Rail Accident Investigation Branch

Rail Accident Report

Derailment at Porthkerry, South Wales
2 October 2014

Report 10/2015
August 2015

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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Preface

The purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences. It is not the purpose of such an investigation to establish blame or liability. Accordingly, it is inappropriate that RAIB reports should be used to assign fault or blame, or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

The RAIB's findings are based on its own evaluation of the evidence that was available at the time of the investigation and are intended to explain what happened, and why, in a fair and unbiased manner.

Where the RAIB has described a factor as being linked to cause and the term is unqualified, this means that the RAIB has satisfied itself that the evidence supports both the presence of the factor and its direct relevance to the causation of the accident. However, where the RAIB is less confident about the existence of a factor, or its role in the causation of the accident, the RAIB will qualify its findings by use of the words 'probable' or 'possible', as appropriate. Where there is more than one potential explanation the RAIB may describe one factor as being 'more' or 'less' likely than the other.

In some cases factors are described as 'underlying'. Such factors are also relevant to the causation of the accident but are associated with the underlying management arrangements or organisational issues (such as working culture). Where necessary, the words 'probable' or 'possible' can also be used to qualify 'underlying factor'.

Use of the word 'probable' means that, although it is considered highly likely that the factor applied, some small element of uncertainty remains. Use of the word 'possible' means that, although there is some evidence that supports this factor, there remains a more significant degree of uncertainty.

An 'observation' is a safety issue discovered as part of the investigation that is not considered to be causal or underlying to the event being investigated, but does deserve scrutiny because of a perceived potential for safety learning.

The above terms are intended to assist readers' interpretation of the report, and to provide suitable explanations where uncertainty remains. The report should therefore be interpreted as the view of the RAIB, expressed with the sole purpose of improving railway safety.

The RAIB's investigation (including its scope, methods, conclusions and recommendations) is independent of any inquest or fatal accident inquiry, and all other investigations, including those carried out by the safety authority, police or railway industry.

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2 October 2014

Contents

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Summary

At 02:30 hrs on Thursday 2 October 2014, a loaded coal train derailed at Porthkerry, between Barry and Rhoose on the Vale of Glamorgan line in South Wales. The last two wagons in the train were derailed when the rail beneath them collapsed. Nobody was injured.

The cause of the derailment was the failure of a section of the left-hand side rail due to a metallurgical defect within that rail. The defect arose due to impurities within the steel which had been present since manufacture. The rail had been installed at Porthkerry in 2008 but had previously been used at another site. The presence of the defect was not discovered when the rail was installed at Porthkerry.

The rail was not replaced before it collapsed due to a combination of factors: visual inspections intended to identify this type of defect had not been carried out, the regular track inspections had not found it and none of the staff responsible for management of the track had identified that the rail needed urgent replacement.

The defect that was later to cause the derailment was eventually discovered on 30 July 2014 during an inspection that was being carried out to monitor a different type of rail defect. However, according to Network Rail's standards, a defect of the type identified did not require urgent attention and therefore a period of 52 weeks was allowed for rail replacement. Consequently no action was taken to address the reported defect before the date of the derailment.

The RAIB has made three recommendations to Network Rail concerning the methods used to detect this type of rail defect, the techniques used to assess its severity and assessing the risk posed by similar rail in other locations.

The RAIB has also identified a learning point for the industry concerning the delegation of inspections by track maintenance engineers.

Introduction

Key definitions

1 Metric units are used in this report, except when it is normal railway practice to give speed and locations in imperial units. Where appropriate the equivalent metric value is also given. The terms left and right are used in this report with respect to the direction of travel of the train.

2 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B.

The accident

Summary of the accident

3 At 02:30 hrs on Thursday 2 October 2014, a loaded coal train derailed at Porthkerry, between Barry and Rhoose on the Vale of Glamorgan line in South Wales (figure 1). The last two wagons in the train were derailed when the rail beneath them collapsed (figure 2).

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

4 Nobody was injured in the accident.

5 Approximately 75 metres of track was destroyed during the derailment and the line was closed until 04:50 hrs on 6 October for recovery of the derailed wagons and repair of the track.

Context

Location

6 The line on which the derailment occurred has two tracks. The 'up' line carries trains in the direction of Barry and the 'down' line carries trains heading towards Aberthaw and Bridgend (figure 3). It is used by heavy freight trains and by passenger trains. Passenger trains can achieve higher speeds than the loaded freight trains, because of the rising gradient on this section of track. The track was designed to have 130 mm of *cant* to cater for passenger trains travelling at 50 mph (80 km/h).

Figure 2: Overview of derailment site

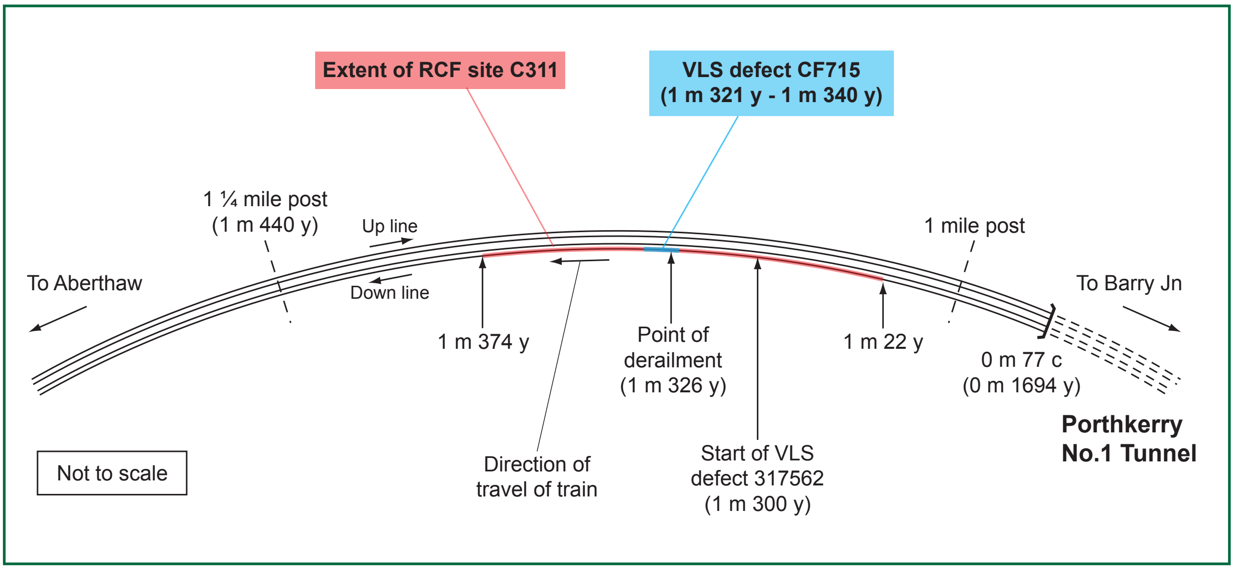

Figure 3: The layout of the key features at the derailment site (see text for meaning of features)

7 The derailment occurred as the train was travelling on the down line round a left-hand curve on a rising gradient. The point of derailment was at mileage 1 mile 326 yards, measured from a zero datum at Barry Junction. The maximum permitted speed at this location is 50 mph (80 km/h).

Organisations involved

8 The train involved was operated by DB Schenker, who also employed the driver.

9 The track was owned and maintained by Network Rail as part of its Wales Route.

10 The track on which the train derailed was installed by Amey Seco Joint Venture in 2008.

11 The rails were ultrasonically tested using train mounted and pedestrian operated equipment manufactured by Sperry Europe.

12 The rails had been ground at various times using a rail grinding train operated by Harsco.

13 DB Schenker, Harsco, Network Rail and Sperry UK freely co-operated with the investigation. Amey Seco Joint Venture no longer exists.

Train involved

14 The train involved was the 00:50 hrs freight train from Avonmouth Docks to Aberthaw power station. It comprised a class 66 locomotive and 21 loaded 102 tonne bogie hopper wagons (type HTA) (figure 4).

Figure 4: Derailed HTA wagon

Staff involved

15 The maintenance of the track was the responsibility of Network Rail's Cardiff infrastructure maintenance delivery unit. The unit was managed by the infrastructure maintenance delivery manager and, reporting to him, an infrastructure maintenance engineer to oversee the delivery of maintenance activities (the infrastructure maintenance engineer had been seconded to another post and the role was being covered by the Swansea *track maintenance engineer* at the time of the derailment). The infrastructure maintenance engineer had a number of specialist managers reporting to him that covered the technical disciplines. These included engineers who were responsible for track maintenance based at Newport, Cardiff and Swansea.

16 The track at Porthkerry was the responsibility of the Cardiff track maintenance engineer. He had 29 years of experience working in the railway industry. All of this time had been spent in track maintenance, initially as a *trackman* then moving on through supervisory roles to become *section manager (track)*. He had not worked in the Cardiff area before being appointed track maintenance engineer Cardiff, 18 months before the derailment. He had never walked the track at the site of the derailment.

17 Each track maintenance engineer had a number of section managers (track) reporting to them, each responsible for maintenance and inspection of part of the track in the track maintenance engineer's area. The section manager for the track at Porthkerry was the Cardiff section manager. He had 32 years of experience working in the rail industry, 29 of them in track maintenance. He had worked in various areas and had been section manager at Cardiff for over 11 years.

18 The infrastructure maintenance engineer post at Cardiff also had a rail management engineer reporting to it. The rail management engineer had 15 years of experience in the industry. He started as a graduate engineer and moved through various technical posts in track maintenance and rail management before becoming area rail management engineer (Wales & Marches) in 2004. In a reorganisation in 2008 he became rail management engineer, South Wales. Following another reorganisation in May 2014, the scope of the rail management engineer's role was expanded to cover the whole of the Wales Route. At the same time, management of the ultrasonic testing, rail grinding and welding teams which was formerly the responsibility of the rail management engineer, South Wales, was transferred to the track maintenance engineer, Newport.

