RAIB
Rail Accident Investigation Branch

Rail Accident Report

Traction control failure causing a signal to be passed at danger, Camden Road
7 April 2006

Department for Transport

Report 10/2007
April 2007

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.

Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby UK
DE21 4BA

Email: enquiries@raib.gov.uk
Telephone: 01332 253300
Fax: 01332 253301
Website: www.raib.gov.uk

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Introduction

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents and improve railway safety.

2 The RAIB does not establish blame, liability or carry out prosecutions.

3 Access was freely given by Alstom, HSBC and Silverlink to their staff, data and records in connection with the investigation.

4 Appendices at the rear of this report contain Glossaries:

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

Summary of the report

Key facts

5 A class 313 *electric multiple unit* (EMU) was returned to passenger carrying operation following attention in Alstom's Works at Wolverton with incorrectly connected traction control wiring.

6 The fault in the control circuits caused the EMU to pass a signal at danger at Camden Road by one coach length. No other equipment was damaged or casualties caused.

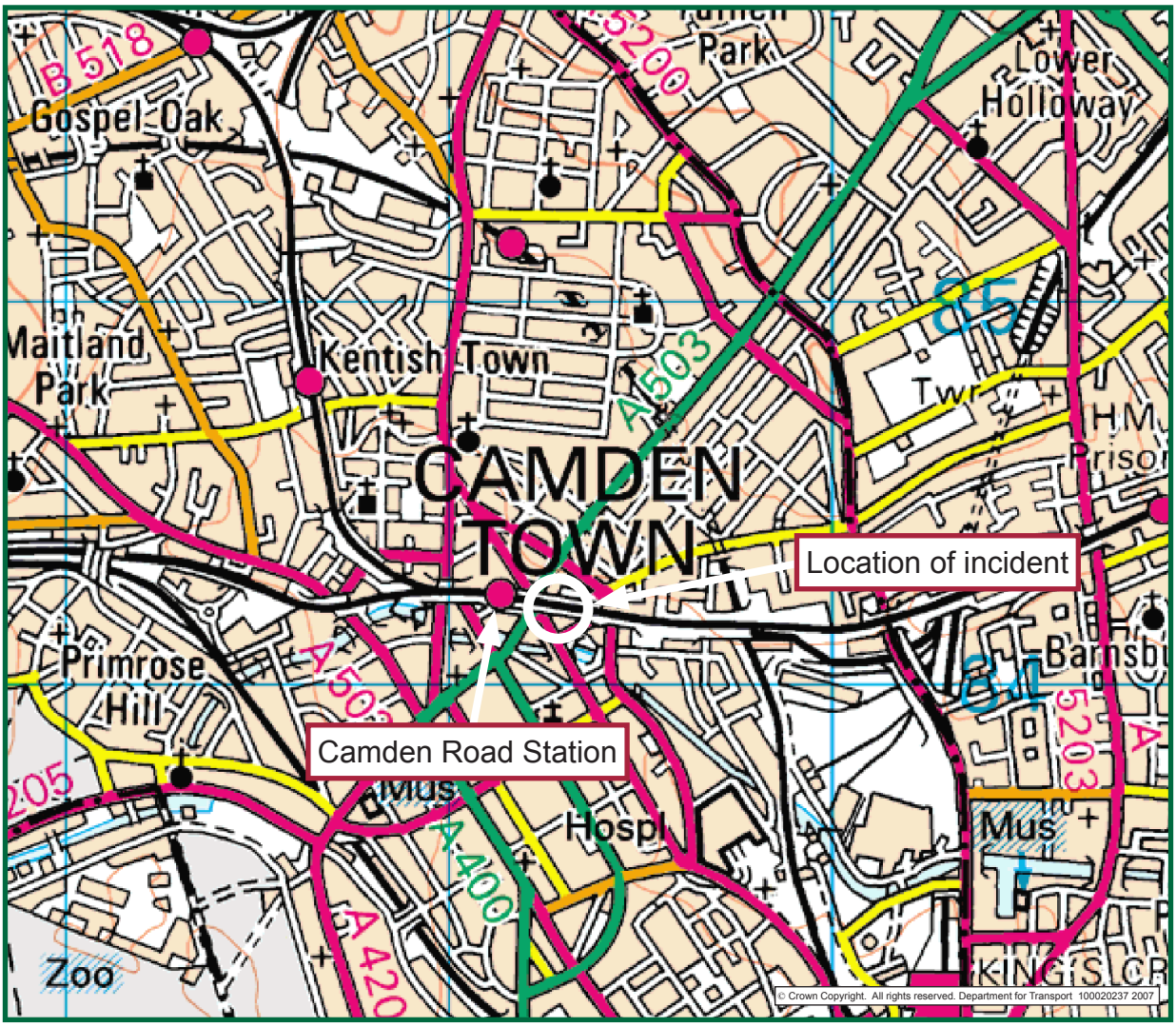

Figure 1: Extract from Ordnance Survey map showing location of incident

Immediate cause, causal and contributory factors, underlying causes

7 The immediate cause of the accident was a unit being placed in traffic with incorrectly connected wiring (paragraphs 36, 61, 70).

