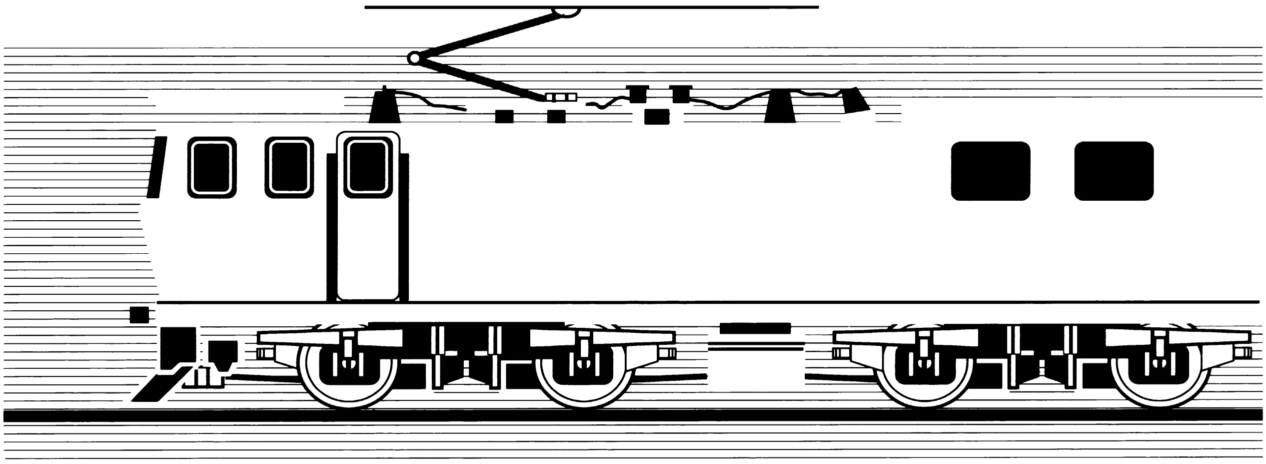
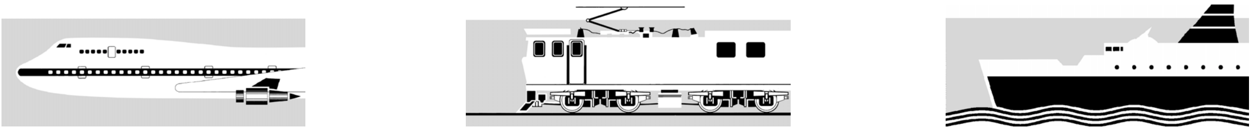


RAILWAY OCCURRENCE REPORT

04-132 overhead power failures, Wellington suburban rail network **4 December 2004 – 24 January 2005**



TRANSPORT ACCIDENT INVESTIGATION COMMISSION
NEW ZEALAND

Report 04-132

overhead power failures

Wellington suburban rail network

4 December 2004 and 24 January 2005

Abstract

On Saturday 4 December 2004, a Tranz Metro[1] electric multiple unit passenger train travelling from Wellington to Paraparaumu became disabled between Kaiwharawhara Station and Tunnel 1 when the traction overhead contact wire failed due to tensile overload. The failure was brought about by a combination of poor electrical contact between the contact wire and stirrup clamping plates, and a build-up of corrosion products.

On Monday 24 January 2005, a Tranz Metro electric multiple unit passenger train travelling from Upper Hutt to Wellington became disabled between Petone and Ngauranga when the traction overhead contact wire failed. The cause of the failure was similar to the incident that occurred on 4 December 2004.

There were no injuries.

The safety issues identified were:

- the early detection and replacement of safety-critical components before failure
- the safety of passengers on disabled trains.

One safety recommendation has been made to the Chief Executive of ONTRACK[2] and one to the Chief Executive of Toll NZ Consolidated Limited.

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[1] Tranz Metro was the group within Toll Rail with responsibility for the operation of suburban train services in Wellington.
[2] ONTRACK was the access provider that controlled the use of the network by rail operators.

Contents

Figures

Abbreviations

ºC	degrees Celsius
BS	British Standard
EMU	electric multiple unit
ETP	electrolytic tough pitch
km	kilometre(s)
km/h	kilometres per hour
LEMU	locomotive engineer multiple unit
mm	millimetre(s)
mm^2	square millimetre(s)
MPa	megapascal(s)
NIMT	North Island Main Trunk
RIC	rail incident controller
WEA	Wellington Electrified Area

Data Summary

Train type and number:	passenger Train PA04 and passenger Train 3639
Classification:	electric multiple units
Date and time:	4 December 2004 and 24 January 2005
Location:	Wellington suburban rail network
Persons on board Train PA04:	crew: 6 passengers: 480
Injuries:	nil
Persons on board Train 3639:	crew 4 passengers 600
Injuries:	nil
Damage:	moderate to both traction overhead system and passenger rolling stock
Operator:	Toll NZ Consolidated Limited
Investigator-in-charge:	P G Miskell

1 Introduction

1.1 On 4 December 2004 and 24 January 2005, Tranz Metro electric multiple unit (EMU) passenger services were disabled because the traction overhead contact wire failed.

1.2 Because of the commonality of the 2 incidents, investigations into them have been combined into one report, although each incident is dealt with separately. The incidents are summarised below:

- **Occurrence 04-132:** on Saturday 4 December 2004 at about 2250, EMU passenger Train PA04, travelling from Wellington to Paraparaumu with about 480 passengers on board, was disabled at 3.246 kilometres (km) on the North Island Main Trunk (NIMT) Up Main line, between Kaiwharawhara and the south portal of Tunnel 1. The overhead power was isolated before the passengers were detrained on to an empty service on the Down Main line. The passengers arrived back at Wellington Station at about 0058
- **Occurrence 05-104:** on Monday 24 January 2005 at about 1315, EMU passenger Train 3639, travelling from Upper Hutt to Wellington with about 600 passengers on board, was disabled between Petone and Ngauranga on the Wairarapa Line. The overhead power was isolated and a light locomotive dispatched from Wellington to recover the disabled train. Train 3639 arrived at Wellington Station about 90 minutes after it was disabled.

2 Wellington Electrified Area

2.1 General

2.1.1 The Wellington Electrified Area (WEA) extended from Wellington to Paraparaumu on the NIMT, Wellington to Upper Hutt on the Wairarapa Line, Petone to Melling and Wellington to Johnsonville. The WEA network included about 300 km of main line, loops and storage sidings. Commuter trains operating within the WEA were powered by a 1600 volt direct current overhead system.

2.1.2 The overhead traction system consisted of a catenary wire supported by traction poles about every 60 metres (m). From the catenary wire, the contact wire was suspended on dropper wires. The dropper wire length varied, so that the contact wire was a uniform height above rail level. Power was conveyed from the catenary wire to the contact wire by feeder wires. Power was conveyed from the contact wire to the EMU through the pantograph mounted on the roof of the EM passenger cars. In overlapping sections the 2 contact wires were kept apart by stirrups.

