



Office of Transport Safety Investigations

## BUS SAFETY INVESTIGATION REPORT

BUS FIRE

VALLEY HEIGHTS

NEW SOUTH WALES

30 JUNE 2017



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# CONTENTS

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<b>TABLE OF FIGURES</b>	<b>ii</b>
<b>EXECUTIVE SUMMARY</b>	<b>iii</b>
<b>PART 1 FACTUAL INFORMATION</b>	<b>1</b>
Events leading up to the occurrence	1
The occurrence	2
Incident location	3
Environmental conditions	4
Bus information	4
Fire extinguisher and alarms	5
Events following the occurrence	5
<b>PART 2 ANALYSIS</b>	<b>8</b>
Introduction	8
Initiation of the primary fire	8
Factors contributing to continuation of the fire	12
Abrasion and deterioration of the cable insulation	13
Risk management	15
Background to bus engine bay fire suppression systems in NSW	16
Remedial actions taken	17
<b>PART 3 FINDINGS</b>	<b>19</b>
Contributory Factors	19
Other Safety Factors	20
<b>PART 4 RECOMMENDATIONS</b>	<b>21</b>
Comfort Delgro Corporation Australia	21
Transport for NSW	21
Roads and Maritime Services	21
<b>PART 5 APPENDICES</b>	<b>22</b>
Appendix 1: Water Mist Fire Suppression Systems	22
Appendix 2: Sources, References and Submissions	23

## TABLE OF FIGURES

---

Figure 1: Incident location	1
Figure 2: Engine bay of bus 3751MO	3
Figure 3: Engine bay showing part of the FSS network of hoses, pipes and nozzles	6
Figure 4: Distribution hose routed underneath the A/C compressor baseplate	7
Figure 5: Alternator cable, showing the join where an extension was attached	10
Figure 6: Cable showing close-up of the join and evidence of 'arc melt'	10
Figure 7: Exterior of the alloy alternator end case.	11
Figure 8: Interior of the alternator end case.	11
Figure 9: Contact between distribution hose / main chassis harness (alternator)	12
Figure 10: Distribution network for bus 3751MO	16

## EXECUTIVE SUMMARY

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On Friday 30 June 2017 a ComfortDelGro Australia bus was returning to its depot at Valley Heights following the installation of an engine bay fire suppression system. On the journey the driver of the bus noticed a number of electrical faults with the bus ignition and door systems. As a result, the driver called a depot mechanic who relieved him and returned back to the depot with the defective bus. As the bus entered the workshop the mechanic saw smoke emitting from the rear of the bus. The mechanic was not able to turn off the bus with the ignition switch as heat had damaged a pressurised air hose from a pneumatic solenoid to the engine shut-off cylinder

The mechanic inspected the engine bay and observed that the fire suppression system had deployed. The mechanic noticed that a small fire was still active so he utilised a large conventional fire extinguisher to fully extinguish the fire. The engine bay of the bus sustained moderate damage. There were no reports of injuries.

The investigation found that the initial fire started due to an electrical short circuit between a bolted joint to the main alternator cable and the rear of the alternator housing located in the engine bay at the rear of the bus.

It was probable that a newly installed distribution hose associated with the fire suppression system network had disturbed the pre-existing position of the main alternator cable.

It was recommended that the operator examine the design and placement of electrical cabling on similar model buses to reduce the likelihood of short circuit events occurring. It was also recommended that Transport for NSW review the effectiveness of quality assurance procedures and contractual compliance for buses retrofitted with engine bay fire suppression systems

Further recommendations were made to the operator, Transport for NSW and the Roads and Maritime Services. Full details of the Findings and Recommendations of this bus safety investigation are contained in Parts 3 and 4 respectively.



## PART 1 FACTUAL INFORMATION

### Events leading up to the occurrence

- 1.1 On the morning of 30 June 2017, a technician completed the retrofit installation of an Engine Bay Fire Suppression System (FSS)<sup>1</sup> to bus 3751MO at a purpose-operated facility at Len Waters Estate NSW.
- 1.2 A bus driver from ComfortDelGro Australia's (CDC) St Marys depot was allocated the task of retrieving the bus from that facility and driving it back to its home depot at Valley Heights (See Figure 1).

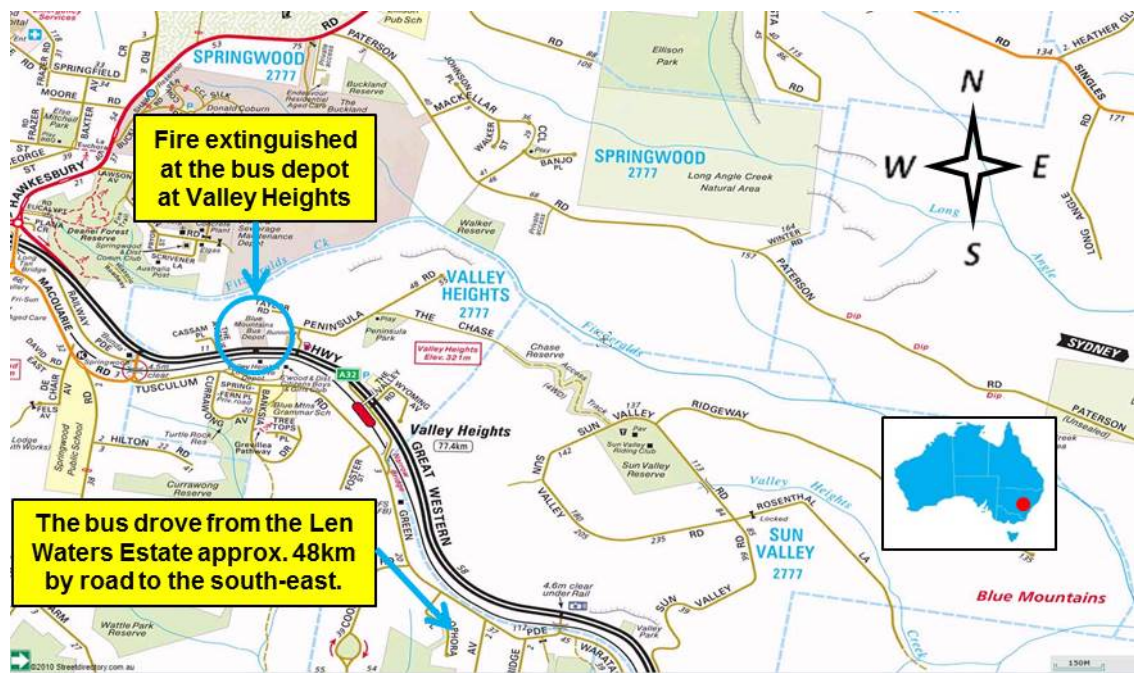


Figure 1: Incident location

- 1.3 Before taking the bus from the facility the driver received basic operating instructions for the FSS from the installation technician. The driver conducted a pre-departure visual inspection of the bus and a visual inspection of the FSS. The driver then checked the available maintenance records to see if the bus had any outstanding defects. Satisfied the bus had no obvious defects, and in the absence of any alarms or anything irregular, the driver drove the bus out of the facility, bound for Valley Heights.

