London Underground

Tube Lines

Health, Safety Quality and Environment

Formal Investigation Report

Joint investigation into the uncontrolled movement of a rail grinding unit between Highgate and Warren Street stations on the 13 August 2010

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MAYOR OF LONDON

Transport for London UNDERGROUND

Contents

1 Executive Summary

1.1 On the 13 August 2010 a rail grinding unit operated by Schweerbau under contract to Tube Lines became stalled at Archway station. An out of service passenger train was coupled to the rail grinding unit, using an emergency coupler and the passenger train towed the rail grinding train northbound. As the vehicles left Highgate station, an emergency brake application occurred on the passenger train as it exceeded the restricted speed of the recovery. The resulting compression forces were sufficient to cause the emergency coupler to fail. The rail grinding unit rolled southbound down the gradient.

1.2 Passenger trains were directed away from the path of the rail grinding unit and an unsuccessful attempt was made to derail the train using points at Mornington Crescent. The rail grinding train came to a halt at Warren Street station. There were no injuries and the rail grinding unit and points received significant damage. The incident was reported to the Rail Accident Investigation Branch and the Office of the Rail Regulator who have both started their own investigations.

1.3 This investigation considers the approval regimes for plant and rolling stock and the interactions between the two processes and how that impacted on the interaction between the coupler and trains. The operation and emergency plans are reviewed and the impact that these documents had on the decisions made regarding the method of rescuing the rail grinding unit. The failure mode of the coupler is discussed in technical detail and how this caused the two vehicles to separate.

1.4 Previous incidents are listed in the report with particular reference to the incident at West Hampstead, approximately a month before this incident, and the impact that this had on the method of rescue. The effect of human factors principles in decision making and risk perception are discussed.

1.5 The investigation provides conclusions, root cause analysis and reasonably practicable recommendations to prevent recurrence. The immediate causes have been identified as:

a) The RGU was defective and required rescuing;
b) The RGU had its braked isolated and no secondary retention was provided;
c) Compressive forces from the assisting train's emergency brake application exceeded the design strength of the emergency coupler;
d) The RGU rolled on the gradient.

1.6 The root causes have been identified as:

a) Flawed emergency coupler design
b) Flawed approvals processes for the emergency coupler and the RGU emergency plan
c) Emergency coupler approved as plant and RGU approved as rolling stock
d) Change from the original intention to use battery locos to rescue the RGU without adequate change control
e) Design of RGU affecting the ability to repair the RGU in tunnel sections
f) Time pressure for service resumption affecting decision making

2 Terms of Reference

On the morning of Friday 13 August 2010, a rail grinding unit (RGU) grinding rails between Highgate and Archway broke down. During the recovery of the vehicle, where it was being towed by a non service Northern line train, the emergency coupler failed. This resulted in the RGU rolling without control from Highgate to Warren Street where it came to a halt.

A Formal Investigation has been commissioned jointly by London Underground (LU) and Tube Lines (TL). The remit of investigation is to:

- confirm 'what' happened,
- identify 'why' the incident occurred i.e. the immediate and basic causes and contributory factors which led to the incident,
- review the actions taken immediately following the incident and their effectiveness, and
- develop recommendations to address the immediate and basic causes and contributory factors.

In particular the scope of investigation should include:

a) Failure mode of tow bar arrangement
b) Adequacy of and compliance with defective train recovery method statement at failure site (including use of a passenger train as the tow vehicle and factors around ability to control slow speed operation)
c) The clarity of roles and responsibilities at the site of the RGU failing (Archway/Highgate) and consideration of the adequacy of the passenger train / RGU coupling arrangements. Confirm who was in charge of the a) site and b) recovery method and its adequacy.
d) Adequacy of the Operational Safety Plan
e) RGU reliability
f) The original design process and consideration of single point failure of bar, secondary means of attachment (e.g. chains), impact of gradient and any alternative braking means (and any interrelationships Service/Emergency/Parking brakes)

    - 2002 Design assumptions, verification and testing
    - Any subsequent review activities (noting some review in 2004)

g) The July 2010 West Hampstead incident and prohibition of pushing in RGU recovery
h) Incident Management - confirming the assurances processes applied across the full incident area (Finchley Central / Highgate to Warren Street).
i) Control of recovery activities and train movements and clarity of control and communication between LU Operations, TL Operations and the Emergency Response Unit (ERU)
j) Lessons learnt in relation to other potential vehicle formations where Brake Systems on part of the formation may be degraded or inoperative.

    - immediate actions to be briefed to Rostered Duty Officers (RDO) and Infrastructure Duty Officers (IDO) and ERU to ensure escalation and oversight of recovery methods
    - assessment of the wider Engineering Vehicle Fleet and ensuring robust recovery arrangements for train/vehicle failures

Trevor Bellis has been appointed as Formal Investigation leader and the other members of the Investigation Team are as follows:

Mike Shirbon (Nicole Bernard) LU
Ed Wells TLL
Richard Thomson TLL
Roger Creed TLL
Graham Neil LU
Ian Rawlings LU
Steve Peak LU
Trades Union representatives LU & TLL

3 Methodology

3.1 The causes of the incident have been investigated through:

- Interviews with staff involved in the incident or use of the RGU
- Evidence from on site investigations
- Investigation FIR panel meetings
- Reviews of procedures / documentation (emergency plans, operational safety plans etc.)
- Photographs and CCTV footage
- Structural engineering report on emergency coupler
- Root cause analysis

4 Timeline

Time	Event
03:30/45	Problem with the RGU engine reported to Service Control Schweerbau operatives on site attempted to repair RGU. Network Operation Control (NOC) requested the Emergency Response Unit (ERU) to assist
04:10	Duty Manager Trains (DMT) requested by Service Control to organise an out of service passenger train and operator to assist with rescue and make way to Highgate
04:22	An out of service passenger train (T106) was requested by Service Control from East Finchley to rescue the RGU. Train operator sent to Highgate depot (early current was requested but the Train Operator waited to depart to timetable at 05:08)
04:24	Service Control (SC) requested early traction current recharge from the Track Access Controller (TAC) to facilitate movement of passenger train to site
04:31	ERU informed the NOC that their estimated arrival at Highgate is 05:10
04:52	Early current recharge arrangements agreed with TAC DMT ensured all staff were clear of track by checking with the Tube Lines Manager All staff clear of track awaiting traction current recharge
05:08	Assisting train T106 departed Highgate depot to timetable with DMT and technical officer (TO)
05:10	Formal Incident Management (FIM) introduced, Service Control appointed the DMT as silver control
05:12	Emergency Response Unit (ERU) attended site

Time	Event
05:16	TO started to peg all train stops from East Finchley to Highgate on route to RGU as per Signal Operations Manager instructions (concern of RGU grinding stones striking train stops)
05:30	T106 departed East Finchley DMT told not to peg any more by the Signaller as RGU stones will be secured
05:36	T106 authorised to approach RGU passing signals at danger
05:42	T106 drew up to RGU. RDO and LIM informed
05:52	DMT requested to the SC for traction current to be is switched off between Highgate and Kentish Town southbound to allow track access for coupling.
06:05	Trains coupled and RGU brakes isolated. No estimated time for completion of recovery provided
06:27	DMT informs Service Control that necessary arrangements have been made for the wrong direction move (WDM) with communications between trains established
06:32	7 points and 23 points secured between Highgate and East Finchley for the WDM to start
06:39	Coupled trains depart Highgate SB platform travelling NB. The T/op, Tube Lines Operational Manager and TO were travelling in the front cab of the T106. In the rear cab was the DMT and ERU looking onto the RGU. The front cab of the RGU had the RGU supervisor and in the rear the RGU operator.
06:41	Emergency coupler failed and RGU rolls southbound un-braked. Schweerbau staff jumped from RGU onto Highgate platform
06:42	DMT requested traction discharge. Request denied by Service Control to assist with moving trains from path of RGU
06:43	Service Control instructs operator of T107 at Archway to close doors, depart and non-stop at all stations.
06.45	Service Manager instructs Camden Town Station Supervisor clear all customers from platform 4
06.50	18 points at Mornington Crescent were set against the RGU in an unsuccessful attempt to derail the RGU. The points were damaged and the RGU slowed.
06:50	Passenger trains at Tottenham Court Road and Embankment are instructed to non-stop and routed out of the path of the RGU
06:58	RGU stopped at Warren St southbound platform and rolled back 60m short of tail wall. ERU directed to Warren Street in consequence.
06:59	Northern line Charing Cross branch suspended
07:02	SC requests the DMT to move the train 106. DMT refused in order to preserve evidence
07:12	Northern line service resumes Archway to Camden Town
07:20	British Transport Police (BTP) confirmed the RGU had no staff on board
07:28	ERU secure RGU with scotch blocks
07:45	The incident is reported to the Rail Accident Investigation Branch (RAIB) and Office of Rail Regulator (ORR).
08:20	LU RAIB Accredited Agents attend Warren Street and Highgate.

5 Background

5.1 Rail grinding is a standard track maintenance activity which re-profiles the rail head and removes imperfections from worn rails, improving the ride quality and increasing the life of the track. Rail grinding equipment is mounted on a specialist train to increase efficiency and is used on London Underground (LU), in addition to a number of other railways internationally. All railway vehicles that operate on LU infrastructure must be approved by the LU Rolling Stock Engineer, have plant approval and have operating instructions and emergency plans.

