RAIB
Rail Accident Investigation Branch

Rail Accident Report

Derailment near Exhibition Centre station, Glasgow
3 September 2007

Department for Transport

Report 04/2009
February 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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This report is published by the Rail Accident Investigation Branch, Department for Transport.

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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, First ScotRail, HSBC Rail and Railcare Springburn Ltd 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;
- technical terms (shown in *italics* the first time they appear in the report) are explained in Appendix B;
- key technical standards are listed in Appendix C; and
- a summary of derailment hazards is explained in Appendix D.

5 Left and right refer to the position as viewed along the direction of travel.

Summary of the report

Key facts about the accident

6 The last carriage of an empty stock 3-car class 318 electrical multiple unit (EMU) train became derailed at low speed as it passed over *facing points* between Exhibition Centre and Anderston stations, Glasgow. The carriage tilted over and came to rest at an angle of approximately 75 degrees against the tunnel wall.

7 Four First ScotRail staff members were on board the unit, two of whom were in the rear carriage.

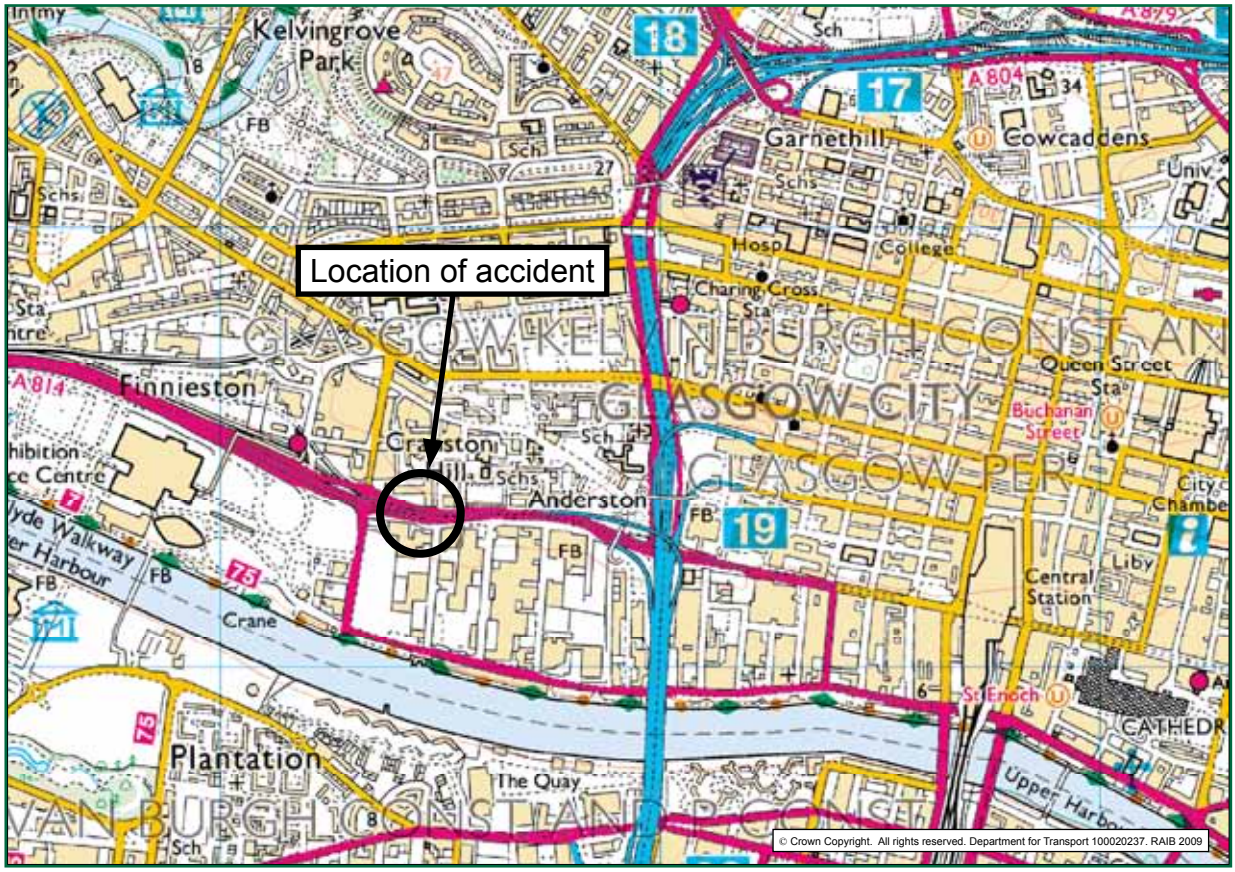

Figure 1: Extract from Ordnance Survey map showing location of accident

Immediate cause, causal and contributory factors, underlying causes

8 The immediate cause of the derailment was 201A facing points not being fit for the passage of trains in the facing direction, due to a defective rail profile and a lack of lubrication.

9 The following factors were considered to be causal to the derailment:

- the right-hand *switch rail* displayed a defect that presented an incline for the wheel *flange*;
- the incomplete grinding and incorrect inspection undertaken by the inspection / maintenance team when rectifying an existing defect; and
- the recently ground switch rail was not lubricated.

10 A contributory factor was the lack of independent supervision of grinding and inspection work undertaken by the inspection / maintenance team.

11 A possible contributory factor was the wheel profile on the derailed train. This did not play any part in initiating the derailment sequence, but it may have assisted it once it had begun.

12 The underlying cause was that no practical demonstration in the use of the *TGP8 track gauge* was provided in the training given to the inspection/maintenance team.

Severity of consequences

13 Two members of First ScotRail staff were slightly injured.

14 Train services were suspended on the 'Argyle Line' between Rutherglen and Partick stations in Glasgow for 2 days whilst investigation, recovery and repair work took place.

15 One carriage sustained significant damage.

Recommendations

16 Recommendations can be found in paragraph 159. They relate to the following areas:

- introduction of a policy for practical demonstrations during training;
- assessment of risks associated with points on *slab track*;
- research to study the effects of derailments at points on slab track*;* and
- review of processes for the quality checking of work on points and *crossings*;

The Accident

Summary of the accident

17 At 08:34 hrs on Monday 13 September, train 5V06, an empty coaching stock train formed by a class 318 3-car unit became derailed at 201A facing points which form part of a *cross-over* in Stobcross Tunnel between Exhibition Centre and Anderston stations, Glasgow.

18 The first two carriages of the unit remained on the rails, the third was derailed by all wheels and toppled over to the left, coming to rest at an angle of 75 degrees from vertical and leaning against the tunnel wall.

19 There were four members of First ScotRail staff on board. Two, who were travelling in the rear carriage, suffered minor injuries as a result of the accident.

The parties involved

20 The infrastructure was owned and maintained by Network Rail.

21 The unit was owned by HSBC Rail (UK) Ltd, a rolling stock leasing company. They were responsible for the overhauls on the unit.

22 The unit was leased to and operated by First ScotRail Ltd, the Train Operating Company (TOC) with the franchise for internal passenger services in Scotland. They were responsible for undertaking routine maintenance and repairs.

23 There were four First ScotRail staff on board the train:

- a trainee driver based at Yoker depot. He was in the leading carriage at the time of the derailment and at the controls of the train;
- a *driver mentor* based at Yoker depot who was in the leading cab and supervising the trainee driver. He has been qualified as a driver since 1980 and as a mentor since April 2007. He was competent in the class 318 traction and also the route travelled;
- a train driver based at Motherwell depot who was travelling in the rear carriage; and
- a ticket examiner based at Dalmuir station who was also travelling in the rear carriage.

24 A Track Inspection Special Examination team of two switch and crossing (S&C) inspectors were the last to maintain and examine 201A points. Both men had about 30 years experience in track work, the last seven of these based together in what is now Network Rail's Scotland West track maintenance depot at Shettleston. Both were qualified (see paragraphs 86 to 87) to undertake work defined in Network Rail company standards NR/SP/TRK/053 'Inspection and repair procedures to reduce the risk of derailment at points' (issue 3) and NR/SP/TRK/054 'Inspection of cast crossings and cast vees' (issue 3) along with their associated rail grinding repairs. In this report where the inspectors are mentioned individually they are referred to as Inspectors '1' and '2'.

25 The S&C inspectors belonged to a unit headed by a Special Inspections supervisor. He had 26 years experience on the railways and had been in this – or a similar – post for the previous nine years. He also was qualified in NR/SP/TRK/053 and NR/SP/TRK/054 procedures.

Location

26 Exhibition Centre station is located on the 'Argyle Line' which runs between Rutherglen and Partick stations via Glasgow Central Low Level. See Figure 2 for details.

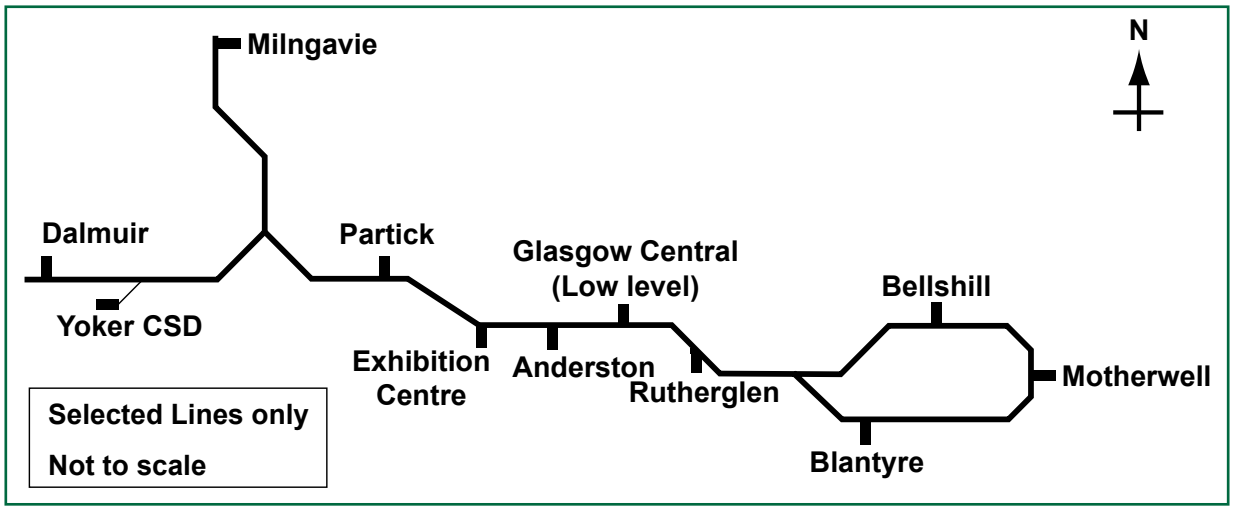

Figure 2: Simplified area map showing the routes travelled by unit 318254 on 3 September 2007

27 Figure 3 shows the location of 201A points within Stobcross Tunnel between Anderston and Exhibition Centre stations.

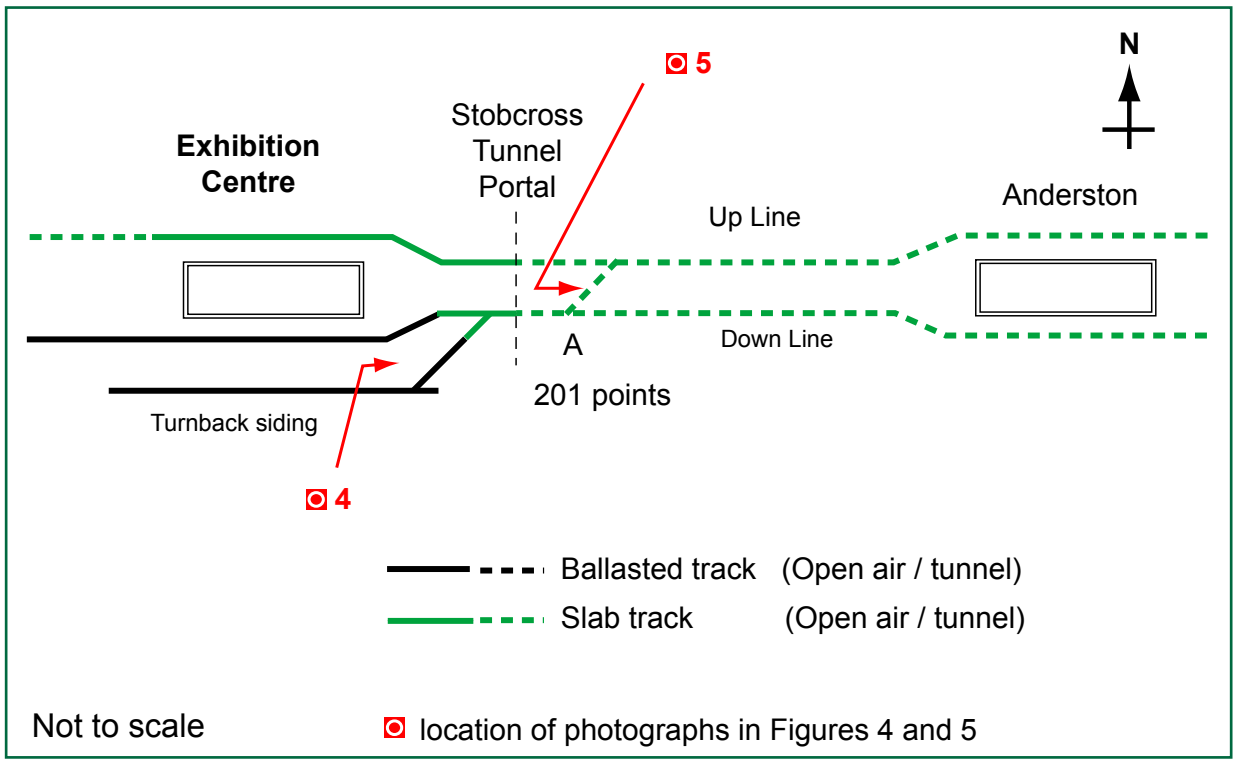

Figure 3:Track layout of the line between Exhibition Centre and Anderston stations