2.1.3 The overhead lines were inspected and maintained by a team of 8 traction linemen.

2.2 Traction overhead contact wire for WEA

2.2.1 ONTRACK's Code Supplement CST/202 stated in part:

> $161mm^2$ contact wire is manufactured to British Standard (BS) 23:1970 ["Copper and Copper-Cadmium Trolley and Contact Wire for Electric Traction".]
>
> The original thickness of the contact wire is 15mm ± 0.15mm.
>
> Planning for the replacement of the wire must commence when the wire thickness reaches 8.5mm.
>
> The wire must be replaced before it wears to a wire thickness of 8.0mm.
>
> The contact wire thickness is to be measured using a micrometer or an approved go, no go gauge.

The measurement frequency and accuracy shall be as shown in the table:

Contact Wire Thickness	Frequency of Measurement	Accuracy Required
Less than 9mm	1 yearly	± 0.1mm
Greater than 9mm	6 yearly	± 0.5mm

2.3 Code inspections of the traction overhead within WEA

2.3.1 ONTRACK's Code Supplement E/CST/213 required scheduled inspections of the traction overhead at intervals of 3 months, 6 months, 12 months and 6 years.

2.3.2 The purpose of the 3-monthly inspection was to ensure that the overhead equipment was safe for the passage of pantographs. The inspection, which looked for foreign bodies near the overhead, equipment damage, missing equipment, parting or burning of wires and signs of pole movement, could be carried out from an EMU, a Hi-Rail vehicle or on foot.

2.3.3 The 6-monthly inspection was carried out from an EMU fitted with a video camera. The inspection required the traction supervisor to inspect the overhead closely to ensure the equipment was being maintained to the Code. In addition, the traction supervisor was required to inspect in detail one tension length, of about 1.5 km, and maintain a record of their findings.

2.3.4 The 12-monthly inspection was more detailed and was carried out as a foot patrol. A requirement of this inspection was to check dropper wires for damage, alignment, excessive movement and loose clips, particularly at overlaps that had stirrups.

2.3.5 All parts of the overhead system were inspected in detail every 6 years and, where necessary, corrected to the Traction Code. All wire joints including contact wire splices and connections were inspected for wear, security, corrosion and damage. A record of the minimum wire thickness and location of each wire run must be maintained. The passage of EMUs was observed at overlaps to ensure pantographs were not fouling out-of-running wires and that the take-over was smooth.

3 Factual Information

Occurrence 04-132

3.1 Narrative

3.1.1 On Saturday 4 December 2004, Train PA04 was the Tranz Metro EMU passenger service from Wellington to Paraparaumu. The 8-car train was made up from four 2-car sets consisting of a powered EM passenger car and a non-powered ET passenger car. Each 2-car set was permanently coupled with the ET passenger car on the north end of the EM passenger car. The train was crewed by a Grade 1 locomotive engineer, a train manager and 2 passenger operators plus 2 security personnel. The train departed from Platform 8 at about 2248 and was conveying passengers returning from an event at Wellington Stadium.

3.1.2 After departing Kaiwharawhara at about 2250, the locomotive engineer powered up as the train started a steady 7 km climb. The train was travelling at about 60 kilometres per hour (km/h) when the locomotive engineer felt the train surge. He looked ahead and saw sparks and what appeared to be a blue haze around the contact wire, which then started to shake violently.

3.1.3 Realising that there was something wrong with the overhead, he pushed a button on his panel to lower all pantographs. He said that the contact wire appeared to burn out in front of him and then whiplashed back along the train.

3.1.4 After the train came to a stop, the locomotive engineer radioed train control and advised that his train was disabled between Kaiwharawhara and Tunnel 1, and that he thought the contact wire had been pulled down.

3.1.5 The failed contact wire destroyed the pantograph to the first elbow on the rear 3 powered cars, EM1119 south end, EM1102 south centre and EM 1269 north centre. The pantograph on leading powered car EM1298 was intact but mangled.

3.1.6 The windows on the rear doors on both sides of EM1269, the fourth passenger car on the train, were broken.

3.1.7 At the time of the dewirement, Train 6387, a Paraparaumu to Wellington EMU passenger service, was exiting Tunnel 1 on the Down Main line and drifted to a stop about 40 m past the rear of Train PA04. At about 0005, power was restored to the Down Main line and Train 6387 continued on to Wellington Station.

3.1.8 After Train PA04 became disabled, staff walked through the train checking the welfare of passengers and instructed them to stay inside their respective passenger cars.

3.1.9 At about 0034, Train 6391, an empty 8-car service from Porirua, arrived and was positioned on the Down Main line alongside disabled Train PA04. Wheelchair ramps carried on board the EMUs were connected between the doors of the 2 trains to provide a level platform for the passengers to detrain from the disabled service. Train 6391 arrived at Wellington Station at about 0055.

3.1.10 There were no injuries to the passengers or crew on Train PA04.

3.2 Site information

3.2.1 The initial failure on the contact wire occurred at a stirrup for an overlap[3] between portal structures at 3.246 km and 3.307 km on the Up Main of the NIMT (see Figure 1). Damage to the contact wire extended from 2.821 km to 3.307 km.

3.3 Locomotive event recorder

3.3.1 EMUs were not equipped with locomotive event recorders.

3.4 Inspections of the WEA overhead contact wire

3.4.1 Inspection records confirmed that the following code inspections of the WEA overhead system between 0 km and 8 km had been carried out:

- 3-monthly cab run inspection on 1 November 2004
- 6-monthly pantograph inspection on 30 June 2004
- one-yearly inspection from the ground on 31 March 2004
- 6-yearly close-up inspection on 6 June 2001.

[3] The contact wire was not continuous but supported in tension lengths of about 1.5 km. The tension lengths were overlapped between adjacent special portal frame structures about 60 m apart. The lateral separation between the overlapping contact wires was maintained by stirrup connections.

