Rail Accident Investigation Branch

Rail Accident Report

Derailment at Archway
2 June 2006

Department for Transport

Report 24/2006
December 2006

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.

Derailment at Archway, 2 June 2006

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 Rail Accident Investigation Branch does not establish blame, liability or carry out prosecutions.

3 Access was freely given to London Underground Ltd, Tube Lines, and ALSTOM Transport staff, data and records for the purpose of this investigation.

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

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

Summary of the report

Key facts about the accident

5 At 10:51 hrs on 2 June 2006, a London Underground Ltd (LUL) Northern line tube train became derailed while entering the *reversing siding* at Archway station, north London. The only person on board, the train operator, was unhurt.

6 The rear bogie of the last *car* was derailed, and the car became wedged across the entrance to the siding tunnel. Services on the High Barnet branch of the Northern line were suspended for the rest of the day. After recovery of the train and repairs to the track were carried out overnight, normal services resumed the following morning.

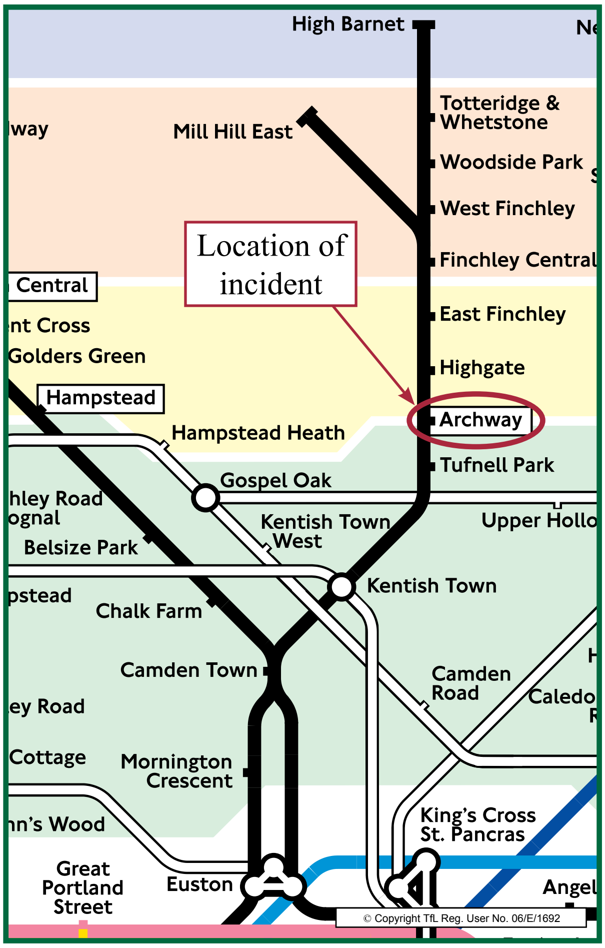

Figure 1: Extract from London Underground diagram showing location of accident.

Immediate cause, contributory factors, underlying causes

7 The immediate cause of the derailment was a broken *switch rail* in the *points* leading to the reversing siding.

8 A causal factor was:

- the presence of a piece of *surface scale* and an associated shallow indent at the lower back edge of the switch rail and the lack of a chamfer on this edge, which together created the conditions for a *fatigue crack* to develop.

9 Contributory factors were:

- the presence of *voids* below the timber *bearers* of the points which permitted the rails to deflect an abnormal amount each time a train passed over;
- the lack of support given by the *stock rail* to the switch because of the loose fastenings in the assembly, arising from the poor condition of the timbers;
- the impossibility of detecting cracks in the part of the foot of the rail that is not in line with the rail web.

Recommendations

10 Recommendations can be found in paragraph 81. They relate to the following areas:

- modification of the detail design of LUL *bullhead* switch rails to reduce the likelihood of stress raisers occurring on the lower edge of the rail;
- assessment of the risk arising from the use of unmodified bullhead switch rails on LUL, and replacement where appropriate; and
- review of the track inspection system to ensure that faults are consistently detected and correctly identified, and that appropriate remedial action is taken arising from inspections.

The Accident

Summary of the accident

11 At 10:51 hrs on Friday 2 June 2006 train T6, a six car tube train of *1995 stock,* departed from Archway station en route to the reversing siding (Figure 3), which lies between the northbound and southbound lines a short distance north of the station. There were no passengers on the train.

12 As the train passed over the points leading from the northbound line to the siding, the *trailing* bogie of the last car became derailed to the left (facing the direction of travel) causing damage to the negative *current rail*, and causing the electric traction supply to be discharged.

13 After a discussion with the *service controller,* and recharging of the traction supply, the train operator attempted to move the train forward. After moving a short distance the last car, which was derailed, became wedged across the mouth of the siding tunnel, and the train stopped again.

14 The train operator, who was unhurt, left the train via the end door at the rear. The train was re-railed just after midnight the same day, and following track repairs normal services resumed at 07:30 hrs on Saturday 3 June.

Figure 2: The derailed train seen from the rear.

The parties involved

15 The train was operated by London Underground Ltd (LUL). Tube Lines is contracted to LUL for the maintenance and renewal of both the infrastructure and the train. The train is maintained by its builders, ALSTOM Transport, under contract to Tube Lines.

Location and infrastructure

16 Archway station was the original terminus of the Charing Cross, Euston & Hampstead Railway, which opened in 1907 (when the station was known as Highgate). From the north end of the northbound platform, a straight continuation of the tunnel led to a reversing siding. When the Northern line was extended to East Finchley in 1939, the new northbound track diverged from the route to the reversing siding about 20 m beyond the end of the northbound platform at Archway (Figure 3). Consequently, there is a left-hand curve at this point which is taken by all trains leaving Archway on their journey to East Finchley, Mill Hill East or High Barnet. No trains are timetabled to reverse at Archway, but the siding is used to reverse trains in order to fill gaps in the southbound service during periods of disruption, and to restore timetabled operation during service recovery.