8 This was because specified testing was not carried out after altering a wiring connection during repair at Wolverton Works (paragraphs 53, 74, Recommendation 1).

9 In addition, the following factors were considered to be contributory:

- the generally poor condition of the cable identification numbers; and specifically the absence of cable identification numbers adjacent to the terminals on the *interlock* blocks of the *Supply Changeover Switch* (SCS) (paragraphs 45, 89, 94, Recommendations 2, 4);
- the lack of a formalised procedure for identifying cables when they are disconnected from terminals during the removal of electrical components (paragraphs 45, 46, 91, Recommendation 3);
- the contracted *test specification* did not mandate a test sequence (paragraph 73, Recommendation 5);
- the testing staff had limited understanding of the class 313 systems, but were allowed to carry out minor rectification work (paragraph 53, Recommendation 6); and
- the design of the traction control circuits was such that a false feed caused by a single incorrect connection prevented the *linebreakers* from opening (paragraph 101, Recommendation 7).

Recommendations

10 Recommendations are detailed in paragraph 120. They relate to the following areas:

- the instructions for and methods of testing the class 313 units following repairs;
- the condition of cable identification on current and new rolling stock and the method of identifying cables disconnected during the repair process;
- the accessibility of wiring diagrams for use by staff at Wolverton Works; and
- the control of risk arising from the design of the control circuitry.

The Incident

Summary of the events

11 On 7 April 2006, train 5L50, the 16:22 hrs Willesden TMD to Camden Road, an empty train with no passengers on board, which comprised class 313 unit number 313104, passed signal CR1102 at danger by one coach length when approaching Camden Road station. No other trains were involved in the incident.

12 The driver reported that the unit had failed to respond to his application of the brakes and to a *Train Protection and Warning System* (TPWS) intervention on the approach to the signal. He stopped the train by switching off power to the unit's *auxiliary system*.

13 Another class 313 unit was sent to recover 313104 to Willesden Traction Maintenance Depot (TMD). The *traction motors* on 313104 had to be isolated to allow the combined train to move westwards towards Willesden rather than continuing eastwards in the direction in which it had approached Camden Road.

The parties involved

14 The train was operated by Silverlink Train Services *Train Operating Company* (TOC), a member of the National Express Group, which for management purposes is grouped with c2c Rail as 'London Lines'. The train driver was an employee of Silverlink.

15 Willesden TMD is operated by West Coast Traincare Ltd, a subsidiary of Alstom Transport. Among other contracts, it carries out light maintenance of class 313 on behalf of Silverlink, reporting to the Silverlink depot at Bletchley where the trains are allocated.

16 Wolverton Works, Milton Keynes, was also operated by Alstom Transport. It carries out overhauls of the class 313 fleet, under contract to HSBC Rail (UK) Ltd, who are the owners of the trains. This facility is now managed by Railcare to whom the appropriate recommendations are directed. It had carried out the *C6 Repair* immediately prior to the incident.

17 The railway infrastructure at Camden Road is owned and operated by Network Rail (London North Western route). The performance of the infrastructure and the infrastructure manager's staff had no bearing on this incident.

Location

18 Camden Road station is on the 'North London' line then connecting Richmond - North Woolwich. The location is shown in Figure 1.

19 The signalling is controlled from Camden Road Junction signal box, located at the west end of the station. Signal CR1102 is at the east end of the eastbound platform and controls movements of trains from Camden Road towards Caledonian Road.

The Train

20 Unit 313104 is one of 64 three-car electric multiple unit trains built by British Rail Engineering Ltd at York in 1976/77. All of the trains are capable of operating on both 25 kV ac *overhead line* and 750 V dc *third rail* electrification systems. All of class 313 are owned by HSBC Rail (UK) Ltd.

21 Twenty-three trains (class 313/1) have been fitted with extra current collection equipment for operation on services on the North London and Euston – Watford dc lines, and are leased to Silverlink. The remainder (class 313/0) are leased to First Capital Connect and operate on Great Northern suburban services.

External circumstances

22 The weather was dull and dry and had no bearing on the incident.

Events preceding and immediately following the incident

23 Unit 313104 had undergone a C6 Repair at Alstom's Wolverton Works. This involved the removal, renovation and replacement of various electrical components, including the Supply Changeover Switch.

24 Alstom released the unit from the Works at Wolverton on 4 April 2006 and authorised it to be returned to Silverlink TOC under its own power.

25 This journey was from Wolverton to Willesden TMD which only entailed running on routes electrified by 25 kV ac overhead line.

