



Rail Accident Investigation Branch

Rail Accident Report



**Person trapped in a train door and dragged at
Jarrow station, Tyne and Wear Metro
12 April 2012**

Report 26/2012
December 2012

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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Any enquiries about this publication should be sent to:

RAIB	Email: enquiries@raib.gov.uk
The Wharf	Telephone: 01332 253300
Stores Road	Fax: 01332 253301
Derby UK	Website: www.raib.gov.uk
DE21 4BA	

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Person trapped in a train door and dragged at Jarrow station, Tyne and Wear Metro 12 April 2012

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Summary

At around 09:55 hrs on 12 April 2012, a passenger became trapped in one of the doors of a train at Jarrow station. The passenger had arrived on the platform as the doors were closing and had placed her arm in the path of the closing door. The closing doors trapped her arm, and a few seconds later, as the train left the station, the passenger was forced to run alongside it. A timely activation of the emergency door release by a passenger inside the train allowed the passenger to free herself and she fell onto the platform. The passenger left the station immediately. CCTV evidence suggests that she did not sustain significant injuries.

The RAIB investigation found that, in addition to the passenger's actions, the following factors led to the incident:

- there was a fault condition on the set of doors involved in the incident which, with the arm trapped, not only disabled the obstruction detection system and prevented the door reopening, but also enabled the driver to release the train brakes and apply traction power;
- the passenger was unable to pull her trapped arm out of the door; and
- the driver of the train did not notice the trapped passenger in the few seconds between closing the doors and leaving the station.

As a consequence of this incident, the RAIB has made five recommendations, which cover:

- measures to reduce and monitor the number of deliberate door obstructions;
- improvements to the reliability of the door control circuits;
- improving driver's visibility of the platform/train interface at stations;
- changing the method used to test door obstacle extraction forces to one that is aligned with the intentions of the relevant Railway Group Standard; and
- clarifying Railway Group Standard GM/RT2473, which specifies how to test door obstacle extraction forces.

Introduction

Preface

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

Definitions

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

Background

- 4 The Tyne and Wear Metro (TWM) is a light rail system which was originally opened in 1980, and currently comprises 78 route-km and 60 stations. A route map is shown at figure 1.

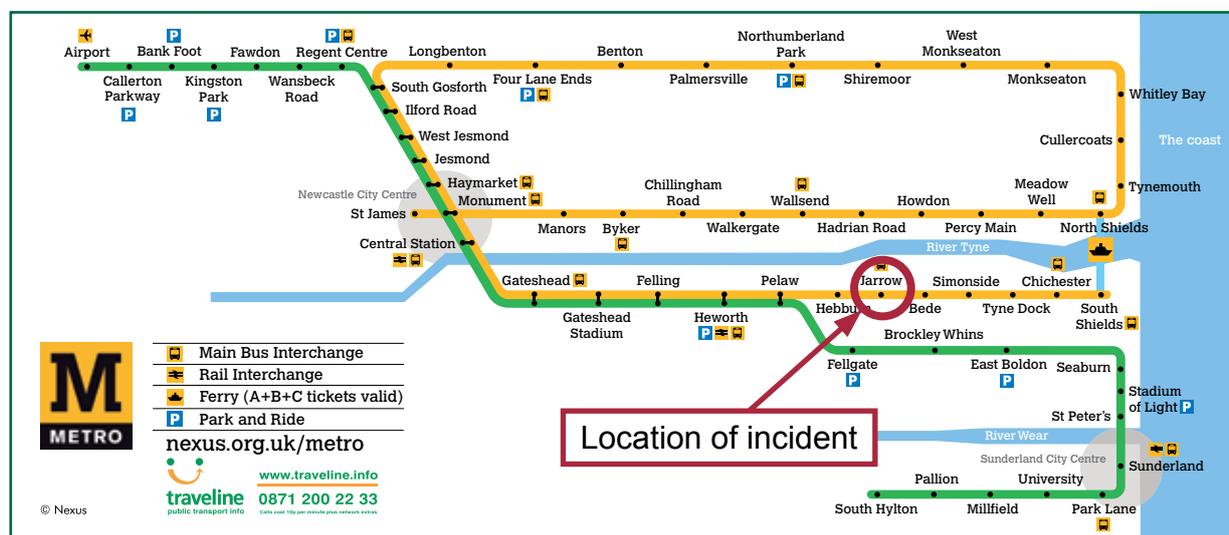


Figure 1: Tyne and Wear Metro network (courtesy of NEXUS)

- 5 The trains and infrastructure are owned by the Tyne and Wear Passenger Transport Executive, trading as Nexus. Operation of the trains and stations is currently leased to DB Regio Tyne and Wear (DBTW) under a seven year concession which commenced on 1 April 2010. The control centre is at South Gosforth. Maintenance of the trains is undertaken at Gosforth Depot. DBTW employs the train drivers and *system controllers*.
- 6 TWM trains comprise two-car electric multiple units, which receive power from 1500 V DC overhead contact wires, and have a maximum speed of 80 km/h. Each articulated car (figure 2) is 27.8 metres long and has a driving cab at each end and four pairs of passenger doors per side. The trains were manufactured between 1978 and 1981 by Metro-Cammell, in Birmingham. They were refurbished between 1995 and 2001 and are currently undergoing another refurbishment programme which commenced in 2010. The vehicle involved in this incident was car 4005 which first entered service in 1980 and was last refurbished in 2001.
- 7 The location of Jarrow station on the network is shown in figure 1 and a closed circuit television (CCTV) image of the incident train approaching platform 2 is shown in figure 3. Platform 2 serves trains heading towards Newcastle Central station, and is on the left-hand side in the direction of travel (figure 4). Passengers reach platform 2 after passing through a small concourse. At the normal stopping position of trains, door 7 is closest to the concourse.
- 8 TWM trains are operated under 'driver only' conditions, which means that the driver is responsible for train dispatch from stations. They are assisted in this by mirrors or television monitors located at the ends of the platforms which enable them to look back at the platform/train interface during station stops and dispatch. At Jarrow there are mirrors for this purpose.



Figure 2: Car 4005 involved in the incident (two such cars make up a TWM train)



Figure 3: CCTV image of train T135 approaching Jarrow platform 2 on 12 April 2012



Figure 4: Platform 2 at Jarrow station

Operation of the train doors

- 9 Each pair of doors comprises two door 'leaves', which are powered by *pneumatic actuators* and which slide on runners at the top and bottom (figure 5). All of the door control equipment is located above the doorway.