19 Network Rail tests its rails ultrasonically for internal *defects* (paragraph 39). The most recent ultrasonic tests of the rail at Porthkerry were carried out by the team leader (rail testing) based at Cardiff. He had 22 years of experience in the rail industry. He started in track maintenance then went on to track inspection, becoming an ultrasonic tester in 2001.

External circumstances

20 The weather at the time of the derailment was dry with light winds and a minimum overnight temperature of 13°C. The weather conditions were not a factor in this accident.

The investigation

Sources of evidence

21 The following sources of evidence were used:

- information provided by witnesses;
- information taken from the train's On-train Data Recorder (OTDR);
- site photographs and measurements;
- examination of the train;
- data from Network Rail's wheel load monitoring installation at Marshfield;
- metallurgical analysis of rail fragments by a metallurgical specialist;
- the Health and Safety file from the 2008 relaying of the track;
- rail testing and inspection records;
- records from grinding trains;
- records from ultrasonic test trains;
- data from track recording trains;
- data from Network Rail's rail defect management system (RDMS);
- weather reports and observations at Cardiff Airport; and
- a review of previous RAIB, and other, investigations that had relevance to this accident.

The sequence of events

Events preceding the accident

22 The train was loaded with coal at Avonmouth Docks and its journey as far as Porthkerry was uneventful.

23 The train passed over a wheel load monitoring installation at Marshfield during its journey. Data from this installation showed that the wagons were evenly loaded and there were no high dynamic wheel loads, such as would be caused by wheel flats.

Events during the accident

24 The front of the train passed the site of the derailment travelling at 16.5 mph (26.5 km/h) and the locomotive and the first 19 wagons passed over the defective rail without incident.

25 As the 20th wagon ran onto the defective left rail, the *field side* of the rail head (figure 5) broke away from the rest of the rail. The weight of the wheels pressed the *gauge side* of the head down so that the wheels ran on the web of the rail. When examined by the RAIB after the derailment, the wheels on the left side of the 20th wagon (rear bogie) and 21st wagon (leading bogie) had marks on the tread consistent with them having run on a sharp edge, such as would be presented by the broken top surface of the rail web.

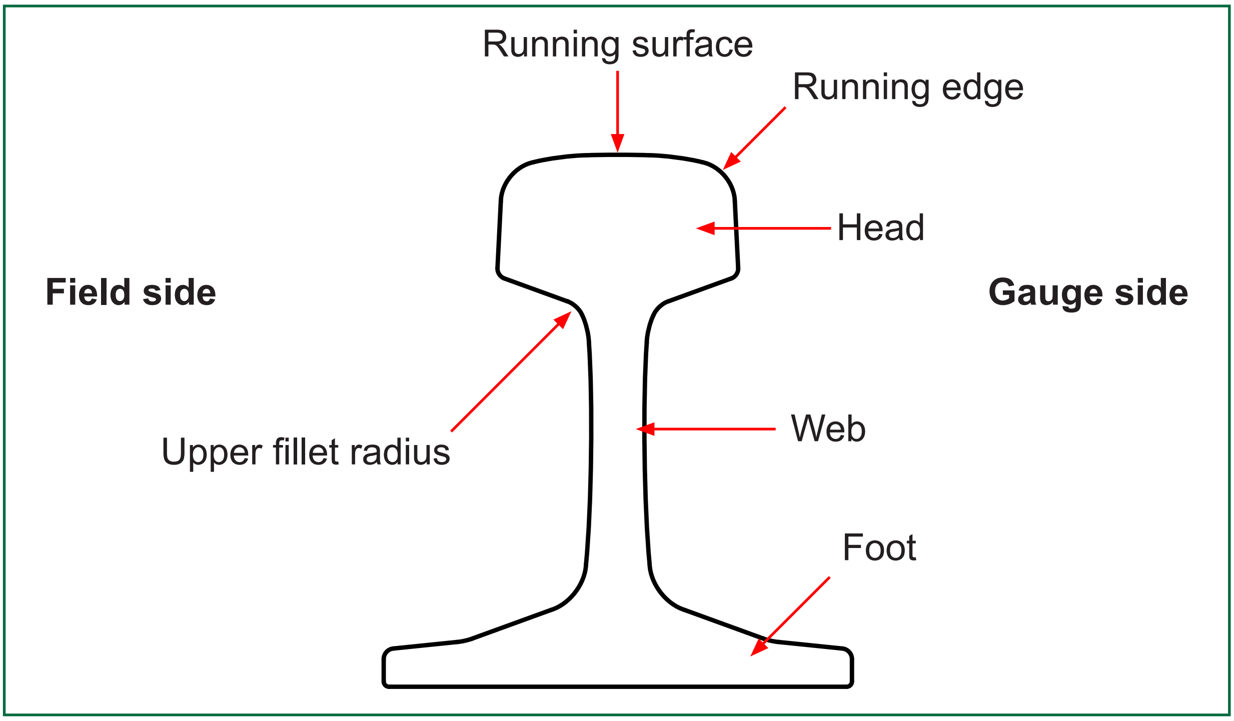

Figure 5: Nomenclature of rail

26 As the wheels ran on the exposed web of the rail, it was left with a smooth surface (figure 6) and the gauge side of the rail head was bent downwards. At the end of this section of rail, the gauge side of the head broke away in several pieces. The whole rail section failed at this point and some wheels struck the exposed end of the next piece of rail, breaking off three more pieces.

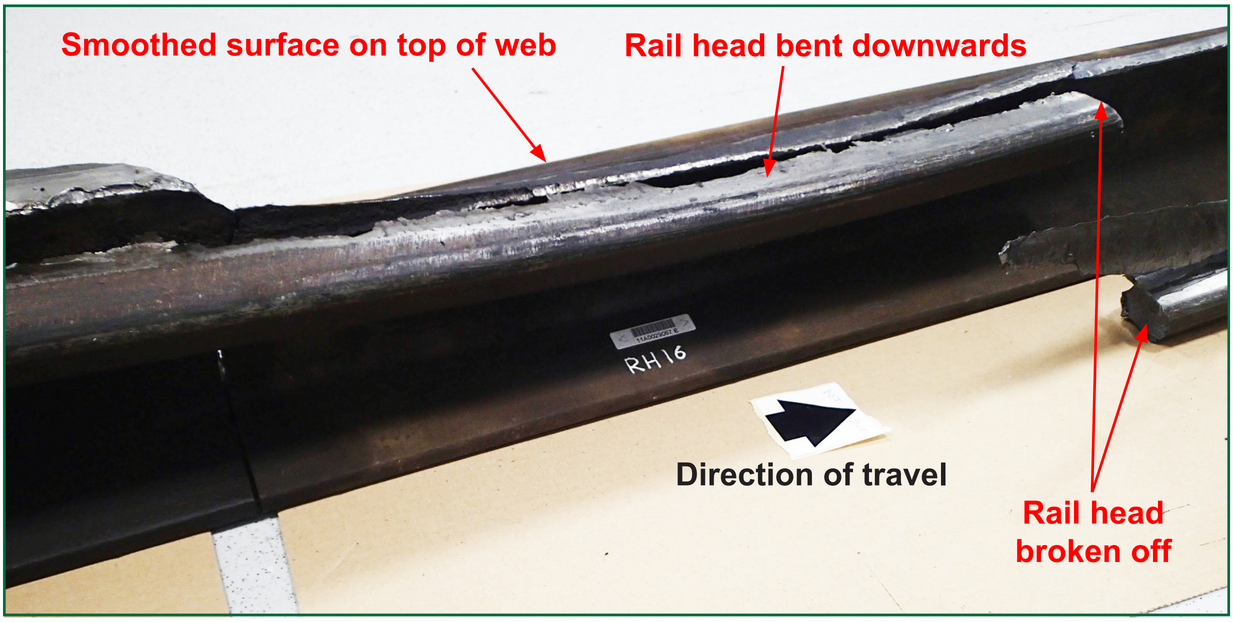

Figure 6: Fractured section of rail, showing smoothed surface of fractured web

27 The exposed end of the following section of rail was struck by the front of the 21st wagon and bent double. This length of rail then fractured near the end of the section of defective rail and the resulting U shaped piece of rail was pushed into the ballast beneath the track.

28 The last wagon, which was now completely derailed, ran through the ballast and diverged from the line of the track pulling the wagon in front of it sideways. Both wagons then ran through the ballast increasing the drag on the rest of the train until it stopped.

29 The driver had the throttle set on full power as the train was climbing the gradient but the train was stopped by the drag from the derailed wagons. The driver tried to restart the train but it was unable to move, despite the brakes being released and sand applied to the rails.

Events following the accident

30 The driver contacted the signaller by radio at 02:30 hrs to report that his train had slipped to a stand. The signaller noticed that two *axle counter sections* on the opposite line were showing failed status and he blocked both lines to traffic so that the driver could walk back and examine the train. The axle counters failed due to cable damage caused by the derailed train.

31 The driver walked back alongside the train and found the last two wagons were derailed. He reported the derailment to the signaller at 02:53 hrs.

32 The signaller reported the derailment to the Network Rail Wales Route control office and a Network Rail *mobile operations manager* was deployed to the site, arriving at 03:30 hrs.

33 Network Rail control reported the derailment to the RAIB at 03:00 hrs and two inspectors were deployed to site to gather evidence.

34 The wagons were rerailed on 3 October and taken to Aberthaw sidings for examination by the RAIB. This revealed no issues with the condition of the wagons that would have contributed to the derailment.

Key facts and analysis

Background information

Track Inspection

35 Network Rail has a standard for track inspection. This is defined in its document NR/L2/TRK/001. The document is divided into several modules which are referred to in the following paragraphs.