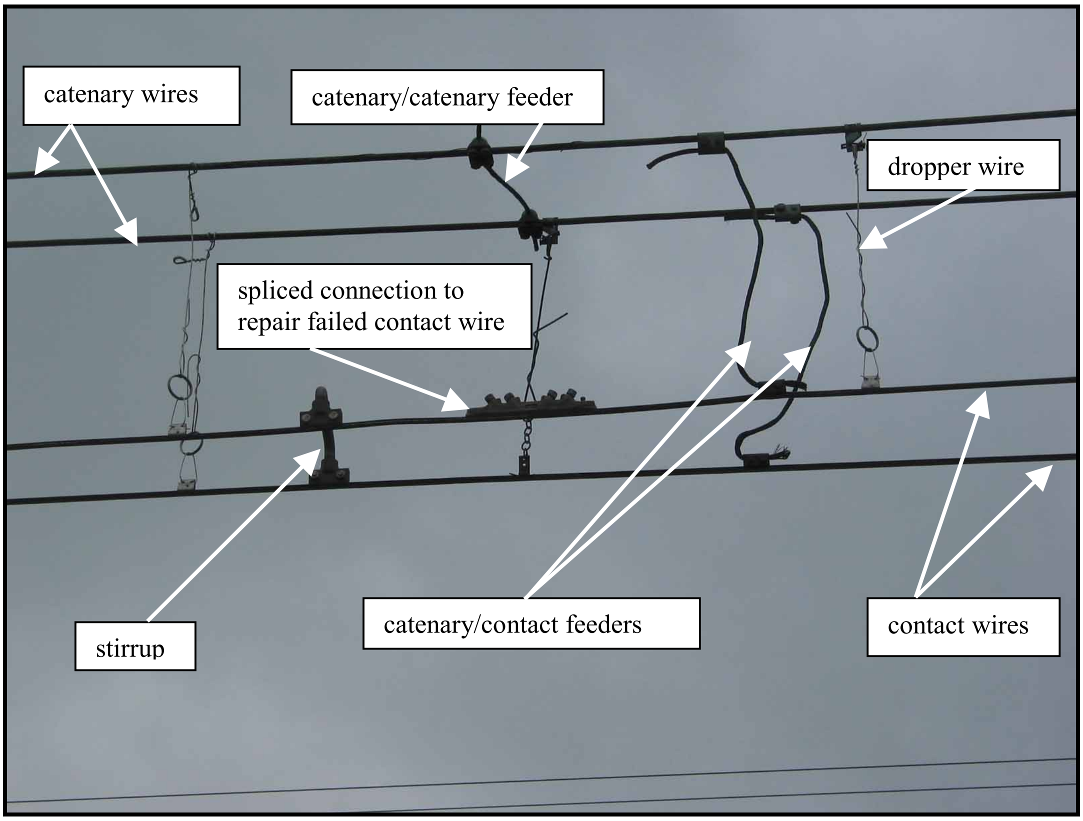

Figure 1
Overlapped contact wires and components

3.5 Visual examination of failed components

3.5.1 A section of the damaged copper contact wire (conductor) and the stirrup connection that included 2 sets of clamping plates were taken for independent testing and analysis (see Figure 2).

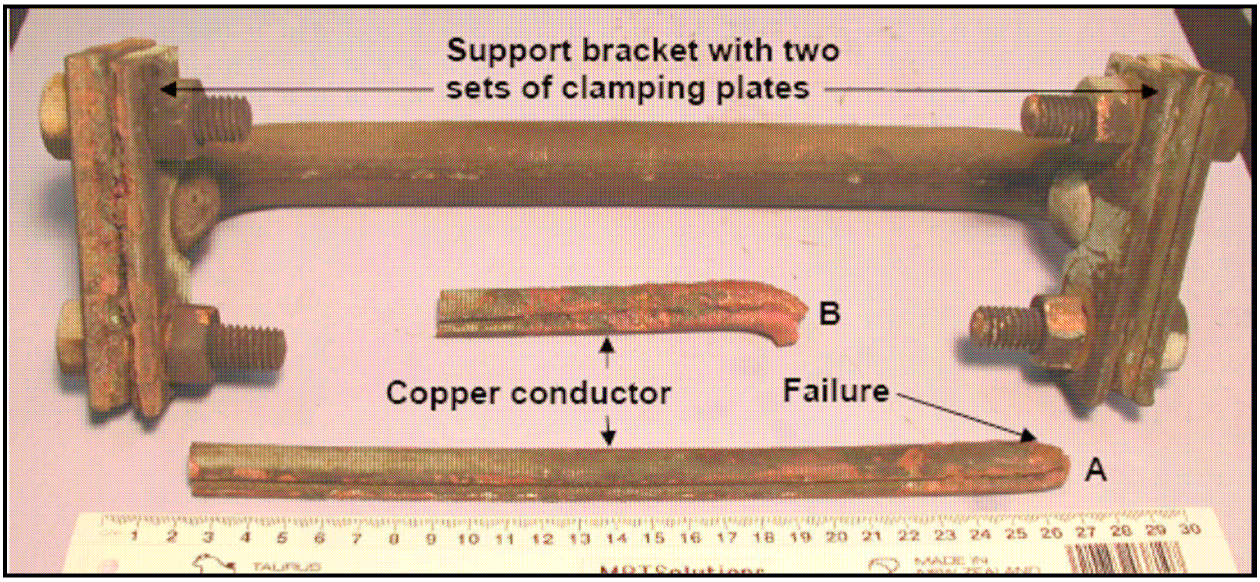

Figure 2
Stirrup assembly and copper contact wire

3.5.2 The general arrangement before separation of the components is shown in Figure 3, and can be described as:

- the contact wire had a rough hourglass shape with a rounded top lobe and a bottom lobe that had worn flat by contact with train pantographs. The waisted central part of the conductor was held by 2 bronze clamping plates about 97 millimetres (mm) long, that have jaws shaped to fit the central part of the conductor
- the plates were bolted to close them on the conductor
- the electrical contact was made between the jaws and the central part of the conductor.

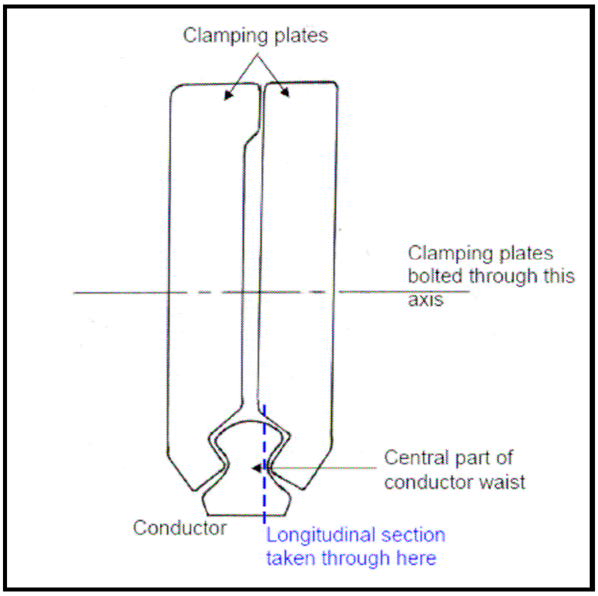

Figure 3
Conductor and clamping plates (not to scale)

The contact wire

3.5.3 The following observations were made on the condition of the 2 short lengths of contact wire labelled A and B in Figure 2. Generally the contact wire had worn on its contact surface such that a flat of almost 14 mm width had developed.

3.5.4 The pieces of contact wire were measured for wear. The thicknesses varied between 10.8 mm and 11.7 mm. The cross-sectional area of the copper conductor near the failure point was measured to be about 120 mm^2.

3.5.5 Sample A had the following features:

- a fracture had occurred at one end, within the clamped portion of the conductor
- the fracture exhibited considerable necking and a clean ductile break consistent with tensile overload (see Figure 4)
- both sides of the central portion of the contact wire exhibited corrosion products within a localised section about 35 mm long (see Figure 4). There was a demarcation at the non-fractured end where the corrosion products were significantly less severe. This appeared to coincide with the end of the contact between the jaws of the clamping plates and the conductor. Red and black material that was probably copper oxides filled the narrowest part of the contact wire
- the regions just above the central part of the conductor near the top lobe exhibited deformation and loss of material in the form of an irregular surface
- the corrosion in areas outside the clamping contact zone was superficial.