17 The signalling at Archway is operated by an *interlocking machine* located in the former signal cabin at the south end of the southbound platform. The interlocking machine (Westinghouse style V, installed in 1992) has 12 levers. It is operated by compressed air in accordance with the standard practice of London Underground, and controlled remotely from the Northern Line control room at Cobourg Street, Euston.

18 The points leading to the reversing siding north of the station were laid with LUL *type C straight cut switches*, made from 95 lb/yd bullhead rail. The rail was rolled in 1991. The switches were machined at LUL's Lillie Bridge depot. They were installed at Archway sometime between 1992 and 2003 (there is no record of exactly when: see paragraph 73).

19 The switches were supported on timber bearers, set in a concrete base in accordance with the usual practice on tube (bored tunnel) sections of LUL.

The train

20 The train was a six-car unit of 1995 stock consisting of cars 51653 (leading), 52653, 53653, 53652, 52652 and 51652 (trailing). It was built by GEC Alsthom Metro-Cammell in 1997, and was maintained by ALSTOM Transport at Golders Green and Morden depots.

Events preceding the accident

21 On 2 June, during the morning peak period, three trains were reversed using the siding at Archway, travelling over 8A points *reverse*, while 64 trains used the points in their *normal* position, set for the northbound line to Highgate.

22 The 68th train to use Archway northbound platform that day was train T6. Train T6 had been in service since 05.48 hrs on 2 June. The train operator who was driving at the time of the derailment came on duty at 08:01 hrs and took train T6 over at 09:45 hrs at Morden. As it approached Kentish Town northbound at about 10:40 hrs on its way to Mill Hill East, train T6 was running some fifteen minutes late. The train operator was instructed by the service controller to terminate the train at Archway, de-train the passengers and reverse via Archway siding to pick up the timetabled path southbound.

Events during the accident

23 The train arrived at Archway at 10:46 hrs. On arriving at the station the train operator noticed that the shunt signal (NN 5) was already cleared for the train to go into the siding. The train operator detrained the passengers himself, checking all the cars, and then got back into the cab.

24 At 10:49 hrs the train operator made a normal start from the platform, and accelerated the train to 10 km/h (6 mph) (the maximum speed possible with the master control switch in the 'forward' position is 17 km/h (11 mph)). He observed from the position of the left-hand switch rail that points 8A were set for the siding. The leading cab had reached approximately two car lengths past points 8B when four alarm messages came up on the in-cab information screen, and the train stopped (Figure 3). The alarms were for the loss of traction current and auxiliary supply on cars one, three, four and six in the train (cars two and five are not equipped with *collector shoes*). The stop appeared to the train operator to be 'normal' for an incident involving loss of power, and he was not conscious of any unusual noise or motion which might have suggested that a derailment had taken place.

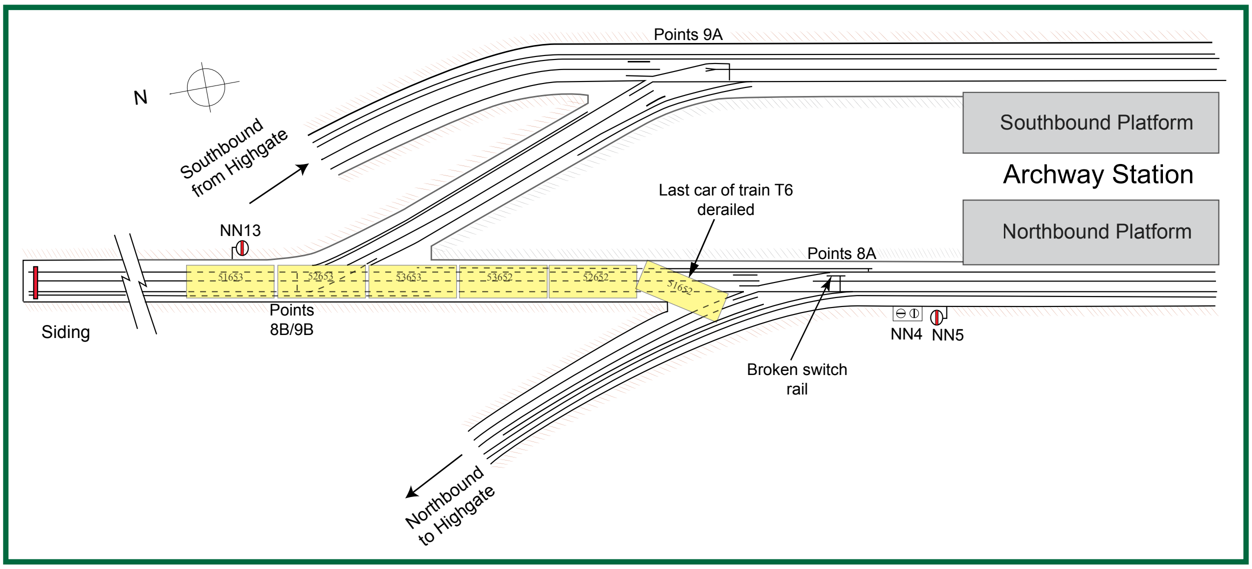

Figure 3: Site plan.

25 The train operator contacted the service controller by radio. They decided that the traction current had probably been lost because of an earth fault. The service controller contacted the station supervisor at Archway and asked him to reset the local circuit breakers. This was done, the current was recharged and the service controller instructed the train operator to proceed into the siding. The train moved a very short distance (less than 2 m) and stopped again, and the train operator observed the same alarms as before come up, as well as an additional alarm for deflated suspension on car six.

