OTSI Office of Transport Safety Investigations

BUS SAFETY INVESTIGATION REPORT

AN INVESTIGATION INTO BUS FIRES IN NSW

2005 - 2012

BUS SAFETY INVESTIGATION REPORT

AN INVESTIGATION INTO BUS FIRES IN NSW 2005 - 2012

Released under the provisions of
Section 45C (2) of the Transport Administration Act 1988 and
Section 46BA (1) of the Passenger Transport Act 1990

Investigation Reference 04601

Published by:	The Office of Transport Safety Investigations
Postal address:	PO Box A2616, Sydney South, NSW 1235
Office location:	Level 17, 201 Elizabeth Street, Sydney NSW 2000
Telephone:	02 9322 9200
	Accident and incident notification: 1800 677 766
Facsimile:	02 9322 9299
E-mail:	info@otsi.nsw.gov.au
Internet:	www.otsi.nsw.gov.au

THE OFFICE OF TRANSPORT SAFETY INVESTIGATIONS

The Office of Transport Safety Investigations (OTSI) is an independent NSW agency whose purpose is to improve transport safety through the investigation of accidents and incidents in the rail, bus and ferry industries. OTSI investigations are independent of regulatory, operator or other external entities.

Established on 1 January 2004 by the *Transport Administration Act 1988*, and confirmed by amending legislation as an independent statutory office on 1 July 2005, OTSI is responsible for determining the causes and contributing factors of accidents and to make recommendations for the implementation of remedial safety action to prevent recurrence. Importantly, however, OTSI does not confine itself to the consideration of just those matters that caused or contributed to a particular accident; it also seeks to identify any transport safety matters which, if left unaddressed, might contribute to other accidents.

This OTSI investigation was conducted under powers conferred by the *Transport Administration Act 1988* and the *Passenger Transport Act 1990*.

It is not within OTSI's jurisdiction, nor an object of its investigations, to apportion blame or determine liability. At all times, OTSI's investigation reports strive to reflect a "Just Culture" approach to the investigative process by balancing the presentation of potentially judgemental material in a manner that properly explains what happened, and why, in a fair and unbiased manner.

Once OTSI has completed an investigation, its report is provided to the NSW Minister for Transport for tabling in Parliament. The Minister is required to table the report in both Houses of the NSW Parliament within seven days of receiving it. Following tabling, the report is published on OTSI's website at www.otsi.nsw.gov.au.

OTSI cannot compel any party to implement its recommendations and its investigative responsibilities do not extend to overseeing the implementation of recommendations it makes in its investigation reports. However, OTSI takes a close interest in the extent to which its recommendations have been accepted and acted upon.

TABLE OF CONTENTS

AN INVESTIGATION INTO BUS FIRES IN NSW 2005 – 2012

Abstract

An examination of the nature and circumstances of bus and coach fires investigated by OTSI in the period 2010 to mid 2012 revealed a number of common safety related issues. As a result, an investigation was initiated to explore the issues in more detail, and to draw on the experience of other national and international jurisdictions. The aim was to identify courses of action, the implementation of which would contribute to enhancing the safety of bus and coach operations in NSW.

The investigation identified an apparent upward trend in the number of fires in recent years, although analysis was hampered by a lack of a central data base. However, data from various sources indicated overall consistency over time in relation to the causes of fires. The majority originate in the engine compartment, while almost all of the remainder occur either in wheel wells or the electrical systems.

The primary concern in a bus fire is the amount of time available to evacuate passengers once a fire enters the passenger compartment. The main factor influencing this is the flammability and toxicity of the materials used in internal furnishings and fittings. Relevant current Australian design rules and standards for such fit-out are very limited in scope and are outdated.

To date it has not been customary to install fire detection, warning and suppression systems in buses and coaches. However, the general desirability of doing so is now being realised and industry response is gaining momentum.

Significantly, the investigation found that the bus and coach fire safety issues experienced in NSW are common throughout the states of Australia and overseas countries that were examined.

