RAIB

Rail Accident Investigation Branch

Rail Accident Report

Train driver receiving a severe electric shock at Sutton Weaver, Cheshire 23 September 2014

Report 07/2015
June 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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Train driver receiving a severe electric shock at Sutton Weaver, Cheshire, 23 September 2014

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Summary

At 19:04 hrs on Tuesday 23 September 2014, a train driver received a severe electric shock at Sutton Weaver, Cheshire. He had stopped his train having seen damaged overhead power supply wires ahead of it. Following a call to the signaller, he left his train and came close to, or made contact with, an electrically live wire which had broken and was low hanging. The train driver suffered serious injuries.

This accident occurred because one of the overhead wires had broken, was hanging down and was electrically live. Two previous trains had come into contact with this hanging wire and consequently tripped the power supply circuit breakers. Each time the circuit breakers had been reset by the Electrical Control Operators in accordance with procedures to make the overhead wires electrically live again. The driver had left the train to obtain information as to his location to assist in restoring train services as he was trained to do, but did not see the broken wire.

The investigation found that the wire broke as some of its strands had fractured due to fatigue, likely initiated and progressed from a high stress area related to an attachment supporting the overhead wire.

The RAIB has made two recommendations. One is for Network Rail to extend the scope of its detailed overhead line examinations to inspect for signs of wire damage at these attachment positions.

The other recommendation is for RSSB, who are the custodian of the railway Rule Book, to review whether clarification is needed relating to the actions that train crew should take if they are required to leave a train where the OLE is known to be damaged and still live.

Following a review of the actions of those involved in attending to the injured driver, one learning point has been made reminding train operators of the importance of contacting the signaller by the quickest means in emergency situations.

Introduction

Preface

1 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.

2 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.

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

Key definitions

4 All dimensions and speeds in this report are given in metric units, except speeds and locations which are given in imperial units, in accordance with normal railway practice. Where appropriate the equivalent metric value is also given.

5 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

6 At 19:04 hrs on Tuesday 23 September 2014, the driver of train reporting number[1] 1F22, the 17:07 hrs London Euston to Liverpool Lime Street service, received a severe electric shock at Sutton Weaver, Cheshire (figure 1). He was walking along the track in front of his train which he had brought to a stand because he had seen that the overhead power supply wires were damaged. He had left his train to find the identification number of the nearest supporting mast of the overhead electrical supply. While walking towards it, he came close to, or made contact with, a hanging wire that was electrically live.

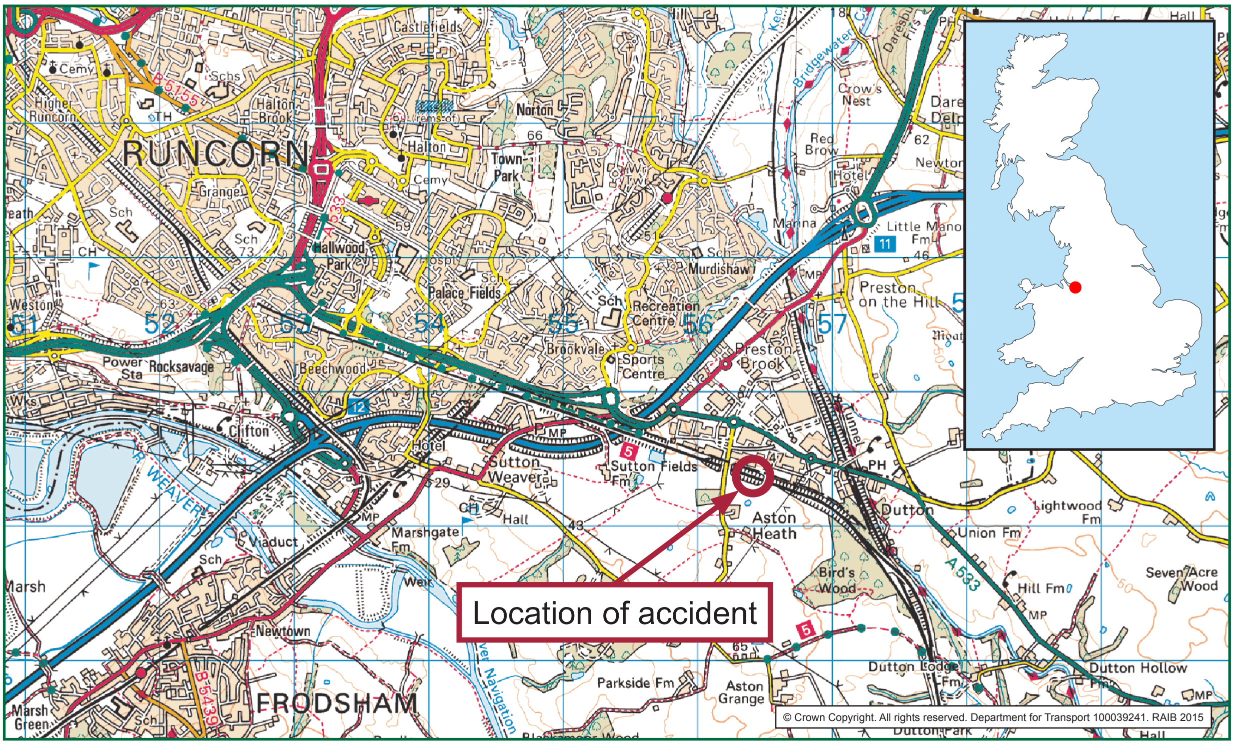

Figure 1: Extract from Ordnance Survey map showing the location of the accident

7 The electric shock caused severe burns to the right-hand side of his body. He also suffered broken ribs, a broken collar bone, and a head wound thought to have occurred when he fell and hit his head against a rail. He was in hospital for ten weeks.

8 Virgin Trains has informed the RAIB that the train driver involved in this accident is making a good recovery.

[1] An alphanumeric code which is allocated to every train operating on Network Rail infrastructure.

Context

Location

9 The accident happened at Sutton Weaver on the Down Liverpool line approximately 1 mile 700 yards (2.2 km) beyond Weaver Junction, where the lines to and from Liverpool diverge from the main line from London to Glasgow.

Figure 2: Location of the accident as viewed in the direction of travel of train 1F22 on the approach to HN103 signal, visible in the centre of the picture, and the OLE mast identification plate (ringed)

Organisations involved

10 Virgin Trains is the train operating company, and is the employer of the driver and the train manager involved in the accident.

