RAIB
Rail Accident Investigation Branch

Rail Accident Report

The derailment of a freight train at King Edward Bridge, Newcastle
10 May 2007

Department for Transport

Report 02/2008
January 2008

This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC;
- the Railways and Transport Safety Act 2003; and
- the Railways (Accident Investigation and Reporting) Regulations 2005.

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

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Contents

Introduction 6

Summary of the report 7

Key facts about the accident 7

Immediate cause, causal and contributory factors, underlying causes 8

Severity of consequences 8

Recommendations 8

The Accident 9

Summary of the accident 9

The parties involved 9

Location 9

External circumstances 11

The train 11

The infrastructure 12

Events preceding the accident 14

Events during the accident 14

Consequences of the accident 16

Events following the accident 16

The Investigation 18

Investigation process and sources of evidence 18

Factual Information 19

Condition of the track 19

Wagons 21

Train operation 25

Previous occurrences of a similar character 25

Analysis 26
Identification of the immediate cause 26
Identification of casual and contributory factors 26
Identification of underlying causes 28
Severity of consequences 28
Conclusions 29
Immediate cause 29
Causal factors 29
Contributory factors 29
Underlying causes 29
Additional observations 30
Actions reported as already taken or in progress relevant to this report 31
Recommendations 32
Recommendations to address causal and contributory factors 32
Appendices 33
Appendix A: Glossary of abbreviations and acronyms 33
Appendix B: Glossary of terms 34
Appendix C: Key standards current at the time 37

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 English Welsh and Scottish Railways (EWS) and Network Rail (NR) to their staff, data and records in connection with the investigation.

4 Appendices at the rear of this report contain the following glossaries:

- acronyms and abbreviations are explained in Appendix A; and
- technical terms (shown in *italics* the first time they appear in the report) are explained in Appendix B.

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

Summary of the report

6 At 06:40 hrs on 10 May 2007 an empty coal train became derailed whilst passing through King Edward Bridge South Junction on the approach to Newcastle station.

Key facts about the accident

7 The train was 6S22, the 01:45 hrs Drax power station to Thornton, and consisted of a class 66 locomotive and 39 empty four-wheel hopper wagons and was travelling at 16 mph (20 km/h) at the time of the derailment.

8 The train ran across the King Edward Bridge in a partially derailed condition, before coming to a stand on the approach to Newcastle station as the result of an automatic brake application (see Figures 1 & 2).

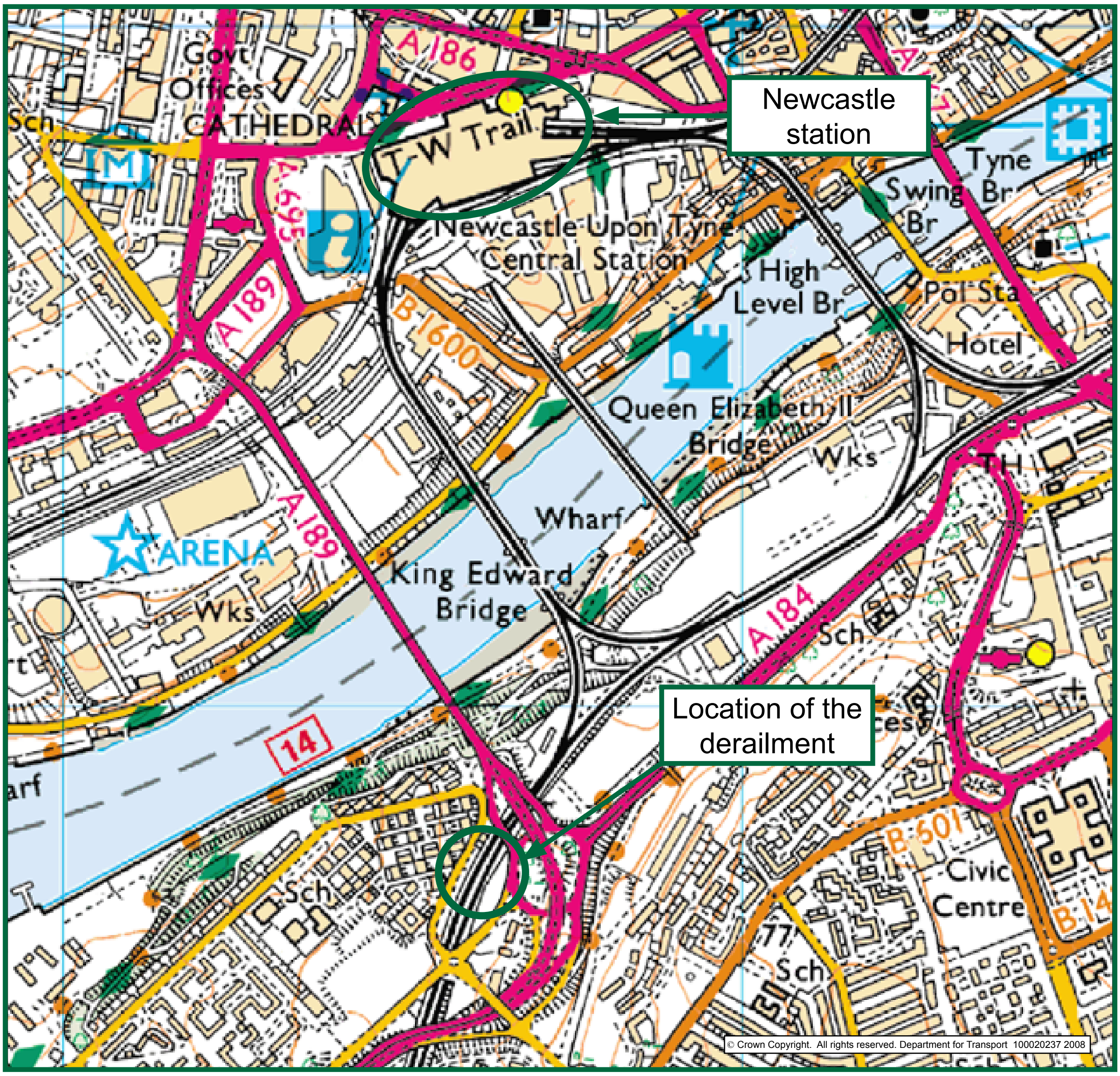

Figure 1: Extract from Ordnance Survey map showing location of derailment

Immediate cause, causal and contributory factors, underlying causes

9 The immediate cause of the accident was that the left leading wheel flange of wagon 352421 rode over the left-hand rail immediately following the insulated joint between 2375A and 2375B *points*.

10 Causal factors were:

a) a *track twist* existed within the crossover which equated to 1 in 164 (34 mm) over the wheelbase of the wagon;

b) the wagon frame had a twist in excess of 30 mm prior to the derailment; and

c) compensatory packing was present above the right leading *axle box* which worsened the effective twist by 10 mm.

11 The contributory factors to the incident were:

a) Network Rail was monitoring the crossover at a frequency which did not ensure that the geometry was maintained in a compliant state;

b) the crossover design geometry was impracticably near to the maintenance limits;

c) British Rail (BR)/English Welsh and Scottish Railways (EWS) have not monitored vehicles for frame twist since 1992;

d) in this wagon fleet significant frame twist appears to develop during service running; and

e) Network Rail did not utilise data from *Wheelchex* to provide information which identified laterally out-of-balance vehicles.

12 The underlying cause was that BR did not transfer the requirement to check frame twist from the General Repair (GR) specification to the revised maintenance regime, because they probably did not consider that frame twist would develop during *normal service* operation.

Severity of consequences

13 There were no fatalities or injuries as a result of the incident. There was considerable track, signalling and other infrastructure damage. This resulted in disruption to rail services on the day of the incident and for several days after.

14 During the passage of the derailed vehicles across the King Edward Bridge, at least one of the derailed vehicles deviated to the left and became foul of the *up* main line. Had a train been passing on the up main line at that time there would have been a collision with the possibility of much more severe consequences.

Recommendations

15 Recommendations can be found in paragraph 155. 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 network;
- a review of the layout design, monitoring and maintenance arrangements for the track at King Edward Bridge South Junction.

The Accident

Summary of the accident

16 At 06:40 hrs on 10 May 2007 train 6S22 became derailed whilst passing through King Edward Bridge South Junction (Figures 1 & 2) on the approach to Newcastle station. The train was the 01:45 hrs Drax power station to Thornton, consisted of a class 66 locomotive and 39 empty HAA and HMA four-wheel hopper wagons and was travelling at 16 mph (20 km/h) at the time of the derailment. An HAA wagon is shown in Figure 3.

17 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.

18 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.

19 Rail traffic was stopped on all lines across and to the south of the King Edward Bridge. Following an initial inspection by the RAIB, the up main line was released for traffic at 11:40 hrs and the down main line at 14:30 hrs on 10 May. Repairs to the points equipment, track and bridge components were completed and normal operations recommenced at 06:00 hrs on 14 May 2007.

