



Office of the Chief Investigator
Transport and Marine Safety Investigations

**Rail Investigation
Report No 2009/03**

Fire on Tram
W Class Tram 946
La Trobe Street
15 January 2009



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THE CHIEF INVESTIGATOR

The Chief Investigator, Transport and Marine Safety Investigations is a statutory position established on 1 August 2006 under Part V of the *Transport Act 1983*.

The objective of the position is to improve public transport and marine safety by independently investigating public transport and marine safety matters.

The primary focus of an investigation is to determine what factors caused the incident, rather than apportion blame for the incident, and to identify issues that may require review, monitoring or further consideration. In conducting investigations, the Chief Investigator will apply the principles of 'just culture' and use a methodology based on systemic investigation models.

The Chief Investigator is required to report the results of investigations to the Minister for Public Transport and/or the Minister for Roads and Ports. However, before submitting the results of an investigation to the Minister, the Chief Investigator must consult in accordance with section 85A of the *Transport Act 1983*.

The Chief Investigator is not subject to the direction or control of the Minister(s) in performing or exercising his or her functions or powers, but the Minister may direct the Chief Investigator to investigate a public transport safety matter or a marine safety matter.

EXECUTIVE SUMMARY

On 15 January 2009, at about 1633, Tram 946 departed the Southbank Tram Depot and travelled along Normanby Street to Melbourne city. At about 1700, just after crossing the La Trobe Street - Spencer Street intersection, a fire broke out in the under-floor motor area of the tram. The driver stopped the tram and the six passengers on board disembarked.

No passengers were injured in the incident. The tram driver suffered from smoke inhalation during his attempt to extinguish the fire.

The tram sustained damage to its No.1 and No.3 traction motors, undercarriage components, electrical cabling and the pantograph. The paint work on the left side of the tram exterior also sustained fire damage. The overhead cable melted and parted due to overheating.

The investigation found that there was an insulation failure that resulted in a short circuit of the field windings of No.1 traction motor. The short circuit caused an abnormally high current flow that resulted in overheating of the electrical components in the system.

The investigation found that tram electrical components were not maintained to a satisfactory standard or maintained to the manufacturer's specification which led to the mechanical failure of components. The investigation also noted that the 'off vehicle' overhaul frequencies for electrical components were excessive.

It was found that the electrical current tripping threshold of the substation circuit breaker has been increased and as a result Tram 946 was not protected for over-current which contributed significantly to the escalation of the incident.

The investigation recommends that Yarra Trams reviews the maintenance standards and maintenance frequencies for electrical components in their evaluation of the tram maintenance program. The investigation also recommends that Yarra Trams ensures that tram drivers undergo basic fire fighting training.

CIRCUMSTANCES

1.1 The incident

On 15 January 2009, Tram 946 was operating Route 30 service from the Harbour Esplanade, Docklands to Brunswick Street and was being driven from the No.2 driving position.

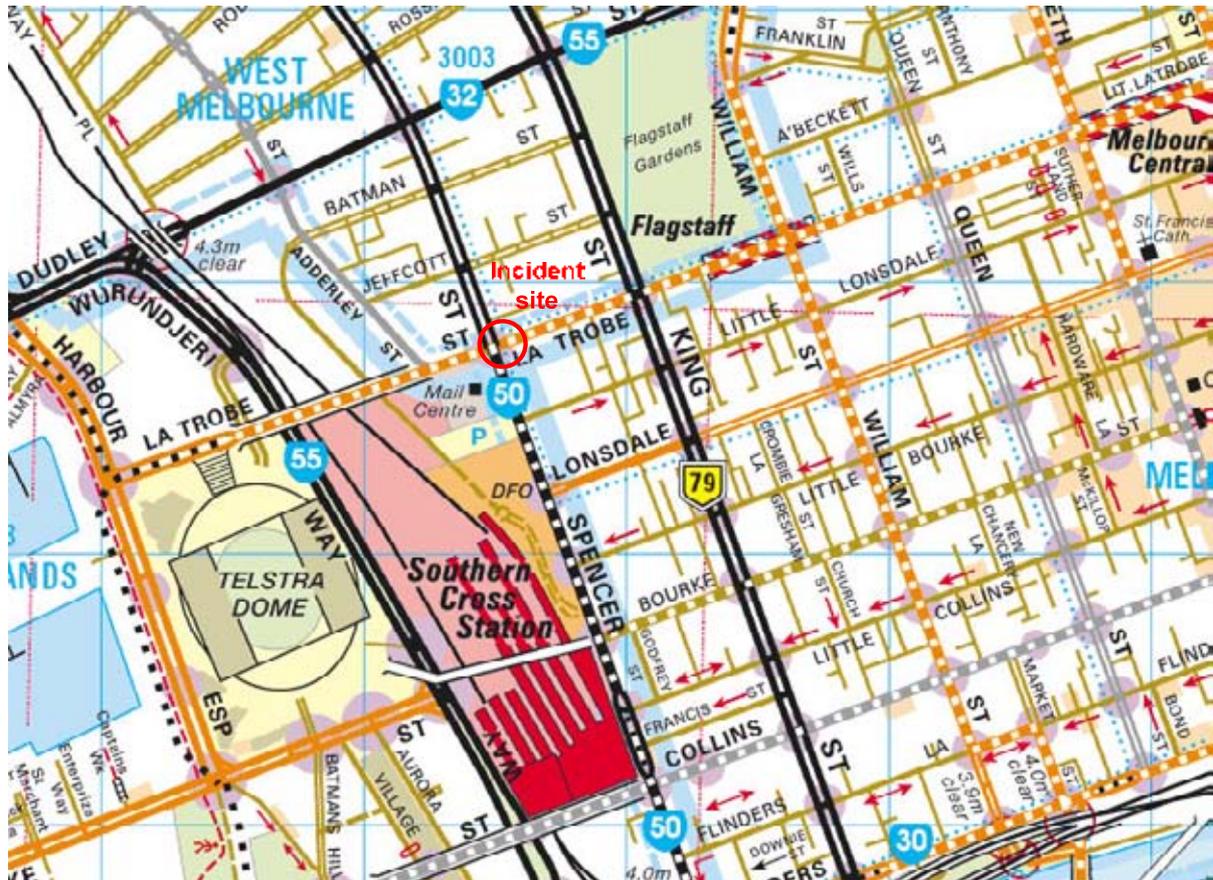


Figure 1 - Location of incident

At about 1700, the tram was travelling towards the CBD on La Trobe Street and had just crossed the La Trobe Street - Spencer Street intersection when a passenger informed the driver that smoke was emanating from the tram. The driver stopped the tram and the six passengers on board disembarked.

The driver then lowered the pantograph and advised Yarra Trams FOC (Fleet Operations Control) of the incident. He then observed sparking on top of the tram and found that the overhead cable was sagging. In order to prevent it from contacting pedestrians he raised the pantograph, in turn raising the cable.