11 Network Rail is the owner and maintainer of the infrastructure, in particular the *overhead line equipment* (OLE) present on this line. It is also the employer of the signallers and the *electrical control operators* (ECOs) on duty at the time of the accident.

12 North West Ambulance Service (NWAS NHS Trust) was the provider of the ambulance and the medical team who attended to the driver following the accident.

13 North West Fire Control (NW Fire Control Ltd) was the provider of the rescue teams who assisted with rescuing the driver and the evacuation of passengers on the trains affected by the accident.

14 All organisations freely co-operated with the investigation.

The train involved

15 Train 1F22 was formed by a Virgin Trains Class 390 Pendolino *electric multiple unit*, number 390156. There were no reported faults with the train on the journey prior to the accident.

The overhead line equipment involved

16 This section of line is double track and is in a cutting (figure 2). Electrical power is supplied by overhead line equipment (OLE) at 25,000 volts (25 kV), alternating current (AC).

17 The OLE in this area is constructed to the design known as Mark 1 (Mk 1) *compound catenary* and became operational on this line in 1962. Unlike more recent designs, which use just two wires running above each track, this design uses three.

18 Mk 1 compound OLE comprises an upper catenary wire, a middle auxiliary wire and the lower contact wire (figure 3). The *pantograph* of a train pushes up against the contact wire to obtain electric power. The catenary and auxiliary wires are structural elements that support the contact wire. They are suspended from cantilevered masts along the track. Between adjacent pairs of wires are dropper wires (generally known as *droppers*) which support the wire below.

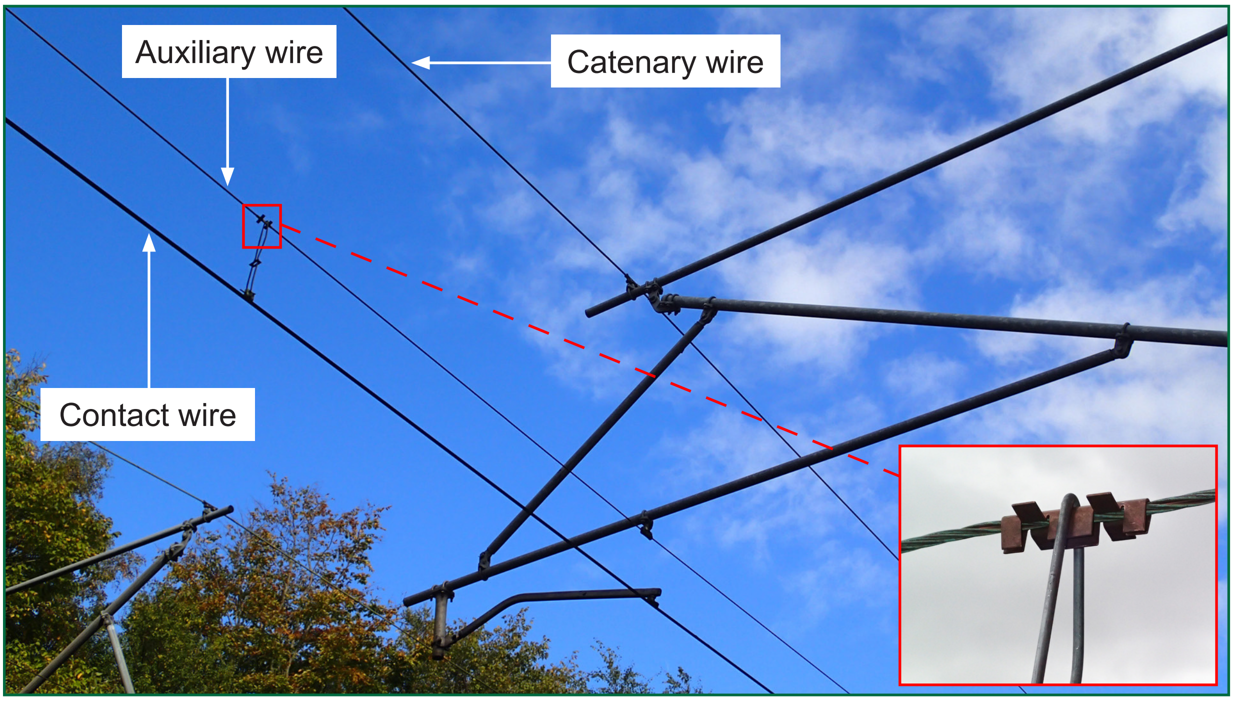

Figure 3: Mk 1 compound catenary with the three wires labelled. Inset shows auxiliary wire protective sleeve on the auxiliary wire.

19 The dropper between the auxiliary wire and the contact wire is fixed to the contact wire at its lower end. The upper end of the dropper loops over the auxiliary wire and sits on a protective sleeve, commonly known as an aeroplane or dropper saddle. This protective sleeve is clamped to the auxiliary wire by having the open ends of its U-channel section squeezed together (figure 3 inset). The dropper is free to move vertically relative to the sleeve and the auxiliary wire but its longitudinal movement is restricted by the four horizontal tabs (wings) at the ends of the sleeve.

20 The auxiliary wire is made from seven strands of a cadmium-copper alloy with an overall diameter of approximately 6.3 mm. It is not electrically insulated from the contact or catenary wires which are all at the same electrical potential, nominally 25 kV.

21 The OLE consists of electrically supplied sections, each of which is protected by circuit breakers. The circuit breakers automatically open (or trip) if an electrical fault is detected in a section. Such faults can occur if any live portion of the OLE comes into contact with anything at an earth potential such as a train body or the ground. The circuit breakers which are associated with the section of OLE related to this accident can be controlled remotely, ie opened or closed, from the electrical control room.

Staff involved

22 The driver involved in the accident had been a driver since 1976 and had driven for Virgin Trains since 1997. He was qualified as a Driver Instructor. His training, competence and medical records were up to date at the time of the accident. There is no evidence that his recent roster pattern would have caused him to be fatigued.

23 The train manager started with Virgin Trains in 2001 and had been in this role since 2002.

24 The OLE section related to this accident was controlled from an electrical control room at Crewe. There were two Electrical Control Operators (ECOs) on duty at the time of the accident.

25 There were Network Rail signallers involved in communications before, during and after the accident based at Halton Junction, Runcorn, Ditton and Winsford signal boxes.