<sup>1</sup> A Fogmaker Fire Suppression System was installed by a representative (technician) of Firestorm Fire Protection Pty Ltd. It was installed as part of a state wide retrofit program managed by Transport for NSW (TfNSW).



- 1.4 En route, the driver noticed a number of electrical issues with the door systems and ignition. As a result the driver called a depot mechanic, who relieved the driver and drove the defective bus back to the CDC Valley Heights Depot.

## The occurrence

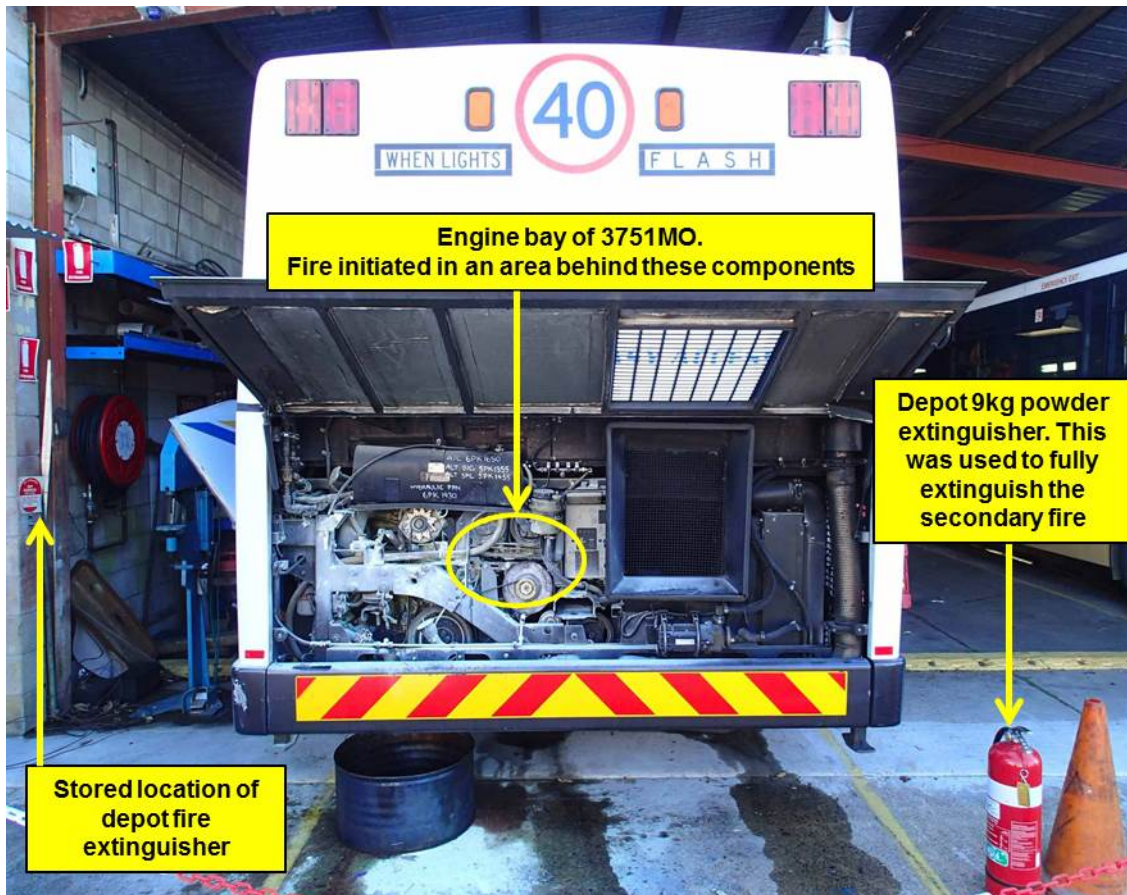
- 1.5 At approximately 1215,<sup>2</sup> the bus entered the workshop area of the CDC Valley Heights Depot. The mechanic said that it was at this point that the FSS dashboard alarm activated and alerted him to the possible presence of a fire.
- 1.6 Shortly after, the mechanic saw smoke emanating from the rear of the bus.
- 1.7 The mechanic unsuccessfully attempted to turn off the bus using the engine shutdown button, located on the driver's dash area.<sup>3</sup>
- 1.8 He then got off the bus and moved to the rear of the bus where he observed fluid dropping from the engine bay area. He then opened the rearmost engine compartment door and saw a small fire in the engine bay.
- 1.9 A large 9kg ABE Type dry chemical powder fire extinguisher was located in the workshop near to the rear of the bus, which the mechanic used to fully extinguish the fire (*See Figure 2*).
- 1.10 At this point, the mechanic was confronted with the situation where the engine was still running, thus increasing the risk that the continual supply of fuel, high pressure liquids and/or electrical energy could reignite the fire.
- 1.11 The mechanic was aware of this risk so he proceeded to access the engine via an internal engine bay floor trap and manually shut down the engine via the fuel injection pump shut-off lever.
- 1.12 Shutting down the fuel injection pump had the effect of isolating the fuel supply to the engine, immediately causing the engine to shut down. This in turn isolated electrical energy to the bus.

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<sup>2</sup> Times in this report are in 24-hour clock format in Australian Eastern Standard Time (AEST): Coordinated Universal Time (UTC) + 10 hours

<sup>3</sup> On this model bus the battery power isolation is controlled by the engine start / stop switch. On some other model buses manual battery isolation switches are found in the battery compartment, or in the engine compartment.

- 1.13 The engine bay of the bus suffered moderate fire damage, mainly confined to wiring looms adjacent to the alternator and the alternator rear housing.
- 1.14 OTSI received notification of the incident and deployed an investigator to the scene that afternoon. The bus was quarantined at the Valley Heights Depot pending further examination.



Source: OTSI

Figure 2: Engine bay of bus 3751MO

## Incident location

- 1.15 Len Waters Estate is a suburb of Sydney located 39km south-west of Sydney's CBD. The bus left from the suppression installation facility at Len Waters Estate, and was driven approximately 48km to Valley Heights Depot. The fire was discovered and extinguished on arrival at the Valley Heights Depot (See Figure 1).

## Environmental conditions

- 1.16 The morning of 30 June 2017 was dry, clear and calm. The Bureau of Meteorology recorded a maximum temperature of 14.9°C at the Springwood (Valley Heights) weather station about 1km west of the Valley Heights Depot.
- 1.17 It was determined that environmental conditions played no part in the incident.

## Bus information

- 1.18 The bus was operated by Blue Mountains Transit Pty Ltd, out of their Valley Heights depot. Since December 2014, Blue Mountains Transit has been a wholly owned subsidiary of the parent company ComfortDelGro Corporation Australia Pty Ltd (CDC).
- 1.19 The bus was a diesel powered, 2003 model Renault Irisbus Agora Line bus, fitted with a Custom Coaches CB60 body. It was registered in NSW as 3751MO. There were six other buses of a similar model in the CDC fleet, two of which were based at Valley Heights.<sup>4</sup>
- 1.20 The odometer reading at the time of the incident was 616,563km.
- 1.21 Maintenance records indicated that the bus had a routine 6-monthly service on 7 June 2017. There were no defects detected relevant to this incident.
- 1.22 A Heavy Vehicle Inspection Scheme (HVIS) inspection was conducted by the Roads and Maritime Services (RMS) on 31 January 2017.<sup>5</sup> No defects were recorded as a result of this inspection.
- 1.23 The bus was authorised to carry 76 passengers, 48 seated and 28 standing. At the time of the incident there were no passengers on board.
- 1.24 There were no previous reported fire incidents for this bus.