He then noticed that No.1 traction motor was on fire and he attempted to extinguish the fire with the on-board fire extinguisher. When the Yarra Trams FOC foreman arrived at the scene he requested the Overhead Power Control Centre (Carlton Control) to electrically isolate the overhead cable.



Figure 2 - Tram 946 fire (Photo: Courtesy Fairfax photos)

The traction motor fire was subsequently extinguished by the Metropolitan Fire Brigade.

1.2 Consequences

No passengers were injured in the incident. The tram driver was affected by the smoke during his attempt to extinguish the fire and was taken to St Vincent hospital and treated for smoke inhalation.

1.2.1 Damage

No.1 and No.3 motors sustained fire damage to armature coils, commutators, field coils and insulation. The structural components of the undercarriage of the tram and electrical cabling also sustained fire damage. The paint-work on the left side of the tram exterior sustained fire damage. The Line Breaker over current coil and the shunt strap overheated and sustained damage due to excessive short circuit current flow. The pantograph sustained damage due to arcing. The overhead cable melted due to local overheating and parted.

2. FACTUAL INFORMATION

2.1 Electrical power supply

2.1.1 Substation supply

The 22,000 volt alternating current (AC) supply from the main transmission lines is transformed and rectified at the substations to generate a line Voltage of 600 volts direct current (DC) to the tram traction system. Substation systems incorporate devices such as feeder circuit breakers to protect the overhead cables and the tram traction system.

The original setting for the feeder circuit breakers was approximately 1,500 Amps. However due to the addition of newer trams to the Melbourne's tram fleet that require significantly higher power, the tripping settings of the circuit breakers have been increased to approximately 3100 Amps.

2.1.2 Overhead cable – La Trobe Street

The Latrobe Street overhead cable was renewed in April 1994. Typically a new cable is approximately 13.5 millimetres in diameter and is replaced when it wears down to eight millimetres. The overhead cable at the incident site was observed to have suffered overheating in tension, melted and parted. The overhead cable diameter before the point of failure was approximately 13 millimetres and was in good condition with minimal wear. Signs of overheating and melting were also observed approximately 100 millimetres from the point of failure (Figure 3). This area is the location of contact with the second carbon strip of the pantograph.

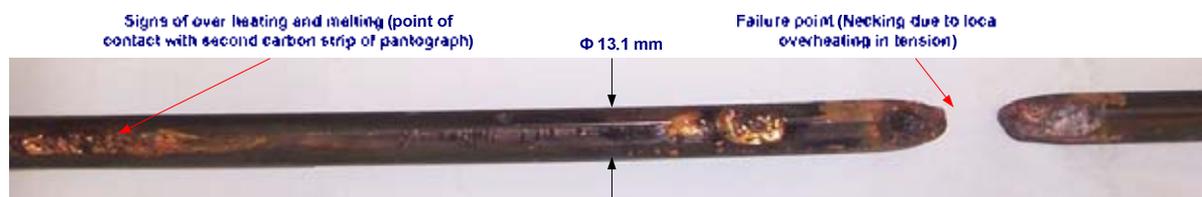


Figure 3 - Damaged overhead cable

2.1.3 Pantograph

The 'current collection system' of Tram 946 consisted of a pantograph model SBE 992 manufactured by Schunk Bahntechnik GmbH (Figure 4). It is of the single-arm design with an electrically insulated drive motor integrated into the base frame of the pantograph. The motor is driven by a 24 volt battery supply and is utilised to raise or lower the pantograph from the drivers console in the tram. The pantograph is designed to handle a nominal current of 1,000 Amps and a peak current of 1,800 Amps. The pantograph can be manually raised or lowered by the use of a crank handle.

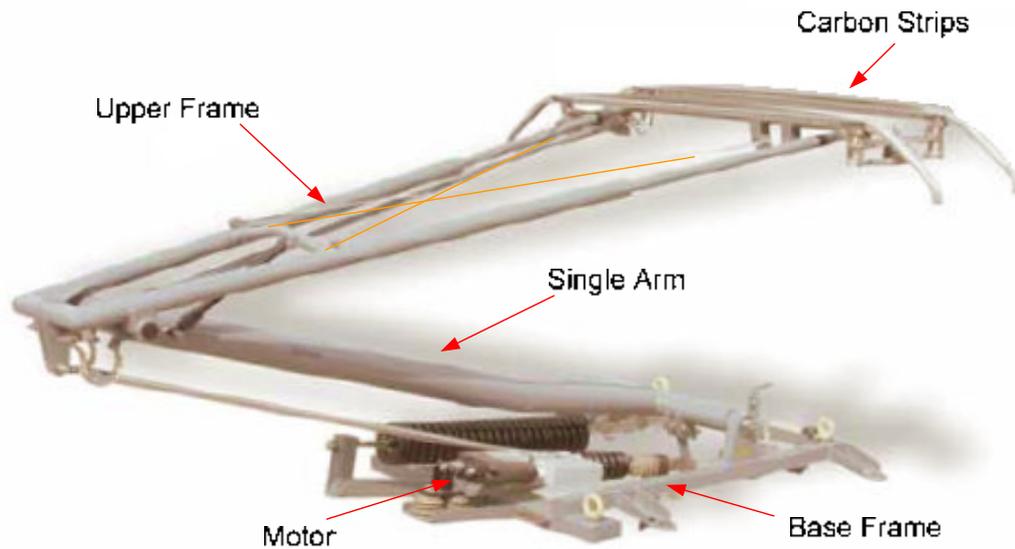


Figure 4 – Type of Pantograph on Tram 946



Figure 5 – Damage to pantograph caused by arcing

The pantograph frame sustained heat damage due to 'arcing'¹ as a result of the contact with the overhead cable (Figure 5).

The carbon collector strips on the pan head overheated and suffered 'corking'² due to heat generated by the extremely high current flow (Figure 6).

¹ Short circuits lead to electric arcing. Surface erosion and melting of material is a sign of electric arc damage.

² Overheating and burning of carbon.