External circumstances

28 The weather conditions did not contribute to the derailment, which occurred in a tunnel.

The infrastructure

29 The original line between Rutherglen and Partick stations via Glasgow Central Low Level was closed and dismantled in the 1960s. It was rebuilt and reopened to traffic in 1979 at the instigation of Strathclyde Passenger Transport Executive. It is known as the Argyle Line, because it runs in tunnels under the route of Glasgow's Argyle Street for part of its length.

30 The signalling on the line between Exhibition Centre and Anderston is *four-aspect track circuit block* controlled by the signaller at the 'east' workstation in Yoker *Integrated Electronic Control Centre* (IECC).

31 Yoker IECC has a timetable driven programme known as *automatic route setting* incorporated into the controls. This checks that a train's timetabled path across a junction is clear of other trains; when it is safe to do so it sets points and signals to the correct condition without intervention from the signaller. This was active on 3 September 2007. The Automatic Route Setting set the route from the *turnback siding* at Exhibition Centre to Anderston over the crossover between the *down* and *up* lines (Figure 3) formed of 201A and 201 B points. When they were proved to be in the correct position and the route ahead was clear of trains, signal YF 830 changed aspect for the train to proceed. Neither the signalling equipment nor the operation of it contributed to the derailment.

32 Electrical traction supply is through single phase 25 kV ac *overhead line equipment* (OLE*)* controlled by Cathcart electrical control room. Neither the OLE, nor the operation of it contributed to the derailment.

33 The track on the section of line between Exhibition Centre and Dalmarnock stations, including that within Stobcross tunnel, is of continuously welded *flat-bottom rails* mounted on a ballastless concrete 'slab track' formation.

34 The left-hand diverging route from the down line is via 201A points. They use *chamfered* switch rails on *full depth* vertical *BS113A* rail laid on slab track and are operated by a *clamp lock point machine*. They are on a left-hand *transition curve* of average 355 metre radius. For simple reference, Network Rail classify these as type 'D' by virtue of their length. They were installed in 1979 and are operated by local *solid state interlocking* at Finnieston, controlled from Yoker IECC.

35 The predominant direction of traffic over 201A points is from Anderston towards Exhibition Centre, in the *trailing* direction. It is only used in the facing direction when traversed by trains travelling from Exhibition Centre turn-back siding towards Anderston. On weekdays in August 2007 there were approximately 120 timetabled train movements in the trailing direction and only one timetabled move in the facing direction.

Figure 4: Photograph of the start of the slab track section at Exhibition Centre station, looking towards Anderston and the western portal of Stobcross Tunnel. This is shown as location **4** *on Figure 3*

The train

36 The train was a 3-car class 318 electrical multiple unit (EMU). This was formed of carriages 77264 (leading), 62870 and 77244. Vehicles 77264 and 77244 are designated as DTS-B and DTS-A (DTS = driving trailer standard class) and 62870 as a PMS (pantograph motor standard class).

37 The carriage that derailed, 77244, was at the rear of the train. It was initially derailed by its leading axle at 201A points, and as a consequence the other three axles derailed as the movement progressed.

38 Unit 318254 was built in 1985 for the Ayrshire electrification scheme and has been based at Shields Depot for all of its life. Routine maintenance was carried out at Shields Depot apart from some minor maintenance undertaken at Yoker carriage servicing depot (CSD).

39 The DTS-A and DTS-B are fitted with type BT13 *bogies*, the PMS has type BP20 bogies. These are in common use on many other EMU fleets in Britain. The *wheel profile*, defining the shape of the running surface and the flange, is designated as P8 and is standard across a wide range of passenger stock.

Events preceding the accident

The infrastructure

40 Network Rail mandates that the track is maintained in accordance with its standard NR/SP/TRK/001 'Inspection and maintenance of permanent way'. The process followed in issue three of that standard, which was applicable at the time, is fully described in paragraphs 73 to 81.

41 All facing points in the Yoker track maintenance area of Scotland West are subject to a 13-weekly NR/SP/TRK/053 detailed inspection. This is more frequently than that standard requires, which is an initial 13 week visual inspection followed by a detailed inspection only if the inspector believes there is a need for it. The requirements are described in more detail in paragraphs 73 to 81.

42 Network Rail requires that each half set of points, comprising a *stock rail* and a switch rail, is renewed when the wear reaches a pre-determined level. The right-hand half set at 201A points was replaced in February 2006. It was this half set that was involved with the derailment.

43 The maintenance records of the points show that they were inspected regularly to meet the periodic inspection requirements. The visit of 13 June 2007 identified issues that made the S&C supervisor increase the inspection frequency to 2 monthly (see paragraph 77).

44 S&C inspectors '1' and '2' visited 201A and 201B points to carry out a scheduled NR/SP/TRK/053 full inspection during the early hours of Thursday 30 August. They identified a hazard 1 defect (paragraph 78 and Appendix D) on the right-hand side half set of points on 201A points. NR/SP/TRK/053 (issue 3) required action to be carried out within seven days.

45 S&C inspector '1' reported the defect to the infrastructure controller in Network Rail's Glasgow operations control who recorded it onto the 'FRAME' defect logging system. This report generated a defect report which the controller passed to the S&C inspector.

46 The following night, in the early hours of Friday 31 August, the same team revisited 201A points and undertook rail grinding work that was intended to eliminate the defect in accordance with NR/SP/TRK/053. Once the grinding was complete they did not apply any lubrication to the newly ground areas where a wheel flange could be in contact with the rail, known as a *flange contact zone*.

47 They carried out a NR/SP/TRK/053 hazard 1 inspection on the points and noted that the defect was removed. However the inspectors did not apply the gauge or interpret the results according to the requirements of NR/SP/TRK053 and letter of instruction NR/BS/LI/063.

48 Inspector '2' called the infrastructure controller to report that the repair had been carried out, and the FRAME defect was closed out.

49 NR/SP/TRK/053 issue 3 required a check to be made on the repair work but did not specify who should do this. Letter of instruction NR/BS/LI/063 required this check to be performed prior to the switches being handed back into traffic. Although the inspectors checked the work they had performed, no independent check was undertaken.

50 A total of three trains (a 3-car class 318 unit, a 3-car class 334 unit and a 6-car 334 unit) operated over 201A points in the facing direction without incident in the days after the repair but before the passage of train 5V06 on 3 September.

The rolling stock

51 On 12 May 2007 Shields Depot staff fitted reconditioned bogies to the DTS-A and DTS-B carriages. They were supplied by Railcare Ltd, Springburn, Glasgow and carried new wheelsets. The depot staff then completed an *'A2' exam* on the unit. Following its return to traffic with these new wheelsets, unit 318254 had run 36,926 miles in traffic prior to the date of the accident.

52 The last scheduled maintenance on 318254 prior to the derailment was carried out on 25 August 2007 at Shields Depot. This comprised of an 'A1' exam, and incorporated a wheel flange height and thickness measurement. Unit 318254 returned to traffic without any significant work orders or defects outstanding.

Train crew and operation

53 On 3 September 2007 unit 318254 departed Yoker carriage servicing depot at 06:01 hrs and ran as empty coaching stock to Milngavie. A driver based at Motherwell was on board. At Milngavie the driver changed cabs. A ticket examiner based at Dalmuir joined the train which departed as the 06:42 hrs passenger service from Milngavie to Motherwell via Blantyre. Next they departed Motherwell at 07:50 hrs to Anderston via Bellshill. See Figure 2 for the route taken.

54 The train's next scheduled passenger journey was to have been the 08:38 hrs from Anderston to Motherwell. To get from the westbound (down) platform to the eastbound (up) platform at Anderston the unit needed to travel via the down siding at Exhibition Centre where the driver changed cabs once more.

55 Before departing Anderston station as empty coaching stock, a Yoker based driver mentor with a trainee joined the train. In accordance with First ScotRail procedures they asked the Motherwell driver if they could take over the controls so that the trainee could gain the experience of a movement into and out of the turnback siding at Exhibition Centre. The Motherwell driver agreed to this and thus became a passenger on his own train, retiring to the public saloon area of 77244 immediately behind the cab.

56 The trainee driver took the train forward into Exhibition Centre turnback siding, secured the brake and changed ends. He then prepared to depart, and pressed the 'train ready to start' plunger at the siding to confirm to the signalling system that the train was ready to depart.

57 The permitted speed at the points from the siding to the down line is 5 mph (8 km/h) and the speed at 201 A and B points (in the facing movement) is 15 mph (24 km/h). On driving his train from the turnback siding the trainee driver did not exceed any of these speed restrictions.

Events during the accident

58 At 08:35 hrs unit 318254 departed from the siding, travelled over the down line as far as 201A points and transferred to the up line at a maximum speed of 12 mph (19 km/h). The first two vehicles completed this manoeuvre successfully but the third, 77244, derailed.

59 The wheel on the right-hand side of the leading axle of 77244 climbed onto the rail *head* so that the flange tip ran along the switch rail. As the switch rail and the stock rail diverged, the wheel dropped between them onto the rail fastenings and then onto the concrete track base. The left-hand wheel tread dropped off the inside of the left-hand stock rail at the same time.

Figure 5: Photograph of the derailed carriage viewed from the Exhibition Centre end. This is shown as location **5** *on Figure 3*

60 The two drivers in the front cab heard a screeching sound and then a loud bang after which the trainee driver applied the emergency brake. As the train slowed to stop, the derailed wheels reached the crossing of 201A points and the whole bogie derailed. The vehicle immediately tilted to the left and fell against the tunnel wall coming to rest at an angle of 75 degrees from vertical.

61 The Motherwell driver had moved into the rear cab and was standing there, and the ticket examiner was sitting in the rearmost saloon area of the third carriage when the derailment occurred. The ticket examiner went into the rear cab to find out what was happening. As the vehicle toppled over both men were thrown and landed on the lower side, sustaining minor injuries.

Events following the accident

62 The mentor driver went back through the carriages to see what the problem was and found the third vehicle on its side. He returned to the driving cab to raise the alarm.

63 The trainee driver in the front cab used the *cab secure radio* to make an emergency call to the signaller at Yoker IECC to advise that the train was derailed and to ask for other trains to be stopped. The mentor driver then placed *track circuit clips* on to the down line rails, as required by the rule book Module TW1 section 20.

64 The Motherwell driver in the rear cab managed to open the cab door and also exited to place track circuit clips on the up line rails. He then returned to help his injured colleague out of the cab and assist him back to Exhibition Centre station. There the station staff member called for an ambulance for the ticket examiner who appeared to have been more badly injured than the driver.

65 The Motherwell driver then returned to the train and retrieved *detonators* to place on the up line at the signal protecting the train as required by the rule book.

66 The mentor driver realised that the air compressor on the unit was running continuously and he believed that it was in danger of overheating. He lowered the *pantograph* to stop it operating.

67 The signaller on the east workstation (paragraph 30) at Yoker IECC applied signalling protection for the site. He did not arrange for the OLE be isolated as this had not been requested.