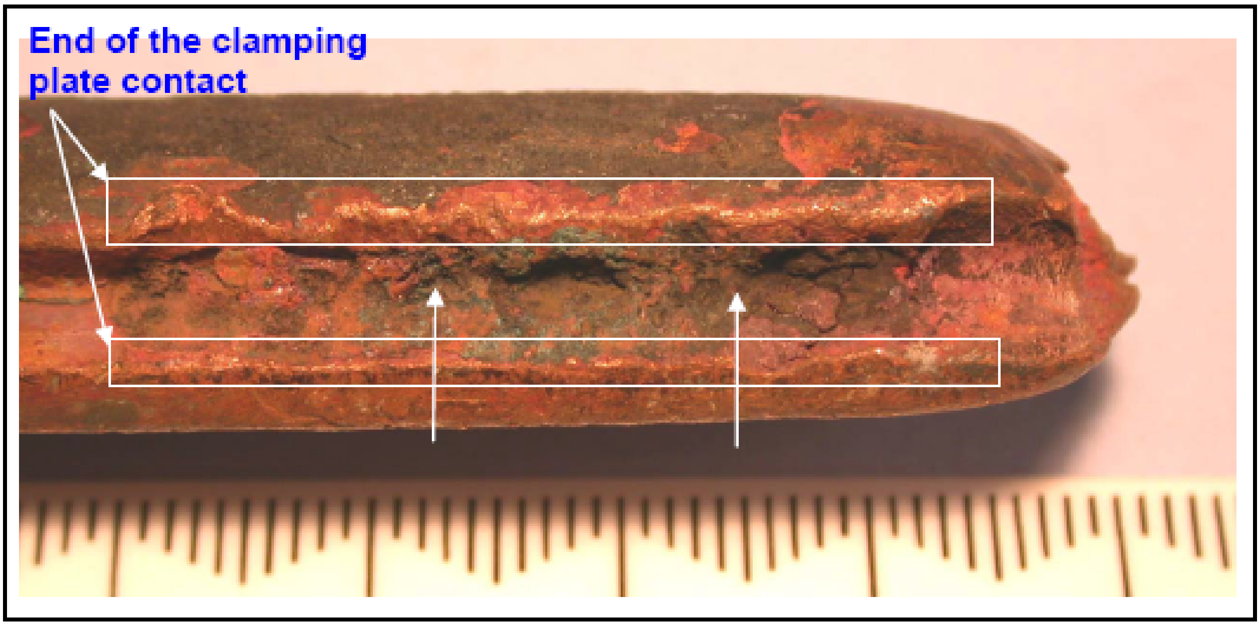

Figure 4
Failed end of the contact wire Sample A

3.5.6 Sample B exhibited severe deformation and a fracture at one end indicated failure by overload in bending and slight twisting (see Figure 5). This short length of conductor also exhibited severe corrosion and possible superficial melting.

Figure 5
Deformation and degradation of contact wire labelled Sample B

Clamping plates

3.5.7 The following observations were made on the condition of the clamping plates:

- there were surface deposits of green and black corrosion around the outside of the plates and on the bolts. The green deposits were distributed generally away from the contact region with the contact wire, although some were present around the jaws
- the interior surfaces of the jaws, where in contact with the contact wire, were corroded along the entire length of the jaws and the corrosion product exhibited colours typical of oxides of copper (see Figure 6)
- corrosion product partially filled the grooves

- melted and re-solidified material was present along the jaws and there were numerous holes in the re-solidified material, indicative of arcing (see Figure 7). When the conductor was placed against the clamping plate, and aligned such that the indication of the limit of contact on the contact wire coincided with the end of the plate, the region of most severe arcing appeared to coincide with the location of fracture A.

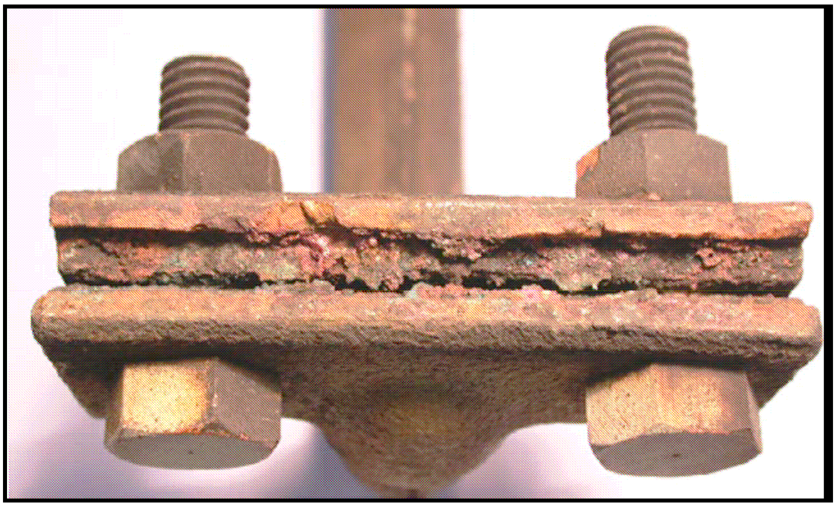

Figure 6
Clamping plate showing degradation

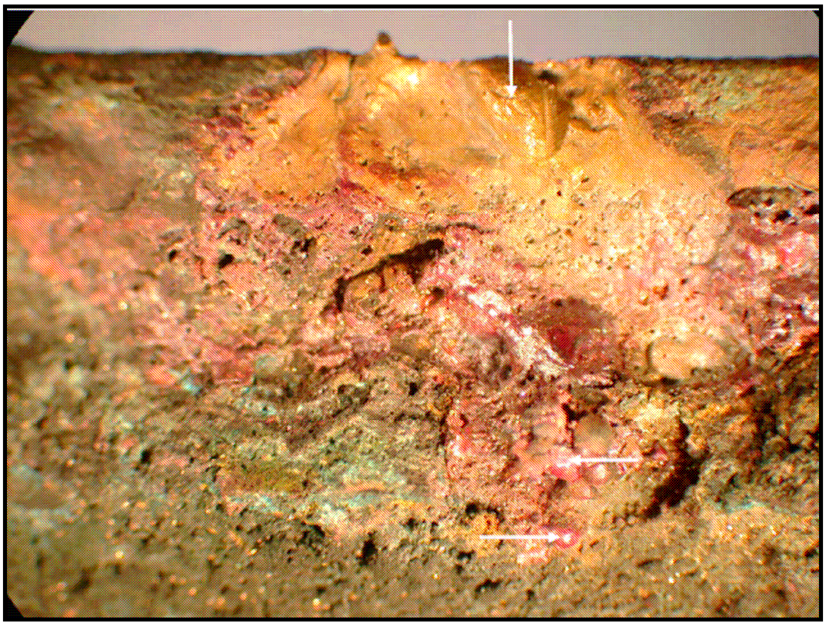

Figure 7
Melted and re-solidified and oxidised material, indicated by globules, arrowed

3.6 Metallurgical examination of failed components

The contact wire

3.6.1 Longitudinal and cross sections were taken from failed conductor sample A and from the end of the long piece of conductor that was relatively undamaged. The longitudinal sections were taken from one side of the contact wire and were prepared for examination under an optical microscope for comparison. The long length was taken as representative of the condition of a relatively undamaged contact wire.

