & Scottish Railway procedures EWS/EP/0079 and EWS/EP/0091 if it identifies a safety or operational performance issue. No audit has been performed on Lafarge or Wabtec since 1998.

English Welsh & Scottish Railway: Accident and Incident Investigation

237 English Welsh & Scottish Railway investigates incidents and accidents in accordance with Railway Group Standard GO/RT3472 'Incident Management and Evidence Gathering' and Railway Group Standard GO/RT3473 'Formal Inquiries, Formal Investigations and Local Investigations'. This process is supplemented by its own Company Standard EWS/OS/001 'Management of Accidents and Incidents affecting the Operational Railway'.

238 The English Welsh & Scottish Railway standard requires an Investigation Manager to be appointed and the investigation completed to ensure safety lessons are learnt. This process was not completed by English Welsh & Scottish Railway in relation to the local investigations into the Northampton incidents (paragraph 247 to 258). No investigative remit or report was compiled to identify root cause and underlying causes and no reporting of the findings was completed or shared with other parties in line with Railway Group Standards. English Welsh & Scottish Railway were unable to provide any records relating to the Baguley Junction derailment in 1997 other than the data on the Safety Management Information System, although RAIB obtained witness evidence that corroborates that English Welsh & Scottish Railway were involved in an Industry investigation (paragraph 239 to 258 and Appendix H).

Previous occurrences of a similar character

239 Incidents relating to the SDT train show the PHA wagons have derailed on twelve separate occasions before the Ely incident with one incident occurring on the branch line in the Ely Dock Junction area in 1990. There have been two reported occasions since the Ely incident (at Peterborough in December 2007 and Mountsorrel in July 2008, both of which are still under investigation). The majority of the historical incidents have been reported as being caused by poor track conditions within yards or sidings. Details of the incidents relevant to the Ely incident are outlined in paragraphs 240 to 267. Details of post investigation methods are detailed in paragraphs 184, 193, 347 and 360.

Baguley Fold Junction, 22 May 1997

240 At 09:30 hrs train 6P54, the self-discharge train, 08:09 hrs Peak Forest to Ashburys, derailed at Baguley Fold Junction. Among the derailed wagons were REDA 16001 to REDA 16007. The cause of the derailment was gauge spread due to rotten sleepers.

241 Wagon REDA 16002 was derailed and collided with wagon REDA16003. The body work on 16002 was damaged. The wagon had no compensatory shims in place in corners 2 (rear right hand corner) and 4 (front left hand corner) and no welding work on its bodywork at the time of this derailment (Figures 42 - 44).

242 The wagons were transferred to Marcroft in Stoke for repair. There are no records of the wagons or a repair ever being undertaken at Marcroft as the archive data was destroyed when the maintenance system was changed from a paper process to a software system.

Figure 42: Detail of damage to vehicle REDA 16002 following Baguley Fold junction derailment. Inset shows no visible packing and no evidence of welding work

Figure 43: Image showing derailed wagon REDA 16003

Figure 44: Image showing derailed wagon REDA16002

243 There is no written record of Railtrack completing an audit on the wagons to authorise the wagons back into service, although RAIB has witness evidence that the Railtrack Private Wagon Registration Agreement department did attend Marcroft and complete an audit and give authority for the wagons to return to normal service (paragraphs 308 to 312).

Small Heath 10 December 2005

244 At 14:50 hrs train 6D38 the 13:12 hrs Small Heath to Mountsorrel Railhead, became derailed at Lafarge Sidings, Small Heath (Figure 45). Five wagons derailed (wagon’s REDA16009, REDA16010, REDA16013, REDA16012 and REDA16011). Two wagons were severely damaged and taken out of the ten wagon set. The eight undamaged wagons returned to Mountsorrel where the conveyer belt was repaired and the train was sent to Northampton for offloading.

245 Wagon REDA16011 was only derailed by one axle (corners 1 and 4). Wagon REDA 16011 wheel-set was lifted and spun and back to back measurements were taken during a visual inspection of the wagon. On the train’s return Wabtec carried out a PPM on the wagons including wagon REDA 16011 which was passed for frame twist, as this test was not in fact undertaken as twist was not identified or suspected in accordance with Section 7 BR11888 and POCL 484. All undamaged wagons remained in service until the next PPM in April 2006. The cause of the derailment was gauge spread due to poor track.

246 The incident is likely to have been the cause of the 36 mm frame twist identified on wagon REDA 16011 by Wheelchex after the Ely incident (paragraph 153 and 188).

Figure 45: Image showing train 6D38 derailed within Small Heath sidings

Northampton 22 August 2006

247 At 22:10 hrs train 6D30 Northampton to Mountsorrel self-discharge train derailed on plain line while travelling at 4.2 mph within the Northampton English Welsh & Scottish Railway depot. Two empty Lafarge wagons PHA 16102 and 16201 (11th and 12th from the locomotive) derailed. The cause was reported to have been due to compacted ballast causing a track twist fault, although the subsequent review suggests that the cause was not correctly identified.

248 These wagons did not have twisted frames. Wagon REDA 16102 was the 11th wagon in train 6L58 at Ely, but did not derail.

Northampton 5 October 2006

249 At 21:00 hrs, five PHA wagons derailed in the English Welsh & Scottish Railway sidings in Northampton while travelling at low speed (Figures 46 & 47). The point of derailment was a track joint with gauge widening to 1457 mm present.

250 The five derailed wagons were REDA 16001, 16002, 16003, 16004 and 16005. These were five of the wagons that were derailed at Ely (wagon REDA 16002 was the first wagon to derail at Ely).

251 Under the terms of GO/RT3473 English Welsh & Scottish Railway and Network Rail conducted a track survey. Network Rail made further observations relating to the loading of the vehicles. A static twist fault of 1 in 273 was identified as the cause of the derailment. No other formal correspondence or information was shared between the parties involved to ensure all parties had a clear understanding of the causal factors and that all areas of the investigation had been completed (paragraph 255 to 258).

Figure 46: Image showing derailed wagons REDA 16001,16002 and 16003

Figure 47: Images of Northampton derailment on 5 October 2006 showing wagons REDA 16001, 16002 and 16003

252 Following the derailment Wabtec undertook a visual inspection of the wagons, but no frame twist check in accordance with POCL 484 was completed, as frame twist was not suspected in any of the derailed wagons. The compensatory shims were not identified and there were no visual markers highlighting the previous packing on 16002. No examination or assessment of the wagons was documented by Wabtec or any other party (paragraph 178 and 188 to 189).

253 The wheel sets and suspension were checked; no damage or feature was reported or documented that might have indicated any frame or suspension misalignment problem. Each derailed wagon had new wheelsets fitted following the incident in line with Wabtec's own procedures following a derailment.

254 The damper plunger on the front left hand suspension (corner 4) of wagon REDA 16002 was replaced due to it being too close to the wear limit. All friction liners were considered to be within tolerance but this was not recorded. The wagons were processed through Private Wagon Registration Agreement maintenance and renewal procedures. The wagons returned to operational use in late October 2006.

255 Network Rail produced a report and concluded that there were several contributory factors that had caused the derailment:

- the empty condition of wagons REDA 16001, 16002, 16003, 16004, 16005;
- the 1 in 273 (static) twist at the point of derailment;
- wide gauge at point of derailment; and
- excessive cant in the area of derailment.

256 Network Rail recommended the track be re-gauged and re-canted throughout the area.

257 Neither English Welsh & Scottish Railway, Lafarge nor Wabtec considered whether the wagons' performance could have been a factor in the derailment. There was very little evidence to show correspondence and the sharing of information took place between Network Rail and the parties involved in the investigation.

258 English Welsh & Scottish Railway produced an incident report and replicated the track survey undertaken by Network Rail but did not produce an investigation report into the incident or appoint a formal Investigation Manager as they are mandated to do in accordance with railway Group Standards. English Welsh & Scottish Railway did not make any recommendations (paragraph 346).

King Edward Bridge 10 May 2007

259 At 06:40 hrs, train 6S22, the 01:45 hrs service from Drax power station to Thornton became derailed while passing through King Edward Bridge South Junction on the approach to Newcastle station. The train consisted of a class 66 locomotive and 39 empty HAA and HMA four-wheel hopper wagons with leaf spring suspensions. The train was travelling at 15 mph (20 km/h) at the time of the derailment (paragraph 384).

260 Following the initial derailment the train traversed the *Up* Carlisle and *Down* Carlisle lines before running across the King Edward Bridge on the down slow line in a partially derailed condition. It came to a stand on the approach to Newcastle station following an automatic brake application. There was significant damage to *points* operating equipment along the route of derailed running, to the down slow line on the bridge, and to the points and *crossings* at Newcastle South Junction.

261 The RAIB has investigated and reported on this derailment (RAIB Report 02/2008-31/01/2008). The RAIB identified three causal factors:

- a track twist within the crossover which equated to 1 in 164 (34 mm) over the wheelbase of the wagon;
- the wagon frame had a twist in excess of 30 mm before the derailment; and
- compensatory packing had been fitted above the right leading axle box which had worsened the original frame twist by 10 mm. The correct placement of the packing would have reduced the effects of the original frame twist.

262 The RAIB made four recommendations in its report. Two are relevant to the derailment at Ely, and refer to:

- checking wagons for frame twist at annual maintenance; and
- using Wheelchex to identify and if possible, warn of, out of balance wheel loading on wagons.

263 The investigation made observations on the lack of available records relating to the service history of the wagons involved in the incident.

Peterborough West Yard 10 December 2007

264 The driver preparing train 6M64, the 23:04 hrs Peterborough West Yard Mountsorrel, on No.1 Reception line at Peterborough West Yard, reported that wagon REDA16081 with GFA suspension had been discovered in a derailed state.

265 The derailment occurred on English Welsh & Scottish Railway infrastructure. A Network Rail MOM attended and reported that the wagon had derailed by one wheelset, with no evidence of railhead flange climb. No other wagons in the train had been derailed

266 The English Welsh & Scottish Railway investigation concluded that the track geometry was the cause of the derailment. In view of the findings from the Ely investigation, English Welsh & Scottish Railway has requested this matter is further investigated by the English Welsh & Scottish Railway Area Manager. At the time of writing this report no conclusions have been reported by English Welsh & Scottish Railway (see paragraph 93).

Mountsorrel Railhead Depot 14 July 2008

267 Upon its arrival at Mountsorrel depot at 03:30 hrs, train 6D30, the 22:10 hrs service from Northampton Freight Depot to Mountsorrel, formed by locomotive 66198 hauling 30 empty PHA type vehicles and 1 empty KJA type vehicle, became derailed by two vehicles on Network Rail's infrastructure. Wagon REDA 16066 formed 19th from the locomotive derailed during the incident with the leading wheelset becoming re-railed, and wagon 16219 (the 20th vehicle), was derailed by both axles. The rear 11 vehicles were unaffected. The incident has been investigated by Lafarge and Network Rail, who have concluded that the derailment was caused by track twist, small frame twists on both vehicles which were within the 6 mm prescribed limit, and the marshalling of the train.

268 Recommendations were made in relation to the track geometry at Mountsorrel, and the wagon behaviour in conjunction with other investigations into PGA and PHA wagon behaviour.

Analysis

Identification of the immediate cause

269 The immediate cause of the incident was the right hand leading wheel flange on wagon REDA 16002 running over the rail head in the vicinity of Hawks user worked crossing. Due to the suspension locking up, the guiding forces from this flange were insufficient to keep the wagon on the track as it rounded the curve. The low vertical load from the wheel resulted in very light marks on the rail head as the wheel flange ran across it.

Identification of causal and contributory factors

Loading of wagons on 6L58

270 Visual observations and simulation studies indicate that the uneven loading of PHA wagons at Mountsorrel (paragraphs 86 - 90), resulting in imbalance of wheel loading (rear to front axle) in combination with the high centre of gravity of the wagons, and the effect of frame twist could produce a derailment risk on track that complies with Network Rail standards (paragraph 283 to 285).

271 The method of loading meant that the wagons were rear axle heavy and over the permitted gross laden weight. The loading of the wagons is considered to be possibly contributory in relation to the effects it may have had on the frictional behaviour of the suspension.

272 The wagon's gross laden weight exceeded the rail network maximum permitted axle load of 25.5 tonnes. The RAIB has not been able to ascertain what the accepted design weight tolerance is to ascertain what effect an overloaded wagon has on the suspension characteristics. The analysis of the gross weights of the wagons show a high proportion were over the specified maximum weight allowed.

273 Tests on a static wagon that is unevenly loaded diagonally and over its maximum load indicate the possibility of a mis-alignment between the pedestal and the saddle of the suspension; this could exacerbate the effect of any frame twist. However, it would also increase the vertical load, and under normal circumstances, when rounding a left hand curve such as the one to bridge 2235, would prevent the wagon's leading right wheel flange climbing up the high right rail.

274 The details of the loads in the wagons of train 6L58 were incorrectly entered onto the order to move slip for TOPS input. The figures on the form were then changed and overwritten. Both entries on the form were incorrect (paragraph 86 to 87).