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<sup>4</sup> All seven Agora Line buses were acquired with businesses purchased by CDC. Bus 3751MO was acquired in December 2014. Although the Agora Line buses were similar models, they had clear differences in the engine bay fit out. As the original manufacturer no longer existed, these low volume buses were no longer supported by the manufacturer and considered 'orphans' within the CDC fleet.

<sup>5</sup> HVIS Inspection: E-Safety Check No. AZ2005417, dated 31 January 2017. RMS also confirmed that Blue Mountains Transit Pty Ltd held current accreditation and that bus 3751MO was in current registration.

## Fire extinguisher and alarms

- 1.25 An Australian Design Rule 58/00 (ADR 58/00)<sup>6</sup> specified that buses were to be equipped with a readily accessible fire extinguisher located in accordance with the applicable Australian Standard.<sup>7</sup> Located next to the driver's seat was a 2.5 kg Dry Chemical Powder type fire extinguisher.<sup>8</sup>
- 1.26 The FSS had a fire/heat warning sensor system that consisted of a pressurised detection line placed in the engine compartment. When any part of the detection line is heat affected and bursts, the system discharges a water based fire suppressant agent and provides audible and visual dashboard alarms.

## Events following the occurrence

- 1.27 On 3 July 2017, a group of representatives from CDC, Transport for NSW (TfNSW), Firestorm and OTSI carried out an inspection of the bus.
- 1.28 Initial findings were that the fire damage was concentrated in the general vicinity of the main engine-mounted alternator.
- 1.29 As access to that area was difficult, a second inspection was reconvened on 10 July 2017. Prior to this second inspection of the bus, larger components were removed by a CDC mechanic to improve access to the fire damaged area.
- 1.30 The inspection group were informed that a similar model Irisbus Agora Line bus from the Valley Heights Depot, (3744MO) was currently undergoing suppression installation. The group travelled to the installation facility and inspected 3744MO. This inspection uncovered similar problems with the alternator cabling to that found on bus 3751MO.
- 1.31 The inspection also identified a number of mechanical and electrical anomalies within the engine bay that were not directly related to the fire,

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<sup>6</sup> Australian Design Rule 58 *Requirements for Omnibuses Designed for Hire and Reward*

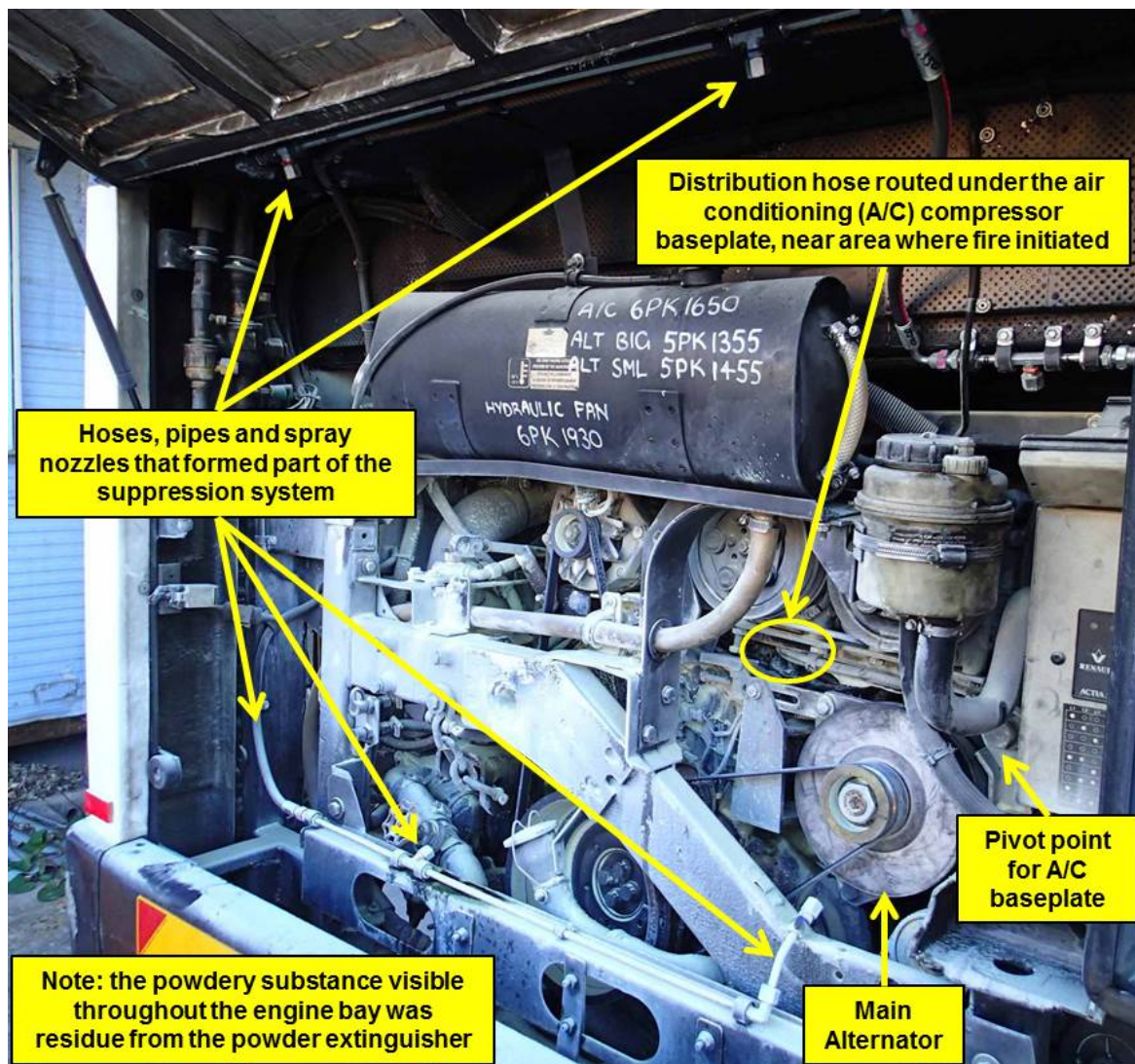
<sup>7</sup> *Portable fire extinguishers and fire blankets – Selection and location*. Australian Standard (AS) 2444—2001.

<sup>8</sup> *Routine service of fire protection systems and equipment*. Australian Standard (AS) 1851—2012. AS 1851 required this type of extinguisher to be checked every six months. The extinguishers' attached service record indicated it was last checked in July 2016.