26 After resetting the circuit breakers the station supervisor had gone onto the northbound platform. From there he could see dust or smoke in the tunnel, and that the rear car of the train appeared to be derailed, so he telephoned the service controller. The service controller contacted the train operator and asked him to go to the rear of the train and examine it.

27 On doing so the train operator discovered that the sixth car was tilted and wedged across the tunnel. He attempted to contact the service controller from the rear cab, but was unable to do so because, with the traction current off, the radio required between 25 and 30 seconds to become active after being switched on, and the train operator only waited 19 seconds before concluding that the derailment had caused a loss of power. He returned to the leading cab and used the radio there to confirm to the service controller that the train was derailed. He was told to stay with the train because the traction current was being recharged to enable trains trapped south of Archway to be moved up to de-train passengers. However, the train operator became aware of an acrid burning smell at the rear (south) end of the train. He was concerned about his personal safety, so he walked to the station platform once he had established, by exchanging hand signals with the operator of the train (T60) that was in the northbound platform at Archway, that suitable protection from train movements was in place. Although this did not comply with the requirements of the rule book, the train operator's actions were understandable given the situation.

Consequences of the accident

28 No-one was injured in the accident.

29 There was slight damage to the bodywork of car six (51652) where it came into contact with the tunnel walls. The negative current rail was displaced, and its supporting insulators were destroyed, for about ten metres. There was some minor disturbance of cables in the area of the entrance to the reversing siding tunnel, but these were put back into place once the train had been removed and did not need renewal. There was no evidence of any electrical arcing which could have produced the burning smell noticed by the train operator.

Events following the accident

30 There were four trains approaching Archway from the south when the derailment occurred. The first of these, T60, arrived in the northbound platform at 11:06 hrs, and the 60 passengers on board were immediately detrained. Passengers on the other three trains were detrained, in accordance with LUL procedures, by 11:17 hrs.

31 The service on the High Barnet branch of the Northern Line was suspended between Camden Town and East Finchley, and replaced by a special bus service. A special timetable was introduced between Edgware and Morden. A shuttle service of three trains was introduced between East Finchley and High Barnet, with a single train providing a service on the branch line from Finchley Central to Mill Hill East.

32 The train was re-railed by LUL's Emergency Response Unit by 00:03 hrs on 3 June, and was moved into the siding at Archway. It was moved to Golders Green depot, via Mornington Crescent, in the early hours of the morning. Repairs to the track were completed during the night, and normal services were restored by 07:30 hrs on 3 June. Points 8A at Archway were temporarily replaced with *plain line* until a replacement switch blade could be fitted.

The Investigation

Key evidence

33 The RAIB's investigation obtained evidence from:

- on-site examination of:
  - the signalling system;
  - the track; and
  - the train.
- laboratory analysis of the fractured switch rail; and
- off-site examination of the train at Golders Green depot.

34 The initial findings from examination of the rail were passed to LUL, who took action to examine other similar switch rails on the network (paragraph 79).

35 Records relating to the maintenance of the points, and the examination of the train, were discussed with staff of LUL, Tube Lines and ALSTOM Transport as appropriate.

Previous occurrences of a similar character

36 The breakage of a switch rail, caused by fatigue, led to the derailment of a passenger train on the national network at Stafford on 19 October 2000. Following this incident the Railtrack (now Network Rail) specification for the manufacture of *flat-bottom* switch rails was changed to include a chamfer on the lower back corner (on the edge where the origin of the crack is shown in Figure 5). This change of design was applied to flat-bottom switch rails on LUL, but an equivalent change to LUL's bullhead switch design was not carried out.

37 There are no records of any similar occurrence on the London Underground system, although about 20 cases of broken rails in plain line occur annually. Such breakages are sometimes detected by the signalling system, because the break in the rail will cause the *track circuit* for the section of line concerned to show 'occupied', and put the protecting signals to red, even though there is no train present. This did not happen at Archway because the position of the break near the end of the switch rail was outside the current path of the track circuit (paragraph 55).