26 No special attention was given to the unit on receipt at Willesden TMD as a follow up to its repair at Wolverton. It was given a scheduled *'A' examination* and the subsequent normal preparation process for taking a *berthed*, but operational, unit into traffic.

27 On 7 April the unit entered traffic for the first time following attention at Wolverton by taking up a *diagram* starting with train 5L50, the 16:22 hrs Willesden TMD – Camden Road via Primrose Hill. The train was powered by the 25 kV ac overhead line as far as Camden Road station. At this location it was scheduled to change its source of power to 750 V dc third rail and form the 16:41 hrs passenger train to Stratford.

28 Approaching Camden Road Junction (immediately before Camden Road station), the train was brought to a stand as signal CR1104 was at 'danger'. Since the train was now stationary on third rail, the driver took the opportunity to change power supply systems there rather than during the stop at Camden Road station.

29 After signal CR1104 cleared to allow train 5L50 to proceed, the driver moved the train towards Camden Road station, accelerating to approximately 15 mph (24 km/h). He shut off power and applied the brake to stop at the station. The unit did not slow down and at the east end of the station passed signal CR1102 at 'danger'. As a result of this the TPWS intervened but, as the brakes were already applied, had no further effect.

30 The driver realised that the traction motors were still delivering power to drive the train forward and moved the *Master Switch* to 'off' in an attempt to remove power, but without effect. The driver then tripped the unit's auxiliary power system. This caused the unit to stop some 20 metres beyond signal CR1102. At some point during this sequence, the driver contacted the signaller to advise him of the situation.

31 No further attempt was made to move unit 313104 until another unit of the same type was attached to the rear to haul it westwards back to Willesden TMD for investigation and repair.

32 As soon as the assisting unit was coupled by the Silverlink staff, and before the driver took power or released the brakes, unit 313104 attempted to move away eastwards towards Stratford. The units were uncoupled and the traction motors on unit 313104 isolated, using the isolation switches in the unit. The units were then recoupled without any further unplanned movement and 313104 was hauled back to Willesden TMD.

Consequences of the incident

33 Silverlink did not report the incident in accordance with regulation 4(1) of The Railways (Accident Investigation and Reporting) Regulations 2005 (the RAIB considers it to have been an incident of a type covered by schedule 1(9), an accident or incident which under slightly different conditions might have led to a death, serious injury or extensive damage to rolling stock, the infrastructure or the environment) and it only became known to the RAIB through the *National Log* on Saturday 8 April.

34 There were no fatalities or injuries to people nor damage to any equipment consequential to the incident.

The Investigation

Investigation process

35 Unit 313104 was held at Willesden TMD for examination by the RAIB in conjunction with Alstom Transport and Silverlink Train Services on the morning of Saturday 8 April 2006.

36 That examination established that the immediate cause was an incorrectly connected wire attached to an interlock terminal on the Supply Changeover Switch of 'B' coach, number 62596. This resulted in the Traction Motors being permanently powered when the unit was operated from a direct current (dc) power supply and when the control sequence reached '*Full Series*' for the first time.

37 The investigation then sought to establish how the wrong connection had been made and why a single wrong connection resulted in a failure of this nature.

38 The following issues were examined:

- procedures and actual 'shop-floor' practices relevant to the removal and replacement of components and subsequent testing of complete systems at Wolverton;
- the testing and checking of units returning to traffic following a C6 repair; and
- relationships between the TOC, its running maintainer, the *Rolling Stock Leasing Company* (ROSCO) and its heavy maintainer.

Sources of evidence

39 Examination of unit 313104 before and during the correction of the defect.

40 Records of the repair of unit 313104 by Alstom at Wolverton.

41 Discussions with Alstom, HSBC and the Silverlink Train Services TOC.

42 Interviews with relevant personnel.

Factual information

Attention given to unit 313104 at Wolverton

43 Unit 313104 received a C6 repair at Alstom's Wolverton *heavy maintenance* plant during March 2006. Among other components, the Supply Changeover Switches (SCS) were removed for reconditioning. Class 313 units have two power cars and each is fitted with its own SCS.

44 The SCS has two positions corresponding to the unit drawing power from either the ac or dc power supply and is moved from one to the other by electro-pneumatic valves. Electrical connections are made to interlocks on the SCS to enable control circuits to detect the position of the SCS.

45 By the time of the C6 repair, the cable identification numbers on the control circuit wiring attached to the SCS had become illegible. The Wolverton Works electrical fitting staff, whose remit is to carry out the repair to the rolling stock, removing the switch from coach 62596 were aware that the identification of the cables connected to the SCS interlocks was inadequate and identified them by attaching labels made of masking tape.

46 For the refitting of the SCS, the staff were entirely reliant on the masking tape labels to identify both the individual cables and the terminals to which they had to be attached.