275 It was established, from the Wheelchex readings at Eastrea, and from weighings of the undamaged wagons following the incident, that approximately 50% of wagons were overloaded, and that the load was generally offset towards the rear of the wagon. Observation of the loading process at Mountsorrel indicated that these discrepancies were due to the numerous tasks required to be undertaken by the loading operator at the same time. Each load of stone arrived at 10 second intervals, with the digital counter re-setting to zero after each load. The tasks overloaded the operator, resulting in his inability to complete them correctly. The peak or uneven loading was not identified by the Lafarge staff after the load was dropped into the wagon, or by the English Welsh & Scottish Railway ground staff who would normally check the load from the overhead gantry point (paragraph 78 to 79).

276 The weighing of the loads after the incident confirmed that the written details of weights on the 'order to move' slip and those entered onto TOPS were not an accurate record of the loads in each wagon.

Track Geometry

Track Twist

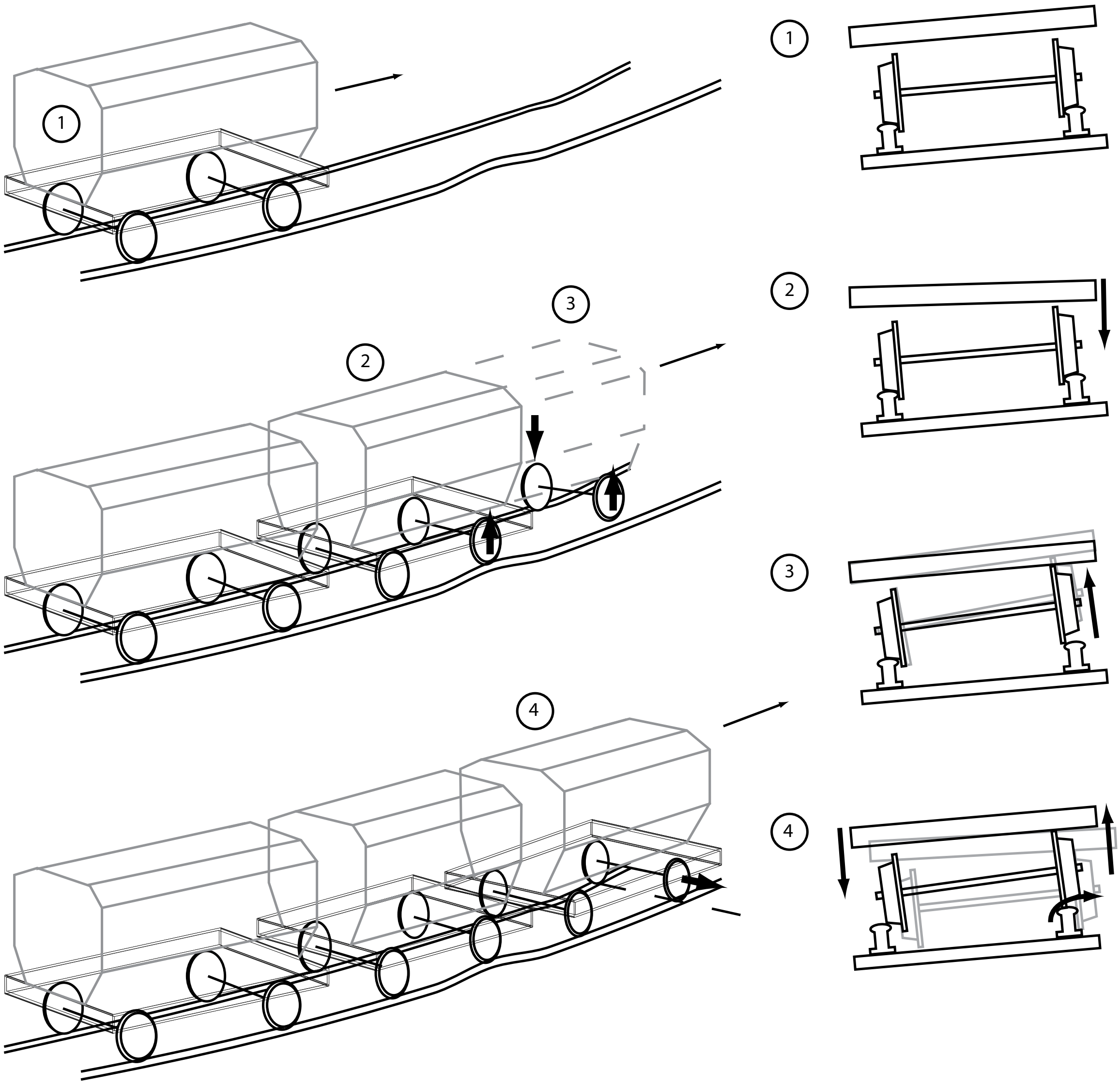
277 The track at Ely had a track twist outside the maintenance limits for track (NR/SP/TRK/001), which increased the cant of the outer (high) right-hand rail on the approach to the point of derailment. The twist of 13.5 mm from sleeper +28 to sleeper +24 would have caused wagon 16002 to initially experience an increased load on the leading right-hand wheel. The twist then reversed to -12.8 mm at sleeper +13, thus off-loading the right hand wheel.

278 The additional compression of the right-hand suspension (Figures 48 (1) and (2)) is believed to have caused the right-hand leading suspension to become locked with the springs highly compressed.

279 The reversal in the twist then caused the wagon to apply an increased load to the front left wheel (Figure 48 (3)) and reduced the load on the front right-hand wheel (Figure 48 (4)). The right-hand wheel remained high and subsequently provided very little contact with the gauge corner of the rail. As the removal of any one feature would have prevented the derailment from occurring, the track twist was causal to the derailment, even though it had not reached the intervention limits (paragraphs 108 to 110).

Point of derailment

280 The flange climb mark at the point of derailment was visible on the right-hand gauge corner, indicating the flange of the right wheel had climbed through and onto the rail head, making intermittent contact with it. The derailment mark was 250 - 300 mm in length, extremely light, and barely visible to the eye, indicating very little or no vertical and lateral load had been present on the leading right wheel flange. The flange climb marks of the right-hand leading wheel did not exhibit the expected behaviour of a leading axle on a left hand canted curve with high right rail, where it would normally be expected that heavy and deep score marks would be left by the heavily loaded wheel (paragraph 101). The drop-off mark on the left-hand rail was clearly visible.



(1) Wagon running normally

(2) Wheel lifts due to track twist

(3) Suspension locks up and wheel stays high as twist reverses

(4) Unloaded wheel derails over high rail

Figure 48: Diagram of simplified derailment sequence (1) to (4)

Frictional lock-up

281 The leading wheelset of wagon REDA 16002 was the only wheelset to derail between the point of derailment and bridge 2235. The flange climb mark occurred in an unusually short distance with flange contact on the gauge corner almost non existent. This is an uncharacteristic feature of a derailment and is indicative of the suspension 'sticking' because it was frictionally locked and subsequently offloading off the wheel.

282 The twist of the track placed a differential load on wagon REDA 16002's front suspension over a short length. The initial load was placed on the leading right wheel which compressed the suspension and reduced the distance between the saddle and pedestal.

283 The effects of the frame twist and incorrect packing probably caused the right-hand mating surfaces of the pedestal and saddle to heat to an abnormal temperature during the journey. The effects of the track twist, frame twist and generated heat in combination with the frictional unpredictability of the suspension at low speed caused the pedestal and saddle to frictionally 'lock-up' with the suspension higher than its normal position on the leading axle of REDA 16002. This caused the leading right wheel to become unloaded. The track twist then reversed, causing the load to be transferred onto the leading left-hand wheel. The reduced vertical force relative to the lateral force on the leading right wheel flange, thus initiated the conditions necessary for a derailment.

284 The light wheel loading, shown by the depth of the impact marks on the sleepers from the right-hand wheel, increased with time and distance from the point of derailment. There was no visual evidence of the frictional breakout of the suspension occurring in one single movement prior to the entrance to the bridge.

285 The evidence supports the likelihood that the frictional lock-up remained and permitted the flange of the leading right wheel on wagon REDA 16002 to climb the outer (high) right hand rail on the approach to Hawks user worked crossing.

Track gauge

286 The gauge over a 3 metre distance on the approach to the derailment point was within the specified maintenance limits and averaged 1442 - 1443 mm. The gauge variation from normal (1435 mm) is believed to have originated from the canted track and heavy-axle freight traffic on the route. The visible damage caused to the Pandrol insulators (paragraph 112) indicates that train movement at low speed produced an increase in the downward and lateral forces on the lower left-hand rail. This is likely to have been the cause of gauge widening and the slight wear on the gauge corner of the low (left) rail.

287 The track gauge became tight to gauge from sleeper -4 (1434 mm) through to sleeper -19 (1424 mm). NR/SP/TRK/001 specifies the track maintenance limits to be 1431 - 1429 mm with maintenance. Intervention is required at 1426 mm. The tight gauge in close proximity to the point of derailment would have forced wagon 16002 to the right and may have increased the frictional values, encouraging the leading right hand wheel flange on wagon 16002 to ride over the high rail. (paragraphs 111 to 112).

Dynamic modelling

288 Network Rail commissioned computer simulation of the track geometry and wagon characteristics, using the Vampire © software system. The simulation used measurements of the performance of two non-derailed PHA wagons, for both coupled and uncoupled states. The torsional tests on wagons 16055 and 16056 concluded that there was a wide range of high value frictional suspension levels which could result in a derailment risk.

289 The dynamic analysis indicated that:

- the removal of the track twist feature reduced the derailment risk.
- there was no evidence to suggest the frame twist on REDA 16001 or its draw bar coupling affected the off loading of the leading axle of REDA 16002.
- a PHA wagon, whether in laden or unladen conditions, would not be compliant with Railway Group Standard GM/RT 2141, Resistance of Railway Vehicles to Derailment and Roll-Over (even without a twisted frame).

290 Although the wagon design predates the Railway Group Standard (GM/RT 2141) the analysis of the model 2141 indicates that the high frictional characteristics of the suspension significantly affect the wagon type's compliance with that standard.

291 The maximum limit for the ratio of change in vertical load on a wheel relative to its nominal load (commonly known as $\Delta Q/Q$) is 0.6. The model predicted values between 0.75 in a laden condition rising to 0.94 in an unladen condition without frame twist and 1.0 unladen condition with twist.

292 The maximum limit for the ratio of vertical load to lateral force on a wheel (commonly known as Y/Q) is 1.2. The model for wagon 16002 predicted a high lateral force and a flange climb of 13 mm, producing a high risk of derailment.

293 The analysis predicted that a PHA wagon type would be prone to frequent derailments, which historical data (six reported incidents since 1997) does not support. However, the simulation data on the behaviour of the GFA dynamic suspension and frictional characteristics was limited.

294 The simulation indicated a point of derailment eight metres from where the derailment actually occurred, indicating the model was subject to some inaccuracies. In January 2008 Network Rail Private Wagons Registration Agreement engineers reported that they had identified further abnormal wear patterns and heat discolouration on lateral guides and friction liners of a PHA wagon. In February 2008 Network Rail commissioned further software modelling. This considered conditions in which the suspension components produced a lack of damping on the wagon. The analysis predicted that a lack of damping would have decreased the risk of derailment at the point of derailment.

295 The simulation included the effects of the frame twist and current data relating to the frictional characteristics causing the leading right suspension to frictionally lock-up, both of which are considered to be primary factors in this incident. There is limited current data on frictional breakout characteristics whilst the wagon is running on the rail network. The investigation has shown the suspension to be unpredictable at slow speed in a loaded and tare condition. This may be different at line speed and should be explored further by Network Rail and Lafarge.

296 The modelling corroborates the conclusion that when defects are present on the wagon, the dynamic interaction of the wagon and the track twist could result in a derailment.

Track recording vehicle

297 Tamping of the track in the area of the point of derailment was intended for the 16 June 2007 although this was scheduled for 24 June 2007. The output of the TRV run showed that the track was within the intervention standards laid down in NR /SP/TRK/001. Correct tamping of the track would have removed the track twist and although the track was within laid down standards, the delay in tamping was causal to the derailment (paragraph 118).

Track Maintenance Engineer

298 The Track Maintenance Engineer was aware of the track faults on his area and was prioritising his work load generally in line with guidelines given in NR /SP/ TRK/001.

299 The track inspection regime is based upon management of the risk to the safety of the line. It recognises commercial issues, rates of deterioration, anticipated failure modes and maintenance planning by the Track Maintenance Engineer (in line with the Network Rail track standard NR/SP/TRK/001 on the frequency of track inspections).

300 The Track Maintenance Engineer reviewed track condition in conjunction with his local knowledge of fault propagation and trends. NR/SP/TRK/001 outlines that the track should be maintained in line with "good practice and that maintenance levels are not normally exceeded and intervention levels are only reached in exceptional circumstances".

301 The Track Maintenance Engineer was managing, on average, 400 level 2 fault locations in any full three-month period.

302 Due to the increased workload of the Track Maintenance Engineer and reduction in maintenance hours available on the Soham branch line (paragraph 121 to 122), the RAIB considers that the Track Maintenance Engineer had no option but to work to intervention limits rather than maintenance limits as defined in NR/SP/TRK/001.

Bridge 2235

303 The structure of the bridge was neither causal nor contributory to the initial derailment, but its location and design did affect the subsequent derailment of the large number of wagons. Risk assessment procedures identify derailment as a factor to be considered in the design or upgrading of a bridge; the fitment of *guard rail*s might have limited damage to the bridge, but there is no certainty of this.