Analysis

Identification of the immediate cause

38 Following the derailment, the state of points 8A is shown in Figure 4.

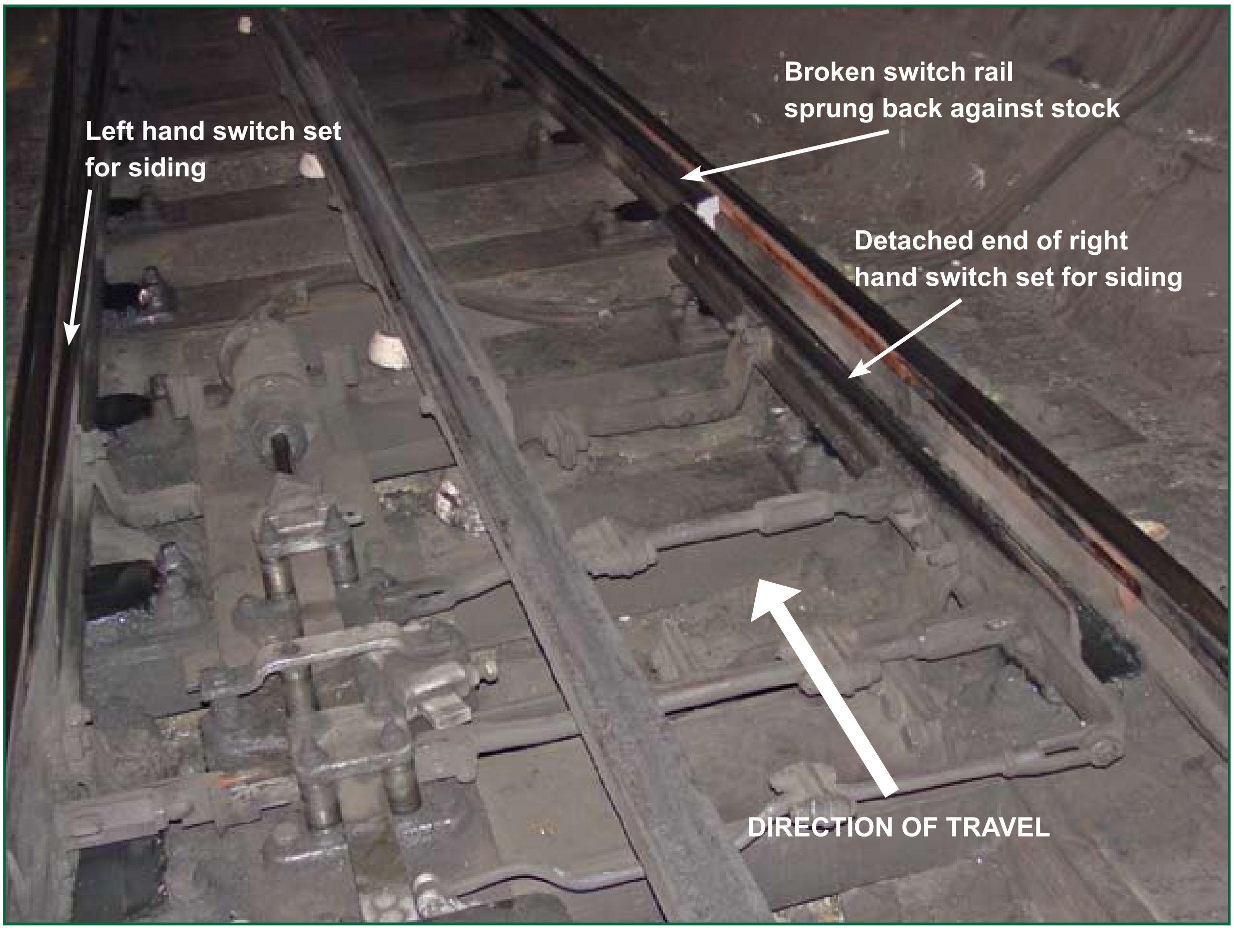

Figure 4: Points 8A as found after the derailment, showing broken switch rail.

39 The broken switch rail was the immediate cause of the accident. The position of the switches combined with the extensive bruising of the running-on end of the broken switch and the absence of any marks on the other portion, showed that the wheels of the train had been following the correct path before encountering the broken end of the switch.

40 There were marks on the broken switch consistent with wheel flanges running along the top surface of the rail, and then dropping off on the right hand side, beginning with the leading wheels of the train. The remainder, except for the last bogie, followed the path taken by the wheels in front (Figures 5 and 6).

41 On the left hand switch there were marks of two flanges climbing over the rail and derailing to the left, corresponding to the trailing bogie of the last car which was found derailed after the accident (Figure 5). It is probable that these wheels were able to be diverted to the left because there were no further vehicles behind to restrain the bogies in line.

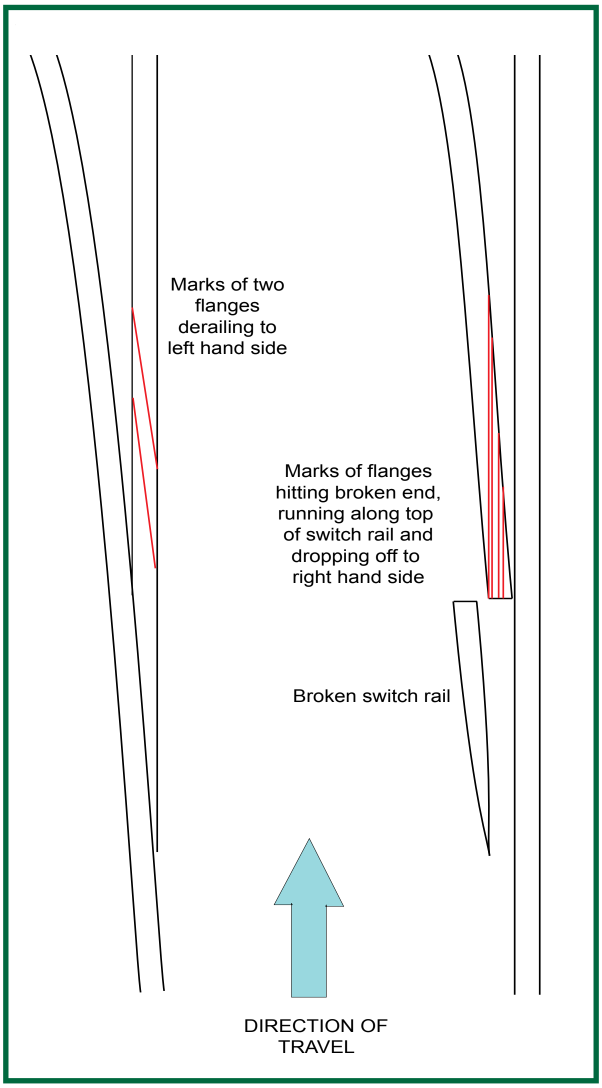

Figure 5: Derailment marks on the rails of points 8A.