47 At the end of the repair the unit is tested to ensure that it is working correctly. These tests are specified in HSBC's Vehicle Instruction EV/V13138 'Final Test – C6 Repair'. At the start of these tests the *motor alternator* (MA) set did not operate and during the testing of the unit the SCS failed to operate properly, being retained in the position corresponding to drawing ac power.

48 Electrical fitting staff were called to investigate and correct the SCS fault.

49 They were uncertain as to where cables should be correctly connected to the SCS. Only a *schematic diagram*, rather than a *wiring diagram* was available, so they examined the wiring layout of another unit. Being in a different sub-fleet (class 313/0 rather than 313/1), this other unit differed from the one under test in having an additional cable connected to one interlock terminal on the SCS. It corresponded to the schematic diagram available to the electrical fitting staff and they used it as an indication of where the remainder of the cables should have been connected. Reconnecting the cables in accordance with the unit examined caused the SCS to operate correctly.

50 Testing staff then correctly tested the SCS successfully. The testing staff are separate from the fitting staff and their remit is solely to test rolling stock on completion of a repair. Any defects found are notified to the fitting staff for them to rectify.

51 The fault on the SCS was rectified and tested before the fault with the MA was addressed. Electrical repair staff called to investigate the MA fault identified the cause as incorrect connections to interlocks on the SCS and the wiring was altered to enable the MA set to run.

52 Testing staff then continued the testing of the unit. This included tests which proved the correct operation of the circuits passing through the SCS interlock contacts.

53 However, having completed the tests on the SCS and its interlock connections, testing staff were still not satisfied that the SCS interlock connections had been made correctly as one wire showed signs of having been retained differently in the *cable loom* at some time. They connected this wire to a different terminal; it was this wire that was found to have been incorrectly reconnected during the subsequent investigation at Willesden. After moving the wire, they did not retest the circuits involved.

54 Further tests were completed successfully. This testing included a traction power test on an ac power supply, but not on a dc supply as no 750 V dc supply is available in Wolverton Works.

Entry of the unit to traffic

55 The unit was released from Wolverton on 4 April 2006 with a *Fitness to Run Certificate* which Alstom Wolverton considered was only valid for a single journey to the leasing TOC.

56 This journey took place from Wolverton to Willesden TMD and the unit was powered throughout by 25 kV ac overhead supply.

57 At Willesden TMD the unit received a scheduled 'A' examination, which does not involve examination or testing of any of the electrical power circuits. This 'A' examination took place because it had become due in the *light maintenance* sequence, which is separate from the heavier attention given at Wolverton, and was completed at 03:30 hrs on 7 April 2006. The unit was then released to enter traffic. It had received no testing on traction power fed from a dc supply.

58 Before taking up the diagrammed working the driver would be required by Silverlink's routine procedures to *prepare* it. The preparation procedure did not involve a brake test or applying power.

59 The incident then occurred during the first journey of the diagram as described in paragraphs 27-30.

Fault investigation after the incident

60 On being returned to Willesden TMD the unit was examined the following day by staff from Silverlink and Alstom under the supervision of the RAIB.

61 The fault was traced to a cable on vehicle 62596 being incorrectly connected to a terminal on the upper interlock block on the SCS, which caused the situation described in paragraphs 65 – 70 (see Figure 2).