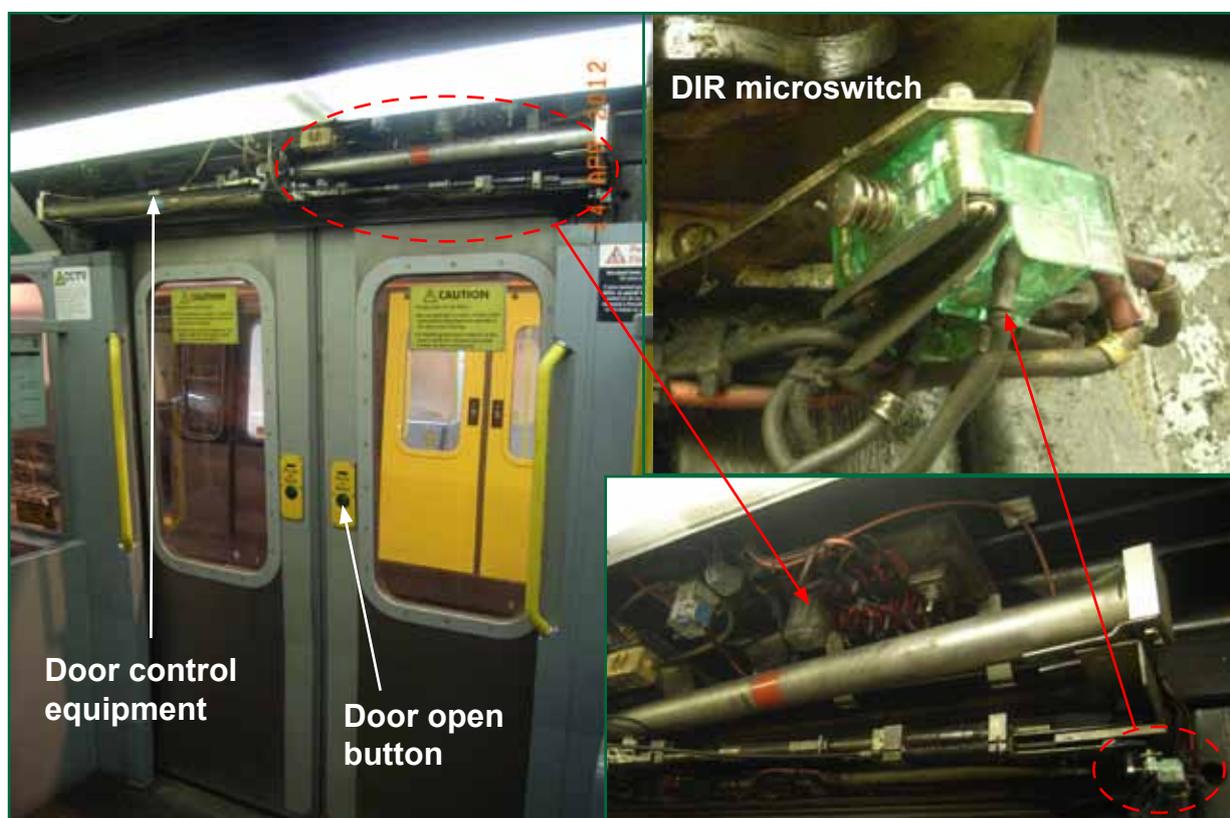


Figure 5: Door control equipment and position of DIR microswitch above door 7

- 10 In normal operation, the doors are controlled by the driver from the cab. When a train arrives at a station, the driver releases a central locking system so that all the doors on the platform side of the train can be opened by passengers, either from the inside or outside, by pushing a button at the centre of the door (figure 5).
- 11 When the train is ready to depart, the driver checks that it is safe to close the doors and starts the door closing sequence by pressing a 'door tone' button in the cab. This activates a 'hustle alarm' and a spoken message ("doors closing") to warn passengers. The driver is then required to check the platform again before pressing the 'door close' button in the cab. When all the doors are automatically detected as fully closed and locked, a safety circuit (called the *traction interlock* circuit) is made (ie completed) by means of a *microswitch* associated with each door leaf, and the driver receives a bell sound and a green light in the cab. With the traction interlock made, the driver is then able to release the brakes and apply traction power to depart from the station.
- 12 There are four microswitches in the control circuitry for each pair of door leaves that are relevant to this incident; one microswitch on each leaf provides an obstruction detection function and another microswitch on each leaf provides the traction interlock function. If an obstacle greater than 15 mm in thickness obstructs the closing doors, the system is designed to detect the obstruction and automatically re-open the doors back to the fully open position. The control system will then automatically try to close the doors again and will continue to 'cycle' in this way until the obstruction is removed. Meanwhile, the detection circuits should neither provide the driver with a green light nor allow the brakes to be released and traction power to be applied.
- 13 In the immediate vicinity of each doorway are two emergency systems; an emergency door release (EDR) and a passenger emergency button (PEB) both of which can be operated by passengers. The EDR (figure 6a) is located to the left-hand side of each doorway at head height. Its purpose is to allow the door closing force to be released in an emergency, such as a person becoming trapped in the doors. It is activated by pulling the lever downwards which then allows the right-hand door leaf to be pushed open manually. It also automatically cuts off traction power and activates the train brakes. The PEB is mounted at the top of a vertical grab pole in the middle of each doorway vestibule (figure 6b). It allows a passenger to stop the train in an emergency by pressing the button. Pressing the button cuts off traction power and automatically applies the train's emergency brake.

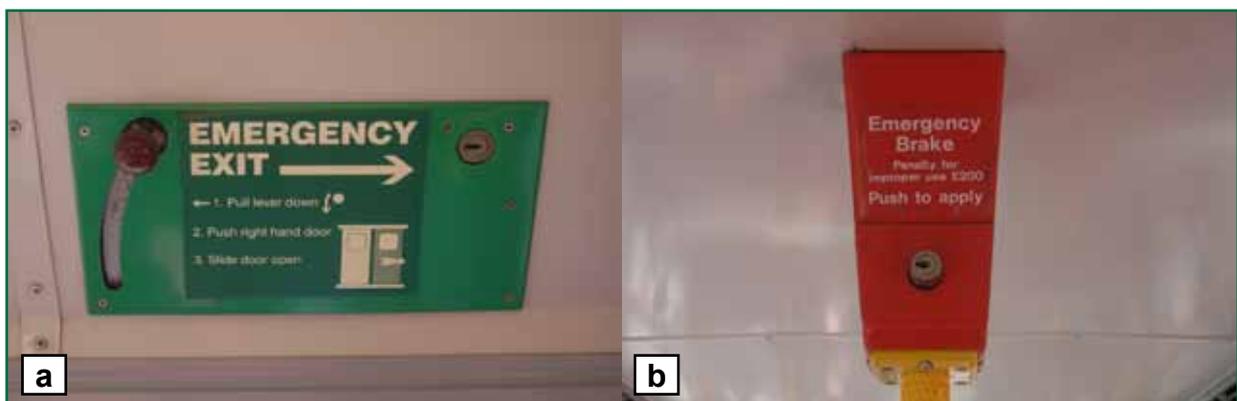


Figure 6: (a) Emergency door release; and (b) passenger emergency button

The incident

Events during the incident

- 14 At around 09:55 hrs on 12 April 2012, train number T135, the 09:43 hrs service from South Shields to St James, arrived at Jarrow station platform 2. After a normal station stop, during which a few passengers alighted and a few others boarded the train, the driver started the door closing sequence. Following the usual 3 - 4 second hustle alarm (paragraph 11), the doors started to close.
- 15 As the doors started to close, a passenger wearing dark clothing (hereafter referred to 'the passenger') arrived on platform 2 and tried to board the train at the fourth door from the front on the left side (door 7). She placed her right forearm into the path of the closing door leaves and as the doors shut, her arm became trapped. The door remained closed and approximately 4 seconds later, the train started to move. The passenger was forced to run alongside the train to avoid being dragged off her feet.
- 16 Video footage from the train's internal CCTV shows that passengers on board the train adjacent to door 7 realised what was happening. One passenger tried to prise open the door manually and when this was unsuccessful, he quickly activated the EDR (figure 6a) around 4 seconds after the train had started to move. A second or so later, another passenger pressed the nearby PEB (figure 6b).
- 17 The passenger was released after having been pulled by the train for around 12 m, but then fell down on the platform. She picked herself up and left the station immediately, without reporting the incident. It is not known whether she sustained any injuries but evidence from CCTV does not indicate any serious injury.
- 18 The emergency brake applied automatically once the EDR was activated and the train came to a stop having moved around 35 m, by which point the leading car was beyond the platform ramp and most of the trailing car was still in the platform.

