



Rail Accident Investigation Branch

Rail Accident Report



**Minor collision between an engineering unit and
two manual trolleys near St. John's Wood
25 October 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.

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Minor collision between an engineering unit and two manual trolleys near St. John's Wood

25 October 2007

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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 Tube Lines, London Underground Ltd, Grant Rail/Trackwork joint venture and Consillia Ltd to their staff, data and records in connection with the investigation.
- 4 Appendices at the rear of this report contain the following glossaries:
 - acronyms and abbreviations are explained in Appendix A; and
 - technical terms (shown in *italics* the first time they appear in the report) are explained in Appendix B.

Summary of the Report

Key facts about the incident

- 5 At 02:40 hrs on 25 October 2007, an engineering unit (consisting of a motorised electric track trolley carrying four persons and two loaded trailers) failed to slow down at the rate the driver expected. The engineering unit was travelling at approximately 10 mph (16 km/h) from St. John's Wood station towards Baker Street station on the London Underground southbound Jubilee line, which was on a 1 in 39 falling gradient. See Figure 1.
- 6 The engineering unit collided at slow speed with two manual trolleys. During the collision the manual trolleys were pushed back about 0.3 m. There were no injuries.

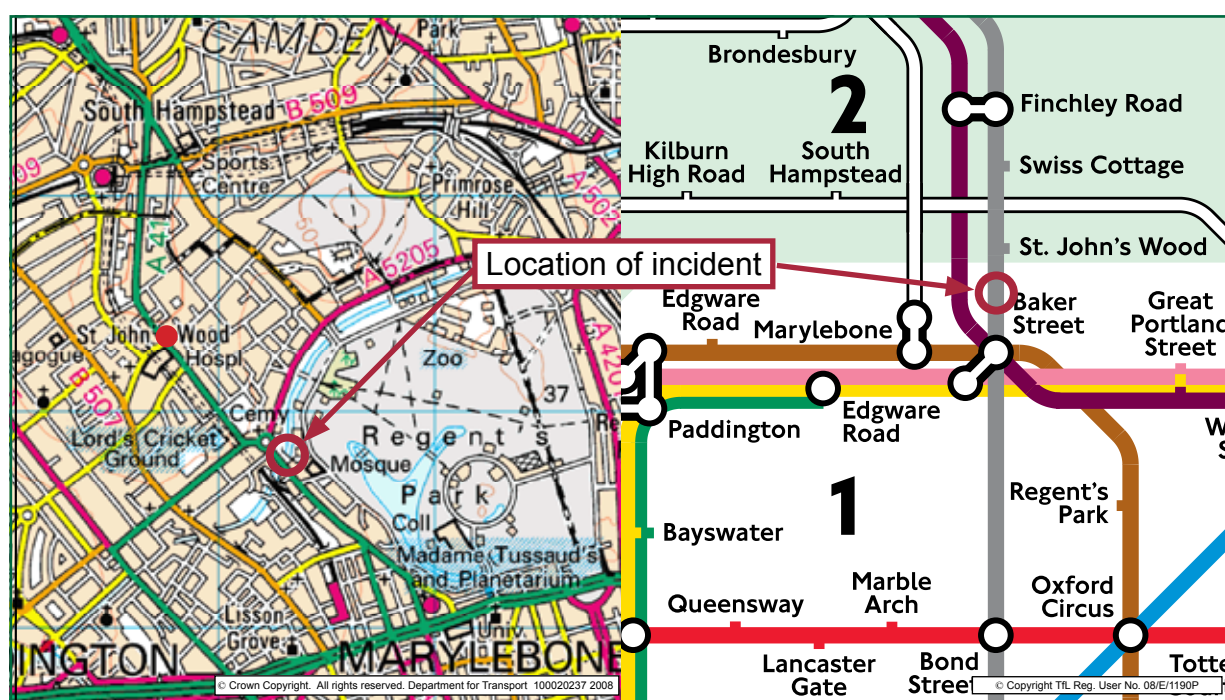


Figure 1: Extracts from Ordnance Survey and TfL maps showing location of incident

Immediate cause, causal and contributory factors

- 7 The immediate cause of the incident was that the operation of the emergency brake failed to slow the engineering unit at the rate expected by the *Track Trolley Operator*.
- 8 Causal factors were:
 - the trailer connected to the electric track trolley, and loaded with 800 kg, had non-operational emergency brakes;
 - the second trailer, loaded with 200 kg, had only 50 % operational emergency brakes;
 - the poor performance of the braking systems on the engineering unit; and
 - the mechanical design of the braking system of the trailers was of a sensitive nature which resulted in the emergency brakes jamming in the 'off' position on one trailer.

- 9 The following factors were contributory:
- The failure of staff to carry out adequate pre-work brake tests;
 - The railhead showed some presence of grease and all wheels of both the electric track trolley and trailers showed high levels of compacted grease;
 - The engineering unit was being driven at approximately 10 mph (16 km/h) (its maximum permitted speed);
 - The gradient on the approach to and at the point of impact was 1 in 39 downwards;
 - Despite his training, the Track Trolley Operator did not fully understand the relationship between the speed, the gradient and the loading of the unit and the impact that this would have on its braking performance and stopping distance. The Track Trolley Operator was not provided with appropriate reference material to assist him in this matter; and
 - There was no clearly defined preventative maintenance regime and an absence of maintenance manuals and schedules for both the electric track trolley and trailers.

Recommendations

- 10 Recommendations can be found in paragraph 205. They relate to the following:
- Three recommendations have been made to Consillia Ltd. These cover the areas of design and operation of the engineering unit including the braking system of the trailers.
 - Six recommendations have been made to Tube Lines. These cover the areas of design, operation and maintenance of the engineering unit and training of the staff involved.
 - Five recommendations have been made to London Underground Ltd. These cover the areas of design, the acceptance and approvals process for on-track plant and training and the reporting of incidents by the staff involved.

The Incident

Summary of the incident

- 11 At 02:40 hrs on 25 October 2007, an engineering unit (consisting of a motorised electric track trolley carrying four persons and two loaded trailers) being used in connection with engineering works on the Jubilee Line of London Underground failed to slow down at the rate the driver expected. The engineering unit was travelling at approximately 10 mph (16 km/h) from St. John's Wood station towards Baker Street station on the southbound line, which was on a 1 in 39 falling gradient. See Figure 2.
- 12 The driver of the engineering unit saw two stationery manual trolleys 50 m ahead. At this point he sounded his horn and applied the normal brake on the electric track trolley. At a distance of 10 m from the manual trolleys, the driver applied the emergency brakes on the unit and shouted a warning and all staff moved clear of the line. The engineering unit collided at slow speed with the two trolleys.
- 13 During the collision the manual trolleys were pushed back about 0.3 m. There were no injuries.

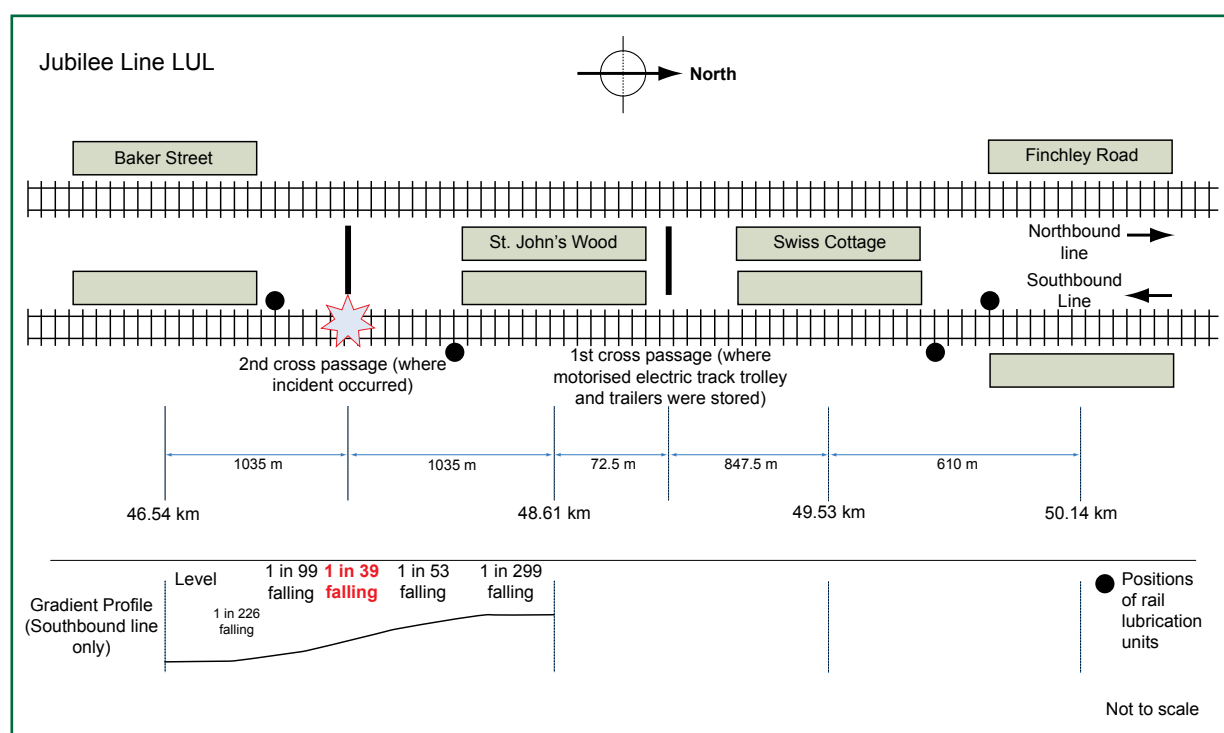


Figure 2: Diagram of the location showing incident on the southbound line. Both lines are in tunnel

The parties involved

- 14 London Underground Ltd (LUL) is the infrastructure operator. At the time of the incident, the infrastructure and rolling stock were managed and maintained under the Public Private Partnership (PPP) by three contractors (Infracos). The Infraco responsible for the Jubilee Line was Tube Lines.
- 15 Tube Lines had contracted with a joint venture made up of Grant Rail Ltd and Trackwork Ltd. This Grant Rail/Trackwork joint venture is known as GTJV. GTJV employed the engineering unit operator and other staff involved in the incident.

- 16 Consillia Ltd are a rail utility vehicle manufacturer. They had manufactured the electric track trolley and the two trailers involved in this incident.
- 17 Tube Lines has a division known as TransPlant, based at Lillie Bridge Depot, west London. TransPlant has a subdivision known as Plant Services. Plant Services maintains a register of and hires out tools, lifting equipment and electric track trolleys and trailers used on the London Underground network. Plant Services supplied the electric track trolley and trailers involved in the incident and also supplied the training for the operators.

Location

- 18 The incident took place on the southbound line of the Jubilee Line between St. John's Wood and Baker Street. Figure 2 shows the location.
- 19 The Jubilee line is a *deep level tube* of the London Underground network. Traction power is supplied via a third and fourth rail *conductor rail* system and at the time of the incident, the traction power was off. Each track runs in a single bore tunnel connected by *cross passages*. At this location there were two cross passages connecting the northbound to the southbound lines. These cross passages are provided for personnel access, draught relief and to store engineering units and track materials such as *ballast*. The first is located 10 m north of the northern end of St. John's Wood platforms and the second is located 972 m south of the southern end of St. John's Wood platforms.
- 20 The gradient falls in the normal direction of trains on the southbound line between St. John's Wood and Baker Street. In St. John's Wood southbound platform the gradient falls at 1 in 299. At the end of the platform the gradient changes to 1 in 53 falling to a point 600 m from the end of the platform. The gradient then changes to 1 in 39 falling for a distance of 500 m as the line passes the second cross passage. The line continues to fall less steeply towards Baker Street station where the platform is level. Figure 2 show the gradient profile for the southbound line between St. John's Wood and Baker Street.