The parties involved

20 The derailed wagons were owned and maintained and the train operated by EWS.

21 The infrastructure is owned and maintained by Network Rail.

Location

22 King Edward Bridge South Junction is located 1.1 km south of Newcastle station. At this location the East Coast Main Line converges with the lines from Carlisle. Crossovers permit moves between down main line and up Carlisle line. Lines to Gateshead head eastwards via a triangular junction with the down Carlisle line. Two main and two slow lines cross the river Tyne at a high level via the King Edward Bridge. A diagram of the track layout is shown in Figure 2.

23 At the north end of the King Edward Bridge, Newcastle South Junction permits moves between all of the running lines on the approach to Newcastle Station platforms.

24 The initial *point of derailment* (POD) was identified as being within the crossover between the up main line (2375A points) and up Carlisle line (2375B points).

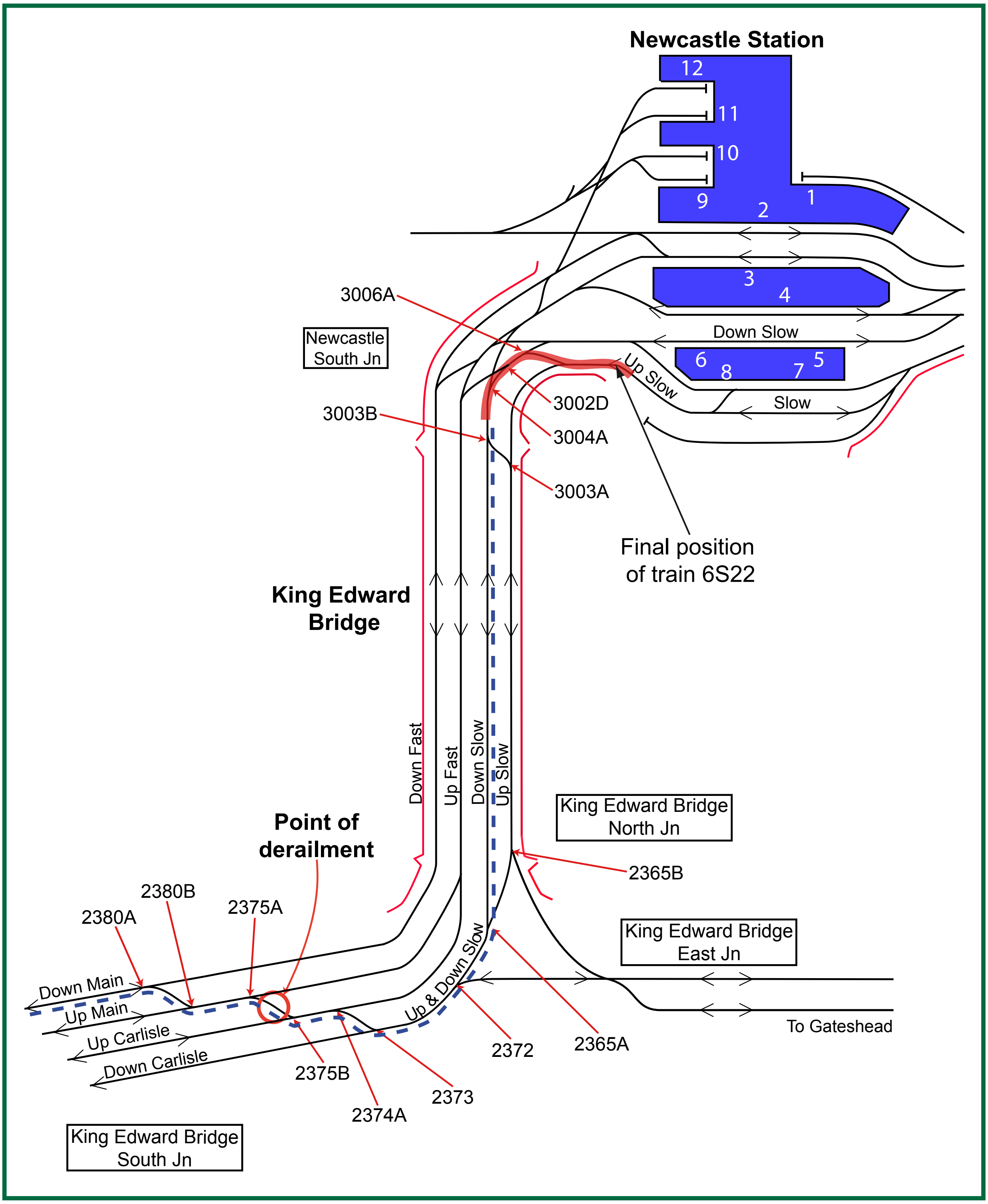

Figure 2: Schematic track diagram in the vicinity of the derailment

External circumstances

25 The weather on 10 May was windy, dry and clear and did not contribute to the incident.

The train

26 The train was formed of class 66 locomotive, 66247, and 39 empty coal hopper wagons; 25 HAAs and 14 HMAs. These wagon types are physically similar. The different designation identifies a minor difference in the braking arrangements.

27 HAA wagons were constructed between 1964 and 1982 to facilitate Merry-Go-Round (MGR) coal delivery requirements to power stations. Around 10,500 were built, although fewer than 1,000 are currently in service. The nominal tare weight of an HAA wagon is 13.5 tonnes. Nominal tare wheel load is therefore 3.375 tonnes.

28 MGR trains are used for automated coal delivery. Trains consisting entirely of these vehicles are drawn slowly, at approximately 0.5 mph (0.8 km/h), through loading bunkers, which rapidly deposit coal into the hopper body from above. The loading system includes a weighing mechanism to ensure that the correct amount of coal is loaded. At the discharge terminal, trains are similarly hauled at slow speed through an under-track discharge unit, where lower hopper doors are unlocked and opened automatically by trackside equipment, to release the contents of the wagon without the train stopping.

29 HAA type wagons consist of a welded chassis comprising two *solebars* and two *headstocks* supplemented by additional cross members and short longitudinal beams. These stiffen the chassis and allow it to absorb *drawgear* and *buffing loads* and also provide mounting points for hoppers and doorgear equipment. A galvanised riveted hopper body sits on the frame with three discharge chutes extending below frame level. External bracing is provided to provide support and stiffen the hopper body. An HAA wagon is shown in Figure 3.

Figure 3: An HAA wagon

30 Suspension is provided by *leaf springs, single links* and *eye bolts* which attach to *scroll irons* welded below the solebar bottom flanges. An *axle guard* provides longitudinal and lateral constraint for the roller bearing axle box, which bears under the leaf *spring buckle*. This arrangement is shown in Figure 4.

31 The vertical positioning of the wagon door control mechanism is maintained within a nominal ± 5 mm tolerance to ensure correct engagement with trackside equipment. To achieve this, *suspension packings* (known in this type of arrangement as *cone packings)* are placed between the axle box and spring buckle as shown in Figure 4. These are varied in thickness and are used to compensate for wheel diameter variations as *wheelset* turning or wheelset replacement occurs.