304 On other rail networks the installation of emergency flange running plates has occasionally been used to mitigate the damage caused by a derailed wheelset. Given the nature of the derailment and the limited number of underbridges of this nature it would not appear to be reasonably practicable to fit guard rails or flange running plates to bridges of this type on a widespread basis.

Wheelchex

System

305 Railtrack in consultation with the Freight Technical Committee were responsible for setting the policy for Wheelchex. The potential risks of diagonally imbalanced loads were not discussed or identified. The automatic processing of data from the Wheelchex system is limited to flagging exceptional impact loads. Network Rail's data analysts undertake reviews, and provide information on such matters as wagon weights and other safety information to private wagon owners each month as part of their role. Although the process was capable of identifying wheel load imbalance, the data analysed before the accident did not include out of balance axle loads. The reactive data processing of the system is an important safety process, but the system is capable of monitoring 'live' data to ensure that wagons are safe and compliant during their journey.

306 The Wheelchex data has provided key information, allowing comparison of the wagons in train 6L58 with each other since March 2005. This enabled the RAIB to understand the performance of the damaged wagons that were involved in the Ely incident (paragraph 128 to 133, 160 to 165, Figures 29, 36, 37 and Appendix F).

307 Prior to the derailment at Ely the ability to use the Wheelchex system to identify wheel imbalance or for condition monitoring was neither identified nor fully appreciated by Network Rail. This is an underlying cause of the derailment.

Wagon REDA 16002

Frame twist and packings

308 Wagon REDA 16002 was severely damaged as a result of the impact with the bridge. Measurement of the frame, axles and wheel sets could therefore not be used to confirm their pre-incident state.

309 Wheelchex at various locations had recorded uneven wheel loads on the wagon since at least 31 March 2005, pre-dating the Northampton (paragraphs 240 to 264) and Ely derailments.

310 Because of the lack of records the RAIB cannot definitely establish how or when the frame twist and packing on wagon 16002 occurred. However, there were no frame packings present when the wagon derailed at Baguley Fold Junction in 1997, and the RAIB considers that the frame packings were fitted after that derailment. No 'Q' marker was painted onto the wagon frame as an aid to identify that shims had been fitted (paragraph 240 to 243).

311 The wheelchex data from wagon REDA 16002 equates to a twist of 40 mm with corners 1 and 3 of the wagon high. Although the wagon was too badly damaged to be tested for frame twist, the 10 mm shims placed in corners 2 and 4 indicate that it is possible that the wrong corners were packed at some stage resulting in the wagon operating from that date with out of balance loading between the wheels. If the same packing had been in corners 1 and 3 the overall effect would have been to even out the loading.

312 The incorrectly shimmed corners 2 and 4 on wagon REDA 16002 would have exacerbated the existing frame twist and wheel load imbalance, and were a causal factor of the derailment (paragraphs 240 to 243).

Suspension components

313 The replacement of individual manganese friction liners and welding of the lateral guides on the pedestal or saddle during PPM may have produced a variation in wear patterns as only the friction liner that is past the limits is replaced and not both mating surfaces. The materials used on both components are identical. However, the surface of one face may already be damaged, contaminated or misaligned when a new welded surface is aligned with the existing mating surface. This may have a detrimental effect on the frictional characteristics of the two surfaces. The wear rate of the two surfaces should continue at the same rate but the surface alignment and profile may not be identical and therefore they may not be in contact as designed (paragraph 201 and Figure 50 (a) and (b)).

314 The measurements taken from the external rib surface of the saddle (Figure 49) and internal surface of the pedestal on wagon REDA 16002 showed a variation of 11 mm increasing to 13 mm either side of the saddle. By comparison wagon 16011 had less wear with a clearance of 8 mm increasing to 9 mm (paragraph 160).

315 The friction liner on the leading right hand suspension showed signs of abnormal heat on areas of the mating faces of the pedestal and damper pad, as well as the lateral guides of the pedestal (Figures 7, 40, 49 (a) to (c) and 50 (a) to (b)).

316 The wear surface on the leading right-hand side guide (corner 1) of wagon REDA 16002 showed two areas that appear to have been over-heated, as well as having significant amounts of wear evident. One area of metal surface damage on the left hand surface of the right hand guide had been ‘smeared’ causing the metal to have a *lapped* appearance (Figure 32 to 33).

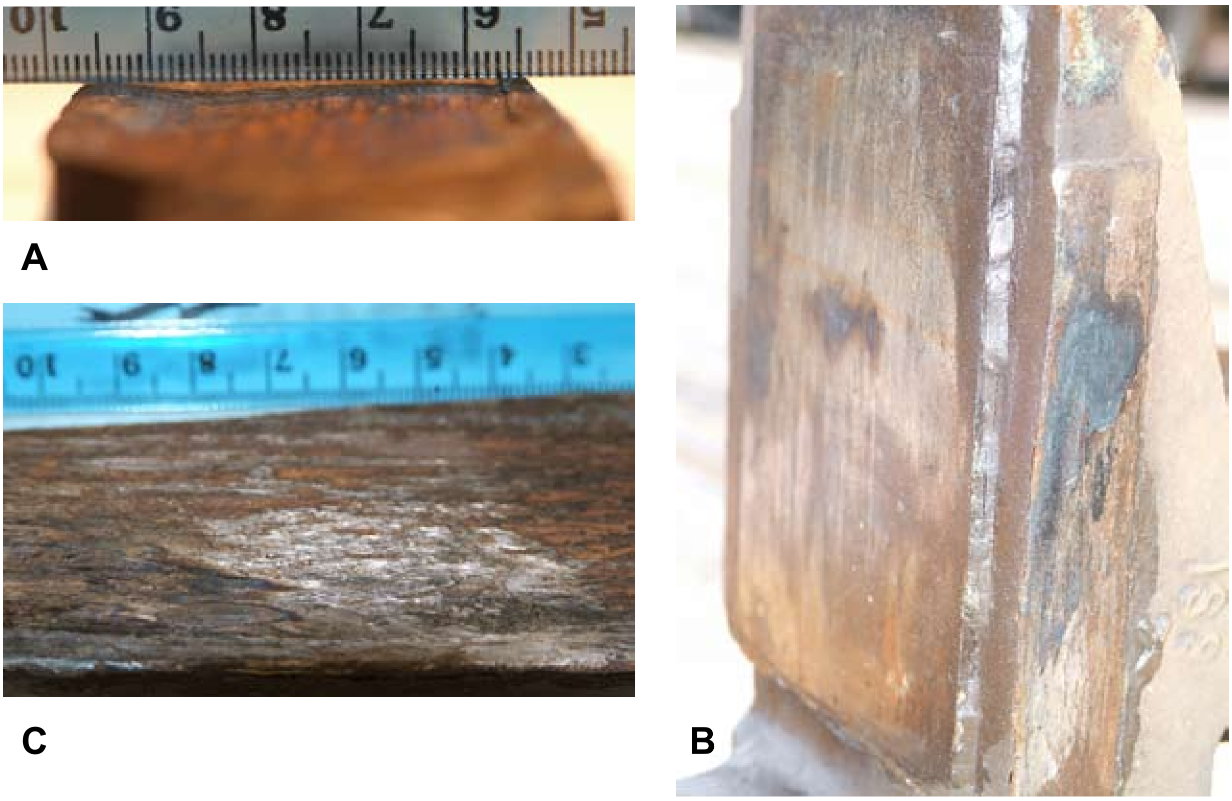


Figure 49: (A) Image of furrowing from front pedestal of REDA 16002. (B) Image of front portion of inner aspect of leading right-hand pedestal. (c) Heat damage and corrosion to pedestal guide

317 A section through the leading right hand pedestal of wagon REDA 16002's left-hand side lateral guide rib where heating was apparent, shows that it had been subject to a considerable amount of abrasive wear resulting in a reduced thickness of the rib of approximately 1.2 mm on one side and 2.0 mm on the other side. The ribs on the right hand side lateral guide from the reference wagon REDA 16011 suggest that they were originally 2.5 mm thick in the undamaged condition; thus the damaged guides had reduced by over 1 mm.

318 A section through the heated area of wagon REDA 16002 shows that the surface and microstructure of the casting was heavily deformed, with evidence of re-crystallisation of the material. The temperature colours that arose as a result of the heating indicated that the temperature had risen to between 300 and 700 degrees Celsius. The worn surface area also had areas where oxidisation and corrosion had formed within and under the heated area, indicating that the heating had taken place over an extended period of time and not just at the derailment site (Figure 49 (a) to (c)).

319 Abrasive damage was also visible on the left hand front axle guide and saddle. The visible temperature discolouration was not as significant as seen on the right hand guide friction liner and rib.

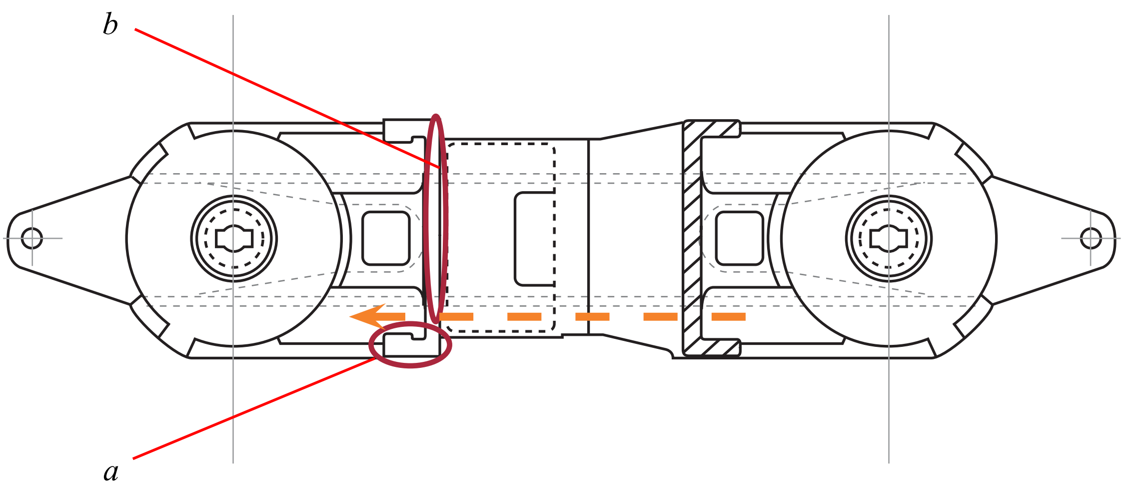


Figure 50: Plan view of Leading RHS pedestal and saddle showing area of frictional heat generation at (a) lateral guide and (b) friction liner

320 The irregular surface wear on the manganese friction liners on the pedestal, saddle and weld on the lateral guides of wagon REDA 16002 showed a furrowing effect had occurred between the two components (Figure 49 (a)). This indicates a misalignment had occurred between the mating surfaces of the saddle and guide friction liners, and the welded surfaces on the lateral guides.

321 While it is possible that misalignment and very high loads may have been applied following the derailment, it is unlikely that the damage to the leading right hand suspension components could have occurred in the time and distance between the derailment point and the wagon coming to rest. The visual examination showed no evidence of similar heat damage occurring to the leading left hand suspension liners. This would have been apparent if the heat damage had been caused by the wheel flange repeatedly striking the sleeper, causing the suspension and friction liners to move up and down at a high frequency.

322 The visual examination and metallurgical analysis show that heat affected areas and oxidisation had occurred on the lateral guides. The heat affected area was overlaid by 'scarring' damage which was caused as wagon REDA 16002 ran onto the bridge and the saddle and pedestal friction liners on the leading wheelset were forced apart. The over-layering characteristic of the damage indicates that the heat damage areas had occurred prior to the incident.

323 There is no historical maintenance data relating to wear rates, mixing old surfaces with new friction liners or weld, and processes to be used if abnormal wear or heat damage is identified. Therefore they are not incorporated into the Mark 4 GFA maintenance manual as an item for inspection.

324 The combination of the frame twist and the frictional characteristics of the suspension caused the normal clearance on the inner surfaces of the right hand pedestal and saddle lateral guides to close, and the surfaces to stick. This caused a variation in the wear rates, a misalignment of the two surfaces and abnormal wear and heat to occur. The frictional characteristics of the suspension were a causal factor in the derailment (paragraphs 194 to 201 Figures 49 (a) to (c)).

Damper pot and damper pad

325 The damper pot was not recovered; however there is no evidence on the mating surfaces of the pedestal (Figures 7 & 40) to suggest the damper pot or damper pad affected the damping force acting on the friction liners and suspension performance.

Springs

326 Destructive analysis of the springs showed that there was nothing to indicate that the material used or their manufacture (including heat treatment) was inadequate. There is no evidence that any springs did not perform as required.

Cup spring

327 The 'cup spring' found on the embankment on the Soham side of Hawks UWC (paragraph 144), was undamaged. The cup spring can only be released if there is a catastrophic failure of the suspension assembly, or the retaining pin (paragraph 40) within the assembly fractures, allowing movement to take place. The fracture of the retaining pin is a known characteristic of post derailment damage on the suspension assembly.

328 The cup spring had no sign of impact or cross contamination (in the form of paint) with the pedestal or other suspension components, which would have been evident if a suspension or derailment failure had occurred.