Events following the incident

- 19 Once the train had stopped, the driver went to investigate the activation of the PEB. He was initially told by passengers that someone had been trapped in a door and might have gone under the train. He went down onto the track to investigate but found nothing. He was then told by another passenger that a woman had trapped her elbow in the door and been dragged along the platform.
- 20 The driver, who was shaken by the incident, reported it to the system controller using the station telephone at Jarrow. He told the system controller that the PEB had been activated and that he had been told somebody had been trapped in a train door. The driver found an eye witness, who had been approaching the platform from a footbridge at the rear of the train and had seen a passenger fall on the platform and asked her to relay what she had seen to the system controller. The eye witness had not seen the trapping itself and could not confirm that a passenger had been trapped in the doors.

- 21 From the available information, neither the driver nor the system controller were sure about what had happened or that someone had actually been trapped in a door and dragged. The passenger had left the station and so her account was not available to them. The system controller then asked the driver if he was fit to continue driving the train and, having established that he was, the controller authorised him to continue the service to South Gosforth station. The driver reset the PEB and departed from Jarrow. He was then requested by the controller to detrain all passengers at the next station (Hebburn) and then take the train empty to South Gosforth, where he was relieved by another driver. This was to minimise the knock-on effect of delays caused by the incident and as a precaution while station security CCTV at Jarrow was checked by the control centre.
- 22 The control centre checked station security CCTV at Jarrow, but this showed nothing of the incident because the camera's view of platform 2 was obstructed by a signal. The system controller remained unaware of the nature of the incident and did not take the train out of service. A full understanding of the incident was only reached by DBTW the following morning, when the train's internal CCTV was downloaded and reviewed. It was then that the RAIB was notified that a 'trap and drag' incident had occurred.

The investigation

- 23 The following sources of evidence were used:
- on train and station CCTV;
 - witness interviews;
 - site visits and sighting tests at Jarrow station;
 - door testing on car 4005;
 - examination of the door control microswitches;
 - relevant DBTW operating and maintenance procedures;
 - relevant staff records;
 - history of previous relevant incidents on TWM; and
 - procedures and statistical data from London Underground (LU) and Strathclyde Partnership for Transport (SPT), for comparison.
- 24 The RAIB's investigation was assisted by DBTW, Nexus, Schaltbau Group (manufacturer of the door control microswitches), LU and SPT.

Analysis

Identification of the immediate cause¹

25 The train departed with the passenger's arm trapped in one of the doors.

Identification of causal factors²

Attempting to board the train while the doors were closing

26 The passenger attempted to board the train as the doors were closing by obstructing one of the doors. This was a causal factor.

27 On TWM trains there are yellow caution notices on both the inside and outside of the doors (figure 7) warning passengers not to leave or enter the train when the warning tone is sounding or when the doors are closing.



Figure 7: Warning notice posted on both sides of each door leaf

28 CCTV footage shows that the passenger arrived on platform 2 after the doors had started to close, and just managed to insert her right arm into the door before it closed onto her arm. The passenger's action suggested she expected the doors to reopen. Usually the door would have reopened (paragraph 12), but in this incident there was a malfunction of the door. This is explained later at paragraph 31.

¹ The condition, event or behaviour that directly resulted in the occurrence.

² Any condition, event or behaviour that was necessary for the occurrence. Avoiding or eliminating any one of these factors would have prevented it happening.

- 29 Obstruction of the doors by intending passengers is commonplace on the TWM. Passengers often try to board trains after the doors have started to close by obstructing the doors, rather than waiting for the next train. Based on a survey carried out by two drivers over a two week period following this incident, DBTW estimates that every year there are on average around 20,000 incidents, across the TWM network, in which people deliberately hold doors open. Such incidents were observed throughout the day. Service frequencies are typically 3 - 15 minutes, depending on the route and time of day.
- 30 The following underlying³ factors probably encourage misuse of TWM train doors:
- The design of the doors is such that when obstructed, they reopen fully. Passengers know that if they arrive late on the platform as the doors are closing, they can simply obstruct the doors and board the train when the doors reopen. In contrast, doors on other UK metro systems only allow a partial reopening, just sufficient to allow the trapped limb to be freed, either by means of a manual 'push-back' facility or automatically when the obstruction is detected. These are discussed further at paragraph 68.
 - At the time of the incident, there were no warnings to passengers or reminders (in the form of station announcements or station information) to reinforce the warning on the door stickers about not trying to board or alight when the doors are closing.
 - There was no active enforcement of deterrents to discourage misuse of the doors, such as fines. Under the Metro's bye-laws⁴, it is an offence to enter or leave the train while the doors are closing and to obstruct or interfere with the train doors, except in an emergency. However, there was no active enforcement of this bye-law (breach of which is punishable by a fine) to discourage misuse of the doors. The operators of the TWM have in the past been reluctant to prosecute people who misuse the doors, because of the difficulties of collecting adequate evidence to secure convictions, and also in the interests of maintaining good customer relations.

Faulty door

- 31 A fault condition on the incident door, probably caused by a defective microswitch, disabled the obstruction detection and prevented the door reopening, and allowed the driver to release the train brake and apply traction power even though this door was partially open. This was a causal factor.**

³ Any factors associated with the overall management systems, organisational arrangements or the regulatory structure.

⁴ Made under Sections 58 and 62 of the Tyneside Metropolitan Railway Act 1973 and confirmed by the Secretary of State for the Environment, Transport and the Regions on 19 December 2000.

- 32 As explained at paragraph 12, passenger doors on the TWM trains are designed to detect obstructions greater than 15 mm in thickness, placed between the lower halves of the door leaves. Having a minimum threshold of detection is normal practice on railway power operated doors to allow for operating tolerances of the doors and the flexibility of the door edge seals. The passenger's arm, being thicker than 15 mm, should have triggered the detection system and reopened the door. The threshold of detection on the TWM trains is more stringent than that specified in *Railway Group Standard* (RGS) GM/RT2473, Issue 1, February 2003 ("Power operated external doors on passenger carrying rail vehicles"), the standard generally used for UK rolling stock doors, which specifies a minimum obstruction thickness of 30 mm for detection. TWM trains have to comply with the requirements of RGS because they run on part of the main line network between Pelaw and Sunderland.
- 33 TWM's maintenance standard requires that each door is tested every 12,000 km (approximately 3 weeks running) to check satisfactory operation, including obstacle detection. TWM's records indicated that the last maintenance check on door 7 was carried out on 26 March 2012 and no fault was found.
- 34 A series of tests were carried out by RAIB and DBTW on car 4005 and the incident door to determine the cause of the malfunction, ie loss of obstruction detection and the making of the traction interlock with the incident door partially open. The findings were as follows:
- The hustle alarm on car 4005 was working correctly.
 - Door 7 operated correctly and no faults were apparent during testing.
 - The left-hand door leaf (when viewed from inside the vehicle) closed slightly ahead of the right-hand leaf (by around 60 mm). Although this lag is not a fault, it was significant in the circumstances of this incident as explained at paragraph 36.
 - The faults that occurred during the incident could only be replicated by holding the traction interlock switch for the right-hand door leaf, called the 'DIR' switch (figure 5), in the depressed position as the door was opened and then closed with an obstruction held in the door. This simulated what would have happened at Jarrow if the DIR switch had stuck in the depressed position. Holding down any of the other microswitches on door 7 and operating the door in the same way did not reproduce the observed faults.
- 35 Since it was only a malfunction of the DIR switch from door 7 that could replicate the condition which occurred during the incident, it was decided to examine this switch more closely. After multiple manual operations of the switch, it was found that it remained stuck down in the depressed position on one occasion (figure 8). This should never happen with a correctly functioning switch. However, after pressing the plunger again, it released and despite further operations of the switch, this fault could not be repeated. The investigation concluded that this switch was capable of intermittent failure and that this fault would explain exactly what was seen to happen in the CCTV footage and post incident testing.