Visual inspection

36 The visual inspection process has several levels and is covered by NR/L2/TRK/001/mod02. The first of these is a basic visual inspection which is usually carried out by manual inspection, where a patroller walks the line. The frequency of the inspections is driven by the track category of the line, which is derived from the speed and tonnage of traffic using it, and the type of track. Track categories range from 1A, for high speed high tonnage lines, to 6, for the low speed low tonnage routes. The down line at Porthkerry was categorised by Network Rail as track category 4. A basic visual inspection was required every 4 weeks for category 4 track made up of *continuously welded rails*, as at Porthkerry.

37 In addition to the basic visual inspection, the section manager (track) and track maintenance engineer were also required to conduct visual inspections of the track. For track category 4, these inspections were required at 26 week and 2 year intervals, respectively.

Track geometry recording

38 This is covered by NR/L2/TRK/001/mod11 and required track geometry to be recorded at maximum intervals of 52 weeks, however at Porthkerry the geometry recording train was planned to operate every 24 weeks to fit in with the recording pattern of the other lines that were part of its schedule.

Ultrasonic Inspection

39 Network Rail tests its rails ultrasonically for internal defects using ultrasonic test trains (UTU). Standard NR/L2/TRK/001 mod06 requires ultrasonic testing at maximum intervals of 26 weeks for category 4 track. The UTU can only test plain line; other rails, such as in switches and crossings, must be tested by equipment mounted on a trolley which is pushed along by the operator (pedestrian testing).

40 The data recorded by the UTU is analysed by Sperry Europe under contract to Network Rail to identify ‘*suspect*’ defects in the rails. Details of these suspects are input to Network Rail’s rail defect management system and a summary of them is emailed to Network Rail’s rail management engineer and *section manager (rail testing and lubrication)* for the area concerned.

41 The ‘suspects’ found by the UTU are treated as such until they are verified by pedestrian testing of the rail. Standard NR/L2/TRK/001 mod06 defines maximum allowable response times between Sperry notifying Network Rail of the presence of a suspect and it being verified by pedestrian testing.

42 The pedestrian testers use the location information, in terms of track mileage, provided from the UTU to identify roughly where the 'suspect' is. The UTU is fitted with a GPS system which tags each suspect with its GPS location. The pedestrian testers go to that location by using a hand held GPS unit to verify that they are at the same GPS coordinates. The standard tells them to test a length of rail each side of that location. This length is the greater of the distance of uncertainty indicated on their GPS unit or 22 yards.

43 If the pedestrian testers verify the presence of the suspect it is confirmed as a defect. The action to be taken is defined in standard NR/L2/TRK/001 mod07 'management of rail defects'. This gives minimum action codes according to defect type, size, location and track category. The details of the defect and the minimum action codes are input to Network Rail's rail defect management system.

44 If the pedestrian testing does not confirm the presence of the defect, this fact is entered into the rail defect management system and communicated to Sperry via another system, VDMA. Sperry can view the verification data in VDMA when analysing the data from the next UTU run, though the data which Sperry can see is limited. When a defect has been removed from the track Network Rail records this fact in the rail defect management system.

Rail Defects

Vertical Longitudinal Split (VLS)

45 Rails rolled before 1976 sometimes contained defects due to the inclusion of impurities from the steel casting process. Steel which was cast into separate ingots was prone to the inclusion of impurities near the end of the ingot. Impurities in the ingot would become elongated as the ingot was rolled into a rail resulting in a longitudinal defect in the rail. Because of the way that the rail shape was gradually formed in the rolling process, these defects tended to occur mainly in the head and web of the rail.

46 These impurities often took the form of changes in the microstructure of the steel which do not disrupt ultrasonic signals and so cannot be detected by ultrasonic testing. However, the changed microstructure is not as strong as the rest of the steel and microscopic fractures can form under loading, leading to a crack forming within the steel. This crack can be detected by ultrasonic testing and is known as a VLS rail defect.

47 In 1976 the steelmaking process for rail steel was changed to the 'concast' continuous casting process. This involves casting the steel in one continuous pour and cutting the resulting string of steel into the separate ingots that the rails are rolled from. This avoids the risk of inclusions due to impurities at the ends of the cast. VLS defects are not found in post-1976 rails.

48 The standard ultrasonic test for rails is known as U15[1], and is carried out with a set of ultrasonic probes on top of the rail looking at various angles down into the rail (figure 7). This test can be done from the UTU or by pedestrian testing. As the U15 test looks down from the top of the rail, VLS defects can be difficult to spot as they are aligned with their smallest dimension, their width, facing the ultrasonic beams. If a VLS defect is suspected, another test can be performed, U8, from the side of the rail. This test uses a hand-held probe to look sideways through the rail head and web. Any VLS defect would be perpendicular to this direction making it easy to spot in the ultrasonic response. As it requires a probe on the side of the rail, U8 testing cannot be performed from a UTU.

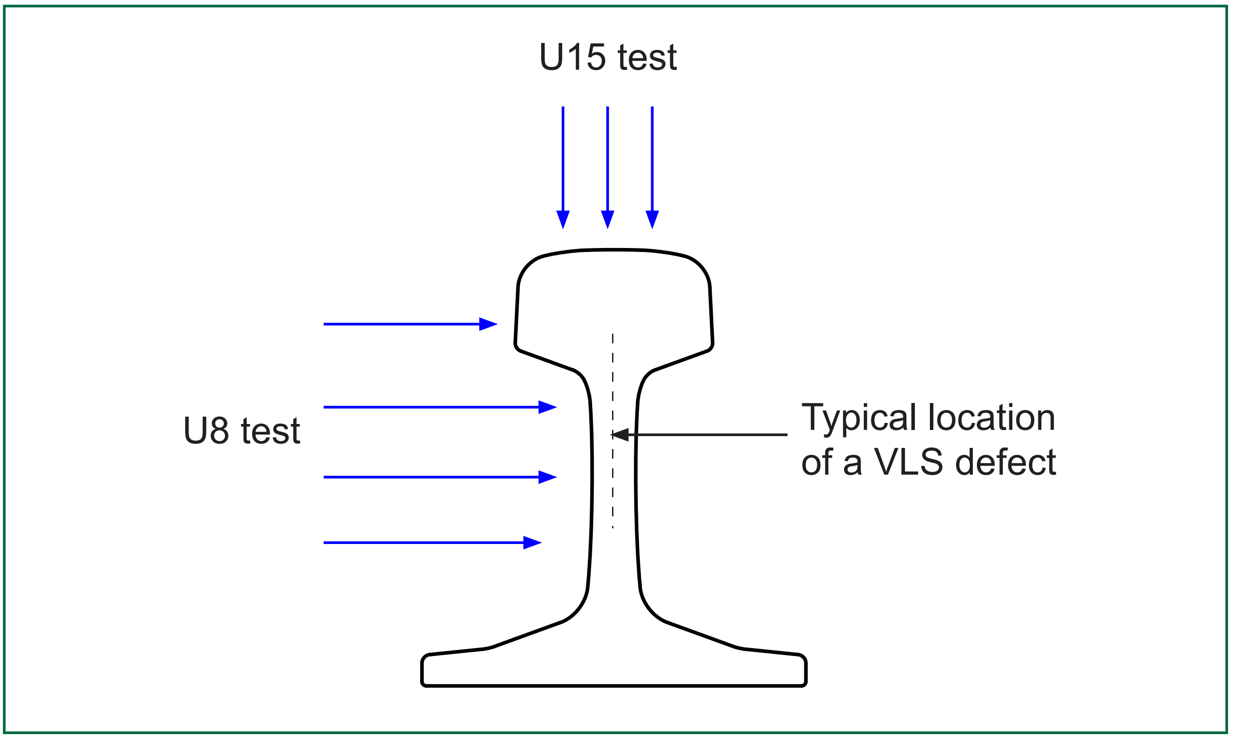

Figure 7: Direction of ultrasound in U8 and U15 tests

49 Since the VLS defect is difficult to identify from the UTU or U15 pedestrian test, Network Rail standard NR/L2/TRK/001 mod06 'Visual inspection and ultrasonic testing of rails' specifies that rails rolled in 1976 or earlier should be visually inspected to look for [signs of] VLS and other defects that cannot be detected by the UTU (such as excessive rail corrosion). The interval between these inspections varies according to the track category and for the track at Porthkerry the interval was 2 years.

[1] Network Rail standard NR/SP/TRK/055 (issue 1A, 1998) defined a series of ultrasonic test procedures, U1 to U14, to be used for rail testing. Letter of instruction NR/BS/LI/276 was issued in October 2012 and defined three further test procedures, U15-U17.

50 Network Rail stipulates the minimum action to be taken when a defect is found in standard NR/L2/TRK/001 mod07 'Management of Rail Defects'. Network Rail's metallurgist informed the RAIB that the minimum actions for VLS in this standard had been derived empirically and were based on many years of experience of this type of defect. This experience had shown that VLS defects could remain dormant in rails for several decades. A VLS defect only became a risk to the safety of the line when it started to grow and this was evident either by a depression in the surface of the rail, disruption in the shiny running band on the head of the rail, a crack appearing on the surface of the head or web and/or by a visible bulge developing. For this reason, two actions were defined; if the defect gave rise to a visible bulge or crack then urgent action should be taken to replace the rail, but if there was no evidence of this then, depending on the track category, the defect should be monitored until it could be removed as part of routine maintenance.

51 The time allowed for the removal of a VLS defect that had not caused cracking or bulging depended on the track category. For track in categories 4 - 6, as at Porthkerry, the standard did not specify a time for replacement of the rail and instead allowed it to be left in track and monitored. Wales Route applied a more stringent action on its route and, on category 4 track, aimed to replace the rail within 52 weeks.

Rolling Contact Fatigue (RCF)

52 Rails in curved track can be subject to RCF. This can occur in the outer (or high) rail of curves in high speed track, where fatigue cracks appear at regular intervals on the rail head. These cracks can grow and turn downwards into the head, breaking the rail. Standard NR/L2/TRK/001 mod07 specifies minimum actions to be taken at sites where RCF has been detected on the high rail.

