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Safety Investigations

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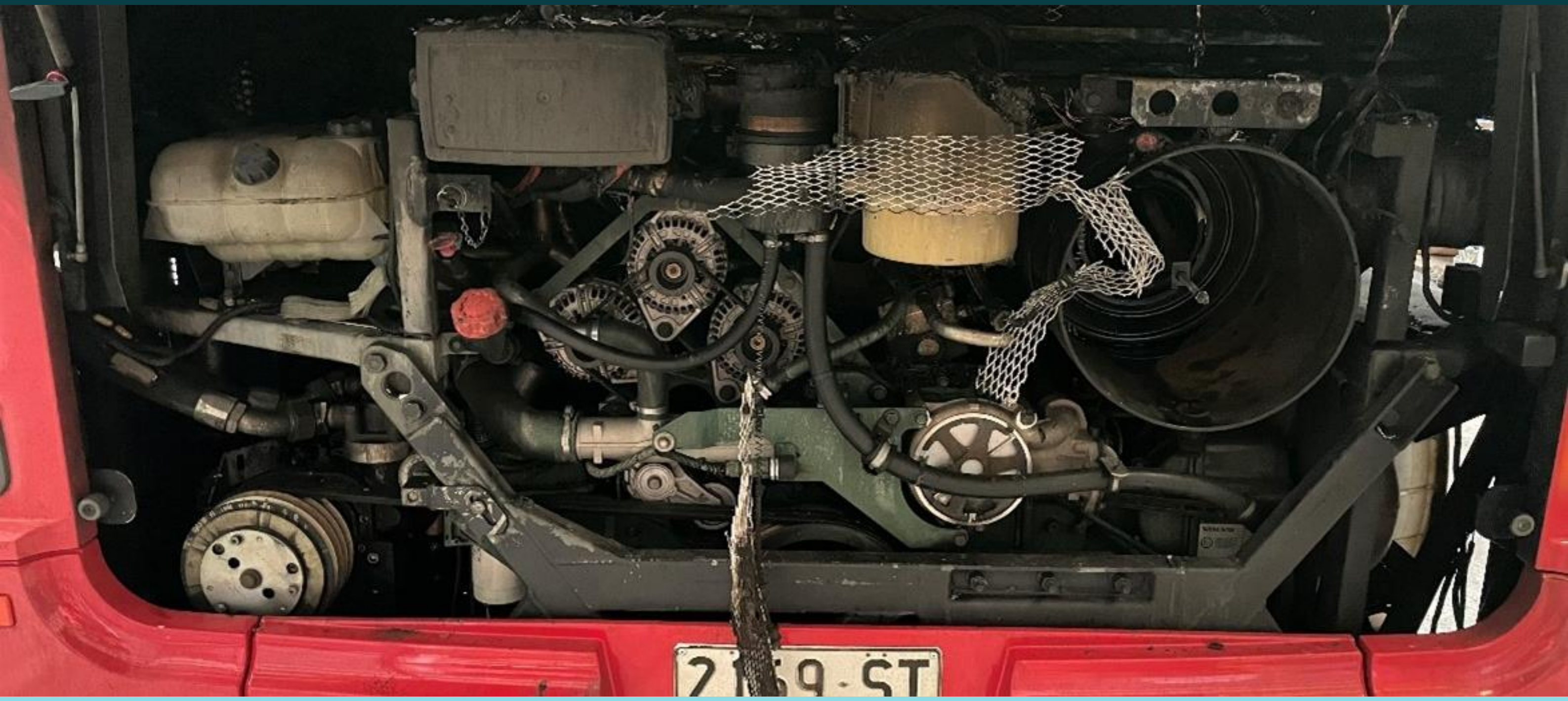
Bus Safety Investigation Report



Bus Fire 2169ST Camperdown, NSW
13 January 2022

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Executive summary

On the afternoon of Thursday 13 January 2022, articulated bus 2169ST caught fire and came to a stop adjacent to the intersection of Parramatta Road and Ross Street, Camperdown.

The bus was travelling westbound with the driver and 12 passengers on board. From the closed circuit television (CCTV) footage, the driver appeared to observe a passing motorist attempting to gain their attention from the next lane. Shortly after, the driver noticed smoke from the rear of the bus, stopped the bus and safely evacuated all passengers.

Fire and Rescue NSW attended and extinguished a fire within the engine bay. The engine bay area of the bus was extensively damaged.

The investigation found that the likely initiation of the fire was a perforation in a silicone hose that fed heated engine coolant to the saloon heater. Coolant leaking under pressure likely contacted hot engine components and ignited.

The investigation also discovered unsecured high amperage wiring in the involved bus post incident, which may lead to an increased risk of an electrical short circuiting causing fires within the passenger saloon area.

The investigation identified safety improvement opportunities in routine component change out programs and life cycle identification-based maintenance.

Recommendations were made to bus and coach operators to incorporate ongoing routine inspection and scheduled change out of silicone coolant hoses and inspection of high amperage electrical circuits, into their maintenance regimes, to reduce the risk of fire.

Full details of the Findings and Recommendations of this bus safety investigation are contained in Parts 3 and 4 respectively.

Part 1 — Factual information

The occurrence

1.1 On the afternoon of Thursday 13 January 2022, articulated bus 2169ST was operating an outbound route 440 service, between Bondi Junction and Rozelle in Sydney, New South Wales (NSW).

1.2 The bus was operated by Transit Systems West Pty Ltd (TSW).

1.3 At 1551:22,[1] as the bus approached the traffic light controlled intersection adjacent to Glebe Point Road and Broadway, closed-circuit television (CCTV) footage showed the driver of 2169ST appearing to glance at the driver's instrument panel, prior to stopping at the intersection.

1.4 For approximately ten seconds that the bus was stopped at the intersection, the driver's attention appeared to be focused on the driver's instrument panel. The CCTV footage showed this behaviour to be out of character up to this point of the journey.

1.5 Following this, the driver continued to drive as normal, briefly slowing down to pick up an intending passenger who then waived the bus on.

1.6 At 1553:03, CCTV footage showed the driver having a prolonged look into their off side(O/S)[2] external rear view mirror, which was closely followed by the driver acknowledging the presence of a passing motorist by raising their hand near the window opening.

1.7 Shortly after, the driver stopped the bus, applied the park brake, and switched off the ignition. The driver stopped in the bus lane, parallel and close to the foot path, approximately 70 metres from the intersection of Ross Street and Parramatta Road.

1.8 The driver then opened all three doors of the bus and instructed passengers to evacuate immediately.

1.9 At 1553:16, internal CCTV footage showed a group of five passengers, seated in the rear passenger saloon area of the bus, evacuate through the rear door. As they exited, smoke was observed to envelope the external rear of the bus and travel externally towards the front. Smoke was also observed entering the rear of the saloon area.

1.10 While the passengers evacuated, the driver left the driver's cabin and exited via the front doors, after pausing to check that all passengers had evacuated from the bus.

1.11 CCTV footage showed the driver, immediately after exiting, look toward the rear of the bus while commencing a call on their mobile phone.

1.12 The passenger evacuation was successfully completed within 11 seconds of the bus stopping and doors opening, without incident or injury. No passengers required assistance to evacuate the bus.

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[1] Times in this report are in 24-hour clock form in Australian Eastern Daylight-saving Time.

[2] The left side when looking forward from the driver's seat in the bus is the near side (N/S). The right side is the off side (O/S).

1.13 The driver re-entered the bus at 1553:50 to remove their Driver Authority card, activate the hazard lights and emergency electrical cut-off switch, and remove the keys from the ignition switch.

1.14 The driver then remained at the front of the bus, ensuring that the passengers moved to a safe location. During this time, the driver contacted the TSW Operation Control Centre (OCC)[3] for assistance by mobile phone.

1.15 By 1555, smoke had filled the rear saloon area up to the rear door, and by 1602, the saloon area to the front door was full of smoke.

1.16 Fire and Rescue NSW began extinguishing the fire at approximately 1603.

Incident location

1.17 The incident occurred approximately 85 m east of a traffic light-controlled intersection of Parramatta Road and Ross Street, Camperdown (Figure 1, Figure 2). The intersection is located approximately 3 km from the Sydney CBD. The bus had been travelling in a westerly direction along Parramatta Road.

Figure 1: Incident location

Source: SIX Maps. Annotated by OTSI

[3] TSW OCC is a central control room that monitors radio communications with drivers.

Figure 2: Bus final stopped position at 1553:12 from forward facing CCTV camera

Source: TSW. Annotated by OTSI

Environmental conditions

1.18 According to the Bureau of Meteorology, the afternoon of 13 January 2022 was overcast and raining, with a light south-easterly wind. A temperature of 21.3°C was recorded at 1500 at the Sydney Observatory Hill weather station, about 4 km north-east of the incident.

1.19 The investigation determined that environmental conditions were not a contributing factor to this event.

Operator information

1.20 TSW operated and maintained a fleet of buses under contract for Transport for New South Wales (TfNSW). TSW commenced operation of this contract on 1 July 2018.

1.21 This contract included operational depots at Leichhardt, Kingsgrove, Tempe, and Burwood with a fleet of 621 buses. 2169ST was operated from their Leichhardt depot.

Driver information

1.22 The driver held a valid Transport for NSW (TfNSW) Bus Driver Authority and Heavy Vehicle licence. The driver transitioned from the former NSW government operator of Metropolitan Bus Service Contract Region 6, State Transit Authority[4] (STA), to TSW which was awarded the contract for Region 6 in July 2018. The driver had gained employment with STA in 2016.

[4] The **State Transit Authority of New South Wales**, also referred to as **State Transit**, was an agency of the Government of New South Wales operating bus services in Sydney. Superseding the Urban Transit Authority in 1989, it was also responsible for the provision of ferry services in Sydney until 2004 and bus and ferry services in Newcastle until 2017. STA ceased trading after 2 April 2022 with its remaining operations to be contracted out by Transport for NSW to replacement operators.

1.23 Records for previous training provided to and completed by the driver of 2169ST by their previous employer, STA, were not transferred to TSW at the commencement of TSW's contract in July 2018.

1.24 Training records requested by OTSI for the driver of 2169ST could not be supplied by the operator for the involved driver's training with the previous employer or TSW.

Driver training

1.25 TSW had a driver training program in place which included annual emergency response training.

1.26 The TSW operator's 'Drivers Guidelines Handbook' contained a page on bus fires and associated actions (Figure 3). On 1 July 2019, TSW released a new Driver Guidelines Handbook, which included Thermal Events/Bus Fire response. TSW had reported that all employees were issued the new book and were allocated paid time to read and understand the handbook.

1.27 Driver training documentation titled 'Fire Control Systems' and 'Predeparture Checks', also contained information relating to the operation of Tyre Monitoring Systems, how to deal with fire in engine bays, operation of fire extinguishers and an overview of the Fogmaker Fire Suppression System (Figure 3, Figure 4).

1.28 It was noted that the Fogmaker Fire Suppression System alarm panel shown in '*Module 22 Fire Control Systems*' was not fitted to 2169ST.

Figure 3: Operator's driver guidelines handbook excerpt

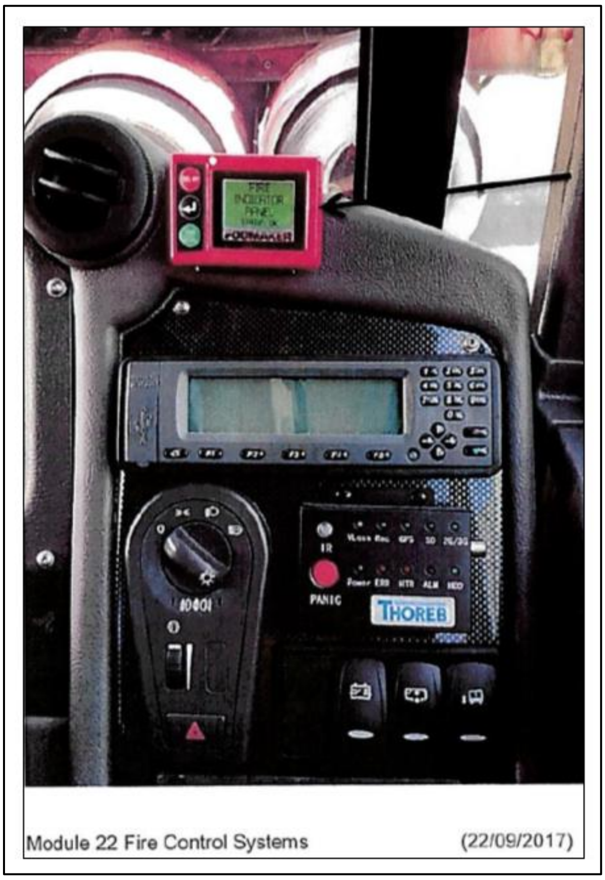
SAFE METHOD/CONTROL MEASURE

In the event of a thermal incident or bus fire, ensure you:

- Remain calm.
- Slow the vehicle in a controlled manner and stop and secure the vehicle.
- **Turn off the bus, switch off the battery and in the case of CNG powered buses, isolate the gas.**
- Open all doors and evacuate the bus, directing customers to a safe location up-wind and off the road (if possible).
- **Call 000** by mobile phone. Do not enter the bus or allow customers to re-enter the bus under any circumstances.