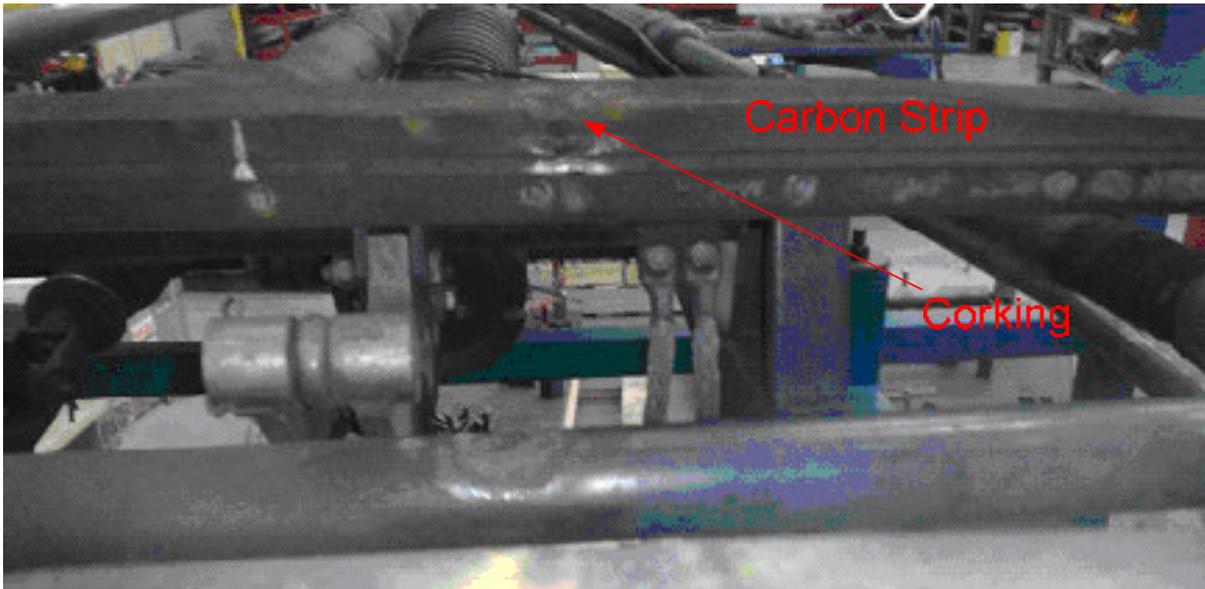


Figure 6 – Corking of carbon strip of pantograph due to arcing

2.2 Tram 946

The W class tram chassis and running gear was built by the Melbourne Metropolitan Tramways Board (MMTB) and the body was built by Ansair Corporation. Much of the body cladding and superstructure frame is of timber construction. The tram is approximately 14 metres long, has a tare weight of 18.4 tonnes and a maximum service speed of 35 km/h. The vehicle has a seating capacity for 46 passengers.

Tram 946 is a SW6 class tram with sliding doors and is a variant of the W class. Tram 946 was commissioned on 19 October 1949. It has four GE (General Electric) traction motors each of 30 kW rating. The electrical control system is an MMTB RC2 system.

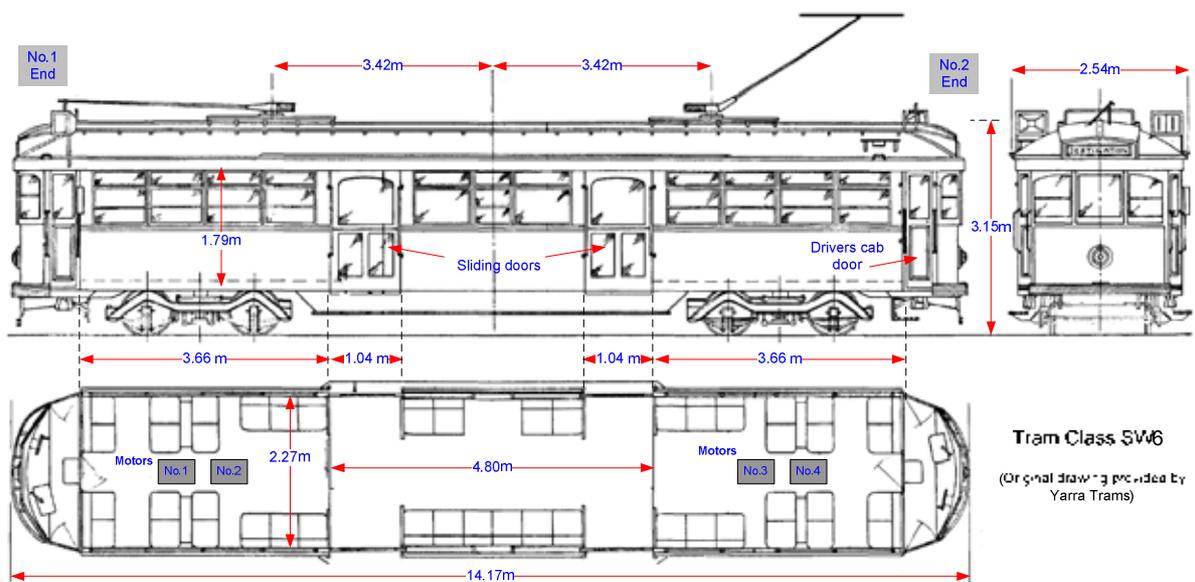


Figure 7 – Tram SW6 Class

Driver's cabins are located at the forward position of each end of the tram. The cabin is full width at the back and tapers forward to form a crescent incorporating two side doors with windows, forward and side windscreens. The driver's seat consists of a folding bench attached to the rear cabin wall placing the driver in a relatively erect position with a good forward view. The rear wall of the driver cabin has four windows and a door with a window providing a good rear view of the passenger cabin.

In 1995 PTC (Public Transport Corporation) commissioned a contractor to modify the W class tram control systems to enable single person operation and improve operational safety.

The W class tram was taken out of service in June 2000 due to a series of braking failures that resulted in accidents. The Safety and Technical Services Branch of the former DOI (Department of Infrastructure) identified various problems that could result in partial or complete loss of pneumatic brakes.

It was also identified that the two back up braking systems, the emergency power cut-off to the traction motors and the mechanical handbrake, were not adequate in emergency situations. The W class trams were returned to service in April 2001, after the installation of a new electro-magnetic braking system.

2.3 Traction system

The traction system on the W class trams was designed over 70 years ago. The modifications carried out to the control systems of the W class trams in 1995 did not include any modifications to the traction circuit.

As shown in the electrical schematic in Appendix A and Figure 8, when the pantograph of the tram is in contact with the overhead cable, the current flows to Circuit Breakers (CB1 & CB2) through a Knife Switch (KS) in the driver's cabin to the Line Breaker (LB). The line voltage is approximately 600 volts DC.