Railhead conditions

- 21 The railhead was dry, but there was some grease on and around the railhead. There are four *rail lubrication units* installed between Finchley Road and Baker Street stations on the southbound line (see Figure 2). Grease is provided through these rail lubrication units connected to the rail (usually in the vicinity of curves) to prevent excessive wear to the wheels and rail and to prevent *flange climb*.

Background

- 22 Major overhaul and upgrade work on the Jubilee Line was contracted to Tube Lines Projects, while maintenance was carried out by Tube Lines Operations. The permanent way upgrade project was contracted by Tube Lines Projects to GTJV.
- 23 GTJV acted as the principal contractor for the rail replacement work at the St. John's Wood and Baker Street areas. Tube Lines determined the scope of work in line with the requirements of LUL track standards and whole life asset management obligations. GTJV carried out the site planning and physical work to execute this scope.

- 24 The type of work that was being carried out on the night of the incident was of a minor nature and involved the movement of track relaying equipment from Baker Street station to the second cross passage as well as the repair of broken *chairs*. Work also included the use of the engineering unit to transport *grout* and *spoil* from St. John's Wood to Finchley Road station and also to the second cross passage.
- 25 The engineering unit involved in this incident was under hire to GTJV from TransPlant.

Rail equipment (engineering unit)

- 26 The first of the present generation of motorised electric track trolleys were introduced into London Underground in 1999, and were the Bance two and four seat versions. Between 2003 and 2005 a different type of motorised electric track trolley made by Consillia Ltd was developed and then introduced from 2005.
- 27 The motorised electric track trolley involved was a Consillia MEC-4 type track trolley, as shown in Figure 3.



Figure 3: MEC-4 motorised electric track trolley

28 Both of the trailers involved were Consillia Ltd MTRL-1 trailers, as shown in Figure 4.



Figure 4: MTRL-1 trailer

29 There is a mechanical and electrical connection between both the electric track trolley and the trailer and between each of the trailers. The mechanical connection is a tow bar (similar to a motor vehicle tow bar arrangement) and the electrical connection is by the use of plug and sockets to provide electrical connections to the red and white *marker lights* and to provide power to the solenoids that hold the brakes off on the trailers. A typical tow bar and electrical connection is shown in Figure 5.



Figure 5: Tow bar and electrical connection

Operators of the engineering units

- 30 On the London Underground network, Track Trolley operators are required to be certificated by LUL. Certification involves training and assessment and is valid for two years. The training requirements are described in LUL HR Training Standard G9333 v A7 (02 June 2004).
- 31 The training for the electric track trolley and trailer operators involved in this incident was conducted by TransPlant at Lillie Bridge depot and included pre-use checking of electric track trolleys, safe working loads, the use and operation of the electric track trolley and trailers, normal and emergency braking and the safe storage of trolleys and trailers.

Events preceding the incident

- 32 The engineering unit had been used at the same location and been used for similar duties for the two nights prior to the incident after being returned from TransPlant after repairs to the trolleys motors. The unit had been operating correctly since its return from TransPlant.
- 33 The engineering unit was being stored in the first cross passage (see Figures 2 and 6). The electric track trolley was split into its two parts (as described in paragraph 57) and stored one part on top of the other. The two trailers were laid against the wall of the passage.

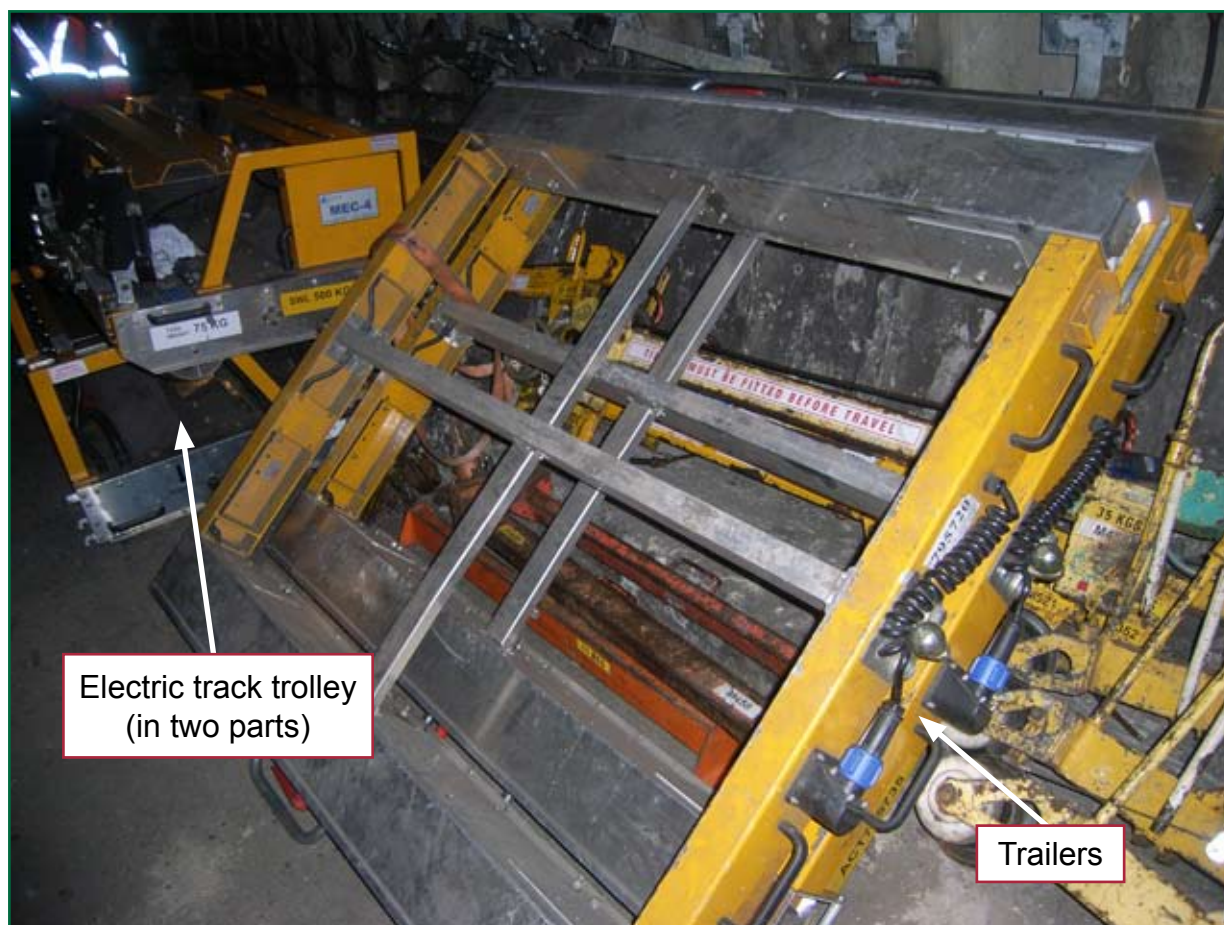


Figure 6: First cross passage at St. John's Wood showing storage of engineering unit

- 34 A Tube Lines *Field Engineer* had signed off the method statement, dated 08 August 2007, for the works to be undertaken on the night of the incident. The method statement (JIM1588-MS-RE-RJ501-001-Rev A) entitled 'Site preparation, installation of air pipes, re-railing and reconditioning works at St. John's Wood-Baker Street-SB Jubilee Line' contained generic references to the use of manual track and *Bance* trolleys. It did not refer to gradients at or around the worksite on the southbound line or the use of Consillia Ltd type motorised electric track trolleys or trailers.
- 35 The Field Engineer was also the *Protection Master* for the work taking place on the night of 24/ 25 October at Baker Street. The engineer, acting as the Protection Master, briefed a number of GTJV staff who were to work with him at the station. The briefing consisted of details of the work to be carried out and safety information, such as the times when the power to the conductor rails would be turned off and on.
- 36 At St. John's Wood station, another Protection Master from Tube Lines briefed the Track Trolley Operator, the *Site Person in Charge* and other members of GTJV staff. Some of the GTJV staff then travelled by road to Finchley Road station to await the electric track trolley and trailers.
- 37 At 02:00 hrs, following the commencement of *engineering hours*, engineering staff from GTJV placed the battery powered electric track trolley and the two trailers on the track at the first cross passage.
- 38 The Track Trolley Operator and a colleague then pushed the electric track trolley to the southbound platform at St. John's Wood to load eight batteries from the platform onto the electric track trolley. The batteries were then correctly connected. The Track Trolley Operator then drove the electric track trolley back to the cross passage.
- 39 The trailers were then connected to the electric track trolley. The brake tests prescribed by TransPlant, and trained to the staff, were not undertaken. The engineering unit was driven, with three passengers, 500 m south towards Baker Street to pick up some bags of spoil that had been left in the second cross passage. The spoil was loaded onto the first trailer (the trailer connected to the electric track trolley), and the unit was then driven in reverse back to St. John's Wood. Tools were loaded onto the rear (second) trailer at this station and then the unit was driven further north to Swiss Cottage station where the tools were unloaded.
- 40 The engineering unit was then driven by the Track Trolley Operator northwards to Finchley Road station carrying the three passengers. At Finchley Road station the spoil was unloaded.
- 41 Approximately one tonne of bagged, dry grout was loaded onto the trailers; forty bags onto the first trailer and approximately ten other bags onto the second trailer. Each bag of grout weighed approximately 20 kg.
- 42 One of the passengers left the unit and the Track Trolley Operator's manager then joined the unit and sat next to the Track Trolley Operator. The unit departed with the Track Trolley Operator and three passengers down the gradient and towards the cross passage situated half way between St. John's Wood and Baker Street. The unit was travelling at approximately 10 mph (16 km/h).

Events during the incident

- 43 As the unit approached the cross passage (see Figure 2) staff were unloading tools from two manual trolleys into the cross passage.
- 44 When the unit was approximately 50 m from the cross passage, and the manual trolleys came into sight, the Track Trolley Operator sounded the horn on the electric track trolley. The Track Trolley Operator then released the driving lever which automatically applied the normal brake on the electric track trolley. The unit began to slow down, but not at the rate that the Track Trolley Operator expected. At approximately ten metres away from the manual trolleys, the Track Trolley Operator applied the emergency brake button on his control console. The unit began to slow down, but again not at the rate the Track Trolley Operator expected. The Track Trolley Operator shouted a warning as he approached the manual trolleys.
- 45 At 02:40 hrs the engineering unit collided at slow speed with the two manually powered trolleys. The manual trolleys were pushed back about 0.3 m.

Events following the incident

- 46 Following the incident, the electric track trolley and trailers were checked by the Track Trolley Operator and his manager. One trailer (ACT795720) was found to have defective emergency brakes and was taken off the tracks and placed into the first cross passage at St. John's Wood station. The electric track trolley and the one remaining trailer (ACT795735) were further used during the night's work.
- 47 At approximately 04:30 hrs (having finished his site work) the Field Engineer completed an initial report and an Incident Report Form. A more detailed report was sent to his immediate manager at 06:00 hrs on 25 October.
- 48 Apart from the Field Engineer, the incident was not reported by other members of staff involved, although the Track Trolley Operator did make an entry into the site diary as requested by his manager.
- 49 The staff involved were not tested for drugs and alcohol. This was because the staff involved did not immediately understand the seriousness of the incident and as a consequence did not report what had occurred until after the end of the work on site.
- 50 During 25 October, the Incident Report Form was sent to managers within Tube Lines. Tube Lines Chief Safety Advisor received this information and reported the incident to LUL, the Office of Rail Regulation (Her Majesty's Railway Inspectorate) (ORR (HMRI)) and the RAIB.
- 51 Tube Lines initiated an internal formal investigation.