53 The inside (or low) rail in curves can also be subject to RCF in situations where it is heavily loaded. This occurs if the line is used by heavy trains travelling at low speed, as is the case at Porthkerry. Fatigue cracks can form on the head of the rail but these do not tend to turn downwards into the head. Rather they join up and lead to pieces of the rail head becoming detached from the surface. This damage can make it difficult to ultrasonically test the rail.

54 Standard NR/L2/TRK/001 mod07 specifies minimum actions to be taken when low rail RCF is detected. It also states that ultrasonic suspects found in rails in RCF sites should be verified to shorter timescales than in non-RCF sites.

The rail at Porthkerry

55 The track at the site was relaid in August 2008 (table 1 lists the key events between then and the time of the derailment). The 'Track Renewals Particular Specification' for the relaying work stated that the reasons for the renewal were poor rail condition throughout the site and formation failure over part of the site. The sleepers were replaced with new concrete sleepers and the rails were replaced with rail which had previously been used at another, unrecorded, site.

Date	Event
10 August 2008	Track relaid
10 February 2011	Rails ground by grinding train to reduce lipping and head spread
8 August 2012	Site declared an RCF site
9 December 2012	Rails ground by grinding train to reduce lipping and head spread
4 February 2013	RCF inspection
7 May 2013	RCF inspection
10 October 2013	RCF inspection
8 November 2013	Ultrasonic inspection with modified pedestrian test unit (‘walking stick’)
16 December 2013	Ultrasonic test train ran, suspect VLS found
18 December 2013	Pedestrian test carried out, but did not confirm suspect VLS
13 January 2014	Rail ground by grinding train to remove lipping
4 April 2014	Ultrasonic test train ran, suspect VLS found
8 April 2014	Pedestrian test carried out, but did not confirm suspect VLS
13 May 2014	RCF inspection
30 July 2014	RCF inspection, found VLS
30 August 2014	Rail ground by rail grinding train to remove lipping
2 October 2014	Derailment occurred

Table 1: Key events affecting the down line at Porthkerry, details in paragraphs 57 to 63

56 Network Rail’s infrastructure database indicated that the rails that were removed in 2008 had been manufactured in 1977 and had been installed at Porthkerry in 1978. Records of rail grinding showed that these rails had been ground in 2004 and twice in 2007. The rails installed in 2008 were ground for the first time in 2011.

57 A track inspection in August 2012 found that the low rail in the curve was showing signs of RCF and the site was declared an RCF site. This meant that regular RCF inspections were required, according to Network Rail’s standard NR/L2/TRK/001 mod07 ‘Management of rail defects’. RCF inspections were carried out at 13 week or 26 week intervals[2] from August 2012 to the time of the derailment.

58 The RCF inspections involved the use of pedestrian ultrasonic test equipment, known as the Sperry ‘walking stick’ (figure 8). This is fitted with double flanged wheels to guide the ultrasonic test wheel along the head of the rail.

[2] Standard NR/L2/TRK/001 mod07 specifies a minimum action for this track category of inspection at 26 week intervals but Wales Route applied a more stringent action of inspection at 13 week intervals. One of the inspections was scheduled at a 26 week interval due to an oversight.

Figure 8: Sperry ultrasonic 'walking stick'

59 During some of the RCF inspections the rail was found to be deformed such that a lip had developed on the field side. This lip made the rail head wider and, in some locations, prevented the walking stick from being pushed over it, as the flanges on each side of its wheels were not far enough apart to cope with the width of the lipped rail. When this was found to be the case the tester reported on the test report sheet that the rail was ultrasonically untestable due to head profile. The rail defects standard, NR/L2/TRK/001 mod07 defines the action that must be taken in these circumstances, which is to replace the rail or reprofile the rail head (by grinding) and retest it within 4 weeks.

60 The Wales Route asset manager (track) had given the Wales Route delivery units dispensation for one of their ultrasonic testers to be permitted to test the rail in these circumstances using a modified walking stick. The modification consisted of removing one of the wheel flanges from each wheel so that the walking stick could cope with rail with lipping. The rail could then be tested. The dispensation stated that, when this modified procedure was employed, it must be recorded on the result sheet and the lipping must be ground off within 6 months so that the next ultrasonic test could be done with an unmodified walking stick. The modified procedure was used for the ultrasonic test carried out as part of an RCF inspection in November 2013.

61 The rail was ground on 13 January 2014 by a grinding train to remove the lipping. The report sheet produced for Network Rail's rail management engineer by the grinding contractor, Harsco, recorded that 28 passes had been made but the work was not completed due to 'lack of sufficient time and poor rail condition'. However, sufficient grinding was completed to allow the use of a standard Sperry walking stick for the next RCF inspection.

62 The RCF inspection on 13 May 2014 did not report any ultrasonic rail defects, but the subsequent one on 30 July 2014 found a VLS defect between 1 mile 321 yards and 1 mile 340 yards. The testers marked the defect by painting its identity number 'CF715' onto the rail at each end of the defect. Their test result sheet also reported that the rail was lipped and would be untestable by the time of the next test 13 weeks later, unless the lipping was removed.

63 A switch and crossing grinder was diverted from another site to Porthkerry on 30 August 2014 to remove the lipping. The report sheet from the grinding shift stated that it had made 25 passes in the possession time available but had not completely removed the lipping. The sheet stated that the rail was in 'very poor condition'.

Identification of the immediate cause

64 The left rail broke up as the train was passing over it.

Identification of causal factors

65 The rail broke because of a combination of the following causal factors:

a) the rail contained an inherent defect (paragraph 66);

b) the inherent defect in the rail was not discovered when the rail was recycled to the site in 2008 (paragraph 74); and

c) the rail was not replaced before the derailment (paragraph 90).

Each of these factors is now considered in turn.

Rail Manufacture

66 **The rail contained an inherent defect that had been present since manufacture.**

67 The branding marks rolled onto the rail indicated that it was manufactured in 1966 by Dorman Long to the BS110A profile. Rail of this age may contain longitudinal defects (paragraph 45).

68 Fragments of the broken rail recovered from the site by the RAIB were subjected to detailed analysis by metallurgists. The analysis included cutting sections through the rail and conducting various tests and analysis.

69 All of the rail breaks occurred in one 60 foot length of rail which was connected to the adjacent rails by a *thermit weld* at one end and a *flash butt weld* at the other.

70 The presence of impurities in steel can be revealed by making a *sulphur print* of the surface of a cut section. This shows sulphide compounds in the steel which can reveal *segregation* within the metal. The metallurgist produced a sulphur print of a section of this rail (figure 9) which showed that there were distinct signs of segregation of the metal in the centre of the web which extended up into the head.

71 Examination of the fracture face of one of the sides of the VLS fracture showed indications of multiple defects in the steel oriented in the rolling direction of the rail (figure 10). This is consistent with impurities in the steel at manufacture being elongated along the rail as it was rolled.

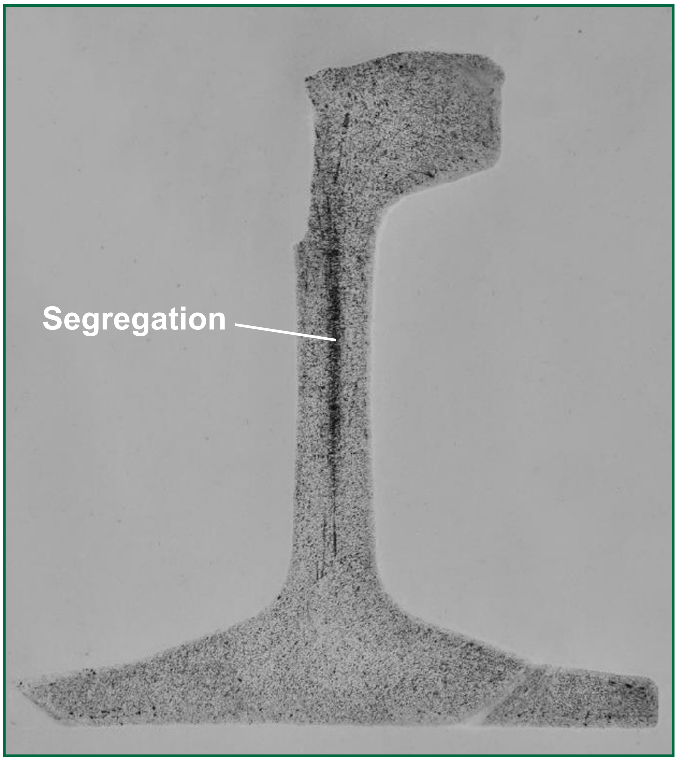

Figure 9: Sulphur print of rail showing segregation in web extending up into head (image courtesy of Serco Rail Technical Services)