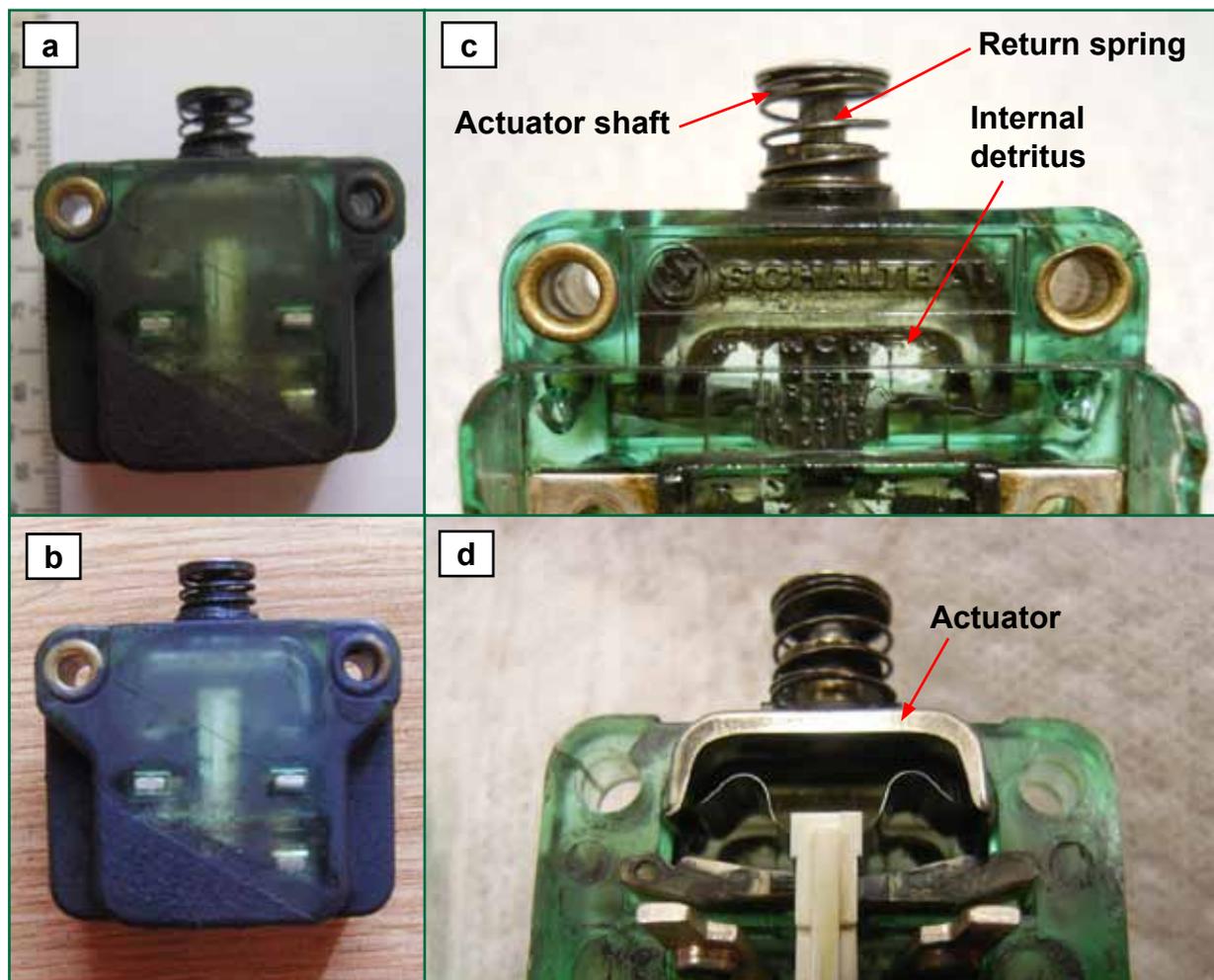


Figure 8: DIR microswitch showing (a) normal actuator position, (b) actuator stuck down, (c) accumulated internal detritus and (d) switch with cover removed

- 36 Normally, when the doors open, the actuator shafts of the traction interlock switches on each door leaf are released and extend from the switch bodies under the action of the return spring (figure 8c). This breaks the traction interlock circuit and energises the obstruction detection circuit of each door leaf, ready for the next door closure. If, when the doors open, a traction interlock switch sticks in the depressed position for some reason, the obstruction detection circuit on that door leaf is not energised and is therefore disabled. In this incident, the obstruction detection circuit on the right hand door leaf was disabled but the corresponding circuit of the left hand door leaf remained active. However, when the passenger placed her arm into the closing doors, the left-hand leaf was leading slightly and so did not detect any obstruction by the time it had fully closed. The lagging right-hand leaf then trapped the passenger's arm against the already closed left-hand leaf but it could not detect the arm because its obstruction detection was already disabled.
- 37 Additionally, because the traction interlock circuit was not broken by the right-hand door leaf microswitch (DIR switch) when the door opened at Jarrow station, it remained in this condition even when the door had only partially closed against the passenger's arm. When all the other doors on the train had closed, the complete traction interlock circuit around the train was made (even though door 7 was partially open) and the driver was able to release the train brake and take traction power.

- 38 When the DIR switch was stripped down and examined with the assistance of Schaltbau, a significant amount of *debris* was found to have accumulated inside the switch (figure 8) together with an oily residue. It is almost certain that the debris did not get into the switch during manufacture. Further, had it done so, it would almost certainly have been picked up in Schaltbau's quality control process or during installation by the train manufacturer, Metro-Cammell. Additionally, there was no evidence of other switches having similar internal contamination. The oily residue was probably from the light proprietary penetrating oil used by DBTW to clean the switches, once removed from the train, during periodic maintenance. Schaltbau do not use any lubrication when the switches are manufactured.
- 39 It is not known when this switch was fitted. Even if it had been in service since car 4005 was originally built, the switch would have operated for less than 1.2 million cycles, well within its design life of 10 million cycles. The actuation and return forces of the switch were tested and found to be within design tolerance. The general condition of the switch did not indicate excessive wear which could explain a malfunction.
- 40 The contamination in the switch was abnormal and is the most likely cause of the switch sticking down. There are two possible paths for the contamination to enter the switch:
- the clearance between the actuator shaft and switch body into which the shaft can pull in contaminants from outside as it slides; and
 - the joint between the actuator shaft and actuator, which was noted to be slightly loose and around which a ring of debris had accumulated.
- 41 The switches have an ingress protection (IP) rating of 40, which means they are only specified to offer protection from ingress of granular foreign bodies of diameter greater than 1 mm and from water splash. They would not offer full protection from dust or light penetrating oil and therefore the IP rating of the switch is not consistent with the service environment. However, DBTW report that generally the switches remain clean inside even though they become dirty on the outside due to the dusty railway environment and grease used around the mechanical parts of the door control mechanism.
- 42 DBTW replaces around thirteen door control microswitches each year (excluding refurbishment programmes) which represents around 0.5% of the total number of switches in service in the fleet size of 90 metro cars. The reasons for the replacements are not documented but DBTW believe some are due to switch failures and others due to damage arising from incorrect installation, such as cracked casings. DBTW reports that none of the previous failures have caused the type of malfunction seen in this incident. All of the six previous incidents of people being trapped and dragged on the TWM since 2001 (appendix C) involved hands, which may not always be detected by the doors (paragraph 32). There is no evidence of switch or door malfunction being a factor in those previous incidents.