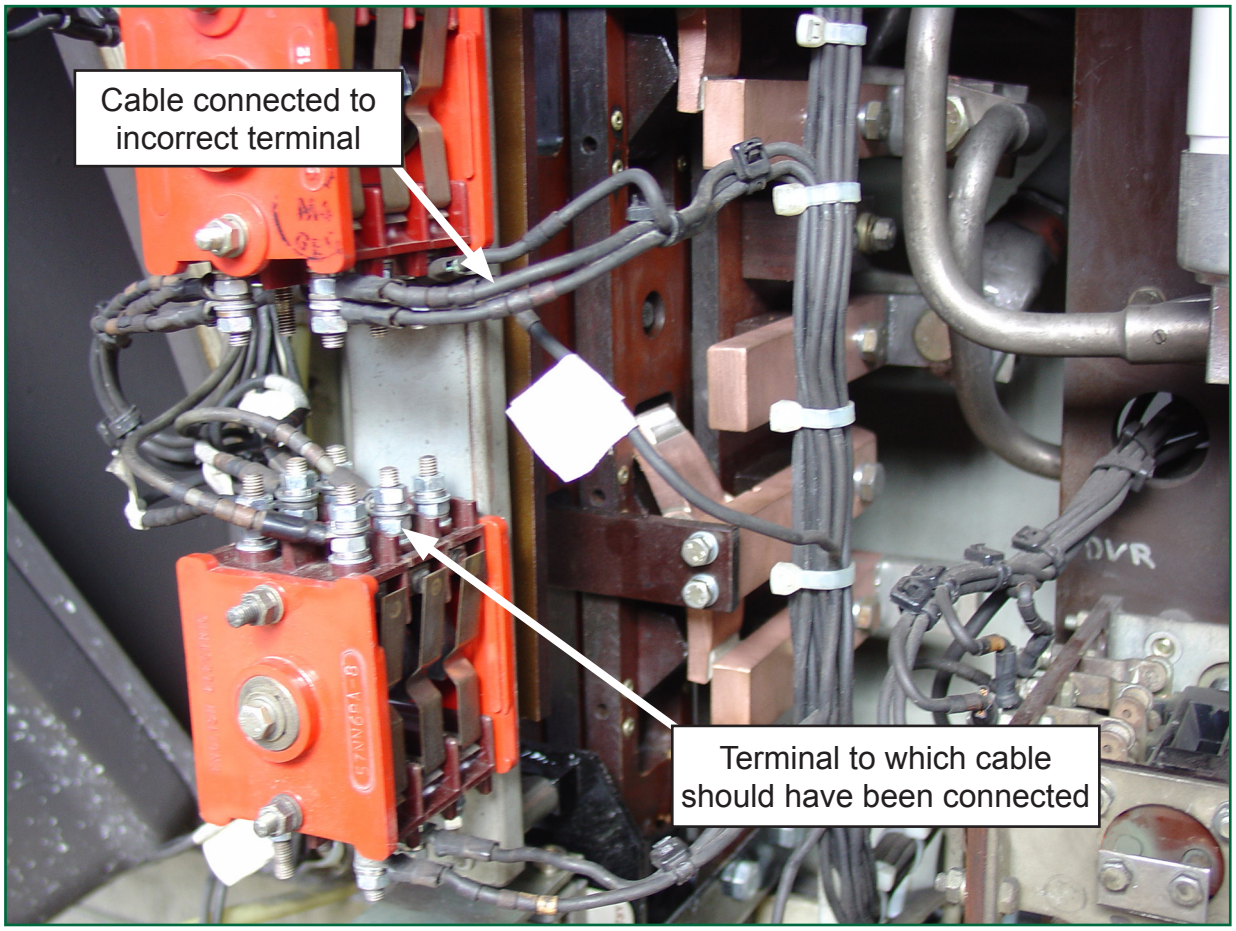

Figure 2: The Supply Changeover Switch and connections as found during fault investigation

62 The cable concerned had a masking tape identification lettered 'TRM' on it and the number 5305. The original cable identification numbers were no longer visible.

63 The identity of the cable was established, indicating that it should have been connected to the top of the lower interlock block as shown in Figure 2. It was re-connected accordingly and this eliminated the fault.

64 After testing, including movement on both ac overhead and dc third rail systems to ensure that the unit operated correctly, it was returned to traffic.

Analysis

Identification of the immediate cause

65 The wrongly connected wire explained the behaviour of the unit.

66 The incorrect connection by-passed various relays used to control the power *contactors*. This caused the power contactors to remain closed, when the control sequence reached 'Full Series' for the first time after the dc supply was selected.

67 Due to the wiring error, the power contactors remained closed when the driver put the controller to 'Off' and commenced braking. The traction power was sufficient to overcome the unit's full service brake application.

68 Switching off the auxiliary power system removed the electrical feed keeping the power contactors closed, allowing them to open and the unit to stop.

69 Coupling the recovering unit to 313104 caused the auxiliary power to be reapplied from the recovering unit, closing the power contactors and again causing the unit to attempt to move.

70 The immediate cause of the incident was therefore the putting into traffic of a unit with incorrectly connected electrical control circuitry.

Identification of causal and contributory factors

The test process

Test procedure

71 The integrity of the traction power control when working on the dc electrification system was totally reliant on inspection and testing the installation of components as no dc traction power system is available at Wolverton for an operational test.

72 The electrical supply changeover system and the traction control system are interlinked and require to be tested in that order. Therefore, any change to the connections to the SCS made after the traction control system has been tested necessitates a retest of the traction control system.

73 The test procedure is specified by the ROSCO in the repair contract. It recommends that the tests are carried out in the order listed, but does not mandate it.

74 The test sequence had not been adhered to (see paragraphs 47 – 53), so that circuits which had been altered during the course of testing to rectify an unrelated fault were not retested, causing the wiring error to go undetected.

Testing staff

75 Testing staff are appointed from within Wolverton Works by competitive selection of applicants. Applicants have to be time-served fitters or electricians and conduct tests according to their trade.

76 The testing of the control wiring of these units is a safety critical activity as defined in the Railways (Safety Critical Work) Regulations 1994, which were in force at the time of the incident (they have since been replaced by the Railways and Other Guided Transport Systems (Safety) Regulations 2006). All staff carry identification in accordance with the Regulations and the Quality Plan for the overhaul of the class 313 units requires them to have been assessed as competent in accordance with the relevant Regulations and Railway Group Standards.