5.2 The rail grinding unit (RGU) referred to throughout this report is a Schweerbau RGU 2000/02 and was introduced by Infraco JNP (a subsidiary of LU in 2002). The RGU and operating staff are provided by Schweerbau under contract to Tube Lines (TLL). The RGU is piloted to site by a 'Conductor' and is operated by Schweerbau staff within a protected 'specified area'. The RGU is required to comply with the LU Rule Book and with an 'operational safety plan & instruction' (OSP&I) document originally prepared by Infraco JNP Ltd and subsequently updated by Tube Lines. The RGU Emergency Plan is owned by Schweerbau.

5.3 The RGU had previously failed on 17 July 2010 at West Hampstead (the cause of the failure was separate to this incident). The recovery of the RGU by a passenger train took longer than expected due to concerns that the emergency coupler and tow-bar was at risk of contacting the negative current rail when pushing the RGU. The investigation into this incident was not concluded before the Highgate incident, although the initial findings identified that towing the RGU reduced contact between the tow-bar and negative rail and a redesign of the tow-bar was required. The key learning points from the West Hampstead incident were that towing was preferable to push-outs due to the proximity of the tow-bar to the negative rail and that the grinding stones should be secured in the 'up' position during rescue. The structural integrity of the emergency coupler was not identified as a concern from the investigation into the West Hampstead rescue. The case for continued service stipulated that the RGU was to be rescued by towing (see section 9.3.2).

5.4 On the night of 11/12 August the RGU undertook normal rail grinding activities at another location. During this work the tunnel telephone wires became detached from the tunnel wall due to the heat and vibration from the RGU and the staff provided to clean the site were required to reattach the wires. In consequence, the track was not properly cleaned and a number of signal failures occurred during traffic hours on the 12 August. As a result and to prevent a recurrence of this or similar problems, a Tube Lines Operational Manager attended the works on the following night (12/ 13 August).

6 Incident summary

Date:	13 August 2010
Time:	06:41
Location:	Highgate Station (southbound road, north of station limits)
What Happened:	A stalled RGU was being towed northbound on the southbound track by an out of service Northern line passenger train. As the coupled trains approached East Finchley the emergency brake activated due to the train exceeding the speed permitted by 'restricted manual' mode. The emergency coupler failed under the compressive force and the RGU rolled southbound, coming to a halt north of Warren Street station.
Consequences:	No one was injured. The RGU inter-car couplings and the points at Mornington Crescent suffered significant damage. The Northern line train received minor damage. Services were suspended on the High Barnet and Charing Cross branches of the Northern Line from the start of traffic, through running was resumed at 1758. The RGU was at least 500m from passenger trains in the area.

7 Incident response

7.1 Response to the stalled Rail Grinding Unit

7.1.1 The rail grinding work was completed at approximately 03:30 hours on the 13 August 2010 and the RGU was prepared by the operatives to travel back to its stabling location prior to the 'specified area' being handed back. The engine could only achieve 'low idle' and was found to be in the restrictive emergency mode due to a pressure level reading failure, although this was not known at the time. Emergency mode is intended to prevent further damage to the RGU. The engine was unable to achieve 'high-idle' or sufficient rpm to move under its own power. High-idle is required in order to obtain sufficient air pressure from the compressor to release the brakes. The options available to the Schweerbau operatives were as follows:

a) Fix the fault on the RGU in situ;

b) Use an emergency drive system and secondary compressor to drive the RGU in low idle up to 5 km/h, or

c) Request an assisting train to rescue the RGU.

7.1.2 Option a) was halted at 04:50 as further repairs were not possible in the tunnel environment. Option b) required the connection of a secondary air compressor to

the engine via a belt. This proved difficult due to limited space between the engine access panels on the side of the RGU and the tunnel walls. The Schweerbau and Tube Lines staff on site were conscious of potential delays to service and unable to confidently predict when the route would be clear. The TTL manager informed the Service Controller that a tow out may be required if the RGU could not be fixed and arrangements were made to provide an assisting train. An out of service passenger train was provided. The Schweerbau staff continued with their efforts to fix the RGU, late surrender protection was provided and then later withdrawn following the arrival of the assisting train.

7.1.3 The RGU was prepared for being towed. This included coupling the RGU with an assisting out of service passenger train and the release of the brakes of the RGU. The brakes are required to be released in compliance with the RGU Emergency Plan as leaving the spring applied parking brake on would result in the RGU wheels locking thus causing wheel 'wheel flats' (friction based damage to non-rotating wheels). It is unclear who took responsibility for the implementation of the Emergency Plan, although it appears that the Emergency Plan was complied with. The passenger train was driven to the RGU from Highgate with a Duty Manager Trains (DMT) and a Technical Officer (TO) on board. During the previous West Hampstead failure incident in July, the grinding stones lowered (due to low hydraulic pressure) and train stops were damaged when the RGU was recovered. As a result, the TO began to secure all train stops. This was halted when it was confirmed that the grinding stones could be secured in the 'up' position. The two trains were coupled using an emergency coupler, in accordance with the OSP&I and the RGU emergency plan, and the necessary arrangements were made to tow the train in the wrong direction northbound. The RGU was required to be towed rather than pushed following the findings of the recovery of the RGU at West Hampstead. Further detail on this aspect is discussed in section 11.

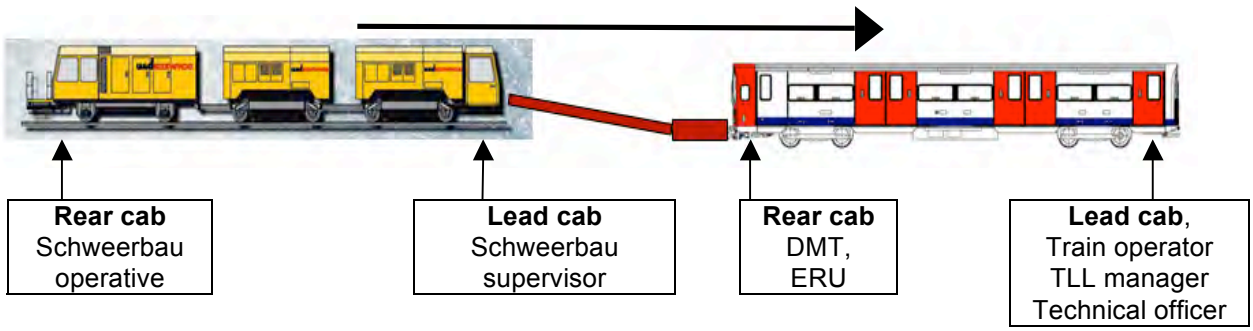


Figure 1: Locations of people on the coupled trains

7.1.4 The coupled trains were towed by the passenger train with the Train Operator, Tube Lines (TLL) manager and TO in the leading cab and the ERU manager and DMT in the rear cab. The Schweerbau operatives were in the front and rear cab of the RGU. It was agreed that in the event of a problem, the Schweerbau operatives would flash a torch at the staff in the rear cab of the passenger train, approximately 3 metres in front. All staff with Connect radios were on the passenger train and no Connect radio was available for the Schweerbau operatives on the RGU who are not issued with Connect radios or trained in their use as they normally have other Tube Lines staff wtiht them who do have Connect radios.

7.1.5 The RGU Emergency Plan specifies that the assisting train should not exceed 5mph. The passenger train was in 'restricted manual' mode with a restricted speed of 17kph (10.2mph). The passenger train successfully towed the RGU for over 1km at speeds up to 10mph. However, as the passenger train departed Highgate station, train speed exceeded 17kph (10.2mph) causing an emergency brake application as the passenger train was in 'restricted manual'. The coupler failed under the compressive forces which resulted from the emergency braking.

7.2 Response to the failed emergency coupler

7.2.1 The DMT in the rear cab of the passenger train (overlooking the coupler) immediately informed the Service Controller that the emergency coupler had failed and the RGU was rolling southbound down the gradient on the southbound road. The southbound Northern line is predominately downhill from the incident site. This report was made using an emergency call on the 906 number using a Connect handheld radio. The DMT requested that the Service Controller switch off traction current. The request to switch off traction current was refused as it would not have stopped the RGU and current was required to move in service passenger trains out of the path of the RGU. The two Schweerbau operatives jumped from the RGU on to the platform and ran alongside it as it rolled through Highgate station at slow speed. Service Control were unaware at this time that the Schweerbau operatives were no longer on the RGU.

7.2.2 Southbound train 107 at Archway, which had just entered service from Archway sidings, was informed of the situation and instructed by Service Control to non-stop at stations until further notice. Service Control routed Train 107 onto the Bank branch of the Northern line and the RGU was routed onto the Charing Cross branch. This option was chosen for expediency as the points self 'normalise' to the Charing Cross branch. At the same time the NOC was informed of the incident by Service Control and requested to arrange for support from the emergency services. The Camden Town Station Supervisor was instructed to clear customers from the southbound Charing Cross branch platform.

7.2.3 An attempt was made to derail the RGU by setting 18 points at Mornington Crescent against the path of the RGU. A derailment would have caused significant asset damage but the FIR panel concluded that this was preferable to the uncontrolled movement continuing unchecked. The potential outcomes of the incident were a collision either with another train or with the infrastructure, either of which might have resulted in serious injuries or fatalities (Service Control were not aware that the Schweerbau operatives were no longer on the RGU). The derailment attempt failed to stop the RGU as it split and ran through the points. However, this slowed down the RGU which was being monitored by Service Control on signalling diagrams and station CCTV. Service Control then planned to route the RGU into Kennington sidings and arrangements were made to move two passenger trains at Tottenham Court Road and Embankment out of the path of the RGU, and by the time that the RGU passed through Euston station, the Charing Cross branch southbound was clear of passenger trains.