26 Both Network Rail and Virgin Trains have their own controllers based in operational control centres at various locations. One of the duties of a controller is to receive information on, and manage the performance of train services. They also have to react to emergency situations.

External circumstances

27 The accident occurred at dusk. The visibility was sufficient for the driver to observe that the OLE was sagging ahead of his train as it was silhouetted against the darkening sky.

28 The driver and the train manager reported that there was light drizzle and the forward facing CCTV on the train shows that windscreen wiper was operating during the approach to Sutton Weaver, and while the train was at a stand.

The investigation

Sources of evidence

29 The following sources of evidence were used:

- witness evidence;
- sections of the broken wire and protective sleeves from this and other sites with broken auxiliary wires;
- voice recordings from drivers, signallers, the ECOs and operational control room communications;
- the on-train data recorder (OTDR);
- forward facing closed circuit television (FFCCTV) recordings taken from the train;
- electrical control room logs;
- site photographs and measurements;
- Network Rail's historical records of auxiliary wire breakages;
- Network Rail OLE inspection procedures; and
- control room logs from the British Transport Police (BTP), NWAS and NW Fire Control.

Key facts and analysis

Sequence of events

Events preceding the accident

30 At 16:32 hrs the driver of train 1F22 signed on for duty at London Euston station. The train departed on time at 17:07 hrs and the driver has reported that the journey was uneventful until approaching Sutton Weaver just before 19:00 hrs.

31 At 18:20 hrs, the logs from the Crewe ECO show that the circuit breaker associated with the section of the Down Liverpool line at Sutton Weaver automatically tripped. Another train, train 1F52, was passing through this section at the time and, having lost power, coasted to a stand at HN24 signal (this signal is the one beyond HN103 signal shown in figure 2).

32 At approximately 18:21 hrs, the driver of train 1F52 left the cab and used the *signal post telephone* to report to the signaller at Halton Junction signal box that he had seen a flash and the train had lost its *line light*. (This is an indication which, when illuminated, shows the driver that the train has an electrical supply from the OLE.) During this phone call the driver left the phone and went back to the cab and checked his line light. He then told the signaller that the line light had re-illuminated and that he was going to walk in the *cess* to the rear of the train to examine the pantograph in accordance with the Rule Book (paragraph 83 refers).

33 The line light had re-illuminated because the ECO had reclosed the circuit breaker at 18:22 hrs in accordance with procedures (paragraphs 63 and 64 refer).

34 While the driver of train 1F52 was still checking the pantograph, the signaller at Halton phoned the ECO to inform him that the driver had seen a flash. The signaller was told by the ECO that a circuit breaker had tripped. However, the circuit breaker did not trip again following its closure and the driver of train 1F52 reported to the signaller that there were no displaced wires in contact with his train. The train was therefore allowed to proceed on its journey. The ECO contacted the OLE maintenance team at Crewe to alert them of a problem in the area.

35 At 18:53 hrs, the logs from the ECO record that the same circuit breaker tripped again. At this time, train 1F53 was passing through this section and, as for the preceding train, having lost power it coasted to a stand at HN24 signal.

36 The circuit breaker was reset by the ECO at 18:55 hrs. Because this was the same circuit breaker that had tripped earlier, the ECO asked the signaller at Winsford signal box, who was in control of trains approaching Sutton Weaver on the down line, to caution the next train approaching the area (paragraph 65 refers). Around this time the ECO updated the OLE maintenance team who were on their way to Sutton Weaver.

37 The Winsford signaller told the ECO that the next train approaching Sutton Weaver was train 1F22, but it could not be cautioned as it was beyond Weaver Junction and had already passed all controlling signals.

38 At 18:57 hrs the driver of train 1F53 reported to the Halton signaller that he had seen a flash and had lost his line light. The signaller passed this information to the ECO.

39 Because train 1F53 was stationary at HN24 signal, the signals on the approach to Sutton Weaver were displaying *restrictive aspects*. Consequently the driver of train 1F22 slowed the train down on the approach to the red aspect displayed by HN103 signal, the signal before HN24 signal.

40 At 18:59 hrs train 1F22 stopped approximately 50 metres on the approach to HN103 signal. The driver made a call to Halton signal box, using the GSM-R radio, informing the signaller that the overhead wires in front of his train were hanging lower than he expected them to be. The driver could not see the identification plate on the signal, as he was too far away from it, but the signaller was able to identify which signal the train was on the approach to. The signaller mentioned to the driver that he was aware of an electrical problem in the area. He then told the ECO that train 1F22 had stopped on approach to HN103 signal and the driver could see that the OLE was damaged.

41 At 19:02 hrs the driver of train 1F53 contacted the signaller again and told him, following his examination of the train, that there were no wires caught in the train's pantograph and that the train's line light was illuminated. Since this was the second circuit breaker trip in the same area, the ECO requested, via the signaller, that train 1F53 remain at HN24 signal until further investigations into the location of the fault were completed.

Events during the accident

42 Around 19:00 hrs, the driver of train 1F22 asked the train manager to come to the front cab and informed him that the wires were low in front of the train. The train manager stated that he saw that the droppers were tangled around the contact wire when he looked through the front windscreen. The driver has informed the RAIB that he then told the train manager that he was getting out of the train to read the identification number of the closest OLE mast, known as the *structure number* (figure 2). He did this so he could inform the signaller to assist in restoring the OLE and the recovery of his train. This is consistent with the requirements of the Rule Book[2] (paragraph 81 refers). The train manager said he would phone Virgin Trains control room to inform them of the situation.

43 The driver switched on the train's *hazard lights*, put on a high visibility vest and got out of the train from the left-hand door (as viewed in the direction of travel) situated in the vestibule area behind the front cab. At this time the OLE section circuit breaker was closed, the OLE was energised and the line light on train 1F22 was illuminated.

44 The driver walked along the cess to the front of his train and then stepped into the centre of the track that his train was on and walked away from his train. The driver considered walking on the track to be safer than the cess as there were rails in the cess (figure 2) and his stationary train was protecting the line behind him. When he reached a point approximately 10 metres in front of his train, he came close to, or made contact with the low hanging end of a live, broken auxiliary wire.

45 At 19:04 hrs the ECO logs record that the associated circuit breaker tripped for a third time that evening.

[2] GE/RT8000/AC, Rule Book Module AC, AC electrified lines, section 12.6.