Source: TfNSW

Figure 4: Fogmaker EBFSS Smart Panel



Source: Transit Systems

Bus information

1.29 The bus was a Volvo B12BLEA, registered in NSW as 2169ST, and fitted with a Volgren CR228L body. The bus was first registered in October 2010 and was powered by a six-cylinder; turbo charged Volvo diesel engine in a horizontal configuration.

1.30 The engine was rated to comply with Euro 4/5 and EEV[5] emission requirements.

1.31 The bus was an articulated configuration, with three entry/exit doors, and was 17.7m in length. TSW operated 36 of this model bus in their fleet.

1.32 The cooling system of the bus is used to transfer thermal energy developed by the engine and transmission into atmospheric air via a heat exchanger unit (Figure 5, item #3). The system also supplies heated coolant to body builder connections to the saloon heater circuit (Figure 5, item #13).

1.33 The bus was last serviced in December 2021, in accordance with the documented maintenance schedule.

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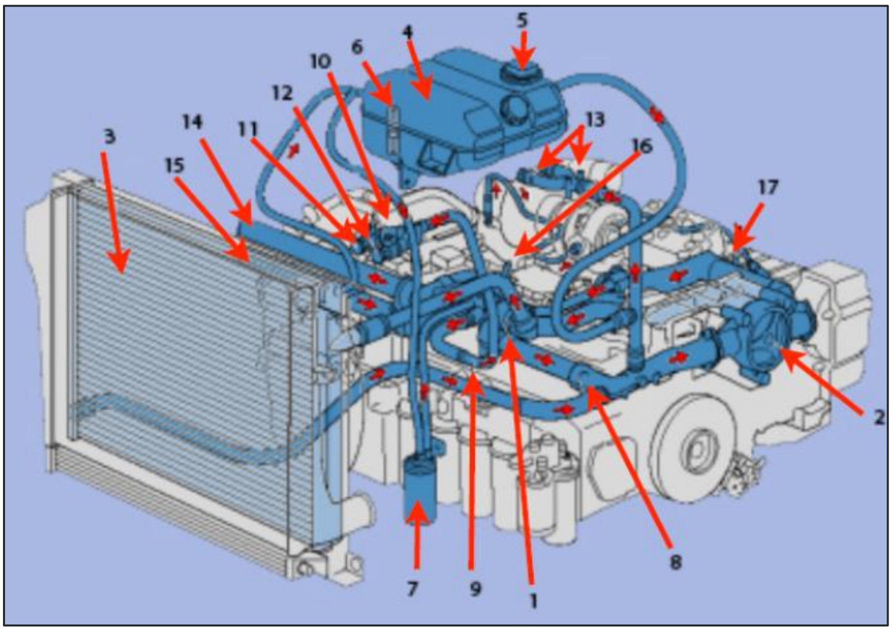
[5] The EEV standard is intended to create an internationally agreed benchmark which can be adopted by EU member states and air quality conscious urban authorities in establishing truck operator tax-concession incentive schemes and low-emission zone entry rules. The EEV emission standard: a stepping stone to Euro 6? | Automotive World https://www.automotiveworld.com/articles/82896

Figure 5: Volvo B12BLEA cooling system components



Source: Volvo Bus Australia

1.34 The fire was confined to the rear of the engine bay from approximately the area of the transmission to the rear of the engine bay causing considerable damage to the upper surface of the engine assembly and components located in the rear upper engine bay area (Figure 6).

1.35 Heat and flame damage was evident on the rear panels above the engine bay access hatch and the O/S rear engine bay access panel (Figure 7).

1.36 Examination of the engine bay found no evidence of residual oil or diesel fuel.

Figure 6: Damage to engine assembly viewed from interior access panel

Source: OTSI

Figure 7: Damage to rear exterior of bus

Source: OTSI

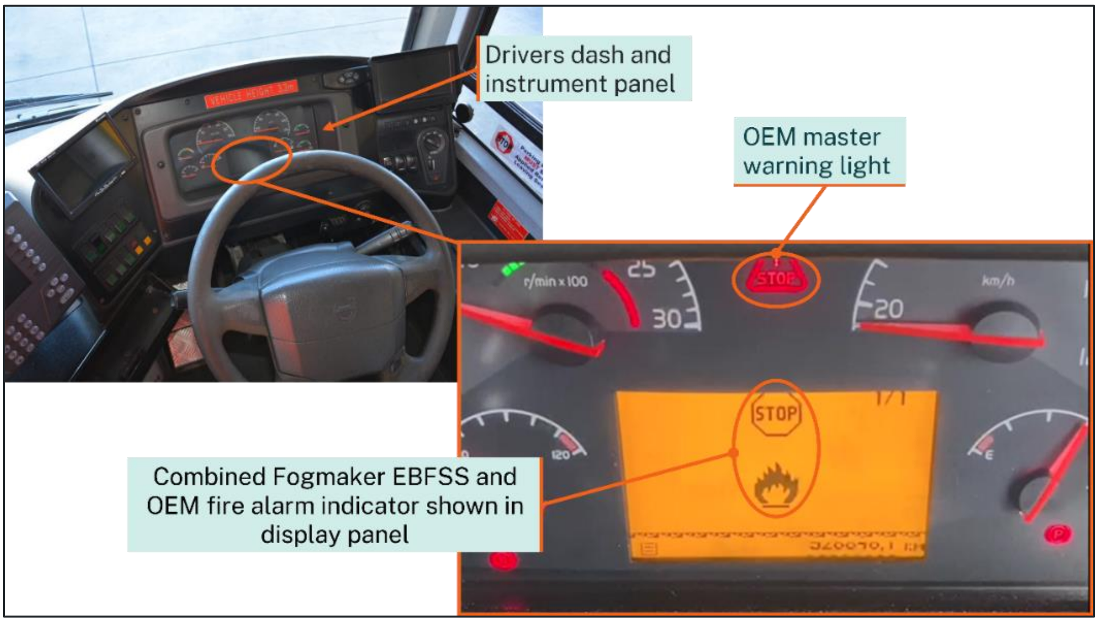
Engine bay fire suppression system and fire alarms

1.37 The bus was fitted with two separate engine bay fire alarm systems, one fitted by the Original Equipment Manufacturer (OEM) and the other incorporated into the Fogmaker Engine Bay Fire Suppression System (EBFSS).

1.38 The OEM and EBFSS fire alarms were incorporated into the instrument panel and utilised the same audible alarm in addition to other systems: high engine temperature, low engine oil pressure, and low brake air pressure (Figure 8).

1.39 Both the OEM fire alarm and EBFSS alarm also utilised the OEM master alarm warning light. This was depicted by a red triangle with the word stop (Figure 8). This symbol was also utilised by the same alarm systems as mentioned in 1.38.

Figure 8: Drivers instrument panel engine bay fire alarms



Source: OTSI / TSW – Annotated by OTSI

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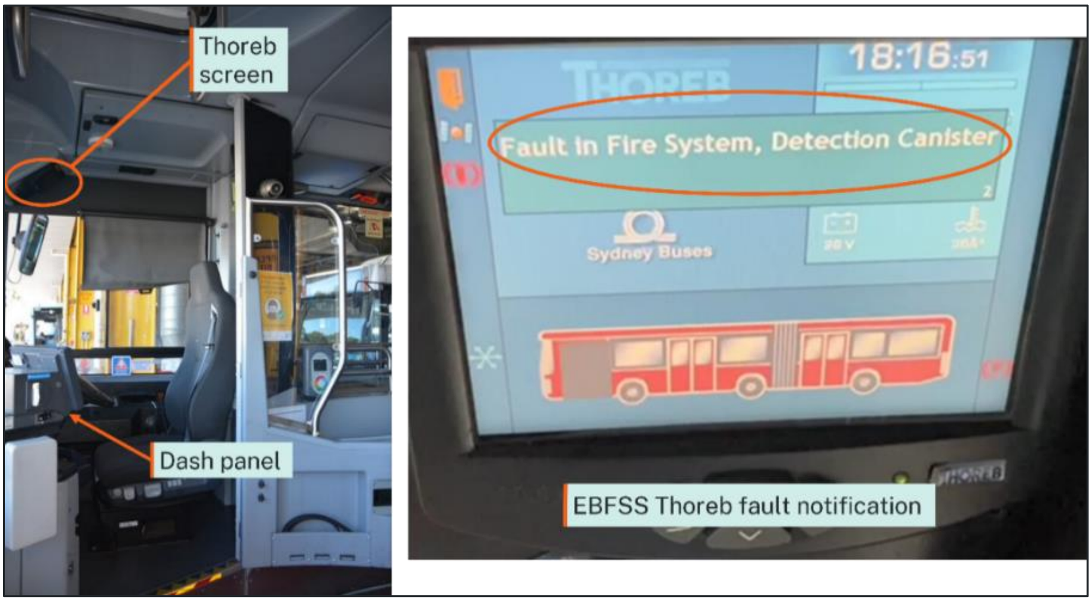
1.40 The Fogmaker EBFSS system had two separate alarms. In addition to the alarms previously mentioned, a visual only fault indicator appears on the Thoreb[6] display panel (Figure 9).

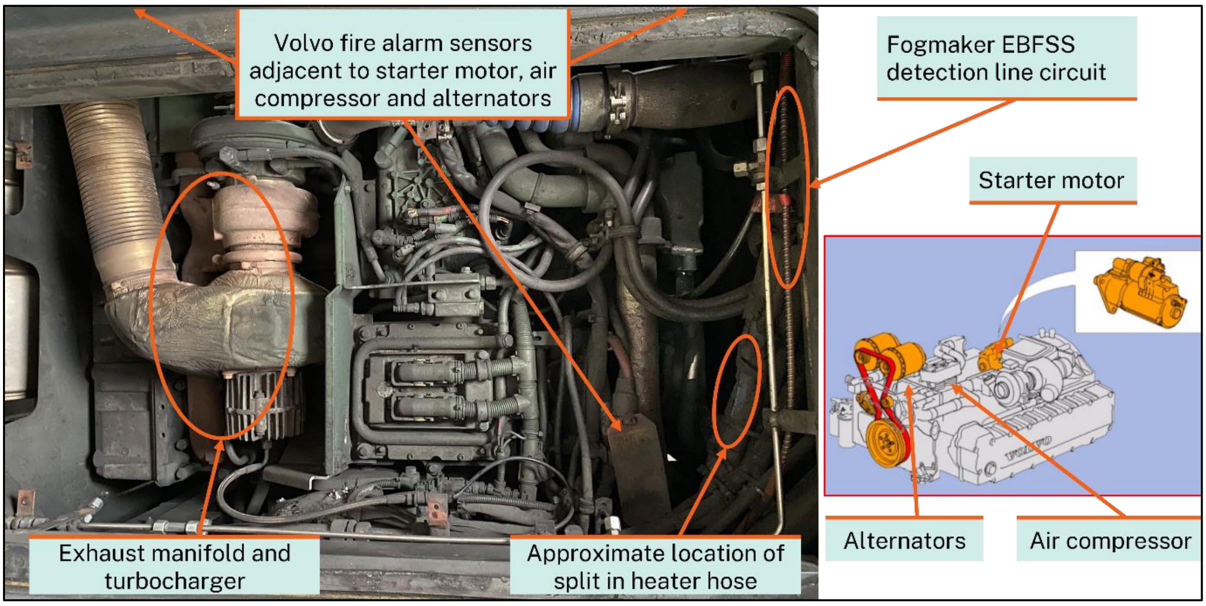
Figure 9: Location of Thoreb screen, driver's dash panel and Thoreb fault notification



Source: OTSI

1.41 The OEM fire alarm utilises three thermal sensors located on the engine assembly. Of the three sensors, two are set to activate at 110°C and the other at 150°C. They are located adjacent to the starter motor (110°C), alternators (110°C), and air compressor (150°C) (Figure 10).