The passenger was unable to free her arm

- 43 The passenger was unable to pull her trapped arm out of the door. This was a causal factor.**

- 44 CCTV shows that the trapped passenger was unable to release herself by pulling her arm out. This could be because she may not have pulled hard enough (perhaps expecting all along that the doors would reopen) or it could be that the extraction force required was too high for her to overcome.
- 45 For obstructions thicker than 15 mm, the door system is designed to detect the obstacle and reopen to release it. Therefore, in common with general railway practice, there is no mandated RGS nor DBTW requirement to measure the extraction force for such obstacles. However, obstacles thinner than 15 mm (eg fingers and clothing) could become trapped between the door leaves and to mitigate this risk, TWM undertakes testing of the doors to check that the extraction forces are compliant with the limits specified in RGS GM/RT2473. Extraction forces for such obstacles are discussed later at paragraph 61.
- 46 In order to assess the level of force required to extract a large obstacle such as an arm, a wooden block 70 mm x 70 mm in cross section was trapped between the door leaves on four doors of car 4005, including door 7, at the top, middle and bottom of the doors (ie 12 measurements). These were compared with the maximum extraction force specified in GM/RT2473 of 150 N (applicable to thin objects, as explained in paragraph 45). There was a wide variation in the force required to extract the wooden block, ranging from 79 N to 363 N (average of 193 N) when pulling from the outside. All but two of the measurements were above 150 N. When pulling from the inside, the forces ranged from 73 N to 274 N (average of 175 N) with seven of the twelve measurements above 150 N. The maximum extraction forces in the middle of door 7 when pulled from outside and inside were 152 N and 149 N respectively.
- 47 The above results indicate that although the extraction forces on the incident door were broadly compliant with the values specified in RGS GM/RT2473, it may be difficult to pull out a trapped arm from some other doors. The variation in the measured extraction forces was due to a combination of two factors:
- variation in the force applied to the obstacle by the door, which in turn is due to variations in the force applied by the door actuators and the height of the obstacle in the door; and
 - variation in the friction between the rubber door edge seals and the block, which is dependent on the condition of the rubber and any surface contamination⁵.

The driver did not notice the trapped passenger

48 The driver did not notice the trapped passenger in the time between closing the doors and departing from the station. This was a causal factor.

- 49 The driver of train T135 qualified as a TWM train driver in May 2000. His certificate of competence to drive trains issued by DBTW and his biennial medical assessment, which included an eyesight test, were in date at the time of the incident. His last practical driving assessment, which he passed successfully, was in September 2011 and his last operational refresher training was on 15 March 2012. He had not been involved in any previous relevant safety related incidents.

⁵ Variation in the hardness of the rubber could also affect the amount of friction. This was investigated in tests carried out by DBTW. Across a sample of twelve door edge seals from two different suppliers it found that the *Shore A hardness* varied by less than +/- 10% of the mean value.

50 The train dispatch procedure to be followed by the driver is set out in TWM's document OPS.019, 'Defensive driving', dated 31 March 2010, as follows:

- check signal;
- check platform;
- sound door tones;
- check platform;
- close doors;
- check platform (to ensure nobody is trapped or caught in the doors), and
- check signal.

There are three separate checks of the platform/train interface in the procedure; however, it is only the last of these which is relevant to this incident because the passenger arrived just as the doors had started to close.

- 51 The final check of the platform/train interface should be done after the driver has closed the doors and observed the green light, which confirms that the doors are fully closed and locked. At Jarrow station the check of the platform/train interface is usually done by means of a mirror at the end of the platform (figure 9). If visibility is impaired for any reason, it is the driver's responsibility to ensure that he can clearly see the platform/train interface and to do this the driver can either look out of the side window or get out of the cab and onto the platform.
- 52 For the driver to have a view of the whole of the platform/train interface from the cab using the platform mirror, the train must be positioned at a particular point on the platform. At Jarrow platform 2, this position is clearly indicated by a marker on the fence at the end of the platform and the driver must stop the train at or close to this marker. Tests at Jarrow station showed that deviation of up to about 1 metre can be tolerated, without a significant loss of view. Beyond this amount of deviation the driver cannot see the whole train and therefore cannot correctly perform the station duties by using the platform mirror only.
- 53 A reconstruction was carried out, using a test train, to check the visibility of the platform/train interface from the driver's cab at the stopping position of train T135. This stopping position could be determined from CCTV images of the incident train. The reconstruction confirmed that the view from the platform mirror included the whole of the platform/train interface (figures 9 and 10). However, the platform mirror is angled relative to the platform and so the side of the train forms the background to any person standing next to it. It is therefore not a true view along the side of the train.
- 54 There was a period of around 6 seconds between the passenger first arriving on the platform and the train departing, and around 4.5 seconds between the passenger becoming trapped and the train departing. During this latter period she should have been visible in the platform mirror but the driver cannot explain why he did not see her.



Figure 9: Typical view of the platform/train interface from the driver's cab through the mirror on platform 2 at Jarrow station (Note that the station canopy shadow at the time of the incident would not have been so pronounced)

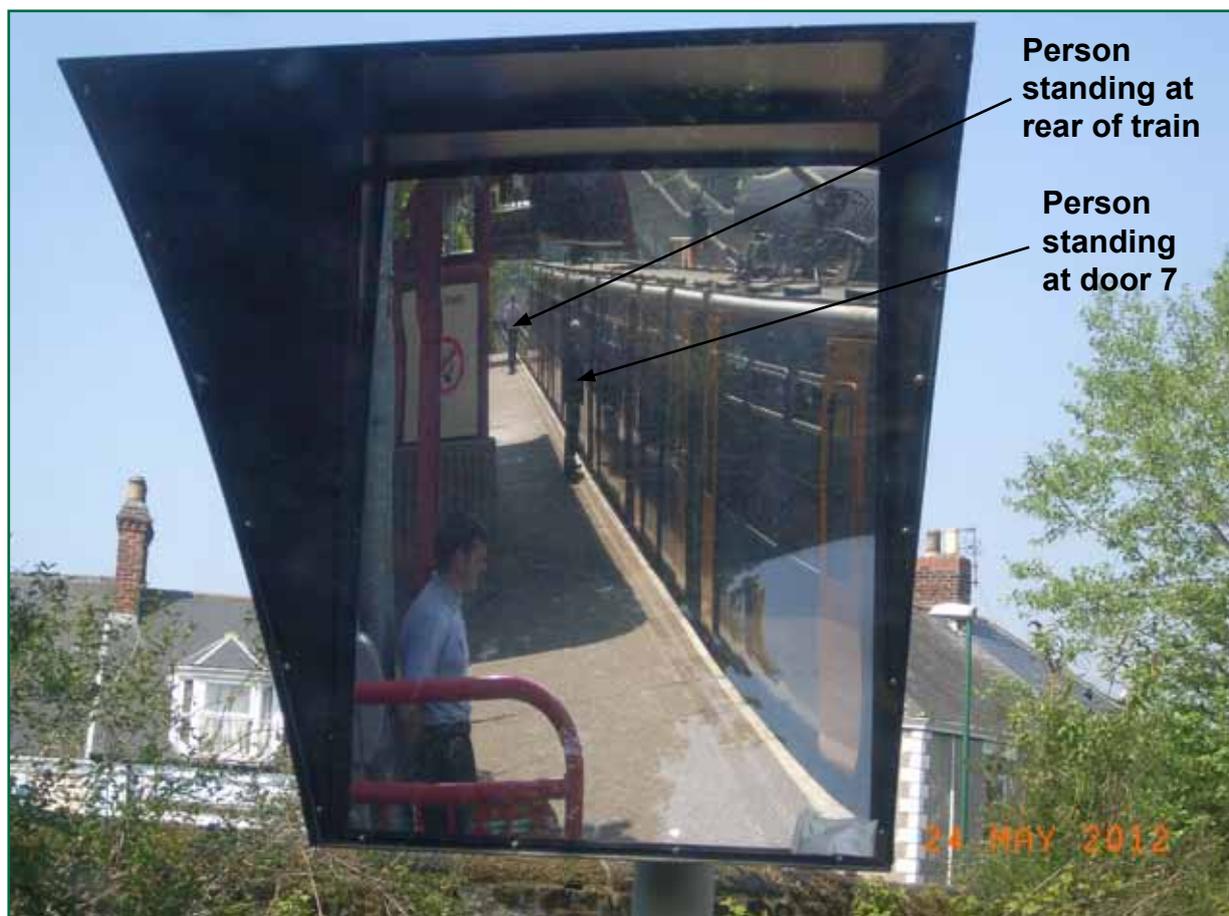


Figure 10: Zoomed in view of figure 9. Note difficulty in distinguishing person in dark clothing at door 7