Consequences of the incident

- 52 Neither the electric track trolley, the trailers nor the manual trolleys derailed or suffered damage.
- 53 Although the collision between the engineering unit and the manual trolleys on this occasion was minor and no injuries were sustained, there was the potential for a more serious collision had the circumstances been slightly different.

The Investigation

Sources of evidence

54 The main sources of evidence used in this investigation were:

- on site examination and testing of the electric track trolley and trailers at St. John's Wood southbound line;
- testing of the electric track trolley and trailers' performance at Lillie Bridge depot and on a 1 in 30 test track;
- detailed mechanical and electrical testing of the electric track trolley and trailers by the RAIB;
- witness statements;
- information provided by managers and other staff regarding procedures and training;
- Tube Lines documentation; and
- Network Rail M&EE Networking Group Code Of Practice (COP) no. 18¹

¹ COP 18 was issued following the Network Rail Larkhall trolley runaway (RAIB report ref: 20/2006 issued on 2 November 2006) and addressed a number of failings that had been identified. These included a key reduction in Safe Working Load on these trolleys to 50% of the previously rated load.

Key Information

Rail Equipment

55 The engineering unit involved in the incident was made up of the following:

Motorised electric track trolley MEC-4 AC795718 A/B

- 56 The electric track trolley was manufactured by Consillia Ltd in May 2006 (manufacturer's number MEC-4/06/0016) and delivered to Tube Lines TransPlant on 16 May 2006, becoming asset number AC795718 A/B. It is a battery powered electric track trolley (utilising two motors turning all four wheels) and has a maximum speed of 10 mph (16 km/h).
- 57 This type of electric track trolley consists of two half trolleys, which need to be joined together to form a four wheeled vehicle incorporating four plastic seats. Space is available under the seats to house a maximum of eight batteries, although the trolley will operate correctly with four.
- 58 The trolley has the capability to tow a maximum of two trailers depending upon the total load and gradient of the track. It has a Safe Working Load of 500 kg and this is stipulated on a plate fixed to each half of the trolley. The maximum towing capacity of the MEC-4 is 2000 kg on the level based on one operator with four batteries. If eight batteries are used the current capacity increases from 140 Ampere hours (Ah) to 280 Ah and doubles the endurance rating of the trolley. Each battery weighs 25 kg.
- 59 The maximum towing capacity of the MEC-4 is shown in the table below:

Gradient	Load
Level	2000 kg
1 in 100	2000 kg
1 in 60	2000 kg
1 in 40	1000 kg
1 in 29 (maximum operational limit)	650 kg

N.B. These figures above are based on one operator with four batteries.

Table 1: Maximum towing capacity of the electric track trolley

- 60 The driver's controls are mounted in between each pair of seats; a master and slave console is provided to facilitate driving in either direction. The driver's controls include an ignition switch, an emergency stop button, a horn button, a combined speed and brake control via a joystick and lighting switches for work and spot lights. A display is also provided showing battery voltage and distance covered.

- 61 The MEC-4 has both a normal brake (known as the ‘dynamic brake’) and an emergency braking system. The dynamic brake system is activated via the motor controller and applies two spring applied disc brakes (which also act as the automatic parking brake). The release of the brakes is automatically activated when the Track Trolley Operator applies power via the motor controller. The application of the dynamic brake is not designed to operate the brakes on any trailers that are being towed.
- 62 The emergency stop button activates the two spring applied disc brakes and also two spring applied brake shoes. The parking brakes on both halves of the trolley must be in the ‘off’ position to release the brakes and enable the motor control system. The maximum braking rate under normal braking is specified as 1.4 m/s/s. Under emergency braking, the deceleration rate is specified at 1.5 m/s/s. The application of the emergency brake is designed to operate the associated emergency brakes on any trailers that are being towed.
- 63 The stopping distance of the electric track trolley will vary depending upon the gradient and load being towed.
- 64 Upgrade works were undertaken by Consillia in November 2006. These included modifications to parts of the emergency braking system. However, these did not affect the functionality of the braking system and had no relevance to this incident.
- 65 TransPlant had hired out this trolley on previous occasions, the first being 31 October 2006. There had been no significant problems with this trolley.

Trailers MTRL-1

- 66 Each trailer has a Safe Working Load of 1000 kg that is stipulated on a plate fixed to each trailer. The maximum carrying capacity of the trailer(s) as stipulated by the Consillia operating manual is shown in Table 2.

Gradient	Load (utilising 1 trailer)	Load (utilising 2 trailers)
Level	1000 kg	2000 kg
1 in 100	1000 kg	2000 kg
1 in 60	1000 kg	2000 kg
1 in 40	500 kg	1000 kg
1 in 29 (maximum operational limit)	325 kg	650 kg

Table 2: Maximum carrying capacity of the trailer(s)

- 67 The carrying capacity of the trailer is determined by the tractive effort of the electric track trolley, the braking capability and the load that can be safely carried or towed.

68 Each trailer has combined parking and emergency braking in the form of spring applied shoe brakes (one per wheel). These brakes are initially placed in the 'off' position by the Track Trolley Operator moving the brake lever to the 'brake off' position while the brake release function from the electric track trolley is active. The release function energises an electrical solenoid on the trailer which holds the brakes off. The brakes are automatically applied if either (a) the ignition on the electric track trolley is switched off, (b) the emergency stop button is operated or (c) the electrical connection between the electric track trolley and the trailer is broken i.e. in each case the solenoid is de-energised. A photograph of the braking system in its 'brake on' position is shown in Figure 7.

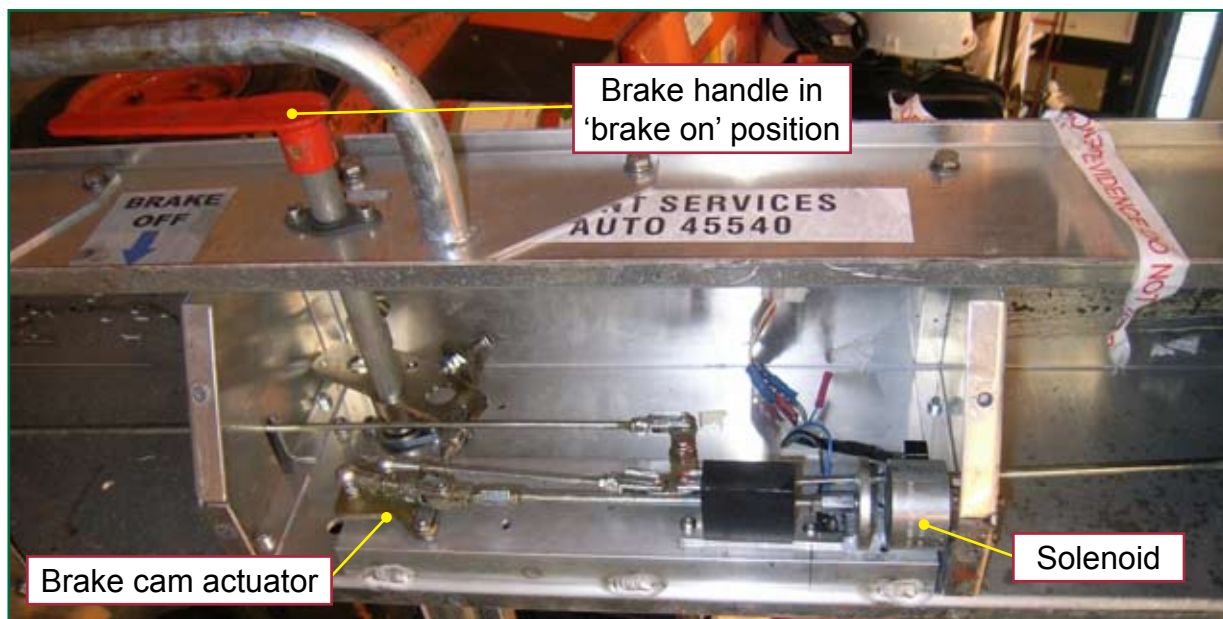


Figure 7: Trailer side showing brake system with brake on and solenoid de-energised

69 Figure 8 shows the brake system in the 'brake on' position. The combined manual and electrical operation of the brakes to their 'off' position is described below (the numbers with arrow heads in Figure 8 refer to the numbers below):

1. the Track Trolley Operator moves the brake lever into the brake 'off' position;
2. the brake cam actuator follows this movement and turns anti-clockwise (shown with dotted lines);
3. the rod connecting the brake cam actuator to the solenoid moves to the right;
4. the solenoid plate latches to the main solenoid as the system is energised;
5. the rod connecting the brake cam actuator to the brake pivot moves to the left; and
6. both rods connecting the brake pivot to the spring applied brakes move to the left and right respectively, thereby pulling the brakes off against their return springs.

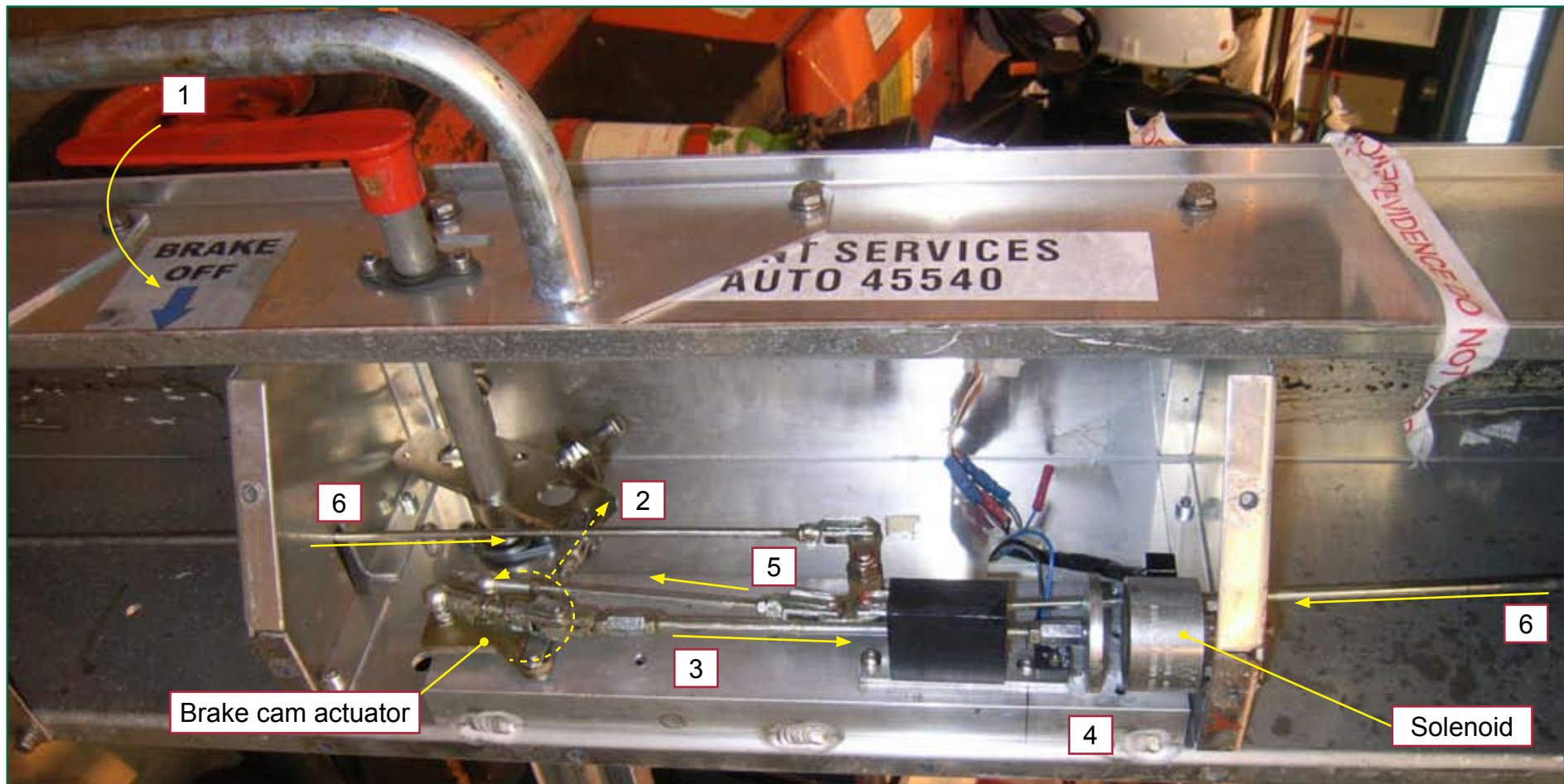


Figure 8: Trailer side showing operation of the braking system (the arrows indicate the direction of movement)