Events following the accident

46 The train manager, who was about to inform Virgin Trains control of the situation on his mobile phone when the accident happened, told the controller that he thought the train driver had received an electric shock. He told them that he wanted to get out of the train to assist the driver and asked that the controller contact the signaller to stop all trains in the area. He could see that the driver was lying on the ground and moving.

47 There was then a series of phone calls (paragraphs 86 to 90 refer in more detail) between:

- the train manager and the Virgin Trains controller;
- the Virgin Trains controller and the Network Rail controller; and
- the Network Rail controller and the ECO.

48 These calls were over an eight minute period from 19:06 hrs onwards. At 19:10 hrs arrangements were made to ensure that the power would remain switched off on both lines in the affected area. At 19:14 hrs, the train manager was told by the Virgin Trains controller that it was safe to leave the train and assist the driver, but not to touch the OLE. He then went to the driver's assistance.

49 At 19:17 hrs, the train manager phoned 999. At 19:19 hrs the train manager made an emergency call on the GSM-R radio in the front cab to the signaller at Halton. He informed the signaller of the structure number of the nearest OLE mast, which he had noted down after attending to the driver.

50 The signaller at Halton passed on these details to the Network Rail controller and the signaller told the controller the location of the train and the nearest access point to the railway.

51 The train manager asked whether there were any medically trained people or police officers on the train, and a doctor came forward offering assistance. They both attended to the driver, assessing his condition and making him as comfortable, warm and dry as they could. The train manager put some glow-sticks close to the dangling end of the broken wire, which he reported was hanging about 0.6 m (2 feet) above the ground.

52 By 19:35 hrs, ambulance staff, British Transport Police, and the local Network Rail Mobile Operations Manager met at the access point and were briefed on the safety arrangements before entering the railway. The driver was then attended to by the paramedics and carried from site by a fire and rescue team at about 20:30 hrs and taken to hospital.

53 At about 21:00 hrs, the 168 passengers on board train 1F22 and the 75 passengers travelling on train 1F53, which was still at signal HN24, and their train crews were evacuated with assistance from the fire and rescue service. This was completed by 22:10 hrs. Another train which had been trapped in an electrically isolated section on the Up Liverpool line was moved at around 23:00 hrs. The OLE fault team repaired the broken auxiliary wire and the line was restored to normal service at 04:05 hrs on 24 September 2014.

Identification of the immediate cause[3]

54 **The immediate cause of the accident was the driver coming close to, or making contact with, live, low hanging OLE.**

Identification of causal factors[4]

55 The accident occurred due to a combination of the following causal factors:

- the auxiliary wire had broken and was hanging down (paragraph 56);
- the auxiliary wire was live (paragraph 63); and
- the driver left the cab and came close to, or made contact with the live auxiliary wire (paragraph 68).

Each of these factors is now considered in turn.

The broken auxiliary wire

56 **The auxiliary wire had broken before, or during, the passage of train 1F52 at 18:20 hrs. The driver of train 1F52, and the subsequent train, train 1F53, both reported seeing a flash as they passed the area.**

57 The approximate positions of the two ends of the broken auxiliary wire following the accident are shown in figure 4. The end closest to London was hanging low to the ground, and the end closest to Liverpool remained close to the catenary and contact wires.

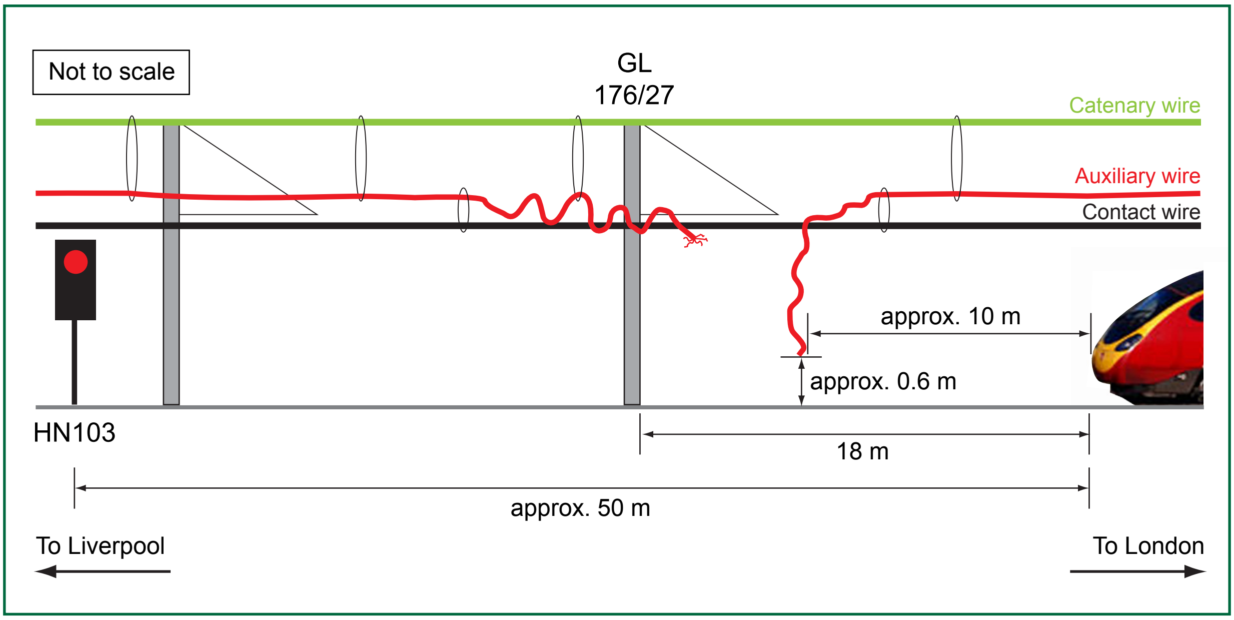

Figure 4: Approximate positions of the ends of the broken auxiliary wire, the train, HN103 signal and the nearest OLE mast

[3] The condition, event or behaviour that directly resulted in the occurrence.

[4] Any condition, event or behaviour that was necessary for the occurrence. Avoiding or eliminating any one of these factors would have prevented it happening.

58 Examination of the recovered sections of the auxiliary wire showed that the broken end closest to Liverpool had signs of mechanical damage in the form of unwound strands at various angles, together with fused copper deposits on the strand ends (figure 5). Some areas on the section closest to London showed signs of electrical arcing and mechanical damage (figure 6). This damage and the reported flashes are indicative of the broken wire making contact with the two trains preceding train 1F22. Examination of train 1F52, found arcing damage to parts of its pantograph.