The investigation makes four recommendations for action by Transport for NSW:

- In consultation with and on behalf of all interested parties, establish a permanent resource dedicated to building a comprehensive State-wide bus fire reporting regime, maintaining the data base, and undertaking research and analysis of causes, effects and trends in bus fires within the State, nationally and

internationally. Advocate for other states and territories to maintain data in the same format to facilitate improved monitoring and analysis.

- As a matter of priority, advocate strongly for the development and implementation of new design rules and standards for bus fire warning and suppression systems and materials of construction and fit-out. Such rules and standards should draw on those approved by the United Nations Economic Commission for Europe. If this work does not attract high national priority, take the initiative to develop and implement design rules and standards for NSW as an interim safety measure.
- Continue to provide material support and assistance to industry initiatives consistent with the relevant strategies contained in both the State and Australian Government road safety strategies.
- Provide support and assistance to the bus and coach industry in relation to the development and implementation of training of drivers in dealing with vehicle fires including the evacuation of passengers.

In addition, all bus and coach service operators are referred to the risk-based approach to fire mitigation systems advocated by the Bus Industry Confederation and BusNSW, particularly the implementation of thorough routine and scheduled inspection, maintenance and servicing plans and programs.

Acknowledgements

OTSI has a limited integral research capacity but, for this investigation, has been fortunate to be able to rely on several major sources of information and advice.

A number of the papers referred to were delivered to the Second International Conference on Fires in Vehicles – FIVE, held in Chicago in September 2012.

OTSI would like to thank all the agencies and individuals who assisted with the provision of information and provided constructive feedback on the draft report. Particular thanks go to Mr Luke Hardy, the Technical Manager of the Australian Bus Industry Confederation, which is leading the development of an industry based code of practice – a Bus Fire Mitigation Advisory, and Mr Fredrik Rosén, the Marketing Manager at the Department of Fire Technology at the SP Technical Research Institute of Sweden, which is taking a prominent lead in the development and implementation of contemporary design rules and standards concerning bus fire safety.

Introduction

Between January 2005 and June 2012 OTSI received 115 reports of fires occurring on buses and coaches which were engaged in providing public passenger services.[1] In the 2½ years to mid 2012, OTSI examined the circumstances of 15 significant bus fires in NSW.[2] These incidents are listed at *Appendix A*.

From the results of these examinations, it became apparent there were a number of common safety-related issues. Primarily, they were:

- the lack of warning to the driver who, on most occasions, was unaware of the fire until alerted to a problem by another party;
- the speed at which the fire consumed the vehicle once it had reached the interior;
- the general inability of portable fire fighting equipment to make any inroads into suppressing or extinguishing the fire once it had gained a hold, and
- the lack of uniform training of drivers across the industry in the handling of fire related emergencies.

As a result, the Chief Investigator initiated an investigation to:

- quantify the extent to which fire constituted a risk to the safety of bus and coach operations in NSW;
- compare the NSW experience with that of other jurisdictions, both national and international;
- identify bus fire causative and contributory factors and the extent to which they are systemic to bus and coach operations;
- identify best practice measures to mitigate both the potential for, and the effects of, bus fires, and
- recommend courses of action which would contribute to enhancing the safety of bus and coach operations in NSW.

---

1 The term ‘bus’ is used throughout to cover both buses and coaches except where it is necessary or appropriate to differentiate.

2 The findings from these examinations are available on the OTSI website at www.otsi.nsw.gov.au

The Bus Industry in Brief

In a presentation to the 2012 National Road Safety Forum, the Bus Industry Confederation (BIC)[3] reported that, as of January 2011, there were 87,883 registered buses in Australia operated by more than 3,000 companies.[4] Based on sales data, it is estimated that around 1,500 new buses are being delivered into the Australian market annually.