70 Figure 9 shows the brake system in the 'brake off' configuration.

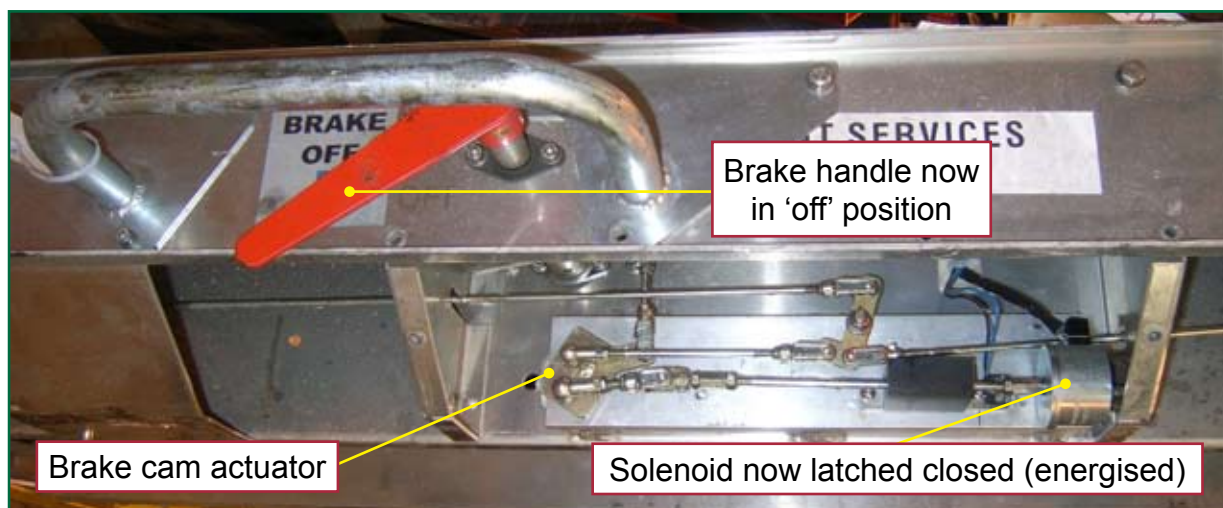


Figure 9: Trailer side showing brake system with brake off and solenoid energised

71 The solenoid and brake cam actuator systems are enclosed behind a metal plate. Only Consillia staff normally had access to this area.

Trailer ACT795735

72 This trailer was manufactured by Consillia on 23 December 2005 (manufacturer's number MTRL1/05/0021) and was delivered to TransPlant on 3 January 2006 becoming asset number ACT795735. It is designed to be used with the MEC-4 electric track trolley.

73 Before the trailer was placed into service, upgrade and modifications works had been undertaken by Consillia in July 2007. These included modifications to parts of the emergency braking system. However, these did not affect the functionality of the braking system and had no relevance to this incident.

74 As part of the above upgrades and modifications work, Consillia also carried out a full brake test. This used a bar which was attached to the wheel, providing a rotational attachment point 0.5 m from the centre of the wheel. A digital spring balance was used to measure the force required to overcome the holding force of the brakes. This was recorded in both directions for each wheel.

75 This was the first time that the trailer had been hired out from TransPlant. The hire had started on 18 September 2007.

Trailer ACT795720

76 This trailer was manufactured by Consillia on 30 September 2005 (manufacturer's number MTRL1/05/0011) and was delivered to TransPlant on 24 October 2005 becoming asset number ACT795720.

77 The same upgrade and modifications work as described in paragraph 73 was undertaken by Consillia in May 2007.

78 As part of the above upgrade and modification work, Consillia also carried out a full brake test as detailed in paragraph 74.

79 TransPlant had hired out this trailer on previous occasions, the first being 14 May 2007.

Training and Competence

- 80 The Track Trolley Operator involved with the incident was trained by Tube Lines to operate and drive the Consillia Ltd electric track trolley and trailers. His LUL 'Safety on the Track' certificate showed that his Track Trolley Operator qualification was due to expire on 9 March 2008. The Track Trolley Operator had driven both Bance and Consillia type units for three years on LUL infrastructure with no previous incidents.
- 81 The Track Trolley Operator was also certificated as a Protection Master (Engineering Hours) and a Site Person in Charge (Engineering Hours).
- 82 The training and training materials for the electric track trolley and trailers involved in this incident was provided by TransPlant at Lillie Bridge depot. The most recent course attended by the Track Trolley Operator was on 13 April 2006. This covered the pre-use checking of electric track trolleys, safe working loads, the use and operation of the trolley and trailers including normal and emergency braking and their safe storage.
- 83 The training course notes were based on the TransPlant safety plan document, 'Operational Safety Plan & Instructions for any make, type and model of two-man & four-man, self propelled Track Trolley and their compatible trailers when operating on the LUL railway system', first issued in July 2005, (and at revision A3 as of October 2007).
- 84 The training course notes on the operation of the electric track trolley states that once the trolley has been assembled on the track, the Track Trolley Operator should 'Check the brakes are working (one brake at a time)'. The notes do not say how this is to be carried out.
- 85 The training course notes on the operation of the trailers state that once the trailer has been assembled, the Track Trolley Operator should 'Check the brakes are working (brakes are 'on' until released by pushing down the handle once connected to the track trolley)'. The notes do not say how the brakes are to be checked.
- 86 The training course notes did not include information on what to do in the event of grease being found on the wheels.
- 87 The training course notes also contain a section entitled, 'Braking Performance'. This section states that:
- 'The braking performance of these types of motorised trolleys will vary depending on the following factors which an operator **Must** be aware of and **Must** respond to when driving a motorised track trolley. The factors are:
- whether a motorised track trolley is towing one or two trailers;
 - whether the motorised trolley and trailers are empty or fully loaded;
 - whether the running rails are wet or dry;
 - whether the wheels of the motorised track trolley and trailers have become coated with grease;
 - the gradients over which the motorised trolley and trailers are required to travel; and
 - the speed at which the motorised trolley is being driven'.
- 88 The training course notes state that 'four/six or eight batteries' must be used, although the Consillia manual states that either a set of four or a set of eight may be used.

- 89 The training course notes document included the operation of both Bance and Consillia type electric track trolleys and trailers. The course document did not have a unique reference number, was unsigned, and was not version controlled. The Plant Services manager, a TransPlant manager and a Health and Safety manager from Tube Lines had approved the training material in December 2005 by the signing of a separate validation certificate.
- 90 The TransPlant document ‘Operational Safety Plan & Instructions for any make, type and model of two-man & four-man, self propelled Track Trolley and their compatible trailers when operating on the LUL railway system’, first issued in July 2005 (and at revision A3 as of October 2007), and the training course notes are handed out to all Track Trolley Operator trainees on the completion of the course.
- 91 The personnel who undertook the pre-hire checks on the Consillia electric track trolley and trailers were based at TransPlant’s Lillie Bridge depot. They were trained to undertake their duties, and managers checked their work through informal observation and end product checks. However this process is not recorded.
- 92 All staff that are new to TransPlant are given an induction, which includes familiarisation with the plant manuals and depot operations, and undertake a three months probation.
- 93 TransPlant has a competence management programme. The competence assessment process was developed for Tube Lines by a company that undertakes similar work across the rail industry in the UK.
- 94 The competence process within Tube Lines was audited in 2007 by LUL and gained accreditation.

Gradient profile

- 95 Following a previous incident where a manual trolley ran away on a gradient, which was investigated by the RAIB², the Network Rail M&E Engineers Networking Group conducted further tests and produced a Code of Practice (COP 18). In this COP the risks associated with the operation of trolleys on gradients were recognised and, as an initial response, a reduction in the working load capacity of manual trolleys of 50 % was mandated.
- 96 LUL and the Infracos operating on the LUL network are not officially represented on the above group. However, they had been sent the COP and, in response, had also reduced the working capacity of manual track trolleys to 50 % of their original rated capacity. This was achieved initially by the issue of a ‘Health, Safety & Environmental Alert’ on 20 January 2006, which restricted the load to half of that designated on the manual trolley. Subsequently manual trolleys used on the LUL network were re-plated, with a load rating of half of the original value.
- 97 Since the COP related to manually propelled trolleys, the Infracos saw no need to change the safe working load of motorised trolleys and their trailers.

² RAIB report 20/2006 – Report on the runaway manually propelled trolley between Larkhall and Barncluth Tunnel: 2 November 2005

98 TransPlant document ‘Operational Safety Plan & Instructions for any make, type and model of two-man & four-man, self propelled Track Trolley and their compatible trailers when operating on the LUL railway system’, first issued in July 2005 (and at revision A3 as of October 2007), section 7.9.5, states that Track Trolley Operators must be aware that the braking performance will vary depending on (as well as other factors):

‘the gradients over which the trolley and trailers are required to travel (particularly when travelling “down-hill”)’.

99 This factor was reflected in the training material provided by TransPlant (paragraph 87).

100 LUL and Tube Lines do not provide Track Trolley Operators with details of the gradients at their individual sites of work.

Maintenance

101 There was no maintenance manual or documented maintenance schedule (time based or operated distance dependent) for either the electric track trolley or the trailers manufactured by Consillia. Consillia and TransPlant had not undertaken any regular maintenance of the units involved in this incident.

102 Consillia rectified any defects that were found with either the electric track trolley or trailers. This included defects that were found when units were returned from hire.

103 TransPlant undertook pre-hire basic checks to test the operation of the electric track trolleys and the brakes on the trailers before they were released on hire. These pre-hire checks consisted of a simple tick list of items to be checked. No guidance was given on how these checks should be performed and the pass/fail criteria.

104 No other records of any additional preventive maintenance by TransPlant exist. Any defects that were found were corrected by Consillia.

105 The electric track trolley no. ACT795718A/B had its last service by Consillia on 29 November 2006. The electric track trolley was examined by TransPlant technicians on 26 October 2006 and 19 October 2007. At both examinations the electric track trolley passed all of the following items (as listed on the TransPlant pre-hire check list):

- visual inspection of the frame/ welds/ pins/ electrical plugs and sockets;
- tow bars;
- brake levers under manual operation;
- emergency (brake) operation;
- brake operation when powered up;
- operation of white and red lights;
- hand test of brake shoes;
- correct SWL and tare labels fitted;
- wheel assemblies; and
- tool box.

106 There are no specifications for the correct operation of the brakes. The brakes are not set or adjusted by TransPlant staff.