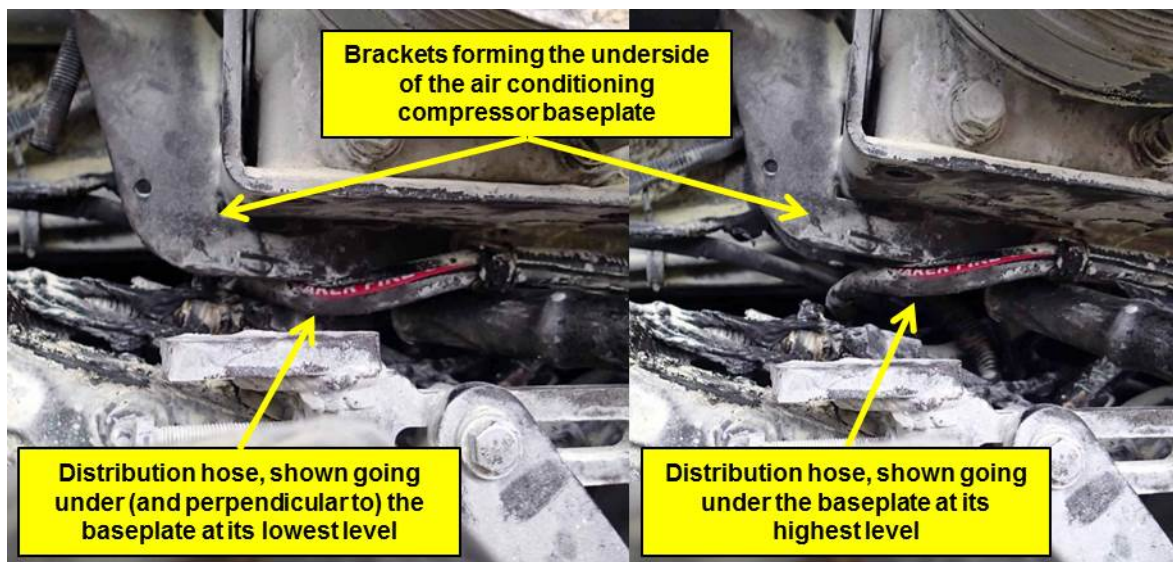
however in the opinion of TfNSW representatives, these required immediate rectification.

- 1.32 Given the risk identified in the inspection of 3751MO, the suppression installation work was suspended. This was pending rectification of the pre-existing mechanical and electrical issues and independent review of routes for the suppression tubing.
- 1.33 Further, TfNSW engaged the services of a consulting mechanical engineer to undertake a forensic technical examination of the thermal damage on the bus. It is noted that this inspection also took place on 10 July 2017 following removal of components critical to the diagnosis of the incident.



Source: OTSI

Figure 3: Engine bay showing part of the FSS network of hoses, pipes and nozzles



Source: OTSI

Figure 4: Distribution hose routed underneath the A/C compressor baseplate

## PART 2 ANALYSIS

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### Introduction

- 2.1 The investigation focussed principally on the factors that contributed to the initiation of the fire event, installation of the FSS, findings from inspections and forensics report and contributing factors of the fire continuation.

### Initiation of the primary fire

- 2.2 The initial bus inspections that were carried out identified that the fire initiated in the engine bay amongst wiring at the back of the main alternator. These and further details were confirmed by the TfNSW forensics report which found that *“an electrical short circuit<sup>9</sup> occurred in the area where a join in the cable carrying a positive electrical load between the alternator and the battery, made contact with the (grounded) aluminium alternator end casing”*.
- 2.3 There was evidence of electrical arcing on both the join in the cable and alternator end casing. The main area of fire damage was concentrated on cabling near, and attached to, the alternator. A variety of cabling was located in this area. These included a pre-existing main chassis wiring harness and electrical cabling associated with the alternator. These were immediately adjacent to or in the vicinity of a newly installed distribution hose<sup>10</sup> associated with the FSS network.
- 2.4 It was observed that the routing of this distribution hose transverses across the top of the main alternator cable, placing downward pressure on the cable. It was also intermingled amongst existing electrical cabling, static mechanical components and moveable components. Notably, it ran perpendicular to one end of the framework of the air conditioner (A/C) compressor baseplate (See *Figures 3 and 4*). It was noted that this baseplate pivoted on an axis point at the opposite end (See *Figure 3*). The routing of this hose restricted available

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9 An [electrical] short circuit is an abnormal connection between two nodes of an electric circuit. This results in an excessive electric current and potentially causes circuit damage, overheating, fire or explosion. [1] Allan R. Hambley (2005). Electrical engineering: principles and applications. Prentice Hall. pp. 637–. ISBN 978-0-13-147046-0. Retrieved 20 April 2011.

10 The *Fogmaker Installation Manual (Version 2.2, page 16)* stated that the distribution hose: *‘It is a special hose that is designed to be able to absorb vibrations to prevent vibration damage to the pipe lines’*. The function of this flexible distribution hose was to transport extinguishant (water with a foam additive) from a piston accumulator to the network of stainless steel pipes, which in turn fed the discharge nozzles. Once released through the nozzles, the extinguishant formed a high-pressure water mist that filled the entire fire affected area.



clearance of the baseplate through its range of movement. When the baseplate was at its lowest point, it exerted increased pressure on the distribution hose, pushing it firmly against the underlying main chassis wiring harness containing the alternator cable (*See Figure 4 and 9*).

- 2.5 Inspection of this area indicated that the position of the distribution hose had probably disturbed the pre-existing position of the alternator loom. This equated to the joint in the alternator cable resting against the alternator end casing (*See Figure 9*). Closer examination of the joint in the cable and alternator end casing revealed evidence of arcing specific to the area where they now made contact.
- 2.6 The pressure exerted on the main chassis harness by the distribution hose was exacerbated by the A/C compressor drive belt not being fitted at the time of the incident. In normal operation the A/C drive belt is tensioned by an air bellows pushing against the A/C base plate frame in an upwards direction which in turn keeps tension on the A/C compressor drive belt. This results in the A/C compressor base plate maintaining an operating height above that which was observed following the fire incident.
- 2.7 The chassis cable, a multi-stranded insulated copper wire, also exhibited evidence of an extension<sup>11</sup> cable fitted to accommodate the output of an additional alternator. The original cable and the extension were joined by two cable lug connections secured using a nut and bolt arrangement and insulated with a heat shrink insulating material. The short circuit occurred between the end of the threaded section of the bolt and the rear housing of the main alternator body.
- 2.8 The TfNSW forensics report confirmed: *'Examination of the bolt clearly depicts copper deposition/fusion derived of the cable terminal..... The scanning revealed clear evidence of copper deposition fused to the aluminium alloy which is consistent with electrical arcing.'*<sup>12</sup> (*Refer to Figures 5 through to 8 which highlight the damage to the chassis cable and alternator end case*).