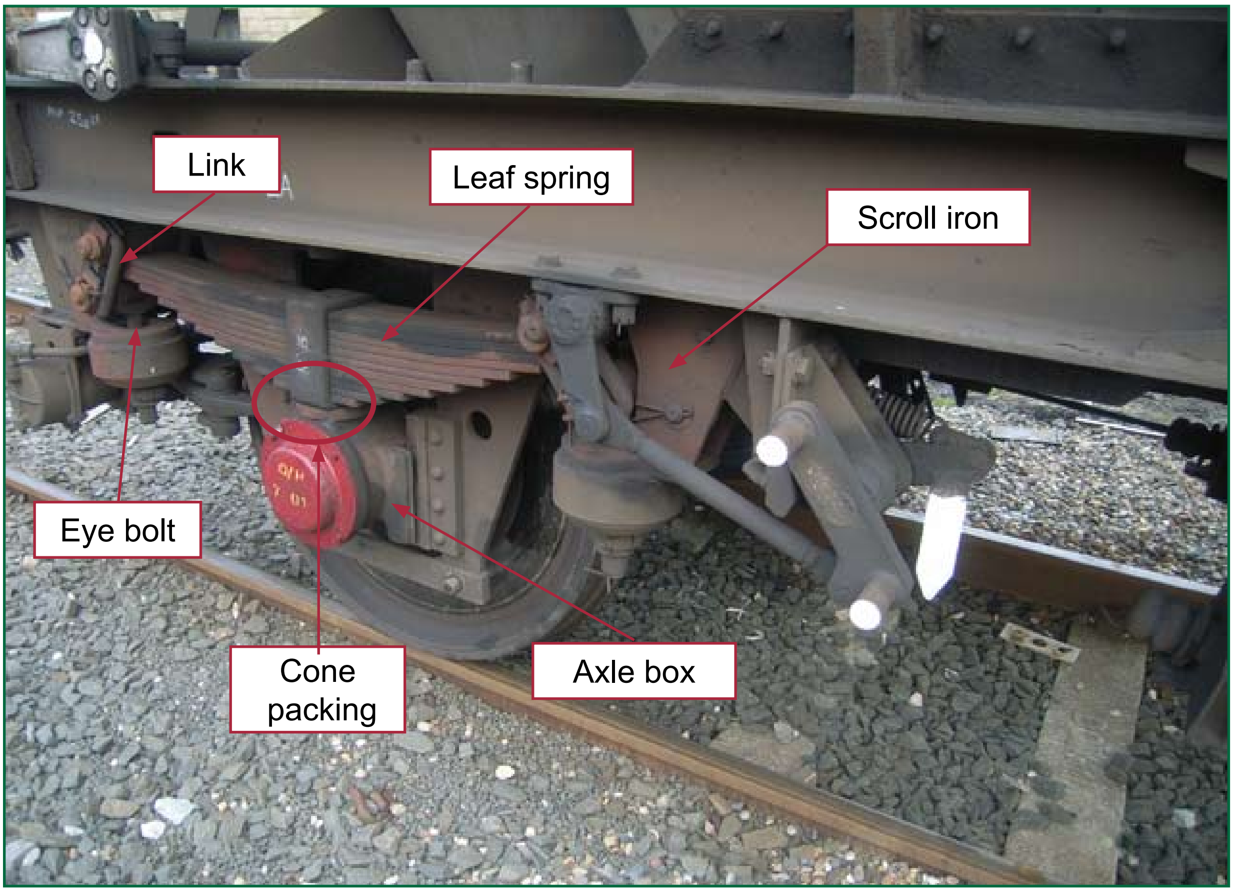

Figure 4: An HAA suspension arrangement

The infrastructure

32 Trains travelling northwards on the East Coast Main Line (ECML) approach King Edward Bridge South Junction on a rising gradient and through a right-hand curve. The Carlisle to Newcastle lines climb to run parallel to, and to the east of the ECML up fast and down fast lines.

33 Trains which require to move to either of the slow lines from the down fast line can pass to the up Carlisle line using a facing crossover consisting of 2380A and 2380B points and a second crossover consisting of 2375A and 2375B points. The two Carlisle lines then merge into the up and down slow line and a facing junction allows trains to travel eastwards towards Gateshead. The up and down slow line splits into the up slow and down slow at King Edward Bridge North Junction and these cross over the King Edward Bridge towards Newcastle station parallel to and to the east of the up and down fast lines. Figure 2 shows the track layout.

34 All points are *113A full depth vertical design* and are operated by *clamplock* point mechanisms. The layout has been in place for several years and there have been no recent changes.

35 In the vicinity of the derailment, rail fastenings are *pandrol clips* and *baseplates* on softwood timber *sleepers*. The plain-line is a mixture of softwood and concrete sleepers with *flat-bottom* rail.

36 The signalling is *track-circuit block* with *four aspect colour-light signals*. The signalling played no part in this incident.

37 King Edward Bridge is a riveted wrought iron lattice girder structure supported by masonry piers and abutments. The deck consists of riveted wrought iron plates formed into a step sided trough. The rails are supported on baseplates fastened to longitudinal baulks of hardwood timber. These timbers are held laterally by *transoms*, originally of timber, but recent replacements are steel fabrications with *tie-rods*. A general view of the construction is shown in Figure 5.

Figure 5: A view of the track construction on King Edward Bridge

38 The *linespeed* is 25 mph (40 km/h) through all points, on the up and down slow and up slow and down slow lines.

Events preceding the accident

39 Train 6S22 was a scheduled MGR service and was on its journey northwards after discharging its load at Drax power station in Yorkshire. At Sessay, 16 miles north of York, the train passed through a Network Rail wheelchex monitoring site.

40 A driver change occurred at Tyne Yard, shortly before the incident.

41 Train 6S22 was signalled to cross from the down fast line through crossovers 2380 and 2375 and to cross King Edward Bridge using the down slow line.

Events during the accident

42 The train departed Tyne Yard, 6.5 km south of Newcastle, at 06:27 hrs. It ran under *caution aspects* as far as signal T221, reaching a maximum speed of 27 mph (43 km/h). After passing signal T221 the driver shut off the power anticipating that, when it came into his view, signal T231, the signal immediately preceding King Edward Bridge South Junction and the signal which would control and indicate his route through the junction, would be displaying a red aspect, as had been his previous experience with similar trains. When he did see the signal, it was displaying a green aspect with the *route indicator* illuminated for the move to cross to the down slow line over King Edward Bridge. The driver reapplied power and the train accelerated slowly, passing through 2380 and 2375 crossovers. Figure 2 shows the route of the train.

43 As the trailing vehicles passed through 2375 crossover the left leading wheel of the 23rd wagon, HAA 352421, mounted the head of the left rail immediately following a *six-hole insulated rail joint*. The wheel flange rode along the rail head for 13 m before dropping outside the rail. At 2375B, the trailing points of the crossover, the trailing axle of 352421 also became derailed to the left (Figure 6).

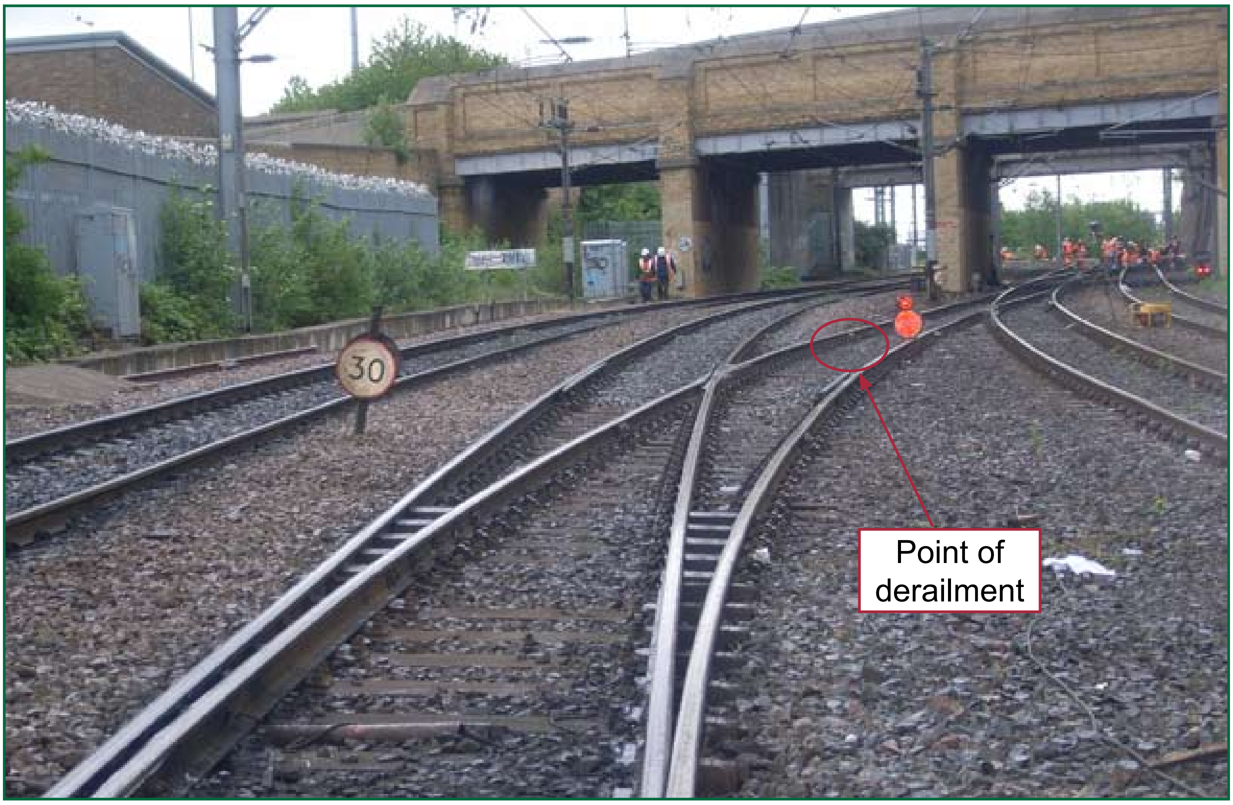

Figure 6: 2375 crossover

44 Wagon 352421 ran a short distance with all of its wheels derailed until reaching 2374A points. These points were facing in the direction of travel and were set to divert the train to the right onto the up and down slow line. Wagon 352421 was constrained by being to the left of the left-hand *stock rail* and was unable to take the set route. The diverging paths of the 22nd (356964) and 23rd (352421) vehicles caused the 22nd wagon (356964), to derail to the left and simultaneously also pulled the coupling at the leading end of 23rd (352421) sharply to the right causing the wagon to tip onto its right side. The side bracing of this wagon's hopper body made contact with the right hand check rail of 2373 points.