- 107 Trailer no. ACT795720 had its last service by Consillia on 3 May 2007. The trailer was examined by TransPlant technicians on 19 January 2007, 14 May 2007 and 18 September 2007. The trailer passed all of the items as listed in paragraph 105 at each examination.
- 108 Trailer no. ACT795735 had its last service by Consillia on 26 July 2007. The trailer was examined by TransPlant technicians on 18 September 2007. The trailer passed all of the items listed at the examination.

Design standards for brakes

Braking system requirements

- 109 ‘Braking system requirements – category VII vehicles³ minimum requirements’, ref: RE/STD/039/Part 7 Issue B was an LUL standard originally issued in 1994. The standard was withdrawn by LUL on 8 February 2006, but it is still used by the Infracos that work for LUL. This standard did not apply to trolleys that carry people but nevertheless was used as a reference in the production of the Tube Lines performance specification for self-powered track trolleys and compatible, unpowered trailers.
- 110 The LUL standard lists a set of general safety guidance. The guidance relevant to this incident is:
- the braking system shall be designed such that the failure of any one single component does not cause more than a 50 % loss in available braking effort; and
 - when travelling at walking pace 3.7 mph (6 km/h) down a 1:29 gradient, the braking system shall stop a fully laden trolley within 20 m of the brakes being applied with 50 % of the braking effort disabled.

Performance specification

- 111 The MEC-4 electric track trolley and MTRL-1 trailers were designed and tested against a performance specification set out by Tube Lines (ref: Performance specification for self-powered track trolleys and compatible, unpowered ‘trailers’, version A3 dated February 2005).
- 112 The performance specification incorporated text extracted from the LUL standard RE/STD/039/Part 7 Issue B. This included the text shown in the first bullet point of paragraph 110. However, the guidance contained in the second bullet point was omitted.
- 113 In section 3.6 of the performance specification, dynamic service and emergency braking rates were defined for level track. The braking rates specified from maximum speed (10 mph) are:
- dynamic service brake, trolley fully laden and towing fully laden trailers shall not be less than 0.8 m/s/s (which equates to a stopping distance of less than 12.5 m); and
 - emergency brake, trolley fully laden and towing fully laden trailers shall not be less than 1 m/s/s (which equates to a stopping distance of less than 10 m).
- 114 There were no specific requirements for braking rates on gradients.

³ Category VII vehicles on LUL are manual or self powered equipment trolleys.

Acceptance and approvals

- 115 The trolleys and trailers involved in the incident were approved in line with a process laid down in the former LUL standard TE-IS-0202 version A2 ('Plant Approval').
- 116 This standard was withdrawn by LUL on 8 February 2006, but it is still used by the Infracos that are working for LUL⁴.
- 117 The evidence related to the application of the acceptance and approval process is summarised in Table 3.

Testing of the engineering unit

Post-incident examination by site staff

- 118 Following the incident at 02:40 hrs, the electric track trolley and trailers were examined by the Track Trolley Operator and his manager and the wheels were found to be contaminated with grease. Later that same shift (and after continued use of the unit) the staff carried out further simple running brake tests on the southbound line in the vicinity of St. John's Wood and it was found that one trailer (ACT795720) had defective emergency brakes. This trailer was taken off the tracks and placed into the first cross passage at St. John's Wood station. The electric track trolley and the one remaining trailer (ACT795735) were further used during the night's work.
- 119 The staff initially believed that the grease had affected the stopping distance of the engineering unit but when the testing was carried later that night, they witnessed that the emergency brake on trailer ACT795720 would stay in the 'brake off' position even when the emergency switch had been operated.

St. John's Wood site testing on 25/26 October 2007

- 120 The RAIB attended St. John's Wood site (including the first cross passage where the unit was stored) during engineering hours on 25/26 October and witnessed initial functional testing of the electric track trolley and trailers.
- 121 Testing showed that the electric track trolley AC795718A/B was in working order. All four wheels of the electric track trolley showed a high level of compacted grease.
- 122 Testing also revealed that on trailer ACT795735, the brake release handle remained in the 'brake off' position even when the emergency brake switch was activated. All four wheels of the trailer showed a high level of compacted grease on their running surface.
- 123 Trailer ACT795720 had a mechanical defect that allowed two wheels on the same end of the vehicle to rotate freely even when the brake release handle was in the 'brake on' position. The trailer could be easily pushed along the track by one person with the brakes applied. All four wheels of the trailer showed a high level of compacted grease on their running surface.

⁴ LUL now have their own standards on plant approval, 'Plant, Tools and Equipment – Performance and Design', ref: 1-172 and 'Plant, tools and Equipment Inspection and Maintenance', ref: 1-173.

Document	Acceptance/ Approval by	Reference	Date	Scope of document/ certification
Braking system requirements – category VII vehicles minimum requirements. (Cat VII vehicles on LUL are manual or self powered equipment trolleys)	LUL Standards manager, Chief Engineers Directorate	RE/STD/039/Part 7 Issue B	October 2000	Standard now withdrawn by LUL but it is still used by the Infracos that are working for LUL.
Performance specification for self-powered track trolleys and compatible, unpowered ‘trailers’	Tube Lines Plant Approvals Engineer	Motorised Trolley Spec	First issued July 1995	Specification (incorporates text from the above standard).
Operational Safety Plan & Instructions for any make, type and model of two-man & four-man, self propelled track trolley and their compatible trailers when operating on the LUL railway system	Tube Lines Plant Approvals Engineer	OSP&I 2&4 Man Track Trolleys Generic – TransPlant	First issued in July 2005	Description of the design and operation of the equipment and an input to a safe system of work.
Plant approval certificate for track maintenance plant or equipment	Tube Lines Plant Approvals Engineer on behalf of The Track Engineer, LUL	PE007 / 1621 (Trolley) PE/007 / 1622 (Trailer)	2 November 2005 2 November 2005	Certificates to confirm that the plant complies with the appropriate statutory regulations, company requirements and track engineering standards for operation within LUL.
Certificate of Technical Conformance for rolling stock	LUL Rolling Stock Engineer	JNP/CTC/186 (Trolley) JNP/CTC/187 (Trailer)	3 November 2005	A ‘type’ approval for new rolling stock certifying that the vehicle complies with those engineering standards appropriate for operation over LUL system – based on a review of the design and testing of the units.
Acceptance for the use of motorised track trolleys and trailers	LUL Customer Services Directorate Head of Operational Support	No reference	24 November 2005	Acceptance of use of both trolley and trailers on LULs infrastructure.

Table 3: Acceptance and approvals process documentation

Tube Lines static testing of other trailers at TransPlant

124 Tube Lines also carried out static testing of other trailers that were stored at TransPlant at Lillie Bridge depot in November 2007. These included the following:

- a visual inspection of the trailers for damage;
- a check to see if the emergency brake could be jammed into the 'brake off' position; and
- a check to see if, when the brakes were applied, any wheels could be rotated by hand.

125 Results indicated that out of 26 Consillia trailers that were in the depot, four trailers had bent axles (two axles on each trailer) and two trailers had minor faults but the brakes did not jam in the off position. TransPlant had also tested two trailers which had not been officially registered. One of these was found to have brakes that would jam in the off position.

Dynamic Testing results from various test sites

126 Table 4 shows relevant results data from the testing of the electric track trolley and trailers involved in the incident, both on level track at Lillie Bridge depot, on 31 October 2007, and on a 1 in 30 gradient at the Ecclesbourne Valley Railway (EVR) near Derby on 15 November 2007. All tests were undertaken with the vehicles moving at full speed of between 9 and 12 mph (14 and 19 km/h).

127 Table 5 shows the final tests undertaken at the EVR, again on a 1 in 30 gradient, on 6 March 2008, which were undertaken by Tube Lines and Consillia. Tests were carried out on trailers that Consillia had modified in an attempt to improve the performance and reliability of the brakes. The modifications to the braking system were adjustments to the installation set-up values: the distance on the adjustable link between the brake cam actuator and its connection to the solenoid (see Figure 11). All tests were undertaken at full speed, except the test indicated as 'note 3'. This test was undertaken at 7 mph (11 km/h).

Test Location	Vehicles involved in the incident on 25.10.07	Formation of test unit	Loading of test unit	Type of braking note 5	Gradient	Railhead condition	Distance to stop note 4	Notes
Lillie Bridge	Yes	Trolley only	2 persons 8 batteries	Dynamic	Level	Dry No grease	6.5 m	note 1
Lillie Bridge	Yes	Trolley only	2 persons 8 batteries	Emergency stop	Level	Dry No grease	6.05 m	note 1
Lillie Bridge	Yes	Trolley and 1 trailer carrying 1000 kg load	4 persons 4 batteries	Dynamic	Level	Dry No grease	18.3 m	note 1
Lillie Bridge	Yes	Trolley and 1 trailer carrying 1000 kg load	4 persons 4 batteries	Emergency stop	Level	Dry No grease	7.8 m	note 1
EVR	Yes	Trolley and 2 unladen trailers	2 persons 8 batteries	Dynamic	1 in 30 downwards	Dry No grease	10.85 m	note 1
EVR	Yes	Trolley and 2 unladen trailers unbraked	2 persons 8 batteries	Emergency stop	1 in 30 downwards	Dry No grease	16.6 m	note 1
EVR	Yes	Trolley and 1 trailer carrying 1000 kg load 2nd trailer unladen	2 persons 8 batteries	Dynamic	1 in 30 downwards	Dry No grease	40 m	note 1
EVR	Yes	Trolley and 1 trailer carrying 1000 kg load 2nd trailer unladen	2 persons 8 batteries	Emergency stop	1 in 30 downwards	Dry No grease	30.9m	note 1 and emergency brakes on laden trailer ACT795735 mechanically held off
EVR	Yes	Trolley and trailer ACT795735 carrying 1000 kg load 2nd trailer unladen	2 persons 8 batteries	Dynamic	1 in 30 downwards	Grease applied to railhead	> 50 m	note 1 and grease applied to both railheads for 2.3 m starting 2 m in rear of the predefined braking point
EVR	Yes	Trolley and 1 trailer carrying 1000 kg load 2nd trailer unladen	2 persons 8 batteries	Emergency stop	1 in 30 downwards	Grease applied to railhead	35.85 m	note 1 and emergency brakes on laden trailer ACT795735 mechanically held off

Table 4: Results from testing at Lillie Bridge depot and EVR on actual vehicles involved in the incident

Test Location	Vehicles involved in the incident on 25.10.07	Formation of test unit	Loading of test unit	Type of braking note 5	Gradient	Railhead condition	Distance to stop note 4	Notes
EVR (March 2008)	No	Trolley and 2 unladen trailers	2 person 8 batteries	Dynamic	1 in 30 downwards	Dry No grease	9.15 m	note 2
EVR (March 2008)	No	Trolley and 2 unladen trailers	2 person 8 batteries	Emergency stop	1 in 30 downwards	Dry No grease	3.9 m	note 2 note 3
EVR (March 2008)	No	Trolley and 1 trailer carrying 1000 kg load 2nd trailer unladen	2 person 8 batteries	Dynamic	1 in 30 downwards	Dry No grease	46.1 m	note 2
EVR (March 2008)	No	Trolley and 1 trailer carrying 1000 kg load 2nd trailer unladen	2 person 8 batteries	Emergency stop	1 in 30 downwards	Dry No grease	9.8 m	note 2

Table 5: Results from testing at EVR on modified trailers

Notes from tables 4 and 5:

Consillia specification states, for the electric track trolley only, a stopping distance of 7 m under dynamic normal braking and 6.5 m under emergency braking on level track.

Note 1: Tests undertaken by Tube Lines and witnessed by both the RAIB and Consillia.

Note 2: Tests undertaken by Tube Lines and Consillia on trailers that had brake modifications carried out.