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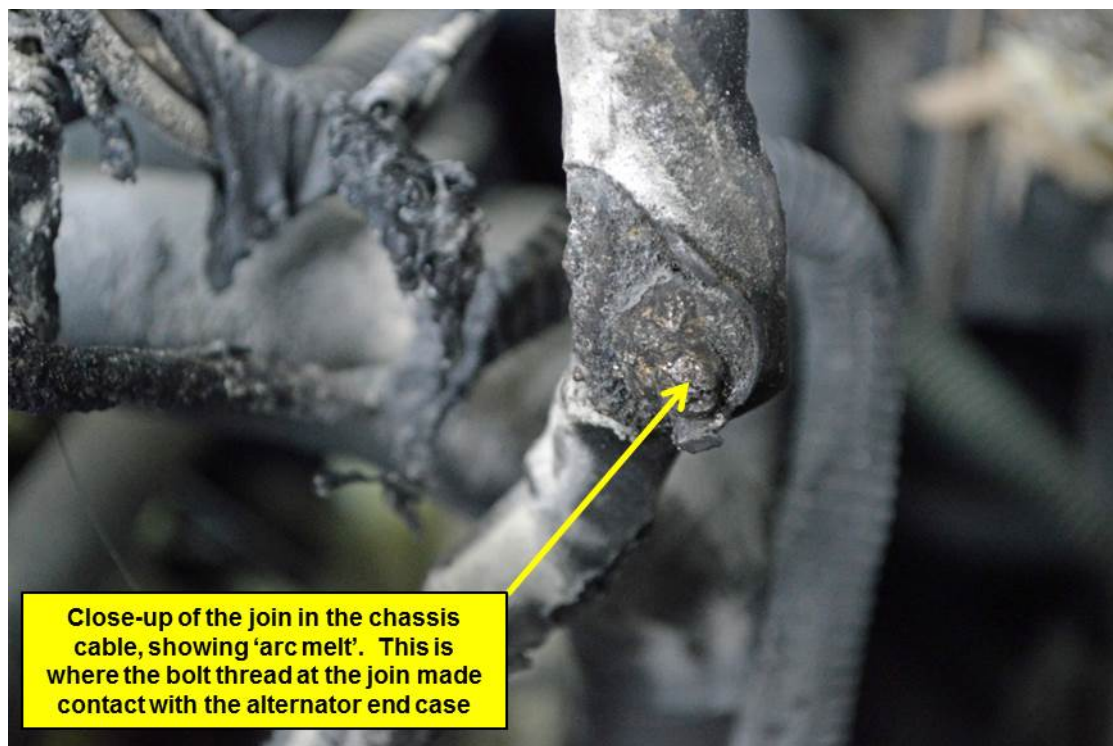
<sup>11</sup> This and other buses were acquired amongst businesses purchased by CDC. CDC was not able to find evidence that this modification occurred after acquiring the bus.

<sup>12</sup> Kennedy's Engineering & Forensics Report: *Report on Thermal Damage to Custom Coach – Registration 3751MO, Blue Mountains Transit, Date of Incident 30-06-2017*. 15 August 2017. p.2



Source: Firestorm Fire Protection Pty Ltd

Figure 5: Alternator cable, showing the join where an extension was attached



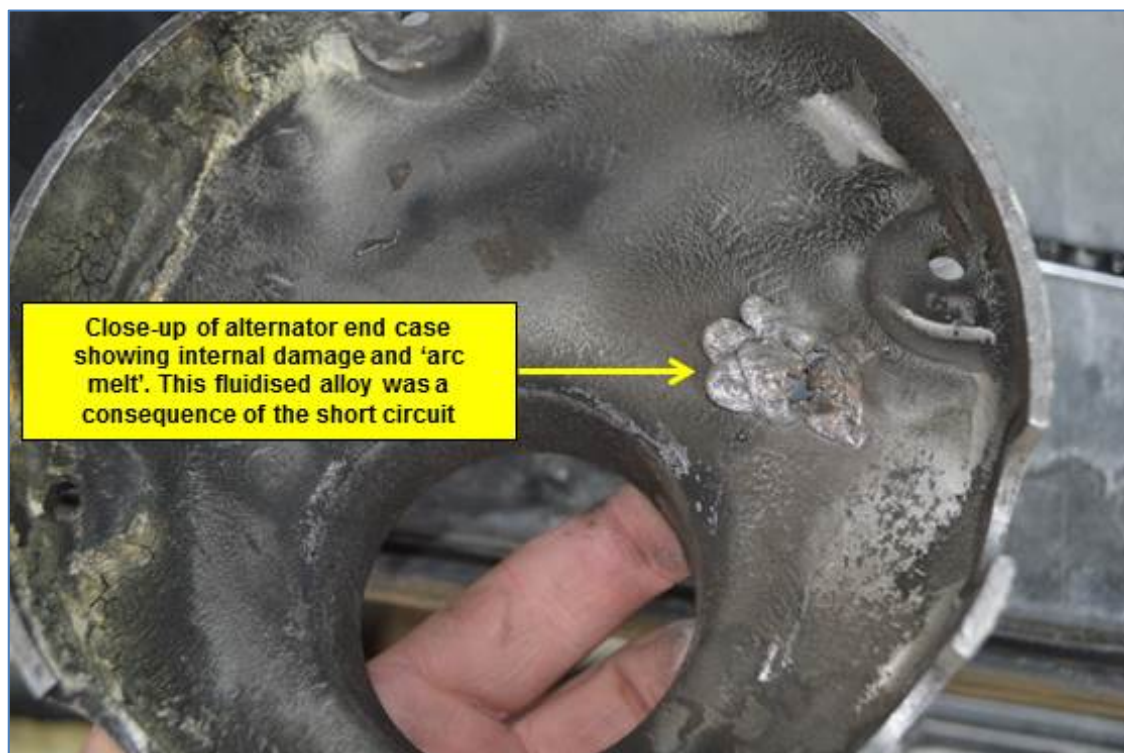
Source: Firestorm Fire Protection Pty Ltd

Figure 6: Cable showing close-up of the join and evidence of 'arc melt'



Source: Firestorm Fire Protection Pty Ltd

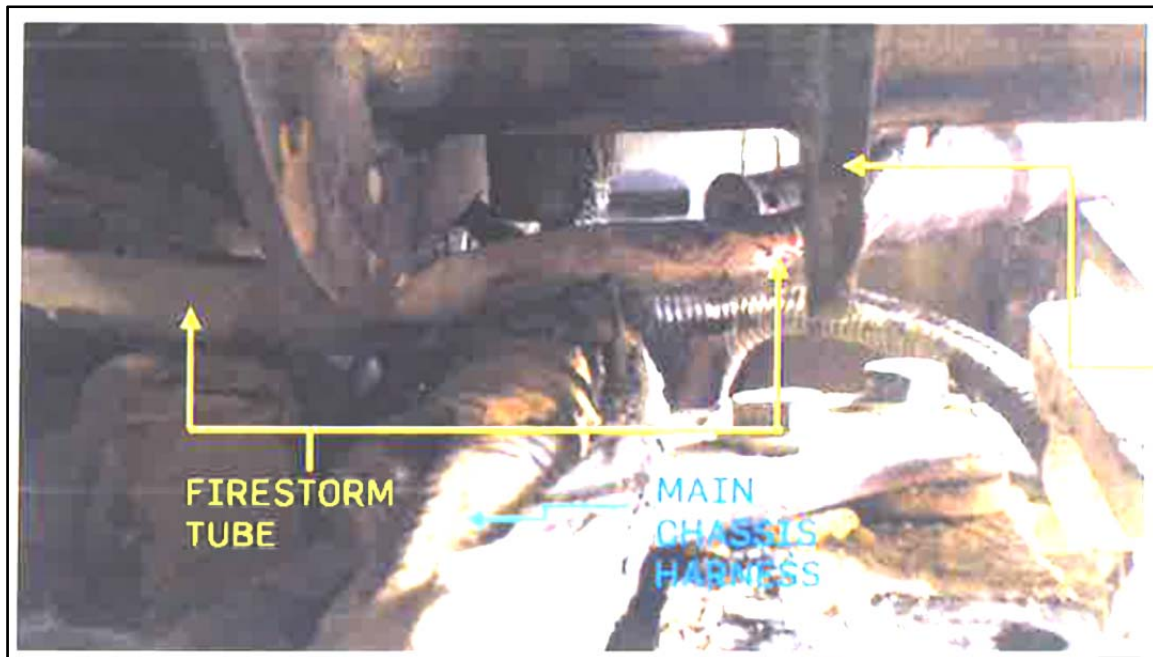
Figure 7: Exterior of the alloy alternator end case.