329 There was no physical evidence on the surfaces of the right or left hand saddle and pedestals to indicate that any catastrophic failure of the spring assembly had occurred before the derailment or that the retaining pin had fractured. There were no primary or secondary springs found at this location. There was no evidence of suspension failure of the spring assembly occurring before or at the point of derailment.

330 The RAIB has concluded that the cup spring is identical to and originated from a PHA wagon at the Ely derailment site, but there is no evidence of how the spring came to be in the location where it was found. The cup spring is considered to have been in that position as a consequence of the accident recovery, and was not causal or contributory.

Wheel sets and axles

331 Back to back measurements of E616740 showed the wheelset to be within specification. Examination of the wheelsets enabled the RAIB to conclude that there was no evidence of any seizure of the axles or bearings, or of failure of wheelsets, that contributed to the accident.

Wagon 16001

332 It cannot be definitely established how the frame twist on wagon REDA 16001 occurred and there is no evidence of packing ever being fitted. The RAIB considers it likely that it was as a result of the derailment at Baguley Fold Junction in 1997. At that time there was no additional packing fitted for frame twist compensation and no visible evidence of incident damage (paragraphs 240 to 243).

333 Wheelchex has recorded uneven wheel loads for wagon REDA 16001 since at least 31 March 2005, pre-dating the Northampton and Ely derailments (paragraph 155)

334 The wagon examination did not provide any obvious visible indication of a frame twist and the wagon being out of compliance. The wagon suspension components and clearances were within specification. Measurements taken of the *bump stop clearances* provided the only indication that a frame twist existed, with a difference of 19 mm between corner 1 and 4.

335 Measurements showed that the wagon had a 31.8 mm twist (1 in 150) over the 4775 mm wheelbase and 36 mm of actual twist (1 in 133) when the frame was separated from the suspension components.

336 The POCL 484 process requires a maintainer to check a wagon for frame twist. This requirement is a subjective visual check by the engineer (paragraph 184). It is extremely difficult to identify frame twist visually without the aid of markers. The only positive means of identifying twist is by measurement of the frame.

337 As there were similar levels of twist in wagons REDA 16002 and 16001 the RAIB considers that the lack of a requirement to measure the frame by the maintainer and by the standards applies to wagon REDA 16002 as well as wagon 16001. The subjective assessment in accordance with pre incident POCL 484 version 1 was therefore not effective. The subjective assessment guidance within POCL 484 is considered to be an underlying cause in not identifying the frame twist on wagons REDA 16002 and REDA 16001 before the incident.

338 The bar coupling between wagon REDA 16001 and wagon REDA 16002 showed no signs of pre-incident damage or constraint and is not considered to have had any dynamic effect on wagon REDA 16002. The frame twist on wagon REDA 16001 did not contribute to the derailment.

Private Wagon Registration Agreement

339 The private wagon owners and British Rail entered into an agreement by which wagons were registered for a 25 year period. The Lafarge PHA wagons are due for re-registration in 2013.

340 The wagon owner is required to have a maintenance policy in conjunction with their maintainer, as mandated in GM/RT 2004 and POCL 564 v.2 (circa 2005). Lafarge do not have a separate policy as they sub contract this to Wabtec.

Investigation of previous incidents

341 No investigation report or witness evidence was made available to the RAIB by Network Rail, English Welsh & Scottish Railway, Wabtec or Lafarge relating to the 1997 derailment of wagons 16001 and 16002 (inter alia) at Baguley Junction until the records for the incident were located by chance by a Lafarge Manager in 2008, resulting in the identification of the Railtrack investigation report dated 17 June 1997. This was due to the inaccurate information that had been entered onto SMIS. This reduced the RAIB's ability to identify historical evidence at an early stage that was pertinent to the investigation and accident at Ely (paragraphs 343 to 346).

342 The Network Rail and English Welsh & Scottish Railway investigations into the Peterborough and Northampton incidents were focused on track geometry faults and did not consider wagon behaviour or include a thorough examination of the wagons. The parties involved did not identify the root and underlying causes of the incidents in compliance with Railway Group Standard GO/RT 3473 and did not consider wagon examination to be a factor for investigation. The view taken by the investigators was that the incident was a derailment at low speed and short in distance. Track faults were identified, which caused the scope of the investigation to be reduced.

343 The Network Rail Safety Management Information System SMIS was searched in the early stage of the investigation. Details of incidents and wagon details had been entered incorrectly and therefore could not be located. A further review was conducted and known details of derailment involving the PHA REDA wagons are listed in Appendix H.

344 The inaccurate information input and retrieval onto SMIS is a quality of information issue. Data quality is dependant on the person entering the correct information in the correct format and data fields, which if done incorrectly or omitted may affect the collation and analysis of the data at a later stage. The critical data fields relate to the wagon details and type (CARKND) and SMIS inputters may not be aware what a CARKND is or how a given vehicle number this relates to the wagon type. Since British Rail, the system has not had an equivalent of a derailment form (D2) although the subject has been discussed by Network Rail and is currently being reviewed. Although some detailed forms for the collection of data were devised by Railtrack on the creation of SMIS, these were not generally used.

345 Network Rail undertake SMIS data quality checks, but these are generic and do not cover all data fields. The inaccurate information shown on SMIS was not causal or contributory to the incident. Network Rail and the Rail Safety and Standards Board are currently reviewing the quality of SMIS data (paragraph 229 and 370).

346 The lack of a comprehensive investigation into the wagons after the Northampton incident meant that the frame twist on wagon REDA 16002 was not discovered. This is a causal factor for the derailment at Ely eight months later (paragraphs 249 to 258).

Identification of underlying causes

General Repair (GR)

347 Paragraphs 174 to 179 explain the removal of the requirement for regular general repairs, and the consequent loss of measured frame twist checks. Paragraph 184 explains the BR 11188 Section 7 instruction to maintainers to check for frame twist after a derailment and refers the maintainer to POCL 484 which only requires the maintainer to complete a frame twist check if suspected. The omission of a mandatory measured frame twist check within PPM and BR 11188 is an underlying cause of the incident (paragraph 360).

PHA Wagon design

348 The PHA design has grandfather rights and met the BR wagon design standards at the time of its introduction onto the rail network.

349 A British Rail Research report was commissioned by British Rail to research the effects of various wagon and suspension types on ground borne vibration (TM 037 BRB 1988). The research report included test results and also contained analysis on frictional break-out characteristics of the GFA and other suspension types. Two-axle Gloucester suspensions on PHA wagons were identified as having the worst friction performance levels on the rail network. The analysis of frictional distribution on the suspension suggested that only 10% of the wagons had friction values below the design level; the average was 1.5 times over the design level, while 10% were over 2.1 times the design level.

350 In 1997 Railtrack commissioned research on the effect of ground borne vibration produced by freight wagons. Several types of wagon were reviewed and a report (TR 097) produced. The report concluded that high track forces were generated by two axle type wagons. The PHA type wagon with GFA suspension was given the highest track access charge (category (A)) because of the high track maintenance costs that it generated (paragraph 194).

351 The conclusions of the research (TR 097) provided the following improvement options in relation to the GFA suspension:

- phasing out of the pedestal suspension in the long term in favour of less damaging suspension types (it also highlighted that this option may not be cost effective);
- speed and load restrictions should be instigated for this type of wagon;
- redesign of the suspension components to ensure friction levels are close to the design values; and

- a review or modification of the loading and unloading procedures and the introduction of some type of shield to prevent contamination of the suspension components to reduce the effect on friction levels.

352 There is evidence to suggest that in 1996/1997, Railtrack's strategy was to prevent any additional wagons with GFA suspension using the rail network and any wagon requiring re-build would not be authorised. This decision was not implemented from the late 1990s; this decision is believed to be connected with commercial pressures on Railtrack regarding freight traffic.

353 The improvement options from the research were not implemented by Railtrack, nor were they considered by Network Rail; in addition the report was not published within the Private Wagon Registration Agreement community although the issues may have been discussed. The train operators and wagon maintainers therefore had no opportunity to assess the maintenance implications of the report. This is considered to be an underlying cause of the derailment (paragraphs 216 to 230).

354 Uneven wheel loading data from Wheelchex is sufficient, if appropriately analysed, to identify in real time, suspected frame twist or offset loading.

Severity of consequences

355 While there were no injuries as a consequence of the incident, the train driver conducting the preliminary inspection of the train after the incident, walked between and under damaged wagons REDA 16000 and REDA 16001. This act could have resulted in personal injury to the driver.

356 The environment agency placed water booms on the river to minimise any environmental damage.

357 The closure of the River Great Ouse to navigation had a significant impact on the local tourist Industry.

Conclusions

Immediate cause

358 The immediate cause of the incident was the right hand leading wheel flange on wagon REDA 16002 running over the rail head in the vicinity of Hawks user worked crossing. This was caused by the leading right hand suspension sticking, or fictionally locking up, with the result that only the tip of the wheel flange was in contact with the rail. As the wagon rounded the curve only very small guiding forces acted on the flange, which were insufficient to keep the vehicle on the track. The low vertical load from the wheel resulted in very light marks on the rail head as the wheel flange ran across it.

Causal factors

359 Causal factors were:

- The frictional characteristics of the GFA suspension caused irregular wear and a misalignment to take place between the friction liners and lateral guides of the axle pedestal and the suspension saddle. This generated a frictional lock-up of the right leading suspension (paragraphs 313 to 324, Recommendations 2 and 4).
- The frame had a twist of approximately 20 mm (beyond the 6 mm limit) before the derailment; and wrongly placed compensatory packing was present above the leading left and trailing right axle boxes creating an effective twist of 40 mm, significantly greater than the 6 mm prescribed limit for twist. The resultant twist worsened the effect of the diagonal wheel load imbalance (paragraph 312, Recommendation 2,5 and 7).
- A track twist of 1 in 222 existed immediately before the point of derailment. This is outside the maintenance limits but within intervention limits but not so severe as to require attention within 14 days (paragraph 279, Recommendations 9 and 10).
- Tamping that had been intended for the week before the derailment did not take place (paragraph 298, no Recommendation)
- English Welsh & Scottish Railway Wabtec, Lafarge and Network Rail did not identify frame twist features and a lack of corrective maintenance during an investigation into a previous derailment involving the wagons that were subsequently involved in the Ely incident (paragraphs 341 to 346, Recommendations 7 and 14).

Underlying causes

360 The underlying causes were:

- Network Rail and the Freight operators did not recognise the ability of the Wheelchex system to be capable of preventative or reactive data processing in identifying wagon deficiencies relating to diagonally imbalanced wheel loads (paragraph 307, Recommendation 1);
- Since 1992 British Rail (BR) , English Welsh & Scottish Railway and later other companies within the Freight Industry had not regularly monitored vehicles for frame twist (paragraph 235), Recommendation 2 & 5);
- Improvement options from a research report relating to the effects of contamination on the pedestal suspension assemblies were not published or implemented within the Private Wagon Registration Agreement (paragraph 351, Recommendation 4); and
- The omission of a mandatory requirement to complete a measured frame twist check within PPM and BR 11888 (paragraph 347, Recommendation 8).

Observations

361 The weighbridge facility was not used at Mountsorrel after the loading of 6L58. This would have confirmed the weight and excessive loading but would not have identified wheel load imbalance of the wagons before the train departed (paragraph 272, Recommendations 12, 13, 15 & 16).

362 The increased frequency of rail traffic on the Soham branch at the weekend meant that the engineering hours available to the Track Maintenance Engineer had reduced. The caused the Track Maintenance Engineer to manage his workload to intervention limits rather than maintenance limits (paragraph 298, Recommendation 9).

363 The software model used to analyse the derailment concluded that the PHA type could not comply with GM/RT2141 in tare or laden conditions (paragraph 289, Recommendation 3).

364 There is duplication within the BR manuals relating to maintenance activities. Cross references do not identify current Railway Group Standards, or current POCLs (paragraph 193, Recommendations 4 and 8).

365 The BR and GFA maintenance manuals do not incorporate maintenance or corrective action for friction liner heat-related issues (paragraph 324, Recommendations 8 and 11).

366 The investigation identified a number of wagons with frame twist. None of the wagons previously fitted with shims had the required ‘Q’ marker on the frame (paragraphs 310 to 312, Recommendations 6, 7 and 8).

367 The English Welsh & Scottish Railway ground staff and Lafarge staff at Mountsorrel were not able to implement all necessary procedures to ensure the peak load distribution on the train was correct (paragraphs 270 to 276, Recommendations 12 & 13).

368 Numerous discrepancies relating to train consist details and weights were identified during the investigation (paragraphs 274 to 276, Recommendation 16).

369 The non-attendance of maintenance contractors on the date specified for the calibration of Eastrea wheelchex site was not identified by Network Rail or its sub contractor (paragraph 130, no Recommendation).

370 The Private Wagon Registration Agreement department has responsibility for the audit and registration of private owner wagons and facilitates the various technical discussion forums so that the sharing of safety related information and other engineering issues affecting the Private Wagon Registration Agreement companies can be discussed. Historically the collation of information relating to derailments was undertaken within British Rail and later with subcontractors. This is not undertaken centrally by the Private Wagon Registration Agreement department as Network Rail and other safety case holders have a duty to input incidents onto the Rail Safety and Standards Board, Safety Information Management System (paragraph 228 and Appendix H). The collation of wagon incidents and derailments affecting Private Wagon Registration Agreement companies may provide Network Rail and specifically the Private Wagon Registration Agreement department with an opportunity for pattern analysis and enhance the sharing of accurate information within the freight operating forums (paragraph 305 to 307 and 341 to 346, no recommendation).