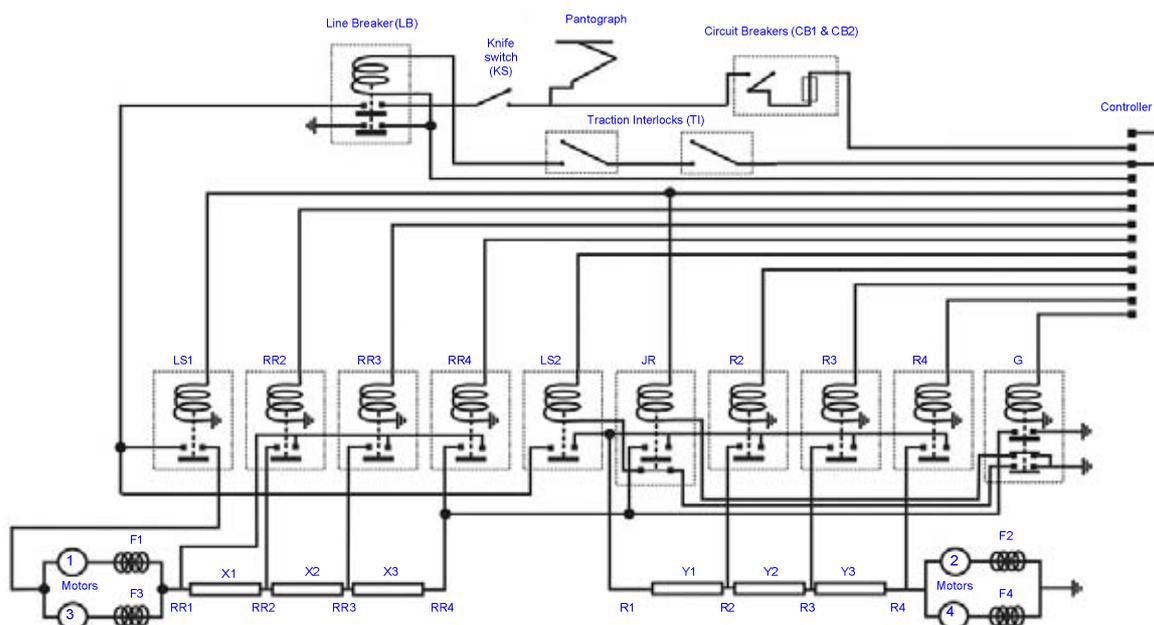


Figure 8 – Traction system circuit diagram

Figure 9 shows motors No.1 and No.3 (Motor group M1) permanently connected in parallel and motors No.2 and No.4 (Motor group M2) connected in parallel. Motor groups M1 and M2 can be configured to operate in series or in parallel by opening or closing Grouping Contactors LS1 and LS2.

When the controller is operated the Line Breaker operating coil is energised and the Line Breaker is closed, supplying current to the Grouping Contactors (LS1 & LS2) and the Step-Up Contactors. The traction interlocks (TI) prevents the Line Breaker from closing, until all the doors are in the closed position, brake air pressure is at least 40 psi and the safety pedal is engaged by the driver.

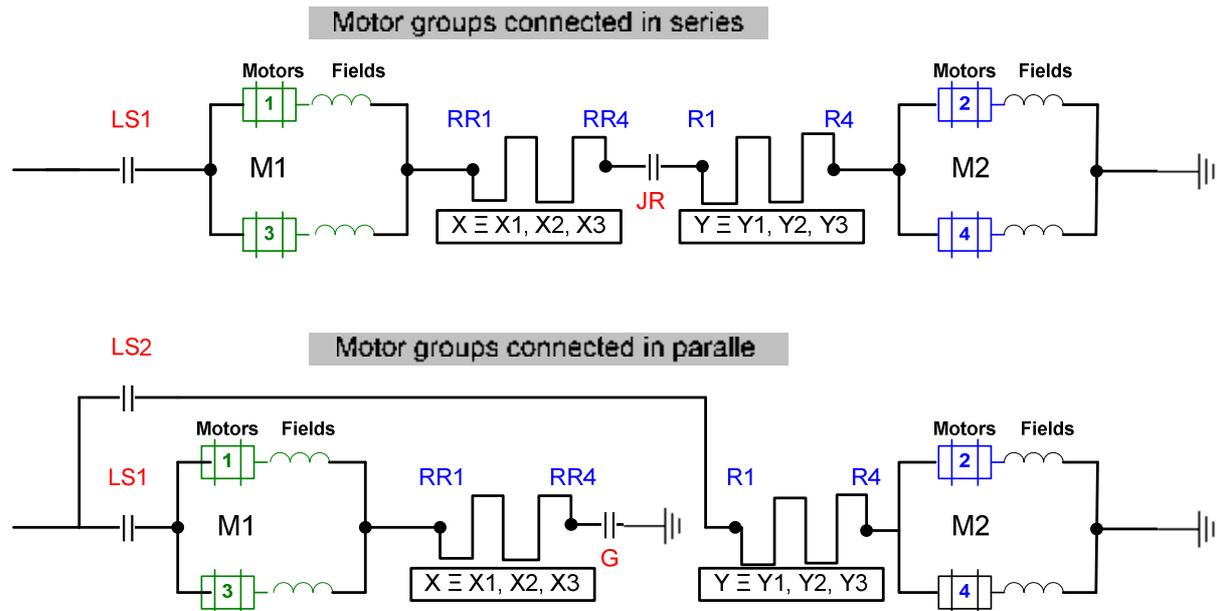


Figure 9 – Motor groups connected in series and parallel

A speed controller is located in both No.1 and No.2 drive positions. The controller can only be operated when the 'key' is placed in the 'key lock' and in the forward or reverse position (Figure 10). The Line Breaker and the step-up contactors are engaged by the tram driver operating the controller. As each step up contactor is engaged the corresponding resistor (X1, X2, X3, Y1, Y2 & Y3) is by-passed increasing the current to the traction motors and in turn increasing the power output from the motors.

Once all the resistors have dropped out in the series configuration of the motor groups, the maximum current in this configuration is reached. In order to further increase the current to the motors the controller is moved to the next notch where the motor groups M1 and M2 are connected in parallel by opening contactor JR, closing LS1 and LS2 grouping contactors and closing the Ground contactor (G). Once again the controller is rotated in the clockwise direction, engaging more step-up contactors which in turn drop out the resistors increasing the current to the traction motors.

In the parallel configuration, the resistors are divided into two sections (X and Y sections), one for each motor group (Figure 8 and 9). By connecting the motor groups M1 and M2 in parallel a 600 volt DC supply is individually provided to each motor group. Once all the resistors have dropped out in the parallel configuration the maximum current is reached and the traction motors develop the maximum power and in turn maximum speed.

Any anticlockwise movement of the controller handle opens the ratchet switch and interrupts the current supply to the Line Breaker and all the Contactors. The controller handle then has to be returned to the stop position and engaged again if power is required.



Figure 10 – Traction system controller

2.3.1 Traction motors



Figure 11 – Traction motor damage

The traction motors on W Class Tram 946 are series-wound DC motors, operating on approximately 600 volts. Each tram has four traction motors which are mounted in groups of two on either end of the tram and are suspended between the bogie frame and the driven axle. No.1 and No.3 motors sustained fire damage to armature coils, commutators, field coils and insulation.

2.3.2 Line Breaker

The Line Breaker consists of the operating coil that closes the main contacts, a holding coil that keeps the contacts in the closed position and an over-current coil that interrupts the current to the operating coil when the tripping current is exceeded. Under normal operating conditions the Line Breaker over-current trip is set at 400 Amps.

Post incident inspection of the Line Breaker revealed that the moving contacts were seized in the closed position. The contacts were seized due to friction between the moving contact arm spindle and the bronze bush as a result of corrosion. The current shunt strap was detached from the moving contact and the tension in the moving contact spring was weak.

The seized contacts were prised open and the clearance between the contacts was measured to be 22 millimetres. The specified gap for this type of Line Breaker is 16 millimetres (Figure 12).

The spring clips on the cover of the Line Breaker were slack, hence the cover did not firmly close and the cover was also cracked, exposing the components to moisture and debris from the road and rails.