Figure 5: Splayed wire strands on the Liverpool section of the broken auxiliary wire

Figure 6: Electrical arcing damage on the London section of the broken auxiliary wire

59 Metallurgical examination of the strand ends of the wire section closest to London showed that it had failed by two distinct mechanisms (figure 7). The angled fracture faces on at least three of the seven strands are fatigue fractures[5] which had developed following many load cycles and not just a few overloading events. The remaining three or four strands then failed in tension as they were no longer able to carry the normal tensile load applied to them in supporting the contact wire below. The wire was also examined for possible overheating damage caused by electrical arcing. None was found, discounting this as a possible contributor to the failure.

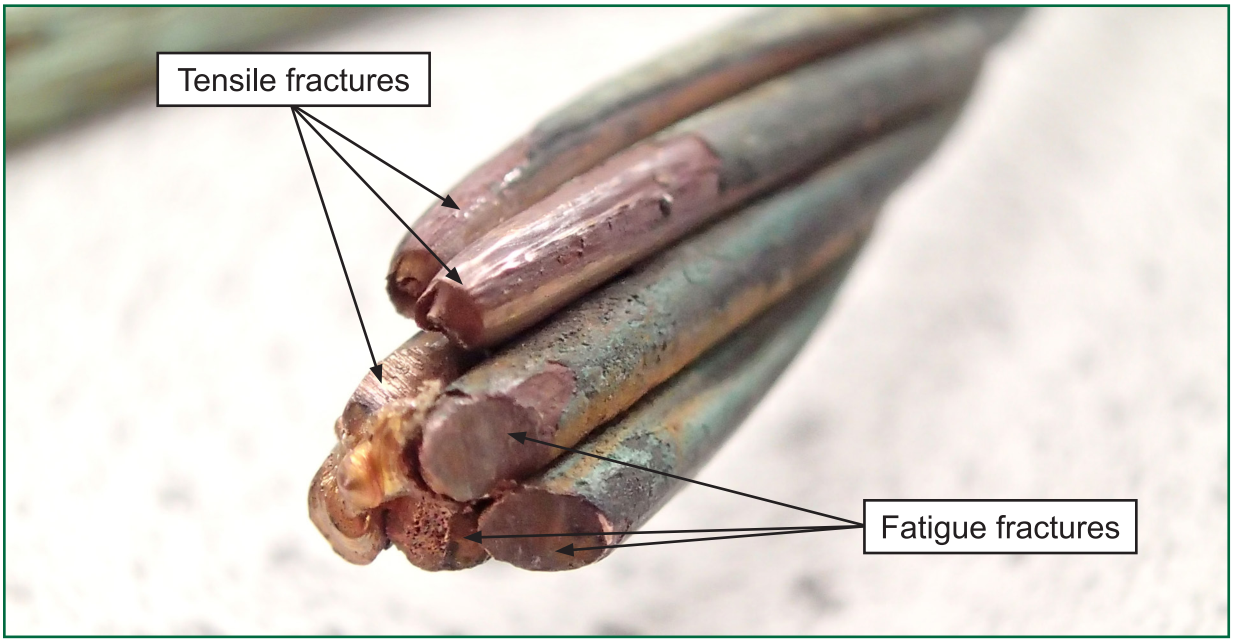

Figure 7: End of the London section of the broken auxiliary wire

60 The wire had developed a green coating (known as verdigris) on the exposed surfaces of the strands. However a short length of the wire at the broken end of the section closest to London was discoloured black rather than green. This suggests that the failure took place within a section of wire within a protective sleeve (figure 8).

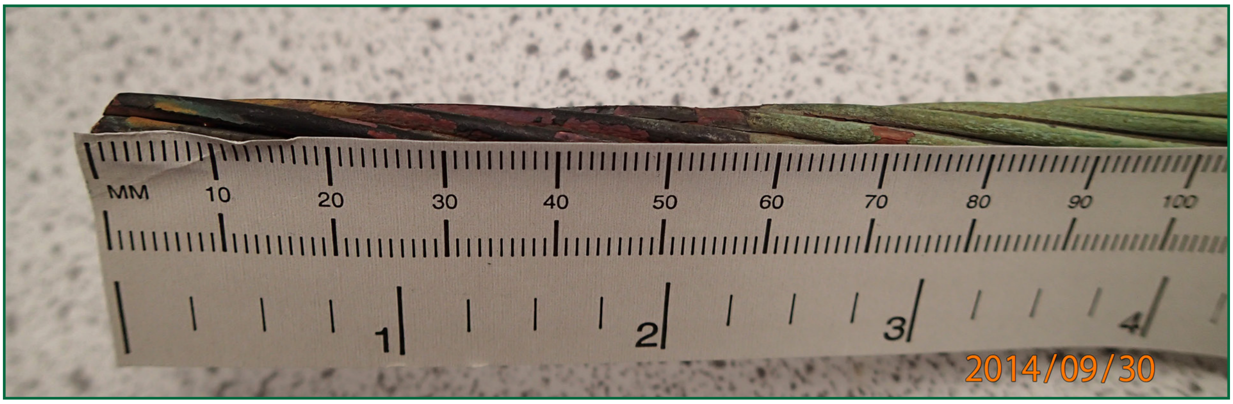

Figure 8: End of the London section of the broken auxiliary wire showing dark discolouration where it has been within the protective sleeve

[5] Fatigue fracture - material failure caused by repeatedly applied loads, where the nominal stress to cause failure may be less than the ultimate tensile strength of the material.

61 Several days after the accident, a damaged protective sleeve was found adjacent to the auxiliary wire failure point (figure 9). When the broken end of the wire was placed in the position in the sleeve indicated by the discolouration, the break was found to be coincident with an area of the sleeve that had been subjected to localised loading by the upper loop of the dropper wire impacting on it. This has led the RAIB to conclude that the recovered sleeve is likely to have been the one present prior to the auxiliary wire breaking.

Figure 9: Protective sleeve found at the scene of the accident. Red arrow indicates the groove created from contact with the loop of the auxiliary wire dropper.

Figure 10: Position of the London end of the broken auxiliary wire relative to the protective sleeve. Red arrow indicates line of wire breakage coincident with the sleeve inner protrusion, which is coincident with the groove shown in figure 9.