Note 3: This test was undertaken at a speed of 7 mph (11 km/h).

Note 4: All tests were specified to take place with the vehicles moving at full speed. Actual speeds were verified for each test and varied between 9 mph and 12 mph (14 km/h and 19 km/h).

Note 5: Dynamic braking operates on the electric trolley only. Emergency braking operates on the electric trolley and any trailers that are being towed.

Static testing by the RAIB

- 128 The RAIB undertook its own testing of the electric track trolley and the two trailers involved in the incident.
- 129 Testing involved the dismantling of the braking system on trailer ACT795735 to understand why these brakes appeared to jam in the 'brake off' position even though the emergency braking system had been operated. Trailer ACT795720 was also examined to understand why two wheels on the same end of the vehicle were able to rotate freely even when the brake release handle was in the 'brake on' position.
- 130 Electric track trolley AC795718 A/B was examined to ascertain if there was an electrical problem (constant or intermittent) that would have prevented the solenoids on the trailers from releasing. The track trolley's braking system operation was also examined when either one or two trailers were connected.

Mechanical system of the trailers

- 131 On examination of trailer ACT795735, it was found that the brakes could be jammed in the off position by the operation of the brake handle. This happened intermittently and the brakes would operate if the brake handle was lightly touched or the trailer was knocked by a person's hand.
- 132 Tests were undertaken including the step by step dismantling of the braking system to ascertain what particular component was causing the brakes to jam in the off position. Figures 10 and 11 show the brake system in the jammed position.

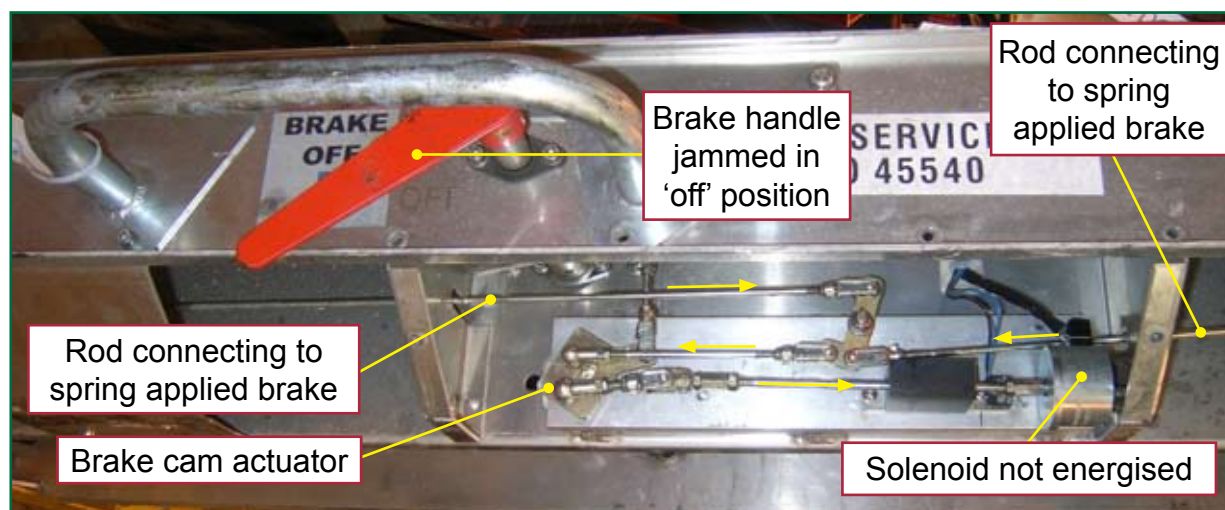


Figure 10: Trailing side showing brake handle and brake cam actuator with connecting rods in jammed position

- 133 No individual component was identified as the cause of the jamming. However, the system was sensitive to the angle of the brake rods connected to the brake cam actuator and its turning moment. The number and thickness of washers in the assembly appeared also to have an affect on the operation, although when these were altered, jamming of the brakes would still occur under some conditions.
- 134 Following reassembly of the braking system in accordance with the Consillia MTRL-1 Build Manual (ref 19/5/2007-iss 2) and measurements taken prior to dismantling, oil was applied to the moving parts of the braking system. This caused the brakes to operate more reliably although jamming in the off position was still observed occasionally.

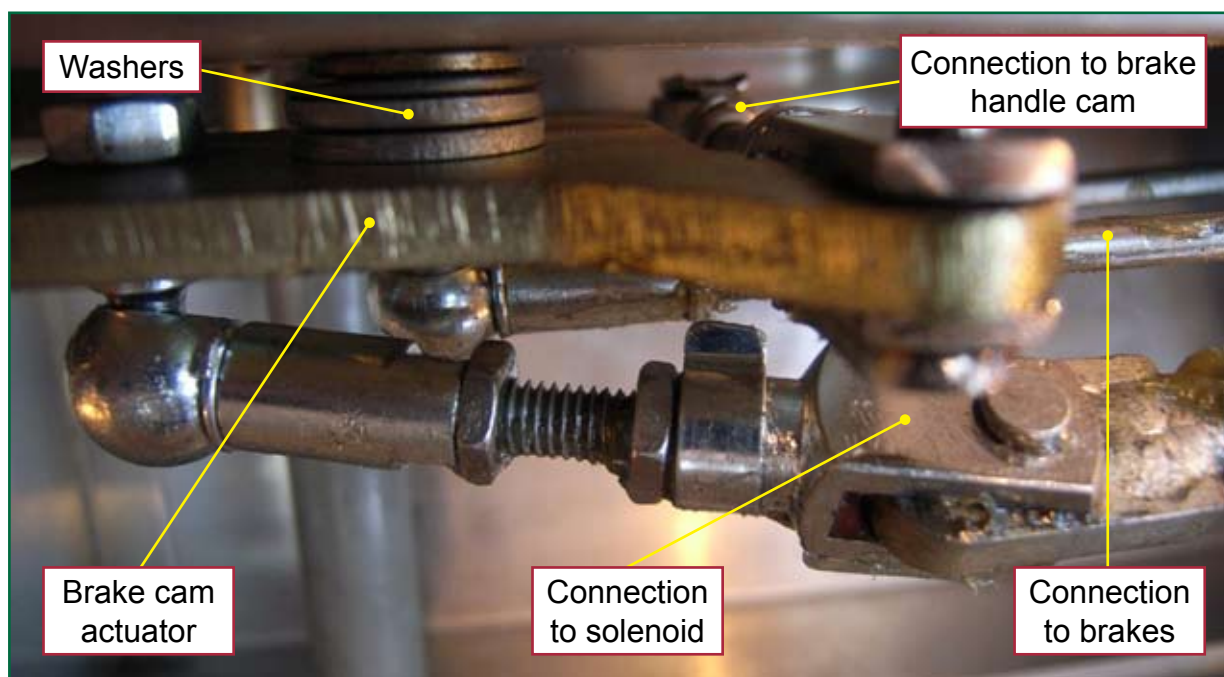


Figure 11: Detailed view of brake cam actuator with washers and connecting rods and clevis

135 Tests were also undertaken using updated set-up values from Consillia⁵ and it was found that the jamming of the brakes in the off position would still occur intermittently. The brakes were then re-assembled to their original configuration and the brakes could not then be jammed in the ‘off’ position.

136 The axles at one end of trailer ACT795720 were bent and the brake shoes were incapable of fully touching the wheel rims. Evidence suggested that trailer ACT795720 had either fallen over or been dropped onto two wheels on some occasion prior to the day of the incident. The damage had rendered the brakes ineffective on those two wheels. The emergency brakes were tested on this trailer, but did not jam in the off position.

Electrical system

137 Results confirmed that there was no defect with the electrical systems on the electric track trolley or on either of the trailers. When the track trolley and trailers were connected together using the tow bars, the complete electrical braking system operated correctly.

Reporting of the incident

138 The staff were unaware of the need to preserve any evidence or of the correct LUL, GTJV and Tube Lines procedures to report the incident.

139 The incident was reported to the RAIB at 11:20 hrs on 25 October 2007.

⁵ Updated set-up values were re-defined by Consillia Ltd following the incident of 25 October 2007 and during their own testing of other similar engineering units.

Previous occurrences of a similar character

Notting Hill

- 140 On 24 May 2006, a manually propelled track trolley being used in connection with engineering works on the Circle Line of London Underground ran away. The trolley travelled 450 metres down a gradient of 1 in 70, reaching a speed between 5 mph (8 km/h) and 12 mph (20 km/h) and collided with a stationary trolley of a similar type at the site of planned work. The two trolleys travelled together a further distance of between 15 metres and 20 metres and came to a stand.
- 141 The RAIB investigated the incident and published a report on 2 May 2007 (ref:12/2007). All reports produced by the RAIB are available on the RAIB website, www.raib.gov.uk.
- 142 The immediate cause of the trolley running away was an ineffective brake, even though the brakes had been applied. Other causal factors were that the pre-use checks for Track Trolley Operators were not carried out on the trolley and that the brake system had been modified in a way that reduced its effectiveness.
- 143 Contributory factors, relevant to this investigation, were the failure to adequately appreciate the risks arising from not carrying out the pre-use brake tests when operating trolleys on gradients and that Track Trolley Operators were not provided with appropriate gradient information.
- 144 The relevant recommendations made by the RAIB are shown below. These have all been accepted by the named stakeholders:
- LUL should amend site management procedures to record satisfactory completion of pre-use brake checks. This recommendation is still under review;
 - LUL together with Tube Lines should review and determine how to ensure Track Trolley Operator's are aware of and know how to apply the controls to mitigate the risks relating to gradients when operating track trolleys. This has been implemented;
 - LUL should ensure that the training of Track Trolley Operator's includes the provision of appropriate reference material to carry on site. This has been implemented;
 - LUL should revise the Site Person in Charge training and reference material to ensure that the Site Person in Charge's responsibilities for accident and incident reporting are defined. This has been implemented;
 - LUL in consultation with Tube Lines should ensure that all contracts and subcontracts for work on the network are aligned in respect of legal accident and incident reporting requirements. This has been implemented; and
 - The Network Rail M&EE Networking Group should consider the participation of LUL and the Infracos in its activities. This recommendation was considered and liaison established with LUL and the Infracos.

Larkhall

- 145 On 2 November 2005, a trolley ran away down a gradient on the Network Rail Larkhall branch in southwest Scotland. Deficiencies were identified in the performance of the braking system on the trolley and also the operational arrangements at the site. The railway industry also carried out tests, and as a direct result the M&E Networking Group issued a Code of Practice (COP 18) to address a number of the failings that had been identified. A key change was the reduction in Safe Working Load on these trolleys to 50 % of the previously rated load. This provides a greater factor of safety against loss of brake performance.

146 The RAIB investigated the incident and published a report on 2 November 2006 (ref: 20/2006).

147 Most of the issues found during the investigation into the incident at Larkhall are not relevant to this incident. Those issues found during the Larkhall investigation which have relevance to the incident on 25 October 2007 are:

- No consideration of the risks associated with the use of trolleys on gradients in the method statement. This issue has been addressed by an RAIB recommendation which has been implemented by Network Rail;
- Briefings to staff did not include reference to the risks of operating trolleys on gradients. This issue has been addressed by an RAIB recommendation which has not been implemented by Network Rail;
- The fitness for purpose of site pre-use checks. This issue has been addressed by an RAIB recommendation which has been implemented by Network Rail; and
- Instructions to staff and contractors to ensure that accidents and incidents are reported to the RAIB as required by the RAIR Regulations 2005. This issue has been addressed by an RAIB recommendation which has been implemented by Network Rail.