3.6.2 The following observations were made:

- the grain structure that extended up to about 10 mm along the contact wire from the fracture face was consistent with the material having been heated to the annealing temperature. However, no significant grain growth was observed
- there was deformation of the grains immediately adjacent to fracture A, consistent with the strain experienced under tensile overload
- the structure in a cross-section taken several millimetres back from the fracture contained recrystallised grains mostly towards the centre part of the conductor. However, on one side of the conductor, the structure exhibited grain growth. The other side exhibited some recrystallisation while the central bulk of the material appeared to be relatively unaffected by heat
- copper and copper oxides on the surface of the central part were up to about 0.5 mm thick (see Figure 8)
- inclusions in the structure were consistent with electrolytic tough pitch (ETP) copper.

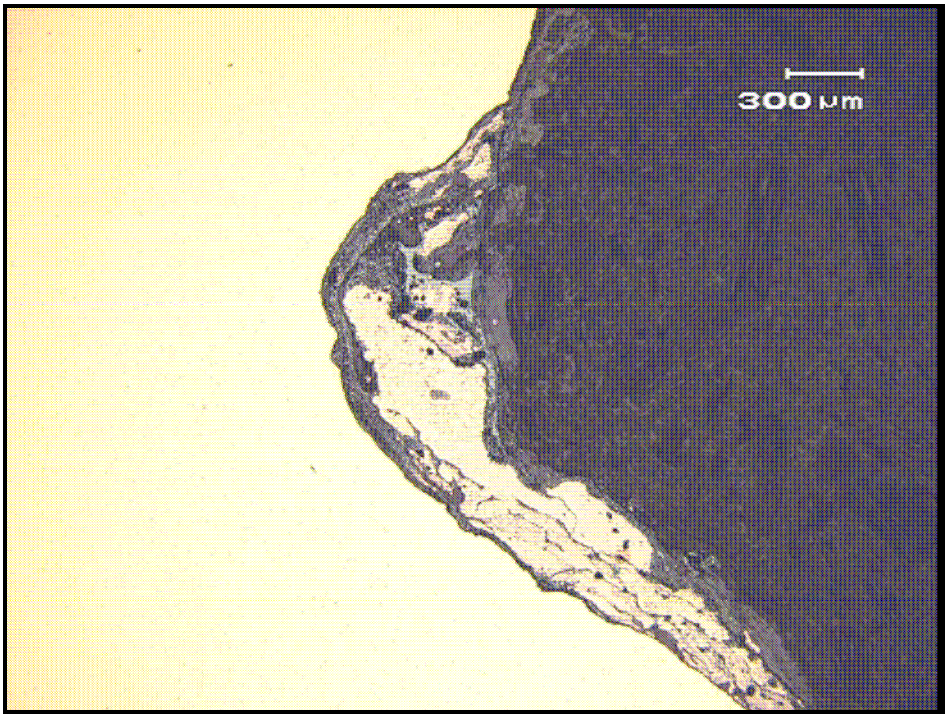

Figure 8
Copper and copper oxides in the central part of the contact wire

The clamp

3.6.3 A cross-section of one of the jaws of the clamping plate was examined and the following observations made:

- the microstructure exhibited a cast structure
- the region around the jaw exhibited intergranular cracking that extended to more than 0.5 mm
- the surface was irregular with indications that material was missing
- the corrosion products were up to about 0.3 mm thick on the surface of the jaw region.

Hardness tests

3.6.4 The longitudinal sections of the contact wire were hardness tested using a Vickers hardness-testing machine with a one-kilogram load. The results are presented below.

Region	At fracture A	At start of necking of fracture A (about 6 mm from fracture)	17 mm back from fracture A
Vickers hardness values	68.1, 68.1, 71.5	103, 105, 105	125, 125, 129

Hardness values of 112-114 were consistent with hard drawn copper. Hardness values of 63-75 were consistent with annealed copper.

Chemical analysis

3.6.5 Samples of the contact wire and clamping plate were analysed to identify the material and corrosion products.

3.6.6 The contact wire appeared to have been manufactured from ETP high conductivity copper. The clamping plate was manufactured from a leaded tin bronze.

3.6.7 Several regions of the corrosion product on the central part of the contact wire were analysed. Some deposits contained oxygen and chloride ions while others were more typical of copper oxides. The superficial green corrosion product was copper chloride. The corrosion products on the surface of the contact wire and clamping plates were mostly oxides of copper.

3.7 Evacuation procedures

3.7.1 Toll Rail's evacuation procedures, Code Supplement CSR 3.2, dated 17 September 2001 stated in part:

> **4.5 Evacuation**
>
> In the event of an emergency where it is deemed necessary to evacuate the train, the Driver and the Guard [train manager] will confer as to the best method to be used. Assistants must not detrain or allow passengers to detrain. Seek out or wait for instructions from the Guard or Driver. The Driver will ensure the overhead is safe and/or isolated before authorising evacuation. Consideration must be given to ensuring passengers are not exposed to any further danger such as trains on the other line (in double line areas), following services or dangerous underfoot conditions. Passengers must be escorted to safety.

3.8 Personnel

The locomotive engineer

3.8.1 Although the locomotive engineer had maintained his Grade 1 certification for about 25 years, he had driven EMUs exclusively for the past 13 years.

3.8.2 The locomotive engineer saw a blue glow on the contact wire as the train was accelerating away from Kaiwharawhara towards Tunnel 1. He said that he saw the contact wire shaking from side to side. He activated the pantograph lower button straight away, but because the train was almost at the location of the contact wire failure, the pantographs on the EM passenger cars did not retract in time to prevent them being damaged.

3.8.3 After the train stopped and the train controller had been advised of the situation, the locomotive engineer said that he walked through the train instructing passengers to stay inside their respective passenger cars because the contact wire could be hanging between the passenger cars. The overhead contact wire was treated as live until confirmation was received from an attending traction lineman that the overhead had been isolated and earthed.

3.8.4 The locomotive engineer conferred with the train manager and insisted that all passengers be kept on the train until a recovery plan was established.

The train manager

3.8.5 The train manager had worked for Tranz Metro for about 15 months and had been a qualified relief train manager for about 6 months. The train manager was seconded to the train manager's roster for the fortnight before this incident, and gained full-time appointment as a train manager on 5 December 2004.

3.8.6 About 30 minutes before the train was scheduled to depart, the train manager met the 2 passenger operators on the station platform. The train manager elected to travel in the middle passenger cars and reminded the on-board staff that, collectively, they were responsible for the care and comfort of the passengers. The passenger operators were encouraged to take their time before giving "right-away" at stations, and then only when passengers were well clear of the doors.

3.8.7 The train manager said that while the train was disabled, staff offered reassurance to passengers and kept them informed of developments.

3.8.8 Staff and security personnel stood by all doors that were used to transfer passengers from their disabled train to Train 6391 waiting on the Down Main line. Detraining was carried out in an orderly manner and was completed in about 10 minutes. A final check of the disabled train was made to confirm that all passengers had detrained.