62 The localised loading had caused a groove on its upper surface and an associated inner protrusion (figure 10). It is likely that this protrusion caused a local high stress area on the wire which contributed to the initiation and propagation of the fatigue fracture. Network Rail provided the RAIB with two other sections of broken and partially frayed auxiliary wires and protective sleeves. The broken wire section was associated with a circuit breaker trip at another location in June 2014, and the partially frayed wire section was found during a routine inspection. The regions of the completely broken and partially frayed strands on the respective samples were also related to their positions within protective sleeves. The breakage line of the completely broken wire coincided with the end of the sleeve and some of its strands showed signs of fatigue fracture. The ends of the sleeve are other likely positions at which the stress in the wire may be increased (as there is a localised change in stiffness) promoting the initiation and development of fatigue fractures.

The auxiliary wire was live

63 **The ECO reset the circuit breakers following the two tripping events at 18:22 hrs and 18:55 hrs (paragraphs 33 to 36). The resetting of a circuit breaker is normal practice as it may have tripped due to a short circuit caused by, for example, a tree branch or a bird temporarily connecting the live OLE to the earthed structure.**

64 Following both trips, the control room procedures were followed correctly. These state that a circuit breaker can be manually reclosed after at least one minute. This is to allow the ECO to identify any trains in the tripped electrical section which are carrying dangerous goods. The trains in the area were identified by means of phone calls from the ECO's to the controlling signal boxes.

65 Following the second trip at 18:53 hrs, an attempt was made to caution train 1F22 which was approaching this section of track (paragraph 36). The procedures allow an ECO to request assistance in the identification of the location of an OLE fault. A cautioned train is required to travel at a slow speed so to be able to stop within the distance that the driver can see to be clear and to be able to examine the condition of the OLE in front of the train.

66 Although train 1F22 had already passed the signal at which it could be cautioned (paragraph 37), it approached the damaged OLE section slowly as a result of restrictive signal aspects.

67 The design of Mk 1 compound OLE is such that an auxiliary wire can break, hang low to the ground and both it, and the contact wire, remain live allowing trains to continue to operate. Only when the auxiliary wire makes contact with an object at earth potential (eg a train body), will the circuit breaker trip, isolating the supply.

The driver left the cab and came close to, or made contact with the live auxiliary wire

68 **The driver left the train and walked along the track ahead of it to read the OLE structure number (paragraph 42) as he could not see it from the cab. He did this because he believed that it was important to accurately describe the location of the fault to assist the OLE maintenance team in restoration of the infrastructure, and to assist in the recovery of his train. The Rule Book requires him to report any problems or incidents with the OLE to the signaller, including the extent of damage to the OLE and the nearest OLE structure number (paragraph 81 refers).**

69 The driver did not see the auxiliary wire hanging down in front of his train when he was in the cab, nor as he walked towards it. The train manager has stated that he saw through the front windscreen that the overhead wires in front of the train were damaged, but he also did not see the hanging wire.

70 The auxiliary wire was relatively thin (6.3 mm in diameter) and was green in colour (paragraph 60). Although it was not yet dark and the OLE wires could be seen clearly silhouetted against the sky, the hanging end of the thin auxiliary wire was in front of a background of trees and undergrowth on the side of the embankment. The FFCCTV images also show that there was light rain falling on the windscreen, which would have reduced visibility through it, and also inclined the driver to keep his head and eye line lowered when walking in front of his train.

71 The driver has since stated that had he seen the hanging auxiliary wire from the train's cab, he would have stayed on board and requested an emergency electrical switch off.

72 The RAIB has observed that the letters and numbers on the OLE structure number plate closest to the train were in a worn condition (figure 2). The RAIB consider that even if in a better condition, it would have been difficult to read them from a distance 18 metres through a wet train windscreen and with the light conditions present at the time.

Identification of underlying factors[6]

Hidden wire fatigue failures in Mk 1 compound catenary

73 **Network Rail OLE inspections did not include detailed examination of the condition of the auxiliary wire strands within protective sleeves to identify wire strand breakage or fatigue precursor indications possibly present on the wire and/or the sleeve.**

74 At the time of the accident there were two Network Rail inspection work instructions applicable to this section of the line at Sutton Weaver. Both are within the Overhead Line Work Instructions document NR/L3/EPL/27237. Work instruction NR/OLE B1 specifies non-intrusive, ground-level visual inspections with an inspection frequency of eight weeks for this category of track. This inspection is solely visual (assisted by binoculars) and includes checking for parted or stranded (partially broken) wires and damaged, displaced or missing droppers.

75 The other work instruction, NR/OLE B10, specifies intrusive, high-level inspections. These are 6-yearly for this category of track and involve taking line blockages and the use of elevated work platforms. The inspection includes checking that fittings are secure and in their correct positions, checking for sleeve wear and damage and checking the droppers. If stranded or damaged wires are detected during these inspections they are recorded with Network Rail's work planning system (Ellipse) and then attended to, depending on the defect category.

76 Network Rail also has infrastructure measurement trains that record the forces and deflections of the contact wire when it is loaded by a pantograph. However, unless the auxiliary wire has already broken (with an associated loss of support from the droppers), this is not able to detect a partially broken wire or the onset of a fatigue failure.

77 Network Rail has informed the RAIB that approximately 6% of its OLE on the London North Western route (LNW) has Mk 1 compound catenary (in terms of track miles). Much of the Mk 1 system that had been on the West Coast main line was converted to a simple two-wire system (by removal of the auxiliary wire) during the West Coast modernisation completed in 2008. This was to allow trains to run faster than 110 mph (176 km/h), which is the maximum speed allowed under Mk 1 compound OLE. There had been plans to replace the remaining sections of Mk 1 compound OLE, including Sutton Weaver, in 2007. The estimated cost for this project was £30 million and it was not progressed due to a weak business case based upon the small cost savings from reducing train delays by increasing the reliability of the OLE.

78 Network Rail records of auxiliary wire breakages on the whole LNW route (either full breakages or partially frayed wires detected during inspections) show that there were 29 occurrences from 1995 to 2014. There has been a reduction in the average annual breakages since 2007; this is likely to be due to the reduction in the amount of Mk 1 compound OLE in service since 2008.

[6] Any factors associated with the overall management systems, organisational arrangements or the regulatory structure.