Whiteball

148 In 2003 at Network Rail's Whiteball Tunnel, near Taunton, a loaded Permaquip Type B trolley was being used within a worksite under a *possession*. The trolley ran away for approximately 770 yards on a 1 in 127 falling gradient. This incident predated the RAIB's existence and was investigated by Network Rail.

149 Relevant recommendations and actions from the Whiteball investigation were:

- 'Network Rail to ensure that all site method statements address the risks imposed by gradients within the vicinity of the worksite and if plant was to be used or intended for use';
- 'Network Rail to review competency, assessment and training of staff operating rail mounted equipment'.

Other LUL incidents not recorded

150 The RAIB has become aware of an allegation that another safety related incident at St John's Wood had occurred two years before this one, when an overloaded trolley and two trailers had failed to brake in the expected distance. This alleged event was neither reported nor investigated.

Analysis

Identification of the immediate cause

151 The operation of the emergency brake failed to slow the engineering unit at the rate expected by the Track Trolley Operator and was the immediate cause of the collision.

Braking performance of the trailers

152 The test data contained at Table 4 shows that the brakes of the engineering unit did not always perform according to the performance specification described at paragraph 113. In particular it was found that:

- the dynamic braking performance with one loaded trailer was below that specified;
- the dynamic braking performance was reduced still further by the presence of a 1 in 30 gradient;
- the emergency braking performance was significantly reduced by the presence of a gradient of 1 in 30; and
- the emergency braking performance of a unit consisting of one electric track trolley and two trailers (one laden) was seriously degraded as the brakes on one of the trailers were disabled and the other trailer had only 50 % braking.

153 The poor performance of the dynamic brake was related to the fact that it is only applied to the electric track trolley unit and not to the trailers. The stopping distance that would be expected when the trolley's dynamic brake was applied was increased due to the fact that it was towing loaded trailers on a 1 in 39 falling gradient.

154 The poor performance of the braking systems on the engineering unit was a causal factor.

Reliability of operation

155 The brakes of trailer ACT795735 could be jammed in the off position because of the sensitive nature of the braking system. Although this jamming occurred intermittently it is likely that the brakes were jammed in the off position when the Track Trolley Operator applied the emergency brake button on the electric track trolley. The fact that the emergency brakes did not operate on this trailer (and the trailer therefore effectively had no braking) was a causal factor.

156 The brakes of trailer ACT795720 were only effective on two wheels which resulted in a 50 % reduction in emergency braking. This was because the trailer had been dropped or fallen heavily onto its other two wheels causing them to bend away from the brake shoes and thus rendering the brakes ineffective. The damage and the non-operation of the brakes had not been identified by the staff using this trailer. The fact that the emergency brakes only operated on only two wheels was a causal factor.

Gradient

157 The gradient at and approximately 500 m on the approach to the cross passage where the incident occurred was 1 in 39 falling.

158 The gradient of the track affects the stopping distance of the engineering unit, both when the normal and emergency braking systems have been used (see Table 4). The gradient was therefore a contributory factor in this incident.

Loading (materials and personnel)

- 159 The Consillia technical specification states that either four or eight batteries may be used to operate the electric track trolley. The use of eight batteries will double the endurance rating of the trolley and will also double the weight. The technical specification details the towing capacity of the trolley with one operator with four batteries (paragraph 59).
- 160 At the time of the incident, evidence suggests that the trailer nearest to the electric track trolley (ACT795735), that did not have operational emergency brakes, was loaded with approximately 800 kg of bagged, dry grout. The second trailer (ACT795720), that had only 50 % operational emergency braking, was loaded with approximately 200 kg of grout. The total weight of approximately 1000 kg being towed on the gradient of 1 in 39 meant that the unit was operating at just above its maximum capacity. The first trailer had also been loaded with much more material (and weight) than the second trailer and the load was not evenly distributed. The overloading of the trailers, including the additional weight of four batteries and three members of staff on the trolley, was therefore a contributory factor.

Speed

- 161 The Track Trolley Operator was driving the engineering unit at approximately 10 mph (16 km/h). This was the maximum speed of the electric track trolley and the maximum speed as detailed in the training course material and the LUL and Tube Lines approval certificates.
- 162 Had the unit been travelling at a slower speed on its approach to the second cross passage, then it may have been able to stop before it struck the two manual trolleys. Although the unit was within permitted speed limits, the speed of the engineering unit was thus a contributory factor.

Rail condition

- 163 The railhead was dry and there was some grease on and around the railhead. After the incident, all of the wheels of the engineering unit showed high levels of compacted grease.
- 164 The results, as shown in paragraph 126, show that stopping distances are increased when grease is introduced onto the railhead.
- 165 Given the measured effect of grease on braking performance, the railhead conditions were a contributory factor.

Maintenance of the trailers

- 166 There was no maintenance manual or maintenance schedule for the Consillia electric track trolley or trailers produced by Consillia for use either by itself or by TransPlant. TransPlant undertook basic pre-hire checks on the units but these provided little guidance on the nature of the checks to be carried out (paragraph 105).
- 167 Had the damage to the axles of trolley ACT795720 existed at the time of the pre-hire check performed by TransPlant on 18 September 2007, it is uncertain that the specified checks would have detected the consequent poor braking performance. However, since it is not known whether this damage existed at that time, this factor cannot be described as either causal or contributory.
- 168 The absence of a maintenance manual or schedule resulted in the units operating without a sufficient check or examination of the brakes and their operation. This was a contributory factor.

Actions of the Staff involved

Pre-work checks

- 169 The Track Trolley Operator drove the trolley from the platform at St. John's Wood back to the first cross passage (about 10 m) and the unit started and stopped correctly and he concluded that the braking system was working correctly. No other braking tests were undertaken, either individually or when the trolley and the two trailers were connected mechanically and electrically.
- 170 Although the pre-work checks of the Track Trolley Operator should have included individual tests of the brakes on all three units as stipulated in the training notes, there was no procedure or method on how this should have been done. The Track Trolley Operator thus relied on the moving brake tests to confirm the braking of the engineering unit. The fact that comprehensive pre-work brake tests were not carried out by the Track Trolley Operator was a contributory factor in this incident. In addition, it is considered that the absence of procedures on how pre-work testing should be undertaken was an underlying factor.

Driving of the unit

- 171 The trailers connected to the electric track trolley were loaded at just above the maximum specified for the gradient that the unit was to travel over. The Track Trolley Operator and also the Site Person in Charge of the engineering unit did not fully understand the relationship between the loading of the trailers and the gradient.
- 172 The Track Trolley Operator had three years experience at driving these types of engineering units including the Bance types. The Bance units were restricted to a maximum speed of 5 mph (8 km/h). The Consillia units had a maximum of 10 mph (16 km/h) in either direction and the engineering unit was being driven at this speed prior to the incident.
- 173 Neither LUL Ltd nor Tube Lines provide Track Trolley Operators with information on gradients at sites of work. There was also no gradient information in the specific method statement for the work (paragraph 34). The absence of information on gradients was an underlying factor.
- 174 It is believed that the Track Trolley Operator did not fully understand the relationship between the speed, the gradient and the loading of the unit and the impact that this would have on its braking performance and stopping distance. This was a contributory factor.

Competence and training

- 175 The training material contained some important omissions. In particular:
- how pre-work checks should be undertaken on both the electric track trolley and trailers; and
 - what to do in the event of grease being found on the wheels.
- 176 The absence of clear and practical methods for the Track Trolley Operator to use in checking the braking system was a contributory factor.
- 177 As described in paragraph 171, the Track Trolley Operator had driven these types of electric track trolleys and trailers for three years and had also experienced irregular brake and motor performance of both the Bance and Consillia type units.

Design

- 178 Post incident examination revealed a number of mechanical problems on the trailers.
- 179 These problems were directly linked to the design of the trailer and its braking system. This design featured lightweight components such as the brake cam actuator and brake rodding. Examination and testing carried out on the trailer has demonstrated that the design was overly sensitive to foreseeable types of mechanical damage and the exact set up and adjustment of key components. This sensitivity meant that the braking system had the potential to jam in the 'off' position even when set-up in accordance with the manufactures specification.
- 180 The fact that the braking system was sensitive to minor changes was inconsistent with the need for reliable operation in the railway environment. The railway environment is harsh and the use of these units involved lifting them continually on and off the track. The units, while out on hire, were generally stored in cross passages where the electric track trolleys had to be split into two and stacked and the trailers had to be upended and leant and secured against the passage wall.
- 181 The unreliable and sensitive nature of the mechanical design of the trailers was a causal factor in this incident.

Design approvals

- 182 The performance specification prepared by Tube Lines omitted LUL guidance on braking performance on gradients. For this reason there was no requirement for the designers of the engineering unit to demonstrate braking performance on gradients.
- 183 The acceptance and approvals process applied by Tube Lines and LUL was evidenced by a range of signed certificates. This process was based on the review of design documentation and test data provided by the supplier, Consillia Ltd. Despite the application of this process the following deficiencies were not detected and corrected:
- substandard performance of the dynamic brake (when operating with trolleys or when on a downward gradient);
 - the potential for unreliable operation of emergency brakes on the trailer;
 - the sensitivity of the brakes to mechanical damage to the axles; and
 - the absence of a comprehensive preventative maintenance plan and associated documentation (eg manuals).
- 184 Because the process as applied did not detect the potential weakness of the design and the associated maintenance documentation, there is a need for LUL and Tube Lines to jointly review the adequacy of their acceptance and approval processes. Such a review should assess the degree to which the existing processes are capable of checking that adequate engineering safety management systems and techniques have been applied to the specification, design, testing and maintenance planning for new equipment⁶.
- 185 The inadequacy of the acceptance and approval process for the trolley and trailers was an underlying factor in the incident.

⁶ current good industry practice is contained in Engineering Safety Management (the 'Yellow Book'), Issue 4.0.

Other factors for consideration

Incident reporting

- 186 After the incident occurred, there was confusion amongst those on site as to whether the incident was reportable and if it was, then who was responsible for reporting it and the timescales for this to be carried out.
- 187 The Field Engineer working with the manual trolleys was the most senior person on site. Although no discussion took place between him and the others on site regarding their subsequent actions or reporting, he did subsequently submit an Incident Report Form regarding the event after having finished his site work.
- 188 It was later on the morning of 25 October that the Incident Report Form was sent to managers within Tube Lines. Tube Lines Chief Safety Advisor received this information and made further enquiries and also reported the incident to LUL, ORR (HMRI) and the RAIB.
- 189 The key issues related to the reporting of the incident were:
- although the Site Person in Charge was the person on site with responsibility for safety, he was not aware of his responsibilities for reporting to GTJV, GrantRail's control centre or Tube Lines in the event of an incident;
 - although an Incident Report Form had already been raised by the Field Engineer, it is unclear that the entry made by the Track Trolley Operator into the site diary would have been elevated and actioned by managers within GTJV or Tube Lines;
 - the Site Person in Charge and other staff were unaware of the RAIB (and the need to preserve any evidence) and had not been fully briefed by Tube Lines or GTJV; and
 - consequently GTJV and LUL did not immediately report the incident to the RAIB.

Drugs & Alcohol testing

- 190 As a consequence of the late reporting and a lack of appreciation of the seriousness of the incident no drugs and alcohol testing was undertaken on the staff involved.

Conclusions

Immediate cause

191 The immediate cause of the incident was that the operation of the emergency brake failed to slow the engineering unit at the rate expected by the Track Trolley Operator.

Causal factors

192 Causal factors were:

- the trailer connected to the electric track trolley, and loaded with 800 kg, had non-operational emergency brakes (paragraph 155, Recommendation 1);
- the second trailer, loaded with 200 kg, had only 50 % operational emergency brakes (paragraph 156, Recommendation 1);
- the poor performance of the braking systems on the engineering unit (paragraph 154, Recommendation 1); and
- the mechanical design of the braking system of the trailers was of a sensitive nature which resulted in the emergency brakes jamming in the 'off' position on one trailer (paragraph 181, Recommendation 1).