68 In accordance with their internal procedures Network Rail and First ScotRail sent response staff to the site, informed the British Transport Police, and reported the derailment to the RAIB.

Consequences of the accident

Personnel

69 The two First ScotRail staff in the rear carriage sustained minor injuries. The Motherwell based driver suffered from shock and was unable to return to work for several weeks.

The train

70 The third vehicle, 77244, sustained significant damage. The second vehicle, 62870, suffered damage, particularly in the *bar coupler* housing areas.

The infrastructure

71 The Argyle Line was closed for two days to allow investigation, primarily for the recovery of unit 318254 and for repairs to the infrastructure.

The Investigation

Sources of evidence

72 Evidence was gained from:

- an examination of the train;
- the *on-train monitoring recorder* (OTMR) records from the train;
- the maintenance history of unit 318254;
- the maintenance and repair history of class 318 and 334 units;
- the independent testing of derailed vehicle 77244 so that the performance of wheelsets, bogies and suspension could be understood;
- the source and history of the wheelsets;
- an examination of the infrastructure, in particular;
    - the stock and switch rails of the right-hand switch half-set on 201A points;
    - a full track geometry survey of the vicinity;
    - the maintenance and repair history of 201A points; and
    - the maintenance of repair history of other points within the maintenance area;
- training processes and briefings;
- staff training and competence records; and
- witness evidence.

Key Information

Planned inspection and maintenance of facing points

Inspection and repair procedures to reduce the risk of derailment at points

73 When compared with plain track and trailing points, facing points present a greater risk of derailment if rail profiles are excessively worn, damaged, or if the two rails forming a *switch half set* are not correctly matched together. These risks mean that facing points are subject to inspections at intervals not exceeding three-months; NR/SP/TRK/053 provides a detailed specification for this activity (paragraph 41). The purpose of inspection is to ensure that the wheels of a vehicle passing over the switch blades follow the intended path, and that there are no defects which could lead to derailment.

74 NR/SP/TRK/053 gives information on five recognised derailment hazards, numbered 1 to 5, which are each subject to specific checks. It specifies the requirement for increased levels of inspection as wear develops on the side of the railhead (paragraph 77). Further information on the five derailment hazards is given in Appendix D.

75 At the time of the derailment 'Issue 3' of NR/SP/TRK/053 was applicable. This has since been superseded by 'Issue 4' and renumbered to NR/L2/TRK/053.

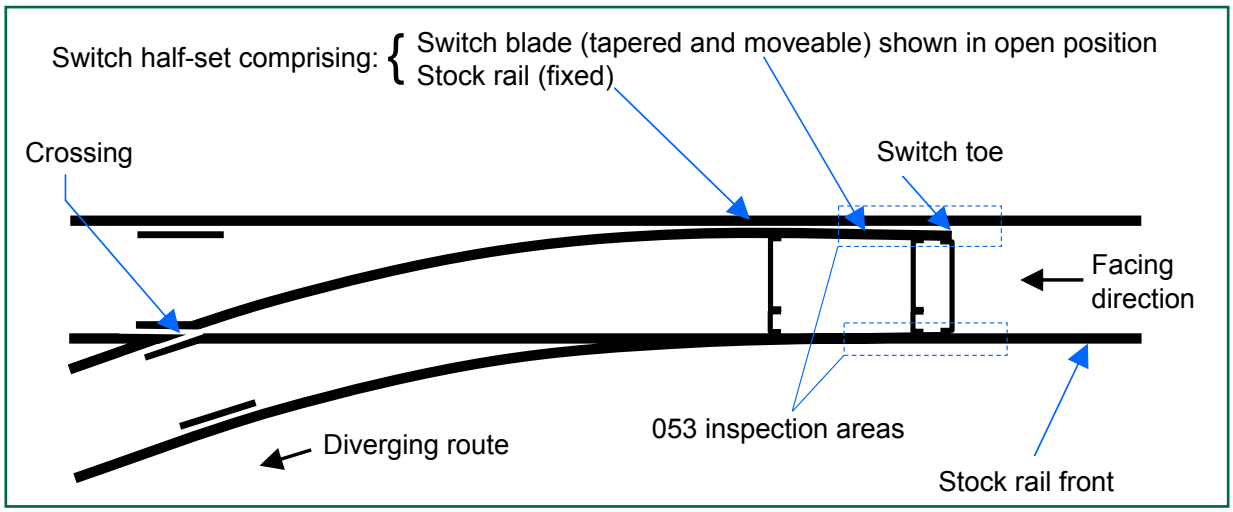

Figure 6: Simplified diagram of S&C (left-hand turn-out shown e.g. 201A points)

76 The detailed inspection of NR/SP/TRK/053 (issue 3) involved a close examination of rail profiles for one metre in front of the switch *toe* (refer to Figure 6) and for two metres beyond, using gauges provided for this purpose. A replacement sidewear gauge and a new track gauge (TGP8), compatible with the *P8 wheel profile*, was introduced by Network Rail during 2005. It had originally been developed by the Area Track Engineer – Scotland West. The wheel profile forming part of the gauge allows the user to visualise how a wheel would sit upon the rail head. The team inspecting 201A points used a TGP8 gauge.

77 The inspection prescribed by NR/SP/TRK/053 (issue 3) required sidewear on the *stock rail front* to be checked for a distance of one metre from the switch toe using a two-piece gauge. It gave a dimensionless value referred to as a 'step'. New rail typically has a sidewear reading of step 18 and this value gradually reduces as the rail becomes more worn (Figure 7). It is not possible to visually assess deterioration in sidewear without using the gauge. NR/SP/TRK/053 (issue 3) required the frequency of inspections to be increased to two monthly when the sidewear on the switch fronts fell below step 12 and monthly at step 9 or below, but did not specify the type of inspection required. In addition, at step 9, a replacement switch half set was to be ordered with arrangements made to replace the half set as soon as possible, and 'the condition of the points is to be closely monitored'. At step 6, train movements in the facing direction were prohibited. Therefore, under normal maintenance conditions, the affected half set was to be replaced before sidewear reached step 6 to avoid service disruption. An order could typically take three months to complete. Fitment could take place within a few hours of the half set being delivered to site, although *possession* of the line to enable this to be undertaken safely might delay the activity.

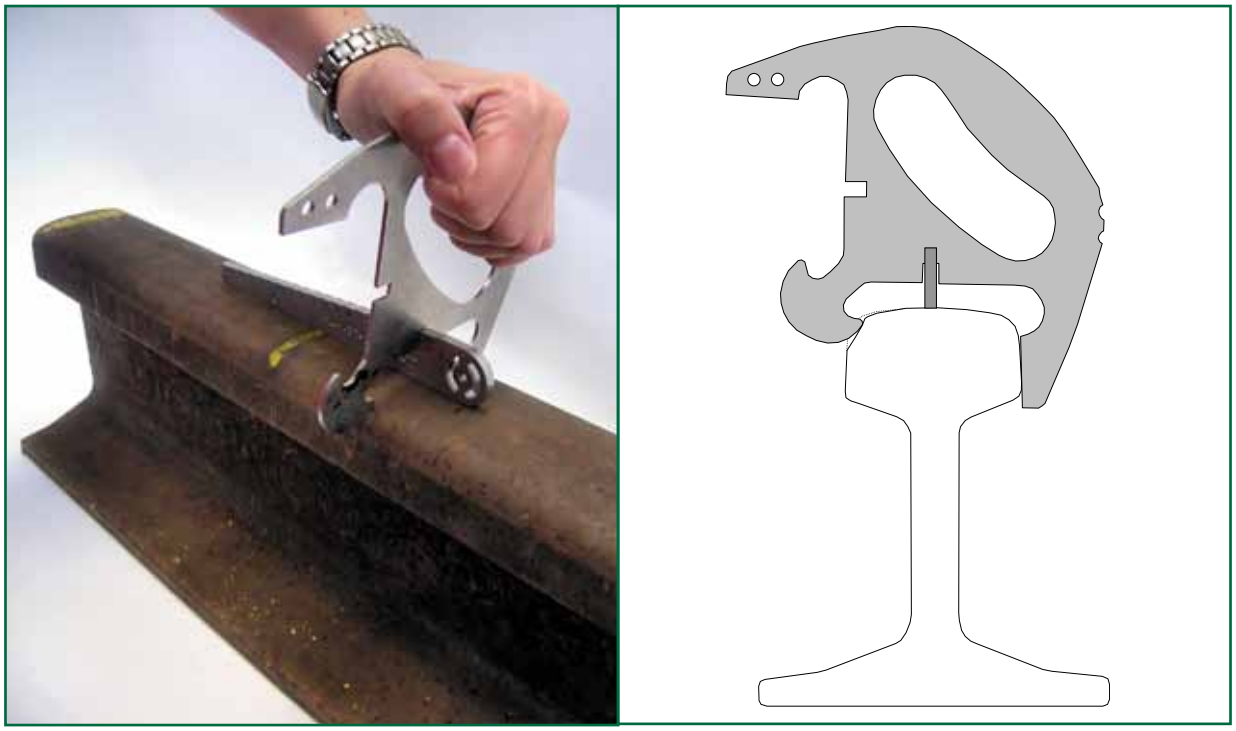

Figure 7: Illustrations of NR4 sidewear gauge on new and sideworn rail

78 Following the visual identification of a possible hazard, or as part of a detailed inspection, the assessment of derailment hazards 1 and 2 (Appendix D) is undertaken by visually comparing the height and profile of a switch blade relative to its stock rail; hazard 1 exists if the top of the switch blade is above the base of any sidewear visible on the stock rail, and hazard 2 exists if the angle of the switch blade face is shallower than the sidewear on the adjacent stock rail and less than 60° to the horizontal following reprofiling (Figure 8). A derailment hazard is avoided if the contact point between the flange of the wheel and the rail does not present a ramp for a wheel flange to climb.

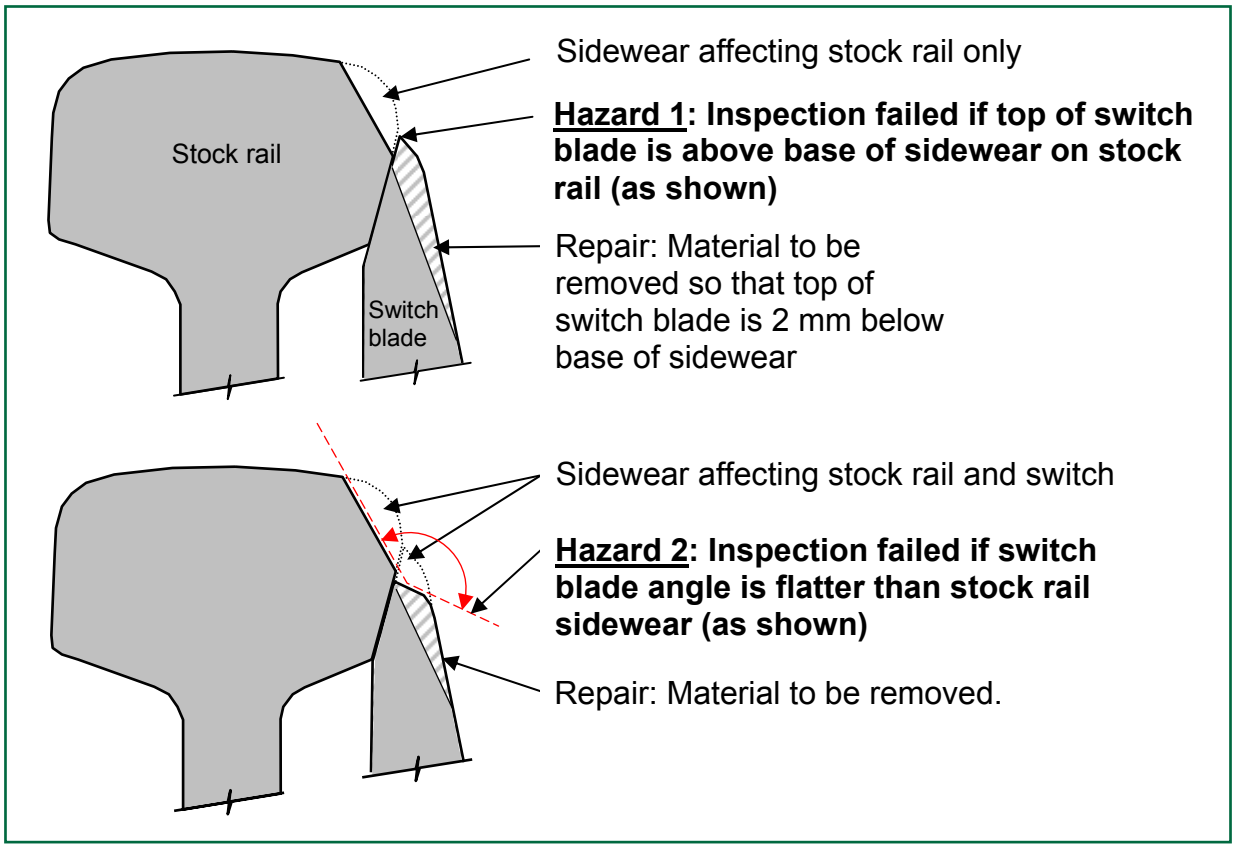

Figure 8: Illustration of derailment hazards 1 and 2 as defined by standard NR/SP/TRK/053 (issue 3)

79 The introduction of the TGP8 gauge (Figure 9) in 2005 allowed a more accurate assessment of a derailment hazard 2 risk to be made. The gauge allows the contact point of a wheel flange on the switch blade to be visualised and an indicator line drawn normal to the 60° flange contact angle (Figure 10) allows a defective switch blade profile to be positively identified. To be acceptable, the flange contact angle must be at least 60° to minimise the risk of a derailment occurring should a high coefficient of friction develop between the wheel and the rail.