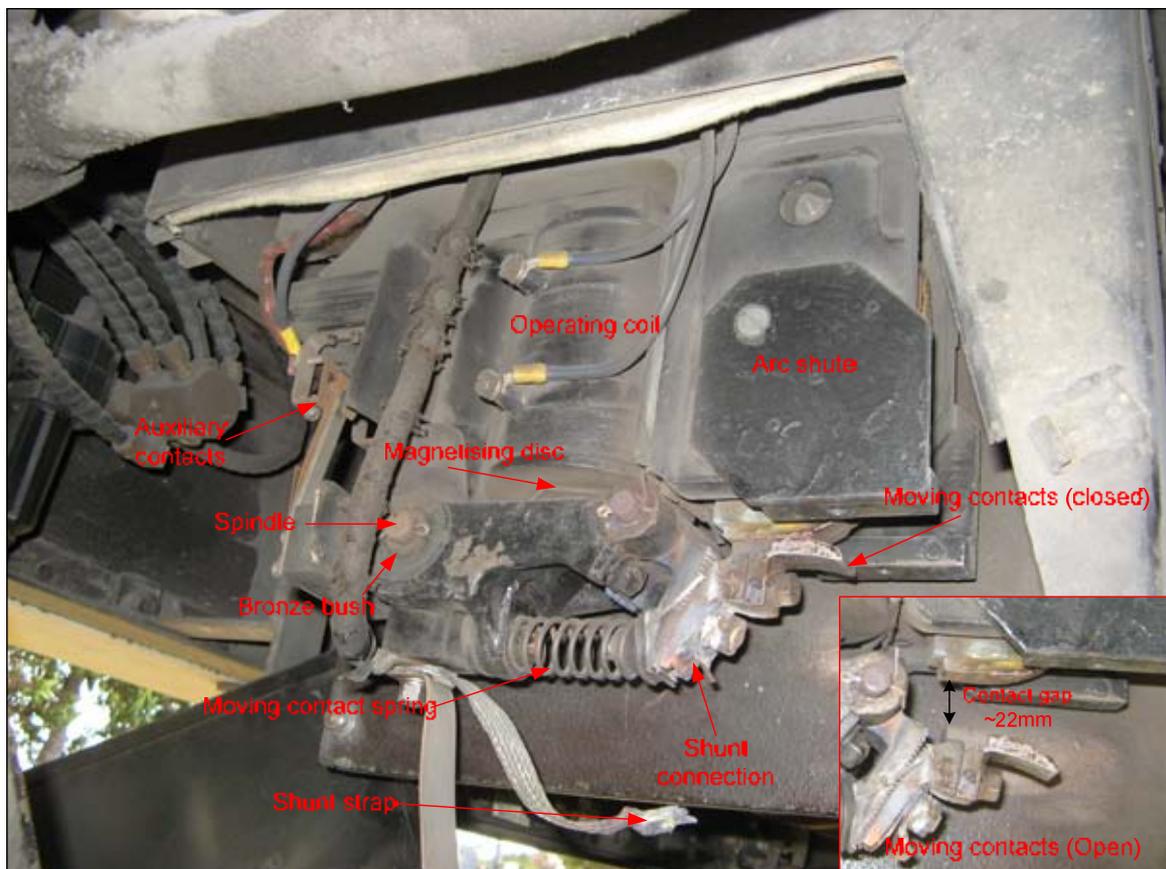


Figure 12 – Line Breaker

2.3.3 Grouping contactor – LS1

The grouping contactor LS1 contacts stay closed during ‘series’ and ‘parallel’ operation of the motor banks M1 and M2. Post incident inspection of this grouping contactor revealed that the moving contacts were welded in the closed position. The insulation post was also found to have suffered overheating damage (Figure 12).

2.3.4 Contactor wiping action

When contactors close in a high current circuit, arcing occurs, resulting in high temperatures and welded contacts. Electrical contactors incorporate a contact wiping device that causes a shearing motion to break welds and clear oxidation or contaminants between a set of contacts. A spring loaded toggle lever actuator engages and directly bears upon the movable contactor to rock the contactor on the actuator support. After initial contact is made a lost motion connection between the actuator and contactor support imparts a rocking action to the contactor to shear and break any welds between the fixed contact and moving contact. The spring is an integral component in this mechanism and the spring tension is critical for its correct operation.