Source: Firestorm Fire Protection Pty Ltd

Figure 8: Interior of the alternator end case.





Source: CDC Investigation Report - Preliminary Findings Relating To Engine Bay Fire on 3751MO

Figure 9: Contact between distribution hose / main chassis harness (alternator)

- 2.9 Following the short circuit and commencement of this initial fire, the newly installed fire suppression system successfully detected the heat from the fire and activated the water mist extinguishant. It is inconclusive whether the system initially extinguished or suppressed the fire.
- 2.10 However, as the engine had not been able to be remotely shutdown, this allowed the affected cable to remain powered and all other fire components were still present. It is probable that the continuous supply of electrical energy through the chassis cable was the main factor that contributed to the continuation of the fire.

### Factors contributing to continuation of the fire

- 2.11 The bus had a 24 V DC volt electrical system, comprised of two 24 V DC alternators and two 12 V DC batteries. The batteries were connected in series to provide a total of 24 V DC. The batteries were located in a compartment outside and below the driver's cabin area. The combination of the alternators and batteries distributed power to the numerous systems required for the bus's operation.

- 2.12 The mechanic said that when he arrived at the depot and realised a fire had initiated, he attempted unsuccessfully to shut down the bus by pressing the dash mounted engine shutdown button.
- 2.13 The attempt to shut down the engine did not work as heat had damaged an air hose carrying air under pressure from a pneumatic solenoid to the engine shut-off cylinder.<sup>13</sup> Its function was to shut off the fuel supply to the engine.
- 2.14 As the engine shutdown system relied on continual air pressure, air losses meant that it was not able to perform its function. Post-incident testing of this air hose confirmed that air was present and flowing up to the point where the air hose was damaged.
- 2.15 Shutting down the engine of the bus would normally cut off electrical power throughout the main electrical supply circuits. This meant that whenever the engine was still running, there would be a continuous, unprotected supply of electrical energy via the main cable between the batteries at the front of the bus to the cable and alternator in the engine bay. It is probable that this continuous supply of electrical energy was one of the main factors that propagated the fire observed by the mechanic.
- 2.16 Nonetheless, other factors needed for fire development still existed. These included continuation of the contact between the alternator cable and alternator case (ignition source), residual heat, further build-up of heat (from the continuous supply of electrical energy), oxygen and fuel (plastics, rubber and insulated coverings of wiring and cables).

### **Abrasion and deterioration of the cable insulation**

- 2.17 The chassis cable, including the area around the cable lugs and joining bolt, was wrapped in a thin single layer of heat shrink insulation. The purpose of this was to act as insulation and to protect the wiring within from damage if the cable was subjected to vibration or direct contact with heat sources, moving parts or other electrically charged components.

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<sup>13</sup> The engine shutdown button activated pneumatic solenoid valve which in turn supplied compressed air to an air activated cylinder on the engine mounted mechanical fuel injection pump. The system provided shutdown of the engine by moving the injection pump fuel rack to the no fuel position cutting off fuel supply to the fuel injectors.

- 2.18 The TfNSW forensics report stated “*insulation was diminished due to abrasion*” in reference to the alternator end case (See Figure 6 and 7). Abrasion of this protective insulation would have diminished its effectiveness as a protective barrier. Ongoing abrasion would have increased the risk that the insulation would fail, leaving the internal conductive components exposed and prone to damage, failure, or in this case, damage from contact with other metallic components causing unwanted current flow, leading to short circuiting.
- 2.19 The TfNSW forensic report did not go into further detail about how quickly this abrasion may have occurred. Given that the wiring modifications pre-dated purchase of the bus in December 2014, it is reasonable to conclude that since that time, and during normal operation, the insulation would have been subjected to normal deterioration and some degree of abrasion. As with any of the wiring in the bus, it would have continued to deteriorate until it failed, or when issues were detected and replaced during periodic inspection and maintenance. It was considered unlikely that all the abrasion would have occurred in the (48 km) journey from the FSS installation facility back to the Valley Heights Depot.
- 2.20 Nonetheless, OTSI considered that it was probable that the insulation failed immediately following the work that was carried out in and around the restricted confines of the engine bay. It is likely that some aspect of the FSS installation contributed to the final deterioration of the protective insulation; or alternatively, inadvertently repositioned the cable more firmly against an abrasive surface, such that the rate of abrasion was increased.
- 2.21 The bolted terminal arrangement by which the alternator cables were joined, which was identified as being the initiation of the short circuit, is not considered to be acceptable practice. The TfNSW forensic report supports this by stating “*somebody has modified the cable length by fitting an extension. This methodology is not an acceptable process, whereas the total cable should have been lengthened with an alternative connection point.*”

## Risk management

- 2.22 Under direction and project management from TfNSW, the FSS contractor was contractually engaged and responsible for the installation of the fire suppression system. It was also required to install according to a pre-determined safety framework and implement a handover process to the bus operator. Retrofit installation of the suppression system into the Angora Line fleet was a scheduled, but non-routine operation.
- 2.23 According to the terms for the supply and Installation of Fire Suppression Systems - TfNSW Contract TfNSW2016-028, Attachment 2 - Suppliers Returnable Schedule 7: Section 16 - Wiring Cables and Connectors, the contract states in point 16.1 – *“All aspects of the system including lines, wiring, hoses, cables, and lines must be properly bracketed, insulated and isolated to avoid chaffing and to protect against heat sources, using heat shields”*. In point 22.1: *“As required by SPCR183, the contractor must undertake a design risk assessment process for each Bus Type in collaboration with the contract bus OEM supplier, the Contract Bus Owner and TfNSW”*, in point 22.5 *“The contractor must also conduct a further risk assessment when variations in Contract Bus and or chassis layout, could change the fire risk potential or system performance”* and in point 22.9 *“For each assessed design, the risk assessment report shall include:*
- a) Fire-risk identification within the engine compartment*
  - b) The gross volume of the engine compartment*
  - c) The protected fire risks in the engine compartment*
  - d) Installation drawings including placement of extinguisher agent container, pressure vessel, controller, piping systems, detection system, hoses, etc.”*
- 2.24 Requests were made to TfNSW to supply details of the retrofit program for the bus and also provide details of the completed installation from the FSS contractor. The information supplied to OTSI did not include risk assessments for the installation or complete as built schematics as prescribed above in the contract.