The bus industry is reported as delivering some 1.5 billion urban public transport passenger trips annually while the coach sector moves more than 1.6 million domestic travellers. Doing so involves total travel in excess of 6 billion passenger kilometres per year.

Bus Fires Nationally Since 2005

It proved to be impossible to accurately determine the number of bus fires that have occurred in Australia in any given period as consolidated records are not held by any State or National agencies. It is clear that the incidence of bus fires is greater than any individual set of formal records shows. In addition, information kept by various agencies differs in the detail recorded. Information was most readily available for NSW, Victoria and Western Australia (Perth).

New South Wales

In NSW, OTSI receives reports from accredited bus operators conducting public passenger services as required by the *Passenger Transport Act 1990*.[5] Since 2010 all accredited bus operators have also been required to create an electronic record in the Transport for NSW (TfNSW) Bus Incident Management System (BIMS). The BIMS data is more extensive than that maintained by OTSI as it includes all accredited bus and coach operators, not just those providing a public passenger service.

---

3 The Bus Industry Confederation is the national representative body of the Australian bus industry. Its membership includes operators, suppliers and associated businesses, and its partners include the state industry representative bodies.

4 Hardy, L '*Bus Industry Confederation Safety Advisories*', presentation to the National Road Safety Forum 2012, Canberra, 24 August 2012.

5 Despite the legislative requirement not all minor fires are reported. In examining the data, the term "thermal incident" was found to be used on occasions instead of "fire" in some operators' reports.

Fire and Rescue NSW maintains records of the bus fires they attend but the detail recorded varies from that kept by TfNSW and OTSI. The different sets of records kept are therefore not entirely compatible and the differences in the detail preclude accurate correlation of the data.

Of the 15 fires examined by OTSI in the 2½ years to the end of June 2012, eight involved the total destruction of the vehicle while damage to the other seven varied from minor to significant, with significant indicating the likelihood that the engine would have to be replaced or rebuilt. Causes of the fires could be broadly attributed to electrical faults on four occasions, wheel or tyre problems on two occasions and oil, coolant or fuel system faults on the remaining nine occasions of which five were associated in some manner with the turbocharger.

In addition to the 15 fires it attended, OTSI received reports of a further 32 bus fires over the 2½ year period. The majority of these fires were extinguished by the driver in a timely manner using the onboard portable extinguisher, and resulted in very minor damage. However, on four occasions the fire was neither extinguished nor suppressed. On three occasions the situation was resolved at the smouldering stage. Two buses were destroyed, one sustained significant damage and three sustained moderate damage.

Twelve fires originated in the engine bay, seven in the wheel well and six in the driver's compartment mostly associated with wiring, fuses and/or relays under the dashboard. Two fires were caused by electrical faults elsewhere, two were caused by exposure to the hot exhaust stack and one cause could not be determined. Two fires were caused by debris caught up in the bus; one where a rag was found within the inlet filter of the engine and the other where the bus ran over a mattress on the road which was trapped under the rear axle and resulted in the destruction of the bus.

Victoria

Transport Safety Victoria (TSV) received 21 notifications of bus fires over the period May 2005 to June 2011: four were attributed to electrical causes, two to oil or fuel causes, three to wheel or tyre problems and 12 to causes unknown. All bus operators are currently required to report incidents which are prescribed in regulations made under the *Bus Safety Act 2009* (Vic), including fires. Prior to 1 January 2011, such a reporting requirement applied only to buses with a seating capacity of 12 or more.

Western Australia

Transperth is the operator of the public transport systems in the greater metropolitan area of Perth. Transperth recorded 11 fires involving compressed natural gas (CNG) powered buses since they commenced introduction into service in 2005. (All these fires occurred in 2008 and 2009.) Four buses were destroyed while six of the fires were extinguished by the bus driver before major damage was caused. The other fire was extinguished by a recently fitted fire suppression unit. Of the buses destroyed, three were attributed to faulty oil supply pipes to the turbocharger and the fourth to a coolant leak.