Figure 9: A TGP8 gauge (not the one used at 201A points) - note the dummy wheel profiles on lower left and right extremities.

80 Use of the TGP8 gauge was mandated by document NR/BS/LI/063: 'Letter of Instruction – Grinding of Points', applicable from 20 December 2006.

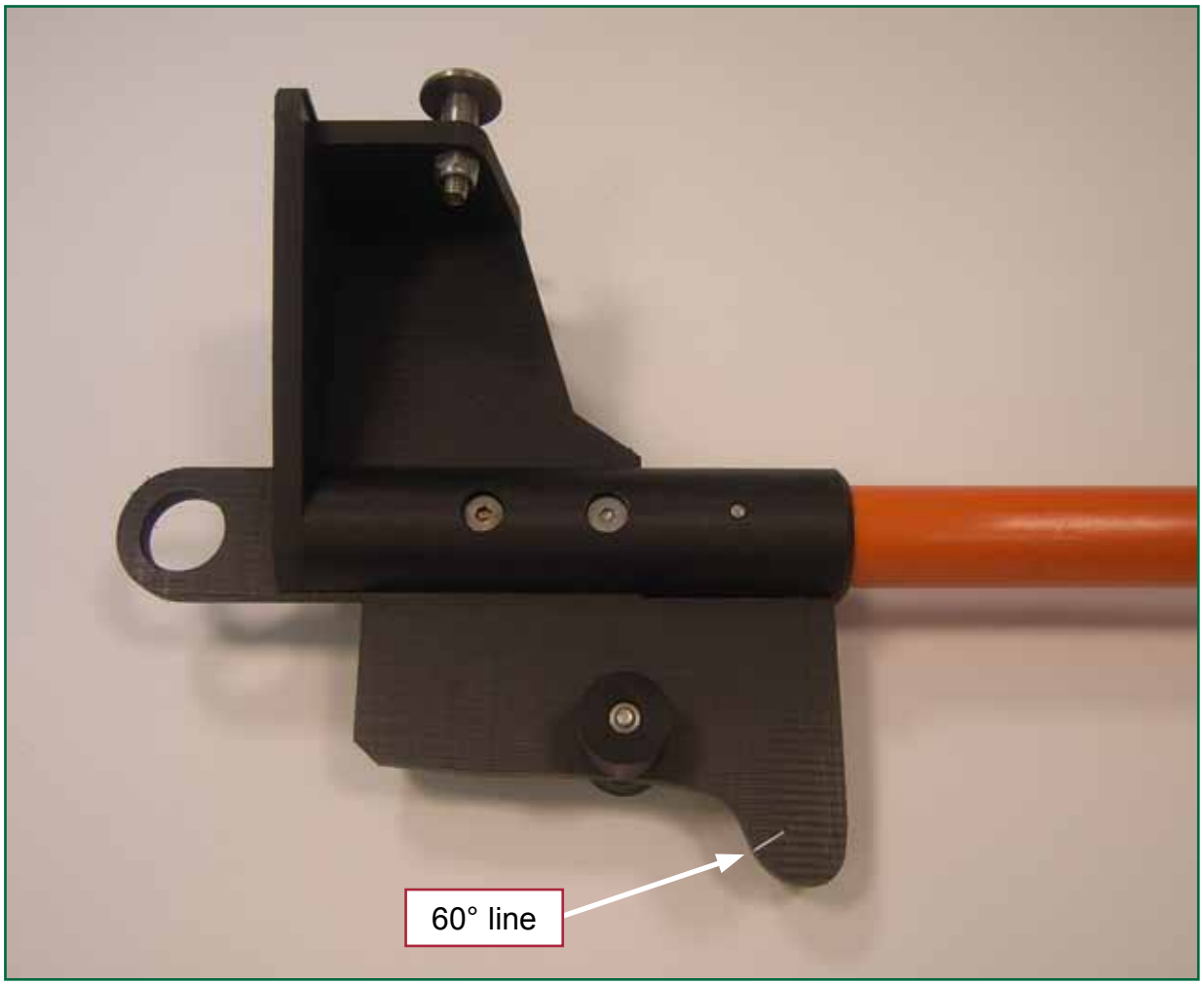

Figure 10: Close up of a TGP8 gauge showing the 60° indicator line

81 NR/SP/TRK/053 (issue 3) required that if a derailment hazard was identified then follow-up action had to be taken within a prescribed timescale. Repairs may involve: rail grinding - to reduce the metal present on the switch or stock rail; welding - to build up sufficient metal on the switch or stock rail; or the complete replacement of the affected switch half set.

Track in the vicinity of the points

82 Following the derailment a track survey was undertaken in the vicinity of 201A points to check the gauge and whether track twist existed. The results of this indicated there was an area of tight gauge at the switch blades, 1429 mm at the worst point and with an average of 1430 mm. The minimum gauge permitted by *Railway Group Standard* (RGS) GC/RT5021 'Track System Requirements' at vertical points is 1430 mm with a maximum of 1438 mm No track twist was present and apart from the defect identified in the next paragraph, there were no other factors present to initiate derailment.

83 There was a hazard 2 defect present on the right-hand switch rail from about 400 mm to about 710 mm from the toe. Presentation of the TGP8 gauge wheel profile clearly showed that the contact point was at 46°, significantly and noticeably below the 60° indicator line (Figure 11).

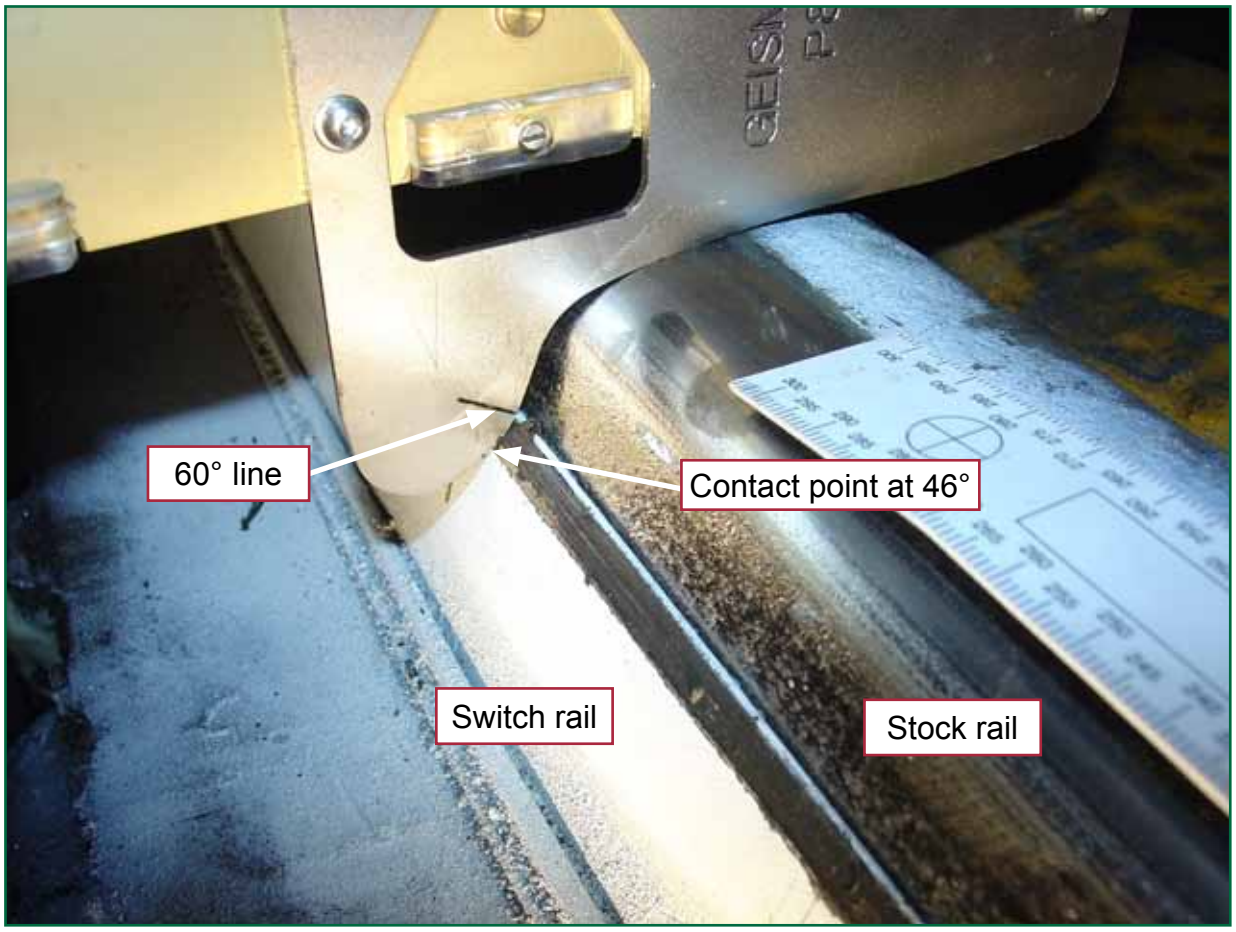

Figure 11: The TGP8 gauge used by the track inspection special examination team and 201A switch right-hand half set, with the 60° indicator well above the switch rail contact point

84 On the right-hand switch rail there was a fresh flange climb mark present from a point 410 mm from the toe, and this continued as a flange running mark across the rail head before dropping off the outside of the switch rail at the point where it diverged from the stock rail. A corresponding drop mark was noted on the left-hand stock rail where the left-hand wheel tread had been pulled off the rail.

85 The route of the derailed wheelset was visible by score marks in the concrete slab and broken fastenings until the left-hand wheel was 1000 mm short of the crossing. At this point there was evidence that the wheels on the second axle had derailed to the right, and had steered the third vehicle, 77244, towards the *six-foot* side of the track (Figure 12).

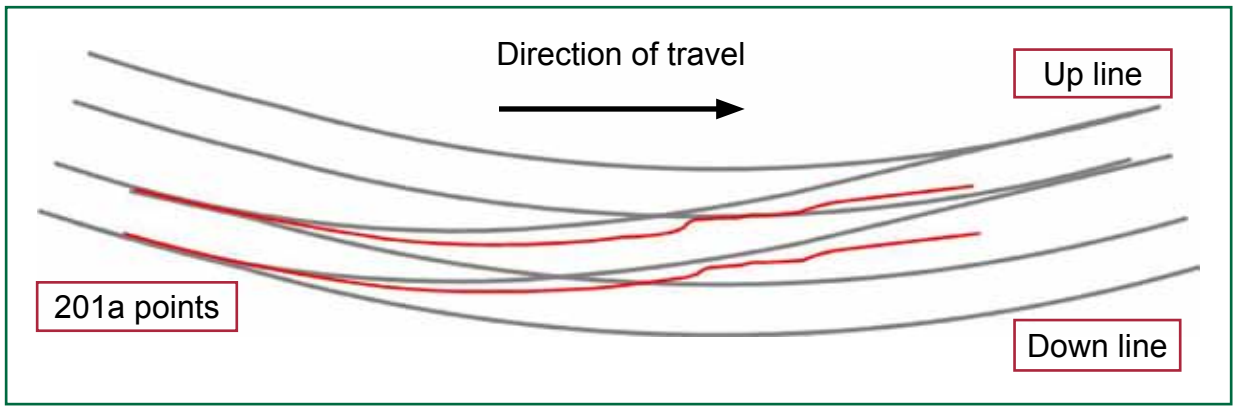

Figure 12: Illustration of the trajectory taken by the derailed wheelsets

Training and competency

86 Initial training in the NR/SP/TRK/053 process is undertaken at a Network Rail training centre. For Scotland West staff this is at Larbert, about 20 miles from Shettleston. There are sets of points available there for practical fault-finding. Staff trained there are examined and if found to be competent are given suitable certificates with expiry dates. In the periods between the formal training courses and recertification their work is overseen by their line supervisor.