Figure 10: Location of OEM fire sensors and EBFSS detection tube



Source: Volvo Bus Australia / OTSI. Volvo image annotated by OTSI

6 Thoreb is a brand name for a communication platform designed to work as a router/gateway for the vehicle. It can forward information from the vehicle's chassis CAN bus (A Controller Area Network (CAN bus) is a vehicle bus standard designed to allow microcontrollers and devices to communicate with each other's applications without a host computer) to other systems in the vehicle, it can also route information between different sub-systems, inside the vehicle as well as to external systems via 3G/4G.

1.42 Bus 2169ST was one of 150 Volgren bodied B12BLEA Volvo buses supplied to the former NSW government agency STA. The buses in this supply contract were the first new buses delivered to STA fitted, as new, with an Engine Bay Fire Suppression System (EBFSS). The system fitted was a Fogmaker water mist type with a 6.5 L agent tank and at the time of installation, the system was required to comply with Australian Standard (AS)5062-2006: *Fire protection for mobile and transportable equipment*.[7]

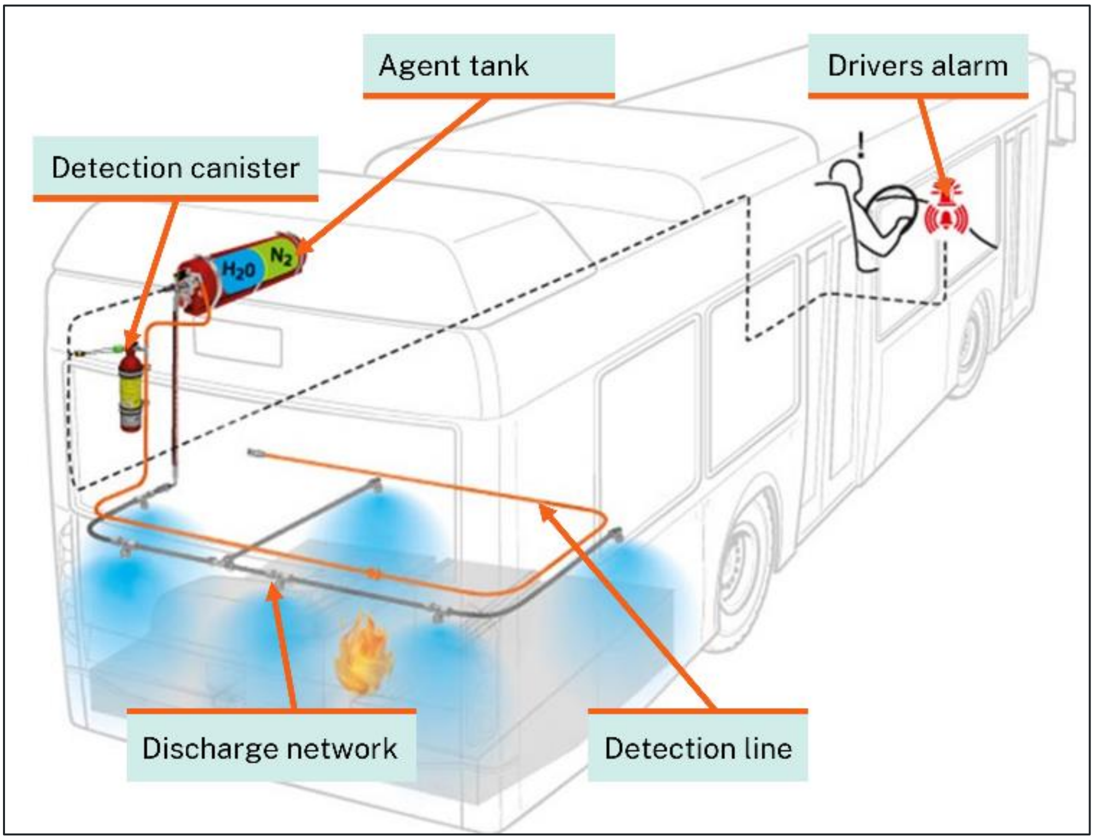
1.43 As bus 2169ST was built in 2010, it pre-dated the requirements of the "P- Mark"[8] systems by TfNSW, which was a requirement for the EBFSS retrofit program commenced by STA in 2013 and TfNSW in 2015.

1.44 Fogmaker is a Swedish company that has been developing, manufacturing, and marketing fire suppression systems for engine compartments with high pressure water mist.

1.45 A water mist system acts by reducing the temperature in the area of the fire while the water vapour mist expands providing a blanket over the fire, preventing oxygen from reacting with the fuel.

1.46 The main components of the system are the detection canister, detection line network, agent tank and discharge network (Figure 11).

Figure 11: Basic engine bay fire suppression system layout



Source: Volvo Bus Australia / OTSI. Volvo image annotated by OTSI

[7] AS5062-2006 specifies fire risk management procedures and the minimum requirements for fire protection system design, installation, commissioning, and maintenance for use on mobile and transportable equipment.

[8] The "PMARK" is internationally recognised as the global standard in assessing fire suppression systems in engine compartments of buses and coaches. All systems undergo full testing as required by the SP (technical research institute of Sweden) to gain "P" Mark accreditation.

1.47 The detection canister contained a mixture of Nitrogen and a propylene glycol-based fluid pressurised to approximately 24 bar (350 psi). The detection line consisted of tubing connected to the detection canister which ruptured when the temperature reaches the design temperature of the detection system between 160°C to 180°C. When the tube ruptured the detection system depressurised. This loss of pressure in the detection system triggered the release valve on the agent tank.

1.48 Once the release valve was triggered, suppressant in the agent tank was released under approximately 105 bar (1522 psi) of pressure throughout the discharge network. The discharge duration was approximately 30 seconds.

1.49 The suppressant was delivered as an atomised spray. It consisted of 97% demineralised water and 3% aqueous film forming foam (AFFF) agent. The AFFF provided a thin aqueous film at the fuel/air interface that suppressed the combustion reaction.

1.50 As the atomised suppressant contacted the fire and hot surfaces, the water converted into steam increasing approximately 1600 times in total volume. This had an effect of forcing oxygen away from the flame front, denying it the oxygen necessary to support combustion.

1.51 The Fogmaker EBFSS alarm relied on signals from two pressure switches: one attached to the detection canister and the other to the agent tank. A signal from only one switch, either the agent tank or detection canister, gave a fault notification which displayed on the Thoreb screen above the driver in visual form only (Figure 9).

1.52 If both switches provided signals, as a result of loss of pressure in both the detection canister and agent tank, a fire alarm was provided to the driver on the instrument panel in both audible and visual forms (Figure 8).

1.53 The EBFSS was last serviced on 30 November 2021 in accordance with the six-month inspection criteria. The five yearly service and hydrostatic pressure check was due in March 2022. On inspection, following the incident, both the agent tank and detection canister had fully discharged (Figure 12).

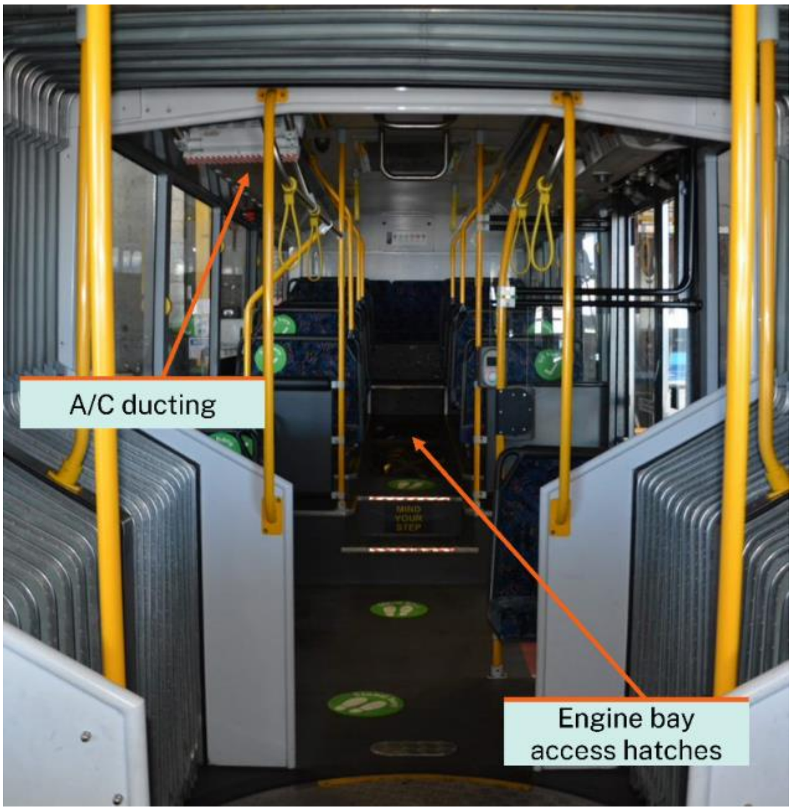
Figure 12: Fire suppression detection cannister and agent tank

Source: OTSI

Bus inspection: other risks identified

1.54 During the inspection of the bus, the O/S rear interior air conditioning (A/C) duct panels were removed to determine if the fire had penetrated the saloon area (Figure 13).

Figure 13: Bus interior



Source: OTSI

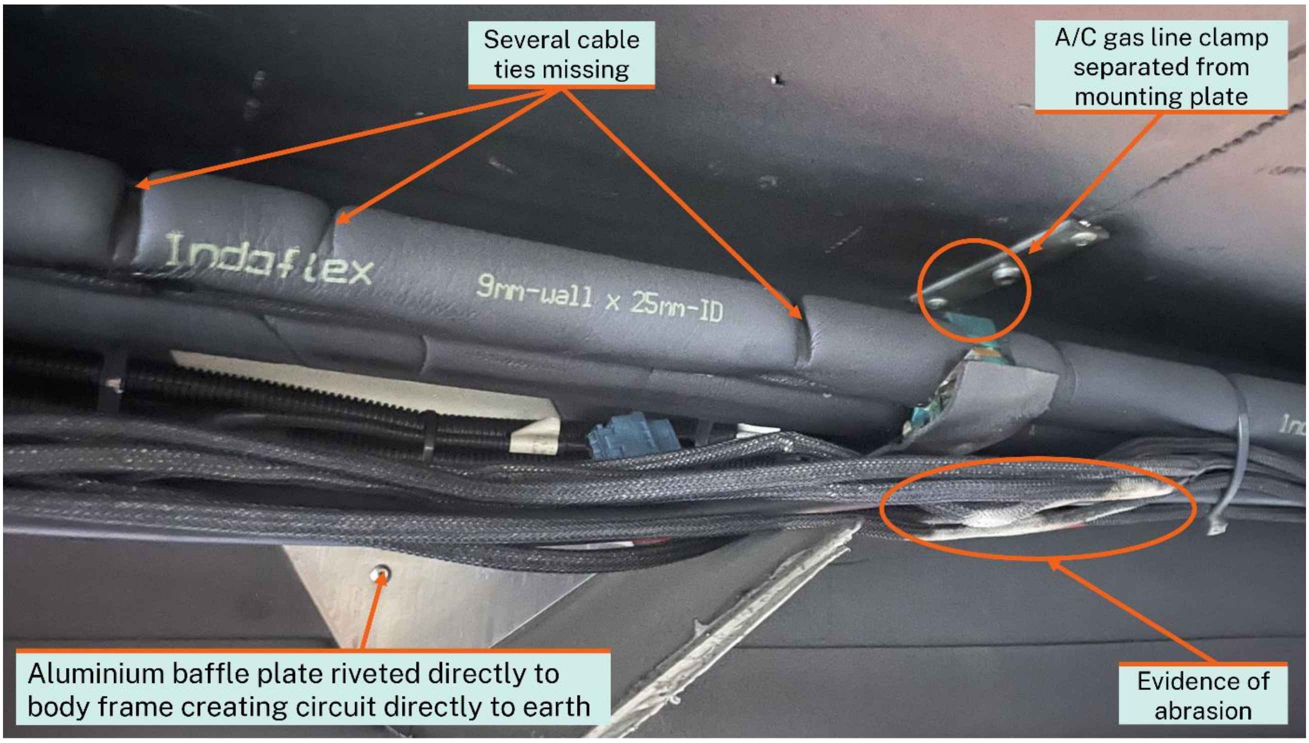
1.55 In this area, there were several wiring looms associated with the A/C system, saloon area wiring, and the main A/C gas supply and return lines. Examination identified that numerous cable ties were missing or had broken, over a section of wiring looms approximately four metres in length. The cable ties were designed to secure the wiring looms to the A/C gas lines (Figure 14,Figure 15).