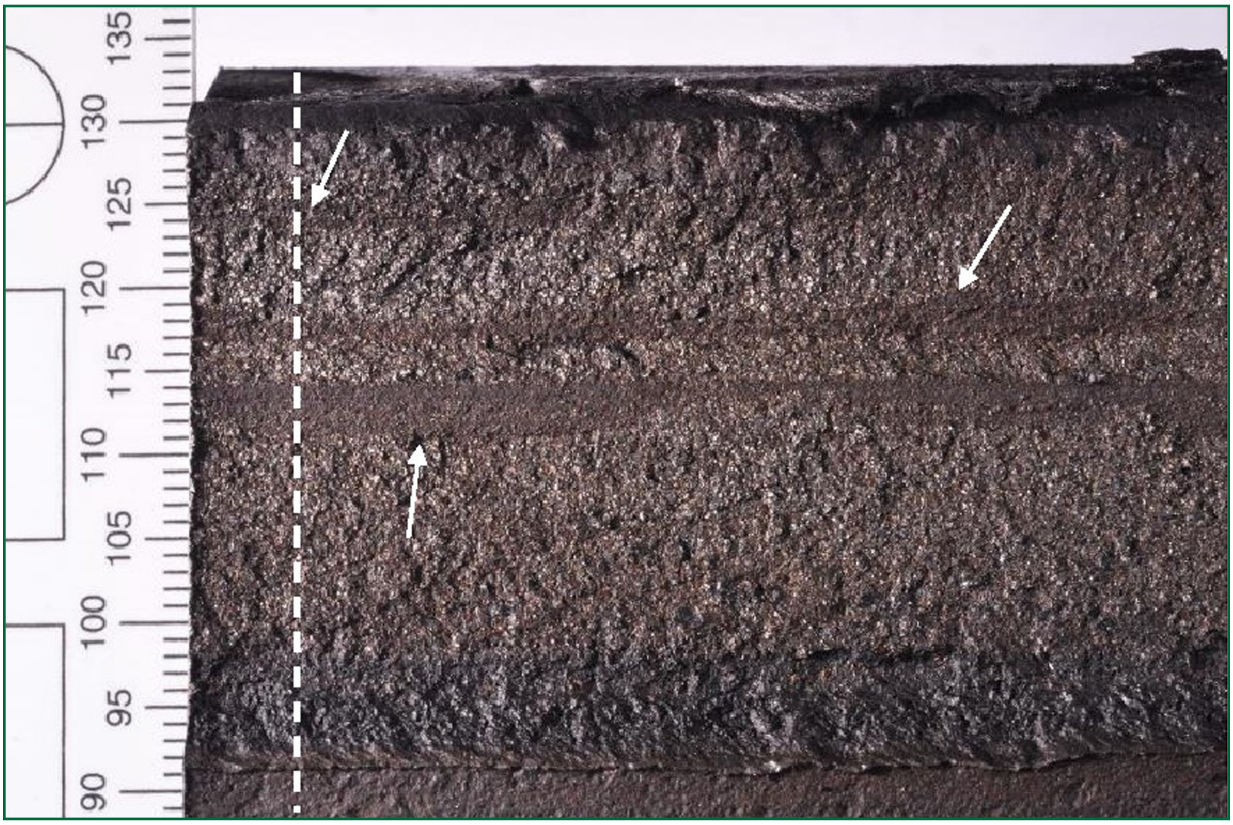

Figure 10: Fracture face of VLS crack showing multiple defects (arrowed) oriented in the rolling direction (image courtesy of Serco Rail Technical Services)

72 The position of the split within the rail cross section was evident in several places where the rail had completely broken. In addition to these breaks, there was a length of rail each side of the broken area where the split had opened up within the rail head but had not yet led to complete failure. The RAIB asked Network Rail to cut out a short length of apparently undamaged rail on the approach to the point of derailment (figure 11). This revealed that the piece of rail cut out was in two pieces, with fractures between the head and web at the *upper fillet radius* (figure 12). The cut ends of the rail revealed the extent of the split in the head (figure 13).

Figure 11: Apparently intact rail on the approach to the point of derailment

Figure 12: The two pieces of rail seen in figure 11

Figure 13: Cross-section of rail showing extent of VLS

73 Evidence of the split in the head was found in all of the rail samples which the RAIB recovered from the site. As stated in paragraph 69, these were all from the same length of rail, and were due to an inherent defect present in the steel at the time of manufacture.

Rail Installation

74 **The inherent defect in the rail was not discovered when the rail was installed at Porthkerry in 2008.**

75 The specification for the track renewal (paragraph 55) stated that new concrete sleepers and serviceable BS113A grade A rail were to be used. At the time of the renewal there was a Network Rail standard, NR/SP/TRK/002 issue 2, 1999 'Serviceable rail for use in running lines', which required that serviceable rail was tested and inspected before reuse.

76 The track was relaid by Amey Seco JV in August 2008. As required by the Construction (Design and Management) Regulations 2007 (the CDM Regulations), a health and safety file was compiled for this work. The file contained various construction records, including a form entitled 'I&I Track – Plain Line GEOGIS/Construction details'. This stated that all of the rail installed during the renewal work was cascaded[3] BS113A rail of *normal grade* rolled in 1977. This information was used to update Network Rail's infrastructure database.

[3] The terms 'serviceable' and 'cascaded' can be applied to rail which has been used in one location then removed to another location for further use. At the time of the relaying in 2008, Network Rail's track construction standard NR/SP/TRK/102 issue 5, 2002, did not distinguish between these two terms. However, a later revision, NR/L2/TRK/2102 issue 6 in 2010 defined the term 'cascaded' to mean rail that was removed from one location and taken straight to another with no testing or examination.

77 The health and safety file also contained copies of weld inspection certificates for the rail welds made during the relaying work. These gave details of the type and profile of the rails joined along with the position of the weld along the track. The RAIB used the information on these certificates to produce a graphical representation of the age and profile of the left (low) rail (figure 14). This showed that the predominant rail type was normal grade BS110A rolled in 1966. There was only one grade of rail specified in the British Standard for rail (BS11:1959, 'Flat Bottom Railway Rails') in 1966, and this corresponded to the modern 'normal' grade, but amendment 2 to that standard in January 1964 stated that the chemical composition and properties required from the steel should be agreed between the manufacturer and customer. It is possible that British Railways agreed improved properties with Dorman Long for these rails because, when tested by the metallurgist, the chemical composition was found to be close to the modern *'wear resisting A' grade*.

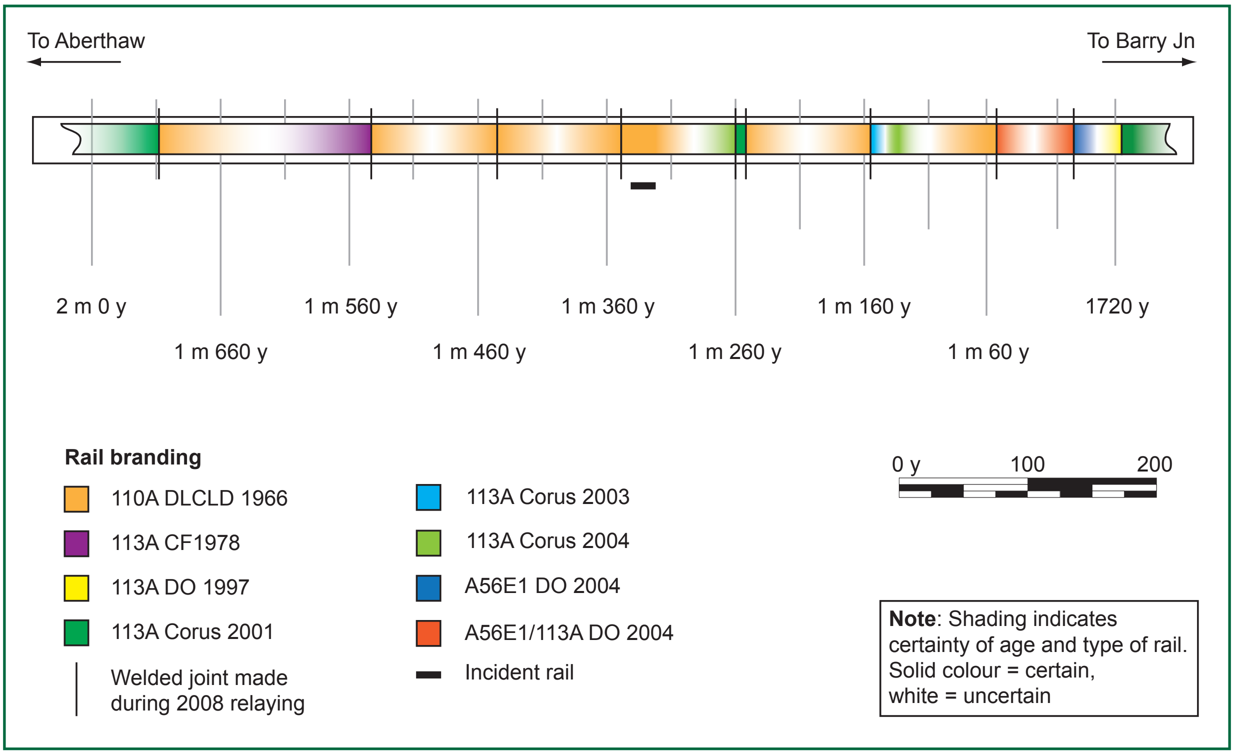

Figure 14: Plan of left-hand rail at Porthkerry showing rail type and age

78 In addition to the BS110A rail, the weld certificates also recorded lengths of newer rail of normal grade BS113A section. Contrary to what was declared on the plain line GEOGIS/Construction details form (paragraph 76), no lengths of 1977 rail were recorded on the welding certificates.

79 The health and safety file did not record where any of the rail had been used before its installation at Porthkerry in 2008. Network Rail has been unable to provide the RAIB with any indication of the rail's previous use. However, given the age of the rail when it was installed at Porthkerry and its subsequent relatively rapid collapse, the RAIB has concluded that it is likely to have been used on a relatively lightly loaded line.

80 The health and safety file does not record whether any testing of the rail was done before, or during, the relaying work. Consequently, there are three possibilities regarding the status of the VLS defect at that time (2008):

a) the VLS defect may not have been present (paragraph 81);

b) the VLS defect may have been too small to detect (paragraph 86); and

c) the rail may not have been tested (paragraph 89).

Each of these factors is now considered in turn.

The VLS defect may not have been present in 2008

81 Longitudinal defects such as VLS arise from inclusions in the rail (paragraph 45). These inclusions may not develop into defects if the rail is lightly loaded and in lightly trafficked lines they can remain 'dormant' for many years. The rail that was installed at Porthkerry in 2008 had been in use at another location for over 40 years.

82 After installation at Porthkerry, the rail was subject to the standard regime of regular ultrasonic and visual inspection. The VLS defect was not found until December 2013 when it was picked up as a suspect VLS defect during analysis of the UTU data. Pedestrian testing was carried out close to the location reported by the UTU but the suspect VLS was not confirmed.

83 The next UTU run in April 2014 also found suspect VLS at this location and, again, the pedestrian testing did not confirm it, but did report intermittent loss of rail bottom signal. The loss of rail bottom signal means that something within the rail has interrupted the path of the ultrasonic beam from the rail head to the foot and back.