371 The safety management responsibilities of the staff and systems within the Private Wagon Registration Agreement department were documented in the Network Rail Safety Case but are not documented in the Network Rail Safety Management System (paragraph 181, no recommendation).

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

Network Rail

Increased traffic affecting track maintenance

372 This issue was recognised by the industry's formal investigation into the derailment near Grayrigg on 23 February 2007, and recommendations were made to address this issue (J1.11). In response to this recommendation Network Rail has reviewed, enhanced and reissued company standard NR/L2/OPS/031 "Risk assessment and briefing of timetable change", which now has a specific requirement to take into consideration the impact of timetable change on:

- the ability to undertake inspection, examination or testing;
- the ability to secure access to undertake maintenance; and
- the long term condition of the asset.

Issue 6 of NR/L2/OPS/031 had an issue date of 26/08/2008, and a compliance date of 1 December 2008.

373 Network Rail carried out tests on PHA and PGA wagons at Boston in January and February of 2008. These highlighted the heat damage and abnormal wear patterns on wagons still within the recognised wear limits, and the locking up of the suspension (Figures 51 & 52). The Private Wagon Registration Agreement department has now highlighted these previously unrecognised factors to the wagon owners and maintainers. The department has also commissioned further work in order to understand the implications of the wear patterns and heat generation in relation to the type and specification of friction materials and maintenance implications for Private Wagon Registration Agreement companies. This work was ongoing at the time of writing this report.

POCL 484

374 Network Rail's Private Wagons Registration Agreement department has undertaken to research the frictional behaviour of the suspension to understand and evaluate its implications. The fitting of instrumentation to PHA and PGA wagons to monitor the suspension characteristics and heat generation between the pedestal and saddle friction liners has been agreed but no date has been fixed for the work to be done.

375 Network Rail issued POCL 484 version 2 in September 2007, in relation to the requirement to undertake a mandatory frame twist and wagon inspection in conjunction with NIR 2302 /2007 (Appendix G). Network Rail is currently collating all historical data for Private Wagon Registration Agreement wagons, and has requested Private Wagon Registration Agreement companies to audit their own wagons to confirm records were held and were accurate for the wagons they owned (Figure 53). The review and industry feedback also highlighted the following items;

- the process of using Wheelchex data to assist in identifying abnormal wagons proved successful, with reasonable correlation being demonstrated between Wheelchex abnormal wheel loads and proven frame twist measurements from Private Wagons Registration Agreement companies;

- frame twist in excess of the limits mandated by the current POCL was identified on a rigid tank wagon;
- some Private Wagons Registration Agreement companies were taking frame twist measurements incorrectly (paragraph 380); and
- Network Rail has completed checks on wagon 'foot prints' of four owners using Wheelchex, with over 300 wagons reported by Wheelchex as being within the 6 mm limit.

376 The Private Wagon Registration Agreement department issued POCL 484 version 3 in October 2007; it includes maintenance processes to manage the risk imported to the railway by unidentified twisted wagons operating on the system.

377 This document incorporated a new procedure for measuring wagons for frame twist which specifies the use of optical levelling equipment rather than the 'Tyle' gauge. Version 3 is due to be reviewed by the Private Wagons Registration Agreement department again in 2008.

National Incident Report 2302 / 2007

378 Network Rail's Private Wagon Registration Agreement department issued a National Incident Report (NIR), number 2302 on 5 September 2007 (Appendix G), as a result of the Ely investigation. This requested freight operating companies and Private Wagon Registration Agreement companies to ensure that wagons were checked for frame twist and to ensure their records for such data were recorded and up to date. The NIR advised the Industry of action to be taken in relation to historical data.

379 Since issuing NIR 2302 and POCL 484 version 3, further two-axle wagons have been identified with frame twist in excess of the prescribed 6 mm limit. These wagons were identified by wheelchex data. Subsequent inspections revealed wagons with the following levels of frame twist:-

- PCA wagon – 15 mm;
- PHA wagon – 27 mm;
- TTA wagon - 28 mm.

380 It also became apparent that at some maintenance locations, wagons appear to have been incorrectly measured for frame twist and some maintainer's records did not reflect the physical condition of the wagons. It was not possible for Network Rail to determine whether this is a local or national issue.

Review of wagon unloading and suspension characteristics

381 As a consequence of the findings from the Ely incident, Network Rail Private Wagon Registration Agreement engineers witnessed the unloading of PHA wagons. One of the wagons was observed to exhibit frictional lock-up momentarily before releasing itself.

382 Examination of the wagons identified a variation of wear patterns and heated areas between the lateral guide surfaces on the axle horn / pedestal and the saddle, all of which have identical tolerances. Some suspension saddle lateral wear faces were not in contact with the pedestal and had no visible wear, while others were in contact and showed significant wear and heat discolouration.

Figures 51 & 52: Wear and heat damage to pedestal liners of SDT PHA wagons

383 Network Rail reported that wagon REDA 16041 had signs of heavy lateral wear in some areas, similar to wagon REDA 16002. The area of wear displayed evidence of heat damage with 'blueing' visible on the top outer face of the lateral guide, indicating a temperature of 300 degree Celsius temperature had been achieved. The abnormal wear patterns on these wagons are still under investigation by Network Rail (Figures 51 & 52).

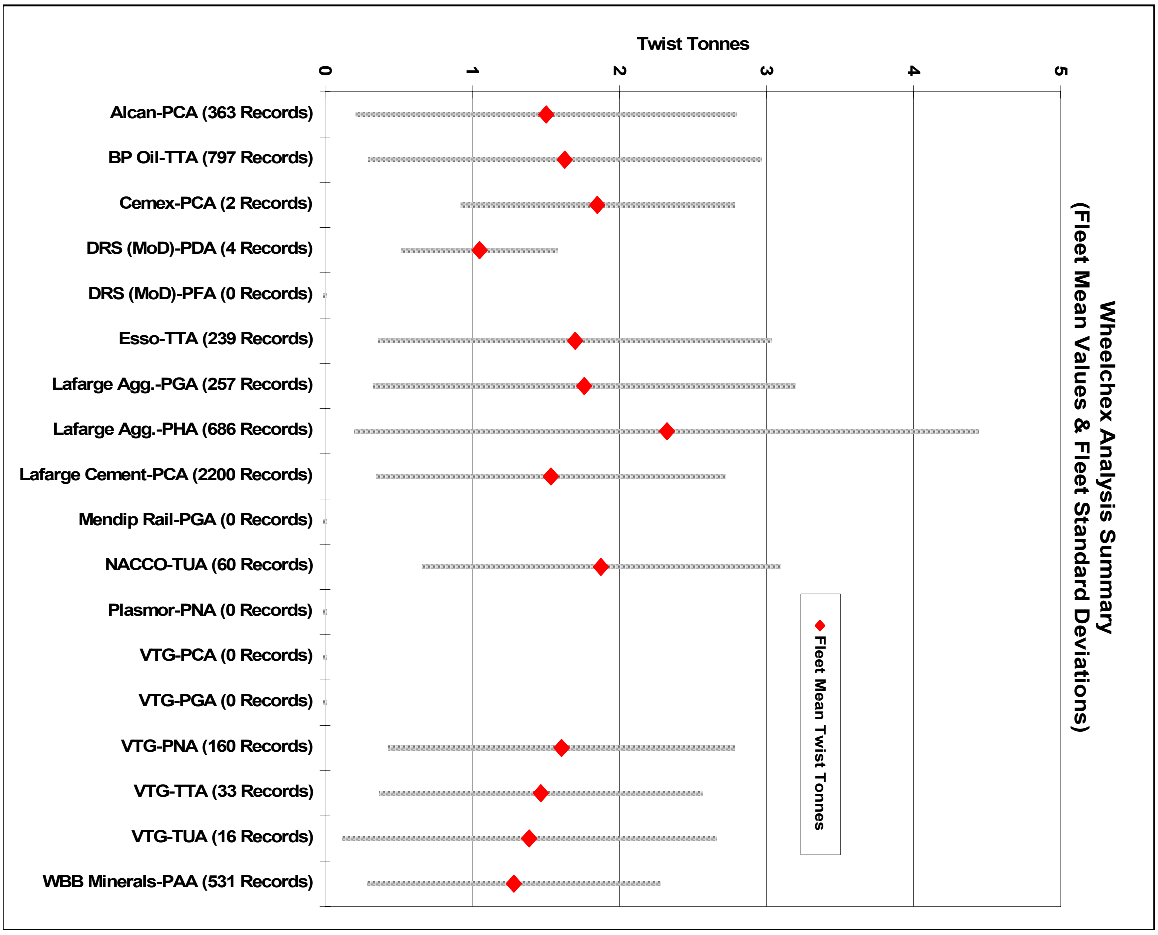


Figure 53: Network Rail review of PWRA companies. Red diamond indicates the mean value and grey horizontal bar indictes deviation from the mean value of wheel imbalance in tonnes. The data highlights the PHA wagons above average wheel imbalance compared to other wagon types

Wheelchex

384 As a result of the incident on the King Edward Bridge (paragraph 259) Delta Rail has provided proposals to Network Rail for modifications to the software to enable automatic identification of abnormal diagonal wheel imbalance. The system does not have Automatic Vehicle Identification (AVI) or tagging of wagons and manual identification will still be required, which Network Rail is now reviewing.

385 Network Rail's analysis of the particular group of PHA wagons operating from the Lafarge Quarries concluded that they display a completely different range of Wheelchex results from any other type of two-axle pedestal suspension wagons registered with Network Rail's Private Wagon Registration Agreement Department (Figure 53). The cause of this variation in data may be the environment the wagons work in resulting in contamination of the friction liners and changes in the frictional suspension characteristics. Work is ongoing to identify the cause of this variation.

386 Network Rail has been monitoring the operation of Lafarge's PGA hopper wagons with similar suspension types over wheelchex sites with a view to understanding the vehicle dynamics.

387 The long term strategy will be to determine future 'corner-load' alarm parameters on the Wheelchex or similar future system. The results may also show that the wagon's dynamic performance is satisfactory and within current vehicle standards.

388 Network Rail is currently researching the use of a new vehicle detector system, known as 'Gotcha'. This equipment was installed on 17 December 2007 at Banbury, and is locally recording wheel impact and wheel imbalance data.

389 Network Rail is attempting to link the site location electronics to a remote server. To enable the data transfer. Lloyds Register Rail has been requested to develop means to report abnormal diagonal wheel imbalance as part of the remote server improved functionality back to the Private Wagon Registration Agreement department.

390 Network Rail is reviewing the quality of the data entry processes onto SMIS to ensure search parameters will correctly identify the data.

Wabtec

391 Wabtec has:

- implemented the new POCL 484 version 3;
- started to carry out frame twist checks yearly at VIBT to introduce a datum point, the need for which arises from a lack of records since the GR revisions stopped;
- introduced procedures to carry out frame twist checks after any incidents;
- updated the Wabtec maintenance manual to incorporate the above;
- introduced a new system to keep complete records;
- worked with Network Rail to identify wagons with high axle loads; and
- liaised with Network Rail regarding the fitting of instrumentation to a PHA wagon to improve understanding of the suspension characteristics.

Lafarge

392 Lafarge has:

- Introduced documented loading procedures at Mountsorrel. The procedures incorporate safety margins for wagon loads, visual residual ballast checks before loading and contingency procedures in the event of the computer system failing (December 2007).
- Introduced a system (December 2007) to record all briefings and assessments to ensure competence in their procedures for loading wagons.
- Started managing the actions to be taken by its wagon maintainers, Wabtec to comply with POCL 564.
- Now set the transfer gap between slugs of material being delivered to the loading hoppers at Mountsorrel to a minimum of 20 seconds. This should ensure that the loading hopper is clear before the next slug arrives, thus assisting in the prevention of wagon overload and excessive disparity between wagons. It should also give more time for the operator to carry out his duties.

English Welsh & Scottish Railway

393 English Welsh & Scottish Railway is currently reviewing the Northampton and Peterborough derailment investigations.

Recommendations

394 The following safety recommendations are made[1]:

Recommendations to address causal and contributory factors

1 Network Rail should investigate the capability of Wheelchex or a similar system to produce data to identify laterally out of balance wagons, and should instigate a system to use this data to reduce risk from such wagons (paragraphs 360 and 378 to 389).

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 (paragraph 359).

3 Network Rail and PHA wagon owners should review the risks arising from the derailments of these vehicles and whether in light of the Ely incident the current mitigation measures are adequate in respect to the compliance of the PHA wagon and the suspension characteristics of the PHA wagon against the requirements of GMRT/2141, including the effects of contamination and frictional breakout. If appropriate, Network Rail's Private Wagons Registration Agreement department should require the owners of these wagons to take such steps as are necessary to ensure they comply with its requirements (paragraphs 359, 360, 363 and 374).