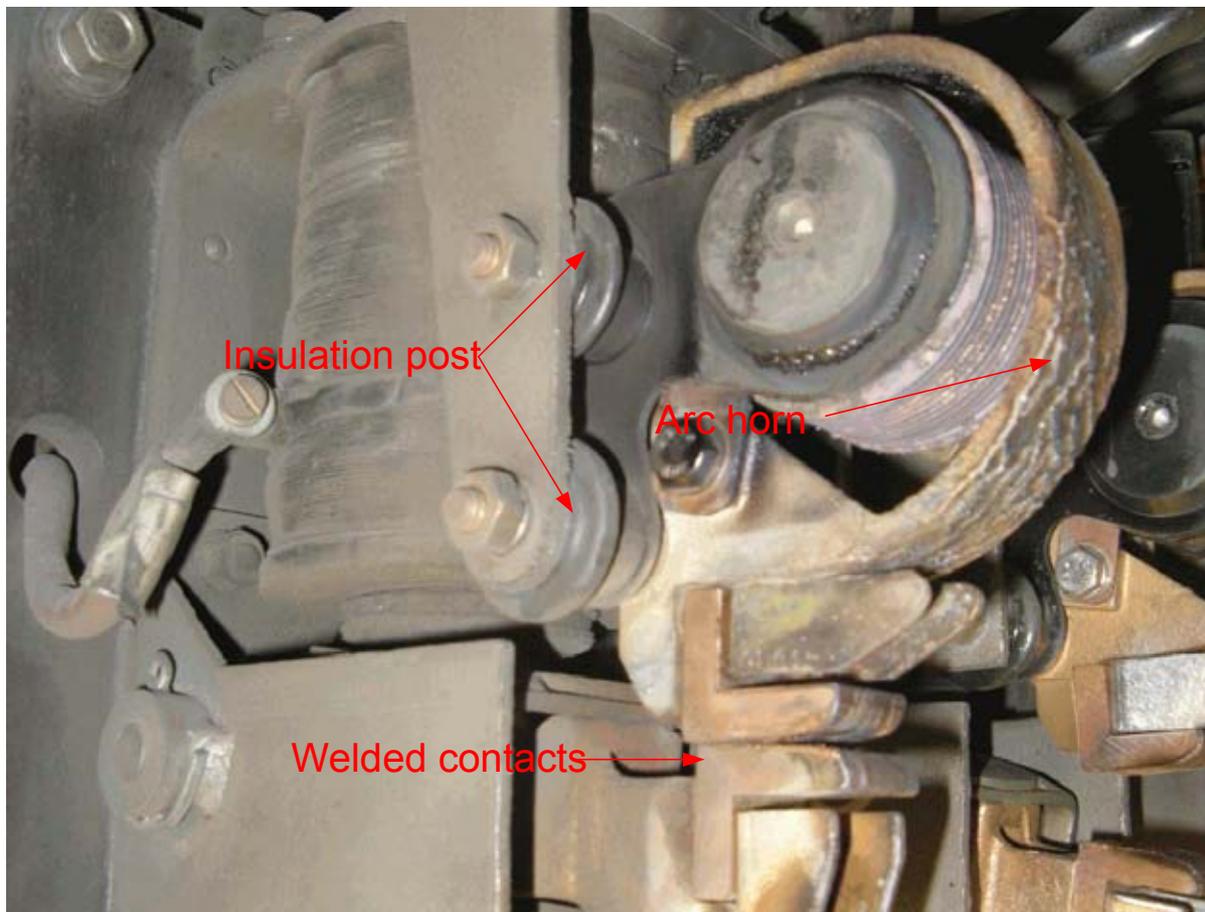


Figure 13 – Grouping contactor LS1

2.4 Maintenance

A ‘Technical Maintenance Plan’ (TMP) details the maintenance requirements for W class trams. The plan specifies the maintenance frequencies and the service activity required.

As per the TMP the traction motor armature and field windings are required to be inspected at 1,400 kilometres, the brush assembly to be inspected and cleaned at 20,000 kilometres and the motor overhauled at 500,000 kilometres.

The TMP requires that the Line Breaker is inspected and cleaned at 1,400 kilometres and overhauled at 500,000 kilometres.

Maintenance requirements are specified in numerous service modules (Tram Work Modules) and the equipment is required to be maintained to the specifications noted in these modules.

Yarra Trams advised this investigation that there is a high turnover of tram electrical technicians which has resulted in a reduction of maintenance skills especially with respect to the specialist skills required for the maintenance of W class trams.

2.4.1 Traction motor maintenance

In accordance with the Tram Works Module, the 1,400 kilometre maintenance requirements for the traction motors specify the following:

- Remove all traction motor inspection covers and clean area around commutator, insulators and brush holders.
- Check motor brush condition & measure all brush lengths, record length of the shortest brush and check pigtails.
- Verify surface condition of motor commutators is acceptable.
- Inspect all brush holders, verify that all hammers are seated and refit all brush inspection covers.
- Verify that all earth and traction motor cables are secure and in serviceable condition.

The condemning limit for the brushes is specified as 23 millimetres and the brushes on both No.1 and No.3 motors were well within the minimum requirement. The maintenance module does not specify the requirement for insulation resistance testing (Megger tests), continuity testing of the motor windings or any major service requirements for traction motors.

Yarra trams could not provide the investigation with a record of the last overhaul date or the installation date for either of the damaged traction motors.

2.4.2 Contactors and Line Breaker maintenance

In accordance with the Tram Works Module, the 1,400 kilometres maintenance requirements for the Line Breaker (LB) and Grouping Contactor (LS1) specify the following:

- Remove traction contactor arc chutes, inspect them for damage and clean them.
- Check that contactor wiring is serviceable and terminations are secure.
- Replace any worn contact tips and verify smooth contactor operation by hand.
- Verify correct opening and closing sequence of interlock fingers. Clean the cotton reels.
- Refit all contactor arc chutes. Ensure the armature is free and does not foul the arc chutes.

- Remove and clean Line Breaker cover and check that wiring is serviceable and terminations are secure.
- Replace any worn contact tips and verify smooth Line Breaker operation by hand.
- Verify that all Line Breaker resistors are generally secure and that fasteners hold securely when refitting the cover.

Maintenance records provided by Yarra Trams indicate that the 'Tram Works Module 1,400 kilometre service was carried out on 15 November 2008. Yarra Trams could not provide the investigation with a record of the last overhaul date or the installation date for the Line Breaker or the Traction Contactors.

2.5 Driver – Tram 946

The driver of Tram 946 joined the PTC (Public Transport Corporation) in 1999 and has been in continuous employment as a tram driver with M>Tram and Yarra Trams. He has been trained to drive all the classes of trams and has nine years experience driving W class trams. He has undergone regular Yarra Trams mandated refresher courses and driver assessments.

On the day of the incident he commenced his shift at 1623. At about 1633 he took over Tram 946 from the 'starter' at the Southbank depot and commenced his first trip from the depot to Harbour Esplanade at Docklands.

He advised that it was normal practice for the previous driver of the tram to complete a 'sign off sheet' when handing over the tram to the depot. Any defects experienced by the previous driver are required to be noted on the 'sign off sheet'. He stated that he was not advised of any defects in the tram when he took it over. He said that he spent approximately five minutes on pre-departure tests of the tram and did not find any defects.

The driver stated that he progressed along Clarendon Street onto Spencer Street and then onto La Trobe Street until he reached Harbour Esplanade. At Harbour Esplanade he changed ends to #2 driving position and commenced his trip to Brunswick Street.

He stated that as he was progressing along La Trobe Street and had just crossed the Spencer Street intersection when a passenger shouted to him that the tram was on fire. He said that he looked through the side rear view mirror and noticed a large plume of smoke from the side of tram. He stopped the tram, checked to see if there was any traffic on the road, and let the passengers out. He said that there were about six passengers in the tram at the time of the incident and within 15 to 20 seconds all the passengers had disembarked the tram. The driver was of the opinion that if the tram was carrying a larger number of passengers there was a possibility that the passengers may have suffered from smoke inhalation.

He said that he lowered the pantograph, got off the tram and called Yarra Trams FOC (Fleet Operations Centre) and advised them that the tram was on fire. He stated that he would have taken approximately 20 to 30 seconds to lower the pantograph from the time the tram was stopped. He said that he then noticed that the overhead cable had parted and dropped onto the frame of the pantograph and was 'bouncing around sparking'. He stated that he lifted the pantograph back up to prevent it from coming into contact with pedestrians as it was 'hanging at head high'.

The driver said that he then opened the No.1 motor hatch and attempted to extinguish the fire with the on-board fire extinguisher. He stated that he suffered from mild smoke inhalation during his attempt to put out the fire.

When asked if he had experienced any abnormalities with the tram prior to the incident he said that he had stopped at three tram stops before the intersection and had not experienced any problems with the tram or noticed any smoke. He stated that he missed a 'notch on the controller' a couple of times and had assumed that it was the way he operated the controller or it was a defect in the controller which was a common occurrence in the W class trams. He explained that 'missing a notch' occurred when the controller was moved from one position to another and there was no response. In this situation the controller had to be moved back to the stop position and the acceleration resumed by moving the controller up through the control positions. When asked if the tram was sluggish in its operation he stated that the only time the tram appeared to operate erratically was when he 'missed a notch'.

When asked if there was a procedure in case of a fire, the driver stated that he was not aware of a procedure, but it was standard practice to shut off the power and lower the pantograph after an incident, which is what he did in this case.

He further stated that there was no specific training with respect to fires on board trams or briefings on previous incidents during refresher courses.