84 The VLS defect had developed to the extent that it caused significant loss of rail bottom signal at the time of the RCF inspection on 30 July 2014, and this triggered a U8 test from the side of the rail which found the longitudinal extent of the defect.

85 The fact that the regular ultrasonic testing process did not find the defect between 2008 and 2013 but then found it on both subsequent runs implies that the defect was developing over time and it is possible that it was not present when the rail was installed in 2008.

The defect may have been too small to detect in 2008

86 The test that would have been carried out if the rail had been tested before or during installation was an ultrasonic test with probes looking down into the rail. This was not designed to find VLS defects (paragraph 48). However, a split developing in the rail can lead to the ultrasonic signal from the rail bottom becoming blocked. This will only occur when the split becomes large enough to disrupt the ultrasonic beam. A small vertical crack may therefore be undetectable using this test.

87 Given that subsequent testing from the top of the rail by the UTU in 2008 did not find a defect, it is likely that if the defect had been present, it would have been too small to be detected.

88 Where a rail is suspected of containing a VLS defect the most appropriate test to confirm this is the U8 test, which is carried out from the side of the rail. Network Rail's standard NR/SP/TRK/055 'Rail Testing: Ultrasonic procedures' only requires a U8 test to be performed when a U15 test has found a loss of rail bottom signal greater than 50% over a length of 50 mm or more, with the signal boosted by a defined amount.

The rail may not have been tested before installation

89 As stated in paragraph 75, the rail specified for the renewal was serviceable grade A 113A rail and, according to standard NR/SP/TRK/002, this should have been ultrasonically tested before installation. However, there is no record in the health and safety file of any testing of the rail before, or during installation. It is therefore possible that the rail was not tested.

The rail was not replaced

90 **The rail was not replaced before it collapsed under the train. The following factors contributed to this:**

a) the visual inspection intended to identify VLS in pre-1976 rails was not carried out (paragraph 91);

b) the regular visual track inspections did not find the defect (paragraph 93);

c) the VLS was not confirmed following earlier UTU testing (paragraph 101); and

d) once discovered, the defect was not identified as needing urgent replacement (paragraph 105).

Visual inspection to identify VLS in pre-1976 rails was not done

91 Network Rail's standard NR/L2/TRK/001 mod06 clause 4 states 'Visual inspections of rail are carried out to identify rail head damage, vertical longitudinal splitting (VLS), significant rail corrosion and lipping on adjustment switches.' The standard states that these inspections are required for all pre-1976 rail.

92 This inspection was not done on the rail at Porthkerry because Network Rail's records stated that this rail was rolled in 1977 (paragraph 76). If this inspection had been done, it would have increased the likelihood of the VLS being detected as this inspection should have been focussed on finding this type of defect.

Regular visual track inspections did not identify the defect

93 Basic visual inspections were required every 4 weeks (paragraph 36). The most recent basic visual inspection before the derailment was performed on 14 September 2014. The patroller reported 'no actionable defects' on the TEF3015 'Basic Visual Inspection Report' form. Patrollers are not looking for rail defects but are expected to report anything that might endanger the continued safe operation of trains.

94 Supervisor's inspections were required every 26 weeks (paragraph 37). The most recent one before the derailment was undertaken by the section manager (track) on 23 July 2014 and he recorded his findings on a TEF3022 'Supervisor's Visual Inspection Report' form. The inspection walk covered the line between Aberthaw and Barry, a distance of 5 miles (8 km). The completed TEF3022 form contains observations and actions for various issues identified during the inspection. Some of these were linked to a specific track, for example comments regarding the alignment of the down line, and some were made with regard to the railway as a whole, for example comments regarding the track drainage.

95 The section manager (track) made a comment about the left (low) rail on the down line: 'Coming out of the tunnel mouth on the Down to 1m 15 where we had this poor rail on the left-hand rail. Still poor its looking better since we had the grinder through but not brilliant' [sic]. Nothing was entered against this item in the columns for work required and priority.

96 The report form did not contain any work items to deal with the rail at the site of the derailment and the form ended with the comment 'It is what it is around here, it's the formation and rail problems which aren't going to go away until things are renewed, re-ballasted and re-railed. Just got to keep doing our best to keep it going'.

97 Inspections by the track maintenance engineer were required every 2 years (paragraph 37). The most recent track maintenance engineer's inspection was done by an asset engineer from the route asset manager (track) team on 23 July 2014. The track maintenance engineer was on leave at the time and so delegated his inspection to the asset engineer (standard NR/L2/TRK/001 mod02 allows the track maintenance engineer to delegate his inspection to a person approved by the route asset manager (track)).

98 The asset engineer completed a TEF3017 'Engineer's Visual Inspection Report' form. This contained the comment 'very poor rail head condition on low rail, low rail head profile, flat spots and bulging. Rerail proposal' against the mileage 1 mile 88 yards to 1 mile 352 yards on the down line. The priority column was filled in 'M12'. The priority of M12 means that the work should be done, or reprioritised, within 12 months. The asset engineer told the RAIB that he did not consider that the bulging was due to a VLS defect needing urgent replacement. He considered 12 months to be a reasonably practical timescale for this length of rerailing to be planned and executed.

99 The part of standard NR/L2/TRK/001 mod02 which allows a track maintenance engineer to delegate his inspection also states that when this is done the track maintenance engineer and the person who does the inspection must discuss the findings and the track maintenance engineer must countersign the TEF3017 form. This was not done. The track maintenance engineer stated that he had been unaware of this requirement at the time. The work items proposed by the asset engineer on the report form were not seen by the track maintenance engineer and therefore not input to Network Rail's Ellipse work planning system.

100 These inspections were not targeted at identification of the signs of a VLS defect, but there was an opportunity for them to be identified. However, in the case of the rail at Porthkerry, identifying such signs by visual inspection was made difficult by the poor condition of the head due to RCF and lipping.

The VLS defect was not confirmed following UTU testing

101 As reported in paragraphs 91 to 100, the normal arrangements for dealing with VLS defects did not identify this defect. However, the track at Porthkerry was tested by the UTU at regular intervals and, whilst the test performed by the UTU from the top of the rail is not designed to find VLS, the analyst who analysed the results from the UTU run on 16 December 2013 suspected that it might be present. Sperry reported the start mileage of the suspected VLS, 1 mile 295 yards, but did not report its extent. It gave it a suspect ID of 317562 in the rail defect management system. The Network Rail ultrasonic tester who went out to verify the suspect went to the GPS coordinates of the start point at 1 mile 295 yards and tested 22 yards each side of this, as he was required to do by standard NR/L2/TRK/001 mod06. He conducted a U15 test and did not find a loss of rail bottom signal for 50 mm or longer, so reported that the suspect was not confirmed as a defect.

102 On the next UTU run on 4 April 2014, the Sperry analyst again suspected a VLS defect starting at 1 mile 300 yards and reported it to Network Rail as a repeat of suspect ID 317562. The Network Rail ultrasonic tester went to the GPS coordinates of the location indicated, 1 mile 300 yards, and tested 22 yards each side. He reported intermittent loss of the rail bottom signal, but as no individual gap in the signal was longer than 50 mm, he did not resort to using test U8 and did not confirm the presence of a VLS defect.

103 The RAIB examined the ultrasonic data from these two runs with a Sperry ultrasonic specialist and identified the length of rail which broke up in the derailment. The welds at the ends of this section of rail were shown in the December 2013 data to be at mileages 1 mile 322 yards and 1 mile 342 yards. This length of rail started 27 yards from the start point of the suspect VLS which Sperry reported to Network Rail in December 2013, but was part of the length that was suspected of containing the VLS defect (figure 15). Neither of the pedestrian tests done to verify VLS suspect 317562 had tested the length of rail which failed during the derailment.

104 The VLS defect was confirmed following a U8 test during an RCF inspection on 30 July 2014 (paragraph 62). The action applied to the defect was 3L, which required that the rail was replaced within 52 weeks.

The VLS defect was not identified as needing urgent attention

105 The process which Network Rail usually employs to identify VLS defects in rail is by dedicated visual inspection (paragraph 91). However, when the down line at Porthkerry was declared an RCF site in August 2012 (paragraph 57), an additional series of regular inspections was begun with the aim of monitoring the progression of the RCF. These included both visual and ultrasonic inspection of the rail. They were carried out by the ultrasonic inspection team, who reported via the section manager (rail testing and lubrication) to the rail management engineer until May 2014, and the Newport track maintenance engineer from then on.