Since January 2011, as a matter of policy, the Public Transport Authority of Western Australia has required all new buses, for both metropolitan and regional fleets, to have fire suppression equipment installed. Just over 50% of their fleet of 1430 buses now have fire suppression installed and this includes all 526 low floor CNG-powered buses.

Insurance Industry

Based on data provided by the Australian Insurance Industry, the BIC determined that there are now up to 70 bus/coach fires per year in Australia.[6] While the BIC is confident in the figures, the record is likely to understate the true situation as the figure only accounts for fires resulting in claims made by insurance policy holders.

Data on the number of claims due to bus fires over the last five years shows a steady annual increase of approximately 20%, or 15% when growth in the fleet is taken into account (see *Figure 1*).[7]

---

[6] Hardy, L '*BIC Technical Update – Bus Door Safety, Fire Mitigation and Vehicle Mass Limits'*, presentation to the BIC 2012 National Conference, Canberra, 28-31 October 2012.

[7] Bus Industry Confederation, *Submission to the Heavy Vehicle Safety and Productivity Program Round Three*, Sydney, September 2012.

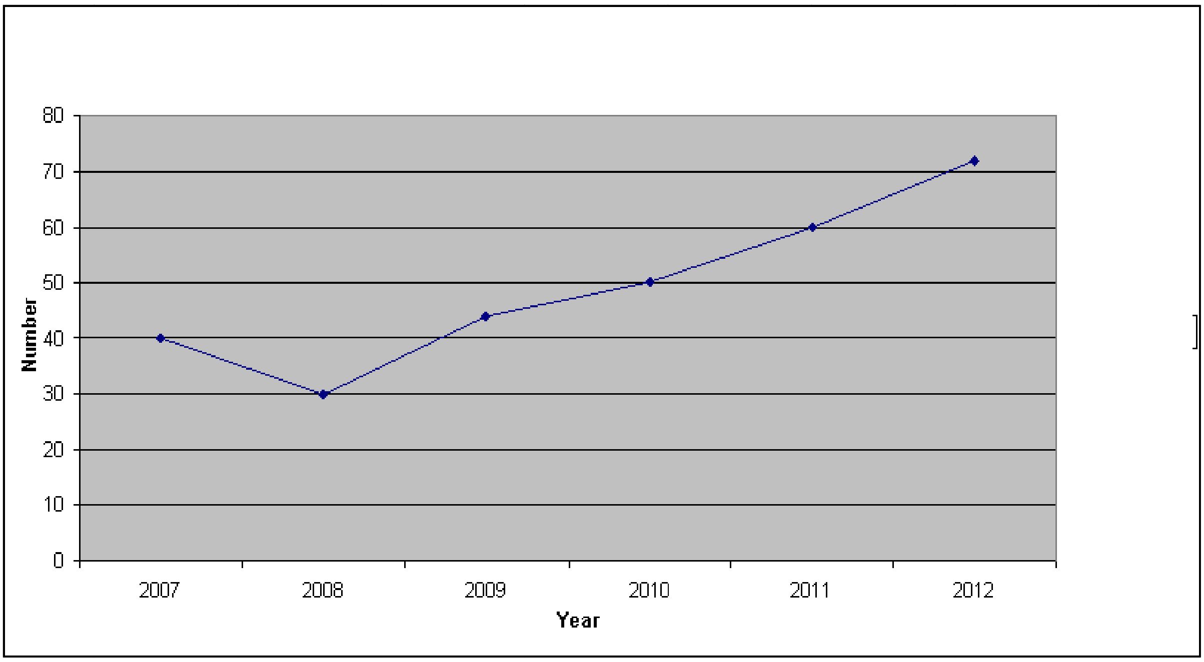

Figure 1: Bus fire insurance claims

The start of the upward trend is roughly coincidental with the commencement of introduction into service of buses meeting tighter emission standards and noise limits. Adoption of European emission standards typically resulted in:

- higher engine operating temperatures
- higher fuel injection and turbocharger boost pressures
- greater use of high temperature catalytic converters
- increased loads on cooling systems.[8]

Compliance with the requirements of Australian Design Rule (ADR) 83/00 *External Noise* has led to full encapsulation of the engine area resulting in greater containment of generated heat and reduced accessibility for inspection and maintenance of engine components.