79 Network Rail has provided evidence to the RAIB that shows that visible auxiliary wire, dropper and sleeve defects are rectified when they are detected. However, broken cable strands can only be visibly detected if they occur outside a protective sleeve (or if one or more broken strands have unwound sufficiently to withdraw from the sleeve end). The findings from the metallurgical analysis indicate that fatigue is more likely to occur in, or around the protective sleeve where there are localised features increasing the stress on the wire strands compared with those sections with no sleeve present. The failure in this accident is an example of wire strands fatiguing within the protective sleeve, and is therefore not detectable by the basic visual inspection. Also, before the accident, inspection of the wire sections within protective sleeves did not form part of the high-level intrusive inspection (paragraph 75).

80 There is insufficient historical data to establish any significant recent increase in the number of wire failures. However, because fatigue failure is a function of cyclic load, which is determined by the number of pantographs passing underneath, it is reasonable to assume that without intervention, the rate of auxiliary wire breaks over a given section will rise with time.

The Rule Book

81 **The train driver left the train when the OLE was known to be damaged and was still electrically live.**

82 The Rule Book[7] requires a driver to report any problems or incidents with the OLE to the signaller, including reporting the train's location, which includes telling the signaller the nearest OLE structure number. In this accident the driver left the train to obtain this information (paragraph 42).

83 Furthermore, the Rule Book[8] requires a driver to visually examine the train's pantograph if the train's line light extinguishes, or if any damage to the OLE has been observed. This is to minimise any possible further damage to the train and the OLE when the train restarts. The examination of a train's pantograph requires that the driver leaves the train and walks beside the track. This was the case with trains 1F52 and 1F53, both of which had tripped the section's circuit breaker within the 50 minutes before the accident. In both cases, the OLE was live when the drivers were outside their trains examining the pantographs (paragraphs 32 and 41).

84 There is no requirement for the ECO to wait until a train has been examined before resetting the associated OLE section circuit breaker to energise the OLE. Circuit breaker trips are most commonly due to a temporary short circuit (paragraph 63). An extinguished line light on a train may be due to an electrical fault with that particular train rather than to a fault with the OLE. For these reasons Network Rail does not consider it practical to wait until a train examination is completed before resetting a circuit breaker, as this would lead to delays by stopping other trains in the electrical section.

[7] GE/RT8000/AC, Rule Book Module AC, AC electrified lines, section 12.6.

[8] GE/RT8000/AC, Rule Book Module AC, AC electrified lines, section 12.4.

85 The competence requirements and dangers associated with OLE are covered within the first four sections of Module AC of the Rule Book. Drivers are trained and assessed to be competent to go on or near lines with live OLE, and in certain circumstances are required by the Rule Book to leave their trains following an OLE incident. However, this accident has demonstrated the potential for harm to a train driver who leaves the train to read an OLE mast identification number, or to examine the pantograph when live OLE is damaged.

Observations[9]

Emergency communications following the accident

86 The RAIB, as part of its investigation remit, has constructed a detailed timeline of the communications between the parties involved in the rescue phase following the accident.

87 The first phone call after the accident was made by the train manager to the Virgin Trains controller, requesting that the controller contact the signaller to stop all trains so that he could leave the train and attend to the driver. This message was then passed on to the Network Rail controller. A further call was made two minutes later by the train manager to the Virgin Trains controller in which the train manager asked for the power to be switched off and for an ambulance to be sent. He again requested that all trains be stopped and mentioned that he was unsure how to contact the signaller.

88 The request for an emergency electrical switch off was passed to the Network Rail controller who contacted the ECO. The OLE on both lines was switched off at 19:10 hrs and the train manager was told of this by the Virgin Trains controller at 19:14 hrs.

89 As a consequence of this method of communication, it was approximately eight minutes after his first call that the train manager was told that it was safe to leave the train, but not to touch the OLE (which can remain an electrical hazard until it has been locally earthed).

90 In two of the calls between the train manager and the Virgin Trains controller, the controller asked the train manager to dial 999. The train manager was interrupted by another call during the first request for him to call 999. In response to the second request to call 999, he told the controller that he was unsure of the location to which to direct an ambulance and that his primary concern was to attend to the driver.

91 As soon as the train manager was informed that it was safe to leave the train by the Virgin Trains controller, he attended to the driver and checked his condition. At 19:17 hrs, he returned to the train and dialled 999. He then left the train and noted the nearest OLE structure number, returned to the cab and made an emergency call to the signaller via the GSM-R radio at 19:19 hrs. After this he, and a doctor who was travelling on the train, stayed with the driver until the emergency services assisted the driver.

[9] An element discovered as part of the investigation that did not have a direct or indirect effect on the outcome of the accident but does deserve scrutiny.

92 In this accident any delays did not affect the outcome (since the driver was attended to by a medical professional), but the timeline suggests that the response of the emergency services would have been around 6 minutes quicker if the GSM-R emergency call facility was used immediately after the accident (table 1). The advantages of this would have been that:

a. the signaller could have arranged for train movements to be stopped, and arranged for an emergency electrical switch off with the ECO, and then could have informed the train manager directly that it was safe to leave the train; and

b. the signaller could have assisted in calling the emergency services and directed them to the location, as he knew where the train was, as well as the nearest access point to the railway.

93 It is likely that the train manager did not use the radio sooner as he was in the process of phoning Virgin Trains control on his mobile phone when the driver was leaving the train. His mobile phone then remained his method of communication during the minutes following the accident.

94 Virgin Trains has told the RAIB that the use of the emergency call facility on the GSM-R radio is part of the initial training given to all of its train crew, but did not form part of its train manager refresher training (paragraph 108, Learning point 1).

95 The RAIB has also observed that the Virgin Trains controller could have reminded the train manager to use the GSM-R radio to contact the signaller when the train manager requested that all trains in the area be stopped, the electricity be switched off and an ambulance attend.

96 The RAIB has observed that throughout a very difficult situation, the train manager was focussed on helping the driver and did all that he could to request assistance from others. This is to be commended.

Risks of coming into contact with live damaged OLE of other designs

97 Network Rail has informed the RAIB that with OLE designs of the *head span* wire type, there is the potential (depending upon where in the span wire section a break occurs) for the wires to be close to the ground while remaining electrically live, so therefore there is a risk of people coming into contact with them. The RAIB therefore conclude that the risk of an incident of this type is not limited to Mark 1 compound OLE.

Previous occurrences of a similar character

98 The RAIB is not aware of any other incidents involving train crew coming into contact with damaged, live OLE equipment on open running lines.