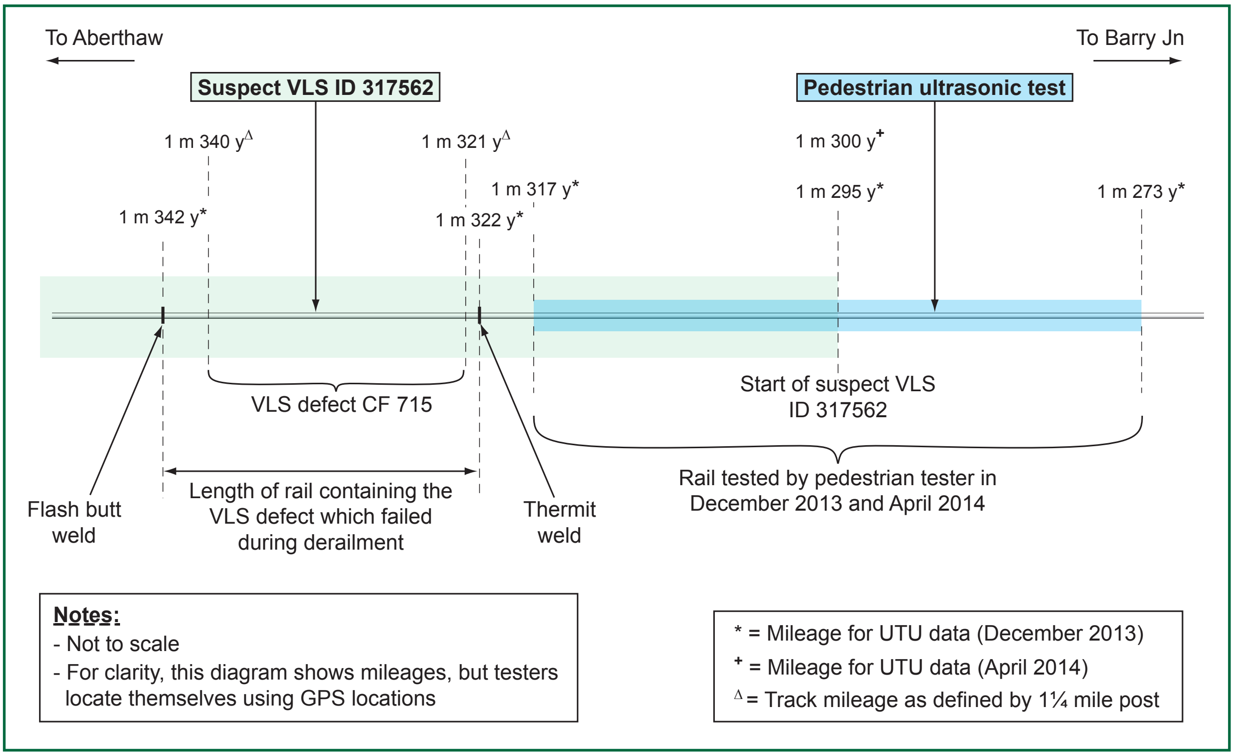

Figure 15: Diagram showing relative position of features on left-hand rail of down line

106 The RCF inspection on 30 July 2014 found the VLS defect (paragraph 62) and assigned it identity 'CF715'. Details of it were input to the rail defect management system. Standard NR/L2/TRK/001 mod07 specifies the minimum action to be taken on discovery of rail defects. The action for a VLS in the head or web of the rail depends on whether the rail shows signs of the split widening; if there are signs, defined as the head spreading by 2 mm or more or there being visible cracking on the surface of the rail, the minimum action is '1B'. Action 1B means that an immediate 20 mph emergency speed restriction should be imposed and the rail should be replaced within 7 days. If there are no signs of the split widening, the action is less urgent and depends on the track category; for the track at Porthkerry the minimum action was '3M', which, for category 4 track, is to retest the rail at 104 week intervals. However, Wales Route had a policy of not leaving defects in track indefinitely (paragraph 51) and, where the minimum action was '3M', applied the next highest action, '3L', which is to remove the defect within 52 weeks.

107 The RCF inspection on 30 July 2014 did not identify any spreading of the head or cracking of the rail due to the VLS, so the action assigned was '3L'. The poor condition of the rail head due to the RCF and the lipping on the field side of the rail head would have obscured visual evidence of head widening. The metallurgical examination of the rail (paragraph 68) revealed that the VLS crack had not reached the rail head, but had broken through to the surface at the upper fillet radius (figure 5). The inspector stated that he used calipers to measure the head width below the lipping and he did not find it was spread by as much as 2 mm. The inspector also stated that he looked for cracking beneath the head of the rail and did not see any evidence of this. The cracking at this position was difficult to identify without conducting non-destructive testing (paragraph 113).

108 The report of the RCF inspection on 30 July 2014 mentioned that the lipping on the rail would be likely to develop to the extent that the rail would become untestable by the time of the next RCF inspection 13 weeks later. The inspector told the RAIB that this comment was made so that the section manager (track) would have time to arrange for a grinder to remove the lipping.

109 The section manager (track) diverted a rail grinding unit from another site to grind the rail at Porthkerry on 30 August 2014. The unit was operated by Harsco who reported the results of the grinding work to Network Rail on a spreadsheet report form. This stated that the unit had ground the low rail between 0 miles 1650 yards and 1 mile 440 yards and had made 25 passes over the site. The 'additional information' section of the sheet stated that 'The cess rail was in very poor condition and very thin in places. Because of this the RCF and lipping was reduced not removed (see attached photos) Unable to properly profile cess rail because of this.' The report was sent to Network Rail as an attachment to an email but the photographs referred to were not actually attached to the email. The rail management engineer stated that he had tried to obtain these photographs but was unsuccessful.

110 The RAIB obtained copies of the photographs taken by Harsco and they show the condition of the rail after the grinding work. One of the photographs (figure 16) shows a dark band in the centre of the rail head which is a sign that the head was starting to collapse into the void formed by the VLS.

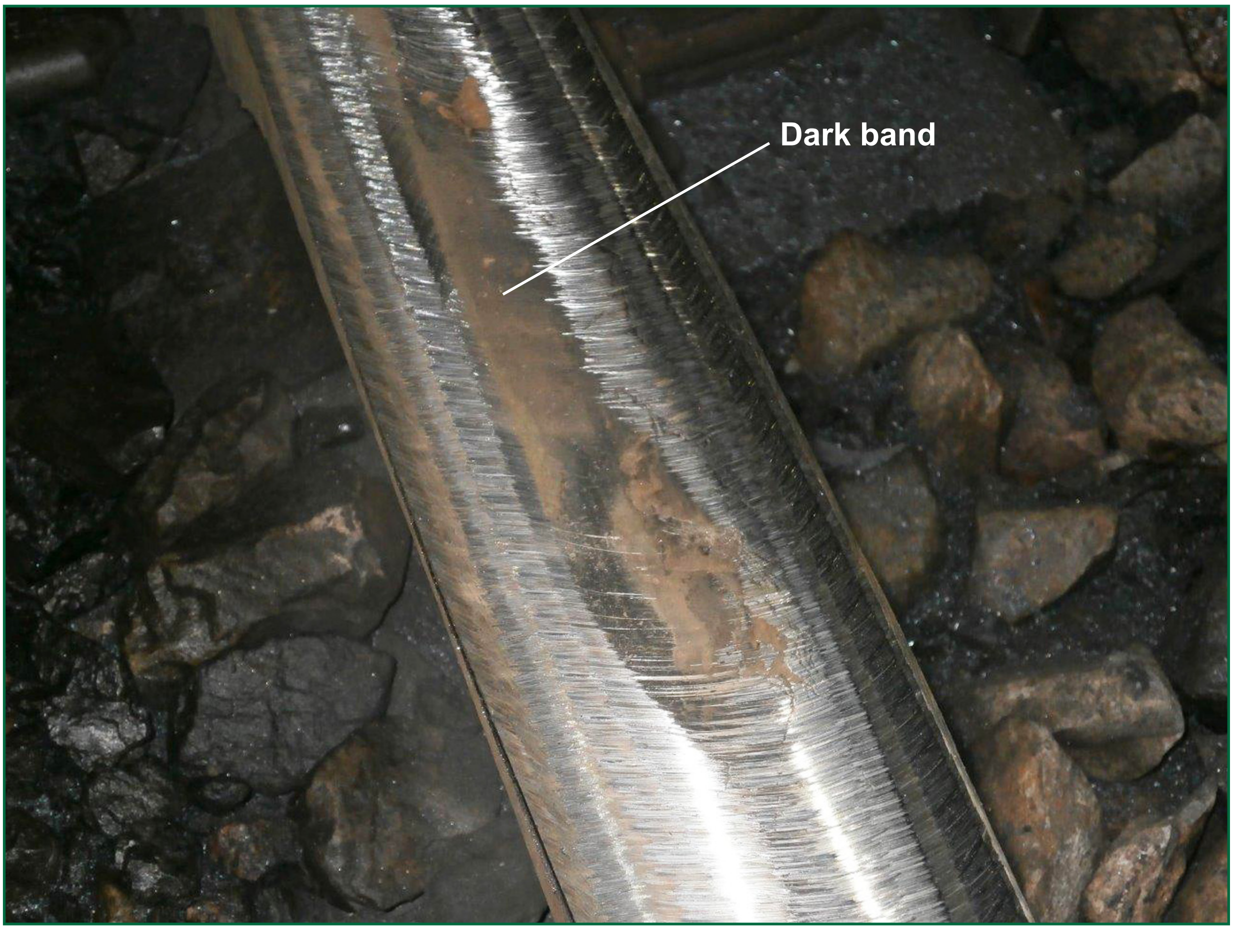

Figure 16: Photograph of left-hand rail taken by Harsco after grinding on 30 August 2014 (dark area shows where rail had started to collapse)

111 It is not possible to determine from the evidence available precisely when the VLS had developed to the extent that the crack broke through the surface or the head became bulged by 2 mm. However, the photograph taken after the grinding on 30 August shows that the head had started to collapse at that time.

112 The report of the metallurgical analysis of the rail fragments (paragraph 68) stated that some of the crack surfaces showed signs of corrosion, indicating that they had been exposed to the air. The report stated that this was likely to have occurred over a period of several months, indicating that the VLS crack had broken through the surface of the rail several months before the derailment. The analysis found that the RCF and VLS cracks were independent (figure 17) and found no evidence of the VLS crack growing up into the area of RCF cracking near the rail head, but the crack had broken through the upper fillet radius in several places. The crack surfaces were smooth, showing that the pieces of rail each side of the crack had rubbed against each other, smoothing off the crack surface. This relative movement could only occur if the rail was loaded in bending after the crack had formed, showing that the crack had been in the rail for some time. On the basis of the corrosion that had occurred to some of the fracture faces, it is possible that the crack had broken through the surface before the inspections by the asset engineer, section manager (track) and ultrasonic team in July 2014.