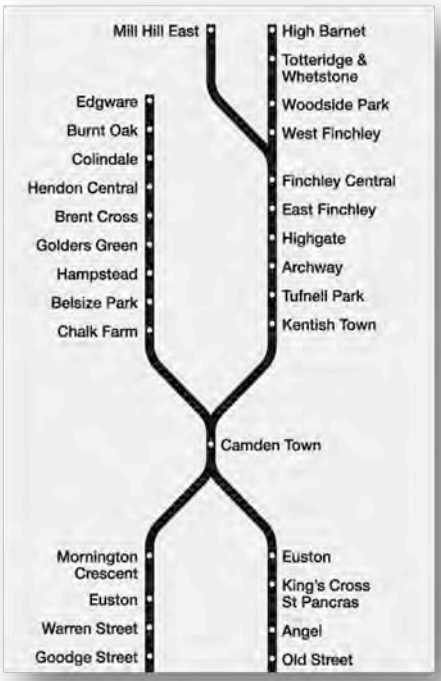


Figure 2: Map of the Northern Line

7.2.4 Using station CCTV, Service Control watched the RGU slow as it rolled up the incline on the approach to the Warren Street southbound platform. The RGU came to a halt partway along Warren Street southbound platform before rolling back down the incline, coming to a halt approximately 60m north of Warren Street station. The Station Supervisor reported to Service Control that the Schweerbau staff were not on the train. Service Control and the NOC arranged for the ERU and other assisting staff to be directed to Warren Street station.

7.3 Initial on site investigation work

7.3.1 The RAIB and ORR were notified of the incident by the NOC in accordance with agreed reporting arrangements. The RAIB advised that they would attend the incident sites at Warren Street and Highgate and requested that LU RAIB 'Accredited Agents' attend site to preserve evidence until their arrival. The standard message that 'rescue not recovery' was permitted by the RAIB and this was communicated to those on site who secured the train. Key evidence was recorded regarding the two parts of the failed emergency coupler at Warren Street and Highgate. Arrangements were made to have the damaged points at Mornington Crescent photographed, on the behalf of the RAIB, to enable the release of this site back to LU.

7.3.2 Details of the damage to the emergency coupler, the RGU and train in addition to the position of train controls were recorded and photographed by LU and the RAIB. The assisting passenger train was removed from Highgate to Golders Green depot and quarantined by the RAIB. Arrangements were made to have the RGU towed into Warren Street platform for further examination. The RGU was later moved to Kennington sidings coupled between two battery locos before being moved to Golders Green depot during engineering hours. The RGU and emergency coupler

were quarantined by the RAIB as evidence for further examination and testing and the ORR issued a prohibition notice on Tube Lines regarding the movement of the RGU without sufficient braking capacity.

8 The Emergency Coupler

8.1 Approval of the emergency coupler

8.1.1 Standard TE-IS-0202 requires a Plant Approval Certificate to be produced for each item of plant or equipment and for it to be registered as approved. Standard TE-IS-0202 requires an OSP&I to describe how the vehicle and plant are to be safely operated. Memorandum 3394 of 14 January 2000 from the LU Permanent Way Engineer to the Infraco JNP Plant Approval Engineer provides delegated authority for the approval of plant as both companies entered 'shadow running'. Plant Approval Certificates have been certified by the Plant Approval Engineer since that date. The approvals process was compliant with the standards in place at the time. The process did not require the emergency coupler to be classified as 'rolling stock' and therefore the coupler was approved by the Plant Approvals Engineer not a rolling stock engineer.

8.1.2 As part of the introduction of the RGU in 2002, it was recognised by Infraco JNP (before PPP and the creation of Tube Lines) that a means of rescuing the RGU was required should it breakdown. This work was led by the Plant Approvals Engineer who approved the emergency coupler using the plant approvals process (TE-IS-0202). A supplier was requested to design and supply two emergency recovery tow-bars and adapt an existing emergency coupler (used to connect passenger trains to other trains) so that the RGU could be rescued by a 'Schoma' diesel loco. The plant approval process was separate from the RGU approval process, with limited rolling stock engineer involvement in the design and alteration to the LU emergency coupler. Rolling Stock Engineers were aware of the development of the emergency coupler, but were not directly involved in the design or approval. The requirements for rolling stock engineer evaluation and sign off have been made more explicit in subsequent updates to relevant standards than those that existed at the time.

8.1.3 The requirements for the emergency coupler were discussed with the supplier and a design developed which would allow the RGU to couple with an assisting train. There were no standards specifying the requirements of the emergency coupler and a bespoke design was created, adapting an existing coupler to connect to a tow-bar. Track Standard TE-DS-0401 sets requirements for draw-gear loads, based on conventional locomotive and wagon structures. This standard permits the use of an 'LU approved rigid tow bar or other suitable means', although the standard does not specify a load requirement. A design specification was not written and the design was not reviewed or verified by a rolling stock engineer. The supplier provided stress analysis calculations to demonstrate that the emergency coupler would be no weaker than the 35mm diameter towing pin on the RGU. The calculations and design did not consider the forces arising from an emergency brake application by an assisting train. The towing pin found on the RGU appears to be 40mm diameter and the result of an uncontrolled change.

8.1.4 The solution consisted of an LU coupler adapted to connect to a tow-bar and a tow-bar with fixings to couple to the RGU (see figure 3). The emergency coupler equipment was tested in the depot using a 'Schoma' diesel locomotive with an auto-coupler rather than the standard 'buck-eye' coupler. The testing took place on level track and did not include an emergency brake application to reflect operational conditions. It was not possible to test the emergency coupler using a passenger train as the emergency coupler was not approved for use on the operational railway. The findings of the tests in the depot were not recorded. The emergency coupler design, testing and approval were signed off by the Plant Approvals Engineer (using the applicable procedures and standards in place at the time). The approvals process did not identify the introduction of a single point of failure, nor consider the forces the emergency coupler would be exposed to during an emergency brake application by an assisting train. The plant approvals process did not link into the rolling stock approvals process for the RGU. Any use of chains, or any other secondary means of coupling, was not recorded in the OSP&I, Certificate of Technical Conformance (CTC) or Emergency Plan.

8.1.5 There is no maintenance regime or maintenance record for the emergency coupler and tow-bar. The FIR panel concluded that the emergency coupler and tow-bar would not be expected to be in need of maintenance or repair given the material and frequency of use. However, in comparison with lifting gear or other train components, it would be reasonable to inspect the emergency coupler and tow-bar annually or after use. Maintenance is not considered to be a causal factor.

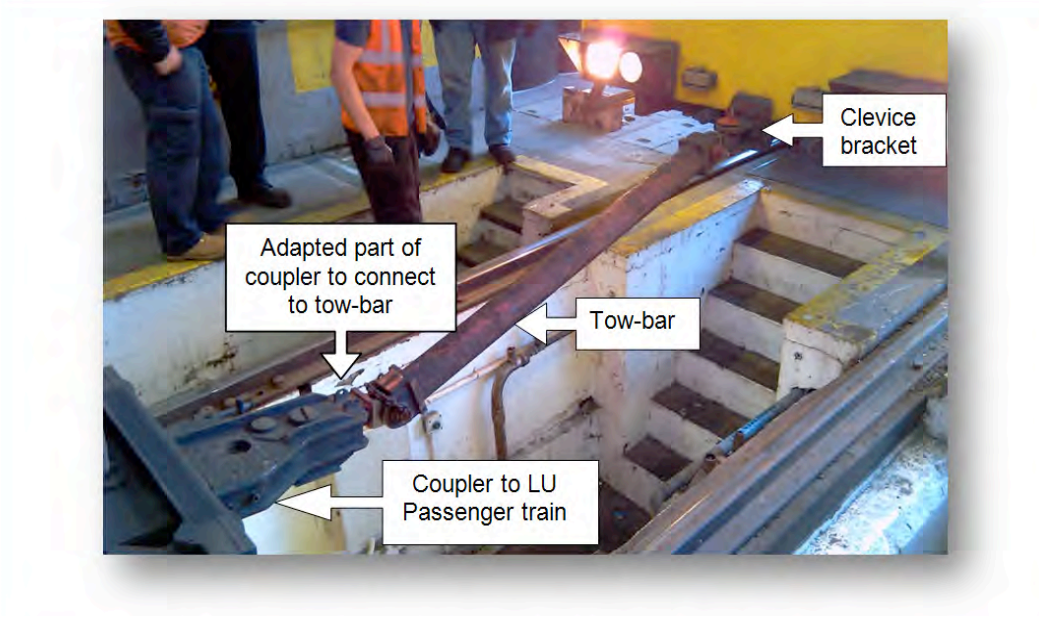


Fig 3: Emergency coupler attached to RGU and passenger train

8.1.6 Excluding the original testing in the depot, the emergency coupler and tow-bar has been used five times since 2002. The emergency coupler and tow-bar was used twice during the rescue from West Hampstead as the RGU was pushed and towed. These movements were repeated in the depot as part of the investigation into the West Hampstead failure accounting for uses three and four. The fifth use of the emergency coupler and tow-bar was during the rescue from Highgate when it failed. The tests following the West Hampstead rescue concerned vertical movement of

the emergency coupler relative to the negative rail and did not lead to any particular concern over the structural integrity of the emergency coupler.

8.2 Failure Mode of the Emergency Coupler

8.2.1 The failed emergency coupler and tow bar have been examined by an LU Structural Engineer to assess the suitability of its design and the likely cause of failure. The emergency coupler and associated fixings were removed by the RAIB for examination. The fracture faces of the emergency coupler have been studied jointly with witness statements and information from the passenger train data recorder (which records details of train operation). The FIR panel consider that the tow bar failed when it went into a compressively loaded condition during an emergency brake application on the passenger train. It was also noted that the RGU inter-car couplings also became distorted under the forces from the emergency brake application on the passenger train. The FIR panel concluded that the emergency braking compressive forces had not been considered during the coupler design or approval stages.