1.56 As the cables were no longer secured, they had abraded against an aluminium baffle plate, within the A/C duct, which was riveted to the aluminium roof frame of the bus (Figure 16).

1.57 Abrasion patterns from contact with other components were also observed on several of the cable bundles in this area and on the main positive feed cable to the A/C roof pod unit (Figure 14,Figure 16).

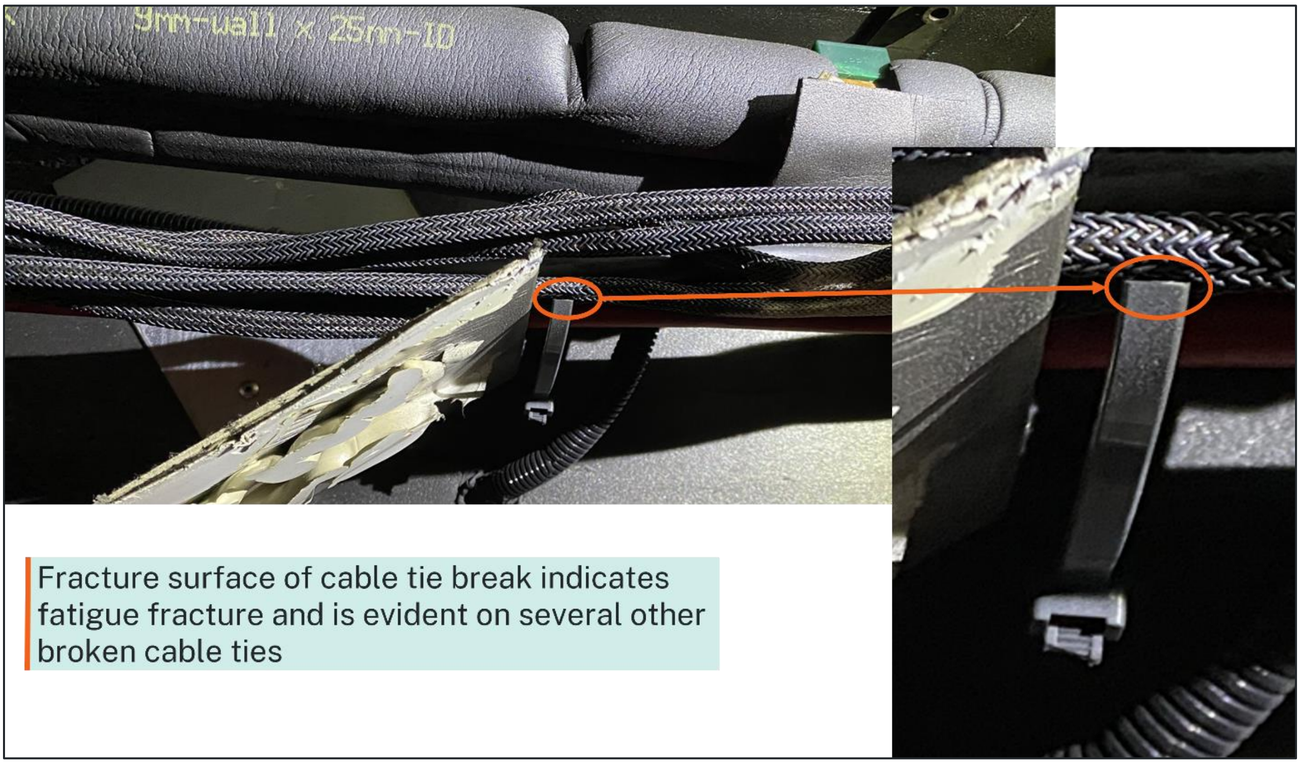
1.58 Also in the immediate area, the A/C gas line clamp securing bolt had dislodged from its mounting plate, which was still attached to the roof frame of the bus (Figure 14).

Figure 14: Unsupported A/C gas lines, A/C wiring and main feed cables



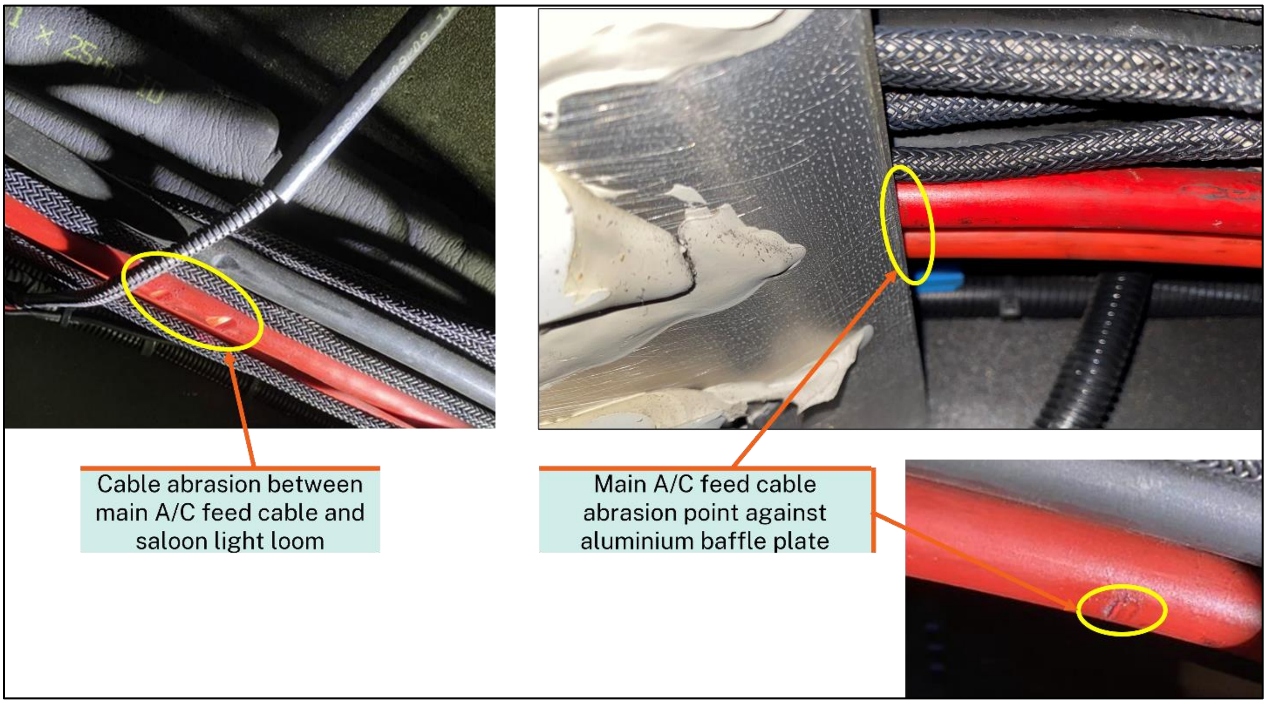
Source: OTSI

Figure 15: Broken cable tie supporting wiring loom



Source: OTSI

Figure 16: Main A/C positive cable abrading against baffle plate and saloon light loom



Source: OTSI

Related occurrences

1.59 OTSI has collated and published summaries of reported bus fire incidents in NSW since 2012. The most recent annual summary of bus fires and thermal incidents in NSW was published in September 2023.[9] In 2021, most fire and thermal incidents (62%) originated in the wheel well area. Twenty two percent of incidents were in the engine bay area and 16% in the bus body.

1.60 OTSI have identified that ethylene glycol-based coolants have been the source of fuel in several bus fires whereas a result, the bus was a total loss. Ethylene glycol-based coolants have also been identified in several bus fires where the coolants have encountered hot engine components. In these instances, a loss of the asset did not occur. The total losses included:

- Bus fire, Hillsdale – Ruptured turbo coolant line, horizontal engine[10], Mercedes OC500LE, STA, 2011 (CNG fuel)
- Bus fire, Surry Hills – Ruptured A/C coolant feed line, horizontal engine, Mercedes OC500LE, STA, 2017 (CNG fuel)
- Bus fire, Railway Square – Ruptured coolant hose, horizontal engine, Mercedes OC500LE, 2016 (CNG fuel).

[9] OTSI Bus Safety Investigation Reports: Bus Fire and Thermal Incidents in NSW from 2013 - 2022, Bus Fire Hillsdale, Bus Fire Surry Hills, and Bus Fire Railway Square are available at www.otsi.nsw.gov.au

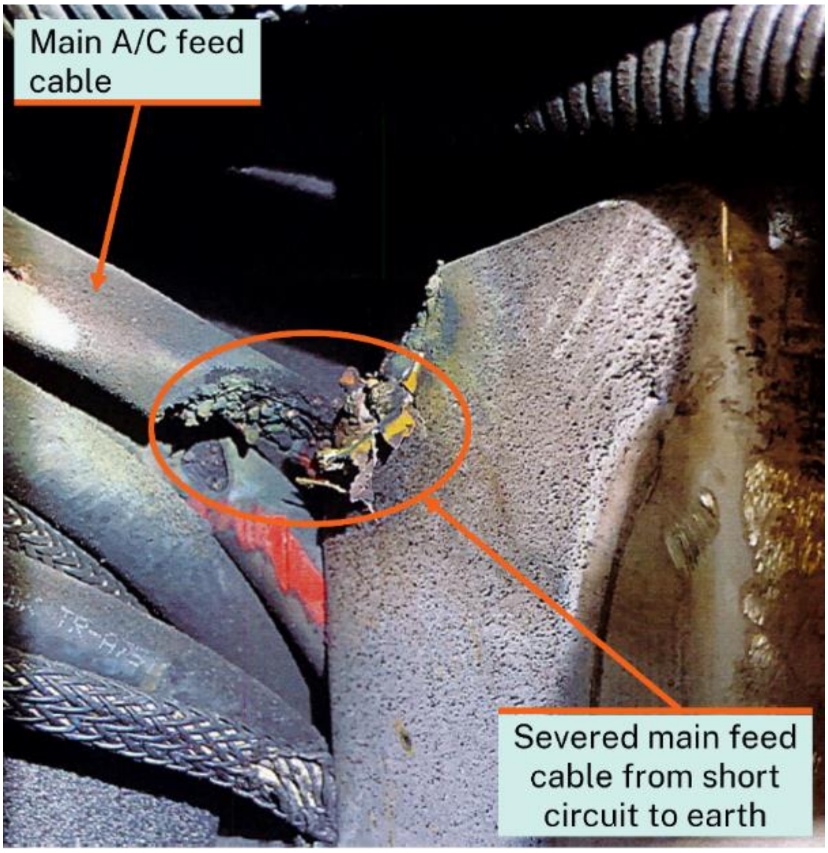
[10] Horizontal engine refers to the configuration of the centre line of the engine assembly when viewed from in front of the engine.

1.61 In March 2019, an STA Volvo B12BLE, registered MO1643, was severely damaged by fire due to a coolant leak from a fracture in the turbocharger coolant feed line. As with the Mercedes OC500LE model buses, the Volvo B12BLE has a horizontally mounted engine layout which allows coolant to pool on hot surfaces of the engine.

1.62 The 2022 OTSI Bus Fire report identified that all body incidents in 2021 were attributed to electrical malfunction or failure. The 12 electrical incidents had a wide variety of origins: wiring insulation abrading, air conditioning control gear, high resistance connections, water ingress to electrical components, and faulty wiring.

1.63 During the investigation, evidence was provided to OTSI that indicated other buses of this type, in the TSW fleet, had experienced main A/C cable abrasion.
Figure 17 shows an example of the main positive A/C cable completely severed due to an electrical short circuit[11] between the cable conductor and the rear main body hoop frame. This area was immediately adjacent to where the cable abrasion was evident in bus 2169ST.