4 Network Rail should review the historical research data and recommendations on the GFA to determine if the recommendations are valid for the current PHA wagon design and its operating and maintenance environment. If it is found to be relevant they should arrange for this research to be briefed to all owners of PHA wagons, and for them to take any necessary steps (paragraphs 360 and 365).

Continued

[1] 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 ORR/HMRI 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 167 to 171) can be found on RAIB's web site at www.RAIB.gov.uk

Recommendations to address other matters observed during the investigation

5 Network Rail should instruct all private wagon owners on the importance of compliance with POCL 484, and in particular with the requirement to mark wagons that have been shimmed for frame twist correction (paragraphs 359, 364 and 374 to 377).

6 Network Rail should instruct all private wagon owners to comply with the requirement to mark wagons that have been shimmed for frame twist correction (paragraphs 366 and 375).

7 Network Rail should brief private wagon owners to retain maintenance records relating to wagons and provide an auditable history on sale or transfer (paragraphs 359 and 375).

8 Network Rail, in conjunction with wagon owners and maintainers, should review, and if appropriate revise, inherited British Rail maintenance manuals so that they are complete in their coverage and that they include processes from the current Railway Group Standards and POCL (paragraphs 347 and 364 to 366).

9 Network Rail should review maintenance hours and resources available for the maintenance of track between Ely Dock Junction and Soham, and provide appropriate levels of time and resource (paragraphs 362 and 372).

10 Network Rail should include guidance in NR/SP/TRK/001 Section 11.4.2 so that additional consideration is given to geometry monitoring frequency and methodology for locations where the dynamic track geometry is likely to deteriorate and exceed the maintenance limit without otherwise being detected (paragraphs 359 and 372).

11 Wabtec and other maintainers of torsionally stiff 2 axle wagons in conjunction with their owners should revise their annual maintenance procedures so they adequately mitigate the risk of derailment which may arise due to frame twist. Post-maintenance wheel weighing or dimensional checks may achieve this (paragraphs 359, 364, 366 and 391).

12 English Welsh & Scottish Railway should review, and if necessary adjust, resource levels at Mountsorrel so that there is sufficient staffing to prepare trains in accordance with their procedures (paragraphs 367 and 392).

13 Lafarge should re brief all staff involved in loading wagons to check peak loadings and residual load safety limits (paragraphs 367 and 392).

Continued

14 English Welsh & Scottish Railway should implement processes so that incident investigation managers are appointed where appropriate, a comprehensive remit is prepared and investigations are completed in accordance with Railway Group Standards and their own procedures (paragraph 359).

15 Lafarge should introduce a system so that the Mountsorrel computer loading system is within calibration and that time intervals are sufficient to allow the wagon payload to be within the accepted tolerance (paragraphs 368 and 392).

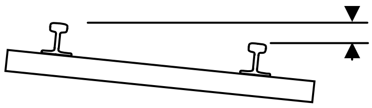
16 Lafarge should introduce and enforce procedures at Mountsorrel so that the staff involved in the loading of wagons, provide an accurate list for input into TOPS (paragraphs 368 and 392).

Appendix A - Glossary of abbreviations and acronyms

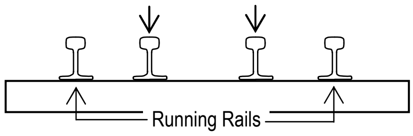
AWS	Automatic warning system
BR	British Rail
EWS	English Welsh and Scottish Railways
FOC	Freight operating company
GFA	Gloucester Floating Axle (suspension)
GR	General repair
HABD	Hot axle box detector
NIR	National Incident Report
MPI	Metal particle inspection
OTDR	On train data recorder
PHA /PGA	Type of Hopper wagon with air brake
POCL	Private Operators Circulation Letter
PPM	Planned Preventative Maintenance
PPE	Personal Protective Equipment
PLRA	Private Locomotive Registration Agreement
PSB	Power signal box
PWRA	Private Wagon Registration Agreement
RA	Route Availability
RSC	Rail Safety Case
RSSB	Rail Safety & Standards Board
SDT	Self-Discharge Train
SMS	Safety Management System
TOPS	Total Operations Processing System
TRV / TRU	Track recording vehicle /unit
UWC	User worked crossing
VAB	Vehicle acceptance body
VIBT	Vehicle inspection and brake test

Appendix B - Glossary of terms

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

Anti separation pin	Pin placed through suspension saddle primary, secondary and cup springs and frame of PHA wagon to retain damping component alignment.
Automatic Warning System	A fail-safe arrangement of permanent magnets and electromagnets placed in the four-foot that convey information about the aspect of the associated signal to the train driver.
Axle box	A cast block containing the bearings for one end of an axle.*
Axle horn	The vertical guide placed either side of an axlebox to restrain it laterally but permit vertical movement of the axle.*
Ballast shoulder	The ballast placed at the ends of the sleepers, timbers or bearers to give lateral stability to the track.
Baseplates	A cast or rolled steel support for flat-bottom rails (FB).*
Brake pipe	In an air brake system, this pipe is pressurised to release the brakes of the vehicles in the train. The actual air pressure required to operate the brake cylinders is provided by the train pipe, which is kept permanently pressurised to supply reservoirs on each vehicle.*
Bump stop clearance	Clearance between axle saddle and underframe or pedestal.
Cant	The design amount by which one rail of a track is raised above the other rail, measured over the rail centres. Valid values of cant currently in force on the national railway network are zero to 180 mm in increments of 5 mm.* 
Chain	A unit of length, being 66 feet or 22 yards (approximately 20117 mm).*
Cess	The area of the track outside the ballast shoulder to maintain drainage.
Crossings	An assembly that permits the passage of wheel flanges across other rails where tracks intersect.*
Cross-level	The measured difference in level between the two running rails of a track.* When the left rail is higher the cross-level is positive (+), and when the right rail is higher the cross-level is negative (-).
Cross members/ girders	A smaller lateral structural member spanning between the main girders of a bridge.

Cup Spring	Small spring that sits within a primary and secondary spring assembly to assist damping on a Gloucester Floating Axle suspension unit.
Damping	Elements of the suspension designed to lower the natural frequency of the suspension and dissipate the vibration and energy of the vehicle.
Down	In a direction away from London, the capital, or towards the highest mileage.*
Dynamic ratio	The difference between the recorded axle load and the peak axle load for the axle.
Ferrobestos	Material used for friction liners.
Flange	(See wheel profile).
Flat-bottom	A rail section having a flat based rail foot or flange.*
Four-foot	Area between the two running rails.
Frictional breakout	A characteristic of a suspension mechanism when locked and then released may cause a risk of derailment.
Frame twist	Physical deformation of the frame which is caused by operational braking techniques, collision with other rolling stock or repair. Compensatory shims or packing is placed in alternative corners up to a maximum of 15 mm to rectify the twist.
Gauge	Distance between running rails.
Gauge corner	The curved profile of the rail head between running surface and the running edge.
General repair	Maintenance process prior to 1992 which entailed a full dismantling, refurbishment and rebuild of the vehicle.
Grandfather rights	The arrangement by which a non-conforming process or situation is allowed to continue because it existed before to new legislation being brought into force.
Gross laden weight	Gross Laden Weight (GLW) is the weight when loaded.
Ground staff	Staff employed to check the train and wagons prior to its operational use on the rail network.
Guard Rail	Rails provided in the four-foot between the running rails at specific locations, such as viaducts and level crossings for added security in case of derailment. Guard rails are not normally in contact with the wheel flanges.
Horn guide	See pedestal.



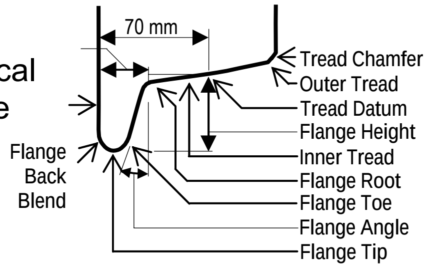
Hopper	A colloquial description of any open topped chute equipped Ballast carrier designed for unloading Ballast onto the Track.*
High rail	The outer running rail of a curved portion of a track, sometimes applied irrespective of the relative heights of the rails.
Journal	The bearings supporting a rail vehicle on its axles. Formerly, these were plain metal on metal bearings running in an oil bath and generally on the ends of the axle. Failure of this lubrication system would result in the bearing overheating.
Lapped	Term used when a surface material is deformed and has the appearance of being smeared.
Loop	A short length of track connected to another line at both ends.
National Incident Report	A railway industry wide system to communicate technical and safety issues.
On Train Data Recorder	Data recorder on train monitoring systems.
Order to Move	A document used to enter details onto the Total Operating Processing System, a mainframe based computer system used to track rail vehicles, their destination, load, location and maintenance information on the network.
Packing	Discs, shims or other material inserted in a suspension to adjust the height of the wagon at that point (see shims).
Pandrol clips	A rail clip for flat-bottom rail (FB) manufactured by the Pandrol company.*
Patroller/Patrolman	A person who carries out a visual inspection of the line.
Pedestal	Alternative term used to describe the axle horn.
PHA / PGA Hopper Wagon	The three letter wagon codes used by Total Operating Processing System (TOPS) to identify the different types of rail vehicle. The first letter describes the type of vehicle, and the last letter describes the type of brakes fitted to the vehicle.*
Plain line	Track without switches and crossings.
Point of derailment	In a derailment, the precise point where the first wheel derailed. The sleeper closest to this on site is normally designated as sleeper zero.
Points	Another name for a set of switches.*
Private Operator Circulation Letter	Letters sent by the Private Wagon Registration Agreeement department within Network Rail to private wagon and locomotive owners to brief them on railway related matters.

Private Wagon Registration Agreement/Private Locomotive Registration Agreement (PLRA)	Prior to Privatisation, a Wagon not owned by British Rail (BR) but moved from place to place by British Rail or a Freight operating company.
Route availability (RA)	A number which describes the effective loading a rail vehicle applies to the Track, ranging from 1 (least) to 10 (most).
Rail Safety Case	The safety case demonstrates a company's capability of discharging its duty as the infrastructure controller
Railway Group Standard	A document mandating the technical or operating standards required of a particular system, process or procedure to ensure that it interfaces correctly with other systems, process and procedures. Network Rail produces Network Rail Company Standards that detail how the requirements of the Railway Group Standards are to be achieved on its system.*
Route indicator	An Indicator associated with a signal that shows a driver which route is set where more than one route is available.*
Saddle	Term used to describe the casting on a suspension unit incorporating the axle journal and spring assembly.
Safety management System	Safety Management System provides the guide to specific arrangements designed to control health and safety risks on the rail infrastructure.
Self-Discharge Train	(Tradename) Previously pioneered by Redland Aggregates, and or operated by Lafarge Aggregates, a train consisting of a special conveyor wagon and a number of special hopper wagons equipped with conveyors to move discharged material to one end of the train. The hopper wagons come in groups of five or ten connected together (42 - 82 metres in length including the motor vehicle) giving a minimum capacity of 185 tonnes, and a maximum capacity (in 30 hoppers) of 1100 tonnes. The system can cope with any size of aggregate, from sand up to normal ballast, and the conveyor has a discharge radius of some 15 m (50 feet).*
Shims	Packing to a maximum of 30 mm (2 x 15 mm) used to compensate frame twist.
Sleepers	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 gauge is maintained between the rails.*
Span	A subdivision of a bridge deck, being that part between an abutment and an adjacent pier, between two adjacent piers or between the two abutments.