- 55 The driver was familiar with the correct dispatch procedure and had not had any previous dispatch related incidents over his twelve years of driving trains on the TWM. He believes that he carried out the final check of the platform after the doors had closed and just before he departed from the station and that he had good visibility of the platform/train interface. The weather at the time was fine and dry. The sky was overcast so there were no strong shadows on platform 2 (figure 3), which might otherwise have adversely affected the driver's visibility of the platform. The driver reported he did not experience any problem with sun glare at the time.
- 56 The CCTV camera on platform 2 was partially obscured by a signal, and hence a full image of the platform during the incident was not available to confirm the visibility conditions. However, the available images do not show any other passengers on the platform at the time of the incident who might have obscured the driver's view. The images also confirm that the shadows around the station canopy were not strong compared to a sunny day.
- 57 There are a number of possible explanations as to why the driver did not notice the passenger standing next to the train prior to the incident:
- He did not do the final check of the platform as he thinks he did, due to a lapse in concentration or due to a momentary distraction, there being no evidence of any other reason, including fatigue.
 - He did his final check as the door began to close (when the passenger was still emerging from the station hall and may have been obscured by other passengers leaving the platform), and not after he observed the green light, as he is required to do.
 - He did the final check correctly after the door had closed and after he observed the green light but did not see the trapped passenger. 'Looked but failed to see' is a phenomenon known to occur when people carry out repetitive tasks and is recognised as a factor in some accidents^{6,7}. Figure 9 demonstrates that even with a full view of the platform it is difficult to discern the presence of a person standing at door 7 in dark clothing or a person standing at the back of the train, against the background of the train. It is clear from other incidents of a similar type on the TWM (appendix C) and other railways (paragraph 69) that the reliability of the visual check is limited by human error, and affected by a range of other factors such as shadows, backgrounds, equipment, platform curvature etc.

Severity of consequences

- 58 It is likely that had it not been for the timely action of the passenger on board the train (paragraph 16) who swiftly activated the EDR, the outcome in terms of injury would have been worse.

⁶ The Department for Transport: A review of the 'looked but failed to see' accident causation factor.

⁷ RAIB investigation into the fatal accident at James Street station, Liverpool, 22 October 2011 (report number 22/2012).

Response to the incident

- 59 The information collected by the driver from passengers and subsequently by DBTW control from the station CCTV was not conclusive as to whether or not there had been a malfunction of a door (paragraph 21). The absence of the trapped passenger from the scene compounded their uncertainty about what had happened. As a result it was not understood that there might have been a fault with one of the doors and this led to the train being allowed to continue in service for the rest of the day. Had another passenger attempted to obstruct door 7 in the same way, it is possible that a similar incident could have occurred.
- 60 DBTW did not have any specific procedures in place at the time of the incident for handling alleged door incidents such as this, where there is no immediate and clear evidence of an incident. Its response to such incidents was based on its rule book, incident management procedures in the Emergency Preparedness Manual, defective on train equipment procedures and scenario training. On 31 July 2012, DBTW issued two new procedures to cover what train crew and controllers should do in the event of apparent door trapping incidents and, separately, trap and drag incidents.

Observation

- 61 To mitigate the risk from the trapping of a relatively thin object (ie below 15 mm thickness) resulting in a passenger being dragged, DBTW tests the train doors routinely every two years, during maintenance exams, to check that the force required to pull out a thin object does not exceed 150 N. This force is specified in GM/RT2473. This standard derives from early drafts of British Standard BS EN 14752:2005 'Railway applications – bodyside entrance systems', but predates its formal issue by two years.
- 62 The last measurement of the obstacle extraction force on door 7 of car 4005 was made on 27 July 2010, when a maximum value of 88 N was recorded, which was compliant with the standard. Measurements made during the post incident testing using DBTW's standard method also indicated compliant extraction forces ranging from 40 N to 115 N (average of 82 N) at the centre of the door.
- 63 The method used by DBTW to check the obstacle extraction force deviates from the intention of GM/RT2473 in two respects:
- The intention of GM/RT2473 (in line with the requirements of BS EN 14752) is that the test obstacle used to measure the extraction force is a rectangular aluminium bar 10 mm thick x 50 mm wide x 300 mm long, with the long edges rounded. It should be mounted with the 50 mm dimension vertical (ie along the door edge). The test obstacle used by DBTW however is a rod of circular cross section of diameter 10 mm and length 50 mm. The rod is connected to a force meter, and positioned between the door edge seals, with the 50 mm dimension in the vertical direction.
 - BS EN 14752 specifies that the extraction force is measured while withdrawing the trapped test obstacle slowly in an outward direction (ie away from the centreline of the vehicle). This is not specified in GM/RT2473. DBTW's practice is to carry out the test by pulling inwards.

- 64 Although these differences are not causal to this incident, the DBTW test method tends to measure lower values of extraction force than using a rectangular bar. Tests carried out during the investigation with a rectangular steel bar gave a range of extraction forces between 74 N and 203 N at the centre of the door (average of 143 N) which were higher than those using the DBTW method (paragraph 62). The cause of the deviation in DBTW's test method from that in GM/RT2473 was a misunderstanding about the test method which arose because of a lack of clarity in GM/RT2473 about the geometry of the test obstacle and its material and no reference to the British Standard which does specify these.
- 65 The RAIB has previously measured extraction forces for thin obstacles (in accordance with GM/RT2473) on other types of rail vehicles, which indicate that the extraction forces on TWM trains (74 - 203 N, average of 143 N) are higher than those measured on a tram⁸ (58 – 116 N, average of 90 N) and similar to those measured on a heavy rail vehicle⁹ (80 – 220 N, average of 164 N). LU carries out tests to their own standard which specifies a piece of double thickness canvas for the obstacle and a maximum extraction force of 90 N.

Previous occurrences of a similar character on the Tyne and Wear Metro

- 66 Prior to the incident at Jarrow, there had been six other incidents of passengers being trapped and dragged on the TWM system since 2001, the earliest date for which reports are available. A summary of the incidents is given in appendix C. In one incident the passenger suffered serious injuries but in the others there were either minor or no injuries. A common feature of all of the incidents was that passengers had obstructed the doors with their hands (which the doors are not designed to detect) and the driver had not noticed the trapped passenger before departing. None of the cases involved trapped arms or legs.
- 67 The RAIB has compared the frequency of trap and drag incidents on the TWM with two other UK metro systems; LU which is much larger than the TWM and SPT which is smaller (table 1). Allowance was made for the relative sizes of each metro operation by comparing the number of trap and drag incidents per billion passenger journeys. The comparison indicates that there is a higher risk (by a factor of around four) of a trap and drag incident occurring on the TWM compared to LU. SPT reports it has not had any trap and drag incidents since at least 2005, when its records started.