45 The train continued along the up and down slow line with the 22nd (356964) vehicle derailed and the 23rd (352421) on its side. During this section of running damage occurred to both of the vehicles, the 23rd (352421) losing hopper door levers and brake gear from its right-hand side and the 22nd (356964) suffering damage to suspension and axle box components. A suspension cone packing, identified as belonging to 352421, was found later in this vicinity. *Stretcher bars* and clamplock point mechanisms along the path of the derailed vehicles were all severely damaged.

46 Although the two wagons were derailed, the remainder of the vehicles in the train negotiated 2372 *facing points*, where the line towards Gateshead diverges. However, the 22nd (356964) vehicle was diverted to the right and dragged the 23rd (352421) in the same direction, before the pull on the leading coupling of the 22nd (356964), caused the two vehicles to follow the preceding part of the train into the sharp left-hand curve approaching the King Edward Bridge. In the view of the RAIB, at some point between 2373 points and this curve the 23rd wagon (352421) was pulled upright by the rotational force between the leading coupling and the right-hand wheels, which were running outside the right-hand running rail.

47 The train ran in this manner, with the two wagons derailed to the right, but now both upright through 2365A facing points and onto King Edward Bridge.

48 The construction of the bridge is such that there is no level deck in the *four-foot* of the tracks (paragraph 37). The left-hand wheels of the 22nd (356964) and 23rd (352421) wagons therefore dropped into the central trough and struck the bridge transoms causing considerable damage. The right-hand wheels rode variously on the flat or corner of the deck plates to the right of the right-hand rail.

49 The vehicles crossed the bridge and onto the ballasted track beyond. By now wagon 352421 had sustained significant damage, including the loss of an outer bearing on the right-leading wheel, a displaced spring and suspension link, and much damage to door operating and braking equipment. Three cone packings from this vehicle were found in this area.

50 On the approach to Newcastle South Junction, points converge from the right (3003B), a *single slip* is present to the left (3004A and 3002D) and a facing point then diverges to the right (3006A). As the derailed vehicles passed through this complex of pointwork, they were subjected to a variety of lateral forces which caused them to take a varied lateral path. At one point a vehicle struck the ends of sleepers on the adjacent up main line. At the conclusion of this section the two derailed vehicles became rerailed. However the track damage and debris, including brake equipment and running gear from the wagons, deposited on the track, subsequently derailed the 24th vehicle (359003).

51 T485 signal at the north end of King Edward Bridge displayed a green aspect with the 'S' slow line indicator illuminated for a move over 3005A points to access the slow line and avoid passing through the station platforms. The train passed T485 and the driver observed the next signal T515 revert to red and he received an *Automatic Warning System* (AWS) horn. Before the driver could make a controlled stop at T515 signal the train brakes were applied automatically.

52 The signal reversion observed by the driver was caused by the signaller placing the signal to red. He had observed a number of track-circuit and points indicators flashing on the signal panel and took action in accordance with normal operating practice.

53 The coupling and brake hose between the 23rd (352421) and now derailed 24th (359003) wagon had parted and initiated the brake application.

Consequences of the accident

54 There were no injuries as a result of the accident.

55 Five wagons were damaged:

- The 22nd (356964) and 23rd (352421) vehicles ran derailed for some distance and suffered significant wheelset, suspension and brake gear damage. There was some frame and hopper bracing abrasion damage to the 23rd vehicle, 352421, as a result of being dragged on its right side.
- The 24th and 25th vehicles sustained damage, predominantly to wheels and running gear, as they became derailed in the final stage of the incident.
- The 26th wagon remained railed and had minor brake pipe damage.

56 From 2375B points on the up Carlisle line to the final position of the derailed vehicles, close to 3005 points, there was considerable infrastructure damage. This included significant lengths of rail and baseplate damage, deformation of point stretcher bars and catastrophic impact damage to Clamplock point mechanisms. The passage of derailed wheels and dragged vehicle components severed a number of control and track circuit cables. The train travelled a total of 850 m after the initial derailment.

57 There was also damage to the track support elements within the structure of the King Edward Bridge. The hardwood longitudinal timbers to the left-hand side were bruised and the transoms spanning between the longitudinal timbers across the trough were smashed, if wooden, or fractured and bent if steel.

58 There was no damage to the overhead traction power supply equipment.

Events following the accident

59 All lines over the King Edward Bridge and to the south were blocked to rail traffic. Rail services were diverted or curtailed.

60 Following the derailment, and without the RAIB's permission, infrastructure maintenance staff from Network Rail entered the derailment site. These staff inspected 2380A and 2380B points and also inspected and lubricated the switch blade of 2375A points on the approach to the initial point of derailment. They also conducted a simple survey of the track in the vicinity of the POD using a cross level gauge.

61 Prior to the arrival of RAIB inspectors, EWS staff downloaded a copy of the data from the *On Train Monitoring Recorder* (OTMR) on locomotive 66247, without it being witnessed by a representative of the RAIB as requested by the RAIB duty coordinator.

62 Both of these actions are in breach of section 7 (1) of The Railways (Accident Investigation and Reporting) Regulations 2005. However it is not considered that either had any effect upon the site evidence or subsequent conduct of the investigation.

63 Following an examination of the site the down main line was handed back to Network Rail at 11:40 hrs. After site surveys were completed 2375A points were returned to the normal position and the up main released to Network Rail at 14:30 hrs.

64 The Carlisle lines and the routes up to and over the slow lines at the King Edward Bridge were released in stages; access was granted to Network Rail for replacement of point operating equipment and consequential track damage repairs at 15:30 hrs. The final handback to Network Rail was to allow the recovery of the train by EWS and this was granted at 15:40 hrs.

65 All trackwork repairs were complete and normal service operations resumed at 06:00 hrs on 14 May.

66 Following examination, the 22nd to 26th vehicles in the train were rerailed and moved to Tyne Yard for further inspection and testing.

The Investigation

Investigation process and sources of evidence

67 The RAIB investigation into this derailment included:

- detailed examination of the site;
- surveying the track in the vicinity of the identified point of initial derailment;
- surveying and weighing wagons involved in the derailment;
- examination and measurement of a representative sample of similar wagons; and
- review of the data from the OTMR.

68 In addition to the examinations listed above, the investigation obtained evidence from:

- Network Rail procedures for the inspection and maintenance of the track;
- Network Rail records of inspection and maintenance of the track;
- records from the Network Rail track recording vehicles;
- interviews with staff;
- EWS records of wagon maintenance; and
- EWS wagon maintenance procedures.

Factual Information

Condition of the track

<u>Inspection standards</u>

69 Network Rail company standard NR/SP/TRK/001, “Inspection and Maintenance of Permanent Way”, specifies the type and frequency of inspections to be performed and also the maintenance limits which apply. These parameters vary according to the *track category* and *track type*. At the time of this derailment issue 2, dated October 2005, was applicable.

70 One of the inspection processes specified in the standard is the use of the Network Rail track recording vehicles. These are programmed to run over the network to measure and record a suite of data related to infrastructure condition. Output from the vehicle recording system is provided to the infrastructure maintenance organisation in two generic forms, a continuous output, both graphical and tabular, of all track measured, and a schedule of all specific locations where parameters exceed the specified levels. NR/SP/TRK/001 includes minimum actions and timescales for remedy of these exceedences.

71 A key measurement is that of track geometry and particularly track twist. Track twists are normally expressed as a gradient (eg 1 in 200) and the standard stipulates that this is derived from the difference in the *cross-level* at locations 3 m apart.

72 There are a number of track sections consisting mainly of loops, platform lines and crossovers, where it is not practicable to programme the track recording vehicles at the requisite frequencies. NR/SP/TRK/001 states that a register of the lines concerned must be kept by the Track Maintenance Engineer and approval shall be sought for alternative inspection methods. It does not specify who can grant this approval.

73 In this case the Network Rail London North Eastern Territory Track Engineer (TTE) had approved the monitoring of crossovers 2380 and 2375 at King Edward Bridge South Junction using a manual track recording trolley at a yearly frequency.

<u>Track geometry</u>

74 The train derailed within 2375 crossover between the up main line and the up Carlisle line. A clear but light flangemark on the head of the rail enabled the point of derailment to be accurately identified. It was evident that a single wheel had climbed onto the head of the high (left) rail immediately beyond a six-hole insulated joint, at 79 miles 35 chains.

75 The RAIB and Network Rail surveyed the track to obtain the vertical geometry of the left and right rails at, and approaching, 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 m base, as prescribed in NR/SP/TRK/001.

76 NR/SP/TRK/001 deems twists below 1 in 200 to be unacceptable and should be rectified within 14 days of detection.

77 To enable calculations to be made which more accurately mimic the geometry experienced by a rail vehicle it was necessary to add measured values for the vertical deflection of the track, taken using *void meters*. Only a limited number of readings were taken and approximations were necessary at some intermediate sleeper positions. Those readings which were obtained indicated that the track voids were of small magnitude.

78 At the point of derailment the loaded twist over a 5562 mm base, the wheelbase of an HAA wagon, was 34 mm (1 in 164). This degree of track twist was also present at a position two sleepers before the POD. There were a number of other locations within the crossover where the twist was more severe than greater than 1 in 200.