8.2.2 The condition of the fracture faces confirm that it was a rapid fracture and that there is no evidence of the features that are usually associated with fatigue based failures that could have been identified through maintenance (e.g. 'beach marks' or dirt ingress, see figure 4 showing bright fracture faces). Furthermore, the emergency coupler and tow bar have been used five times, including this incident, this is believed to be insufficient to provide the significant number of load cycles required to cause a fatigue related failure. The distortion of the material also suggests that a significant bending load was involved in the failure. This is considered to be with the emergency coupler at the limit of its lateral extension and a compressive force from the tow bar during the emergency brake application. There are inaccuracies in the strength and load calculations provided by the emergency coupling supplier. For conventional rail vehicles, a normal coupler is required to be able to withstand a specified compressive force of 1500 tonnes. Whilst not directly comparable, it is indicative that the design strength of the tow-bar is 36.5 tonnes.

Fig. 4: Fracture face of the emergency coupler

8.2.3 The review by the LU Principle Structures Engineer for Rolling Stock identified six weaknesses in the design which are listed below.

1 Three horizontal pivot pins in the coupled arrangement
2 Three vertical pivot points in the coupled arrangement
3 Play within pivot arrangements
4 Height difference between the two couplers
5 The 'auto-coupler' is not designed to couple to a tow bar
6 The total length of coupling

These weaknesses in the design contributed to the failure mechanism or to other potential failure mechanisms in the tow bar and emergency coupler arrangement through leverage and potential for the arrangement to lock. Similar approved coupling arrangements with a difference in coupler height comparable to this situation, have been deemed inappropriate by LU on previous occasions and withdrawn from use by Rolling Stock Engineers. However, this coupling arrangement was introduced after these reviews and the lack of involvement of rolling stock engineers in its development did not allow learning from the previous reviews to be incorporated. Following this incident, an instruction has been issued prohibiting the use of emergency couplers until asset identification controls have been established (see section 15.1).

9 The Rail Grinder Unit (RGU)

9.1 Process for approval of the RGU

9.1.1 The RGU is designed to remove railhead corrugations and other rail wear imperfections, improving the wheel/rail interface by restoring railhead profile. The RGU can travel to site under its own power providing it is fitted with a train protection system which is compatible with the signalling system on the line(s) it is travelling over. . The first use of the RGU was on the Northern Line in November 2002, following the approvals process described below.

9.1.2 In 2002, the Category 1 standard Ta251, 'Introducing new or modified rolling stock to London Underground', detailed the assurance process for introducing rolling stock on to LU infrastructure, but Ta251 did not contain a cross-reference to the plant approval process, hence the disjoint with this process already discussed in section 8. The custodian of Ta251 was the LU Rolling Stock Engineer. The process for rolling stock approval required evidence to be submitted to the LU Rolling Stock Engineer demonstrating acceptability both technically and operationally. The evidence was submitted with a Certificate of Technical Conformance (CTC) signed by the Infraco Rolling Stock Asset Engineers and identified reference documents for approval by the LU Rolling Stock Engineer. An OSP&I was produced and provided the generic safe system of work for the RGU. The OSP&I was approved by LU Operational Standards. Final acceptance to operate the new or modified rolling stock was then given by the LU Operations Support Unit (OSU) on receipt of the signed CTC who wrote to Transplant giving the final consent to operate. The RGU was subsequently operated in compliance with the Rule Book. However, there are

no LU rules that govern the rescue of an engineer's train or vehicle using a passenger train.

9.1.3 The RGU was first certificated as approved for service in possessions only in November 2002, compliant with the above processes. As this was the first rail grinding unit of the type approved for rail grinding on LU, HMRI approval under Railway and Other Transport Systems (Works Plant and Equipment) was sought and granted on 25/11/02. A Case for Safety was prepared by Transplant and approved for operation of the RGU (ref. JNP/0203/0095) was submitted to Infraco JNP SQE Manager on 1/11/02. The RGU was re-approved for service in 2004 and 2008. These approvals were to review any changes in use or modifications to the RGU, rather than a repeat of the original approval.

9.1.4 The RGU was approved for use in 2002 with a memo supporting the CTC, detailing some of the specifics regarding operation of the RGU. Rescue of the RGU is mentioned in the CTC memo although with limited detail. There is little evidence that the plant approval process of the emergency coupler and the rolling stock approval process of the RGU interfaced at the development or approval stages. It is thought that the two approval process were separate with the emergency coupler included in the rolling stock approval process as an approved piece of plant. If this is correct, it is likely that the emergency coupler was not scrutinised by the rolling stock engineers to the same degree that a 'yet to be approved' product under development would have been.

9.2 RGU Operational and Emergency Arrangements

9.2.1 The movement and operation of the RGU was documented in an Operational Safety Plan and Instruction (OSP&I) document prepared by the Infraco JNP Plant Approvals Engineer. The OSP&I details a generic safe system of work for all locations where the RGU could be used. This has a separate purpose to Operational Safety Plans (OSPs), which are authorised by LU Operational Standards for situations where the LU Rule Book is not applicable or cannot be applied. The RGU is classified as rolling stock whilst it is being driven to and from site and classified as track plant whilst it is in use grinding rails. As rolling stock, the RGU is operated in accordance with the LU Rule Book using signals and train-stop based automatic train protection and therefore an OSP is not required. An OSP&I is required for the RGUs use as track plant for grinding activities, and also contains requirements for when the RGU is in use as a train.)

9.2.2 The RGU is piloted to site by a route familiar 'conductor'. All grinding equipment must be correctly stowed during movements to and from sites. The RGU can only be operated within a 'specified area' or a possession with the traction current off. Apart from the Train Master, the conductor and all other staff must be off the RGU when it is rail grinding within a specified area or possession. The breakdown occurred in a 'specified area' and was rescued in traffic hours.

9.2.3 The OSP&I notes that emergency recovery equipment is provided on the RGU to enable it to be recovered in the event of a failure or incident. Details of how the emergency equipment is to be used are detailed in the RGU operating instructions. The OSP&I specifies that rescue movements should not exceed 5mph and that the brakes will need to be isolated as it is not possible to link the braking systems. It does not specify whether the rescue should use a passenger train or engineer's

train or whether it should be a push out or a tow. The original Certificate of Technical Conformance specified that a battery loco should be used but this had not been reflected in any of the current documentation and was not the approach taken most recently in the West Hampstead incident. Within the OSP&I, the Schweerbau machine operator and machine supervisor are responsible for the recovery of the RGU, providing the necessary assistance to the Emergency Response Unit and Tube Lines staff as appropriate. Neither the OSP&I nor the RGU emergency plan makes reference to provision of secondary retention, (e.g. chaining the two vehicles). The RDO instructed that chains should be used during the West Hampstead rescue but the RDO was not involved in managing the Highgate rescue as there was no requirement in the OSP&I or Emergency Plan to consult the RDO (see also section 9.4.9).

9.2.4 As the RGU emergency plan is described in the OSP&I and emergency plan and the rescue was in compliance with this, there was no requirement for authorisation of the move from the Rostered Duty Officer (RDO) or a Rolling Stock Engineer. However, mixed vehicle formations of this nature are very rare on LU and it is very unusual for passenger trains to rescue engineers' vehicles. There are no rules or instructions regarding how LU operational staff should assist in the rescue of an engineers' vehicle. In the absence of such specific instructions in the LU Rule Book, OSP&I or emergency plan and the potential risks associated with this, it would have been appropriate that such a move would require RDO authorisation, but this did not occur.

9.2.5 The rescue of the stalled RGU from West Hampstead (17 July) and Highgate (13 August) were both in compliance with the OSP&I and the emergency plan. However, neither the OSP&I or emergency plan provide sufficient details of how the rescue is to be completed and further decisions were required to be made on site (e.g. type of assisting train, use of additional retention, operation of assisting train, vehicle configuration and direction of rescue). In the absence of specific instructions the LU staff applied the rules for rescuing a passenger train with another passenger train. The decision to tow rather than push the RGU in this incident was as a direct outcome of the West Hampstead rescue.

9.3 Reliability history of the rail grinding unit

9.3.1 The RGU has been in service since 2001 and has been used on LU since 2002. London Underground is responsible for approximately 60 percent of the use of this particular machine. The remaining use of the RGUs is spread across eight clients across Europe. Between 2008 and 2010, the RGU has been used 218 times on the LU network and has experienced four breakdowns. This figure includes the incidents at West Hampstead, Highgate, and an additional breakdown in a possession on the Victoria line requiring a five hour repair.

9.3.2 A review of RGU reliability following the West Hampstead recovery, concluded that performance was acceptable to justify continued use of the RGU, taking account of the nature of the machine and its relative workload. Track maintenance is critical to the safe operation of LU; alternative options are limited due to this being one of only three RGUs in Europe suitable to operate in LU deep, small bore tunnel sections, and given the relative high cost of alterative maintenance techniques that are contrary to LU's 'whole life asset management' principles. The decision to continue use prior to the incident at Highgate is concluded to be justifiable by the FIR panel.

9.3.3 The incident at West Hampstead prompted a review of the emergency coupler due to concerns that it was fouling the gauge and might make contact with the negative rail. Following testing at the depot it was concluded that a redesign of the emergency coupler was required and in the interim the RGU should be towed not propelled and insulation was required on the tow-bar to prevent contact with the negative rail. The focus of the investigation and testing was on the direction of rescue and the vertical movement of the tow-bar. The structural integrity or design strength of the emergency coupler and tow-bar was not identified as a concern from the investigation into this incident.