Stiction	Friction that tends to prevent relative motion between two moveable parts.
Stock Rail	The fixed rail in a switch half set. The other rail is the switch rail.*
Straight air brake	A brake system which acts only on the locomotive wheels and not on the rest of the train.
Supervisor's Plain line inspection	A regular inspection of the track carried out by a supervisor in order to determine the actions necessary to repsond to reports of basic visual inspections carried out by patrollers, review trends in conditions and check that basic inspections, maintenance and renewal work are effective.*
Switches	An assembly of two movable rails (the switch rails) and two fixed rails (the stock rails) and other components (baseplates, bolts, distance blocks, 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 packing the ballast beneath the sleepers.
Tare	The weight of a rail vehicle when it is not carrying any load.
Torsional stiffness	Applied to a rail vehicle, the resistance the vehicle structure has to twisting along its length. high torsional stiffness can exacerbate a non-bogie two axle vehicle's sensitivity to twist faults.*
Track Circuit Block	A signalling system where the line beyond is proved clear to the end of the overlap beyond the next signal using track circuits (TC). Track circuit block can also be implemented using any automatic train absence detector system, such as axle counters.*
Track twist	A rapid change in cross-level. Twist is calculated by measuring the cross-level at two points a short distance apart, and then expressing the difference as a 1 in x gradient over the interval.*
Total Operating Processing System (TOPS)	a mainframe based computer system used to track rail vehicles. It deals with destination, load, and location and maintenance information for all vehicles on the Network. Vehicle data is entered for every movement, allowing virtually real time updates.*
Transom	A timber section fixed between Longitudinal Timbers to ensure the track gauge is correctly maintained.*

Track recording vehicle	Vehicle used for gathering quantitative data about the track geometry of a track on a route. This is normally carried out by means of a specially equipped vehicle. Typically the data recorded is: • alignment; • cant (C or E); • radius; • track gauge; • top; and • twist.
Twist	See 'track twist' and 'frame twist'.
Up	In a direction towards London, the capital, or the lowest mileage.*
User Worked Crossing	A level crossing (LC) where the user operates the barriers or gates.
Vehicle Acceptance Body	A body given authority by RSSB to undertake engineering acceptance for rail vehicles.
Vehicle Inspection and Brake Test	A regular inspection performed on all rail vehicles by train preparation staff and the driver to ensure brake pipe pressure and an effective braking system is functional.
Void	Spaces under sleepers or bearers in the packing area, often caused by inadequate packing or differential settlement between sleepers. Voiding is responsible for track faults such as twist faults, which only appear when the track is loaded.
Void meters	A device that measures the vertical deflection of the track under passing trains, and hence the size of the voids under the sleepers or bearers.*
Wet Bed	An area of ballast contaminated with slurry. Such wet spots spread under the action of passing traffic and can cause twist faults in extreme cases.*
Wheelchex	A type of Wheel Impact Load Detector (WILD) system manufactured by Delta Rail (Formerly AEA Technology). Both rails on a section of straight and level track are instrumented and measure the load imparted by a moving wheel. A large variation in the load imparted by a single wheel indicates the presence of a wheel flat or an out-of-round wheel.
Wheelflat	A flat area worn into the tyre of a rail wheel by prolonged braking or a failure of the brakes to release. A wheel with one or more flats is a square wheel.*

Wheel profile	The shape of a section of a rail wheel taken through the axis of rotation. Typically this is a conical section with a flange on the side of the greatest diameter.*
Wheelset	Two rail wheels mounted on their joining axle.*

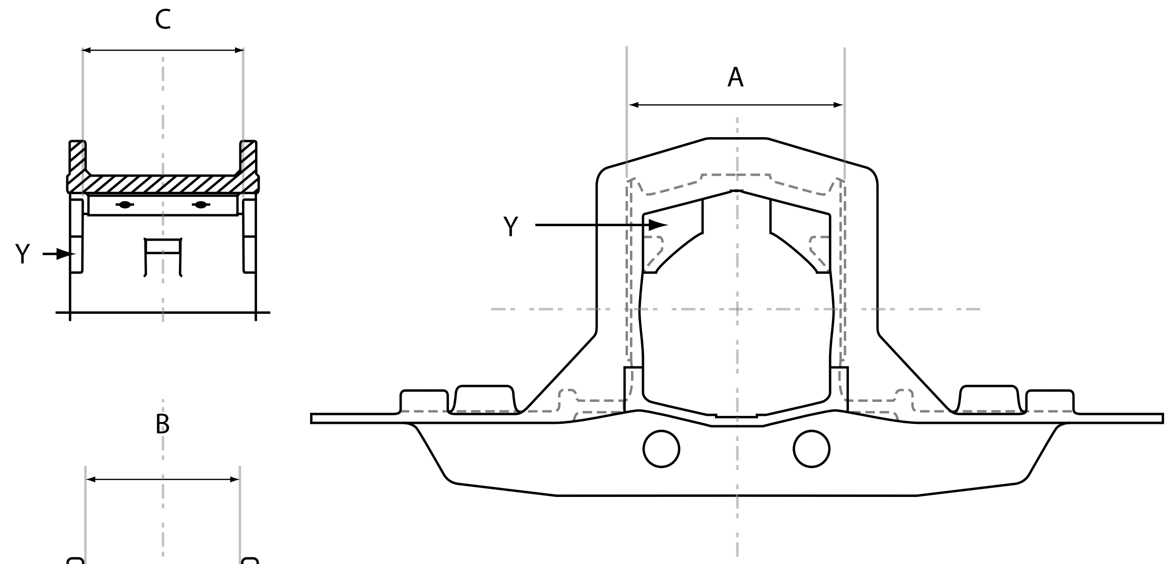


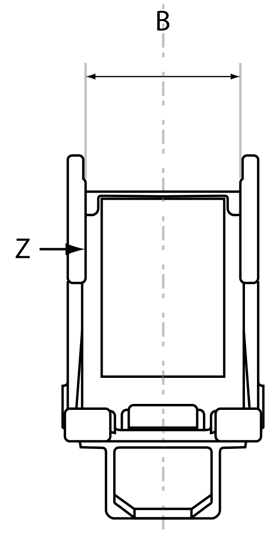
Appendix C - Key standards (current at the time) and reference material

GM/RT2141 Railway Group Standard	Group Standard Resistance of Railway Vehicles to Derailment and Roll-Over Issue 2 October 2000
GM/RT 2004 Railway Group Standard	Requirements for Rail vehicle maintenance
GC/RT 5021 Railway Group Standard	Track system requirements Issue 3,April 2007
GC/RC 5510 Railway Group Standard	Recommendations for the design of bridges
GC/RC 5112 Railway Group Standard	Loading requirements for the design of bridges
GO/RT3472 Railway Group Standard	‘Incident Management and Evidence Gathering’
GO/RT3473 Railway Group Standard	‘Formal Inquiries, Formal Investigations and Local Investigations’ in respect of Accident Management and Investigation.
Network Rail Company Standard RT/CE 080	Management of existing bridges and culverts
Network Rail Company Standard RT/CE 032	Managing existing structures
Network Rail Company Standard RT/CE/S/017	Examination of bridges
Network Rail Company Standard RT/CE/S/035	Assessment of structures
Network Rail Company Standard SP/TRK/001	Inspection and Maintenance of Permanent Way. Issue 2 October 2005
Railtrack Formal investigation into Baguley Fold Junction 22 May 1997.	Report number 97/RNW/10
EWS/ES/0081 Engineering Standard	EWS Engineering Standard Maintenance Specification – MGR & Derivative Wagons Issue 4 April 2006
EWS/OS/001 Company Standard	Operations Safety Management System Management of Accidents and Incidents affecting the Operational Railway
WF/81 BRB Engineering Instruction	Measurement and Compensation of Frame Twist Issue 8 1980

British Rail manual 11888	BRB Instruction Regulations for Repairing private Owner Wagons
BRB Manual (TFT/T/10007) Issued January 1996.	BRB Instruction
‘Green Book’	Examination and Lubrication of British Rail and Private Owners Freight Trains incorporated the repair /testing /labelling and Planned Preventative Maintenance regimes
British Rail manual (BR 11889) issued June 1987	BRB Instruction
‘Blue Book’.	Planned Preventative Maintenance for freight Stock and Departmental Vehicles
British Rail Research (TM 037)	An investigation of the vertical behaviour and suspension parameters of freight vehicles
British Rail Research (TRS 097)	A review of pedestal suspension performance
POCL 484 version 1. Issued 1981	Private operator circulation letter 484 frame twist procedure issued to Private Wagon Owners for maintenance.
POCL 484 version 2. Issued June 2007	
POCL 484 version 3. Issued Oct 2007	
POCL 564 version 2. Issued Sept 2005	Private operator circulation letter 564 Maintenance and overhaul policies for Private Wagons Registration Agreement companies and maintainers.
Delta rail report ES 2007-165 / 179 /256	Dynamic Assessment of PHA wagon at the Ely site derailment.

Appendix D - Diagram of Gloucester pedestal suspension

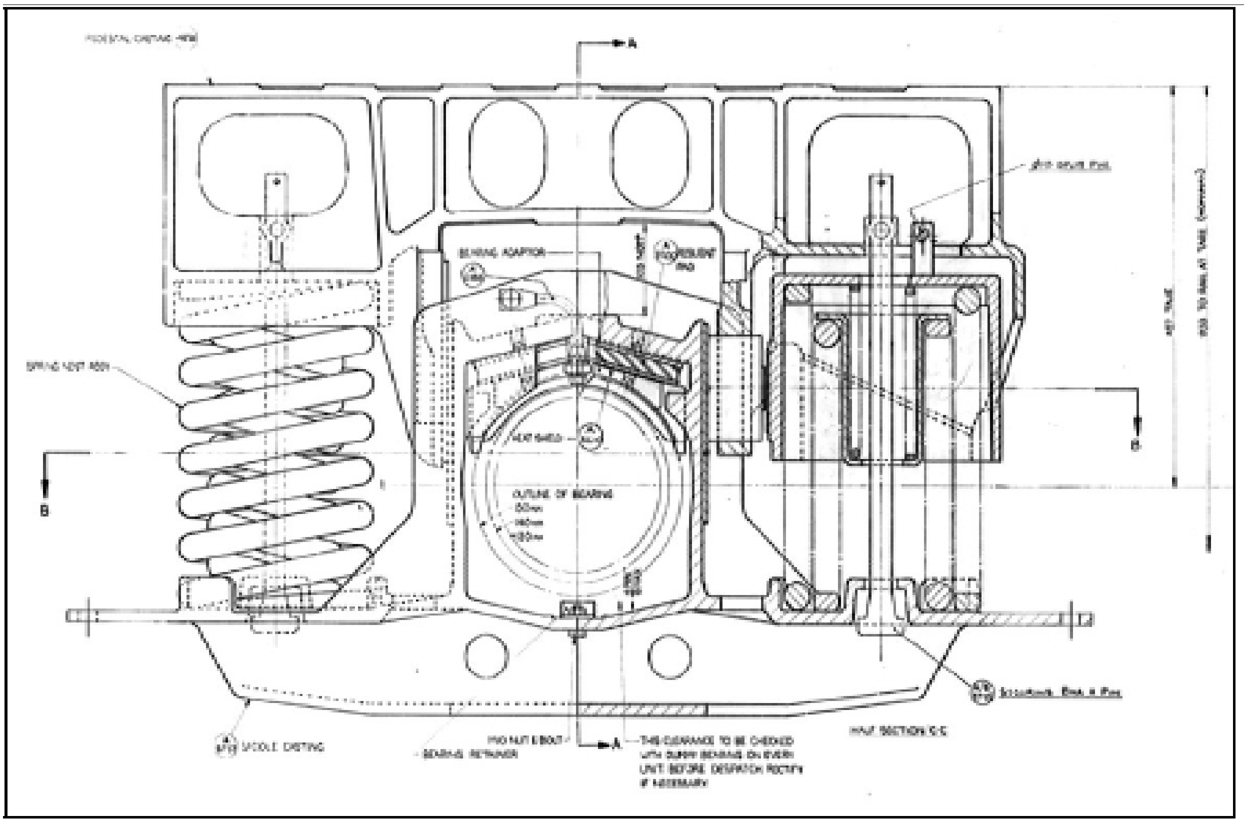


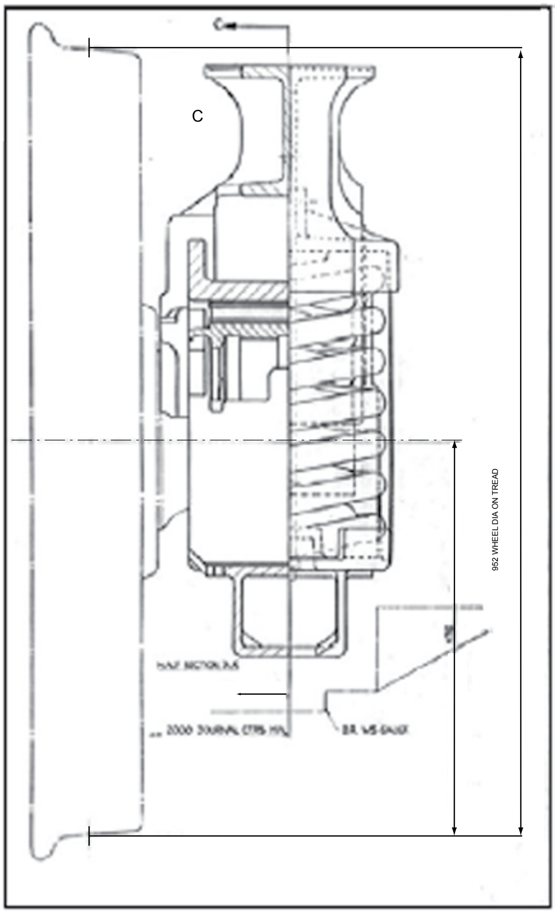


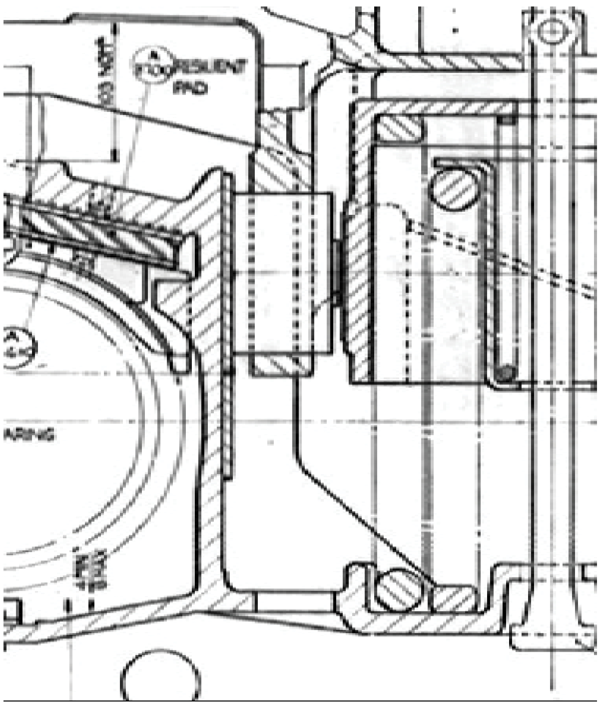
Type	New Dimension (mm)			Limit Dimension (mm)		
	A	B	C	A	B	C
MK IV	312	204	204	309	208	207

Y	Lateral stop plates	Z	Lateral stop pads

Figure 53: Saddle casting and tolerances


A
B
BEARING ADAPTOR
RESILIENT PAD
SPRING NEST ASSY
HEAT SHIELD
OUTLINE OF BEARING
SADDLE CASTING
BEARING RETAINER
THIS CLEARANCE TO BE CHECKED
WITH DUMMY BEARING ON EVERY
UNIT BEFORE DESPATCH RECTIFY
IF NECESSARY
HALF SECTION C-C


C
952 WHEEL DIA ON TREAD


RESILIENT PAD

Appendix E - Aerial image of the derailment site

Aerial view showing rear portion of 6L58

View from Ely side of bridge 2253

Aerial view showing derailed vehicles on bridge 2235 wheelset, red - suspension saddle, blue - wagon 16002

View from Soham bank showing over-turned vehicles

View from Soham side of bridge 2253

Further view from Ely side of bridge 2253 showing first impact point through decking

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Appendix F - Wheelchex

History

1 During the 1990's there was a developing awareness within the rail industry of the benefits of automatic collection of engineering data by systems located at the side of the track or on trains. This data could then be processed and analysed by an operator or engineer to see events or developing trends. The data could then be used to take appropriate action at an early stage, thus avoiding an escalation of the event or reducing the impact of disruption.