79 Network Rail's approved monitoring regime measures the crossover in its unloaded condition. If a survey had been carried out at the time of the derailment the unloaded twist over a standard 3 m base at the POD would have been 14 mm (1 in 214). There were however twists as severe as 1 in 176 immediately preceding the POD.

80 The twist at the POD calculated over the wagon wheelbase of 5562 mm from this same unloaded data is 30 mm (1 in 185).

81 The previous scheduled survey was carried out using the manual recording trolley on 17 May 2006 in compliance with the approved programme.

82 On 7 September 2006 the Network Rail Track Recording Unit (TRU) vehicle passed through the crossover. Although this was not a scheduled path, the measurement and recording equipment was active and the data produced was forwarded to the local maintenance team in line with normal practice. This run detected a 3 m twist within the crossover of 1 in 143. Remedial work took place to correct the defect within the 14 day limit. In February 2007 an insulated joint on the left-hand rail was renewed and moved in an attempt to improve the track geometry.

83 A further pass of the TRU through 2375 crossover occurred on 2 July 2007, only seven weeks after the derailment and again a repeat of the twist fault was detected.

84 At the crossing of 2375A points, 24 sleepers prior to the POD, the cross-level is +90 mm. This is required to match the cross-level on the up main line. The crossing of 2375B points, 19 sleepers beyond the POD, has a cross-level of -29 mm to match the geometry of the up Carlisle line. An overall change in cross-level of 119 mm in 43 sleepers, approximately 30 m, is an average twist of 1 in 254. The cross-level is shown in Figure 7.

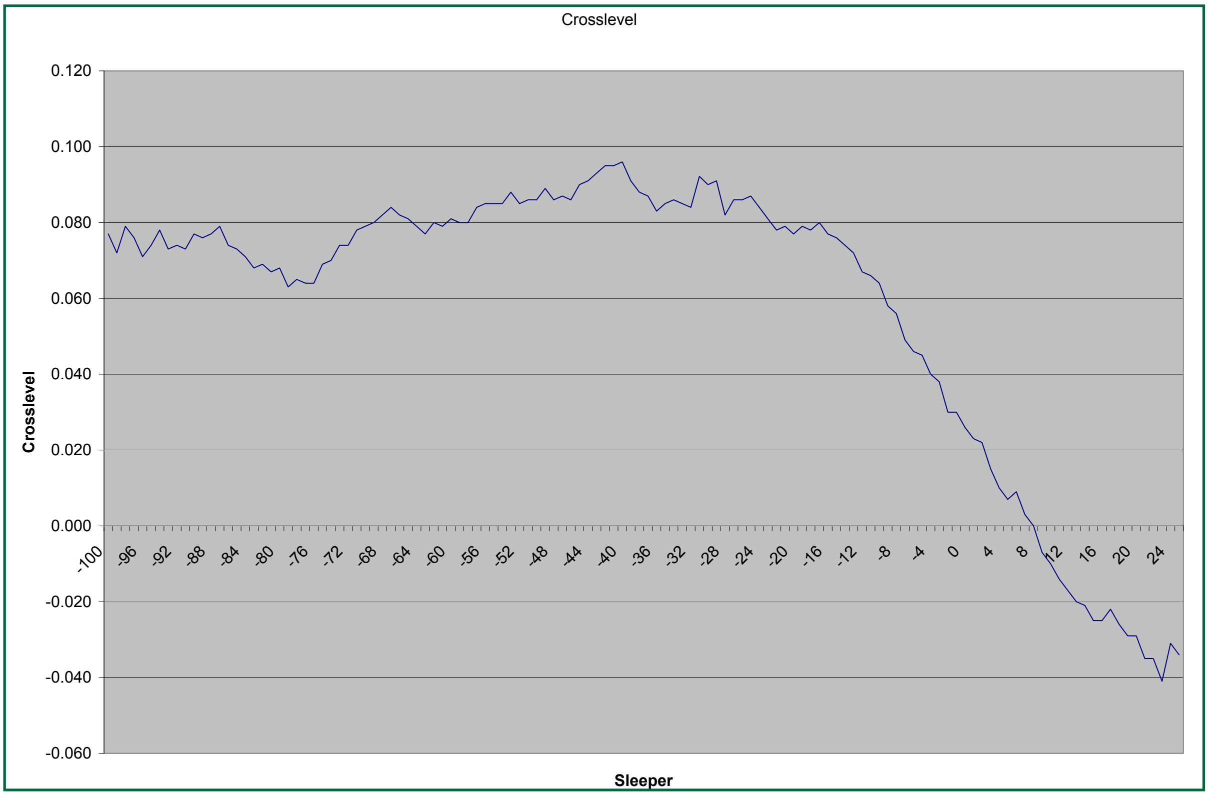

Figure 7: Cross-level through the site

Wagons

Group standards and wagon design

85 A critical parameter in rail vehicle operation is suspension behaviour and the ability to maintain adequate vertical wheel loads whilst traversing irregular track geometry. For a four wheeled vehicle the relevant Group Standard, GM/RT2141, stipulates that the most unloaded wheel must retain at least 40 per cent of its nominal wheel load when subjected to a 1 in 150 twist over the wheelbase of the vehicle. Although HAA vehicles predate the current acceptance regime, they are compliant with the suspension performance requirements when maintained to specification.

86 HAA wagons have a wheelbase of 5662 mm and a twist of 1 in 150 equates to a 37 mm difference in cross-level between the two axle locations.

Wagon maintenance

Process

87 Prior to 1992, HAA and similar wagons were subjected to General Repairs (GR) at wagon workshops on a seven-yearly cycle. During this work, wagons were normally dismantled to individual components, which were repaired, refurbished or replaced as appropriate and wagons reassembled. The majority of HAA wagons received new bodies as part of these works.

88 After chassis refurbishment there was a dimensional check of the wagon frame for any twist as it was considered that there was a risk of some twist being induced during the GR activities. This is referenced in BR Engineering Instruction WF/81 "Measurement and Compensation of Frame Twist", an ex-British Rail (BR) document from 1980 adopted by EWS.

89 The use of this procedure is also specified as part of any post-incident wagon checks.

90 Any frame twist greater than 6 mm and up to a maximum of 30 mm should be compensated for by a corresponding increase in the thickness of the packing above the axle boxes on one or both of the diagonally opposite 'high' corners. A small plate was also affixed to the solebar above any corresponding wheel to indicate the requirement for, and size of, this additional packing.

91 For reasons connected with a reduction in the intensity of use and smaller fleet size, the time-based General Repair programme for these wagons ceased in 1992. The annual cyclic maintenance process, which included the *Vehicle Inspection and Brake Test* (VIBT), was enhanced and further GRs were only carried out on an "as-required" basis. The requirement for frame twist checks remained in the GR and was not incorporated into annual maintenance, thereby removing the requirement for a fixed interval frame twist check.

92 The requirements for annual maintenance of these wagons are given in maintenance specification EWS/ES/0081.

The wagons in train 6S22

93 The wagons in this train had been through their annual maintenance in April 2007 at Worksop wagon maintenance depot. A number of standard checks and maintenance operations were performed during this visit in accordance with EWS/ES/0081, including the exchanging of wheelsets and replacement of brake pads. Maintenance staff are not required to, and did not, record the value of cone packings either before or after this maintenance.

94 The depot completed the maintenance work against the specification. The maintenance record sheets for the four derailed wagons show that some minor additional work was carried out on 359003, 355082 and 352421, none of which is likely to have any relevance to this accident.

95 The wagons were formed into a set and returned to service on 17 April 2007.

The derailed wagons

96 During the incident four wagons, the 22nd to 25th in the train incurred significant damage (paragraph 55). Four cone packings were recovered; three were of 10 mm and one of 20 mm thickness. Wagon 352421, the 23rd wagon, had lost all of its cone packings. None of the other three derailed wagons had any cone packings missing. As such, it is reasonable to conclude that the four packings found at the trackside came from this vehicle.

97 Evidence (paragraph 74) indicated that the 23rd wagon (352421) was the first to derail.

98 There was considerable damage to the suspension, wheelset and brake gear of 352421. A number of frame welds were found to have minor cracks along them. Six were long established and showed no recent movement. A further two cracks did display some recent lengthening. It was not possible to conclusively determine if this was connected with this incident. Other bruising and scarring damage was observed which indicated that this wagon had been involved in previous incidents. Although there were fresh contact marks, including abrasion to the hopper bracing, there was no indication of deformation of the hopper body or tear-out of the rivets, which would indicate that there had been significant rapid distortion of the frame.

99 Following the incident the five wagons 22nd to 26th in train 6S22 were weighed to establish their individual wheel loads. Four further wagons were taken at random from the serviceable fleet as a comparison.

100 The 26th wagon from train 6S22 and two of the comparator vehicles were then subject to a track twist of 29 mm and reweighed, to establish typical generic suspension performance characteristics.

101 The greatest variation from nominal wheel load when positioned on level track was +19 percent. This was not a vehicle from the incident train.