Warning and Reaction Times

In most of the fires examined by OTSI, the bus drivers were unaware of the fire until alerted by other motorists, by passers-by or by passengers as smoke appeared in the rear window and/or commenced entering the interior of the bus. Few buses were

8 Hardy, L op.cit.

fitted with fire or smoke detection sensors and alarms despite modern buses now invariably having rear-mounted engines.

There were occasions when drivers reported either not noticing or not remembering if dashboard mounted alarms activated during the fire sequence. Unfortunately, the sensors were destroyed in the fires so could not be tested to prove whether or not they were operating correctly. Furthermore, no testing had been conducted to determine the optimum location of critical alarm devices on bus dashboards or to determine the most appropriate nature of critical fire alarms such that they would be readily differentiated from other operational warning devices.

One bus had fire sensors but the devices were located on top of the transmission, too far from the seat of the fire in the engine compartment to be of any use. On several occasions, drivers reported not receiving warnings from vehicle diagnostic systems or hearing alarms that might have alerted them to a problem, e.g., temperature or pressure anomalies. On the few occasions where loss of power was experienced before the bus was stopped, the fires were already well underway.

Apart from the challenges of determining where to locate sensors most effectively and what type/s to use, there is the additional maintenance, testing and checking requirements that come with them. It is difficult to detect the range of operating temperatures in and around the engine bay without a propensity for false alarms. If sensors are set to trigger automatic responses, there is the added inconvenience and cost of false alarms.

Bus drivers will not usually be in a position to attempt any fire fighting action immediately on being alerted to a fire, typically at a time when the fire may be in an early development phase or entering a rapid growth phase. After locating and stopping the bus in a suitable location, the driver's first priority is to ensure passengers evacuate to a safe location. The driver is then able to concentrate on the fire but, as experience has shown, may choose to conduct a visual inspection of the situation at the rear of the bus before returning to collect the extinguisher, usually located in a bracket near the driver's seat. Concurrently, the driver must report the situation to the radio/control room and/or the emergency services. Long distance coaches may be better situated to deal with a fire, especially if there is an additional crew member on board such as a tour director or relief driver.

Fire Initiation and Development

Fuel sources

There are ample sources of fuel within the engine bay to feed a fire on a bus: liquid or gaseous fuels, lubricating oil, hydraulic oil and the glycol constituent of coolant. There are rubbers, plastics and other flammable materials used for such applications as containers, hoses, coatings, insulation and sheathing which may be more difficult to extinguish than petroleum based fuels. Some insulating materials may absorb oils and greases over time and so increase the risks of fire. Inside the bus, flooring can be constructed of laminated plywood timber material using flammable glue and covered with matting material such as rubber and/or carpet. Combined, all these make a very ready source of fuel once a fire breaches the bus interior.

Ignition sources

A number of engine and associated components within the engine bay may run at temperatures in excess of 300°C, particularly the turbocharger, engine manifold and exhaust system. Those that are cooled by oil or coolant quickly rise to higher temperatures if the supply is interrupted. Combustible liquids or materials exposed to sufficiently high temperature sources will ignite eventually if contact is continuous.

Wheel well areas are vulnerable to the effects of such occurrences as overheating brakes and friction resulting from debris being caught up and rubbing on tyres. Heat may be generated through friction between loose components rubbing on other components. Insulated wires and cables will short out if their insulation is rubbed away so as to expose bare metal to other metal surfaces. Fire risks are also posed by devices such as electrically operated hand dryers fitted in the toilets of coaches.