Summary of conclusions

Immediate cause

99 The immediate cause of the accident was the driver coming close to, or making contact with, live, low hanging OLE.

Causal factors

100 The causal factors were:

a. the auxiliary wire had broken and was hanging down (paragraph 67);

b. the auxiliary wire was live (paragraph 63); and

c. the driver left the cab and came close to, or made contact with the live auxiliary wire (paragraph 68).

Underlying factors

101 The underlying factors were:

a. Network Rail OLE inspections did not include detailed examination of the condition of the auxiliary wire strands within protective sleeves to identify wire strand breakage or fatigue precursor indications possibly present on the wire and/or the sleeve (paragraph 109, **Recommendation 1**); and

b. the train driver left the train when the OLE was known to be damaged and was still electrically live (paragraph 109, **Recommendation 2**).

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

Actions reported that address factors which otherwise would have resulted in a RAIB recommendation

102 Network Rail conducted a high level intrusive inspection of the auxiliary wire from Weaver to Ditton junctions (approximately eight miles of double track) in October 2014. No auxiliary wire damage was found but some protective saddles were realigned and some missing droppers were replaced.

103 Network Rail is currently conducting more detailed inspections of the OLE between Weaver Junction and Wavertree (approximately eight miles of double track and nine miles of quadruple track). This includes inspecting for damage underneath the protective sleeves. As of March 2015 it had replaced six sections of auxiliary wire (by splicing in new wire), two missing protective sleeves, two missing droppers and realigned 450 droppers.

104 Network Rail LNW has identified 28 single track miles of its infrastructure where Mk 1 compound OLE could, if it fails, come into close or actual contact with members of the public, eg adjacent to station platforms. It has told the RAIB that it plans to request investment authority to remove the auxiliary wires in these sections so that this can be completed by April 2016.

105 On 24 September 2014 (the day following the accident) Virgin Trains issued a general operations notice to all of its operational staff. This informed its drivers that if the OLE is known to be damaged, they are to remain on the train until the OLE has been made safe to be approached, but not touched.

106 On 25 September Network Rail issued a Rule Book instruction reminder via the NIR-online system (the UK railway's national incident reporting system) reminding train crew and others working in proximity to OLE, to treat it as live and not to approach unless assured that the electricity is switched off.

107 Virgin Trains has reported to the RAIB that it has briefed its train managers on the use of the emergency call function on the GSM-R radio and this will form part of future briefings.

Learning point

108 The RAIB has identified the following learning point[10]:

1. This incident reinforces the importance of contacting the signaller 'in the quickest way possible'[11] and of providing regular refresher training for train crew in the use of the in-cab GSM-R radio for emergency calls. It also highlights the benefits of GSM-R, especially when the train driver is not able to take the lead in emergency communications.

[10] 'Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when the RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where the 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.

[11] GE/RT8000/AC, Rule Book Module M1, Dealing with a train accident or train evacuation, section 2.

Recommendations

109 The following recommendations are made[12]:

1 *The intent of this recommendation is to minimise the occurrence of broken auxiliary wires on Mk 1 compound catenary OLE to reduce the potential for people to receive electric shocks.*

Network Rail should revise its work instructions so that inspection staff are aware of what to look for, including possible fatigue damage precursors as found during the metallurgical examinations of this investigation, and during the inspections Network Rail has already carried out (paragraph 99a).

It should produce a plan for the extension of its current detailed examinations of auxiliary wires close to, and within, protective sleeves to identify and rectify broken and damaged wire strands and protective sleeves on all of its Mk 1 compound catenary. Following this, its routine inspections should include this additional examination.

2 *The intent of this recommendation is to minimise the risk to train crew following an incident involving the OLE.*

RSSB[13] should review Module AC of the Rule Book (GE/RT8000/AC) and appropriately clarify the actions that train crew should take if they are required to leave their train in situations where the OLE is electrically live, and may possibly be damaged (paragraph 101b).

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[12] 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.

[13] RSSB facilitates the maintenance, design, and publication of the Rule Book on behalf of the GB mainline railway industry.

Appendices

Appendix A - Glossary of abbreviations and acronyms

AC	Alternating current
ECO	Electrical control operator
GSM-R	Global System for Mobile Communications – Railways
OLE	Overhead line equipment

Appendix B - Glossary of terms

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

Cess	The space alongside the line or lines.*
Compound catenary	An arrangement of overhead line electrification (OLE) equipment where the catenary consists of a catenary wire, intermediate catenary wire (known as an auxiliary wire) and contact wire.*
Dropper	A mechanical component between a contact wire and the catenary wire, which maintains an electrical connection.
Electrical control operator	The person having control over supply to, switching of and isolation of an electrification system in a geographical area.*
Electric multiple unit	A multiple unit that can be driven and controlled as a single unit from the driving cab at the leading end and whose motive power is electricity supplied externally from overhead line equipment (OLE) or conductor rails.*
Global System for Mobile Communications – Railways (GSM-R)	A national radio system which provides secure voice communications between trains and signallers, relaying calls via radio base stations built alongside the railway or on suitable vantage points.*
Hazard lights	Flashing lights on the leading end of a train that may be switched on by the driver to warn the driver of any approaching train that an accident has occurred.*
Head span	A form of overhead line equipment provision where multiple catenary assemblies are supported by transverse wires strung between overhead line structures.*
Line light	A lamp placed in the driving cabs of an electric locomotive or electric multiple unit that shows the driver that the traction supply current is present.*
Overhead line equipment	An assembly of metal conductor wires, insulating devices and support structures used to bring a traction supply current to suitably equipped traction units.*
Pantograph	The device fitted to the roof an electric locomotive or electric multiple unit (EMU) that contacts the contact wire of the overhead line equipment (OLE), allowing the traction unit to draw current. *
Restrictive aspects	A signal indication other than green.
Signal post telephone	A telephone located on or near a signal that allows a driver or other member of staff to communicate only with the controlling signal box.*

Structure number	A unique alphanumeric designation marked on a structure to assist in its identification and location.

Appendix C - Key standards current at the time

GE/RT8000/AC, Module AC, June 2014	Rule Book Module AC, AC electrified lines.
Network Rail NR/L3/EPL/27237, Issue 7, September 2014.	Overhead Line Work Instruction includes: ● work instruction NR/OLE B1 (non-intrusive, ground-level visual inspections), and ● work instruction NR/OLE B10 (High level intrusive inspection)

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