87 S&C inspector '1' was passed as competent in NR/SP/TRK/053 in September 2006; S&C inspector '2' was passed as competent in February 2006 and their supervisor was passed as competent in January 2006. All their competency certificates had a validity of five years.

88 The supervisor and inspectors '1' and '2' worked as a unit, with a two-man team undertaking a scheduled programme of inspections. Usually inspectors '1' and '2' would work together, but if either was on leave or sick, the supervisor would substitute.

89 The supervisor and inspectors '1' and '2' attended a training event in February 2007 at their base in Shettleston. This was a briefing on the letter of instruction NR/BS/LI/063 (paragraph 80), the two main topics of this letter are use of the TGP8 gauge and the need for post-lubrication grinding. This was delivered by the Area Track Engineer (ATE) for Scotland West. During this event over 20 inspection colleagues from other depots in the Scotland West area were present.

90 The ATE explained by way of a 'PowerPoint' presentation and sketching on a whiteboard and flipchart how the TGP8 gauge should be used. The presentation included information contained in Letter of instruction NR/BS/LI/063 but included an additional check that was not included in that document. The additional check was to push the gauge sideways off the head of the stock rail if the original contact was above the 60^0 line; this would identify if a ramp existed on the switch rail upon which the gauge could rest. He provided a gauge with which the staff could familiarise themselves. There was no practical demonstration on rails of either new or worn condition as there were no points available for training at Shettleston (see also paragraph 146). Worn rails would have been needed to demonstrate a failed switch.

91 Although the training was delivered the inspectors later misinterpreted how the TGP8 gauge should be used (paragraph 95).

92 The national introduction date for the TGP8 gauges was in the spring of 2006; its use was made mandatory by Letter of Instruction NR/BS/LI/063 from 20 December 2006. It reached the Area Track Engineer – Scotland West on 21 December 2006 and was briefed out on 26 January 2007.

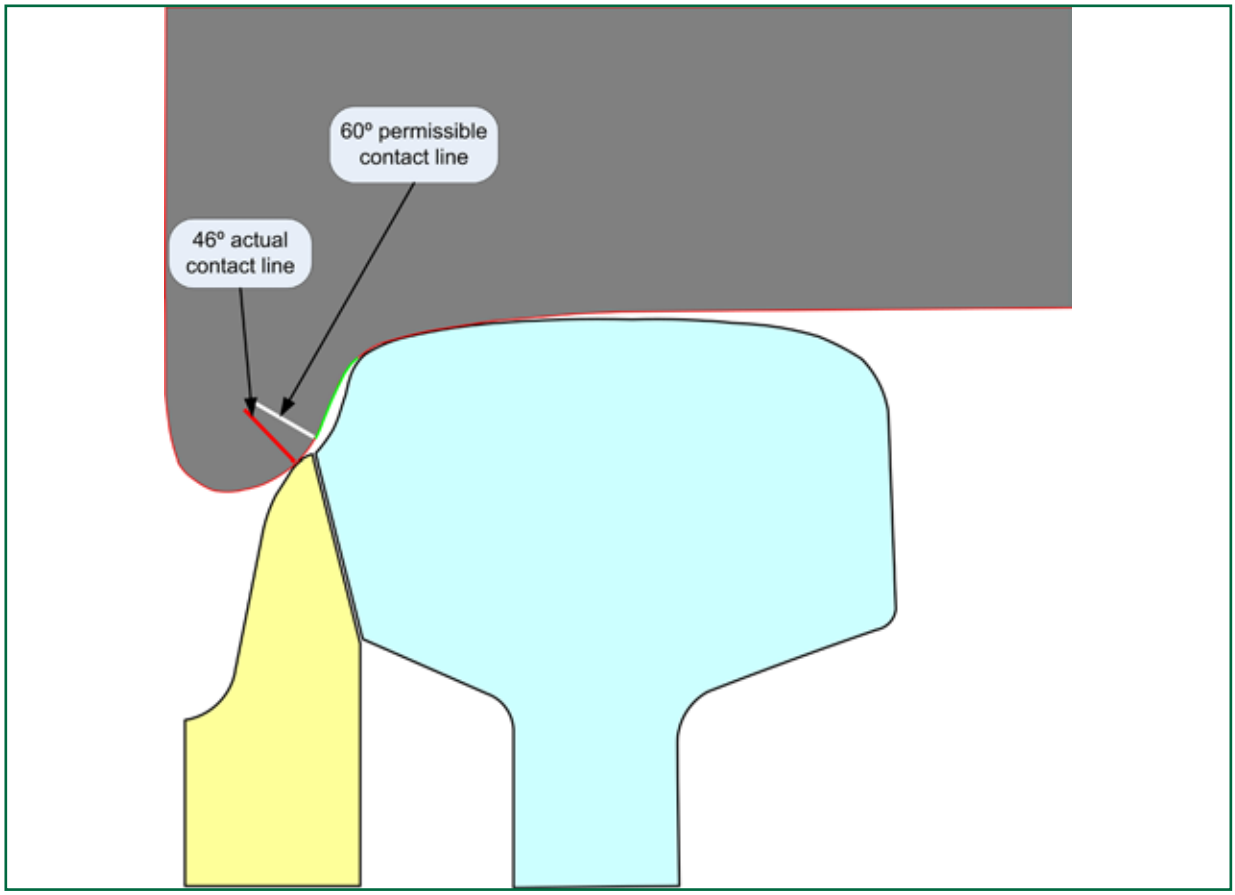

Figure 13: Diagram showing the correct use of the TGP8 gauge (not to scale)

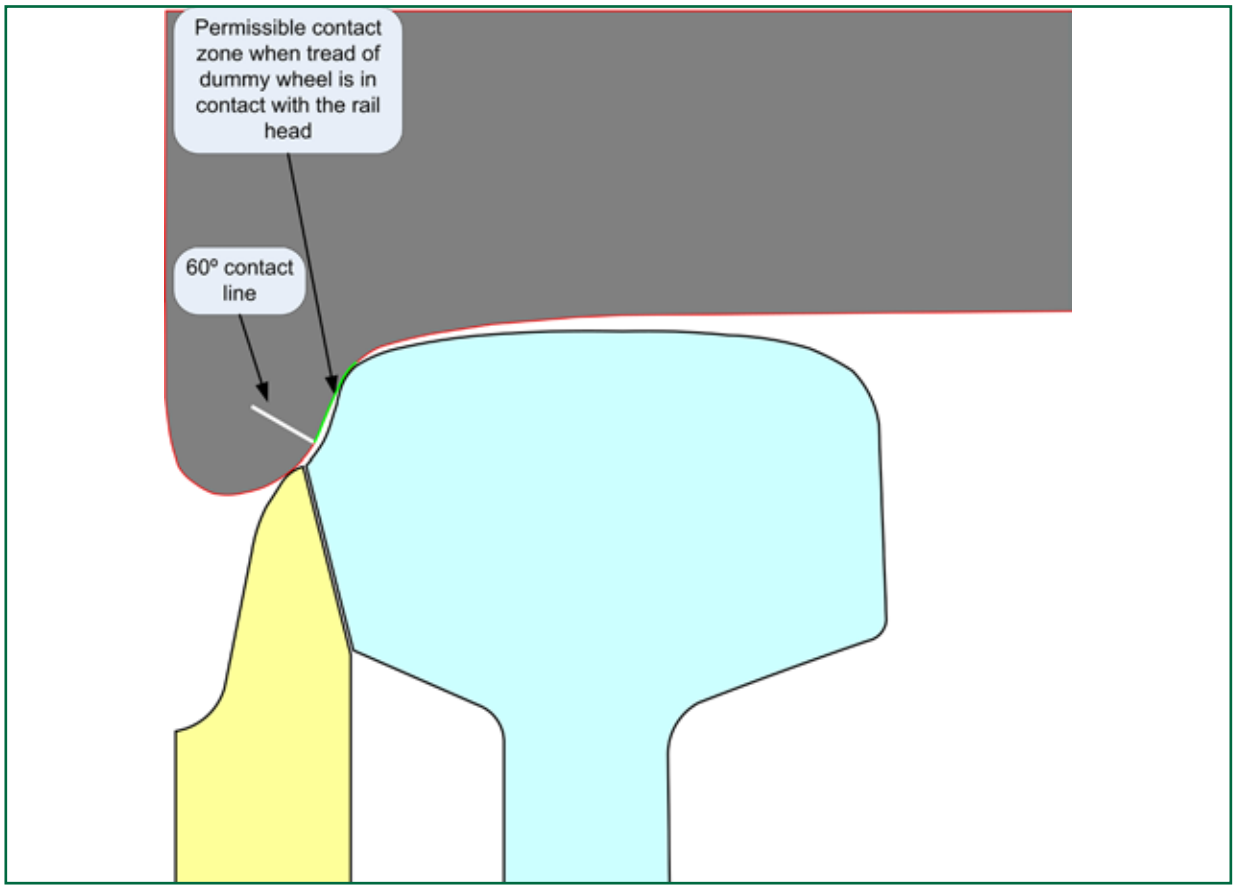

Figure 14: Diagram showing how the TGP8 gauge was used on 31 August 2007 (not to scale)

Audit

93 At the time of the derailment there was no required programme of independent quality audits, and no other checks on the NR/SP/TRK/053 work of the supervisor took place. Neither the supervisor's manager, the Assistant Track Maintenance Engineer at Yoker, nor the Track Maintenance Engineer above him held valid NR/SP/TRK/053 inspection cards. At that time there was no requirement for qualified engineers to keep their competence certificates updated and although they had been previously trained their certificates had lapsed. Neither had instigated any independent verification of the process, preferring instead to pass any technical issues to the Area Track Engineer for Scotland West. Neither the Area Track Engineer nor the Track Maintenance Engineer had undertaken any track visits with the Shettleston team since the date of the NR/BS/LI/063 briefing. As a consequence the misapplication of the TGP8 gauge (paragraphs 47 and 95) went unchecked. However the Track Maintenance Engineer had undertaken off-site document reviews of every set of points in his area.

Work undertaken on 201A points

94 The grinding repair work on 201A points effectively removed the hazard 1 defect (see paragraph 44). It comprised grinding metal off the top of the switch blade so that it was below the flange contact line on the stock rail. However, the TGP8 gauge was misapplied and did not identify that the remedial grinding had not been fully completed, leaving a 'hazard 2' defect on the switch rail. This occurs where the side of the switch rail is not sufficiently inclined, thus presenting a ramp on which the wheel flange may ride up. No follow up check as required by the briefing note attached to the Letter of Instruction NR/BS/LI/063 was undertaken.

95 The NR/SP/TRK/053 tests (paragraph 73 onwards) were not carried out correctly following the grinding repair. The two inspectors did not use the TGP8 gauge in the approved manner, and consequently did not see that the contact angle was less than 60°. Firstly, they did not use the gauge at sufficiently small distances along the switch rail to find the short area with the hazard 2 defect. When measured by the RAIB at the point of flange climb, the contact angle on the gauge was found to be 46° (Figure 11). Secondly, following their briefing, the inspectors pushed the gauge over the switch rail and towards the stock rail so that the profile above the 60° mark made contact with the stock rail. This lifted the tread profile of the dummy wheelset off the rail top by 8 mm, however the inspectors did not notice the potential for the flange, below the 60° mark, to run on to the top of the switch rail.

96 The inspection team also omitted to apply lubricant to the newly ground side of the switch rail. The team were aware that lubricant should have been applied, but discovered that the supply they had with them was exhausted. They did not source any alternative lubricant as an interim measure - for example by taking grease from the *slide baseplates,* this was of the same type. Inspector '2' ticked the box on NR/SP/TRK/053 record form (TEF/3029) to indicate that the gauge corner of the switch rail was lubricated. The inspection team did not advise their supervisor that lubrication was still required, nor did they make any attempt to return to 201A points on the following shift.