9.4 Decisions Associated with the Recovery of the RGU

Rules for the rescue of trains

9.4.1 Rule Book four 'Moving a stalled train and authorised detrainments' details the method of rescuing a passenger train using an assisting passenger train. This method usually involves propelling the stalled train from the rear. Rule Book 18 'engineers' trains, vehicles and trolleys' specifies the requirements for operating engineers' vehicles, including their rescue using another engineers' vehicle. The LU Rule Book does not cover the rescue of an engineers' vehicle using a passenger train. It should be noted that the RGU Emergency Plan or OSP&I does not specify which type of vehicle should be used and that the emergency coupler is not compatible with battery locos. Neither LU, nor Tube Lines nor Schweerbau staff are trained in or rehearse the use of the emergency coupler. The decision that compliance with the Rule Book, OSP&I and Emergency Plan would cover all eventualities was incorrect. The assurance provided by the OSP&I and emergency plan was overestimated.

Use of a passenger train or battery loco for rescue

9.4.2 When the RGU was approved for use on LU, it was specified on the Certificate of Technical Conformance that a battery loco would be used to rescue the RGU. Later in 2002 this changed and it appears to have been assumed that an out of service passenger train could be used. There is no evidence of change control principles being applied to this change or of any consultation with relevant rolling stock engineers. The use of a passenger train and rationale for the change has not been documented in rules, emergency plans or operating instructions. Passenger trains are usually more readily available and accessible than battery locos and Service Control is more familiar with arranging a rescue of a stalled passenger trains using another passenger train. Both are considered by the FIR panel to be factors in the decision making during this incident. The decision to use a passenger train was an error. Testing has since confirmed that it is not possible to couple the RGU to a battery loco using the emergency coupler, despite this being specified in the original CTC. Other than passenger trains, only two 'Schoma' diesel locos fitted with auto-couplers are compatible for use in rescuing the RGU using the emergency coupler. Neither is routinely available.

Rescue of the RGU

9.4.3 Given the timing of the failure, all parties were aware of the service impact arising from the stalled RGU remaining in situ and the need for a prompt resolution. Repair or rescue of the RGU would have provided the desired outcome of clearing the line

for the resumption of service. Repair and rescue were started in parallel, as one did not prevent the progress of the other. If repair proved unsuccessful, the rescue attempt would already be in progress thereby avoiding additional delays. Repair of the RGU was hindered by the side access to the engine being in close proximity to the tunnel wall. This also required traction current to be off which also affected the return to passenger service. In the end, rescue became the preferred option due to the difficulties affecting the repairs and a perception that it would be as effective as repair but within a shorter, more certain timescale.

Orientation of assisting vehicles

9.4.4 The most common means of recovering a stalled train using an assisting train is to propel the stalled train from the rear. This uses a competent person in the leading cab of the defective train covering the emergency brake with continuous communication with the assisting train. This method does not involve any unusual train movements (e.g. wrong direction move) and it is therefore quick and simple to implement. Due to the RGU emergency coupler design flaws (see section 8) the attempts to rescue the RGU at West Hampstead on 17 July were protracted, causing significant service disruption. The initial investigation findings from this investigation required that a stalled RGU should be towed rather than pushed until a revised emergency coupler design was available. The decision to tow rather than push the RGU was directly related to the incident at West Hampstead and the Emergency Plan was amended in early August to reflect this prior to the Highgate incident.

Direction of rescue

9.4.5 The stalled RGU was rescued in a northbound direction as this was the quickest means of removing the RGU from the railway and reduced the service impact by avoiding central London. The northbound route is predominately uphill, but this factor does not appear to have been considered in the decision making. The combination of towing rather than pushing the RGU and moving northbound rather than southbound are contributory factors to the incident. When the emergency coupler failed, the RGU was free to roll down the gradient, but this would not have been possible if the RGU was being pushed northbound uphill or towed southbound downhill. However, the FIR panel recognises that appropriate coupler design and the provision of secondary braking or retention are the appropriate risk controls and should have made the decisions regarding gradient, direction and vehicle orientation irrelevant.

Operating mode of the assisting train

9.4.6 The assisting out of service passenger train was in ‘coupled mode’ (this is discussed in detail in section 10) and the impact of this was that the passenger train was restricted to 17kph (approx 10mph) and the emergency brake activated when this limit was unintentionally exceeded because the train operator had no experience of towing another train. There was no requirement to put the train in ‘coupled mode’, enabling the control systems on two passenger trains to interface, as the RGU systems and passenger train systems are incompatible. However, coupled mode was selected by the Train Operator and DMT on site in accordance with their training for rescuing passenger trains. LU operational staff are not trained in the rescue of engineering vehicles, and in the absence of specific instruction defaulted to their training. The RGU emergency plan specifies that rescues should

be limited to 5mph. The DMT was aware of this although the Train Operator has stated that they were not. The selection of 'coupled mode' and the speed of the passenger train are causal factors in the emergency brake application and resulting failure of the emergency coupler. In addition, it should be noted that either a signal passed at danger or a number of different incidents could also have resulted in the emergency brake being applied either manually or automatically

Braking facility on the RGU

9.4.7 The Schweerbau emergency plan requires the brakes to be isolated during a rescue. It is technically possible to provide a braking facility on the RGU during a rescue, although this requires alterations to be made to the engine on site and the manual installation of a secondary compressor. This proved very difficult in the tunnel environment due to the hinged engine access panels being on the side of the RGU adjacent to the tunnel lining. When rescuing a passenger train with another passenger train, the brakes on the two trains can be connected, but it is not possible to directly link the RGU brakes to other rolling stock. Schweerbau and Tube Lines staff on site were aware that the brakes had been isolated, but perceived the risk as acceptable due to complying with the emergency plan and using approved emergency equipment. They did not identify the single point of failure the towing arrangements introduced.

9.4.8 It is possible to 'push through' the spring applied parking brakes on LU passenger trains. This is a specified requirement for LU rolling stock, but it is not certain if it is possible on the RGU and it is specified in the emergency plan that the brakes should be released. The options available were to isolate the brakes or connect a secondary compressor to release the brakes. The LU staff on site were not aware of the significance of isolating the RGU brakes and therefore did not communicate this to Service Control. The absence of a braking facility on the towed RGU was a contributory factor.

Secondary retention of the RGU

9.4.9 The emergency coupler provided the only means of retention between the RGU and assisting train. In the event of the emergency coupler failing, the role of secondary retention is to prevent the two vehicles separating. During the West Hampstead incident it was recognised that the unit would be an un-braked unit and secondary retention was used, although not specified in the emergency plan. This factor was not considered in this incident and no secondary retention was provided during the rescue. Un-braked units are rare on LU and are usually moved between braked cars. The risk mitigation for such moves is normally controlled at a senior level and does not require decisions from staff on site. Lack of knowledge regarding the handling of un-braked units and awareness of the associated risks are contributory factors in this incident.

Resumption of service (post-incident)

9.4.10 The train service resumed between Archway and Camden Town from 0712 – after the RGU had rolled to Warren Street - before the track could be formally inspected. The resumption of service occurred when a train entered service from Archway sidings. At this time Service Control were busy dealing with the RGU and affected passenger trains and were not aware of the passenger train entering service. The Service Control Manager stated that he would normally operate an out of service

passenger train at caution speed with a duty manager in the front to check for damage or obstructions. The operation of an in service passenger train before the track was inspected was an error caused by pressure and distraction. The passage of this train was taken as justification to continue operating between Archway and Camden Town, while Archway to High Barnet and the Charing Cross branch remained suspended. Premature resumption of service was an error, although this did not affect the nature or outcome of the incident.

10 Performance of the Assisting Passenger Train

10.1 The procedure for coupling and uncoupling 95 Tube Stock trains and for 'push-outs' is contained in the Northern Line Defect Handling Guide. The process specified in this document was applied by the DMT and Train Operator to the rescue of the RGU in combination with the RGU emergency plan. The emergency coupler is not referred to in the Northern Line Defect Handling Guide. The DMT and Train Operator had no experience of coupling passenger trains to engineers' trains.

10.2 In accordance with the Defect Handling Guide, the suspension on the passenger train had been deflated and the hand worked coupler switch set to 'coupled' once the vehicles were together. Deflating the suspension may be used to vertically align the passenger trains' coupler faces. However, these steps are not required when connecting a passenger train and emergency coupler to the RGU as the air and electrical systems are not compatible.

10.3 Setting the passenger train to 'coupled' restricted the speed of the train. This is due to the train expecting to complete an electrical circuit between two passenger trains that would allow the brakes on the assisting train to release whilst proving the assisted train was still attached. As the RGU cannot connect to the electrical supply, the circuit remains incomplete and the round train circuit must be cut out and 'restricted manual' selected before the brakes can be released. The train is restricted to 17kph. If the Train Operator exceeds 17kph an audible and visual warning is generated and the emergency brakes are automatically applied to reduce speed to under 10kph. The emergency brake provides a higher braking rate, -1.3m/s^2 compared with -1.1m/s^2 for the maximum service brake.

10.4 The passenger train has weight sensors which adjust the performance of the brakes and motors according to the weight of passengers aboard the train. However, the passenger train's load weighing system is not capable of detecting the additional 37 tonne load imposed by towing the RGU as the two trains' electrical systems are not compatible and the passenger train would only brake assuming its own weight. To operate the coupled trains the Train Operator would be required to adjust their driving style, demanding more brake and motor via the traction brake controller. The train operator had no experience of motoring coupled to an engineers' train.