77 Training is given in a manner similar to an apprenticeship in that it is 'on the job' training by learning from established testers. A limited amount of specialised training is given in such skills as high voltage testing. As new members progress they are allowed to take on work until they are deemed competent and become testers.

78 'Testers-in-charge' are drawn from established testers, trained and passed out to take charge of the test teams. The method of appointment is similar to that used for testers explained above.

79 There is an on-going assessment regime for testers and testers-in-charge based on generic skills which had temporarily fallen behind the planned programme at the time of the incident. Since then the programme has been recovered and specific training on class 313 units has been given.

80 Alstom were in the process of introducing a National Vocational Qualification at Wolverton.

81 No specific training has been given regarding specific classes of rolling stock, although testers are aware of the processes for testing the installation of various components.

82 The testers working on 313104 had been working on the class 313 since the start of the maintenance contract in April 2004. The only 313-specific training the tester-in-charge had received was an *On Train Monitoring Recorder* (OTMR) course.

83 It was not unusual for test sequences to be adjusted to enable testing to progress while faults were being corrected or other tests took place. The testers might do this to meet the contractually prescribed release time for the unit being tested.

Testing anomalies

84 Due to lack of training specific to the class 313, there was limited understanding by the test staff of the systems being tested, or of the need to adhere to the test sequence. Despite this the testers were allowed to carry out minor rectification work.

85 Thus it was possible for systems to be tested successfully, then altered, to correct other faults found in subsequent parts of the test, without being retested to ensure that the alteration was correct and had not created a further fault in the system.

86 In this instance the crucial alteration to the wiring took place late in the testing process.

87 The perceived need to release the unit to traffic at a fixed time may have caused the testers not to repeat any test related to the circuits involving the SCS interlocks.

88 The lack of a dc traction test facility meant that the conclusive proof of correct operation from a dc electrical power supply could not be achieved at Wolverton Works.

The condition and method of cable identification

89 The wiring was installed in the mid-1970s when the units were built. The identification numbers on the cables have now become illegible.

90 This condition has been reported to HSBC, the owning ROSCO. Replacing identification markers would be a costly operation introducing risk because of the need to remove and replace the connection at both ends of each cable during the process of confirming the identity of that cable, regardless of the type of ident used. The present C6 programme is almost complete and no further C6 overhauls are planned for the units leased to Silverlink. Further C6 overhauls on the units leased to First Capital Connect are some years ahead and are anticipated to be less extensive owing to the planned further life of the units. Consequently, HSBC do not consider correction of the condition to be justified.

91 Electricians at Wolverton Works disconnecting cables have developed their own method of identification. A strip of masking tape is attached to the cable. Letters corresponding to a description of the terminal to which it is connected are written on it. The labels were marked with a three letter code to identify the terminal from which the cable had been removed. The cable concerned was marked 'TRM' to indicate 'Top Right Middle', being the middle terminal on the top right hand side of an interlock block.

92 This system is entirely informal, though generally understood by those removing and refitting equipment, and has been developed as a way of overcoming the illegibility of the proper cable identification. It relies on the staff reconnecting the cables making the same interpretation as those who disconnected them.

93 The incorrectly connected cable was identified as 'TRM', which has been consistently interpreted as 'Top Right Middle'. 'Top' is ambiguous. The SCS has two blocks containing interlocks providing electrical detection of its position; they are mounted one above the other. It could either refer to the top interlock block, or the upper side of the bottom interlock block. In this instance it refers to the bottom block, but the connection was made to the terminal on the upper block.

94 There is no systematic identification of the terminals of the SCS but they may be marked with cable numbers, usually hand written in white paint. No record has been found to indicate how the identification came to be applied.

The control of the traction power

95 The traction power circuit on the class 313 units is supplied either directly from the third rail when working on dc or via a transformer and rectifier when working on ac.

96 The circuit is fed through and controlled by two linebreakers, L and E.

97 Electric current is input to the circuit through linebreaker L at a nominal potential of 750 volts to earth. It then passes through the control resistances and traction motors to contactor E. After passing through contactor E it returns to the power source and the traction circuit is also *earthed* at this point.

98 To ensure that the circuit cannot be made live unless the earth connection is in place, linebreaker L is interlocked with linebreaker E and cannot be closed, or remain closed, unless linebreaker E is closed.

99 As originally designed, the circuits controlling the contactors were fed separately. This resulted in linebreaker L opening frequently when wheelslip or loss of traction current on dc power occurred. This led to a build up of ionised gas in the linebreaker case, in turn causing a *flashover* and subsequent electrical fire.

100 A modification to rectify the above caused both linebreakers to open simultaneously.

101 Since the modification, linebreakers L and E are controlled by the same circuit. This increases the risk of a single fault in that circuit causing the linebreakers to incorrectly close simultaneously and for control of them to be lost.