Rolling stock

History of wheel wear

97 First ScotRail reported that there has been a history of excessive wheelwear on class 318 and 334 units operating over the Glasgow 'North Electric' routes, and particularly on the Argyle line. An independent review was commissioned by First ScotRail and Network Rail in 2004. This review concluded that the Argyle Line tunnels have a high proportion of curved track and the outer rail on several of these curves is subject to high lateral forces due to *cant deficiency*.

98 First ScotRail also reported that they believed that there was insufficient lubrication at the rail / wheel interface on the Argyle Line. They also believed that the high *yaw stiffness* of class 334 units in comparison with other classes of rolling stock, combined with insufficient rail lubrication, could cause high wheel wear. During 2004 Network Rail replaced the multiple manual *lubricators* with one electric unit on each 4 mile stretch of line. A number of modifications were made to the operation of the electric lubricators over the following three years. By the time of the accident Network Rail considered that adequate grease coverage was being achieved throughout the route.

99 The train service (off peak) through the Argyle Line increased from four trains per hour to six in each direction in December 2005 with the opening of the Larkhall branch and this increased the line usage and wheel wear rates by approximately 50 %.

100 Evidence supplied by First ScotRail showed that wheel wear rates had increased in the six months prior to the derailment. This effect is consistent with a reduction in the working number or efficiency of rail lubricators, however it may have been due to other factors such as the performance of yaw dampers, stock usage over various routes or the weather.

Standards applicable to wheelsets on class 318 trains

101 The Railway Group Standard GM/RT 2466 'Railway Wheelsets' defines the standards that wheelsets - including those to the P8 profile - should meet.

Wheel sets on coach 77244

102 The RAIB measured the wheel profiles on coach 77244, the vehicle that derailed. These were compared to the standard P8 profile as described in GM/RT 2466 (Figure 15).

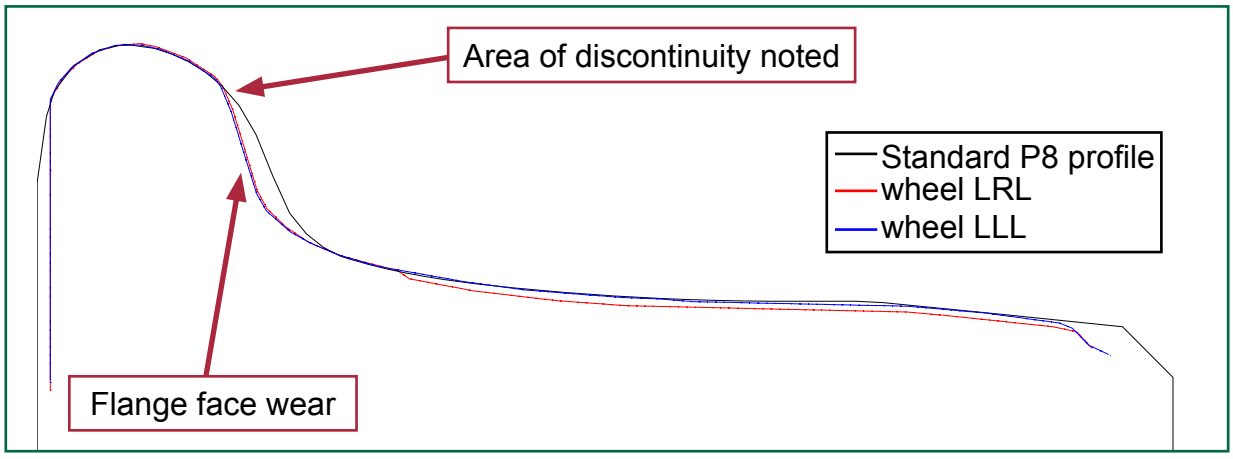

Figure 15: Overlay of wheel profiles recorded on 77244 leading axle

103 There was some damage sustained by all the wheels as a result of the derailment.

104 Certain wheel profiles on coach 77244 showed flange face wear and a discontinuity where the thinning of the flange met the normal profile of the flange tip. Figure 16 shows the nomenclature used for wheelset identification. The discontinuities were found on the wheels in positions LRL, LLL, LRT, LLT and TRT wheels.

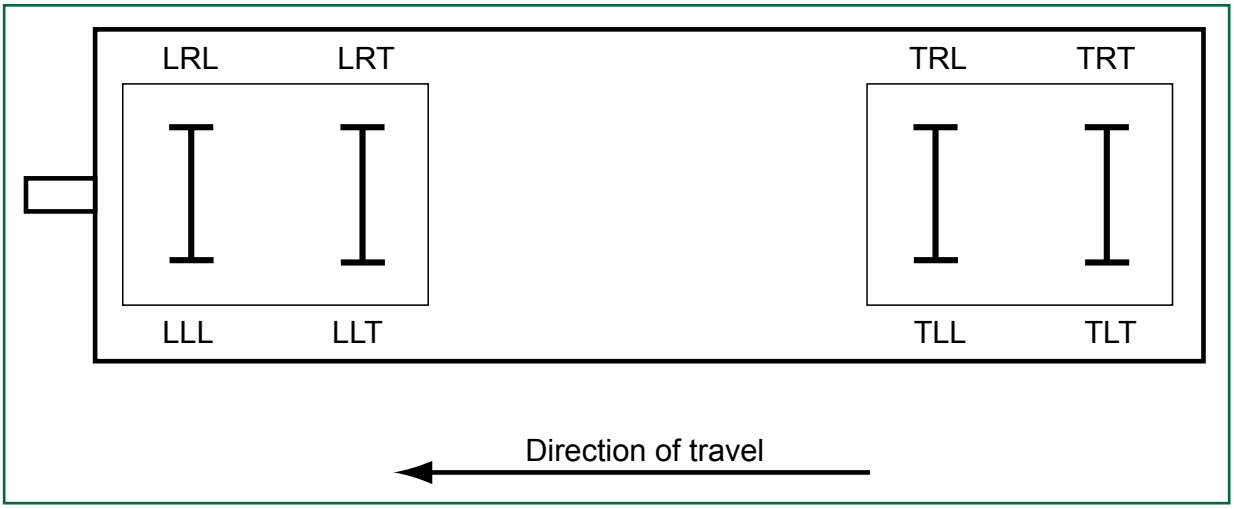

Figure 16: Nomenclature used in describing the bogies and wheelsets of vehicle 77244 (example: LRT is Leading bogie, Right-hand side Trailing wheel)

105 The RAIB examined the available records of the wheelsets from their date of manufacture to the date of the derailment. These include:

- the original (British Rail) engineering drawing S8-C2-8006239 with the master P8 profile;
- the batch certificate of conformity for wheels by the manufacturer (Luccini UK batch E0700167);
- the bogie assembly records at Railcare Springburn (bogie M1212) to HSBC job specification UF6960;
- tyre profiling machine (TPM) records at Shields Depot (note 77244 did not visit the TPM between the fitment of the new wheelsets and the derailment); and
- scheduled mileage-based maintenance records at Shields depot when tyre thickness measurements were taken.

No significant factors were found to suggest a defect had been introduced in the manufacturing or maintenance processes of the wheelsets.

106 The wheelsets did not have corrective reprofiling between the date of fitment (12 May 2007) and the derailment. The discontinuity was measured electronically by use of a computer aided design (CAD) program with the profile of a P8 go/no-go radius gauge overlaid on it. This demonstrated that the discontinuity was within the tolerance permitted by the RSSB 'common domain' document MT288 'Wheelset Tread & Gauging Standard'.

107 The measured flange height of the LRL wheel on coach 77244 was 29.65 mm. This is 0.15 mm larger than the minimum of 29.50 mm defined on the wheelset reference drawing. Other wheels from the same casting batch in stock at Railcare Springburn had a minimum flange height of 30.00 mm.

108 After the derailment the wheelset, back-to-back measurements on coach 77244 were all within tolerance.

Wheel sets on coaches 62870 and 77279

109 The centre coach of the incident train, 62870, was not derailed, and there were no marks visible on the wheels to suggest that flange climb had occurred.

110 A comparative profile of the wheels on coach 77279 of unit 318269 revealed flange face wear and a slight discontinuity at the same point on the flange tip. This unit operated over the same routes as the derailed train.

Suspension on coach 77244

111 The primary suspension system consists of chevron rubber sandwiches. When examined there were displacements on these of up to 25 mm and some were unseated from their locating lugs. Marks observed suggested that these were recent and the result of the derailment action.

112 The secondary suspension is of air cushion type with two airbag units per bogie. Examination revealed that all had been inflated at the time of the derailment, and had sustained damage as a result.

113 Airbag height is controlled by levelling valves. Those on the leading bogie of 77244 were in good condition with no sign of distortion. There was nothing to suggest that they were not functioning normally. Those on the trailing bogie were badly damaged, consistent with this having occurred during or after the derailment.

114 There are a total of four *yaw dampers* between the vehicle frame and the bogies. Some of these were found to be damaged. This damage was consistent with having occurred during or after the derailment. The damper rating was not tested; however there was no sign of leakage or previous reports of rough riding to suggest that they had been operating at less than specification.

115 The anti-roll bars were clean, greased and able to move normally.

116 The vehicle was transported by road to a specialist engineering facility at Derby for static tests for compliance against RGS GM/RT 2141 'Resistance of Railway Vehicles to Derailment and Roll-Over'. These comprised bogie *rotational resistance* and *torsional stiffness* tests. The tests were hampered by the inability to re-inflate one of the secondary suspension airbags on account of the damage inflicted during the derailment. This was the trailing bogie at the time of the derailment.

117 The rotational resistance tests on all bogies were compliant with the above standard, with one exception. For the leading bogie of 77244, rotation at 1 degree per second with the airbags inflated measured a score of 0.119; the maximum permitted is 0.105. This represents an exceedence by 13.3 % which may have been as a result of the derailment damage incurred.

118 The torsional stiffness was measured with all the airbags deflated. The RGS states that a maximum 60 % wheel unloading is permitted with maximum diagonal twist applied. This was performed by elevating one wheel from the position with no twist applied. In the case of coach 77244 in the worst case scenario the maximum value recorded was 66 % wheel unloading on wheel LRL. This exceedence, by a factor of 10 %, may have been as a result of the derailment damage incurred.

Couplings

119 The main purpose of the bar coupler between coaches is to provide a semi-permanent longitudinal connection between the two vehicles, and to allow a limited amount of lateral and vertical movement. It is not designed to prevent excessive twist between adjacent vehicles.

120 The bar coupler connecting coach 77244 to coach 62870 (which did not derail) was examined on site; it had to be flame cut to separate the vehicles for recovery. The bar at the inner end of coach 77244 was not twisted in relation to the body. On subsequent close inspection, witness marks were found on 77244's coupler bar and on the left-hand side coupler pocket that showed that they had been in hard contact.

121 The bar coupler on coach 62870 had corresponding damage to that described for coach 77244. The coupler had been rotated to nearly 90 degrees within its housing and the assembly had sustained localised damage. The coupler had not applied significant force to prevent coach 77244 overturning.

Previous occurrences of a similar character

London Waterloo, 11 September and 24 October 2006

122 There have been several examples of derailment at facing points in recent years as a result of defects created or being allowed to remain in situ following NR/SP/TRK/053 inspections and defective remedial work. Examples include two derailments at London Waterloo station; these were the subject of RAIB report 44/2007.

123 One of the factors identified in the Waterloo report was the lack of an independent follow-up inspection of the points following grinding (or welding) repairs. Had a follow-up inspection taken place, it is possible that the hazard 2 defect on 201A points at Exhibition Centre might have been detected and the misapplication of the TGP8 gauge identified. Also, a follow-up inspection would have been likely to identify the lack of lubrication.

124 The RAIB made a recommendation in report 44/2007 to address the follow-up inspection issue. This was:

> 'Network Rail should introduce the requirement for a follow-up inspection after a standard 053 repair is carried out involving welding or grinding. This should be undertaken by an independent and competent person within a timescale commensurate with minimising the risk of derailment'.

Network Rail did not accept this recommendation, stating that the inspection was catered for in the 'line opening procedure' in updated standard NR/L2/TRK/053 issue 4 which was introduced in October 2007. However this does not meet the independent aspect of the check, because it could be the same person or team that inspects their own work and perpetuates the error. The recommendation specifically called for independence and competency. The ORR is currently assessing its position with regard to the rejection of the recommendation by Network Rail (paragraph 137 discusses the consequences of the lack of independent checks).