102 Data from the wagon weighing tests and the application of the 29 mm track twist was used to calculate an average spring load/twist relationship. This is 0.0431 tonnes change in individual wheel load per mm of wagon twist. This equates to 23.20 mm per tonne.

103 The 23rd wagon, 352421, the first to derail (paragraph 43), was checked for frame twist and found to be 33 mm out of plane. Additionally the vehicle was plated for a 10 mm twist in the opposite direction. The plate was at the right leading corner of the vehicle.

104 The 26th wagon (350676) was checked for frame twist and this was 1 mm out of plane.

105 Because wagon 352421 had been severely damaged in the incident and in order to ensure that there was no possibility of any influence on the frame twist measurement from deformed, missing or damaged suspension elements, the vehicle had its fundamental components replaced or realigned. These included the leading wheelset and axle boxes, suspension links and leaf springs. The four suspension cone packings were replaced with the 20 mm positioned at the right leading corner where the plate indicated that it should be. Following this work the frame twist was re-measured and still recorded at 33 mm.

106 Previous recorded incidents involving this vehicle show:

- 1998 - 7th Sep - Derailed at Scunthorpe Down Main all wheels. 6D15 - became derailed on the down main at Scunthorpe several vehicles derailed including 352421. No further details. Subsequent information suggests that the incident was related to a track twist of 1 in 85.
- 1999 - 11th Jan - Train Divided at Toton, rusted coupling on wagon 352421.
- 2006 - 30th June - Handle out of cradle.
- 2006 - 20th Dec - Derailed at Immingham HIT on coal spillage.

Further wagon checks

107 To assess the fleet condition a frame twist survey was carried out on a random sample of 58 serviceable MGR wagons, approximately 7 per cent of the current operating fleet. Of this sample 50 per cent had frame twist which exceeded the 6 mm maximum specified in WF/81 (paragraph 90). The greatest value of uncompensated twist was 31 mm.

108 One wagon had a twist which was measured at 40 mm. The wagon was plated, identifying the twist as 12 mm. This was partially compensated for by a 10 mm packing.

109 Figure 8 shows the results of this survey.

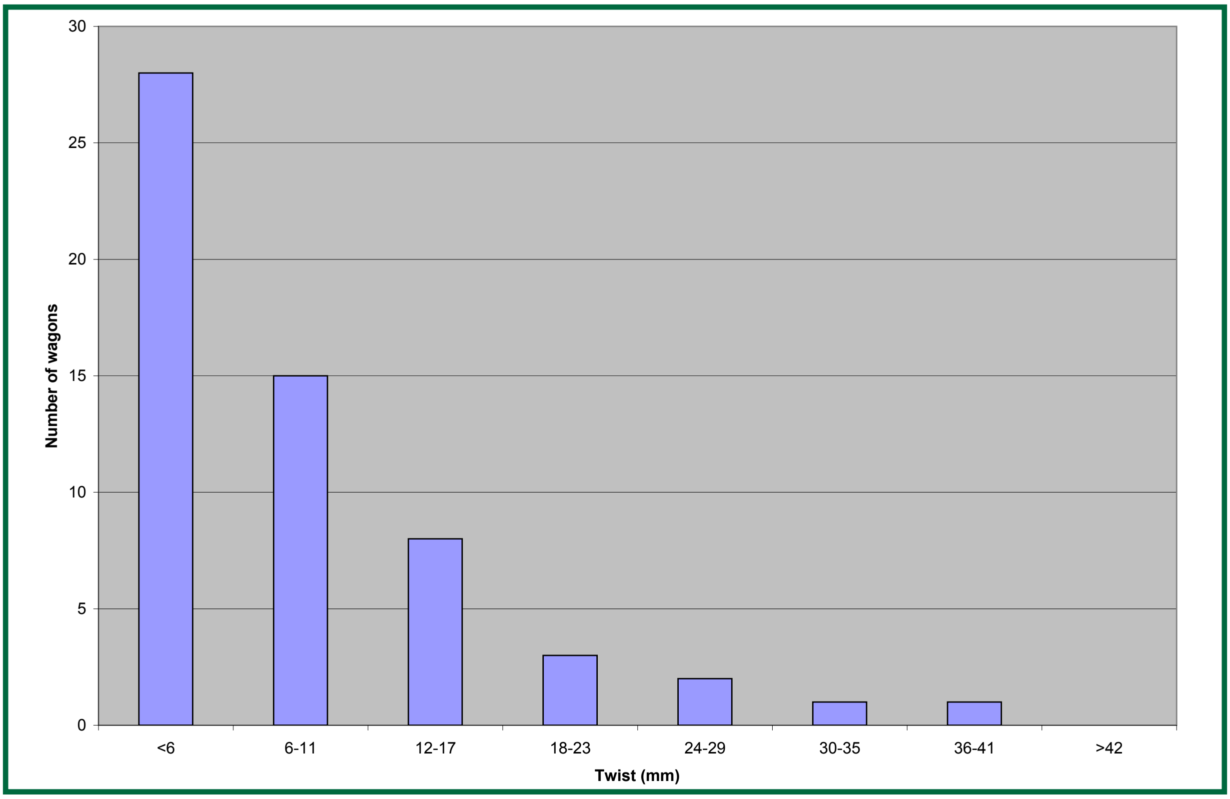

Figure 8: Results of the wagon frame twist survey

110 A feature of the detected twists was a predominance of twist in one direction; that is the left leading and right trailing corners were generally high.

Wheelchex

111 At 03:23 hrs on the morning of 10 May train 6S22 passed through and was detected by the Wheelchex system equipment at Sessay. Although Wheelchex is operated primarily as an alarm system which identifies excessive dynamic loads generated by flat or out-of-round wheels, and initiates a real-time response by Network Rail operations staff and freight operators' rolling stock inspectors. Other reports are available, but are not routinely produced. One of these is an uneven wheel loads report.

112 The Uneven Wheel Loads report for 6S22 is shown in Figure 9.

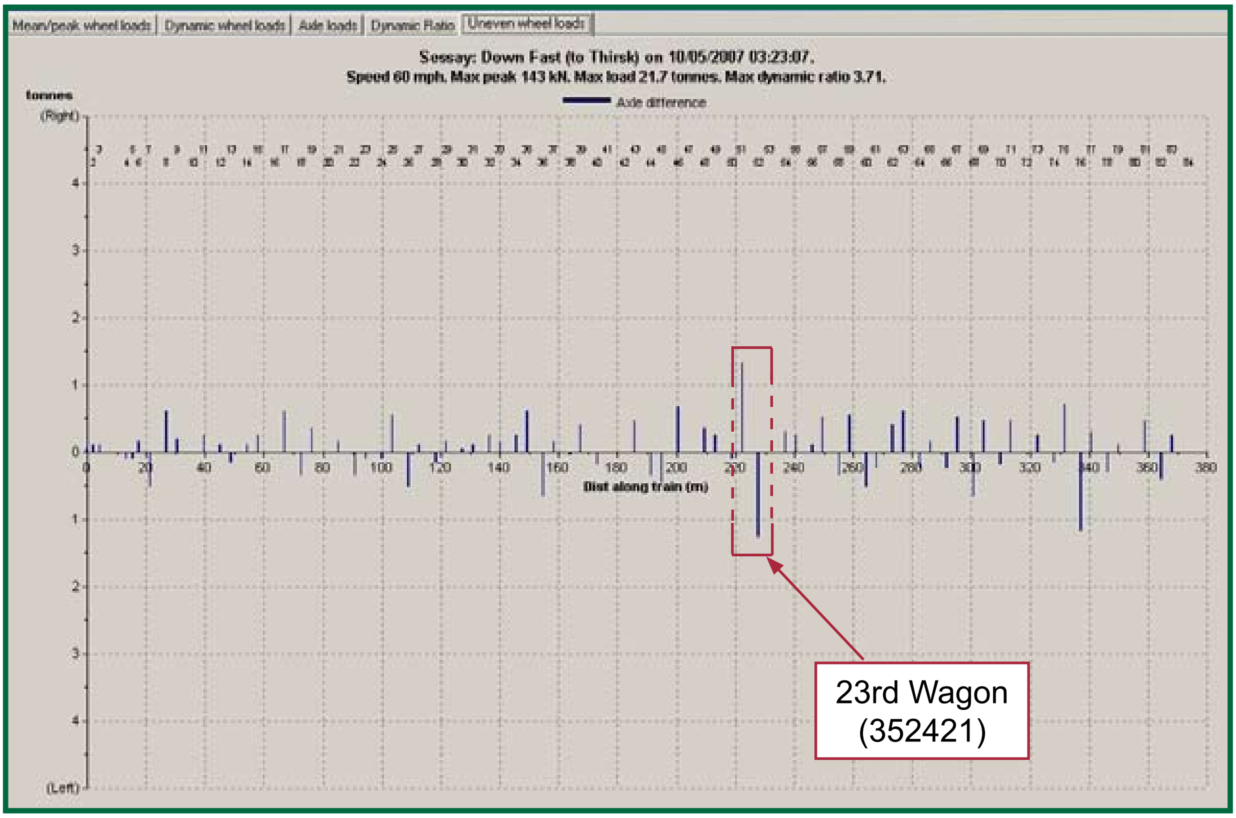

Figure 9: Uneven Wheel Load report for train 6S22

113 The front of the train is to the left of the graph. Vertical bars below the central axis represent the left-hand side of the train, and those above the axis the right.