Figure 17: Cable abrasion between main A/C feed cable and saloon light loom



Source: TSW, annotated by OTSI

[11] A short circuit is a low-resistance connection established by accident or intention between two points in an electric circuit. This excessive electric current potentially causes circuit damage, overheating, magnetic stress, arcing, fire, or explosion. The amount of current that is available in a short circuit is determined by the capacity of the system voltage sources and the impedances of the system, including the fault. (A. Bhatia, BE "Introduction to Short Circuit Analysis" (PDF). PDHonline. sec. What causes a short circuit? 3 July 2019.)

Part 2 — Analysis

Introduction

2.1 The investigation focused principally on the factors that contributed to the bus fire, the immediate emergency response and identification of safety improvement opportunities.

2.2 The findings of related OTSI investigations and the annual summaries of bus fires in NSW, emphasise the importance of identifying risks involved with the release of coolant in the vicinity of ignition sources.

2.3 Additionally, the securing of bus wiring cables, looms, and harnesses, to prevent movement, chafing or vibration while in service, and regular inspection of electrical wiring, are integral factors in the prevention of thermal events and fires.

Initiation of the fire

2.4 The examination of the engine bay and associated components indicate that the likely commencement, ensuing propagation and continuing fuel source for the fire event was based in the vicinity of the near side of the engine bay (Figure 19).

2.5 Adjacent to this area, a longitudinal split in one of two silicone hoses was identified. These silicon hoses transferred heated coolant from the engine to the saloon heater matrix. This split was consistent with a failure of both the inner silicone liner, nylon reinforcement layer, and outer silicone cover.

2.6 The hoses were fitted as original equipment by Volgren, the bus body manufacturer.

2.7 The defect in the hose likely allowed ethylene glycol-based coolant, under pressure of approximately 0.75 bar (10.87 psi), to contact hot engine components in proximity, including the exhaust manifold and or turbocharger. Both of which are located on the O/S, upper surface of the engine assembly (Figure 19).

2.8 Examination of the insulating material, surrounding the exhaust brake assembly directly adjacent to the turbocharger turbine housing, indicated the presence of a residue consistent with Ethylene Glycol based coolant. The odour present from the residue was consistent with the coolant utilised in the bus cooling system. According to the OEM Safety Data Sheet, the coolant was not likely to volatilise rapidly into the air because of its low vapor pressure.

2.9 The engine cooling system of the bus was filled with Volvo VCS 40/60 premixed coolant which was OEM approved. The coolant was an ethanediol (ethylene glycol) based coolant premixed with 40 to 60% demineralised water.

2.10 The coolant also contained, at concentrations of less than 1%, 2-ethylhexanoic acid (2-EHA)[12], Pentahydrate,[13] and Denatonium benzoate.[14]

2.11 The ignition behaviours of engine coolants containing ethylene glycol are based on their thermophysical properties. Some of the thermophysical properties considered are:

I. Flash point[15] (T_{flash})
II. Auto ignition temperature[16] (T_a)

2.12 Representative Tflash and Ta values for glycol-based coolants approximate at 130°C and 400°C respectively.

2.13 For ignition of the coolant to occur, the operational temperatures of hot engine surfaces such as the exhaust manifold, turbocharger assembly and exhaust pressure governor must at least exceed the T_{flash} or T_a values of the coolant.[17]

2.14 For EEV rated diesel engines as fitted to 2169ST, the exhaust gas temperatures can vary from approximately 200°C at idle to 700°C at full load. Insulation surrounding the exhaust pressure governor would reduce the surface temperature of this unit.

2.15 However, the exhaust manifold and the turbocharger turbine housing were not insulated, resulting in a greater transfer of heat energy to the surrounding atmosphere, once operating temperatures were obtained. These surfaces could reach similar external temperatures as the temperature of the exhaust gasses contained within.

2.16 Considering the thermophysical properties of the coolant, the exhaust gas temperatures of the engine, and the lack of evidence toward another fuel or ignition source, it is reasonable to conclude that the coolant leak from the compromised heater hose was the source of fuel for the ensuing fire.

2.17 Additionally, given the volume of the cooling system, location of the header tank (Figure 5, item #4), and that the cooling system was pressurised, it is highly likely that coolant continued to flow from the split in the hose after the engine was shut down. This would supply further fuel to the immediate area of the concentration of the observed fire activity possibly resulting in reignition of the fire.

[12] 2-Ethylhexanoic acid is used to produce corrosion inhibitors for lubricants and automotive coolants. It also serves as wood preservatives and makes lubricant additives as well as synthetic lubricants.

[13] Pentahydrate relates to a metal corrosion inhibitor for use in aqueous solutions, and to antifreeze/coolant compositions containing such a corrosion inhibitor. *0251480 - EP87304607B1 – EPO - Application May 22, 1987 - Publication Jan 02, 1992*

[14] Denatonium benzoate - a bittering agent to render coolant or antifreeze unpalatable - *Standard Test Method for Determination of Denatonium Benzoate in Engine Coolant by HPLC (astm.org)*

[15] Flash point is the minimum temperature at which a liquid gives off vapor within a test vessel in sufficient concentration to form an ignitable mixture with the air near the surface of the liquid.

[16] The autoignition temperature or kindling point of a substance is the lowest temperature in which it spontaneously ignites in a normal atmosphere without an external source of ignition, such as a flame or spark.

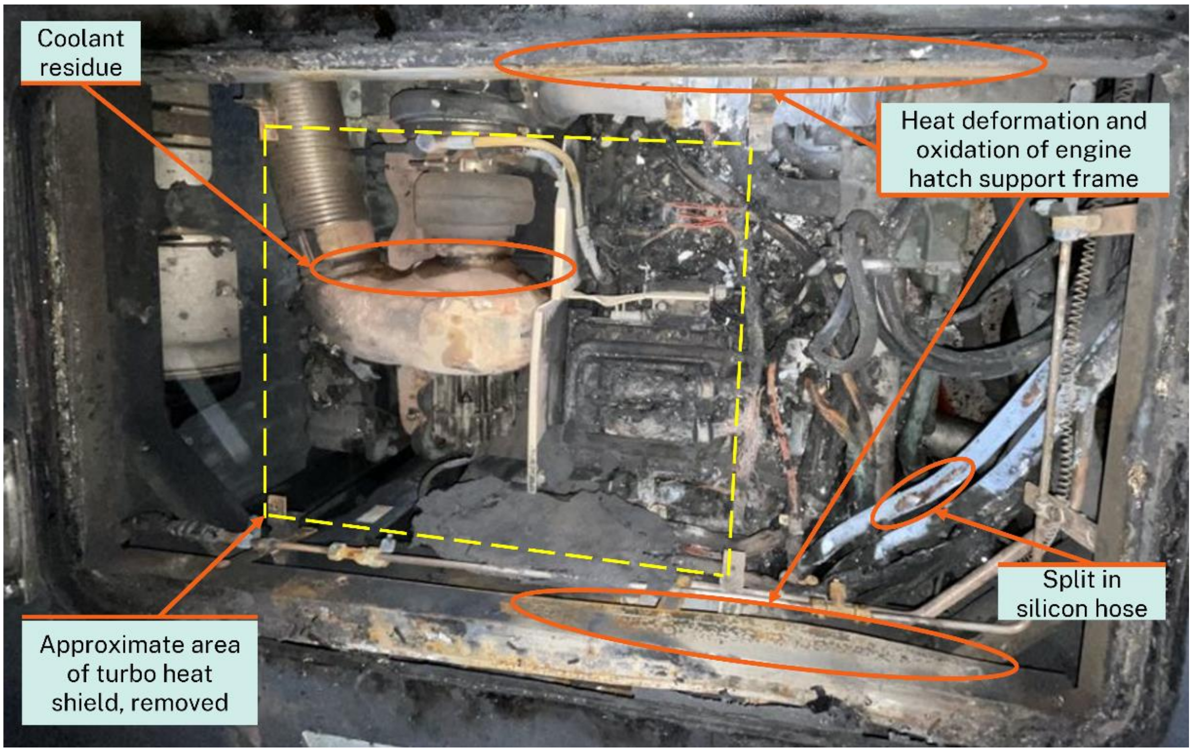
[17] Tewarson, A., Quintiere, J., and Purser, D.," Comprehensive Analysis of Post Collision Motor Vehicle Fires", Technical Report, 3018009, prepared by FM Global, Norwood, MA for Motor Vehicle Fire Research Institute, Charlottesville, VA.

2.18 Figure 18 shows deformation of the engine bay access floor hatch support frame indicating that the metal of the frame had been subjected to a high level of heat. As temperatures rise, steel expands due to thermal expansion. If the steel is restrained during the fire, then internal stresses may be induced in the steel components that can create buckles or other permanent deformations.[18]

2.19 The frame of the engine floor hatch also indicated a high level of concentrated heat adjacent aligning with the expected path of the coolant from the split in the heater hose. During a fire, protective coatings like paint are often consumed. Surface corrosion will then form on the exposed steel surfaces. Rust results from oxidation of the steel, and is a chemical reaction, which is temperature dependent. Exposure to elevated temperatures in a fire can cause thermally enhanced oxidation of the steel (Figure 18, Figure 19).

2.20 Electrical cables and wires in the area adjacent to the damaged hose and throughout the engine bay area exhibited damage consistent with ignition of their insulating material. However, examination of the cables and wires did not indicate any presence of electrical short circuiting prior to or after the commencement of the fire.

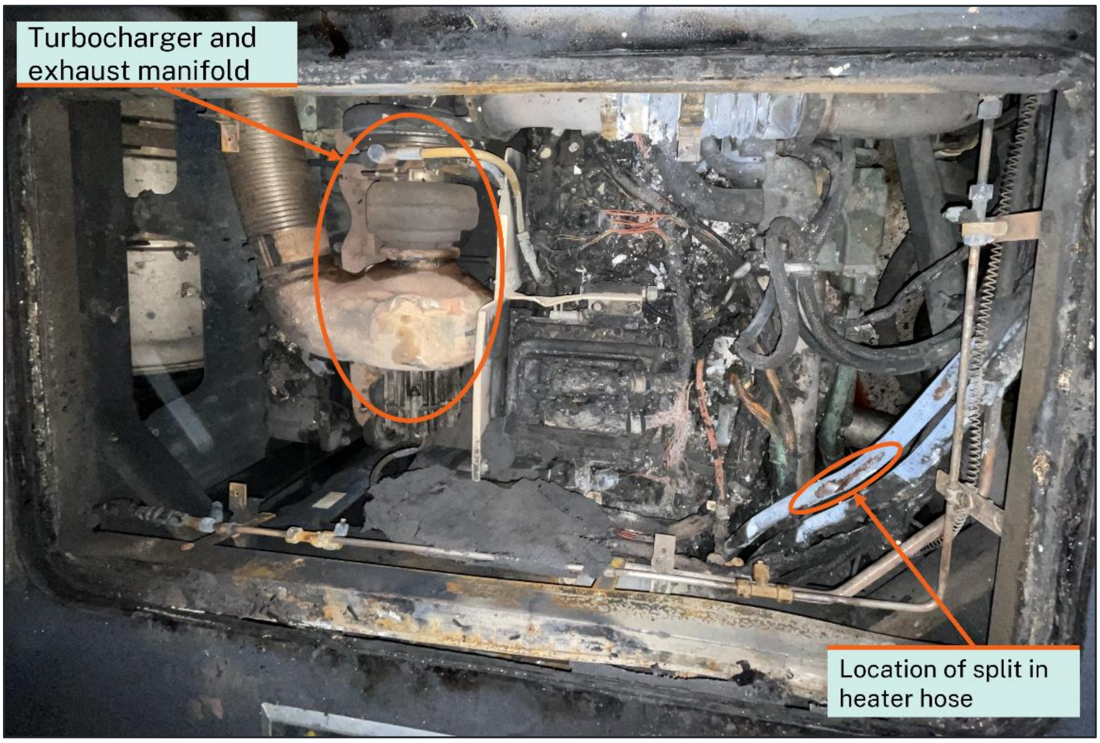
Figure 18: Heat patterns and coolant residue