Glasgow Central, 23 August 2001

125 A class 314 unit derailed on points lying in the *reverse* direction leading to platform 9 at Glasgow Central (High Level). The mechanism of derailment was flange climbing by the right-hand leading wheel of the leading bogie on the leading coach. The condition of the points did not fully comply with Railtrack Company Standard RE/CE/S/053 (Issue 2), in that the switch blade exhibited hazard 2 and hazard 5 failures. The right-hand switch blade had previously been reported with a sharp gauge corner profile on 17 August 2001 but this had not been rectified at the time of the derailment.

126 The rolling stock Maintenance Procedure MP6-19 did not allow for the settling of the secondary suspension causing the vehicle heights to change. This created a condition for the right-hand leading wheel of the leading bogie to be off-loaded by a factor of 39 %

127 The RAIB has reviewed the details of this incident and is of the opinion that it is not directly relevant to the circumstances of the derailment at Exhibition Centre.

Collision at Largs, 1995

128 In 1995, unit 318254 was involved in a serious buffer stop collision at Largs. It caused significant damage to all three vehicles. However, no factors have been found that link this event to the derailment.

Analysis

Identification of the immediate cause

129 The immediate cause of the 3 September 2007 accident was the flange of the leading right-hand side wheel of 77244 climbing upon an incorrectly profiled switch rail at 201A points which presented an NR/SP/TRK/053 hazard 2 defect.

Identification of causal and contributory factors

Track in the vicinity of the points

130 The 1mm tight gauge at the switch blades of 201A points (paragraph 82) would have slightly increased the side contact pressure by wheels on the right-hand switch half-set. High side contact pressure gives flanges more purchase to promote climbing; the primary purpose of lubrication following grinding is to prevent this. This should have been identified during a full inspection immediately following the installation of the half set.

131 Other than the hazard 2 defect and tight gauge present on 201A points, there were no twists or other track defects present to initiate derailment.

Work undertaken on 201A points

The work carried out

132 The presence of the hazard 2 defect (paragraph 94) provided a ramp on which the wheel flange rode up. The presence of the 'hazard 2' defect was a causal factor in the accident.

133 The grinding work to eliminate the defects on the switch blades was not completed (paragraph 94). Further grinding work would have eliminated the remaining hazard 2 defect, however the need for this work was not recognised due to the misapplication of the TGP8 gauge (paragraph 134). The incomplete grinding of the switch blade was a causal factor in the accident.

134 The inspectors misapplication of the TGP8 gauge (paragraphs 91 and 95) led them to conclude that the repair was compliant with the NR/SP/TRK/053 and NR/BS/LI/63 requirements. The misapplication the TGP8 gauge was a causal factor in the accident.

135 The inspection team also omitted to apply lubricant to the newly ground side of the switch rail as required by NR/SP/TRK/053. They also incorrectly recorded that the gauge corner of the switch rail had been lubricated. They did not advise their supervisor that lubrication was still required. Had lubrication been present then it may have prevented the flange climb. The lack of lubricant was a causal factor in the accident.

136 The supervisor had a close and hands-on role in the inspection process of work undertaken by the Track Inspection Special Examination team; his managers were thus content that he was ensuring the quality of their work. The lack of a follow up inspection was a contributory factor in the accident.

The standard in force at the time of the derailment

137 There is nothing in NR/SP/TRK/053, as amended by NR/BS/LI/63 (paragraph 80) that contributed to the derailment. Its content already includes the necessary requirements for serviceable points by defining the rail profiles to be achieved through grinding and by examinations using gauges. The one omission was for an independent check following grinding work (see paragraph 150a). If an independent check had been undertaken it is probable that the defect on the points would have been identified, hence the likelihood of the derailment would have been reduced. The updated standard, NR/L2/TRK/053 issue 4, also fails to mandate any independence for the checks (paragraph 124). The RAIB is of the opinion that any new process that could affect the safety of the railway, such as the use of the TGP8 gauge, should receive some form of independent assessment. Whether this is a single visit, a percentage check, time bounded audit, etc. is dependent upon the risks involved.

Unit 318254

138 Following the derailment of the wheelset the forces acting upon the coupler bar between 77244 and the correctly running 62870 dragged the leading end of 77244 back towards the rails of the correct route. The rear bogie of 77244 negotiated 201A points correctly and was running normally. When the leading derailed axle reached the crossing, further lateral forces had the effect of the forcing the right-hand wheels over the six foot rail of the down line (see Figure 12) and the vehicle started to tip towards the left. Once the centre of gravity was to the left of the left-hand wheels the vehicle toppled over and came to rest against the tunnel wall at an angle of 75° from vertical.

139 Of the four trains that used 201A points in the facing direction following the last grinding and inspection only coach 77244 derailed. The combination of the factors outlined in paragraphs 106, 117 and 118 may have increased the propensity of that wheel to climb the switch rail, but this combination was not causal in itself.

Analysis of the wheel / rail interface

140 Using a proprietary computer program, the profiles of the LRL wheel from coach 77244 were overlaid on the rail profiles obtained from 201A points. Figure 17 shows how the flange climb along the top of the switch blade started.

141 Detailed analysis of the LRL wheel of coach 77244 at the right-hand switchblade of 201A points indicates that the discontinuity described in paragraph 104 would not have initiated wheel flange climb. The discontinuity may have been caused by roll-over of material from the flange thinning however the RAIB found no firm evidence to confirm or discount this hypothesis. Once the wheel climb had started, the profile may have actively assisted further flange climb leading to the subsequent derailment. This was a possible contributory factor to the derailment.

142 The high rates of wheel wear reported by First ScotRail for the six months prior to the derailment (paragraph 97) are consistent with the generation of the wheel profiles found on unit 318254, which were within permitted tolerances.

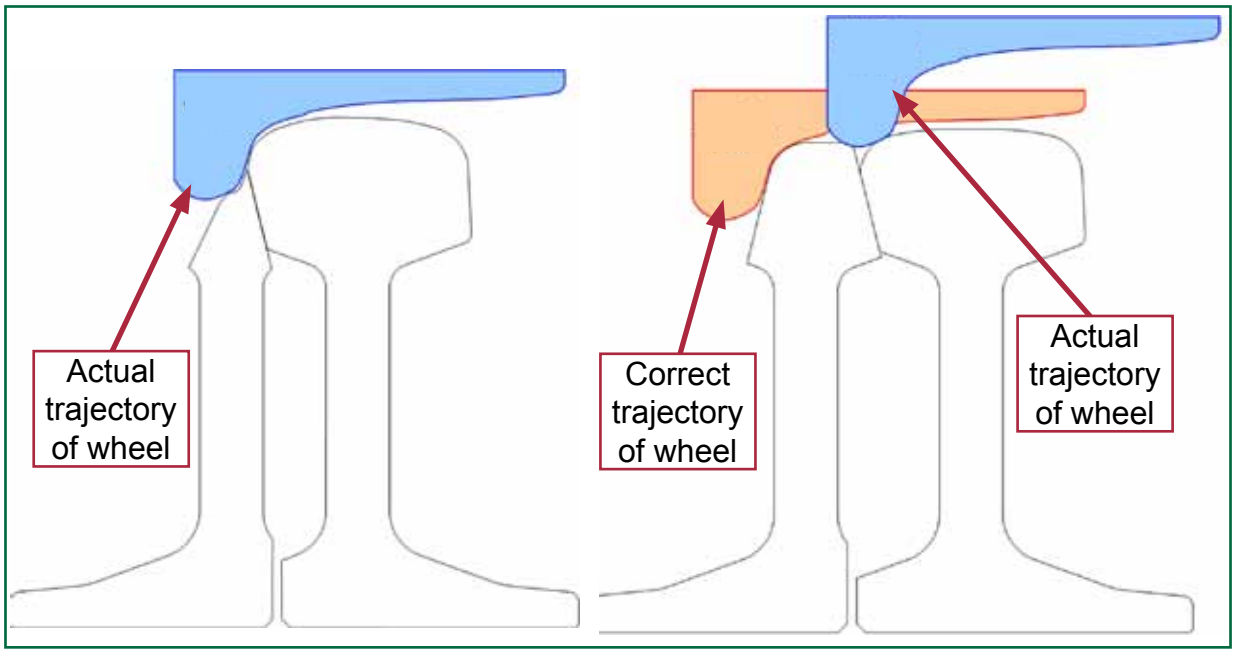

Figure 17: 77244 LRL wheel profile overlaid on 201A switch profile

Analysis of other factors

143 Investigations in the UK, through the European Rail Agency, and through the *UIC* into the effects of derailments on points installed on slab track have revealed no information, either of previous incidents, or of theoretical analysis of the performance of vehicles in such derailments. Information on similar derailments on ballasted track gives an indication that had the derailment at Exhibition Centre been on ballasted track the consequences may not have been as extreme. This may be due to the lack of lateral resistance as the wheels skidded across the concrete slab after derailing, resulting in sufficient momentum to rotate the vehicle when it came up against a rail. For similar derailments on ballasted track it is commonplace for the rails and sleepers to be displaced sideways, thus absorbing some of the derailment energy and helping to mitigate the effects of a wheel striking a rail. The lack of any sideways movement on 201A points when the wheels struck the side of the switch rail near the crossing nose may have increased the impulse forces thus assisting the overturning of coach 77244.

144 There is no evidence that the driving of the train or operation of the signalling system contributed to the derailment.

145 Although bogie *rotational stiffness* of the leading bogie on coach 77244 was slightly higher than permitted (paragraph 118), the effect of this at the tip of the switch blades during the motion of the leading wheelset would have been minimal. It has thus been discounted as a contributor to the accident.

Identification of underlying causes

146 The Area Track Engineer had been the motivating force behind the introduction of the TGP8 track gauge. As such he had developed his own views about how the gauge should be used. These were not totally reflected in the content of the Letter of Instruction NR/BS/LI/063 which did not include a check undertaken by pushing the gauge up over the stock rail head to identify if a ramp or surface existed that could cause the flange to climb on to the rail head. Without a defective switch set on which to practice, the inspectors gained an incorrect understanding of how the gauge should be used. Additionally they did not appreciate that the gauge was to be used continuously over the length of rail, rather than in large discrete steps, such as are commonly used with some other gauges. The lack of opportunity for a practical demonstration of the new TGP8 gauge is the underlying cause of the accident (paragraphs 76, 90 and 95).

Severity of consequences

147 The extent to which vehicle 77244 rotated and toppled over was unusual in such a slow speed and short distance derailment. That may be due to the fact that the derailment occurred on slab track (paragraph 143).

Figure 18: Slab track with fixtures connected directly to the base concrete. Also scores made by the flanges of the derailed wheels.

Conclusions

Immediate cause

148 The immediate cause of the accident was 201A points between Exhibition Centre and Anderston not being fit for the passage of trains in the facing direction.

Causal factors

149 Causal factors were:

a. the right-hand switch and stock rail of 201A points displayed a severe NR/SP/TRK/053 hazard 2 defect. This presented an incline for the wheel flange to climb (paragraph 132, **No recommendation**);

b. the Track Inspection Special Examination team did not complete the grinding work necessary and introduced a S035 hazard 2 condition as a result of grinding away a hazard 1 fault that they had previously identified. The remaining hazard 2 defect was not identified due to the incorrect use of the TGP8 gauge (paragraphs 133 and 134, **No recommendation**); and

c. the Track Inspection Special Examination team did not apply any lubrication to the ground surface area, as required by letter of instruction NR/BS/LI/063. This caused increased coefficient of friction between the switch rail and the wheel flange to assist the wheel climb (paragraph 135, **No recommendation**).

Contributory factors

150 The following factors were considered to be contributory:

a. there was no independent check of the quality of the work completed that identified the hazard 2 fault or the lack of lubrication when the Track Inspection Special Examination team had finished grinding (paragraph 136, **No Recommendation** in this report because Recommendation 6 of RAIB Report 2007/44 'Derailments at London Waterloo 11 September and 24 October 2007' remains under consideration with the ORR); and .

b. a combination of features present on coach 77244 may possibly have assisted with the flange climb once the wheel climb had been initiated by the hazard 2 condition (**No recommendation**).

Underlying causes

151 The underlying cause was that the Track Inspection Special Examination team were not given the opportunity of a practical demonstration of the new TGP8 gauge, and no member of management or training staff followed up to ensure they were applying it correctly (paragraphs 90 and 146, **Recommendation 1)**.