Spread of fire

Once a fire has gained a firm hold in the engine bay or in a wheel well, it will eventually develop to a stage where it can breach a vulnerable point and enter the interior of the bus. Such points are through the rear window once it has been shattered by the heat; similarly, through side windows especially if the fire is in the wheel well, and through the floor especially at maintenance hatches. With the exception of any maintenance hatches directly above the engine, these paths are generally out of and around the engine bay as there is usually some degree of shielding behind the engine bay.

The majority of the materials used for panelling and in the interior fit-out of a bus, including the fixing adhesives, are flammable and generate highly toxic smoke and gases during combustion. By way of example, Table 1 displays an assessment of the main component materials used in a representative bus.

Component	Material	Flammable	Toxic
Roof and side panels	Fibreglass	Yes	Yes
Side panel infill	Polystyrene	Yes	Yes
Seats – base & back cushioning seat material cover roll top handles frames	Plywood Foam rubber Wool & nylon Polycarbonates Stainless steel	Yes Yes Varies Yes No	Yes Yes Varies Yes No
Floor	Plywood	Yes	Yes
Floor covering	Rubber composite Glues & adhesives	Yes Yes	Yes Yes
Window seals	Rubber Glues & sealants	Yes Yes	Yes Yes
Side panels	Resin bonded material	Yes	Yes
Moulded liner	Polycarbonates	Yes	Yes
Wheel chair ramp	Carbon fibre – balsa - fibreglass base	Yes	Yes

Table 1: Main component materials of a representative bus

The toxic smoke and gases released into a relatively confined space pose an extreme risk to passengers and are the most prevalent cause of casualties and fatalities. The concentration of gases and heat can also build up to a point where the gases ignite creating a “flash over”. Examination of bus fires generally shows that fire very rapidly consumes a bus once it enters the interior:

> In a modern bus the fire load of plastic parts installed in the passenger compartment exceeds for example the fire load of the filled diesel tanks.[9]

Immediate evacuation of all passengers in fire situations is therefore imperative, despite the initial level of threat possibly presenting as low. Unlike overseas experience, NSW has been fortunate to date in that no bus fires have resulted in a fatality.

Clause 17 of Australian Design Rule (ADR) 58/00[10] specifies that interior linings not be readily flammable. It does not set standards for fire resistance of bus body materials or interior linings. The closest to a current specification relating to flammability of interior materials is United Nations Economic Commission for Europe (UNECE) Regulation No.118.[11] It contains detailed procedures for determining horizontal and vertical burning rates and melting behaviour of materials used in vehicle interiors. The horizontal burning rate test equates to resisting the spread of fire from a lit cigarette or lighter being dropped on a seat. Vertical burning rates are applicable to hanging furnishings such as curtains and blinds. The same or similar specifications are common overseas, such as in the United States and Germany.

The horizontal flame test is now virtually irrelevant given that the number of fires that start accidentally on bus seats appears to be comparatively quite small. The key issue is the fuel load consisting of interior furnishings and fit-out when a fire breaches the interior of a vehicle.

Experimentation undertaken by the German BAM Federal Institute for Materials Research and Testing, demonstrated that, by comparison, fire safety requirements in the automotive sector were 'on a significantly lower level' to those in the train, maritime and aviation sectors.[12] Such requirements include flammability, heat

---

9 Hofman, A & Dülsen, S 2012, 'Fire safety performance of buses', *Proceedings from 2nd International Conference on Fires in Vehicles – FIVE 2012*, Chicago, USA, p.148.

10 ADR 58/00: *Requirements for Omnibuses Designed for Hire and Reward*, 2006.

11 United Nations Economic Commission for Europe (UNECE) Regulation Number 118: *Uniform technical prescriptions concerning the burning behaviour and/or the capacity to repel fuel or lubricant of materials used in the construction of certain categories of motor vehicles*.