Source: OTSI

[18] https://www.edtengineers.com/blog-post/fire-effects-steel

Figure 19: Location of damaged hose and turbocharger

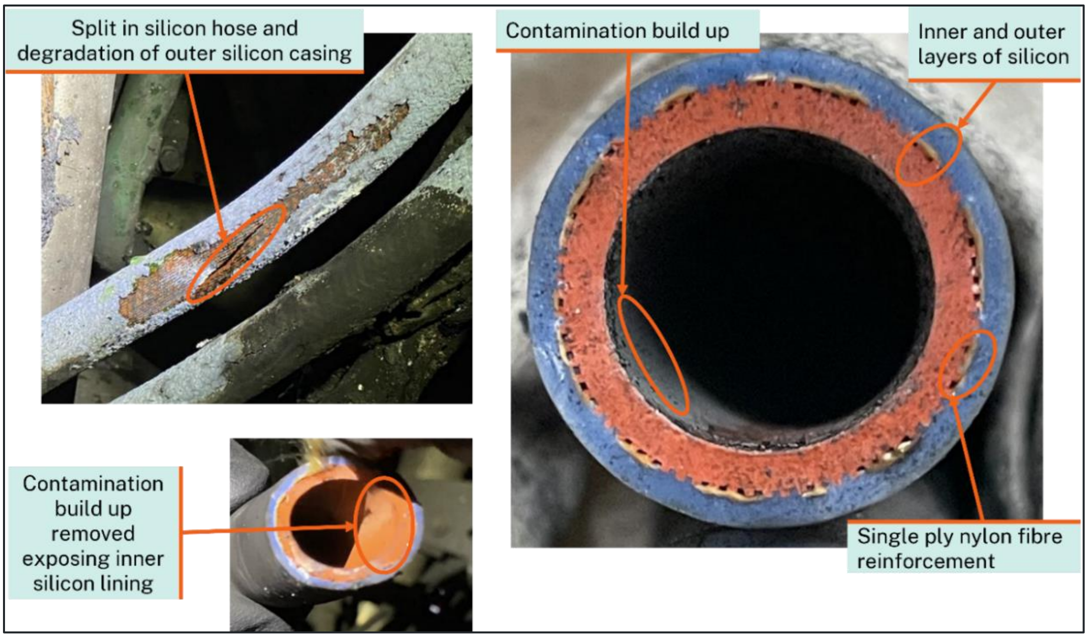


Source: OTSI

Silicone hoses

2.21 The defective hose was one of two hoses connected to the cooling system of the engine that ran forward to supply heated coolant to the saloon heater matrix. The hoses were of silicone construction with a single ply nylon fibre reinforcing layer (Figure 20).

Figure 20: Damage to silicone hose and cross section construction

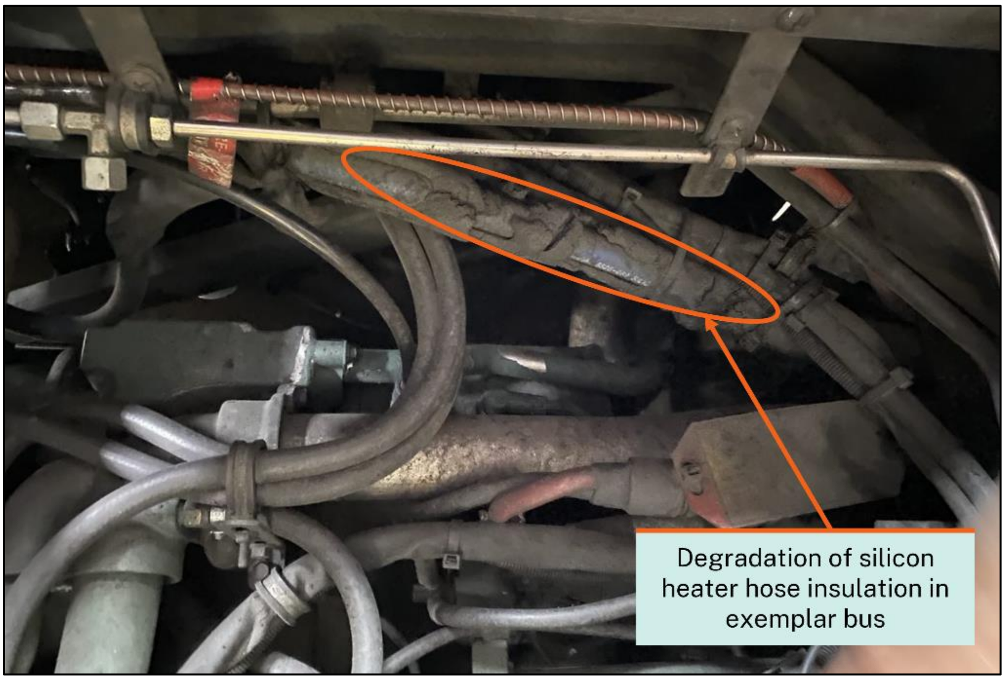


Source: OTSI

2.22 Examination of an exemplar bus of the same make and model revealed that identical silicone heater hoses passing through the engine bay were covered in an NBR/PVC[19] based closed cell, flexible elastomeric foam insulation. The purpose of this insulation was to protect the silicone hose from contaminants and ambient engine bay temperatures.

2.23 Figure 21 shows degradation of this insulation of the exemplar bus, exposing the silicone hose to ambient engine bay temperatures.

Figure 21: Degradation of silicon heater hose outer insulation in exemplar bus



Source: OTSI

2.24 Examination of the two silicon heater hoses fitted to 2169ST indicated that the foam insulation had been consumed by the ensuing fire.

2.25 Silicone rubber is used in engine cooling systems due to its high thermal stability and chemical resistance. Nevertheless, with repeated exposure to harsh conditions, silicone rubbers can degrade over time as part of their ageing process.

2.26 Ageing results in the deterioration of the mechanical properties of silicone such as its tensile strength, tear strength and hardness, eventually leading to its possible failure.

2.27 Several factors, such as temperature, oxygen, water, plasticisers, acids, and bases, can accelerate this ageing or degradation process.

19 NBR/PVC compounds are homogenous butadiene and acrylonitrile copolymer blends with PVC that uses CA/ZN based stabilizers. NBR/PVC blends are recommended for applications that require good resistance to the elements and organic liquids, such as aliphatic oils and nonpolar solvents.

2.28 One of the most crucial factors for silicone degradation is temperature. Studies have shown that silicone ageing or degradation accelerates with increasing temperature.[20,21]

2.29 Studies have also identified temperature or thermal cycling (e.g., between -10 and 90 °C) as a major cause of silicone ageing and failure.[22,23,24] In addition, most components of typical engine coolants, including water, ethylene glycol and corrosion inhibitors have been shown to act as prodegradants for silicone.[25,21,26]

2.30 It should be noted that one corrosion inhibitor, 2-ethylhexanoic acid (2-EHA), used in the OEM extended life coolant for 2169ST has been identified as a silicone prodegradant.

2.31 Certain manufacturers have warned against the use of the coolants containing 2-EHA, a known plasticiser, in engine cooling systems fitted with silicone hoses[27]

2.32 However, OTSI found that although there are studies[25,28] which have shown that residual 2-EHA (leftover by-product of a catalyst used during the production of silicone rubbers) can act as a pro-degradant for silicone, there are some important considerations when it comes to coolants.

1. 2-EHA in coolants is typically at exceptionally low concentrations,
2. Ethylene glycol which is present at a much higher concentration (typically 30-60%) is also a plasticiser which has been shown to be a silicone prodegradant as well,[21] and
3. most importantly, the mechanism of silicone degradation reported for 2-EHA in literature is not unique to 2-EHA and can theoretically be caused by other acids as well. Acid hydrolysis is a major degradation mechanism for silicone rubbers and silicone degradation is known to increase with increasing acid concentration (or reducing pH). Further, several acids have been reported to accelerate silicone degradation at elevated temperatures.[29, 30]

2.33 Finally, ethylene glycol is known to degrade into acidic by-products such as glycolic, formic, and acetic acids, thus reducing the pH of the coolants with age.[31] This suggests that silicone degradation may not be attributed to 2-EHA alone.[26,32]

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20 Patel M., Skinner A. R. Thermal ageing studies on room-temperature vulcanised polysiloxane rubbers. Polym. Degrad. Stab. (2001), 73, 399-402

21 Aronson A., et al. The Combined Effect of High Temperature and Ethylene Glycol (EG) on Polyethylene Terephthalate (PET)-Reinforced Coolant Hose Failure in Combustion Engine. J Fail. Anal. and Prevention. (2021), 21, 462-471

22 Wu F., et al. Degradation of the sealing silicone rubbers in a proton exchange membrane fuel cell at cold start conditions. Int. J. Electro - Chem. Sci. (2020)

23 Wen X., et al. RTV silicone rubber degradation induced by temperature cycling. Energies (2017), 10 1054-1066

24 Kashi S., et al. Mechanical, thermal, and morphological behaviour of silicone rubber during accelerated aging. Polym. Plast. Technol. Eng. (2018), 57, 1687-1696

25 Labouriau A., et al. Aging mechanisms in RTV polysiloxane foams. Polym. Degrad. Stab. (2015), 121, 60-68

26 Wilson T. N. A Comparison of Various Polymers in Select Organic Acid Technology (OAT) Coolants. 2000-01- 1095. SAE Technical Paper (2000)

27 https://penriteoil.com.au/assets/img/api_imgs/Silicone-Hose-Fitting.pdf (accessed on 19 December 2022)

28 Lewicki J. P., et al. The thermal degradation behaviour of polydimethylsiloxane/montmorillonite nanocomposites. Polym. Degrad. Stab. (2009), 94, 1548-1557

29 Li, G., et al. Degradation of the elastomeric gasket material in a simulated and four accelerated proton exchange membrane fuel cell environments. J. Power Sources (2012), 205, 244-251

30 Pehlivan-Davis S., et al. Comparison of accelerated aging of silicone rubber gasket material with aging in a fuel cell environment. J. Appl. Polym. Sci. (2013), 129, 1446-1454

31 Serios N. M. Long term compression stress relaxation evaluation of elastomers OAT coolants. Technical Paper, 3M (2021) https://multimedia.3m.com/mws/media/2065622O/long-term-compression-stress-relaxation-evaluation-of-elastomers-oat-coolants.pdf?elqTrackId=cf10385d906045008abe91c69e763d46 (accessed on 19 December 2022)

32 Hertz Jr D., et al. Elastomer Service Life Prediction in Organic Acid Coolants. 2001-01-1179. SAE Technical Paper (2001)

Fire suppression system alarms and effectiveness

2.34 Review of CCTV footage from the incident indicated that between 1551:22 and 1551:32, the driver of 2169ST was momentarily distracted from their normal driving activities and focused toward the area of the instrument panel. This apparent distraction occurred while the bus was stationary at a set of traffic lights.

2.35 The bus continued for approximately two minutes before coming to a stop at 1553:32, following the driver being advised by a passing motorist of smoke issuing from the bus.

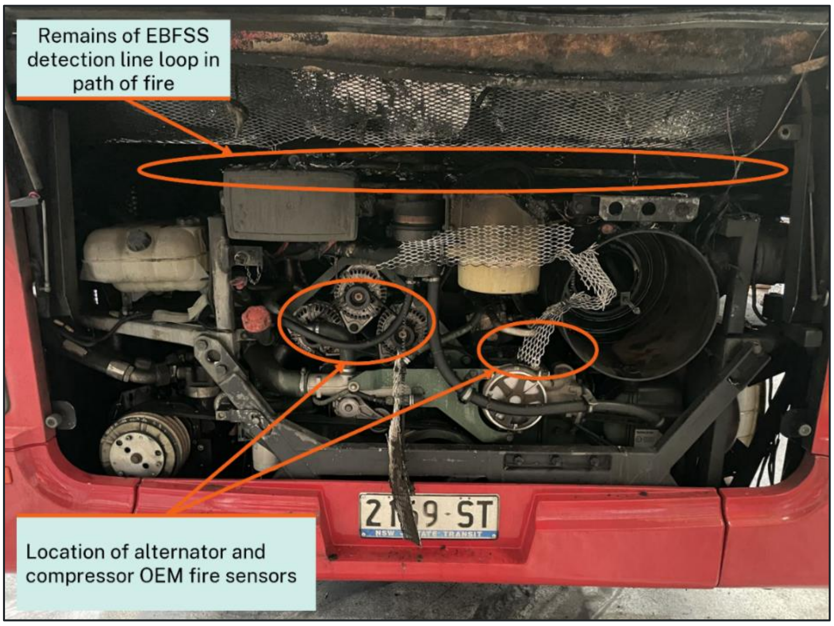
2.36 In consideration of the two minute time frame between the pause at the set of lights and the presence of smoke when the bus came to a standstill, it is likely that the fire had already commenced and activated one of the two fire alarms.