10.5 The position of the train and emergency coupler were preserved by the DMT as evidence and neither were moved prior to the RAIB attending site in accordance with incident response rules. The passenger train was found with the coupler hand worked switch set to 'coupled' with the main line air cock isolated. The 'D to D' part of the emergency coupler was attached to the passenger train auto coupler face

and the combined parts were halfway over to the left hand side end stop from the centre position. The coupled arrangement was also sloping toward the ground from the horizontal (see figure 3). The emergency lights were on in the train and the emergency vents were still running. There was no main line air but the traction air in the southern most car had been isolated. As a result of this evidence, the FIR panel is confident that the analysis of the events leading to the coupling failure is accurate.

11. Incident Management

11.1 The Schweerbau operatives attempted to repair the RGU on site whilst arrangements were made to provide a train to assist with the rescue. It was suggested by the Network Operation Centre (NOC) that Tube Lines request the ERU attend in order to assist and as a backup should the incident become protracted. The ERU were requested to 'assist' not 'recover' and helped those on site with coupling the two trains. When requested to 'recover' the ERU take the lead rather than an assisting role.

11.2 The DMT was formally in charge of the incident response as 'silver control' after being appointed by Service Control and was therefore responsible for the movement of the coupled vehicles. The DMT was not familiar with the RGU or trained in coupling mixed vehicle formations and was therefore reliant on the Schweerbau operatives and Tube Lines manager to lead on the coupling of the RGU. The DMT and Train Operator took responsibility for the passenger train and prepared the train for coupling. It appears that no clear understanding was reached between all parties on site regarding the status of the brakes on the RGU. All brakes on the RGU had been isolated, although this was either not communicated or the implications of this not understood. It was communicated to control rooms that the brakes had been 'released', which may have contributed to an assumption that a braking facility was still available on the RGU.

11.3 It is highly unusual for a DMT to be in charge of the rescue of an engineer's vehicle as LU operational staff are not competent to authorise the movement of mixed vehicle formations. Given the absence of rules and a comprehensive emergency plan regarding the rescue of the RGU, the DMT's lack of familiarity with the RGU and coupling arrangements, authority for the movement of the vehicles should have been escalated to the RDO. The presence of a Tube Lines manager on site (in addition to Schweerbau operatives, and the ERU) may have been a factor in providing the DMT with assurance that the RGU could be moved.

11.4 The movement of the coupled trains was agreed between the DMT and Service Control. The Service Controller authorised the Train Operator to undertake the wrong direction move and communications between the front and rear cabs of the passenger train were between the DMT and Train Operator. The DMT reported the runaway RGU to Service Control immediately using an emergency call on the connect hand held radio. The DMT was instrumental in preserving evidence at Highgate, refusing requests from Service Control to move the train and ensuring the emergency coupler remained untouched.

11.5 The Tube Lines manager was with the RGU due to difficulties experienced during the previous night and throughout the incident liaised with Schweerbau and the LU teams. The Track Access Control team were informed of the broken down RGU by the Tube Lines manager. The Tube Lines manager assisted in coupling the two trains, organised the emergency communications between the Schweerbau and LU employees using a flashlight and then positioned himself in the leading cab of the passenger train during the move.

11.6 The Schweerbau operatives reported that they considered the movement of the coupled trains to be a 'rough ride', the report from those on the passenger train is in direct contrast to this. Rolling Stock Engineers have confirmed that the two vehicles would have experienced different rides due to the nature of the coupling and differences in wheel size and suspension between the two trains. The concern from the Schweerbau operatives was that the RGU would derail, not that the emergency coupler would fail. The RGU emergency plan stipulates that the coupled trains should be rescued at 5mph. The Train Operator was unaware of this and followed the rules for rescuing a passenger train, and due to being in 'coupled mode' the passenger train was limited to 17kph (10.5mph). Once the RGU began to roll un-braked from the passenger train, the Schweerbau operatives, realising they were unable to control the movement of the RGU, jumped from the cabs without injury as it passed through Highgate station.

11.7 The operation of the RGU was initially under the authority of Track Access Control (TAC) as it was working in engineering hours. The rescue of the RGU required the traction current to be switched on early. The TAC and Service Control liaised to facilitate the necessary handover without incident. Service Control were responsible for authorising the various movements of the passenger train and the immediate response to the emergency coupler failing.

11.8 The quick decision making by Service Control undoubtedly prevented the runaway RGU from becoming a more significant incident. The movement of trains out of the path of the RGU was swift and effective. The unsuccessful attempt to derail the RGU was, in these circumstances, an understandable decision and guidance available to staff regarding such decisions should be reviewed in light of this incident. Service Control made these decisions believing that the Schweerbau operatives were still on the RGU and had to balance the risk to the operatives' safety against the risk to customer safety. Service Control was aware that the attempt at derailing the RGU or the secondary plan to route it into the siding at Kennington, could both have had serious consequences for the Schweerbau operatives but assessed that the risk of taking no action was the greater.

12 Previous Incidents

12.1 The table below contains incidents involving the RGU and incidents of uncontrolled movement of passenger trains and engineers' trains

Date	Location	Incident details
17/07/2010	West Hampstead	Engineers' train 543 (RGU) became defective with no forward movement. At 05:50, service suspended between Waterloo and Willesden Green. Technical Staff, ERU and local Duty Manager sent to site. At 07:50, empty northbound train 336 attempted to push defective RGU, but was unsuccessful due to coupler flexing down. At 08:42, empty train 777 ex Neasden depot carried out wrong directional move back to engineers train with plans to pull train to depot. At 09:25, train confirmed as coupled up. At 09:29, RGU pulled back to Neasden depot. At 10:15, both trains confirmed in Neasden depot and all clear given.
21/03/2010	Paddington	Fluff on cable run below platform 3 was ignited by RGU working in engineering possession. Fire Brigade called to site, who raked out the embers once traction current had been discharged. Four further instances of burning were identified which were extinguished by the Fire Brigade using an AFFF fire extinguisher.
07/11/2008	St. John's Wood	Engineering train 547 (RGU) became stalled on the approach to the northbound platform on the Jubilee line. The train was en-route to Lillie Bridge depot ex London Road depot. Initially it was believed that the train could be moved from the south end, but after further investigation, no movement could be obtained from either end of the unit. At 01:18, ERU, LUL Operational Managers from various locations called to site to assist. At 02:47, train-en route to Neasden depot under its own power. ERU advised brakes were hanging on, preventing train movement.
18/05/2008	Victoria (possession Brixton - Highbury & Islington)	During a possession, the RGU became defective in the northbound platform at Victoria at 13:00. Following repair, a plan was made to move the RGU in engineering hours under its own power to Northumberland Park depot. As a precaution two battery locos were provided from Ruislip at 23:00 ready for use should they be needed to assist the rail grinder.
27/10/2005	West Ruislip	Whilst RGU was being tested, the rear door, which was not secured, hit the protection railings and was badly damaged. It had to be removed and the door opening was secured with tape and polythene sheeting.
20/07/2005	Aldgate	Train 235 (involved in the terrorist incident of 7th July) rolled towards Aldgate East when the Spring Applied Parking Brakes were released during recovery. It ran through No. 42 points and came to a halt three car's lengths into the tunnel where it was scotched to prevent it rolling back. There were no injuries.
16/01/2005	Dagenham East	Operator of eastbound T6 received a service brake fault on car 7077 and the train rolled back 4 feet after the train doors had previously been opened. The Train Operator closed doors immediately and put the traction brake controller into the emergency position stopping the train and clearing the fault. Line Controller instructed train to be withdrawn from service at Dagenham East. Duty Depot Manager attended site and was unable to recreate the failure. Cause probably stuck service brake micro switch.
28/04/2001	Camden Town	A DSM travelling on NB T10 approaching the station alleged that the train rolled back 50 yards. The T/Op was relieved from duty and given a D&A test, and train and signalling downloads were requested. It was confirmed the train did roll 41 metres and the brakes were applied.
08/07/2000	Chalk Farm	Train rolled back (through Chalk Farm) until stopped by train stop on signal A130B, having gone about 1 kilometre. T/Op. was unable to contact LC, noted 3 green signals ahead and proceeded to platform. T73 detrained with suspected fault but T/Op. later admitted he may have fallen asleep. Breath test was negative. Rolling speed of about 30 kph max
03/04/1998	Camden Town	NB T111 was detrained and withdrawn from service due to a defective brake on car 1068 which caused the train to roll back when stopped on a gradient.
23/10/1996	Chalfont & Latimer	NB T7 delayed when Operator failed to secure train correctly when changing ends, allowing it to roll back into the fixed red lights. Operator stated while waiting outside the train he heard an audible warning then saw the train rolling backwards. The signal track circuit interrupters associated were damaged, which required 45 points to be secured.

01/06/1996	Finchley Central	Service suspended East Finchley to Mill Hill East / High Barnet when northbound T101 derailed after passing signal NQ59 at danger due to handbrakes released before MGs and compressors were set. The train began to roll when Operator opened leading DVIC and he was unable to prevent leading car 1575 derailing on trap points clear of running lines. Train was re-railed after close of traffic by ERU.

13 Human Factors

Time Pressure

13.1 Time pressure was evident throughout the incident as all parties were conscious that the stalled RGU would have an increasing impact on service. Tube Lines and Schweerbau were aware that the delays to service were undesirable and had recent experience of this from West Hampstead. The time taken to make a decision is increased where the individual is not competent or is unfamiliar with the task. Where this is the case, there will be a greater perception of time pressure, which can affect perception of risk, increasing tolerance of high risks. In this incident there are differing levels of experience and competence regarding the movement, method of coupling and the vehicles in use. Time pressure was a factor in the decision to rescue not repair the RGU, the decision to move the RGU northbound and possibly the perception of risk associated with the rescue.