2 Wheelchex was developed by AEA Technology in 1998 and four systems were installed at locations around the rail network, but these became life-expired in 1999.

3 After privatisation of Britain's main line railways, Railtrack developed a strategy to utilise systems that could protect the assets on the railway infrastructure. Railtrack purchased four new Wheelchex systems. The first installation was at Heaton Chapel, which became fully operational on 29 November 2000.

4 Their location, when originally installed, was based on the following criteria:

- location of broken rail incidents;
- frequency and heavy axle load routes;
- maximise the coverage across train operators; and
- availability of suitable recess points (e.g. sidings) to enable defective trains to be moved out of the way.

5 This system provided the ability to identify and reduce the number of incidents occurring on the network as a result of damaged wheels. Wheelchex data also contributed to the reduction in the number of rail breaks and assisted in identifying vehicles which might develop faults, such as bearing and suspension damage.

6 If a train causes excessive wheel loads, a detector will automatically send a data message to the local route control centre. The Controller or Signaller will then contact the driver and bring the train to a stand at a suitable signal. After consultation and possible examination, the train is then allowed to proceed, at reduced speed, to a suitable location to be taken out of service. The reduced speed is dependent on the class of the train and the severity of the impact forces measured.

7 There are four levels of wheel impact alarm at Wheelchex sites which require the following actions:

- level 1 (200 - 350 kN): a level 1 alarm is advisory and the control centre does not need to stop the train.
- level 2 (350 - 400 kN): a level 2 alarm requires a 30 mph (48 km/h) speed restriction for a freight train until it reaches a suitable location where it can be taken out of service.
- level 3 (400 - 500 kN): a Level 3 requires a 20 mph (32 km/h) speed restriction.
- level 4 (> 500 kN): a Level 4 requires a 10 mph (15 km/h) speed restriction.

Wheel imbalance data

8 Wheel imbalance data is collected from the Wheelchex sites. The table produced represents the load carried on each axle. This is calculated by:

Leading right axle + leading left axle = Total tonnage divided by 2 = mean average.

Mean average - Leading right axle / leading left axle = imbalance.

e.g. Leading left axle records 14.0 tonnes and leading right axle 12.0 tonnes giving a total axle load of 26.0 tonnes and mean average of 13.0 tonnes. To establish the imbalance, the individual axle load is subtracted from the mean average, giving the leading left axle a 1.0 tonne difference from the mean average and leading right axle 2.0 tonnes difference from the mean average.

9 The imbalance between left and right is calculated by the adding the leading left wheel plus trailing right wheel weight, minus the sum of the leading right plus trailing left wheel weight.

10 The orientation is either positive or negative. A positive result is when the leading right hand wheel is heavy and negative result when the leading left hand wheel is heavy. An evenly loaded or non-twisted wagon would have a zero imbalance load.

11 Network Rail are currently collating the data for each type of wagon in order to understand the load, establish parameters and set alarm limits for wheel imbalance loads which may cause a route safety issue.

Hot Wheel / Axle Box detection system (HAW / HABD)

12 The hot wheel detector (HWD) is designed to pick up the heat signature from overheating wheels or brakes and to complement conventional hot axle box detectors (HABDs).

Appendix G - National Incident Report

NIR 838 / 2000	Two Axle Wagons- Friction Damped- Pedestal Suspension Raised by: The Engineering Link
Defect date: 09 February 2000	Vehicle type: Depot / Lineside Equipment
Vehicle number: Vehicle class: Wagon Vehicle hirer: Vehicle sub-hirer	2-axle wagons with friction damped pedestal suspension
Vehicle owner: Use being made of vehicle	Not Specified Systems giving rise to defect:
Defect description	Wheels / Wheelsets Other affected vehicles: Due to the tendency for these suspension units to 'lock', high forces can be imposed on axles, leading to high stresses.
Following extensive stress analysis and risk assessment by T.E.L., it has now been decided that all axles on these wagons must receive magnetic particle N.D.T. before 1st January 2001 Geographical location: N/A Root cause description: Action taken: Justification for advice: For Information: Currently open for The Engineering Link Notified: (Not Known) Acknowledged: (Not Known) Last Review: (Not Reviewed) Status: Open	

NIR 2302 / 2007	
Frame Twist and Its Effect on Wheel Loads and Subsequent Derailment Risk Raised by:	Network Rail Infrastructure Ltd Defect date: 21 June 2007
Vehicle type	Vehicle (Locomotive, Coach, EMU, DMU, Wagon etc.) Vehicle number: REDA 16002 REDA 16011
Vehicle class	PHA Vehicle hirer: N/A Vehicle sub-hirer
Vehicle owner	Lafarge Aggregates Ltd.
Use being made of vehicle	In Operational Service Systems giving rise to defect: Suspension (primary or secondary)
Other affected vehicles Defect description	Significant frame twist was recently identified on an operational two-axle wagon during investigations following a serious freight train derailment. The derailed wagon was also found to have been twisted historically, as frame twist compensation plates were present on the derailed vehicle.
Geographical location	Ely and Mountsorrel

Action taken	It has subsequently been established that both the wagon that derailed and the wagon found with significant frame twist had been recording abnormally high cross-axle wheel loads, diagonally opposed across the two axles, through Wheelchex sites over a period of time. This evidence suggests a permanently offset weight distribution was in existence on both wagons. It is thought that there may be reasonable correlation between actual frame twist and the abnormal diagonally opposed readings recorded by Wheelchex. It is considered likely that an offset load of the magnitude recorded by Wheelchex, for the derailed wagon, would have been a primary factor to the derailment itself. To date it has not been established either when or how the two wagons came to be in the condition they were in, i.e. in the latter case with proven frame twist, and the former case probable frame twist. Historically torsionally stiff two-axle Private Owner wagons would be checked for frame twist at least once every seven years when undergoing “General Repairs”, together with a check if wagons received workshop attention following derailment, or if the wagon body was removed. The frame twist identified on the in-service non-derailed vehicle was over five times greater than the amount permitted by the applicable regulations for this vehicle. The regulation governing the check for the presence of frame twist on torsionally rigid two-axle wagons operating under the Private Wagon Registration Agreements is being reviewed for urgent re-issue to mitigate this risk. Network Rail is analysing data from the Wheelchex system to assist the immediately affected wagon Owner in identifying any other wagons from his fleet that show similar trends with diagonally opposed wheel load readings. Network Rail is evaluating whether the Wheelchex (or similar future system) may be able to provide an indicative warning mechanism in the future for wagons or bogies exhibiting abnormal diagonal twist loads. Wagons owned and operated by other organisations, any of which may be found to be in a similarly poor condition with regard to diagonally off-set wheel loads, making them more prone to derailment.

Appendix H - Historical incidents relating to PHA wagons

	Date and Location	Details of incident (pre 22 June 2007)
1	**28 July 1990** **Ely Dock Junction.**	Train 6Z15 the 1320 Colchester - Leicester became derailed on departure from signal ED58 on the single line at Ely Dock Junction. The second vehicle from the rear, wagon REDA 16220 travelled 300 yards before re-railing. Damage was caused to the point mechanism and cables. The incident was caused by track twist.
2	**13 November 1990** **Dover Archcliffe Junction**	Wagon REDA 16028 derailed. Train details were not recorded. The cause of the derailment was reported as driving technique
3	**12 May 1992** **Ely Dock Junction.**	Train 6M66 the 13.20 Broxbourne to Mountsorrel derailed at Ely. The train was stopped at signal CA 257 (Down main to Ely down / up freight loop). Evidence of derailment damage from Sutton Junction towards Ely was found the trailing wheel set had flange climbed the railhead left hand side in running. The train ran for 7 chains to Lloyds and Martin crossing and then re-railed itself in the length of the crossing. Wagon REDA16076 arrived in Ely in gauge with wheel profile found to be normal. The cause of the derailment was driving / braking technique.
4	**6 February 1993** **Dorridge**	Train 6V20 derailed by one wagon (REDA 16071). The cause of the derailment was reported as voiding caused by wet spots.
5	**30 June 1995** **Neasden**	At 07:40hrs train 6Z28 the 04:00 hrs Mountsorrel to Neasden became derailed between Neasden Junction and Neasden South, approaching signal ME33 on a single line. As a result 100 yards of track was ripped up and 6 wagons derailed (REDA16101). The cause of the incident was gauge spread.

6	**22 May 1997 Baguley Fold Junction.**	At 09:30 hrs train 6P54, the self discharge train, 08:09 hrs Peak Forest to Ashburys derailed at Baguley Fold Junction. Among the derailed wagons were REDA 16001 to REDA 16007. The cause of the derailment was gauge spread due to rotten sleepers (paragraph 240)
7	**14 March 2003 Chesterton Yard**	Wagon REDA 16215 derailed. No other details entered onto SMIS.
8	**10 December 2005 Small Heath Sidings**	At 1450 train 6D38 the 13:12 hrs Small Heath to Mountsorrel Railhead, became derailed at Lafarge Sidings, Small Heath. Five wagons derailed (REDA16009, REDA16010, REDA16013, REDA16012 and REDA16011). REDA16011 was only derailed at one end (corners 1 and 4). The wheel-set was lifted and spun and back to back measurements were taken during a visual inspection of the wagon. Two wagons were severely damaged and taken out of the 10 set. The 8 good wagons returned to Mountsorrel where the conveyer belt was repaired and the train was sent to Northampton for offloading. On the train's return Wabtec carried out a PPM on the wagons and wagon REDA 16011 remained in service until its next PPM in April 2006. The cause of the derailment was gauge spread due to poor track. The incident is likely to have been the cause of the 36 mm frame twist identified on REDA 16011 by Wheelchex after the Ely incident.
9	**27 April 2006 Broxbourne**	Train 6L38 the 01:00 hrs Mountsorrel to Broxbourne Sidings operated by English Welsh & Scottish Railway was formed of 30 PHA 4-wheeled self discharging hopper wagons, each loaded with aggregate. The cause of the incident was gauge spread allowing the left hand leading wheel of wagon REDA 16041 to drop inside the rail.

10	**22 August 2006 Northampton**	At 22:10 hrs train 6D30 Northampton to Mountsorrel self discharge train derailed on plain line while travelling at 4.2 mph within the Northampton English Welsh & Scottish Railway depot. Two empty Lafarge wagons PHA 16102 and 16201 (11th and 12th from the locomotive) derailed. The cause was identified as compacted ballast causing a track twist fault (paragraph 244).
11	**5 October 2006 Northampton**	At 21:00 hrs, five PHA wagons derailed in the English Welsh & Scottish Railway sidings in Northampton while travelling at low speed (paragraph 246).
12	**25 March 2007 Mountsorrel**	Two empty PHA wagons (16023 and 16028) derailed on the points entering Mountsorrel Railhead.
	Ely incident :22 June 2007	
Date and location		**Details of incident (post 22 June 2007)**
1	**10 December 2007 Peterborough**	The driver preparing train 6M64, the 23:04 hrs Peterborough West Yard - Mountsorrel, on No.1 Reception line at Peterborough West Yard, reported that wagon REDA16081 with GFA suspension had been discovered in a derailed state (paragraph 262). English Welsh & Scottish Railway state this incident is still under investigation.
2	**14 July 2008 Mountsorrel**	Train 6D30, the 22:10hrs service from Northampton Freight Depot to Mountsorrel, formed by locomotive 66198 hauling 30 empty PHA type wagons and 1 empty KJA type wagon, became derailed by two wagons on Network Rail's infrastructure. The incident has been investigated by Lafarge and Network Rail, who have concluded that the derailment was caused by track twist, a small frame twist, and the marshalling of the train. Recommendations concern the track geometry at Mountsorrel, and the wagon behaviour in conjunction with other investigations into PGA and PHA wagon behaviour (paragraph 265).

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