2.25 The only schematic received for the installation from the FSS contractor was generic in nature and did not contain dimensions or locations for fitment of the discharge or detection network components (See Figure 10).

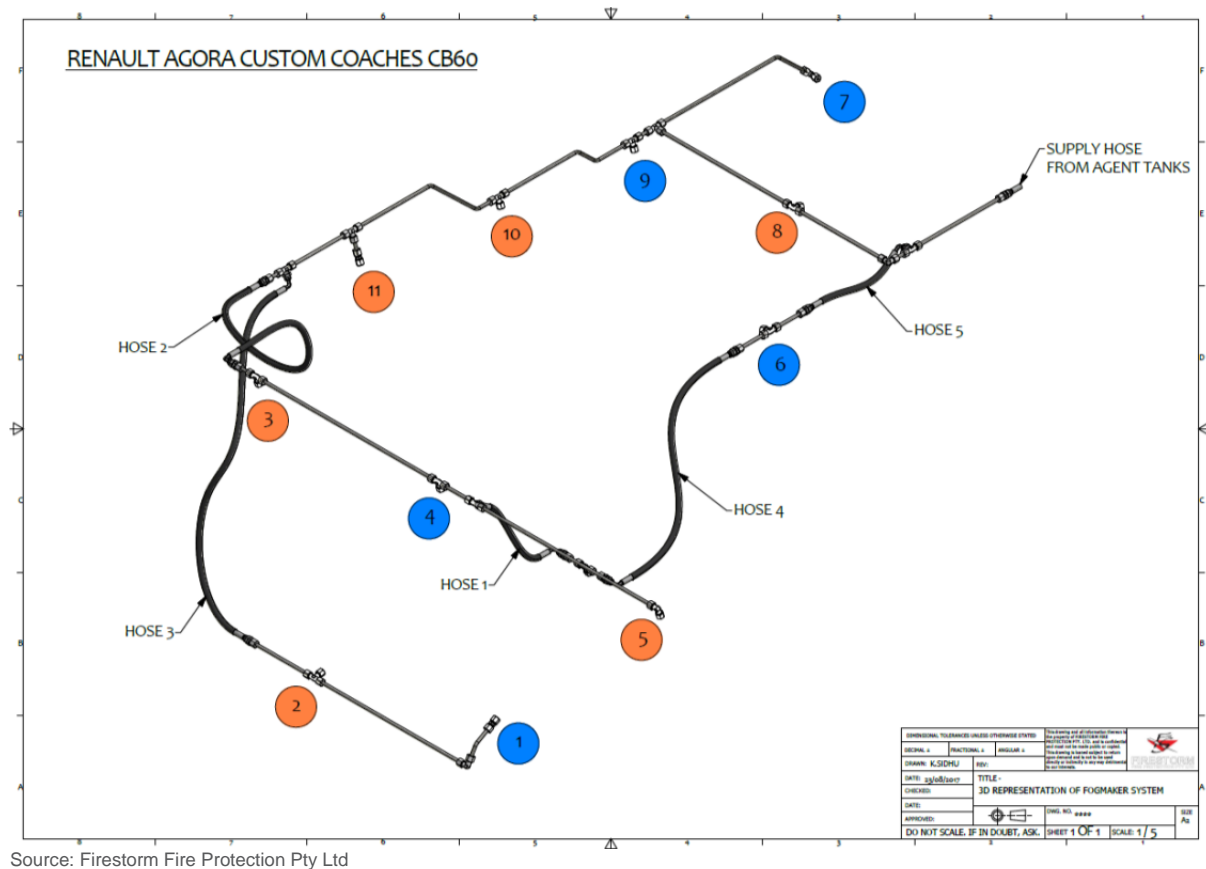


Figure 10: Distribution network for bus 3751MO

2.26 Regarding the installation of the FSS, any residual concerns held by the installer should have triggered a stop to the program until clarification had been sought and received. It is not clear if any such briefing occurred. This briefing would have identified the essential elements of the engine bay, and any precautions, to the installer.

## Background to bus engine bay fire suppression systems in NSW

2.27 The installation of engine bay bus fire suppression systems were commenced by the then State Transit Authority (STA) in 2009 where all new bus supply contracts from 2009 required the bus to be delivered with a fire suppression system installed. In 2013 STA retrofitted their Mercedes Benz OC500LE CNG bus fleet with fire suppression systems.

- 2.28 In a bid to reduce the risk of bus fires, in 2015 the NSW State Government decided to fund, through TfNSW, the installation (retrofit) of engine bay fire suppression in both public and private operator buses. TfNSW also specified that all new buses supplied under TfNSW contracts were to incorporate an engine bay suppression system.
- 2.29 The project to fit these systems in public buses was commenced by STA on 7 December 2015 and was completed within 12 months.
- 2.30 Besides STA buses, there were approximately 2,170 private operator buses covered under the TfNSW metropolitan and outer metropolitan bus service contracts. All buses less than 23 years old were included in the plan to fit engine bay fire suppression systems. This bus, 3751 MO, on the day of the incident, was fitted with its fire suppression system and certified fit for service/normal operations. Subsequently, all remaining privately operated metropolitan and outer metropolitan service buses were retrofitted with engine bay fire suppression systems. *(For more background information about fire suppression systems in NSW see Appendix 1).*
- 2.31 It should be noted that fire suppression systems do not constitute an absolute solution. No one system can be expected to be completely effective in all situations as there is a wide range of potential fire circumstances. However, as a large percentage of bus fires occur in the engine bay, a suppression system located in that area will reduce the risk posed by bus fires.

## **Remedial actions taken**

- 2.32 Following the current incident, CDC conducted an inspection of all alternators and associated wiring fitted to Irisbus Agora line series buses in their fleet.
- 2.33 CDC also identified some additional risk controls required which included:
- Training drivers regarding the operation of the fire suppression system
  - Driver incident and evacuation response skills training.
- 2.34 In this risk assessment, CDC proposed the development and implementation of training material including different scenarios, for bus operator's response to evacuations in an incident or emergency.

- 2.35 CDC is revising the driving training program to increase focus on emergency evacuation and bus fires. It was also developing a training module on fire awareness for maintenance employees.
- 2.36 As the FSS retrofit program was still ongoing at the time of the incident, CDC was still in the process of integrating fire suppression information into its policy, procedures and driver handbooks.
- 2.37 CDC also completed the following actions
- Revised standard operating procedures regarding managing a bus evacuation (driver)
  - Released a safety alert for bus evacuation procedure
  - Revised the bus fire risk assessment
  - Developed a bus evacuation risk assessment.

## PART 3 FINDINGS

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From the evidence available, the following findings are made with respect to the bus fire on an Irisbus Agora Line Custom Coaches CB60 series, registration 3751MO that occurred at Valley Heights, NSW on 30 June 2017.