Availability Heuristic

13.2 Availability heuristic is a bias where events are perceived to be more likely based on the ease with which relevant instances comes to mind, rather than factual data of probability. Familiarity with the vehicles and knowledge of run-away incidents would have affected the perceived likelihood and risk of a run-away incident occurring. The successful towing of the stalled RGU at West Hampstead would have been a more ‘available’ scenario to those on site and therefore considered more likely compared to a run-away train or failed coupler incident which are much less common scenarios. The effect of the availability heuristic was to reduce the perception of risk of a potential run away or coupler failure incident.

Anchoring Heuristic

13.3 People who have to make judgements under uncertainty use this heuristic by starting with a certain reference point (anchor) and then adjust it insufficiently to reach a final conclusion. The ‘anchors’ used during this incident were the RGU emergency plan and the process for coupling two passenger trains. The rules for coupling two passenger trains are not applicable in this situation, but were complied with in the absence of any other rules for the LU staff. Compliance with the RGU emergency plan resulted in a vehicle formation with a single point of failure, this risk is not covered in the plan and was not recognised by those on site due to their perception of the risk. In this situation where approved plans are being complied with it is highly unlikely that the rules would have been challenged.

14 Conclusions

14.1 The failed coupler was an adapted emergency coupler that had been designed and approved by LU JNP Infraco in 2002.

14.2 The procedures in place at the time permitted the emergency coupler to be approved as plant rather than rolling stock. This resulted in insufficient levels of consultation with Rolling Stock Engineers.

14.3 The design of the emergency coupler was inadequate for its intended use and did not take account of the full forces that the emergency coupler may be exposed to. The emergency coupler failed under the forces experienced during an emergency brake application on the assisting train.

14.4 The rescue arrangements for the RGU are specified in the approved OSP&I and emergency plan for the RGU. Additional approval by the RDO was therefore not thought to be required to move the coupled vehicles.

14.5 The absence of a comprehensive set of instructions including all parties for rescuing the RGU contributed to those on site following the most similar rules available A number of decisions were required to be made on site, most notably the decision to use a passenger train and the speed of the coupled vehicles.

14.6 There was a lack of clarity in the understanding of the incident management roles and responsibilities on site, specifically regarding the individual and overall control of the coupled vehicles.

14.7 The train operator was unaware of the 5mph speed limit for the rescue. The speed of the passenger train in restricted manual caused an emergency brake application, resulting in the compressive forces and the failure of the coupler.

14.8 The DMT acting as silver control was unaware that the RGU brakes had been isolated when the passenger train was authorised to move. The emergency plan did not require that this information be communicated.

14.9 The single point of failure and potential risk was not recognised by the emergency plan, OSP&I or in the decision to tow the RGU northbound (uphill).

14.10 The decision to tow rather than push the RGU was a direct result of the incident at West Hampstead in July. The secondary retention methods used at West Hampstead were not applied at Highgate.

14.11 The use of a passenger train in the rescue of engineers' vehicles introduces incompatibility issues at mechanical, systems, procedural and competence levels.

14.12 The modification to the OSP&I and RGU Emergency Plan such that passenger trains rather than engineers' vehicles could be used to rescue the RGU was not subject to change control principles and therefore Rolling Stock Engineers were not consulted on the change.

14.13 The decisions and actions of the Service Control team were recognised as being very prompt in managing the runaway incident.

14.1 Immediate Causes

a) The RGU was defective and required rescuing;
b) The RGU had its braked isolated and no secondary retention was provided;
c) Compressive forces from the assisting train's emergency brake application exceeded the design strength of the emergency coupler;
d) The RGU rolled on the gradient.

14.2 Contributory Factors

a) Decision to rescue not repair the RGU
b) Decision to tow the RGU
c) Decision to rescue the RGU northbound (uphill)
d) The emergency plan did not recognise the risks associated with an un-braked unit
e) The RGU could not be connected to a secondary compressor
f) The RGU and passenger train couplers and brakes are incompatible
g) The brakes on the RGU are required to be isolated
h) The emergency plan introduces a single point of failure
i) A passenger train was used
j) The passenger train was in coupled mode and exceeded 17kph
k) Rolling stock engineers were not consulted on the emergency coupler design
l) The RGU was approved as rolling stock and the emergency coupler as plant
m) No design specification or design review were produced

14.3 Root Causes

a) Flawed emergency coupler design
b) Flawed approvals processes for the emergency coupler and the RGU emergency plan
c) Emergency coupler approved as plant and RGU approved as rolling stock
d) Change from the original intention to use battery locos to rescue the RGU without adequate change control
e) Design of RGU affecting the ability to repair the RGU in tunnel sections
f) Time pressure for service resumption affecting decision making

15 Actions taken since the incident

15.1 The following steps have been taken by LU and TLL to mitigate against recurrence in advance of this report being published. These actions will be reviewed as part of the recommendations arising from this report:

a) Operational Standards Notice 96 'Movement of defective rail vehicles' has been published. OSN 96 requires LU duty engineer approval (via the RDO) for

movements of engineer's vehicles where any brakes are isolated, or movement of a passenger train where the brakes on two or more cars are isolated

b) The LU and TLL plant approvals process has been revised to align with the rolling stock approvals process and now requires Asset Engineer approval. As part of the revised process further guidance is provided for the definitions of plant and rolling stock.

c) LU and TLL procedures for new designs require a 'functional design specification' to be produced. This document details the design specification, function of and approvals process to be followed for new designs.

d) All Transplant emergency couplers and adaptors have been withdrawn until asset identification controls have been established through asset numbering.

e) All OSPs and OSP&Is are now required to be approved by the Directors Risk Assurance and Change Control Team (DRACCT) under the revised category 1 standard 1-538 'Assurance'.

f) Both RGUs have had their approval for use on LU removed

16 Recommendations:

Actions specific to Rail Grinding Unit (root causes 4 and 8 in root cause diagram)

	Action	By	Date
1	Revise the requirements for RGU approval taking account of the findings of this FIR and the Structural Engineer's report regarding the RGU inter-car and emergency couplers. Compliance with the revised requirements to be demonstrated through the formal acceptance process prior to use on the LU network.	Richard Minter	Feb 2011
2	Review the emergency plan, OSP&I, risk assessments and other documentation associated with the operation of the RGU using the lessons learnt from this FIR. The review should: a) Be completed in consultation with the LU rolling stock engineer, b) Seek advice from LU Operational standards regarding the applicability of the Rule Book and OSP&I and any training requirements for LU COO teams c) Produce a comprehensive emergency plan detailing the method of rescue of the RGU, d) Inform the review in recommendation 11	Richard Minter	Jan 2011
3	Review the future strategy for specialist vehicle use taking account of compatibility issues identified in this investigation and future changes to LU systems and infrastructure (ATO and	George Clark & Malcolm Dobell	April 2011

	signal system development).		

Actions regarding process (root causes 1, 2 , 6, 9 and 10 in root cause diagram)

	Action	By	Date
4	Review the TLL and LU plant and rolling stock approvals processes to ensure it contains an appropriate level of independence, peer review and integration with associated process (e.g. change control and approvals / assurance regimes). This should clarify the definitions of plant and rolling stock and the competence required for sign off and be informed by the findings from recommendation 6.	Trevor Jipson, Graham Neil & Richard Minter	April 2011
5	Review all current vehicle related OSPs and OSP&Is to ensure they contain appropriate instructions for normal, degraded and emergency conditions. The review should identify any potential single point failures and take account of combinations of incidents / unplanned events and the findings of recommendation 7. The review should prioritise OSPs & OSP&Is that address vehicle use where rescue or recovery may required.	John Adams / Ian Rawlings	Jan 2011 (for priority OSP & OSP&Is) March 2011 for other docs
6	For each type of emergency coupling system used on engineer's vehicles, a desktop assessment should be carried out to determine if they have any of the design flaws associated with the emergency coupler arrangement used on the RGU. This should particularly focus on novel designs or where height variances are present. If design flaws are identified the arrangement should be removed from use until suitable mitigations can be put in place.	Roger Creed and Graham Neil	March 2011
7	Review the emergency plans for all engineers' and miscellaneous vehicles to ensure adequate arrangements exist for rescue. With appropriate involvement of Rolling Stock Engineers and LU Operations and with particular reference to: • type of assisting vehicle (passenger or engineering), • braking capacity, • secondary retention, • selection of route (gradient, direction, track features etc.) • authority to move mixed vehicle formations, • The role of service control and recommendation 11.	Roger Creed	March 2011
8	Review the purpose, approval and change control of OSP&Is to provide assurance that risks are being appropriately managed consistent with OSPs, emergency plans and the LU Rule Book.	John Adams & Trevor Jipson	Jan 2011
9	a) Assess with Transplant the risk from un-braked units and develop reasonably practicable actions to ensure risks are appropriately controlled. b) The assessment should identify any changes required to engineering, Rule Book and competence based controls and	Graham Neil (with Mark Grey for part b)	May 2011

	the findings from recommendation 7.		
10	a) Re-write guidance note G-184 'Guide to the acceptance of third party vehicles' as a LU standard in consultation with TLL. The standard should address the operation and rescue of engineers' vehicles and fundamental railway safety principles (automatic train protection, signalling, braking and secondary retention). b) Update the LU Rule Book and competence management systems to reflect any changes in requirements arising from 10a)	a)Graham Neil b) Mark Grey	August 2011 August 2011
11	Review the command and control arrangements for the management of incidents involving engineers' vehicles from an LU Operations perspective. This should include overall control of the incident, liaison with 3rd party contractors, the use of passenger trains, authority to move, escalation to the RDO and the requirements of OSN 96. Any competence requirements identified should be reflected in the relevant CMS documentation.	Howard Collins	February 2011
12	Review what information and guidance is available to Service Control staff when making emergency response decisions on the operational railway.	Howard Collins	Jan 2011

Appendix A – Investigation Photographs.