Other factors affecting the consequences

152 The extent to which coach 77244 rotated and toppled over was unusual in such a slow speed and short distance derailment. This may be due to the fact that the derailment occurred on slab track where the rail fixtures are connected directly into the base concrete and have very little flexibility under extreme forces. In ballasted track, there is very often a loosening effect caused by damage incurred to the sleepers (paragraphs 143 and 147, **Recommendations 2 and 3**).

Additional observations

153 Network Rail's does not have a policy of independent checking the quality of work when the supervisor becomes a 'de-facto' team member undertaking inspection or repair (paragraph 93, **Recommendation 4**).

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

154 Network Rail has fully briefed and retrained the track inspection special examination team involved in the derailment in the correct use of the TGP8 gauge and the other parts of the Letter of Instruction LI/63.

155 The Area Track Engineer, Scotland West, has ensured that all his other staff who use the TGP8 gauge are doing so in the correct manner and that they understand the importance of carrying out post-grinding lubrication.

156 The Area Track Engineer, Scotland West, has reviewed his training strategy to ensure that necessary gauges, points and training equipment are available.

157 With respect to the post-inspection checking (paragraph 123), Network Rail issued an update to standard RT/SP/TRK/001 Issue 3, applicable from October 2007. This standard NR/L2/TRK/053 Issue 4 contains a requirement for follow-up inspections. These inspections address the technical requirements but do not require an independent person to check the work.

158 The ORR is undertaking a study into the inspection and repair of switches and crossings by Network Rail. This will be used by the ORR to formulate their response to the rejection by Network Rail of Recommendation 6 of RAIB report 2007/44 'Derailments at London Waterloo 11 September and 24 October 2007' (Recommendation 6 of RAIB report 2007/44 is identical to Recommendation 1 in this report) .

Recommendations

159 The ORR is undertaking a study into the inspection and repair of switches and crossings by Network Rail. This will be used by the ORR to formulate their response to the rejection by Network Rail of Recommendation 6 of RAIB Report 44/2007 'Derailments at London Waterloo 11 September and 24 October 2007' this recommendation states:

> 'Network Rail should introduce the requirement for a follow-up inspection after a standard 053 repair is carried out involving welding or grinding. This should be undertaken by an independent and competent person within a timescale commensurate with minimising the risk of derailment'.

As this recommendation is still open and under consideration by the ORR, the RAIB has not re-made it in this report, which it would otherwise have done.

The following safety recommendations are made[1]:

There are no recommendations to address causal factors

Recommendations to address underlying causes

1 Network Rail should introduce a policy that competence training on the use of tools and equipment shall include hands-on use of the tools and equipment on the infrastructure on which it is intended for use, in order for competence to be assessed from the training (this is not intended to apply to appreciation training, as opposed to competence training).

Recommendations to address other matters observed during the investigation

2 Network Rail should assess the risks associated with the use of points on slab track. If these are found to be substantially different from those of points on ballasted track, Network Rail should develop measures to mitigate any increased risks (paragraph 152).

3 Network Rail should undertake research in order to better understand the effects of derailments at points on slab track, and establish whether the mitigation afforded is sufficient to prevent the overturning of vehicles in the manner described in paragraph 152.

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 the Office of Rail Regulation 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.

4 Network Rail should review its management processes in order to achieve a regular quality check on the methods of work used and the quality of the work performed by track staff maintaining points and crossings. This is to minimise the risk presented when a supervisor is responsible for carrying out the primary work (paragraph 153).

Appendices

Appendix A - Glossary of abbreviations and acronyms

ARS	Automatic route setting
DTS	Driving trailer second (vehicle descriptor)
FRAME	Fault Reporting and Monitoring & Equipment System. A system that records infrastructure defects
IECC	Integrated electronic control centre
OLE	Overhead line equipment
OTMR	On-train monitoring recorder
PMS	Pantograph motor second (vehicle descriptor)
RSSB	Railway Safety and Standards Board
UIC	Union Internationale des Chemins de Fer (International Union of Railways)

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

'A' exam	A scheduled examination for class 318 units carried out at 4500 mile frequencies with differing activities undertaken to balance workloads. Each exam is sequentially numbered: A1, A2 etc. At certain intervals they are replaced by a more heavy exam (B, C etc) that incorporates the fundamental safety checks carried out in all A exams.
Automatic route setting	A computer system capable of routing trains through a junction layout based on the train *reporting number*, timetable information and some procedural rules such as priorities of different classes of train. The system can operate without the intervention of the signaller.*
Bar coupler	Semi-permanent rigid connector between two vehicles of a multiple unit.
BS113A	A rail section weighing 113 pounds per yard. It has been re-titled CEN54E1.*
Bogie	A metal frame equipped with two or three wheelsets and able to rotate freely in plan, used in pairs under rail vehicles to improve ride quality and better distribute forces to the track.*
Cab secure radio	A radio system provided to allow signaller and train driver to communicate safety critical information as securely as if they were speaking on a land line.*
Cant	The amount by which one rail of a track is raised above the other rail, measured over the rail centres.*
Cant deficiency	Effectively the permissible shortfall in cant of the track.*
Chamfered (switch rail)	A points in which the switch rail and stock rail are machined to a matching angled cut.*
Clamp lock point machine	A type of points operating mechanism that moves the switch rails by hydraulic pressure.
Crossing	An assembly that permits the passage of wheel flanges across other rails where tracks intersect.*
Cross-over	A short section of connecting track with points at both ends permitting trains to move from one line to another.
Detonator	A small disc shaped explosive warning device designed to be placed on the railhead for protection and emergency purposes. It explodes when a train passes over thus alerting the driver. Despite not fulfilling the definition of an explosive detonator in any way, detonator is the industry standard term.*

Down (Argyle line)	In this location, the more southerly of the two lines predominantly used by trains travelling west between Rutherglen and Partick.
Driver mentor	A driver qualified to coach a trainee in the practical aspects of driving.
Facing (switch, points or direction)	The condition where two routes diverge in the direction of travel.
Flange	The lip on the running surface of a wheel that ensures that the wheel remains on the rail.
Flange contact zone	That part of a rail section where a wheel flange can potentially make contact.*
Flat bottom rail	A rail section having a flat based rail foot or flange.
Four-aspect (signalling)	Multiple aspect signals capable of displaying red, yellow, double yellow or green aspects.
Full depth (point or switch)	A point in which the switch rail and stock rail are manufactured from the same initial rail section.*
Head (of rail)	The bulbous upper part of a rail section.*
Integrated Electronic Control Centre	A type of signal box that controls the points and signals for a whole route or a large geographical area by electronic means.*
(rail) Lubricator	A device for delivering a measured quantity of lubricant (generally grease) onto the running edge of a rail in order to reduce the friction between the rail and wheel flange on curved track. Rail lubricators are used to reduce noise and increase rail life on such curves.
On-train monitoring recorder	A data recorder fitted to traction units collecting information about the performance of the train.*
Overhead line equipment	An assembly of metal conductor wires, insulating devices and support structures used to bring a traction supply current to suitably equipped traction units.*
P8 (wheel profile)	A wheel profile based on a worn P1 Profile, found on most Passenger vehicles built since 1970.*
Pantograph	The device fitted to the roof an electric locomotive or electric multiple unit that contacts the contact wire of the overhead line equipment, allowing the traction unit to draw current.*

Points	Points are provided to allow trains to move from one track or route to another. This is achieved using a pair of rails that move from one side of the track to the other and allow the route to be selected, normally by the signaller. These rails are known as switch blades and are designed to abut against static rails known as stock rails, a switch blade and stock rail pair is known as a *switch half set.* A set of points incorporates a left and a right-hand switch half set. Points are sometimes referred to as points.
Possession (of line)	A period of time during which one or more tracks are blocked to trains to permit work to be safely carried out on or near the line.
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.*
Reporting number	A four character identifier for a specific train movement. This is used to describe the train to the signalling system, and interfaces with ARS.
Reverse (position points, switches or direction)	The position of the points when set for the lesser used or of diverging route. At 201A points this is when the switch blades are set for trains to cross from the down line to the up line.
Rotational stiffness	The measurement of the rotational motion of a vehicle bogie.
Six-foot	The colloquial term for the space between two adjacent tracks, irrespective of the distance involved.*
Slab track	Track without ballast or sleepers, continuously supported by a continuous reinforced concrete slab.
Slide baseplate	A baseplate on which the switch rail can be moved laterally.
Solid state interlocking	A microprocessor based signalling system.*
Stock rail	The fixed rail in a switch half set. The other rail is the switch rail.*
Stock rail front	The length of stock rail that projects beyond the switch toe.
Switch half set	The assembly for one side of a switch comprising a stock rail, a switch rail and their fittings and attachments.
Switch rail	The thinner movable machined rail section that registers with the stock rail and forms part of a switch assembly.
TGP8 track gauge	A device for measuring the distance between rails and incorporating dummy wheelsets profiled to the P8 standard.
Toe (of points or switch)	The movable end of a switch rail.*

Torsional stiffness	The resistance a vehicle structure has to twisting along its length.*
Track circuit block	A signalling system where the line beyond is proved clear to the end of the overlap beyond the next signal.*
Track circuit (operating) clips	A pair of spring clips connected by a wire, used to short out track circuits by connection across the rails in times of emergency.*
Trailing (point, switch or direction)	The condition where two routes converge in the direction of travel.
Transition curve	A curve with a uniformly varying radius from straight to curve, or vice versa.*
Turnback siding	A siding provided at a through station for the purpose of allowing the traincrew of a multiple unit train to change ends without occupying a platform.*
UIC	Union Internationale des Chemins de Fer, an international organisation formed in 1922 comprising a union of various Railway companies and administrations. It agrees common standards and practices.*
Up (Argyle line)	In this location, the more northerly of the two lines predominantly used by trains travelling east between Partick and Rutherglen.
Wheel profile	The cross section through the flange and running surface of the wheel.
Yaw damper	A shock absorber fitted to certain types of bogies to control their rotation in plan at high speeds.*
Yaw stiffness	The resistance that the yaw damper has to movement.

Appendix C - Key standards current at the time

GE/RT 8000	Railway group standard Rule Book.
GC/RT 5021 Issue 3	Track System Requirements.
GM/RT 2141 Issue 2	Resistance of Railway Vehicles to Derailment and Roll-Over.
GM/RT 2466 Issue 1	Railway Wheelsets.
MT288 (RSSB common domain standard)	Wheelset Tread & Gauging Standard.
NR/SP/TRK/001 Issue 3	Inspection and maintenance of permanent way.
NR/SP/TRK/053 Issue 3	Inspection and repair procedures to reduce the risk of derailment at switches.
NR/SP/TRK/054 Issue 3	Inspection of cast crossings and cast vees.

Appendix D - Summary of derailment hazards as defined in standard NR/SP/TRK/053 (issue 3)

Derailment hazard	Abbreviated inspection criteria	Inspection gauges required
Hazard 1 Sideworn stock rail	Check that top of switch rail is below base of sidewear on stock rail.	Plain rail NR4 sidewear gauge (note b) Metric stepped gauge
Hazard 2 Sideworn stock rail and switch blade	If sidewear is below step 13, check that sidewear angle on switch blade is no flatter than sidewear angle on stock rail.	Plain rail NR4 sidewear gauge Metric stepped gauge TGP8 gauge (note c)
Hazard 3 Stock rail headwear with less worn switch blade	Check the relative height of the switch rail compared with the stock rail.	Switch wear gauge 1 Metric stepped gauge
Hazard 4 Switch blade damage	Check extent and position of any damage to switch blade	Switch wear gauge 2 Metric stepped gauge
Hazard 5 Sharp blade profile (restricted to hardened rails formed from MHT and Austenite manganese steel (AMS)	Check that square lip has not been formed on switch blade. To be inspected weekly for first month, and monthly for first six months	Switch blade radius gauge

Notes:

a. Sidewear and switch blade hogging values are also required.

b. The type NR4 sidewear gauge was introduced in early 2005 and its use was mandated in early 2006);

c. A track gauge incorporating a wheel profile gauge (TGP8) was introduced in spring 2005 and its use mandated from mid-2006. This allows the inspector to assess the degree of wear and the contact position of a wheel flange. An indicator line drawn normal to the 60° flange contact angle indicates the lowest point of the flange which should be in contact with the switch blade and a profile which makes contact below this point is deemed to present a derailment risk (see Figure 13).

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

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