⁸ RAIB investigation report into an incident at Wellesley Road on the Croydon Tramlink, 15 June 2007 (report number 40/2007).

⁹ RAIB investigation into the train door incident at Huntingdon, 15 February 2006 (report number 11/2007).

	TWM	SPT	LU
Annual average passenger journeys	37.9 million (2001 – 2012)	14.6 million (2005 – 2012)	1,348 million* (2003/04 – 2011/12)
Total trap and drag incidents	7 (incl. Jarrow) (2001 – 2012)	0 (2005 – 2012)	45 ¹⁰ (2003/04 – 2011/12)
Average T&D incidents per year	0.58	0	5.0
T&D incident per billion journeys	15.3	0	3.7

[Note: *Value uplifted from 938 million journeys per year to allow for interchanges]

Table 1: Comparison of trap and drag incidents on TWM, SPT and LU

68 The greater the frequency of misuse, the greater is the probability of a coincident door system malfunction and a driver dispatch error resulting in a trap and drag event. One factor which emerges from this investigation is that the design of the door system on the TWM trains probably encourages misuse by passengers (paragraph 30) because the doors reopen fully when they are obstructed (deliberately or otherwise). On LU and SPT, the train doors have a ‘push-back’ feature which enables a person who is trapped to manually force the door back a limited amount (115 mm on LU and 100 mm on SPT), sufficient to release themselves or the trapped object, but not sufficient to encourage deliberate obstruction with the objective of getting on the train. More recent LU trains on the Victoria Line (2009 tube stock) have doors with sensitive edges which automatically reopen by between 25 and 75 mm in the event of detecting an obstruction, before attempting to re-close.

Other trap and drag incidents investigated by the RAIB

- 69 The RAIB has investigated four other incidents involving persons becoming trapped in the doors and subsequently dragged as the train left the platform:
- Huntingdon, on 15 February 2006 (report number 11/2007): a person who was seeing off a passenger and standing near the train got his coat trapped in the closing doors. The driver did not notice that a person was trapped and as the train departed, the person was pulled along the platform and into the train to platform edge gap, sustaining serious injuries. The obstacle extraction forces for the Class 365 vehicle involved were measured and found to be greater than the maximum specified in RGS GM/RT2473 (which was introduced after the Class 365 entered service). The RAIB made six recommendations covering driver training, the platform monitor system, the train’s door seals, door closing mechanism, interior signage and a review of Railway Group Standard GM/RT2473. This latter review related to the correlation between the obstacle extraction force test specified in the standard, door seal design and the forces required to extract trapped objects or materials.

¹⁰ Data provided by LU indicates that this number includes nine incidents in which the person involved appears to have been dragged because he or she did not let go of their trapped bag.

- Wellesley Road, on the Croydon Tramlink, 15 June 2007 (report number 40/2007): a tram pulled away from the tram stop with a passenger trapped in the door. Neither the trainee driver nor his instructor had noticed the trapped passenger. The passenger managed to free himself and avoid injury. Post incident door tests showed the obstacle extraction force was below the maximum force specified in RGS GM/RT2473. The tram operator re-briefed its staff on the importance of carrying out a final check of the platform on departure and ensuring that instructors in the cab are positioned so that they can see the whole platform. Given these measures, the RAIB did not make recommendations.
- Tooting Broadway station on the LU, 1 November 2007 (report number 17/2008): a passenger became trapped by the hem of her coat as she alighted from the train and the train left the station. The train driver had concentrated on the line ahead as he departed from the station and had not also monitored the platform. The passenger managed to free herself but fell on the platform and sustained injury. The RAIB made one recommendation to investigate the reasons for the greater proportion of trap and drag incidents on the Northern Line compared to other LU lines.
- Kings Cross station, London on the mainline network, 10 October 2011 (report number 09/2012): a passenger, who attempted to board the train while the doors were closing, became trapped in a door. The train dispatcher on the platform did not fully check the doors before giving the signal to depart. The trapped passenger was pulled along the platform for a distance of approximately 20 m before she broke free. She suffered bruising to her hand. The train involved was the same type (class 365) as that involved in the Huntingdon accident referred to above. Possible modifications to the door seal had been considered by the industry parties involved, in response to the RAIB recommendation on this issue, but no modification to the seal had actually been made. Therefore the RAIB made a recommendation to review whether a modification could be made to the door seals of Class 365 vehicles at the next planned refurbishment, in order to reduce the risk of trapping of objects and people.

Summary of conclusions

Immediate cause

- 70 The train departed with the passenger's arm trapped in one of the doors (**paragraph 25**).

Causal factors

- 71 The passenger attempted to board the train as the doors were closing by obstructing one of the doors (**paragraph 26, Recommendation 1**).
- 72 A fault condition on the incident door, probably caused by a defective microswitch, disabled the obstruction detection and prevented the door reopening, and enabled the driver to release the train brake and apply traction power even though this door was partially open (**paragraph 31, Recommendation 2**).
- 73 The passenger was unable to pull her trapped arm out of the door (**paragraph 43, no recommendation**).
- 74 The driver did not notice the trapped passenger in the time between closing the doors and departing the station (**paragraph 48, Recommendation 3**).

Underlying factors

- 75 Misuse of the doors by passengers is commonplace on the TWM and appears to be encouraged by the following factors (**paragraph 30, Recommendation 1**):
- the design of the doors, which usually reopen fully when obstructed, encourages people to stop the doors closing if they are late for the train;
 - there were no additional warnings to passengers or reminders in the form of station announcements or other information to reinforce the message on the door stickers about not trying to board or alight when the doors are closing; and
 - there was no enforcement of the Metro's bye-laws which make it an offence to obstruct or interfere with the train doors, except in an emergency.

Observation

- 76 The method used by DBTW to check the extraction force for thin obstacles (less than 15 mm) deviates from the intention of GM/RT2473 and BS EN 14752 (on which it is based) in respect of the geometry of the test obstacle and its material. It also deviates in terms of the direction of pull. These differences arose from a misunderstanding of GM/RT2473, which lacks some of the details given in BS EN 14752 (**paragraph 64, Recommendations 4 and 5**).

Actions reported which otherwise would have resulted in a RAIB recommendation

77 DBTW has reported the following actions it has either completed or is in the process of undertaking, to reduce the risk of recurrence, in discussion with the Office of Rail Regulation.

Passenger education, awareness and enforcement action

- 78 Since 26 April 2012, a programme of automated public announcements has been running across the TWM network which states every 6 minutes: “please do not attempt to board the train once the warning tones have sounded and for your own safety stand well back from the platform edge”.
- 79 Also since 26 April 2012, passenger information boards on the platforms now carry a rolling safety message which reads: “Do not board the train after the warning tone”.
- 80 Advertisements were placed on 15 and 20 March 2012 in the Newcastle Metro newspaper, giving customer safety advice, which included a warning against trying to get on or off the train once the door tones have sounded. DBTW has advised the RAIB that further advertisements are planned.
- 81 New door stickers are being fitted to refurbished vehicles which read: “! Do not obstruct the doors, Maximum fine £1000”. A prosecution has been initiated against a person for deliberately holding train doors open and TWM are considering taking a much firmer line on this issue.
- 82 Yellow lines are being introduced on station platforms to mark the safe position for passengers to stand behind during the approach and departure of trains.