### Contributory Factors

- 3.1 The fire initiated in the engine bay, amongst wiring at the back of the main alternator from an electrical short circuit. This occurred in the area where a chassis cable was carrying a positive electrical load between the alternator and the battery, made contact with the (grounded) aluminium alternator end casing. There was evidence of electrical arcing on both the join in the cable and alternator end casing.
- 3.2 The chassis cable extension connection method of a bolt connecting two terminal lugs created a point of vulnerability for abrasion and perforation of the heat shrink insulation fitted over the joint. This resulted in the internal conductive material short circuiting to ground.
- 3.3 A newly installed distribution hose associated with the FSS network had possibly disturbed the pre-existing position of nearby electrical cables and wiring looms, to such an extent that the joint in the alternator cable now rested against the alternator end casing.
- 3.4 The pressure exerted on the main chassis harness by the distribution hose was exacerbated by the A/C compressor drive belt not being fitted at the time of the incident. In normal operation the A/C drive belt is tensioned by an air bellows pushing against the A/C base plate frame in an upwards direction which in turn keeps tension on the A/C compressor drive belt. This results in the A/C compressor base plate maintaining an operating height above that which was observed following the fire incident.
- 3.5 Due to damage to the engine shut down solenoid air hose, the engine was unable to be shut down by the dash controls. This resulted in an ongoing supply of battery power to the source of the fire in the engine bay. This may have allowed the fire to continue due to the continuous supply of thermal energy.

- 3.6 There is evidence to suggest that the FSS installation on the bus was not consistent with the specifications set out in the TfNSW FSS installation Contract. The methodology for installation of the distribution hose and quality assurance resulted in a defect. This defect was a distribution hose being attached to a moving component (the A/C base plate) and abrading against the alternator cable.

### **Other Safety Factors**

- 3.7 The operation and effectiveness of the engine shutdown button (on dash) was such that it was compromised by the fire event. In the event that the button did not work, the fuel supply needed to be shut off manually. There is an increased risk of re-ignition if the shutdown button system is compromised.
- 3.8 Risks associated with the failure of the engine shutdown button to remove electrical energy and prevent re-ignition were decreased as a result of the efforts by the mechanic in extinguishing the fire and performing a manual shutdown of the engine. The mechanic's efforts effectively prevented escalation of the fire by extinguishing the fire using the depot's large fire extinguisher and performing a shutdown of the engine by accessing the engine bay and manually shutting down the fuel pump.
- 3.9 Despite the automatic operation of engine bay fire suppression systems, drivers need to have an understanding of the system's operation to effect evacuation decision-making.
- 3.10 The application of the P-mark certification to bus engine bay fire suppression systems is a beneficial addition to the risk management process. Further development of the certification system into manufacture and maintenance processes has the potential to reduce the number of bus fires.
- 3.11 TfNSW had FSS as standard fitment for all new buses supplied under the Sydney Metropolitan Bus Service Contracts and Outer Sydney Metropolitan Bus Service Contracts. This requirement does not apply to other public passenger vehicles operating outside these contracts.
- 3.12 The FSS worked as designed and was effective in suppressing the initial fire. Re-ignition or continuation of the fire occurred as all the components of fire mechanism/combustion were still present. A significant factor in this was the continued presence of electrical energy in the wiring.

## **PART 4 RECOMMENDATIONS**

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It is recommended that the following safety actions be undertaken by the specified responsible entity.

### **Comfort Delgro Corporation Australia**

- 4.1 Investigate the practicality of reconfiguring the shutdown process on all buses so that when the driver turns off the ignition the power supply to the engine bay is also shut down.
- 4.2 Examine the design and placement of electrical cabling on similar model buses to reduce the likelihood of short circuit events occurring.
- 4.3 Ensure drivers receive training in the operation of the engine bay fire suppression systems.
- 4.4 Review training for maintenance personnel to increase their awareness of likely fire initiation points with an emphasis on identifying probable fire initiators.

### **Transport for NSW**

- 4.5 Review the effectiveness of quality assurance procedures and contractual compliance for buses retrofitted with engine bay fire suppression systems under - TfNSW contract Installation of Fire Suppression Systems TfNSW2016-028.
- 4.6 Promote the incorporation of fire detection and engine bay fire suppression system requirements into bus industry standards.

### **Roads and Maritime Services**

- 4.7 Ensure monitoring of operator bus maintenance procedures with respect to identified frequent fire initiation causes.

## PART 5 APPENDICES

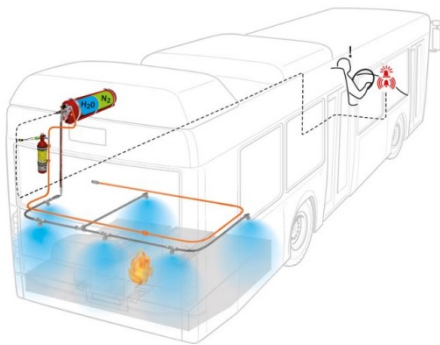
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### Appendix 1: Water Mist Fire Suppression Systems

The installation of fire suppression systems on buses is an effective option for reducing the consequences of fire in and around the engine, or at least suppressing fires until further intervention. Successful operation of such systems may mitigate or eliminate the risks associated with the use of portable extinguishers.

The fire suppression systems fitted to TfNSW contracted buses generally consist of three cylinders located towards the rear of the bus. One cylinder contains a detection fluid stored under pressure by compressed nitrogen gas which is distributed in detection tubes routed around the engine bay and transmission area. The other two cylinders contain a water based extinguishing agent with a foaming additive which is

distributed along a network of hoses and pipes in the engine bay and transmission area.



Detection and activation of the system takes place pneumatically. In the event of a fire, the pressurised detector tube bursts and the resultant drop in pressure activates a valve on the extinguishing cylinders. Pressure switches on the detection and agent cylinders give both

an audible and a visual alarm to the bus driver via a dash mounted alarm display panel. The system activates completely independent of the bus power supply.

When the system is activated, the extinguishing agent in the discharge network is released under pressure as a very fine mist from small nozzles throughout the engine bay and over the transmission, directed into areas of known heat sources. The water mist converts to steam when in contact with heated surfaces, providing a cooling effect throughout the engine bay. The steam also interrupts the supply of oxygen to the fire. The water mist also deposits a layer of foam over liquid flammable products that tend to collect in depressions on and around the engine.



## Appendix 2: Sources, References and Submissions

### Sources of Information

- ComfortDelGro Corporation Australia Pty Ltd (Blue Mountains Transit Pty Ltd)
- Firestorm Fire Protection Pty Ltd
- Transport for NSW
- Roads and Maritime Services

### References

- Australian Design Rule 58. *Requirements for Omnibuses Designed for Hire and Reward.*
- Australian Standard (AS) 2444—2001. *Portable fire extinguishers and fire blankets – Selection and location.*
- Australian Standard (AS) 1851—2012. *Routine service of fire protection systems and equipment.*
- Sydways/Melways/www.street-directory.com.au
- Kennedy's Engineering & Forensics Report: *Report on Thermal Damage to Custom Coach – Registration 3751MO, Blue Mountains Transit, Date of Incident 30-06-2017.*
- Allan R. Hambley (2005). *Electrical engineering: principles and applications.* Prentice Hall. pp. 637–. ISBN 978-0-13-147046-0. Retrieved 20 April 2011.

## 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:

- ComfortDelGro Corporation Australia (Blue Mountains Transit Pty Ltd)
- Firestorm Fire Protection Pty Ltd
- Transport for NSW
- Roads and Maritime Services

Submissions were received from all DIPs.

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.