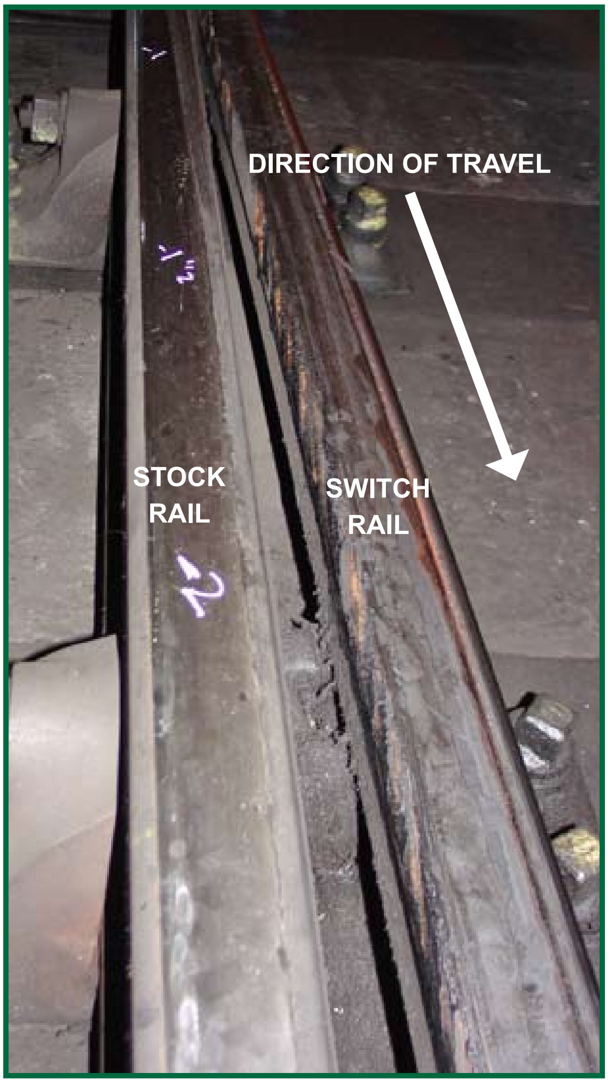

Figure 6: Right-hand switch rail showing wheel marks.

42 Examination of the wheels of the train showed marks on most of the right-hand wheel flanges, consistent with these flanges having met an obstruction and run along a rail head. There was a bruise on the tip of the flange of the leading wheel, suggesting that the broken end of the switch rail was already lying against the stock rail when the leading bogie reached it.

Rail cracking and flaw detection

43 Laboratory examination of the fractured rail section showed that the failure of the rail was caused by the growth of a single fatigue crack which had originated on the bottom machined edge coincident with a piece of surface scale. It is likely that the surface scale was present since the time of manufacture as it is a common type of rolling defect. The presence of the scale defect and a shallow indent that it had made on the lower surface of the rail acted as a stress-concentration, initiating a crack at this particular location (Figures 7 and 8).

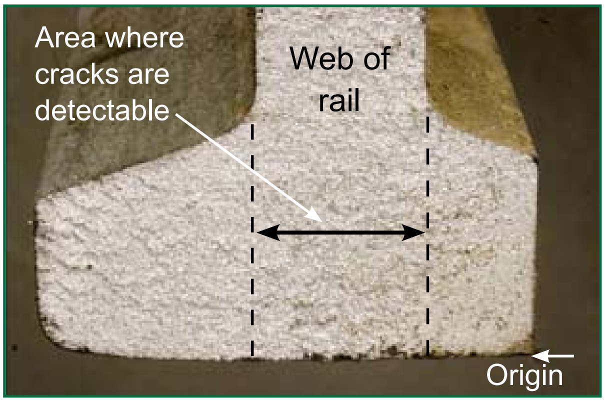

Figure 7: Broken end of rail showing fracture origin and limits of area in which crack detection is possible.

Figure 8: Detail of fracture origin and adjacent 'scale' at edge.

44 The fracture occurred 1.81 m from the switch tip approximately mid-way between rail supports, at a position where the lower surface would have been under maximum tensile stress when trains were passing. The bright, clean and undamaged nature of the fracture surface indicates that the crack had occurred relatively recently. Laboratory analysis confirmed that the features of the surface were consistent with a fatigue crack.

45 Crack detection in rails is normally done by ultrasonic testing, using probes carried on hand trolleys. These can detect cracks in the head and web of the rail, but are unable to detect defects which originated from the bottom corners of the rail until they have developed to the point where they impinge on the area below the web (Figure 7). With this equipment, it is not possible to test the tapered, machined portions of switch rails because the probes are not designed to run on the rail head where it is reduced in width.

46 The crack was in the lower back edge of the switch rail, hidden from visual inspection. There was therefore no practicable means of detecting this crack.

47 The switch rail is believed to have been put into the points at Archway some time between 1992 and 2003 (paragraph 73). There was no evidence of corrosion damage that could have influenced the failure, and the hardness value and composition of the material were within the specified limits for the specified grade of steel, namely British Standard BS11:1995 Grade A.

Mechanism of derailment

48 Examination of the broken switch rail showed that wheel flanges had struck the broken end and run onto the top of the rail, running along it for varying distances before dropping down the outside of the switch rail and regaining their normal path on the stock rail.

49 The last two wheels of the train, however, appear to have been forced to the left on hitting the broken rail end, to the extent that their flanges climbed the opposite (left-hand) switch rail (Figure 5). These wheels passed over the top of the left-hand switch rail and dropped down to run along the northbound main line. The increasing angle between the front and rear bogies exerted a substantial lateral force on these wheels, and after a short distance their flanges climbed the right-hand rail and the bogie became derailed to the right of the northbound running line. It displaced the negative conductor rail and damaged some cables in the tunnel before the last car became wedged in the entrance to the siding tunnel, stopping the train (Figure 2).