114 For each axle within the train, identified by position at the top of the report, the vertical bar indicates magnitude of the imbalance from the average wheel load on that axle.

115 The Wheelchex data on the 10 May shows the following dynamic wheel weights in tonnes, for the 23rd wagon in train 6S22 (352421):

	Left	Right
Leading	1.9	4.5
Trailing	4.5	2.0

116 If the vehicle suspension behaviour was similar to that measured after the incident (paragraph 102) a twist of approximately 30 mm would need to be present to generate these wheel loads, if they had been recorded during static wheel weighing.

117 This does not match the 43 mm effective twist measured in the vehicle frame, but does indicate that a significant twist was present in this vehicle earlier in its journey and before the derailment.

Train operation

118 The OTMR data did not show any relevant issues associated with the operation of the train or the actions of the driver.

Previous occurrences of a similar character

119 There were 15 recorded derailments of MGR wagons in 2005 and 14 in 2006. All except one occurred in power stations or yards and were connected with shunting, propelling or the operation of points.

120 None of the immediate causes was attributed to frame twist in the related investigations carried out by industry. The contribution of the wagon was not assessed in any of these incidents. The presence or effect of any twist therefore remains unknown.

Analysis

Identification of the immediate cause

121 The single, distinct, but light flangemark on the head of the left-hand rail was clear evidence of a derailing wheel. The rail head marks were long and light, which indicates a low vertical load and the absence of a large lateral force. The testing and examination of the wagons in the train concluded that the left leading wheel flange of 352421 rode over the left-hand rail immediately following the insulated joint between 2375A and 2375B points. This was the immediate cause of the incident.

Identification of causal and contributory factors

Track geometry

122 The wagon experienced a track twist over its wheelbase at the POD of 34 mm (1 in 164). This is below the specified maintenance limit of 1 in 200 and requires corrective action to be taken within 14 days of detection. There was a minor alignment fault at the same location. Without these track geometry features the derailment would not have occurred at this location. The track geometry was considered to be a causal factor.

123 Network Rail's monitoring procedure, using a manual track recording trolley, had not been applied since May 2006. In September 2006 a Network Rail track recording vehicle passed over the crossover. Between the manual measurement and the TRU run the geometry had fallen below the maintenance limit. Remedial works took place in compliance with NR/SP/TRK/001. However, despite these remedial works (paragraph 82) the geometry had again fallen below the maintenance limit between the TRU run and the date of the incident. The monitoring of the geometry through the crossover was not sufficiently frequent to ensure that the geometry did not degrade below the maintenance limit, and was a contributory factor. This is confirmed by the degradation in geometry in the seven weeks following the derailment, when another TRU pass occurred.

124 The overall geometry of the crossover (paragraph 84) is undesirable. Only small dimensional changes, particularly in the vertical plane, which are difficult to manage (paragraph 125) may cause some parameters to become very close to or exceed the maintenance limit.

125 Visual inspection normally takes place on unloaded track. Track Inspectors are trained and briefed to observe signs of the presence of voids in the track, if possible, during their regular inspections. The relatively small voids present (paragraph 77) were a critical factor in the geometry becoming non-compliant. Small magnitude voids are difficult to assess and maintenance of acceptable geometry will be difficult to achieve if extremely small tolerances are required.

126 The requirement for the point ends of the crossover to meet the geometry of the respective running lines compromises the rate of change of cross-level within the length available. The geometry is sensitive to minor changes in track support before reaching the maintenance limit (paragraph 84). The poor overall design geometry was a contributory factor.

127 Network Rail standards use a 3 m base for assessment of track geometry. This will not always detect the same magnitude or the same location of twist as experienced by a rail vehicle, which may have a longer wheelbase. However, there is negligible risk of failing to detect non-compliant geometry. The use of a 3 m measurement base was neither a causal nor contributory factor.

Wagon condition

128 From the dynamic wheeloads measured at Sessay and the spring characteristics calculated (paragraph 102), Wheelchex indicates a twist of 30 mm. It is therefore possible that the twist in the frame of the 23rd wagon 352421, the first to derail, was increased by the events during the derailment. However, it is also evident that significant, undetected twist was present prior to the incident.

129 A wagon which is compliant with Group Standard vehicle acceptance criteria should tolerate a 1 in 150 track twist over its wheelbase (paragraph 86). For an MGR wagon this equates to 37 mm. Compliance with this Group Standards requirement should still be achieved by a wagon twisted up to the maximum limit of frame twist. The maximum frame twist allowed for torsionally stiff vehicles is 6 mm (paragraph 90). Therefore an MGR vehicle subjected to the maximum combined vehicle and track twist allowed by the relevant standards of 43 mm should still retain the specified 40 percent of wheel load.

130 Track which is within maintenance limits (a 1 in 200 twist) could present a twist of 28 mm to an MGR wagon. A wagon would therefore need only to be twisted by 15 mm before the Group Standard wheel load limit was exceeded. Wagon 352421 was twisted by at least 30 mm and perhaps as much as 43 mm before this incident. This twist had not been detected during wagon maintenance. The frame twist was a causal factor.

131 Evidence indicates that 352421 had not been checked for frame twist since GR and re-bodying took place in 1989. At that time the indicator plate on the vehicle denotes that a twist of 10 mm was detected, with the right leading corner high, in direction of travel during this incident.

132 The cone packings found at the scene, three of 10 mm and one of 20 mm, match this requirement. When wheelsets are changed it is a requirement to ensure that any cone packings, which are introduced to correct for differences in wheel diameter (paragraph 31), maintain the differential shown by frame twist indicator plates. In the absence of other information it has been assumed that prior to the derailment these packings were configured in accordance with the indicator plate.

133 Measurements taken following the incident found that the frame twist was 33 mm, with the left leading corner high, in direction of travel during this incident.

134 The compensatory packing of 10 mm added to the frame twist of 33 mm created an effective twist of 43 mm. This additional packing was considered to be a causal factor.

135 Wagons should be checked for frame twist after involvement in any derailment or collision. There are no records of any frame twist checks being carried out after the incidents listed in paragraph 106.

136 This type of wagon had not been routinely checked for frame twist since the change to GR procedures in 1992. The fact that this type of wagon had not been routinely checked for frame twist was a contributory factor (paragraph 91).

137 The RAIB examined 58 other serviceable wagons for frame twist. Most had not previously been identified as being twisted. These wagons also had not been routinely frame twist checked since 1992. The majority had frame twists in excess of the 6 mm limit. The twist was predominantly to the same orientation ie left leading and right trailing corners were high in comparison with the right leading and left trailing corners. The RAIB concludes that these wagons had developed twist whilst in service operations, and this was a contributory factor.

Wheelchex

138 Wheelchex equipment collects data which enables the lateral imbalance in wheel loads to be determined. There is a standard report available from the system which provides this information. There are no mechanisms in place within Network Rail to routinely provide this data to or advise train operators of the passage of vehicles which the system detects as having imbalanced wheel loads. Appropriate wheel load imbalance parameters used to initiate such advice have not been developed. The lack of parameters and an associated notification procedure was a contributory factor.

Identification of underlying causes

139 The arrangements for frame twist measurement are included in BR Engineering Instruction WF/81 'Measurement and Compensation of Frame Twist'. This is the procedure adopted by EWS. Clause 6.2 of the instruction requires frame twist to be checked following GR or rebodying "to ensure that the underframe has not distorted in the process".

140 The failure to subsequently include frame twist measurement in any other maintenance procedures after the cessation of GRs, suggests that either distortion or twisting of frames in operational service was not considered to be a high probability, or that the distortion of frames in service had been insufficiently monitored to allow the issue to be identified. These omissions are the underlying cause.

Severity of consequences

141 There were no fatalities or injuries as a result of the incident.

142 There was considerable track, signalling and other infrastructure damage as a result of the derailment. This resulted in disruption to rail services on the day of the incident and for several days after (paragraph 56).

143 Four wagons were severely damaged and will require major repairs before being fit to return to operational service (paragraph 55).

144 During the passage of the derailed vehicles across the King Edward Bridge, at least one of the derailed vehicles deviated to the left and became foul of the up main line. Had a train been passing on the up main line at that time there would have been a collision with the possibility of much more severe consequences.

Conclusions

Immediate cause

145 The immediate cause of the accident was that the left leading wheel flange of 352421 rode over the left-hand rail immediately following the insulated joint between 2375A and 2375B points (paragraph 121).