Contributory factors

193 The following factors were contributory:

- the failure to carry out adequate pre-work brake tests (paragraphs 170 and 176, Recommendation 2);
- the railhead showed some presence of grease and all wheels of both the electric track trolley and trailers showed high levels of compacted grease (paragraph 163, Recommendation 4);
- the engineering unit was being driven at approximately 10 mph (16 km/h) (its maximum permitted speed) (paragraph 161, Recommendation 3);
- the gradient on the approach to and at the point of impact was 1 in 39 downwards (paragraph 157, Recommendation 5);
- despite his training, the Track Trolley Operator did not fully understand the relationship between the speed, the gradient and the loading of the unit and the impact that this would have on its braking performance and stopping distance. The Track Trolley Operator was not provided with appropriate reference material to assist him in this matter (paragraphs 34, 160 and 174, Recommendation 6); and
- there was no clearly defined preventative maintenance regime and an absence of maintenance manuals and schedules for both the electric track trolley and trailers (paragraph 166, Recommendation 5).

Underlying factors

194 The following factors were underlying:

- the absence of procedures on how pre-work testing should be undertaken by Track Trolley Operators (paragraph 170, Recommendation 7);
- the absence of appropriate reference material on gradients for Track Trolley Operators (paragraph 173, Recommendation 8); and
- the design, testing, acceptance and approvals process did not detect that the design of the braking system was deficient and the absence of adequate maintenance documentation (paragraph 185, Recommendations 9, 10 and 11).

Additional observations

195 Site Person in Charge staff are not clearly briefed or aware of their responsibilities, criteria and the correct mechanism for reporting incidents through to the Infraco and LUL (paragraph 189, Recommendations 12 and 13).

196 Pre-hire checks undertaken by TransPlant were a simple tick list of items to be checked and had not been integrated with an overall maintenance regime laid down by Consillia or Tube Lines (paragraph 167 Recommendation 14).

197 The significance and seriousness of the incident appears not to have been appreciated by those on site. Their considerations seem to have been based upon the actual consequences, which were fortunately minor, rather than the potential consequences, which were very significant.

198 It is observed that LUL has still to implement recommendation 1 made by the RAIB following the investigation into an accident at Notting Hill Gate (concerning the recording of pre-use brake tests). The need for this to be implemented is demonstrated by the circumstances of the incident at St. John's Wood (paragraph 145 Recommendation 2).

199 On each side of the trailer there are two unprotected small diameter rods that connect each spring applied brake shoe to the brake system housed behind the metal protective plate. These rods are easily susceptible to external damage. If the rods became damaged or bent, the brake shoes may be held further away from the wheel, rendering the brakes inoperative (paragraph 179, Recommendation 1).

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

- 200 As a result of the site tests undertaken on 25 October 2007, Tube Lines immediately withdrew all Consillia and Bance electric track trolleys and trailers from operational use. Following further investigation and a supporting Tube Lines 'Case for Safety'⁷, the Bance electric track trolleys were released back into service on 12 December 2007. As part of this, all Track Trolley Operators were required to attend a re-training course by TransPlant.
- 201 The ORR (HMRI) issued a prohibition notice (ref: 301122948 and P/TLL/230108/JGT) on 23 January 2008 in respect of the Consillia MEC-4 electric track trolley and trailers.
- 202 Tube Lines have written a 'case for safety' for the return of Consillia MTRL-1 trailers into service following emergency brake set-up modification works undertaken by Consillia and the results of tests on these units at the EVR on 6 March 2008. Following the acceptance of the Tube Lines case for safety paper, the Consillia MTRL-1 trailers have now been returned to service for use on LUL infrastructure. These trailers are currently being used with Bance type electric track trolleys and therefore restricted to a maximum speed of 5 mph (8 km/h) (paragraph 172).
- 203 Consillia now undertakes detailed brake testing when either the electric track trolley or trailers are returned for service or repair. The measurements of brake force required to overcome the brake holding force are recorded. Consillia is also in the process of developing a new combined maintenance and construction/ setup manual in conjunction with Tube Lines.
- 204 GTJV have reminded staff about the requirements to report incidents immediately. A further briefing has been carried out to inform staff of the role of the RAIB, their powers and the responsibilities of GTJV staff to preserve evidence.

⁷ Case for Safety is entitled 'Return to service of Bance Motorised Track Trolleys, following incident on 25th October in the St John's Wood to Baker Street area', Category 02 version R3 dated 12/12/07.

Recommendations

205 The following safety recommendations are made⁸:

Recommendations to address causal and contributory factors

- 1 Consillia Ltd should undertake a review of the design of the braking system on its MTRL-1 trailers. The purpose of the review shall be:
 - to determine sensitivity to the initial set-up, adjustment, lubrication and subsequent mechanical damage; and
 - to identify design modifications to improve the robustness of the design and to restore reliability in service.Any necessary improvements identified should be implemented (paragraphs 192 and 199).
- 2 London Underground Ltd, in consultation with Tube Lines should amend its Track Trolley Operators training to include a pre-work brake test on all wheels of trailers before they are placed on the track and that this is recorded. Once the electric track trolley and trailer(s) have been electrically and mechanically connected, a functional test of the emergency brake should be carried out at that time (this is linked to recommendation 1 in the Notting Hill report, ref: 12/2007) (paragraphs 192 and 198).
- 3 Tube Lines should restrict the operation of the Consillia Ltd MEC-4 electric track trolley and MTRL-1 trailers to a maximum speed of 5 mph (8 km/h) until both recommendations 1 and 2 have been completed (paragraph 193).
- 4 London Underground Ltd, in consultation with Tube Lines, should investigate the safe operation of brakes on all existing types of trolleys when contaminated by grease and review their relevant design, engineering and operational specifications (paragraph 193).
- 5 Consillia Ltd should prepare a maintenance document detailing the maintenance procedures and testing arrangements for MEC-4 electric track trolleys and MTRL-1 trailers and schedules to be carried out by either Consillia Ltd or Tube Lines (paragraph 193).

continued

⁸ Duty holders, 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 Office of Rail Regulation (Her Majesty's Railway Inspectorate) to enable it to carry out its duties under regulation 12(2) to:

- (a) ensure that recommendations are duly considered and where appropriate acted upon; and
- (b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 167 to 171) can be found on RAIB's web site at www.raib.gov.uk

- 6 Tube Lines should ensure that:
- Track Trolley Operators are provided with the appropriate reference material during training; and
 - Track Trolley Operators are trained to understand the information that they are required to carry on site (including information contained in method statements) (paragraph 193).

Recommendations to address underlying factors

- 7 Tube Lines should amend its Track Trolleys Operators training to include how pre-work brake tests should be carried out on motorised trolleys and trailers (linked to Recommendations 2 and 6) (paragraph 194).
- 8 Tube Lines should put in place a process to ensure that gradient data (obtained from either a database or the relevant method statement) is made available to Track Trolley Operators for each site (paragraph 194).
- 9 Tube Lines should review its process for the preparation of specifications for track plant equipment with the objective of ensuring that safety related performance requirements are correctly defined. Any necessary improvements identified should be implemented (paragraph 194).
- 10 Consillia Ltd should review its design validation and testing process against current industry good practice (e.g. Engineering Safety Management: the 'Yellow Book', Issue 4.0). Any necessary improvements identified should be implemented (paragraph 194).
- 11 London Underground Ltd should review the suitability of its process for the acceptance and approvals of trolleys, trailers and other items of on-track plant. Any necessary improvements identified should be implemented (paragraph 194).

Recommendations to address other matters observed during the investigation

- 12 London Underground Ltd, in consultation with all the Infracos, should revise the Site Person in Charge training and reference material to ensure that the Site Person in Charge's responsibilities for accident and incident reporting are defined (paragraph 195).
- 13 London Underground Ltd, in consultation with Tube Lines, should:
- re-brief all staff (including subcontractors) on their obligations to report accidents and incidents; and
 - issue guidance on the circumstances in which they should do so (paragraph 195).
- 14 Tube Lines, in consultation with Consillia Ltd, should clearly define the pre-hire checks that are required to confirm the correct operation of the equipment, the method for doing so and the pass/fail criteria to be applied (linked to the maintenance document to be written in response to recommendation 5) (paragraph 196).

Appendices

Appendix A - Glossary of abbreviations and acronyms

Ah	Amp hours
COP	Code of Practice
EVR	Ecclesbourne Valley Railway
GTJV	Grant Rail Ltd/ Trackwork Ltd joint venture
LUL	London Underground Ltd
ORR(HMRI)	Office of Rail Regulation (Her Majesty's Railway Inspectorate)
PPP	Public Private Partnership
RAIB	Rail Accident Investigation Branch

Appendix B - Glossary of terms

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

Ballast	<p>Crushed stone, nominally 48 mm in size and of a prescribed angularity, used to support Sleepers, Timbers or Bearers both vertically and laterally. The stone used is generally Granite, but Limestone has been employed.*</p> <p>Sometimes known as shingle by the staff of the Infracos.</p>
Bance (trolley)	<p>A trolley (either motorised or not) that has been manufactured by a company called R Bance & Co Ltd.</p>
Chairs	<p>A cast or fabricated support for Bullhead Rail.*</p>
Conductor rail	<p>An additional rail, generally of a unique section such as 150 Pounds Per Yard, used to convey and enable collection of electrical traction current at track level. Conductor rail systems carry voltages of the order of 600 - 1000 Volts, generally DC. The conductor rails are supported on conductor rail insulators.*</p> <p>The London Underground system uses two conductor rails, one at a nominal voltage of +450 direct current located outside the running rails, and the other, at a nominal voltage of -150 direct current centred between the running rails. Both are higher than the running rails.</p>
Cross passage	<p>A passageway that connects two running tunnels. It is used for ventilation, pressure relief, staff and emergency access.</p>
Deep level tube	<p>A part of the London Underground system that uses circular, or near circular, bored tunnels beneath the surface.</p>
Engineering hours	<p>On London Underground (LUL), the period of time from when the traction current is switched off to the time the traction current is switched back on.</p>
Field Engineer	<p>An engineer who is designated to act as the Tube Lines company representative.</p>
Flange climb	<p>A fault condition in which the lateral force exerted on a rail wheel is sufficient to force the rotating wheel up the gauge face of the rail. Once the flange tip clears the railhead a derailment normally occurs.*</p>
Grout	<p>A type of bagged cement.</p>
Marker lights	<p>Lights that are permanently installed at either end of the electric track trolleys and trailer and are lit either white or red depending on direction of travel.</p>
Possession	<p>A period of time during which one or more tracks are blocked to trains to permit work to be safely carried out on or near the line.*</p>
Protection Master	<p>The person responsible for providing protection from operational risks when no passenger trains are moving during engineering hours.</p>

Rail lubrication unit	A device for delivering a measured quantity of lubricant (generally grease) onto the Running Edge (RE) of a running rail in order to reduce the friction between the rail and wheel flange on curved track. Rail lubricators are used to reduce noise and increase rail life on such curves. The general principle relies on passing trains operating a small piston pump to move lubricant from a reservoir to an applicator mounted on the rail web. Colloquially known as a Greaser.*
Site Person in Charge	The person in overall control of the work site in engineering hours and in a specified area and a possession, including the movement of a trolley and its trailer(s) both on and off the track.
Spoil	Ballast contained in waste sacks.
Track Trolley Operators	A person trained and certificated, on London Underground, to take charge and use electric track trolleys and trailers.

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