2.37 It is likely that what drew the drivers attention to the instrument panel was either the OEM fire alarm or the EBFSS alarm.

2.38 Therefore, the driver's focus on the instrument panel prior to being advised of the fire would suggest they were either unaware, or unfamiliar with the alarm that had likely appeared on the instrument panel.

2.39 The OEM fire alarm sensors were located adjacent to the starter motor, air compressor and alternators and are below the level of the EBFSS detection line (Figure 10,Figure 22).

Figure 22: Location of EBFSS detection loop and OEM fire sensors



Source: OTSI

2.40 It is likely that heat from flame activity was forced across the engine assembly, towards the upper EBFSS detection circuit by the air flow from the engine cooling fan. As such, the EBFSS alarm would have activated and provided an alarm on the driver's instrument panel.

2.41 Continued operation of the bus, following the likely discharge of the EBFSS, may have degraded the effectiveness of the EBFSS to extinguish the ensuing fire, due to continuing flow of coolant into the area, residual heat from the engine, and thermal activity. It is likely that following the discharge of the EBFSS the fire either continued or reignited.

2.42 Two previous fires (Surry Hills, and Railway Square) investigated by OTSI involved glycol-based coolant leaks. In both instances, the buses were fitted with similar pre "P" Mark Fogmaker EBFSS. Following discharge of the systems, the fires either continued to burn or reignited.

2.43 While the engine bay fire suppression systems fitted to buses may extinguish a large portion of fires, the objective is to suppress the fire sufficiently so that passengers can be safely evacuated.[33]

2.44 In this occurrence, continued operation of the bus after a likely activation of the EBFSS, reduced the time margin for safe evacuation of the passengers. CCTV footage indicated that smoke was not visible when the bus was stationary at the set of traffic lights. An evacuation at that point would have provided the passengers and driver with additional time for a safe evacuation, and likely limited exposure to smoke.

2.45 With smoke observed to be entering the bus's saloon area, during the later evacuation, there was a reduced period for safe evacuation, after the EBFSS activation, before smoke entered the salon area, and fire escalated.

2.46 However, the evacuation in this instance was effective and all passengers were evacuated within 11 seconds of the bus coming to a standstill.

Asset management/inspection maintenance

2.47 TSW maintenance records indicated that the EBFSS system was serviced and maintained in accordance with relevant standards and OEM requirements.

2.48 Regular scheduled services and inspections of the engine bay cooling system were based on the requirements of the OEM. The last service/inspection conducted on the bus on 11 September 2021 did not identify any defects or repairs to the two silicon heater hoses, or any other component of the cooling system.

2.49 At the time of the incident, the bus was required to undergo a bi-annual inspection by TfNSW inspectors. The inspection report was titled *AZ2487775, Roads and Maritime Services NSW, Heavy Vehicle Inspection Scheme (HVIS) Inspection Report*. The inspections criteria were contained in the '*Rules for Authorised Inspection Stations (Heavy Vehicles), Road Transport (Vehicle Registration) Regulation 2017 or Heavy Vehicles (Vehicle Standards) National Regulation (NSW')* including the '*National Heavy Vehicle Inspection Manual (NHVIM) Version 2.3, July 2018'*.

2.50 The NHVIM applies to all vehicles that have a gross vehicle mass (GVM) or aggregate trailer mass (ATM) greater than 4.5 tonnes. It provides consistent criteria for when a vehicle should fail a heavy vehicle inspection and therefore be considered defective.

2.51 The NHVIM version 2.3 July 2018 and version 3.0 October 2021, *Section 11 –* E*ngine, Driveline, and Exhaust*, had no specific requirement to identify coolant leaks from the engine, associated components of the cooling system or condition of any of these components.

2.52 The most recent compliance inspection conducted on 2169ST, 03 September 2021, did not identify any defects on the bus according to the criteria contained within the NHVIM.

33 Bus Industry Confederation Fire Mitigation Advisory 2014

Driver training/alarms

2.53 Following notification to OTSI of a thermal incident or bus fire, additional information from the bus operator would be requested by OTSI. This request was facilitated using a *Bus Fire / Thermal Incident Information Collection Form*.

2.54 Information requested includes the date that the driver of the incident bus was last trained in evacuation procedures and the use of fire extinguishers.

2.55 For the calendar year 2021, OTSI received 52 information collection forms from TSW. Of the 52 forms received, 15 (28.8%) documented "*Ex-STA – No records kept*" for the date the involved driver was last trained.

2.56 Similarly, for the calendar year 2022, 46 information collection forms were received, with 16 (34.7%) noting for training, "*Ex-STA – No records kept*".

2.57 This information indicated that for 31 drivers, and the driver of 2169ST, there was no supporting evidence that training in evacuation procedures and/or the use of a fire extinguisher was provided by the operator since the commencement of the TSW contract in July 2018. In addition, the involved operator did not have documented assurance records of training provided to their drivers under STA, in absence of the provision of training under the TSW contract.

2.58 The recorded behaviour of the driver, at the lights at Glebe Point Road and subsequent delayed stop after the likely activation of the EBFSS, indicated that the driver may have been unfamiliar or unaware of the functionality of the OEM and Fogmaker fire alarms.

2.59 This may have been influenced by the limited information supplied by TSW, in relation to the fire suppression systems fitted to their fleet. With the EBFSS information provided by TSW, not specifically identifying the type of visual fire alarm fitted to 2169ST, the driver may have been unaware of the altering functionality. Confusion may have also resulted from several differing OEM systems in the TSW fleet and on 2169ST using the same audible and visual master alarm.

2.60 A review of the TSW training documents obtained by OTSI, identified that the functionality of the OEM and EBFSS alarms incorporated into the instrumentation panel fitted to 2169ST was not included in the driver training.

2.61 This was due to the training material focusing on the Fogmaker smart panel system, which had a separate screen and alarm to alert the driver to an engine bay fire. This alarm panel was not fitted to 2169ST.

2.62 While the driver did not stop the bus immediately at the time of the likely EBFSS activation, the driver's actions, after bringing the bus to a stop, indicated that the evacuation and securing procedures of the bus were performed in accordance with TSW's evacuation procedures.

Other factors of increased risk

2.63 During the post incident inspection of 2169ST, the cable ties securing cabling in the O/S rear A/C duct were discovered to be fractured. This enabled the cables to chafe against several surfaces potentially exposing the cable conductor. Once exposed, the conductor can come into contact with metal surfaces increasing the risk of an electrical short circuit.[34]

2.64 The fracture pattern of cable ties differed from those normally seen from the pattern found when cable ties are cut, such as with side cutters. However, the fracture surface observed was consistent with fatigue fracturing and embrittlement.[35]

2.65 Most standard cable ties are primarily made of Polyamide 6/6, more commonly known as 'Nylon 6/6'.

2.66 Nylon, as a hygroscopic material, can absorb and hold moisture from its surroundings. This means that nylon cable ties absorb and/or lose moisture according to their environment.

2.67 Nylon cable ties are naturally brittle post manufacture and prior to a moisture content conditioning process. However, most nylon cable ties will become brittle in conditions where there is a combination of extreme temperatures and very low humidity.[36]

2.68 When dry, nylon is stiff and brittle, and when moist it is pliable and tough. Most nylon cable tie brittleness problems come about from exposure to dry conditions and as a result the moisture in the tie is fully desorbed. Dry ties will exhibit several failure modes. The most common failures under dry desorbed conditions are the pawl breaking out of the head and/or the strap snapping.

2.69 The A/C system fitted to the bus is designed to cool the air within the saloon area by passing liquid refrigerant inside the evaporator coil converting it to gas. The heat from the saloon air is absorbed into the refrigerant, thus cooling the air as it passes over the coil and is blown into the A/C ducting distribution network. Additionally, as the saloon air passes over the coil, moisture is removed from the air reducing the humidity content within the ducting network.

2.70 It is possible that the reduction in the humidity within the A/C ducting network affected the moisture content of the cable ties supporting the cabling attached to the A/C gas lines, causing them to become brittle and break (Figure 14,Figure 15).

2.71 It is also possible that this process was exacerbated by excessive movement of the A/C gas lines due to the securing fasteners holding the gas line clamps becoming loose and dislodging from the overhead support brackets (Figure 14).

2.72 A Fire Mitigation Electrical check was carried out prior to the incident on 23 November 2021. A check of the security and condition of the cables in the OSR A/C duct within work order (W/O) 232462 (Figure 23) is listed as item 40 (*Check main cables security/mounting in A/C ducting*).

2.73 Review of this document found the security and condition of the cabling had been ticked as a "*Pass*". This inspection was carried out seven weeks prior to the incident.

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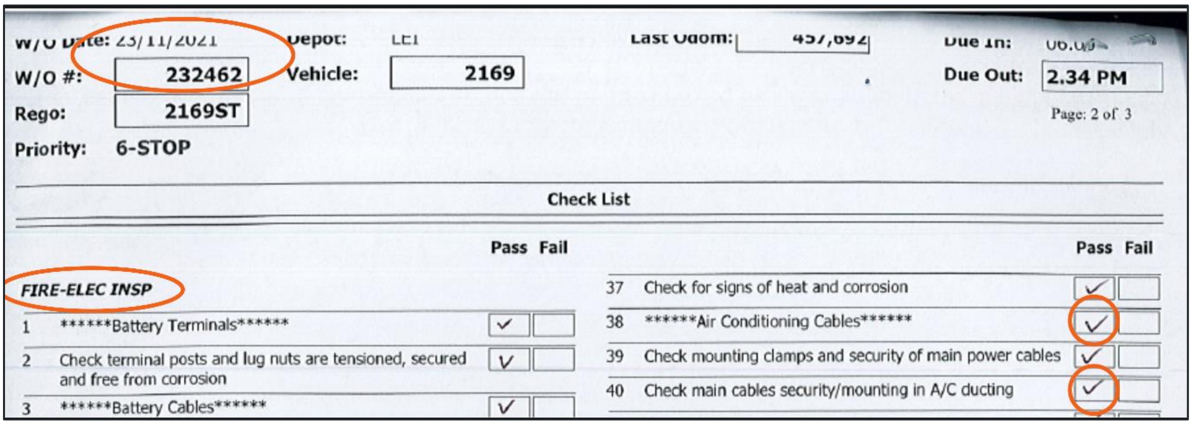
[34] Short circuit is an abnormal connection (including arc) of relative low impedance, whether made accidentally or intentionally, between two points of different potentials. IEEE 2006 IEEE *Recommended Practice for Calculating Short-Circuit Currents in Industrial and Commercial Power Systems* (New York: IEEE) p 7

[35] Embrittlement is a significant decrease of ductility of a material, which makes the material brittle. Embrittlement is used to describe any phenomena where the environment compromises a stressed material's mechanical performance, such as temperature or environmental composition.