Detection of the broken rail

50 RAIB's survey of points 8A gave the following results for the rail top level:

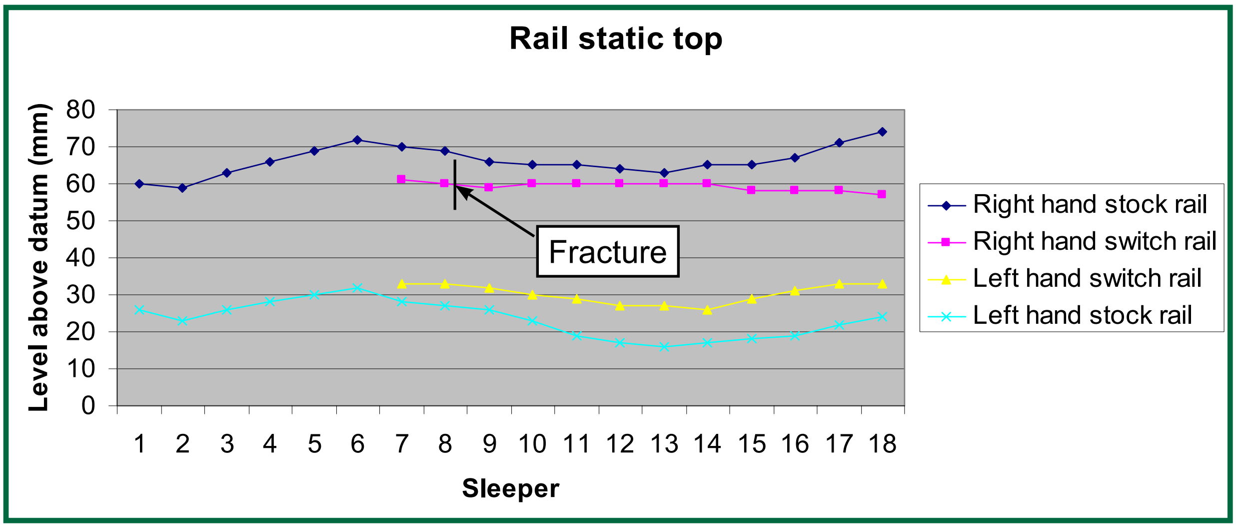

Figure 9: Rail height, points 8A.

51 Figure 9 shows that the head of the right hand switch rail was 7 mm below the head of the stock rail at the point where the rail broke. High dynamic loadings occurred as wheels dropped from the stock rail onto the lower head of the switch rail. Void measurements taken after the derailment indicate that there was about 5 mm gap beneath the bearer at the point where the rail broke. This, combined with the low height of the switch rail, would have reduced the impact experienced by the train operator when the right-hand wheel encountered the broken rail end. The total flange height is about 27 mm, and so there would have been a lift of about 15 mm (less some deflection of the rail end) when the flange of the leading wheel struck the broken end of the rail.

52 It is not possible to be certain exactly when the final fracture of the rail occurred. However, the rail is not likely to have been broken on the previous occasion when points 8A were set for the siding, at 09:27 hrs. After that, 23 trains passed over the rail with the points set for the northbound line, and it may have fractured under any of them without either being detected or, because of the way the points are constructed, compromising the safety of the line.

53 When the points were changed for the siding at 10:46 hrs, as T6 approached, it is possible either that (1) the *heel end* of the switch rail remained in position alongside the stock rail, and only the broken tip moved across, or (2) that the whole switch rail moved, with friction between the fractured faces keeping them together. In the first case, the broken rail end would have been visible from the direction in which trains approached it (Figure 4). However, in the darkness of the tunnel it would have been very difficult to see, and as the train operator was checking the position of the left-hand rail to confirm that the route was set for the siding he would not have been aware that there was anything wrong. In the second case, the deflection of the rails caused by the approach of the leading wheels of the train would have been the trigger that caused the fractured faces to part and the heel end of the switch to spring back against the stock rail to the position in which it was found, probably after the break had passed out of the train operator's field of vision.

54 The low speed of the train and the flexibility and lack of support of the broken end of the rail combined to minimise any lurch as the leading wheels struck the broken end, and in any case there is normally a degree of unevenness experienced when passing over points. Since the train operator did not drive trains into the siding at Archway very often, there is no reason why the motion of the train should have given him the impression that anything was wrong.

55 The broken rail was not detected through the signalling system because the fracture occurred in a part of the rail between a track circuit bond and the end of the switch. As is normal, this portion did not form part of the current path for the track circuit.

Identification of causal and contributory factors

<u>Operation and maintenance of the train</u>

56 The train was being driven in accordance with the speed limits laid down for this section of line and for moves into sidings. There were no faults on the train that could have affected what happened. The operation, condition and maintenance of the train are not considered to have contributed to the derailment.

<u>Signalling system</u>

57 The signalling system was operating correctly, and did not contribute to the derailment.

<u>Track condition</u>

58 The rail at the point where the fracture took place was supported on timber bearers, set in concrete. Track in tube tunnels is constructed in this manner to prevent the track moving from its designed position, because of the extremely limited clearances that exist between the trains and the tunnel. This form of construction produces a hard and unyielding form of track support. Each time a train passes over an impact loading is imposed, to a greater extent than is the case for conventional ballasted track. LUL estimate that, as a result of this, there are twice as many rail breaks per km in concrete track as occur in ballasted track.

59 The voids beneath the bearers in the area of the rail break meant that the rails were not firmly supported, and permitted both the stock rails and the switch rails to move during each load cycle. This would have increased the impact loading and therefore the stress in the lower part of the rail section and is likely to have contributed to the development of fatigue cracks.