Train crew re-briefing

- 83 An operating notice was issued to train crew on 1 May 2012, about safe train dispatch, stressing the importance of paying special attention to the final check between the doors closing and departing from the station, and making sure they have a clear view of the platform-train interface.
- 84 All drivers received a re-briefing during April and May 2012 about performing station duties and the importance of performing a final check of the platform, after the doors have closed, to check for anyone who may have become trapped. A programme for carrying out monitoring checks by train crew inspectors to check that drivers are correctly performing their dispatch duties has been put in place.
- 85 Prior to these post incident briefings, DBTW report that between April and October 2011, it had shown a safety video to their its crew, to raise awareness of the importance of vigilance when performing station dispatch duties. The safety video, which was facilitated by RSSB¹¹ on behalf of the UK rail industry, featured a reconstruction of a trap and drag event, and was issued to the industry in October 2010.

Train doors

- 86 DBTW has reported that it is carrying out an engineering review of how the integrity of the door switches can be improved to improve their reliability.

¹¹ The company that trades as RSSB is registered as the Rail Safety and Standards Board.

Procedures for handling door incidents

- 87 On 31 July 2012, DBTW issued two new procedures, which set out actions, roles and responsibilities in the event of a trapping and (separately) a trap and drag incident. Both procedures require that the train is withdrawn from service and returned to depot for testing.

Recommendations

88 The following recommendations are made¹²:

- 1 *The purpose of this recommendation is to reduce the number of deliberate door obstructions on the Tyne and Wear Metro network, by raising passenger awareness, thereby reducing the risk from future trap and drag incidents.*

DB Regio Tyne and Wear should:

- a. develop its current actions, reported at paragraph 77, to reduce the frequency of door obstruction by passengers into an ongoing long term strategy and implement this; and
- b. introduce a system of monitoring the frequency of door obstructions on its network, in order to check the efficacy of the measures implemented in (a) and to optimise the strategy where appropriate (paragraphs 71 and 75).

- 2 *The intent of this recommendation is that the reliability of the door control circuits on the TWM trains is increased in order to minimise the risk of a similar malfunction to that which occurred in this incident.*

DB Regio Tyne and Wear should identify ways to improve the reliability of the door obstruction detection and traction interlock systems, including consideration of improvements in:

- design of the control circuitry;
- ingress protection of the microswitches;
- switch cleaning method;
- replacement procedures;

and implement identified improvements (paragraph 72).

continued

¹² Those identified in the recommendations, have a general and ongoing obligation to comply with health and safety legislation and need to take these recommendations into account in ensuring the safety of their employees and others.

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

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

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

- 3 *The intent of this recommendation is that the visibility of the platform/train interface at stations on the TWM is as clear as reasonably practicable and consistent with the dispatch arrangements for each station.*

DB Regio Tyne and Wear should:

- a. review the visibility of trapped passengers from driving cabs at stations on its network, including consideration of how lighting, shadows at different times of the day, colour of passenger's clothing and train paint schemes may adversely affect that visibility; and
 - b. implement identified improvements, to include consideration of realignment of platform mirrors and provision of additional CCTV monitors (paragraph 74).
- 4 *The intent of this recommendation is that the test method used for checking the door obstacle extraction forces is aligned with those specified in the relevant industry standards.*

DB Regio Tyne and Wear should change the test method it uses for checking compliance of its train doors against the obstacle extraction forces specified in Railway Group Standard GM/RT2473, so that it is also aligned with the requirements specified in BS EN 14752:2005 (paragraph 76).

- 5 *The intent of this recommendation is to clarify the test method used to measure the obstacle extraction force specified in Railway Group Standard GM/RT2473.*

RSSB should clarify the section in Railway Group Standard GM/RT2473 relating to the obstacle extraction force (section B6.3b) with respect to the geometry and material of the test obstacle and the direction of pull, and/or cross reference BS EN 14752 (paragraph 76).

Appendices

Appendix A - Glossary of abbreviations and acronyms

CCTV	Closed Circuit Television
DBTW	DB Regio (a subsidiary of Deutsche Bahn)
EDR	Emergency Door Release
IP	Ingress Protection
LU	London Underground
PEB	Passenger Emergency Button
RGS	Railway Group Standard
SPT	Strathclyde Partnership for Transport
TWM	Tyne and Wear Metro

Appendix B - Glossary of terms

Detritus	Unwanted accumulated debris such as dust particles.
Microswitch	A snap-action miniature electrical switch which is actuated by a small physical force applied to a button or lever.
Pneumatic actuator	A device powered by compressed air, which is used to drive or move a mechanical system, such as a sliding door.
Railway Group Standard	A document mandating the technical or operating standards required of a particular system, process or procedure to ensure that it interfaces correctly with other systems, process and procedures. Compliance with RGS is a requirement of the GB main line railways but RGS are sometimes also adopted by other railways in the UK as best practice.
Shore 'A' hardness	A measure of a particular rubber compound's resistance to indentation. It is usually measured by an instrument called a durometer against two scales; an 'A' and a 'D' scale, suited to softer and harder compounds respectively.
System controller	A person or persons located at the control centre of the railway, or section of railway, who monitors, and if necessary intervenes in, the operation of the railway to maintain its smooth running or minimise the impact of any incidents or delays.
Traction interlock	A round-train safety circuit which needs to be completed or 'made' by a series of switches installed on safety critical components such as doors before the train can move. If a component has not been closed and locked the circuit should not be completed.

Appendix C - Previous trap and drag incidents on the Tyne and Wear Metro

North Shields, 29 January 2001:

An eight year-old boy trapped his hand in a door and was dragged along the platform into the tunnel between North Shields and Tynemouth. The boy became free just inside the tunnel and fell on to the track. He suffered a cut head and minor bruising to his body. The boy was reported by passengers as having been “mucking around” with the doors prior to the incident. The driver closed the doors and got the ‘all doors clear’ light and although he saw the boy near the door when he was about to depart, he assumed the boy was clear of the doors.

Monument, 1 September 2001:

A passenger became trapped in the doors after holding the doors open for another passenger and her daughter. The driver did not notice the trapped passenger and departed the station. The passenger was able to extricate herself from the door after the train had moved a short distance and did not suffer any physical injuries.

Monument, 30 June 2004:

A passenger who had arrived late to board the train placed her hand into the closing doors. She was pulled free of the door by another passenger just as the train moved off and was reported to have been dragged a few steps. She did not suffer any physical injuries.

Gateshead, 9 April 2008:

A passenger, who was attempting to board the train late, placed a hand into the doors and was trapped by her fingers. Four seconds after the doors had closed, the driver pulled away. The passenger was dragged a distance of about 5 metres before she managed to free herself, but then stumbled and fell and struck her head on the platform surface beside the headwall of the tunnel. The passenger sustained serious injury and needed to be removed by the ambulance service. The RAIB was notified of the incident. Having ascertained the circumstances of the incident from CCTV and that the door passed all its post incident tests, it decided not to carry out an investigation.

South Hylton, 5 August 2009:

A passenger, who attempted to board the train late, put her fingers into a closing door. Her fingers became trapped and the train moved off, dragging the passenger down the platform. A passenger on the train pushed the emergency button and the train stopped before the end of the platform was reached. The total distance dragged was around 50 m. The passenger was freed from the door and was not injured. The RAIB was notified and carried out a preliminary investigation which found that the cause was due to the driver not carrying out the final check of the platform/train interface. It informed TWM that it intended to monitor the situation with respect to trap and drag incidents.

Central station, 27 July 2011:

A passenger attempted to board the train while the doors were closing. The door trapped her hand and the train departed from the station without the driver noticing the trapped passenger. The passenger had to run 3 - 4 m before she managed to pull herself free without injury. At the same time a passenger on board pulled the PEB and the train was brought to a stop.

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Any enquiries about this publication should be sent to:

RAIB	Telephone: 01332 253300
The Wharf	Fax: 01332 253301
Stores Road	Email: enquiries@raib.gov.uk
Derby UK	Website: www.raib.gov.uk
DE21 4BA	