102 The incorrect connection in 313104 introduced such a fault. However, this would have been detected by the correct application of the test procedures.

Certification of a unit as fit for service

103 Alstom's Business Improvement Manager signed the Fitness to Run Certificate provided he was satisfied that the staff competent to carry out the various items of work, including testing, had done so and signed to that effect.

104 Alstom Wolverton considered that it certified a unit as fit to make a single journey returning it to the TOC. There is nothing on the certificate issued for 313104 to indicate this limitation.

105 Alstom Wolverton did not intend to certify a unit as fit for passenger service after a C6 repair since if it was provided to the Works in an unfit state for passenger use – for example with seats missing – it would be returned to the TOC in the same condition.

106 Alstom Willesden accepts the unit from heavy repair understanding it to be in the same operational status as it was dispatched to that repair facility. Therefore, as unit 313104 was sent for repair in a condition fit for passenger service, Willesden believed when it returned from repair at Wolverton Works it was fit for passenger service.

107 The TOC, while actively auditing the performance of Alstom Willesden, has contracted that any unit it takes over from them will be in fully operational condition. Therefore it carries out no routine checks other than drivers' preparations.

Severity of consequences

108 There were no consequences of the incident in terms of damage or injury to people. There are at least 4 locations in north London where an ac to dc change is made. Had the incident occurred at a different time or location, a collision with another train or buffer stops with commensurate injury could have occurred.

109 The prompt action of the driver in switching off the auxiliary power enabled him to stop the train after passing signal CR1102 by about one vehicle length. This response was highly commendable.

Conclusions

Immediate cause

110 The immediate cause of the accident was a unit being placed in traffic with incorrectly connected wiring (paragraphs 36, 61, 70).

Causal and contributory factors

111 The following factor was considered to be causal:

- the specified testing was not carried out after altering a wiring connection during repair at Wolverton Works (paragraphs 53, 74, Recommendation 1).

112 The following factors were considered to be contributory:

- the generally poor condition of the cable identification numbers and specifically the absence of cable identification numbers adjacent to the terminals on the interlock blocks of the SCS (paragraphs 45, 89, 94, Recommendations 2, 4);
- the lack of a formalised procedure for identifying cables when they are disconnected from terminals during the removal of electrical components (paragraphs 45, 46, 91, Recommendation 3);
- the contracted test specification did not mandate a test sequence (paragraph 73, Recommendation 5);
- the testing staff had limited understanding of the class 313 systems, but were allowed to carry out minor rectification work (paragraph 53, Recommendation 6); and
- the design of the traction control circuits was such that a false feed caused by a single incorrect connection prevented the linebreakers from opening (paragraph 101, Recommendation 7).

Factors affecting the consequences

113 The prompt action of the driver and the location at which the incident occurred contained the severity of the incident (paragraphs 29, 30).

Additional observations

114 The availability of a wiring diagram would have assisted the electrical fitting and testing staff when they endeavoured to check the accuracy of the wiring connections (paragraph 49, Recommendation 8).

115 Had the unit been given a *sequence test* in dc mode before it entered traffic, the fault would have become apparent (paragraphs 54, 88, Recommendation 9).

116 The certification of unit 313104 when it left Alstom Wolverton for Alstom Willesden did not indicate any limitation on the validity of the certificate, allowing Alstom Willesden to assume that the unit had been received from Alstom Wolverton in a suitable condition to enter traffic (paragraphs 104, 106, Recommendation 9).

Actions already taken or in progress relevant to this report

117 Alstom and HSBC have jointly examined the test procedure and specified which tests must take place sequentially.

118 Alstom Wolverton introduced a form to be completed recording cables removed from and to be reconnected to the SCS and similar components.

119 HSBC Rail and Silverlink have developed and are implementing a modification to the traction control circuits that significantly reduces the risk of the line breakers closing due to a false feed. It is planned for completion by the end of April 2007.

Recommendations

120 The following safety recommendations are made[1]:

Recommendations arising from causal and contributory factors

1. Railcare (Wolverton) should establish procedures which ensure that after the reconnection of cables the circuits affected are tested in accordance with an appropriate test procedure before testing is declared complete (paragraph 111).

2. HSBC and Silverlink (as appropriate) should examine the condition of cable and terminal identification on class 313 rolling stock to establish its condition and the nature of any corrective action necessary (paragraph 112).

3. While cable and terminal identification remains illegible, Railcare (Wolverton) should develop and implement a documented method of recording the terminals from which cables have been removed during the component replacement process (paragraph 112).

4. HSBC should put in place arrangements to ensure that clear cable and terminal identification is maintained throughout the life of rolling stock which it procures (paragraph 112).