60 Voids develop because the timber bearers (or sleepers, on sections of plain line) suffer from abrasion and erosion. There is also some shrinkage of the timber with time, and of the concrete surround as it dries out. If the wear and shrinkage is uniform, settlement of the entire assembly may reduce the extent of voiding. However, settlement is unlikely to be totally uniform and varying degrees of voiding will occur in practice.

61 Rail breaks on the tube sections of LUL are often in mid-span between sleepers (which are further apart than on open-air lines because their spacing has to correspond with the length of the tunnel lining sections in which they are laid). Such breaks usually originate from fatigue cracks in the foot of the rail. On open-air sections, sleeper spacing is closer together, there are fewer rail breaks and those that do occur are mostly associated with bolt holes.

62 The originating point for the fatigue crack was the sharp edge at the lower back of the switch rail. If this sharp edge were replaced by a chamfer or radius the stress concentration in this area would be reduced, and hence fatigue cracks would be less likely to originate there (**Recommendation 1**). Flat-bottom switches in use on LUL already have a chamfer for this purpose.

63 Where switches with this sharp edge are already in use in the track, there is currently no method available for detecting a crack which originates at the lower back corner (see paragraphs 45 and 46). Therefore any such bullhead switch has the potential to crack, and the risk associated with its continued use needs to be assessed (**Recommendation 2**)

<u>Rail head condition</u>

64 Whilst the head and gauge face of the broken rail showed evidence of *rolling contact fatigue* (Figure 10), the degree of wear was not significant (paragraph 74).

Figure 10: Rolling contact fatigue marks on the switch rail, overlaid by wear on the gauge corner.

65 The *gauge face* of the rails in the area of Archway is lubricated by automatic lubricators which operate each time a train passes over them. The quantity of grease found on the rail head indicated that the lubricators were functioning correctly. The degree of wear of the rail was quite low (paragraph 74) and the condition of the railhead is not considered to have contributed to the derailment.

Track inspection and maintenance

66 The inspection and test regime specified by LUL track includes patrolling inspection at least twice weekly, as defined in LUL standard E8301 A6 *Track safety inspections - patrolling and supplementary measures*, and inspection of the junction work (points) by a suitably qualified person at a frequency determined by a risk-based process, defined in LUL standard E8309 A1 *Track safety inspection - junctionwork*. For the Archway points, this interval was four weeks (the highest frequency), because of the intensity of traffic passing over them. Patrolling inspections are visual inspections to enable detection and reporting of track defects, and correction and notification of any conditions which present a risk to the safety of the train service. Junctionwork inspections require detailed inspection against a list of features, and involve both subjective assessment and measurement of the condition of the junction components.

67 The results of both of these types of inspections are recorded on paper, and reviewed by the inspection manager for the section of line. The manager then enters the inspection details onto the *Maximo* computer system. Where remedial work is required, the system generates a fault number which is entered on the original report form. A works order to carry out repairs is produced, and the work is allocated to an individual, a gang, or a contractor. On completion, the details of the actual work done are recorded on paper. Plans exist for this information to be entered on Maximo, but the work done was not being entered to Maximo at the time of the incident.

68 At Archway, patrolling inspections of the track were carried out on 23 May, when the points were found to be in need of oiling and cleaning, and on 26 May when no problems with the points were identified. The most recent junctionwork inspections took place on 1 May and 21 May. Various worn components and items requiring tightening were identified on both occasions. There is a lack of consistency between the two inspections relating to the condition of the timber bearers. The inspection on 1 May identified two timbers as being in poor condition and requiring renewal. No renewals were carried out before the next inspection on 21 May. This was done by a different person, who found all the timbers to be in good condition. After the derailment, some timbers were found to be in poor condition (paragraph 69). The consistency of inspections is the subject of **Recommendation 3**. However, neither type of inspection could have identified the extent of voiding under the bearers, as the inspections can only take place when trains are not running.

69 Loose fastenings in the right hand switch of points 8A at Archway were identified at the inspection on 21 May. This problem had also been noted at inspections on 17 January and 13 April 2006, and had been corrected by work carried out on 3 May, but had evidently recurred. The poor condition of the timber bearers is the reason for the difficulty in keeping the fastenings tight. After the derailment, the points were replaced by plain line to enable the line to be reopened. The timbers were later found to be in too poor a state to support new switches, and required replacement before the points could be reinstated.

70 The loose slide chairs and fastenings in this switch meant that the stock rail would be giving less than the intended level of support to the switch rail when the points were set for the left-hand (main line) route, and would have further increased the stresses at the outer edge of the switch rail.

Track quality recording

71 The LUL track recording train runs over the system on an 8-week cycle, and before the derailment it last ran over the High Barnet line on 10 May 2006. Irregularities and quality deficiencies are recorded at three levels, representing the maintenance target, the maintenance limit, and the safety standard for the track. Values exceeding level two (the maintenance limit) for 2 m twist and alignment were recorded at the points at Archway. These did not require any immediate action, but remedial work was programmed to be carried out: this was overtaken by the derailment.

72 Information from the track recording train is supplied to inspection managers, who prepare works orders using the Maximo system, as for other types of inspection. The actual information from the track recording train is not entered on the Maximo system.

Other factors for consideration

The age of the rail and records of rail replacement

73 There are no records relating to the installation of the switch rail which broke, and so there is some doubt about the date when it was put in at Archway. The rail has not been changed since Tube Lines took over responsibility for maintenance in 2003. LUL managers who were responsible for the section of line in earlier years believe that it was not changed during their stewardship. It is therefore probable that the switch rail had been in place since the early 1990s.