Causal factors

146 Causal factors were:

a. A track twist existed within the crossover which equated to 1 in 164 (34 mm) over the wheelbase of the wagon (paragraph 122).

b. The wagon frame had a twist in excess of 30 mm prior to the derailment (paragraph 130).

c. Compensatory packing was present above the right leading axle box which worsened the effective twist by 10 mm (paragraph 134).

Contributory factors

147 The following factors were contributory:

a. Network Rail was monitoring the crossover at a frequency which did not ensure that the geometry was maintained in a compliant state (paragraph 123).

b. The crossover design geometry was impracticably near to the maintenance limits (paragraph 126).

c. BR/EWS have not monitored vehicles for frame twist since 1992 (paragraph 136).

d. In this wagon fleet significant frame twist appears to develop during service running (paragraph 137).

e. Network Rail did not utilise data from Wheelchex to provide information which would have identified laterally out-of-balance vehicles (paragraph 138).

Underlying causes

148 The underlying cause was that BR did not transfer the requirement to check frame twist from the GR specification to the revised maintenance regime, because they probably did not consider that frame twist would develop during normal service operation (paragraph 140).

Additional observations

149 During the rationalisation of EWS wagon maintenance activities over recent years a number of wagon maintenance facilities have been closed. Hard copy records to provide an auditable trail of individual maintenance histories were not available for some wagons involved in this incident.

150 A derailment occurred at Ely in Norfolk on 22 June 2007. Although the wagons were of another generic type with a different design of suspension, they were a torsionally-stiff two axle vehicle. Frame twist is thought to be a factor in this derailment.

151 Interrogation of the SMIS database using HAA, HMA or MGR as a key field identified no recorded previous incidents. Further work analysing the content of free text fields did identify some incidents in previous years. The reliability of SMIS as a system to identify safety events has limitation.

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

152 Network Rail is reviewing the status of the existing Wheelchex sites and the capability for the system to proactively assist in mitigating the risk to the network. EWS have requested information regarding the technical capability of Wheelchex to assess the potential for it to assist in the management of its wagon fleet, including the detection of frame twist or other unbalanced wheel loads.

153 Network Rail has issued an *National Incident Report* (NIR) to all owners and operators of torsionally-stiff wagons in response to wagon frame twist issues detected during another incident. This NIR includes wagon types such as the HAAs and HMAs involved in this incident.

154 EWS have revised the maintenance specification, incorporating the post-maintenance requirements given in Recommendation 1.

Recommendations

155 The following safety recommendations are made[1]:

Recommendations to address causal and contributory factors

1 EWS and other operators of two axle wagons on the Network Rail system should ensure that their annual maintenance procedures adequately mitigate the risk of derailment which may arise due to frame twist. This could be achieved by post-maintenance wheel weighing or by increased dimensional checks (paragraphs 146, 147, 148).

2 Network Rail should investigate the capability for Wheelchex data to be used to identify out-of-balance lateral wheel loading on vehicles and if practicable to instigate a warning system using Wheelchex to minimise the risk to the network (paragraph 147).

3 Network Rail should review and amend the design and maintenance of the layout of the up main line to up Carlisle line crossover at King Edward Bridge South Junction or implement any necessary measures to ensure that it does not become out of specification within the monitoring interval (paragraphs 146, 147).

4 Network Rail should include guidance in NR/SP/TRK/001 Section 11.4.2 to ensure that additional consideration is given to the 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. This may occur because of the proximity of the design geometry to the maintenance limit, where there is difficulty identifying the geometry or loaded parameters or where geometry deterioration rates are high (paragraph 147).

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[1] Duty holders, 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 them to carry out their duties under regulation 12(2) to:

(a) ensure that recommendations are duly considered and where appropriate acted upon; and

(b) report back to the 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 the RAIB's website at www.raib.gov.uk.

Appendices

Glossary of abbreviations and acronyms — Appendix A

AWS	Automatic Warning System
MGR	Merry-go-round
NIR	National Incident Report
POD	Point of Derailment
VIBT	Vehicle Inspection and Brake Test

Glossary of terms

Appendix B

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

113A full depth vertical design	A Switch in which the vertical axes of the Stock Rails are at right angles to the plane of the longitudinal axis of the Bearers or Timbers. The rail used is 113 lb/yard flat bottom section.
AWS	A fail-safe arrangement of permanent magnets and electro-magnets placed in the four-foot that convey information about the aspect of the associated signal to the train driver. If a magnet is not energised in connection with a caution aspect, stop aspect, a horn will sound in the drivers cab. Failure to acknowledge this horn will apply the train brake.
Axle box	A cast block containing the bearings for one end of an axle.*
Axle guard	The part of the frame in which the axle box slides up and down.
Baseplates	A cast or rolled steel supports for Flat-Bottom Rails (FB).*
Buffing loads	Dynamic loads imposed on a wagon frame through buffer contact with adjacent vehicles.
Caution aspects	A signal aspect that indicates to the driver that the next signal may be displaying a stop aspect.*
Clamplock	A hydraulic ram arrangement that operates and positively clamps the Closed Switch to the Stock Rail.*
Cone packings	Discs inserted between the top of an axle box and bottom of leaf spring to adjust the height of the wagon at that point. See also Suspension packings.
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 (-).
Down	In a direction away from London, the capital, or towards the highest mileage.*
Drawgear	The collective term for all the equipment used to connect a Rail Vehicle to another Rail Vehicle for haulage purposes.*
Eye bolts	A suspension element with a loop on one end and threads on the other end. Used to attach the end of a spring to a scroll iron.
Facing Points	A set of points installed so that traffic travels from switch toe to switch heel in the normal direction of traffic.*
Flat-bottom	A Rail Section having a flat based Rail Foot or Flange. *
Four aspect colour-light signals	Colour Light Signalling capable of displaying four Aspects. *

Four-foot	The area between the two Running Rails of a Standard Gauge Railway. This is a little odd as the actual dimension of this space is 1435 mm (4' 8½") (previously 1432 mm, 4' 8⅜").*
Headstock	The horizontal beam forming the end of a rail vehicle, used to attach couplings and buffers. *
Leaf springs	A simple spring comprising layers or leaves bound together. The outer ends are anchored and the load is supported at the centre.
Linespeed	The maximum speed at which Trains may run when not subject to any other restriction.*
National Incident Report	A railway industry wide system to communicate technical and safety issues to all bodies.
Normal Service	The planned and anticipated operation of the rail network, vehicles or equipment.*
On Train Monitoring Recorder	A data recorder fitted to traction units collecting information about the performance of the train.
Pandrol clips	A Rail Clip for Flat-Bottom Rail (FB) manufactured by the Pandrol company. *
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*.*
Route indicator	An Indicator associated with a Signal that shows a driver which Route is Set where more than one Route is available.*
Scroll irons	A steel bracket fastened to the underside of a wagon frame and to which the suspension is attached.
Single links	A loop of steel interposed between the eye bolt and leaf spring to provide a degree of freedom to the assembly.
Single slip	A Diamond Crossing with two slip switches to provide an additional directional facility.*
Six-hole insulated rail joint	A Fishplate fitted with six Fishbolt Holes, or a Fishplated Rail Joint made with this type of Fishplate. Normally found as Insulated Fishplates in Main Lines.*
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.*
Solebar	The longitudinal structural members forming the spine of a Rail Vehicle, located below the Carbody. The Solebar is supported by the Bogies or other Running Gear.*
Spring buckle	A retaining strap which wraps round the leaves of a laminated vehicle spring at the centre point.

Stock Rail	The fixed rail in a switch half set. The other rail is the switch rail.*
Stretcher Bar	A bar that links the two switch rails in a set of switches (set of points) and maintains their correct relationship, eg one is open when the other is closed.*
Suspension packings	Discs, shims or other material inserted in a suspension to adjust the height of the wagon at that point.
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.*
Tie-rods	Steel rods positioned to maintain the lateral spacing of longitudinal timbers.
Track category	A description of the use a Track gets, ranging from 6 (little used, low speed) to 1a (very high speed, very high annual tonnage).*
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.*
Track type	A standard designation denoting whether track is of jointed or continuously welded construction.
Transoms	A section, usually timber, fixed between Longitudinal Timbers to ensure the track gauge is correctly maintained.*
Up	In a direction towards London, the capital, or the lowest mileage.*
Vehicle Inspection and Brake Test	A regular inspection performed on all Rail Vehicles.*
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.*
Wheelchex	A type of Wheel Impact Load Detector (WILD) system manufactured by 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.
Wheelset	Two rail wheels mounted on their joining axle.*

Key standards current at the time — Appendix C

EWS/ES/0081	EWS Engineering Standard Maintenance Specification – MGR & Derivative Wagons Issue 4 April 2006
GM/RT2141	Group Standard Resistance of Railway Vehicles to Derailment and Roll-Over Issue 2 October 2000
NR/SP/TRK/001	Network Rail Company Specification Inspection and Maintenance of Permanent Way. Issue 2 October 2005
WF/81	BRB Engineering Instruction Measurement and Compensation of Frame Twist Issue 8 1980

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

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