5. HSBC and Silverlink (as appropriate) should introduce a procedure to ensure that tests specified to those contracted to work on rolling stock mandate any sequence necessary to ensure their integrity (paragraph 112).

6. Railcare (Wolverton) should review the competence and authority of staff carrying out testing to undertake rectification work. Working practices examined in this review should be modified to mitigate any identified risks (paragraph 112).

7. HSBC and Silverlink (as appropriate) should, taking into account other recommendations in this report relating to rolling stock testing, assess the residual risk of a false feed involving the traction control circuitry of a class 313 EMU causing an unsafe condition and carry out any appropriate modifications to mitigate this risk (paragraph 112).

Recommendations arising from observations

8. Railcare (Wolverton) should ensure that electrical fitting and testing staff have access to the relevant wiring diagrams (paragraph 114).

9. Railcare (Wolverton) and West Coast Traincare Ltd should review the processes used to put trains back into traffic to ensure that all departments understand and work within the limitations of any certificates on which they rely (paragraphs 115,116).

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

Appendices

Glossary of abbreviations and acronyms — Appendix A

ac	Alternating current
dc	Direct current
EMU	Electric Multiple Unit
HSBC	Hong Kong and Shanghai Banking Corporation
MA	Motor Alternator
OTMR	On Train Monitoring Recorder
ROSCO	Rolling Stock Leasing Company
SCS	Supply Changeover Switch
TMD	Traction Maintenance Depot
TOC	Train Operating Company
TPWS	Train Protection and Warning System

Glossary of terms — Appendix B

'A' Examination	A routine examination occurring approximately every 21 days as part of the regular maintenance programme.
Auxiliary System	A system on a train powering additional equipment such as compressors or air conditioning which is not part of the traction system.
Berthing	The placing of a locomotive or rolling stock, usually in a platform or siding, unattended and out of immediate use.
C6 Repair	Attention given to an item of rolling stock at a workshop separate from that used for day to day maintenance, involving the replacement of parts with renovated items.
Cable Loom	A group of wires retained to together to maintain them in a safe position.
Contactor	A switch in a heavy duty electrical circuit which controls that circuit.
Diagram	A series of timetabled journeys made by a train or locomotive.
Earth	The connection of one point of an electrical circuit to the mass of the earth to prevent danger of electric shock.
Electric Multiple Unit	A set of semi-permanently coupled vehicles capable of moving under electrical power and controlling one or more other units coupled to it.
Fitness to Run Certificate	A document signed by a competent person indicating that a railway vehicle is in a fit condition to run on the railway.
Flashover	An unwanted electrical discharge between two or more items of equipment usually causing damage.
Full Series	During the acceleration of an electric train, a stage in the control sequence in which the motors are in series with each other and all resistances have been cut out.
Heavy Maintenance	Maintenance carried out on trains, usually away from the operating TOC, which is too invasive to be carried out as part of the light maintenance programme.
Interlock	An electrical contact attached to a switch to ensure that certain electrical circuits operate in the correct relationship to the switch.
Light Maintenance	Maintenance carried out on trains on a day to day basis under the control, though possibly sub-contracted, of the TOC.
Linebreaker	An electrical switch capable of safely interrupting the flow of large electric currents.
Master Switch	A switch on the driver's desk which activates that desk and enables the driver to select the direction of travel of the unit.
Motor Alternator	A rotating electrical machine which provides alternating current to power auxiliary equipment on a train.

National Log	A daily record kept by Network Rail of out of course events.
On Train Monitoring Recorder	Equipment which captures and logs critical parameters of a train's journey such as speed and use of the train's controls.
Overhead Line	Wires suspended above railway tracks used to transmit electricity to drive electric trains.
Preparation	A limited, pre-use examination of a unit, primarily to ensure security of visible components and availability of emergency equipment which takes place each time a unit takes up a diagram.
Rolling Stock Leasing Company	The owner of rolling stock which is leased to the TOC.
Schematic Diagram	A diagram which shows the electrical circuits interconnecting and controlling components, but which does not indicate their physical location or layout.
Sequence Test	A test of the power control system of a locomotive or train which avoids the need to actually apply power or to move any vehicles.
Supply Changeover Switch	A switch selecting the source of traction electricity drawn by the unit, either 25 kV ac via overhead line or 750 V dc via a third rail.
Test Specification	A specification indicating tests required and the order in which they are to be carried out.
Third Rail	An additional rail beside the two running rails used to transmit dc electricity to drive electric trains.
Traction Motor	An electric motor which drives the train wheels.
Train Operating Company	A company that is franchised to run train services over a designated area of the national rail network.
Train Protection and Warning System	A system that provides train stop protection at some signals.
Wiring Diagram	A diagram showing location, routing and termination of electrical cables.

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Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby UK
DE21 4BA

Telephone: 01332 253300
Fax: 01332 253301
Email: enquiries@raib.gov.uk
Website: www.raib.gov.uk