The attending traction lineman

3.8.9 The on-call traction lineman had more than 25 years' experience with the inspection and maintenance of the WEA.

3.8.10 At about 2300, he received a telephone call from his supervisor, telling him about a serious incident near Kaiwharawhara and asking whether he was available to attend. He said that he was, and arrived at the Kaiwharawhara traction depot within about 10 minutes of receiving the call. On the way to the Depot, he called traction control and obtained updated information on the extent of the overhead failure and was informed that there was no overhead power available between Wellington Station and Glenside sub-station on the NIMT and that sections of the Wairarapa and Johnsonville Lines were also without power.

3.8.11 After departing from his depot, he drove along a maintenance access road towards Tunnel 1 and saw 2 stationary EMUs, one on the Up Main line and another a few metres south on the Down Main line. He saw that a section of the overhead on the Up Main line had been brought down then drove south towards Wellington Station to assess the condition of the overhead south of Kaiwharawhara. He advised traction control that because the overhead was continuous south of Kaiwharawhara, the power could now be restored between Wellington and Kaiwharawhara on the NIMT and on the Johnsonville and Wairarapa Lines.

3.8.12 After he had erected earth sticks on the Up Main line to isolate the damaged overhead, a senior manager from ONTRACK arrived on site to assume the responsibilities of the rail incident controller (RIC).

3.8.13 After clearing the contact wire that was fouling the Down Main line, he and other traction staff set about removing the tangled wires from Train PA04 and recovering the damaged pantographs from the roofs of the powered passenger cars. While he was recovering the pantographs, Train 6391, an 8-car empty EMU passenger service, approached on the Down Main line and was positioned with its doors directly opposite the doors on Train PA04.

The train controller

3.8.14 The train controller had held his certification for the Wellington train control desk for about 15 years. His certification was current.

3.8.15 The automatic activation of a strobe light on the train controller's desk following the power outage alerted him to the incident. A traction controller, rostered on duty because of the Stadium event, came to the train controller's booth and confirmed the location of the power outage. At about the same time, the locomotive engineer on Train PA04 called to say that it appeared that the overhead had come down between Kaiwharawhara and Tunnel 1.

3.8.16 Other trains were stopped at Ngaio on the Johnsonville Line and at Petone on the Wairarapa Line because of the power outage on the Up Main line. Power was restored to the Johnsonville Line, Wairarapa Line and NIMT Down Main line between Glenside and Wellington at about 0005 the next day.

3.8.17 The train controller maintained communication with the RIC and together they developed a plan to recover the passengers stranded on Train PA04 by coupling 2 empty passenger cars from PA01 onto empty service Train 6391 at Porirua. He then authorised Train 6391 to travel on the Down Main line non-stop from Porirua to berth alongside disabled Train PA04 for the transfer of passengers.

3.8.18 The train controller then instituted wrong line running between Wellington and Tawa. The procedure permitted an up train to travel on the Down Main line under special conditions, thus allowing passengers from disabled Train PA04 to return to their home stations.

The rail incident controller

3.8.19 ONTRACK's Operations Manager received a call from the Network Control Manager at about 2300, advising him that an EMU passenger train was disabled on the NIMT Up Main line, near or just inside Tunnel 1, and asking him to attend the site in the capacity of the RIC. On arriving on site at about 2345 he was informed that there were no injuries to passengers or crew.

3.8.20 He obtained an update from the traction lineman on the condition of the overhead contact wire and what actions had been taken to protect the work site. After making an assessment of the hazards on site and satisfying himself that all the necessary safety controls were in place, he liaised with the train controller to develop the recovery plan for the stranded passengers.

Witness A, passenger on Train PA04

3.8.21 Witness A was seated on the right-hand side in the front third of passenger car ET 1269, the fourth car on Train PA04. There were 3 other adults but mainly youths travelling in her car. The car was almost full but all passengers were seated at the time of the incident.

3.8.22 She said that the train had departed from Kaiwharawhara and was travelling relatively slowly when she heard 3 loud bangs on the roof, then a cable come through the windows of the rear doors. The train stopped quickly. A number of passengers had thrown themselves on the floor, screaming and yelling, because they didn't know what had shattered the windows.

3.8.23 The witness said that staff told passengers in her car to go back to their seats and that the safest place for passengers was to remain inside their passenger car. She said that at various times about 5 staff came into their passenger car to look at the shattered windows but very limited information was passed on. She said that there was speculation amongst the passengers as to what was happening, and for how much longer the train would be stranded. She overheard some of the youths talking about using the emergency door switch and exiting the train.

3.8.24 She said that the train was stopped for more than an hour before passengers in her car were told why the train had stopped suddenly, what had broken the windows and what the proposed recovery plan was.

3.8.25 After the empty train pulled up alongside the disabled train and ramps were placed door to door between the trains, on-board staff positioned themselves beside the ramps to escort passengers across to the waiting train. She said the passenger transfer was carried out in an orderly manner.

4 Analysis

4.1 The overhead failure occurred at an overlap near the start of a steady 7 km long climb to the north portal of Tunnel 2 at Glenside. Because of the gradient, this was where the highest amount of electrical current was drawn when compared with other sections within the WEA. The inspections of the overhead traction system between Kaiwharawhara and Glenside were current. However, it was unlikely that the particular failure could have been identified during any of the standard 3-monthly cab runs or the 6-monthly or annual inspections. By the time the discolouration and arcing damage became obvious, the fault was probably in the late stages of failure with probably only a short time remaining before the catastrophic collapse.

4.2 Although the wear on the contact wire over time represented a 25.4% loss of cross-sectional area, the minimum dimension for wire thickness had not been reached and the strength of the conductor in its hard drawn state would have been adequate had it not been for other factors.

4.3 The copper contact wire failed through tensile overload in material that had been softened through overheating. Overheating had also occurred locally within the clamped stirrup and this had caused almost complete recrystallisation of the contact wire. The material had, in effect, been annealed in parts. Annealing softened the material sufficiently at the location of final fracture to reduce its tensile strength to a value that could not sustain the applied load.

4.4 The 2 contributors to the overheating were:

- increased resistance due to the formation of corrosion products
- severe arcing between the contact wire and the stirrup clamping plates.

4.5 The presence of chloride ions in the corrosion product was not unexpected because the traction overhead system was close to the sea, and salts were present in the atmosphere. The corrosion of copper in marine environments follows parabolic kinetics, where the average metal loss is proportional to $t^{2/3}$, where t is time. A mix of semi-conducting copper oxides and basic copper chlorides had formed over time in the crevice between the contact wire and the clamping plates, leading to an increase in contact resistance and subsequent local heating. The design average thickness loss of copper from undisturbed exposure to a marine atmosphere during 20 years was calculated to be in the order of 0.018 mm.

4.6 The thickness of the corrosion and copper layer on the surface in the central waisted part of the contact wire far exceeded the expected corrosion thickness under normal conditions. Therefore, additional factors had influenced the build-up of the corroded surface. These factors probably included:

- break-away of the surface corrosion product, exposing new un-corroded material. This may have occurred as a result of relative movement between the conductor and the clamps
- arcing, exposing new material, creating new crevices and trapping bubbles of air and/or gas or vapour
- retention of moisture in crevices
- raised temperatures leading to higher corrosion rates.