[36] UK Electric Ltd t/a Takbro incorporating EA Fixings 2023 - Company Registration No: 2742081

Figure 23: Fire mitigation electrical inspection


W/O Date: 23/11/2021 Depot: LEI Last Odom: 457,692 Due In: 06.00
W/O #: 232462 Vehicle: 2169 Due Out: 2.34 PM
Rego: 2169ST Page: 2 of 3
Priority: 6-STOP

Check List

		Pass	Fail			Pass	Fail
	FIRE-ELEC INSP			37	Check for signs of heat and corrosion	✓	
1	******Battery Terminals******	✓		38	******Air Conditioning Cables******	✓	
2	Check terminal posts and lug nuts are tensioned, secured and free from corrosion	✓		39	Check mounting clamps and security of main power cables	✓	
3	******Battery Cables******	✓		40	Check main cables security/mounting in A/C ducting	✓	

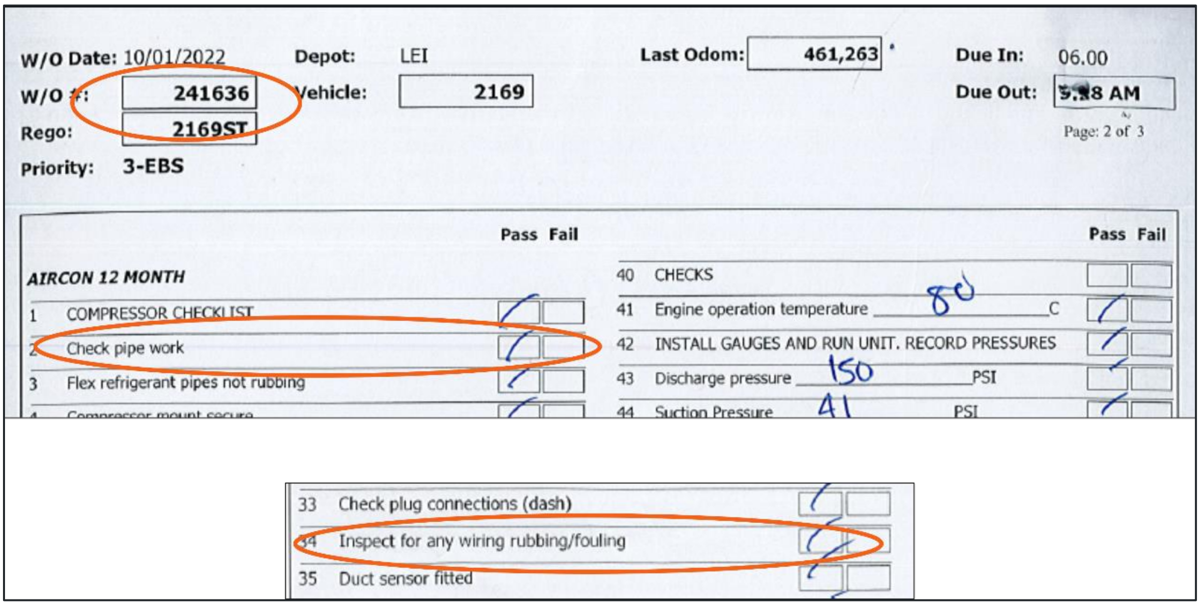
Source: OTSI

2.74 Another inspection was reported as being carried out on the same area of the OSR A/C ducting including the security of the A/C gas lines and associated cabling (Figure 24).

2.75 According to the date listed on the W/O and TSW service records, the inspection was carried out three days prior to the incident. W/O 241636 inspection item 2 (*Check pipe work*) and item 34 (*Inspect for any wiring rubbing / fouling*) were both noted on the work order to be in a "Pass" condition.

2.76 When inspected post incident by OTSI, the condition of the O/S rear A/C duct area wiring, A/C pipe work and number of fractured cable ties indicated that the deterioration was present at the time of the inspection but not identified.

Figure 24: A/C inspection work order


W/O Date: 10/01/2022 Depot: LEI Last Odom: 461,263 Due In: 06.00
W/O #: 241636 Vehicle: 2169 Due Out: 5.58 AM
Rego: 2169ST Page: 2 of 3
Priority: 3-EBS

		Pass	Fail			Pass	Fail
	AIRCON 12 MONTH			40	CHECKS		
1	COMPRESSOR CHECKLIST	✓		41	Engine operation temperature 80 C	✓	
2	Check pipe work	✓		42	INSTALL GAUGES AND RUN UNIT. RECORD PRESSURES	✓	
3	Flex refrigerant pipes not rubbing	✓		43	Discharge pressure 150 PSI	✓	
4	Compressor mount secure	✓		44	Suction Pressure 41 PSI	✓	

		Pass	Fail
33	Check plug connections (dash)	✓	
34	Inspect for any wiring rubbing/fouling	✓	
35	Duct sensor fitted	✓	

Source: OTSI

2.77 In April 2015, OTSI investigated a fire involving an articulated Volvo B12BLEA which was initiated by a failed turbocharger unit. While the initial fire event was unrelated to the interior wiring, heat from the improperly insulated vertical exhaust stack caused the insulation of the main A/C cables to melt and expose the internal conductors. The result was the conductors, a positive and negative, short circuited with each other.

2.78 The short circuit then added additional energy to the interior of the bus causing a fire to start independently of the original event. This secondary event then propagated rapidly through the interior of the bus causing extensive damage to the rear half of the bus.

2.79 That incident highlighted the risk of short circuits within high amperage circuits located within the passenger saloon area and the potential for the rapid spread of fire.

Proactive safety actions

2.80 Post incident, the bus operator initiated an inspection and change out program for the two silicon heater circuit supply hoses for the remaining Volvo B12BLEA Volgren bodied fleet. Hoses that were found to be in similar condition to those found in 2169ST were replaced.

2.81 Changes were made post incident to the content of scheduled 'Fire Mitigation Electrical Inspections' work orders to include conditional monitoring of A/C cables located behind A/C ducting panels.

2.82 TfNSW reported that they have identified opportunities to engage with internal stakeholders to review the assurance activity to the applicable standards for current asset management processes and communicate key findings of the investigation to relevant TfNSW departments.

Part 3 — Findings

From the evidence available, the following findings are made with respect to the bus fire involving Volvo B12BLEA, registration 2169ST, which occurred in Camperdown, NSW on 13 January 2022.

Contributory factors

3.1 A defect occurred in a silicone coolant hose that supplied coolant to the saloon heater matrix. The defect was likely caused by a combination of the engine bay operational environment, degradation of the protective insulation covering, service life and the engine coolant composition.

3.2 The combustible nature of coolant, released under pressure from the defective silicone coolant hose, likely resulted in coolant as the principal fuel source in the commencement of the fire event.

3.3 At the time of the event, the maintenance regime for Volvo B12BLEA CR228L bodied vehicles did not include change out programs for silicone hoses, which increased the potential risk of degraded hoses resulting in failure during operation.

Other safety factors

3.4 The existing inspection regime, for electrical systems in the air conditioning ducting of the involved bus body, did not identify inadequate cable security or wire chafing, which increased the potential risk of electrical fires starting within the saloon area.

3.5 Regulatory inspection of the bus did not include the condition of coolant hoses, insulation, or engine bay coolant leaks.

3.6 There was no supporting documentation to assure that the driver of 2169ST was provided with emergency training during their employment with the involved bus operator, or with the previous operator.

3.7 The involved bus operator did not have documented assurance records of training provided to their drivers under the previous operator, in absence of the provision of training under their own contract.

3.8 The bus operator’s training documentation did not include identification of the instrument panel fire alarm for the involved bus or identical model buses within their fleet, which may have reduced the effectiveness of driver response to an alarm activation.

Other findings

3.9 The engine bay fire suppression system was likely activated and though it would have suppressed the fire, it was not able to extinguish it.

Part 4 — Recommendations

Noting that some remedial safety action has already been implemented, it is recommended that the following additional safety actions be undertaken by the specified responsible entity.

Transit Systems West

4.1 Review training material and competency requirements to ensure that drivers have a thorough understanding of all alarms and warning systems fitted to all buses in their fleet.

4.2 Review assurance processes for scheduled maintenance and inspections to ensure all tasks are completed satisfactorily.

Bus and coach operators

4.3 Consider initiating component change out programs for silicone coolant hoses based on anticipated replacement prior to failure or serviceable life of such components, within existing scheduled preventative maintenance activities.

4.4 Monitor condition of and replacement of unserviceable silicon hose insulating materials to prevent deterioration of the silicone hoses due to ambient temperature effects.

4.5 Incorporate into their maintenance regime ongoing routine inspection of high amperage electrical circuits, including checks for wiring security and abrasion, including replacing broken, brittle and or missing cable ties, to reduce the risk of fire. These checks to include cabling and wiring in A/C ducting and areas not normally accessed in scheduled inspections.

Transport for NSW

4.6 Inclusion in TfNSW contract bus supply panel specifications that the material of the hoses fitted during the body build process, and the projected lifespan of these hoses, are provided for inclusion as part of the operator’s Technical Maintenance Plan. This is to ensure that operators are informed that these hoses are critical components that need to be changed on a time or condition replacement basis.

Part 5 — Appendices

Appendix 1: Sources, submissions, and acknowledgements

Sources of information

- Transit Systems West Pty Ltd
- Transport for NSW
- Volvo VBA
- United Safety & Survivability Corporation
- OTSI Bus Safety Report, Bus Fires in New South Wales in 2021, 2022.
- National Heavy Vehicle Inspection Manual Version 2.3 (July 2018)
- UK Electric Ltd t/a Takbro incorporating EA Fixings 2023 - Company Registration No: 2742081
- AS5062-2006 Commissioning, and maintenance for use on mobile and transportable equipment

Submissions

The Chief Investigator forwarded a copy of the Draft Report to the Directly Involved Parties (DIPs) to provide them with the opportunity to contribute to the compilation of the Final Report by verifying the factual information, scrutinising the analysis, findings, and recommendations, and to submit recommendations for amendments to the Draft Report that they believed would enhance the accuracy, logic, integrity and resilience of the Investigation Report. The following DIPs were invited to make submissions on the Draft Report:

- Transit Systems Pty Ltd
- Transport for NSW
- Volgren
- Volvo

Submissions were received from the following DIP:

- Transport for NSW

The Chief Investigator considered all representations made by DIPs and responded to the author of each of the submissions advising which of their recommended amendments would be incorporated in the Final Report, and those that would not. Where any recommended amendment was excluded, the reasons for doing so were explained.

About the Office of Transport Safety Investigations

The Office of Transport Safety Investigations (OTSI) is the independent transport safety investigator for NSW.

The role of OTSI is to improve safety and enhance public confidence in the safety of the NSW transport network through:

- independent investigation of transport incidents and accidents
- identifying system-wide safety issues and their contributing factors
- sharing safety lessons and making recommendations or highlighting actions that transport operators, regulators and other stakeholders can take to improve the safety of bus, ferry and rail passenger and rail freight services.

OTSI is empowered under the *Transport Administration Act 1988* to investigate rail, bus, and ferry accidents and incidents in accordance with the provisions of the *Passenger Transport Act 1990* and *Marine Safety Act 1998*. It also conducts rail investigations under the provisions of the *Transport Safety Investigation Act 2003* (Cth) and a Collaboration Agreement with the Australian Transport Safety Bureau (ATSB).

The aim of an OTSI investigation is to enhance transport safety by sharing safety lessons and insights with those organisations that can implement actions to improve safety. OTSI uses a 'no-blame' approach to identify and understand contributing safety factors and underlying issues. It does not assign fault or determine liability in relation to the matters it investigates.

An OTSI investigation is independent of any investigation or inquiry that a regulator, NSW Police or the Coroner may undertake. Evidence obtained through an OTSI investigation cannot be used in any criminal or civil proceedings. While information gathered by OTSI in the conduct of its work is protected, the Chief Investigator, under the *Transport Administration Act 1988*, may disclose information if they think it is necessary for the safe operation of a transport service.

OTSI is not able to investigate all transport safety incidents and accidents or matters that are reported. The Chief Investigator focuses the agency's resources on those investigations considered most likely to enhance bus, ferry or rail safety by providing new safety lessons and insights that may be shared.

Many accidents result from individual human or technical errors which do not involve safety systems so investigating these in detail may not be justified. In such cases, OTSI will not generally attend the scene, conduct an in-depth investigation, or produce an extensive report.

OTSI may request additional information from operators or review their investigation reports which may lead to several activities, such as the release of a Safety Advisory or Alert to raise industry awareness of safety issues for action.

OTSI investigators normally seek to obtain information cooperatively when conducting an investigation. However, where it is necessary to do so, OTSI investigators may exercise statutory powers to conduct interviews, enter premises and examine and retain physical and documentary evidence.

Publication of the investigation report

OTSI produces a written report on every investigation for the Minister for Transport, as required under section 46BBA of the *Passenger Transport Act 1990*.

Investigation reports strive to reflect OTSI's balanced approach to the investigation, explaining what happened and why in a fair and unbiased manner. All Directly Involved Parties in the investigation are given the opportunity to comment on the draft investigation report.

The final investigation report will be provided to the Minister for tabling in both Houses of the NSW Parliament in accordance with section 46D of the *Passenger Transport Act 1990*. The Minister is required to table the report within seven days of receiving it.

Following tabling, the report is published on the OTSI website — www.otsi.nsw.gov.au — and information on the safety lessons promoted to relevant stakeholders.

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