2.6 Environment

The closest Bureau of Meteorology observation site is at the corner of Latrobe and Spring Street and is representative of the incident site and surrounding area. At the time of the incident, the day was dry, sunny and clear. The maximum temperature reached at the observation site on the day of the incident was 23.6 °C at about 1600 and was 22.3 °C at the time of the incident.

2.7 Yarra Trams

In April 2004 Yarra Trams acquired responsibility for running the entire Melbourne tram network. The company has eight tram depots, 29 routes, a fleet of nearly 500 trams and about 1,800 staff of which about 1,200 are tram drivers.

Yarra Trams' FOC, located in South Melbourne, controls day-to-day operations, monitoring and communications with trams. Control is achieved through the AVM (Automatic Vehicle Monitoring) system, which enables controllers to pinpoint the location of every tram on the network, receive individual tram scheduling data and provide two-way voice communication between the operations centre and each tram.

2.7.1 General operations, rules and procedures

As part of its safety management system, Yarra Trams has developed and implemented 'Rule book (General Operational Rules and Procedures)'. The Rule book provides guidelines on operational procedures, tram operations, safe interaction with traffic, and interaction with the public and general road rules. New notices and information regarding the operating rules are disseminated to drivers through their depot mail boxes.

Section 102 of the Rule book has a procedure that the drivers are expected to follow in the case of a tram fire. The procedure states "Stop the Tram and ask the passengers to alight. Pull down the trolley pole or lower the pantograph and notify Fleet Operations Centre. On W class trams the handbrake/park brake must be applied. Try to put out the fire using the Fire Extinguisher. Motor hatchways must not be opened unless instructed. DO NOT USE

WATER. The cause of the fire and the part of the Tram affected must be reported to Fleet Operations Centre. Trams must not be moved unless authorised by Fleet Operations Centre. Where practicable, sufficient doors are to be mechanically opened to allow passengers to exit. In all instances where electrical apparatus within the Tram has become exposed, the driver must lower the pantograph or remove the pole from the overhead”.

2.7.2 Driver training

Once qualified to drive trams independently, the driver is subject to six-monthly follow-up assessments, where his/her driving ability and safety adherence is assessed by the senior depot trainer. Drivers are required to undertake a refresher training course every 12 months on tram operations and procedures and general skills on interaction with other traffic and public behaviour.

Yarra Trams also conducts safety workshops at each tram depot, approximately once a year. The workshop is conducted by a senior safety manager and attended by all workers assigned to that depot, other than those on rostered leave and those engaged in driving trams at that time.

When a new model of tram is introduced, the driver is required to undergo ‘conversion training’ involving theory and practical components covering fault finding, cabin layout and controls, and driving/braking on-road test. Yarra Trams has developed a training manual for each model of tram.

Yarra Trams advised the investigation that in the past, specific incidents and accidents were discussed by the safety managers during the refresher training programs. However this practice was discontinued as drivers of trams involved in incidents objected to discussion of incidents that they had been involved in.

2.8 Regulation

2.8.1 Public Transport Safety Victoria (PTSV)

PTSV (Public Transport Safety Victoria) monitors Yarra Trams compliance with the *Rail Safety Act 2006* and the Rail Safety Regulations 2006. Part 9 of Schedule 2 of the regulations requires rail safety operators to have in their Safety Management System ‘processes to ensure, so far as reasonably practicable, that corrective action is taken in response to any safety risks identified following inspections, testing, internal audits, investigations and reporting of hazards or incidents undertaken by the rail operator’. PTSV monitors Yarra Trams compliance with Part 9.

2.9 Tram fire incident history

Incident records provided to the investigation by PTSV indicate that there were a total of eight fires on trams from 2004 to 18 March 2009. Five of these fires were on W class trams including this incident. The reasons for the above fires include motor insulation failure, failure of Line Breakers, Grouping Contactors and Step up Contactors.

3. ANALYSIS

3.1 The incident

It is most probable that the No.1 traction motor field insulation failure resulted in the initial short circuit in the system. The short circuit caused an abnormally high current to pass through No.1 traction motor, Line Breaker (LB), Grouping Contactor (LS1) and No.3 Traction Motor. The Line Breaker is the primary over-current protection device on the tram. As the Line Breaker contacts were mechanically seized in the closed position, the current flow was not interrupted and resulted in the overheating and welding of the contacts on the grouping contactor and the overheating and damage to No.3 Traction Motor and overheating and fire in Traction Motor No.1.

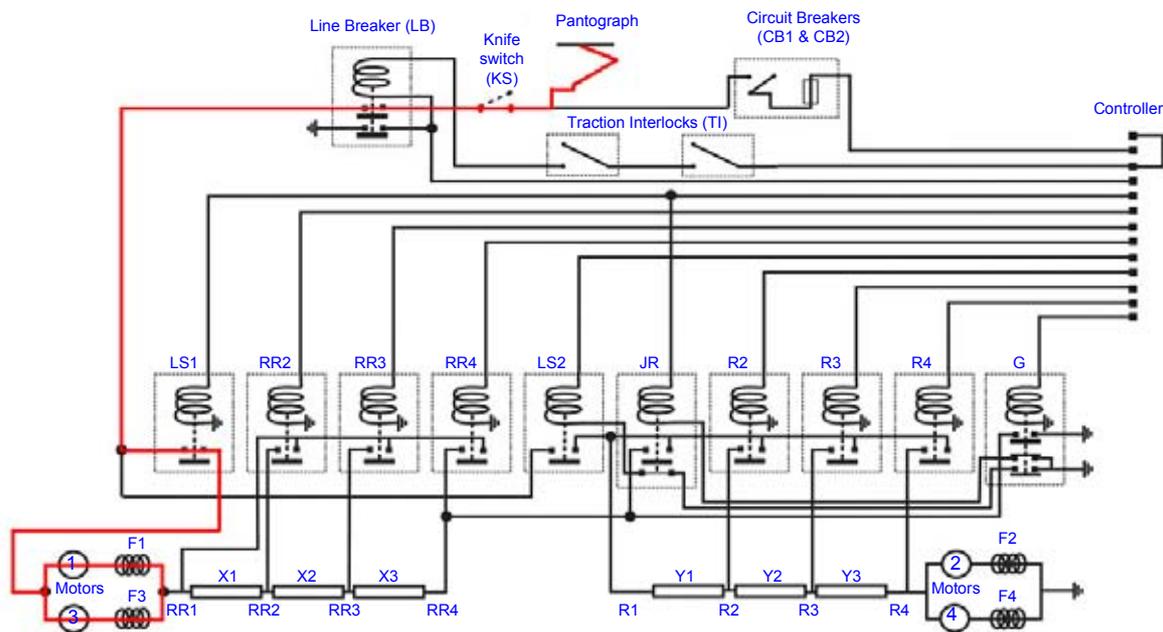


Figure 14 – Traction system circuit diagram with short circuit

In this instance the rate of change of current and the peak current value during the short circuit on the traction motor did not exceed the tripping threshold of the substation feeder circuit breaker. As a result, the substation circuit breaker did not operate to interrupt the abnormally high short circuit current and extremely high temperatures were generated between the overhead line and the pantograph carbon strips resulting in the melting and parting of the overhead cable.