4.7 Corrosion had occurred on the leaded bronze clamping plates, mostly at the jaws. The intergranular corrosion seen in the region of contact with the contact wire was typical of stress corrosion cracking and there was evidence on the surface of material having been lost. In this region, corrosion was significantly modified by the effect of arcing. The thickness of the observed corrosion products was about 0.3 mm. This figure far exceeded that of published data on corrosion rates under normal environmental conditions. Therefore, it was likely that overheating occurred as a result of the build-up of corrosion products and this may have significantly contributed to the occurrence of stress corrosion cracking within the clamps.

4.8 Arcing would have created crevices and trapped moisture, causing corrosion and increasingly poor clamping and contact on the contact wire. The intergranular corrosion was severe enough to promote loss of material from the surface of the jaws. This degredation mechanism may have become a cycle in which the build-up of corrosion products became a consequence of, as well as a contributor to, arcing.

4.9 The temperature developed in arcing may have melted some copper chloride (melting temperature 620ºC) present in the clamped area and perhaps vaporised the compound. Therefore, some of the evidence of corrosion may have been lost in this way.

4.10 Because there was current flowing through the stirrup, it was possible for a voltage potential difference to exist between the 2 contact wires at an overlap structure and for arcing to occur.

4.11 Arcing caused significant melting and holes in the bronze jaws of both sets of clamping plates, and possible indications of superficial melting on a part of contact wire sample B. The bronze alloy would have melted at temperatures in excess of 800ºC. The contact wire would have melted at about 1083ºC. These temperatures are more than sufficient to have caused recrystallisation and grain growth for the copper conductor.

4.12 The annealing temperature for ETP copper was reported as between 260ºC and 649ºC, depending on the amount of cold work applied during drawing. Hard drawn wire is drawn down by about 60% in cross-section area to develop the "hard" temper condition and has a tensile strength of about 345 megapascals (MPa). Over a short period of between 10 and 60 seconds, the temperature required to anneal material that had been reduced in area by 60% ranged from 260ºC to 204ºC respectively. This indicated that annealing could occur over a very short time period and at a low temperature.

4.13 While the time period of arcing was short, the temperatures required for arcing greatly exceeded those required for annealing. Other regions of the contact wire exhibited grain growth that indicated that, in some places, higher temperatures were reached than were required just to cause recrystallisation. It was therefore likely that the temperature in the copper exceeded 260ºC.

4.14 The cross-section where grain growth was present also indicated that overheating was localised, even across the contact wire's section, and that the bulk of the underlying material was not severely degraded. Failure had not occurred across this section. While the region of failure in Sample A did not exhibit significant grain growth, more material across that section was probably softened than had been softened elsewhere along the conductor. Therefore, the bulk strength was lower in this region than that which exhibited grain growth.

4.15 Hardness values showed significantly softer material was present at the fracture. The hardness values of the region relatively unaffected by heat were consistent with those of hard drawn copper, with a tensile strength of about 406 to 427 MPa, while those at the fracture were consistent with annealed material with a tensile strength of about 252 to 255 MPa.

4.16 After the incident, on-board staff ensured the safety of the passengers by keeping them on the train until the recovery plan was implemented. With youths making up the majority of passengers, it was understandable that some frustrations were directed at staff because of the lack of information made available to them while they were kept on the train for about 100 minutes with emergency lighting only and no toilet facilities.

5 Findings

Findings are in order of development and not in order of priority.

5.1 The traction overhead contact wire failed due to tensile overload brought about by softening due to overheating.

5.2 The tensile strength in the fracture zone was about 250 MPa compared with about 420 MPa in the region unaffected by heat.

5.3 The major contributor to the overheating was a combination of the formation of corrosion products and severe arcing between the contact wire and the clamping plates of the stirrup for the overlap.

5.4 The observed corrosion depth of 0.33 mm on the contact wire far exceeded the design average of 0.018 mm, resulting from undisturbed exposure to a marine environment for 20 years.

5.5 The temperature in the copper contact wire at the fracture zone had exceeded 260ºC.

5.6 The profile of the failed contact wire was within Code limits.

5.7 The inspection regime for the overhead system in the area where the failure occurred was current.

5.8 The actions of the locomotive engineer did not contribute to the dewirement.

5.9 On-board staff ensured the passengers were not exposed to unknown hazards by keeping them on the disabled train until it was safe for them to detrain.

5.10 The transfer of passengers from the disabled train was carried out safely and in an orderly manner.

Occurrence 05-104

6 Factual Information

6.1 Narrative

6.1.1 On Monday 24 January 2005, Train 3639 was the scheduled 1230 Tranz Metro EMU passenger service from Upper Hutt to Wellington. The 8-car train was made up of four 2-car sets consisting of a powered EM passenger car and a non-powered ET passenger car. The train was crewed by a locomotive engineer multiple unit (LEMU), a train manager and 2 passenger operators, although one was unwell when outward Train 3638 departed Wellington at 1135.

6.1.2 Train 3639 departed Upper Hutt on schedule at 1230, but because of the high number of passengers waiting at stations en route the train departed Petone at 1310, some 7 minutes behind schedule. The rear 2 cars were locked off and all passengers were confined to the front 6 passenger cars. Most of the passengers were attending an event at Wellington Stadium scheduled to start at 1400.

6.1.3 The LEMU said the train was not exceeding the 40 km/h temporary speed restriction when approaching the down intermediate signal for Ngauranga. Near the end of the restriction he saw, about 80 m ahead, a section of the overhead contact wire hanging down about 2 m. He activated the pantograph lower button, and quickly made a slight airbrake application.

6.1.4 When the train stopped, the hanging contact wire with stirrup attached was in contact with the fourth passenger car. The LEMU contacted train control to advise of the situation and that the train was disabled at 6.73 km.

6.1.5 The LEMU said that traction staff arrived on site about 15 minutes after the incident, and within 25 minutes the overhead had been isolated.

6.1.6 At about 1430, relief locomotives pulled the disabled train into Wellington.

6.1.7 A traction lineman completed a spliced connection and power was restored at about 1655. Normal services resumed on the Up Main line at 1710, and the first down train departed Ngauranga at 1730.

6.2 Inspection of the overhead contact wire

6.2.1 The last detailed 6-yearly maintenance inspection through the section where the failure occurred was carried out in March 2004. The close-up inspection was carried out from an elevated platform on the back of a Hi-Rail vehicle.

6.2.2 The faults found during the inspection included such things as rusty pins and steady wires, and worn arms. Repairs were carried out soon after the inspection.

6.3 Examination of failed components

6.3.1 The overhead contact wire failed at 6.73 km on the Down Main line at a stirrup for an overlap. Because the location and nature of the failure were identical to those described in Occurrence04-132, no detailed examination of the failed components was undertaken. The analysis and findings described in Occurrence 04-132 are also applicable to this incident.

6.4 Personnel

The locomotive engineer multiple unit

6.4.1 The LEMU of Train 3639 had worked in the rail industry for 9 years and had been driving EMUs for about a year. His certification was current.