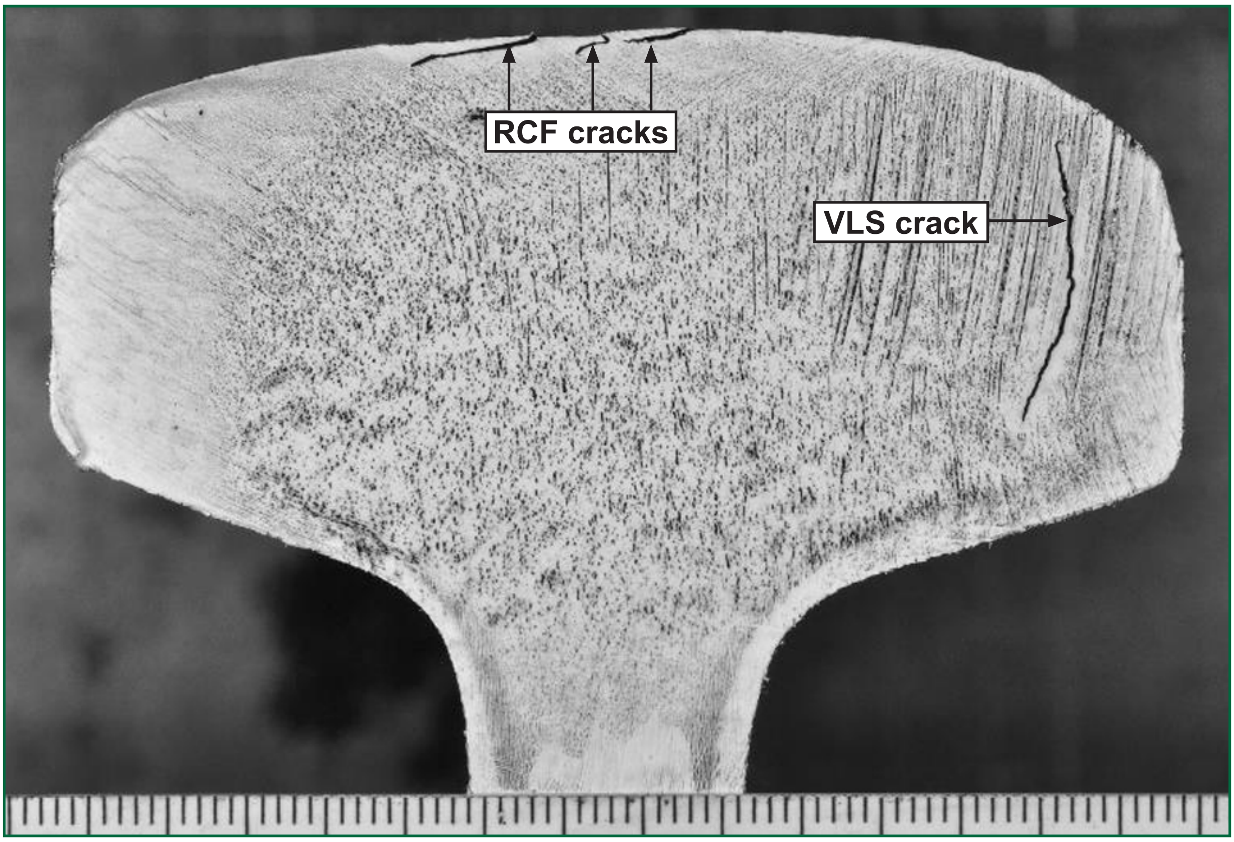

Figure 17: Magnetic particle inspection of the rail cross section at the start of the VLS section (image courtesy of Serco Rail Technical Services)

113 The rail samples recovered by the RAIB only contained one piece of 'unbroken' rail where the crack had reached the surface. This crack was difficult to see with the naked eye and was only evident after magnetic particle inspection had been carried out.

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

114 Network Rail requested Sperry to report the length of *linear suspects*, such as VLS, and Sperry issued the instruction to its analysts in an ‘Operations staff brief’ on 25 November 2014. The length information entered by Sperry is transferred to Network Rail’s rail defect management system and is visible to the staff verifying the defect on the track.

115 Network Rail made enhancements to its RDMS, and other systems, in December 2014 to improve the feedback of suspect verification information to Sperry.

116 Network Rail Wales Route tested all low rail RCF sites to check for loss of rail bottom and to perform U8 testing of any pre-1976 rail installed as the low rail in those sites. No further VLS defects were found.

117 Network Rail Wales Route retested all of the VLS defect locations that had been reported over the previous 12 months which had not had the VLS defect confirmed and tested 44 yards each side of the reported GPS position of the start of the suspect. Two new VLS defects were found; both were more than 22 yards from the reported start point.

118 Network Rail issued a briefing note to its rail management engineers in October 2014 advising them of the details of the accident and specifying additional U8 testing of pre-1976 rail which is suspected of containing VLS defects.

119 Network Rail’s supply organisation, National Delivery Service (NDS), issued an instruction to its suppliers in 2011 not to supply pre-1976 rail as serviceable rail.

Summary of conclusions

Immediate cause

120 The left rail broke up as the train was passing over it (paragraph 64).

Causal factors

121 The causal factors were:

a) The rail contained an inherent defect present since manufacture (**paragraph 66**).

b) The inherent defect in the rail was not discovered when the rail was recycled to the site in 2008. This causal factor arose because of one of the following:

   i. The VLS defect was not present (paragraphs 81 to 85 and 119);

   ii. The VLS defect was too small to be detected (paragraphs 86 to 88 and 119); or

   iii. The rail was not tested (paragraphs 89 and 119).

c) The rail was not replaced before it collapsed (**paragraph 90**). This causal factor arose due to a combination of the following:

   i. The visual inspection intended to identify VLS in pre-1976 rails was not carried out (paragraphs 91 to 92, **Recommendation 3**).

   ii. The regular visual track inspections did not find the defect (paragraphs 93 to 100, **Recommendations 1 and 2**).

   iii. The VLS was not confirmed following earlier UTU testing (paragraphs 101 to 104, **Recommendation 2**).

   iv. Once discovered, the defect was not identified as requiring urgent attention (paragraphs 105 to 113, **Recommendation 2**).

Learning point

122 The following learning point[4] is made:

1 When a track maintenance engineer's inspection is delegated, it is important that the person who does the inspection and the engineer discuss the findings of the inspection and that it is clear who shall follow up the identified actions.

[4] 'Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where RAIB has not identified management issues that justify a recommendation) and the consequences of failing to do so. They also record good practice and actions already taken by industry bodies that may have a wider application.

Recommendations

123 The following recommendations are made[5]:

1 *The intent of this recommendation is to improve the processes for detecting VLS defects in rails to increase the likelihood of detection before they develop to the extent that they can cause rail failure.*

Network Rail should review the methods it uses to verify suspected VLS type defects in rails and make improvements to increase the likelihood of their detection. The methods to be considered should include always using a U8 test when verifying VLS suspects, regardless of the extent of loss of rail bottom signal (paragraph 121c.ii).

2 *The intent of this recommendation is to improve the process for detection of surface breaking cracks from VLS defects which have been identified as being present in the rail.*

Network Rail should improve the detection of surface breaking cracks and head spread. The methods to be considered should include the use of non-destructive test methods such as dye penetration or magnetic particle inspection to look for cracks, particularly at the upper fillet radius (paragraphs 121c.ii, iii, iv).

3 *The intent of this recommendation is to control the risk arising from having rail that is liable to contain VLS defects in use in track.*

Network Rail should assess the risk of having unidentified pre-1976 rail in use in track, in particular at sites where cascaded rail has been installed, and take measures to mitigate this risk (paragraph 121c.i).

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[5] Those identified in the recommendations, have a general and ongoing obligation to comply with health and safety legislation and need to take these recommendations into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, these recommendations are addressed to the Office of Rail and Road to enable it to carry out its duties under regulation 12(2) to:

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

(b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 200 to 203) can be found on RAIB's website www.gov.uk/raib.

Appendices

Appendix A - Glossary of abbreviations and acronyms

GPS	Global positioning system
NDS	National Delivery Service
ORR	Office of Rail Regulation (now called the Office of Rail and Road)
OTDR	On-train data recorder
RCF	Rolling contact fatigue
UTU	Ultrasonic test train
VLS	Vertical longitudinal split

Appendix B - Glossary of terms

Axle counter section	A length of track where the presence or absence of a train is detected by a system which counts the individual axles in at one end and out at the other.
Cant	The amount by which the outer rail in a curve is elevated above the inner rail.
Continuously welded rails	Rails which are welded together into one long length.
Defect	A feature within a rail which has been confirmed as being an internal defect.
Field side (of a rail)	That part of the rail which is furthest from the centre line of the track.
Flash butt weld	A type of rail weld usually made in the factory which uses electrical current to fuse the rail ends together.
Gauge side (of a rail)	That part of a rail which is closest to the centre line of the track.
Linear suspect	A feature within a rail which may be an internal defect which extends along the length of the rail.
Mobile Operations Manager	A member of Network Rail staff who responds to incidents affecting the operation of the railway.
Normal grade	Rail steel is graded according to its hardness and resistance to wear. 'Normal' grade has the lowest wear resistance and hardness.
Section Manager (rail testing and lubrication)	The Network Rail manager who manages the staff who carry out pedestrian ultrasonic testing and who maintain the equipment used to lubricate the rail in locations where it is subject to heavy wear.
Section Manager (Track)	The Network Rail manager who manages the staff responsible for the maintenance of a defined section of track. The section manager (track) reports to the track maintenance engineer.
Segregation	The phenomenon whereby impurities in steel are concentrated at a location leading to disruption of the uniformity of the metal.
Sulphur print	A test technique which involves placing a photographic sheet impregnated with acid in contact with a steel surface to obtain a record of sulphide compounds within the steel.
Suspect	A feature within the ultrasonic test data which may be an internal rail defect.
Thermit weld	A type of rail weld joining rails which is made by casting molten metal into the joint on site.

Track Maintenance Engineer	The Network Rail engineer with responsibility for managing the safety of the line over a defined area.
Trackman	A member of staff employed to carry out basic track maintenance tasks.
Upper fillet radius	The area of the rail where the underside of the head meets the web (figure 5).
Wear resisting A grade	Rail steel which has higher wear resistance than normal grade.

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