3.2 Design of system

The substations feeding the network are specifically designed to protect the overhead cables during a cable short circuit or a major short circuit on a tram. The substation circuit breaker is required to act as secondary electrical protection for trams.

Newer trams added to the Melbourne tram fleet require significantly higher power and draw higher currents in comparison to the W class trams. The tripping currents of the substation feeder circuit breaker have been increased to allow for the operation of these newer trams. As a result of the increased tripping current thresholds, the W class trams are no longer protected against over-current by the substation feeder circuit breaker.

The design and method of speed control causes the Line Breaker to experience a large number of operations during normal service. Each time the tram controller is moved a notch to increase or decrease the speed the Line breaker is opened and closed. As a result, the Contactors and Line Breakers are subjected to heavy wear and require frequent and labour intensive maintenance.

3.3 Maintenance

In general the maintenance requirements specified in the 'Tram Work Modules' for the Traction Motors, Contactors and Line Breakers were not sufficiently comprehensive. The more comprehensive 'off vehicle' overhaul frequency of 500,000 kilometres for the Traction Motors, Line Breakers and Contactors is excessive. Five of the incidents of fires on W class trams can be attributed to the failure of motor insulation, failure of Line Breakers, Grouping Contactors and Step up Contactors. There were no records for the 500,000 kilometre overhaul of the Traction Motors, Line Breaker or Traction Contactors; hence the investigation could not determine the last overhaul or the installation of these components on the tram.

3.3.1 Line Breaker

It is highly unlikely that the fire in No.1 traction motor would have occurred if the Line Breaker had operated correctly. The excessive clearance between the contacts resulted in reduced moving contact spring pressure, which in turn was inadequate to assist in the opening of the contacts. The corrosion and resulting friction between the moving contact arm spindle and the bronze bush ensured that the contacts remained in the closed position despite the operation of the over-current relay in the Line Breaker.

It is evident that the defects in the Line Breaker were not detected during the 1,400 kilometre inspections. The scheduled maintenance tasks in the 'Tram Work Module' are not sufficiently comprehensive and did not include critical elements such as clearances between contacts.

3.3.2 Traction motors

Traction motors are only replaced when they fail. Under normal service conditions the protection devices would have interrupted the current supply as soon as No.1 traction motor shorted out and prevented the overheating and fire damage to the motor and tram. However, if the maintenance system included routine insulation resistance testing, the deterioration of the motor windings (coils) may have been detected and the short circuit prevented.

3.4 Driver's actions

The Yarra Trams Rule book requires that in the case of a fire, the tram is stopped and passengers requested to alight the tram. The procedure then instructs the driver to lower the pantograph and notify FOC. The procedure also requires the driver to attempt to extinguish the fire, but states that the motor hatchways must not be opened unless instructed.

Despite admitting that he was not aware of a specific procedure with respect to dealing with a tram fire the driver of Tram 946 followed the correct procedure with respect to the evacuation of the passengers from the tram. The task was straightforward as there were only six passengers on the tram and there was minimal road traffic. However, if the tram was carrying a larger number of passengers there was a possibility that the passengers may have suffered from smoke inhalation. There is a further possibility of passengers colliding

with road vehicles if a larger number of passengers attempt to alight quickly from a tram in an emergency situation.

In this instance the driver could not lower the pantograph as the overhead line had parted and lowering the pantograph would have put the pedestrians in the vicinity of the tram at risk.

Although the Yarra Trams Rule book requires drivers to attempt to extinguish tram fires, drivers receive no training in fire fighting. The Yarra Trams Rule Book states that “motor hatchways must not be opened unless instructed”. The driver of Tram 946 opened the No.1 motor hatch and attempted to extinguish the traction motor fire with the on-board fire extinguisher and suffered smoke inhalation as a result. The driver’s attempt to extinguish the fire was unsuccessful and the fire was subsequently extinguished by the Melbourne Fire Brigade.

4. CONCLUSIONS

4.1 Findings

1. The driver of Tram 946 was appropriately qualified to drive this class of tram.
2. The Grouping Contactor contacts welded together due to over-current and arcing.
3. The Line Breaker was seized in the closed position resulting in the non-interruption of the abnormally high current flow.
4. The Line Breaker and Traction Motors were not maintained to a satisfactory standard.
5. The Line Breaker was not maintained to the manufacturer's specification which led to the mechanical failure of the component.
6. The 'off vehicle' overhaul frequency of 500,000 kilometres for Traction Motors and Line Breakers is excessive.
7. There were no records for the 500,000 kilometre overhauls of the Traction Motors, Line Breaker and Traction Contactors on the tram.
8. Tram drivers do not receive training in fire fighting.

4.2 Contributing factors

1. There was an insulation failure that resulted in a short circuit of the field windings of No.1 traction motor.
2. The short circuit caused an abnormally high current flow that resulted in overheating of the electrical components in the system.
3. The current tripping threshold of the substation circuit breaker has been increased and as a result Tram 946 (W class trams) was not protected against over current by the substation feeder circuit breaker.
4. The maintenance requirements in the 'Tram Work Module' for the traction motors did not include insulation resistance or continuity testing.
5. Maintenance requirements for the Line Breaker do not take into account the inordinate number of operations that the Line Breaker is subjected to during normal service.

5. SAFETY ACTIONS

5.1 Safety actions taken since the event

1. Yarra Trams is currently evaluating the content and maintenance frequencies in the Technical Maintenance Plan for W class trams.
2. Yarra Trams has reviewed the overhaul requirements and frequencies for Line Breakers. They have also audited the performance of the overhaul venue and concluded that the current model of Line Breaker is no longer capable of functioning to the current system operating criteria.
3. Yarra Trams is presently trialing a newer model of Line Breaker operating on a 24 volt control system that will allow Yarra Trams to monitor tripping and shut down the tram electrical systems on some fault criteria.
4. Yarra Trams has carried out an assessment of the wiring system on W class trams and is presently fitting out three trams with the newly specified wiring systems.
5. Yarra Trams has instituted an electronic database for the recording of all maintenance data of tram components.

5.2 Recommended safety actions

Safety Issue

The Line Breaker and Traction Motors were not maintained to a satisfactory standard.

RSA 2009001

Yarra Trams ensures that the current maintenance standards are reviewed in their current evaluation of the maintenance plans for W class trams.

Safety Issue

The 'off vehicle' overhaul frequency of 500,000 kilometres for Traction Motors and Line Breakers is excessive.

RSA 2009002

Yarra Trams review the maintenance frequencies for tram electrical components in their current evaluation of the maintenance plans for W class trams.

Safety Issue

Tram drivers do not receive training in fire fighting.

RSA 2009003

Yarra Trams ensures that tram drivers undergo basic fire fighting training.