6.4.2 After advising train control of the train's location, the LEMU went through the train and advised passengers of what had caused the power failure. He said that there were many people standing in the front 6 cars. Initially, he was unsure why the rear 2 cars were locked and had no passengers.

6.4.3 While walking through the train, he noticed that a door from the luggage compartment on the fifth car was open. He looked out and saw that the train manager and one of the passenger operators had alighted and were near the front of the train. He secured the door before returning to the driver compartment. On arrival, he instructed the train manager and passenger operator to stay clear of the train until the overhead had been isolated.

6.4.4 The Tranz Metro customer service manager arrived on site shortly afterwards and advised the LEMU of the recovery plan. The LEMU went back through the train and gave passengers an estimated time of arrival at Wellington Station.

6.4.5 On returning to the driver compartment, he saw that the door light on his panel had gone out, indicating that someone was trying to open, or had opened, one of the doors. He walked through the train for a third time telling people, particularly those in the door wells, to stay on the train and not to try to open the doors because the overhead was still being treated as live.

The train manager

6.4.6 The train manager on Train 3639 had held his certification for about 30 months.

6.4.7 The train manager said that although one of the passenger operators was unwell and had complained of having food poisoning, there were no suitably qualified personnel available to replace him before Train 3638 departed from Wellington. The unwell passenger operator could not carry out his normal duties, so the train manager decided to isolate the doors on the rear 2 passenger cars before Train 3639 departed Upper Hutt and returned to Wellington.

6.4.8 The train manager said that he was probably in the fifth or sixth car when the train departed Petone. He had checked passengers' tickets in cars 6 and 5 and had just met one of the passenger operators in the luggage compartment of car 5 when the train slowed and then stopped.

6.4.9 The passenger operator opened the door of the luggage compartment and saw that the overhead was down and resting on car 4. The train manager said that because there were so many people standing in the aisles it would have been difficult to get through to the driver to find out what was happening, so they decided to jump clear of the train without being in contact with both the coach and the ground simultaneously.

6.4.10 He stayed clear of the train until the overhead was isolated and he had received assurance from a traction lineman that it was safe to climb back on board the train. When he was back on the train he opened the central doors at the rear of car 6 that allowed passengers to spread out into cars 7 and 8.

7 Analysis

7.1 The failure mechanism for the traction overhead contact wire in this incident was identical to that identified in Occurrence 04-132, and no further analysis is required.

7.2 The health of one of the 2 passenger operators rostered for Train 3639 may have been satisfactory when he started work. However, by the time Train 3638 departed from Wellington his condition had deteriorated to such an extent that he was unable to carry out his duties. Procedures for this situation existed, and staff should be aware of their responsibilities to stand themselves down, as soon as it is safe and prudent to do so, if they become unwell for any reason.

7.3 With no relief staff available at Wellington, the train manager probably hoped that the health of the passenger operator would improve before the train started its return journey from Upper Hutt. However, it may have been prudent for the passenger operator to have stood himself down or the train manager to have stood him down before the train departed from Wellington. Had either done so there may have been an opportunity to allocate another passenger operator to join the train at Upper Hutt for the return journey that was expected to have a high passenger loading.

7.4 Having recognised that the health of the passenger operator had not improved before Train 3639 was ready to depart Upper Hutt, and having been advised that there were no relief staff available at short notice at Upper Hutt, the train manager probably thought that by closing off 2 of the 8 passenger cars he and the other passenger operator could better manage the expected number of passengers. However, the subsequent crowding of the 6 cars, each with an average of 100 passengers, probably led him to take the decision to exit the train to make contact with the LEMU more quickly. Despite the number of passengers in the cars, it would have been more prudent for the train manager to stay on board, in accordance with procedures. Had he walked through the passenger cars, he would have met the LEMU coming from the opposite direction. He could also have taken the opportunity to reassure the passengers and instruct them to stay on board the train.

7.5 The train manager's prime responsibility was the safety of the passengers. In the event of an emergency that could lead to an evacuation, the LEMU and train manager were required to confer as to the best method to be used and the LEMU was required to ensure that the overhead traction system was safe or isolated before authorising such evacuation.

7.6 The decision by the train manager and a passenger operator to exit the train from the luggage compartment door of the fifth passenger car, before they received confirmation that the overhead power was isolated, put their personal safety at risk. Once they had exited the train, the passengers were left under the supervision of the LEMU and a passenger operator who was not well enough to carry out his duties. A safety recommendation to address this issue has been made to the Chief Executive of Toll NZ Consolidated.

7.7 By leaving the luggage compartment doors open, there was an opportunity for passengers to follow the train manager's example and put their own safety at risk. The passengers probably would not have known to jump clear of the train and not be in contact with the ground and the disabled train simultaneously. Fortunately, that risk was eliminated when the LEMU locked the doors in the luggage compartment after walking through the crowded passenger cars looking for the train manager.

8 Findings

Findings are listed in order of development and not in order of priority.

8.1 The traction overhead contact wire failed due to tensile overload brought about by softening due to overheating.

8.2 The major contributor to the overheating was a combination of the formation of corrosion products and severe arcing between the contact wire and the stirrup clamping plates.

8.3 The temperature in the conductor had exceeded 260ºC.

8.4 The wear limits on the failed copper conductor had not been exceeded.

8.5 The inspections of the overhead traction system between Ngauranga and Petone were current when the failure occurred.

8.6 The actions of the LEMU did not contribute to the failure of the contact wire.

8.7 One of the passenger operators on Train 3639 was not well enough to carry out his duties, leaving one train manager and one passenger operator to check tickets and care for the safety of nearly 600 passengers.

8.8 The train manager and passenger operator alighted the train after the train became disabled and before they received confirmation that the overhead power was isolated.

9 Safety Actions

9.1 On 18 November 2005, ONTRACK stated in part:

> A trial of infrared imaging was carried out as a possible method of early failure detection. The trial was not entirely successful and will need further refinement.
>
> A video run of all lines [in the WEA] was completed in May 2005. The run highlighted areas requiring attention. Areas with excessive stagger have been rectified.
>
> A check of the tensioning of the contact wire and catenary has been carried out. Retensioning of critical areas was underway.

10 Safety Recommendations

10.1 On 11 May 2006 it was recommended to the Chief Executive of ONTRACK that he:

> inspect all stirrup connections at regular intervals and replace components that exhibit excess corrosion. (021/06)

10.2 On 25 May 2006, the Chief Executive of ONTRACK replied:

> All stirrup connections were reviewed within 2 weeks of the incident and all those exhibiting excess corrosion were replaced.
>
> Stirrups and other overlap/turnout components are now being inspected at more frequent intervals.

10.3 On 11 May 2006 it was recommended to the Chief Executive of Toll NZ Consolidated Limited that he:

> reinforce with operating staff the need to remain on the train in situations that could put their own and the lives of passengers at risk. (022/06)

10.4 On 15 May 2006, the Chief Executive of Toll NZ Consolidated Limited replied in part:

> Toll NZ is presently reviewing procedures for operating personnel involved in incidents involving traction overhead failures. This review and associated staff briefings will be completed by 30 September 2006.

Approved on 18 May 2006 for publication

Hon W P Jeffries
Chief Commissioner

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