74 A switch rail such as this would normally be expected to wear out before reaching the limit of its fatigue life. Considering the likely age of the rail and the extremely heavy traffic over the line, the degree of wear of the head of the rail is quite low and indicative of the effectiveness of the lubrication of the track in the area. In this case fatigue, accelerated by the surface flaw and the poor support, caused the failure of the rail before it had worn significantly.

75 Tube Lines' computer system (Maximo) will, among other things, ensure that records of rail replacement are readily available. In time, it will enable the age of rails to be included in the information available to maintenance managers.

Conclusions

Immediate cause

76 The immediate cause of the accident was the breakage of the right-hand switch rail of points 8A at Archway.

Causal and contributory factors

77 A causal factor was:

- a piece of surface scale and associated shallow indent at the lower back edge of the switch rail and the lack of a chamfer on this edge, which together created the conditions for a fatigue crack to develop from the lower back edge **(Recommendations 1 and 2)**.

78 Contributory factors were:

- the presence of voids below the timber bearers of the points which permitted the rails to bend and produced high stresses in them each time a train passed over;
- the lack of support given by the stock rail to the switch because of the loose fastenings in the assembly, arising from the poor condition of the timbers, which also increased the stresses in the switch rail;
- the impracticability of detecting cracks in the part of the foot of the rail that is not in line with the web;
- the lack of consistency between the two inspections relating to the condition of the timber bearers **(Recommendation 3)**.

Actions already taken or in progress as a result of this investigation.

79 Following the derailment, LUL and its contractors carried out a visual examination of all bull-head switch rails on the network. No cracks were found.

80 LUL's investigation found that train operators were not fully aware of the correct procedure for activating the cab radios in the 1995 stock. Briefing has now been provided for all train operators on the sequence of operations and the time required for this process.

Recommendations

81 The following safety recommendations are made[1].

1 LUL should modify their design specification for bullhead switch rail to include a chamfer or other means of reducing the likelihood of stress raisers occurring on the machined lower edge of the rail (paragraph 77).

2 LUL should assess the risk arising from the continued use of unmodified bullhead switch rails in junction work (particularly facing points) and replace such rails where appropriate (paragraph 77).

3 Tube Lines should carry out a review of their track inspection system to ensure that faults are being consistently detected and correctly identified, and the appropriate level of remedial action is being programmed (paragraph 78).

[1] Responsibilities in respect of these recommendations are set out in the Railways (Accident Investigation and Reporting) Regulations 2005 and the accompanying guidance notes, which can be found on the RAIB web site at www.raib.gov.uk.

Appendices

Glossary of abbreviations and acronyms — Appendix A

HMRI	Her Majesty's Railway Inspectorate
LUL	London Underground Ltd
ORR	Office of Rail Regulation
RAIB	Rail Accident Investigation Branch

Glossary of terms Appendix B

Bearer	Timber (or concrete) transverse sleeper supporting the rails in switches and crossings.
Bullhead	A type of rail characterised by a narrow and deep base or ‘bottom’, little used outside the UK.
Car	London Underground term for a passenger coach.
Collector shoes	Flat metal pieces which are attached by a wooden insulating beam to the bogie frames of a train, and slide along the current rails to collect electric current for traction purposes.
Current rail	Rails mounted on insulators standing outside (positive) or between (negative) the normal running rails, through which DC electricity is supplied to electric trains on the London Underground.
Fatigue crack	A crack in a component which is initiated and developed by repeated cyclic loading.
Flat bottom	A type of rail characterised by a broad and shallow base or ‘bottom’, used worldwide.
Gauge face	The inner edge of each running rail (within the four foot) closest to where the wheel flanges run.
Heel end	The fixed end of the switch rail, and by extension that end of the whole points assembly.
Interlocking machine	A remotely controlled mechanism for commanding the operation of points and signals on London Underground, normally operated by compressed air but also capable of being worked manually.
Maximo	Tube Lines’ computerised asset management system.
Normal	A position for a set of points, corresponding to the default position of the controlling switch or lever.
Points	The items of permanent way which may be aligned to one of two positions, normal or reverse, according to the direction of train movement required.
Plain line	Straight or curved track which contains no switches or crossings.
Reverse	The position for a set of points which corresponds to the actuated position of the controlling switch or lever.
Reversing siding	A siding which is placed between two running lines specifically for the purpose of reversing the direction of travel of trains.
Rolling contact fatigue	Cracking of the top surface of the rail caused by contact stresses associated with the rolling action of wheels on the rail.
Service Controller	The LUL employee responsible for operational control of the Northern line.

Stock rail	The fixed rail at each side of a set of points.
Straight cut switch	A design of switch in which the rail is machined to fit against the side of the head of the stock rail, intended to give extra thickness for the switch rail.
Surface scale	A defect in the surface of a steel rail arising from the rolling process, resulting in the presence of a thin flap of partly oxidised steel on the surface, covering a shallow indent.
Switch rail	The moving portion of rail on each side of a set of points.
Track circuit	An electrical device using rails in an electric circuit which detects the absence of trains on a defined section of line.
Trailing	The last vehicle or bogie in the direction of travel.
Type C	The third shortest of the standard range of switches, corresponding to a radius of 246 m.
Voids	Spaces which develop under sleepers or bearers as track is used, due to wear or settlement.
1995 Stock	A fleet of trains built for the Northern line of LUL between 1996 and 1998 by GEC Alsthom Metro-Cammell.

Key standards current at the time — Appendix C

London Underground Standards:

2-01302-240	Track – Dimensions and Tolerances
E8301 A6	Track safety inspections – patrolling and supplementary measures
E8309 A1	Track safety inspection – junctionwork
TE-IS-0102-A2	Quality Inspections
TE-MTS-0602-A2	Switch maintenance

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

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