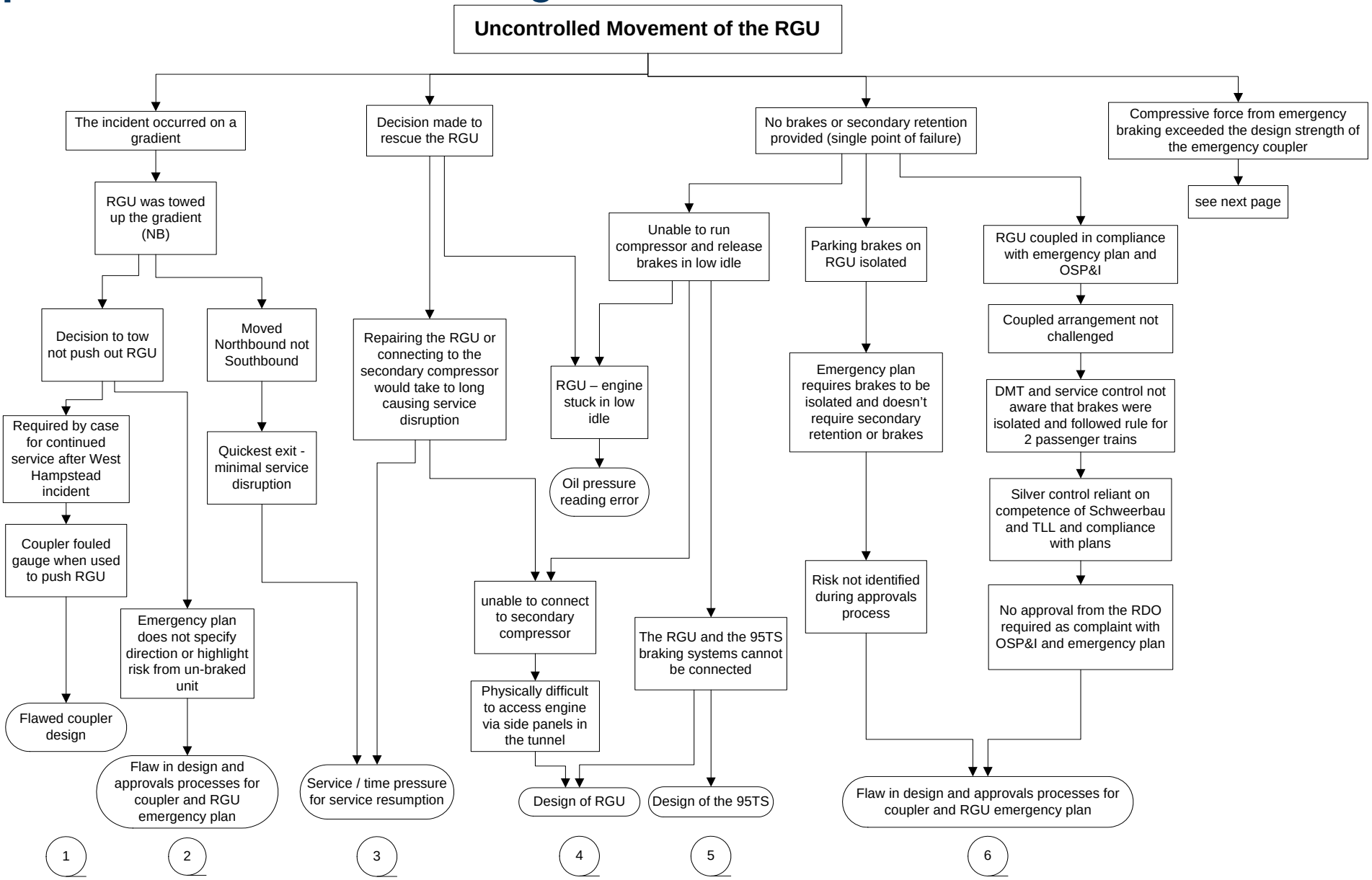
Figs. 5 & 6 Intact and damaged coupling points on the RGU

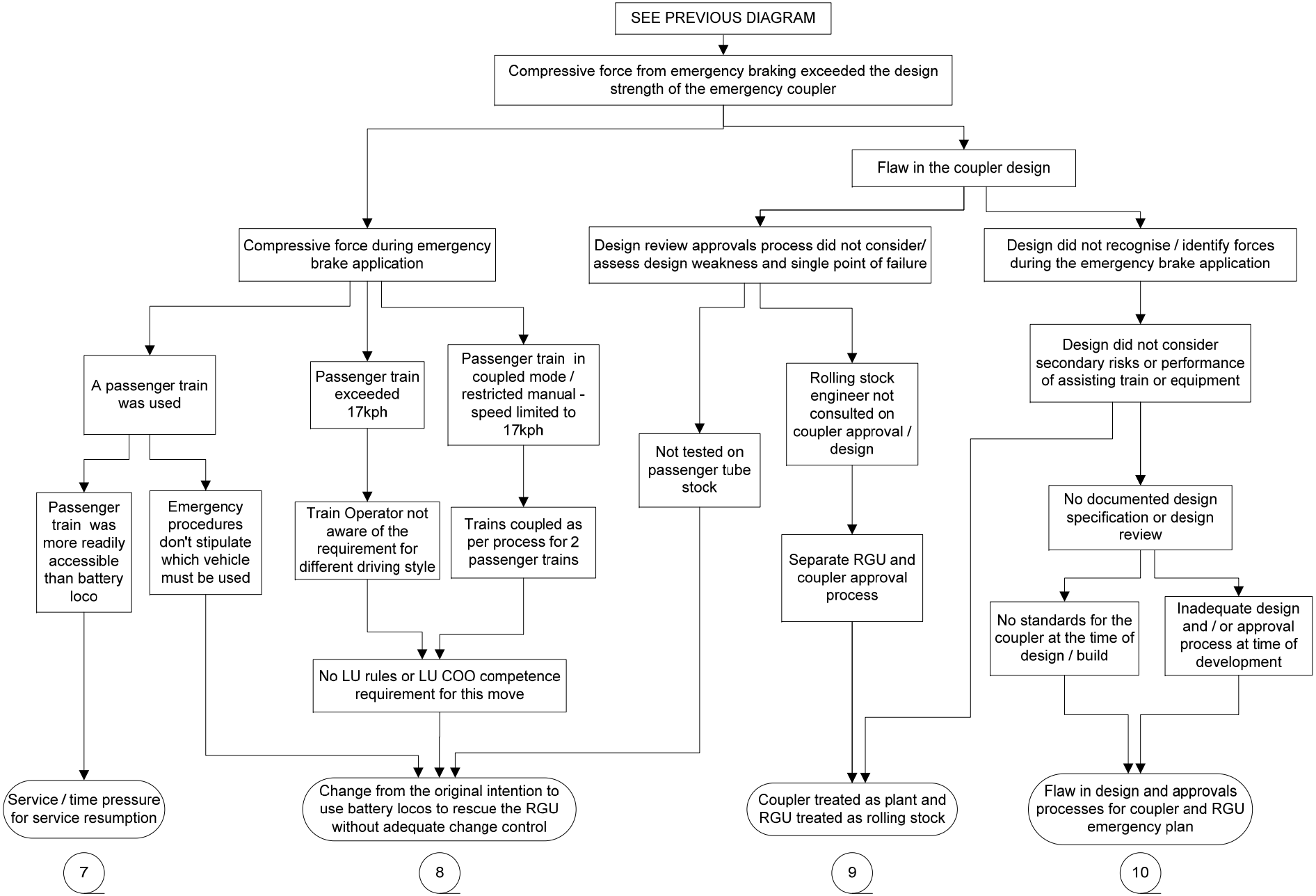
Fig 7. Configuration of LU train, emergency coupler, tow-bar and RGU

Fig 8 & 9 Damaged and intact coupler used to connect tow-bar to LU passenger train (note point of failure in image on the left)

Fig 10 emergency coupler and tow-bar showing point of failure (note bent metal on tow-bar implying a 'tear' rather than fatigue shear)

Appendix B –Root Cause Diagram




SEE PREVIOUS DIAGRAM
Compressive force from emergency braking exceeded the design strength of the emergency coupler
Compressive force during emergency brake application
Flaw in the coupler design
Design review approvals process did not consider/ assess design weakness and single point of failure
Design did not recognise / identify forces during the emergency brake application
A passenger train was used
Passenger train exceeded 17kph
Passenger train in coupled mode / restricted manual - speed limited to 17kph
Not tested on passenger tube stock
Rolling stock engineer not consulted on coupler approval / design
Design did not consider secondary risks or performance of assisting train or equipment
Passenger train was more readily accessible than battery loco
Emergency procedures don't stipulate which vehicle must be used
Train Operator not aware of the requirement for different driving style
Trains coupled as per process for 2 passenger trains
Separate RGU and coupler approval process
No documented design specification or design review
No standards for the coupler at the time of design / build
Inadequate design and / or approval process at time of development
No LU rules or LU COO competence requirement for this move
Service / time pressure for service resumption
Change from the original intention to use battery locos to rescue the RGU without adequate change control
Coupler treated as plant and RGU treated as rolling stock
Flaw in design and approvals processes for coupler and RGU emergency plan
7
8
9
10