The UNECE is a regional commission of the United Nations with the aim of promoting pan-European economic integration. Members include representatives from Europe, the former Soviet Republics and North America.

12 Hofman, A & Dülsen, S op.cit., p.157.

release rates, smoke production and smoke toxicity. Comparative testing of smoke production and toxicity revealed that, with the exception of side panel material, ‘bus interior materials fail the requirements of similar rail vehicles’.[13] In a test of the fire behaviour of passenger seats from a 1995 model bus, a 2005 model bus, a coach and a train, the train and older bus seats performed the best while the later model bus seats produced significantly higher levels of heat release rates. Seats provide the greatest single source of fire load in the passenger compartment.

The airline industry has strict regulations as to what is prohibited from being carried on board by passengers who must make a declaration before travelling that such items are not in their luggage. In contrast, there are no industry-wide restrictions on what can be carried in the large luggage storage areas on coaches located directly under the cabin and separated only by the plywood flooring. Hence, coaches may carry a wide range of hazardous material such as aerosol sprays, LPG bottles used in camping and cooking, petrol driven power tools and gas cylinders. In the case of a coach fire in Texas in 2005 (discussed later), the coach was carrying 18 medical oxygen cylinders, two of which were in use inside the cabin.

Portable Fire Fighting Equipment

ADR 58/00 requires buses to be equipped with a readily accessible fire extinguisher selected and located in accordance with Australian Standard (AS) 2444—2001, *Portable fire extinguishers and fire blankets – Selection and location*. An ABE powder type extinguisher meets the minimum standard for a bus but two are required for a coach, one of which has to be mounted ‘near the under-floor area or engine’.

In several incidents examined, the rear-mounted extinguishers on coaches could not be accessed due to a combination of their proximity to and the intensity of the fire. Additionally, they are not necessarily stored in the same location on all vehicles and there is no requirement for their location to be clearly indicated from the outside of the vehicle.

Six of the 11 Transperth fires were extinguished using portable extinguishers by opening the engine bay hatches and directing the powder on to the seat of the fire.

13 Hofman, A & Dülsen, S op.cit., p.154.

In contrast, portable fire extinguishers had little to no effect on the fires examined by OTSI on the occasions they were used. They were generally discharged in an upward direction from below the engine bay hatch or side of the bus. This is inefficient in that the powder is therefore sprayed below the fire or onto the chassis and sub frames rather than blanketing the fire.

The exposure risk to personnel attacking fires with portable extinguishers increases if engine bay hatches are opened to gain direct access to the seat of the fire, predictably an approach not generally approved by operators. The risk can be significantly reduced by providing strategically located access ('peep') holes into which extinguisher hoses can be inserted and manoeuvred to point in the general direction of the fire if its location can be readily ascertained. General exposure risk also increases the longer the fire has had to develop and the proximity of the fire to more volatile fuel.

Fire Suppression Systems

The installation of fire suppression systems on buses would seem to offer an effective option for reducing the consequences of fire in and around the engine, or at least suppressing fires until emergency service fire fighting appliances arrive. Successful operation of such systems may eliminate or at least mitigate risks associated with the use of portable extinguishers.

As a result of four of its buses being destroyed by fire, Transperth retrofitted fire suppression systems to all of its CNG-powered buses. A subsequent engine fire was experienced in one of the retrofitted buses which was saved from extensive damage through the fire being confined to the engine bay area and prevented from reaching the interior of the bus.

Along with a portable fire extinguisher, a fire suppression system saved an STA articulated bus from serious damage when it experienced a fire in the fuse box in March 2011. The system is similar to that fitted to Transperth buses and is designed to activate when it detects a significant heat source in the engine compartment or transmission area. All recent NSW State Transit Authority (STA) articulated passenger buses have been fitted with suppression units as have all buses that have been placed in service since 2011.

In response to a bus fire in July 2011, the STA called tenders for the placement of fire suppression systems on all its 254 Mercedes OC500LE CNG-powered buses. STA's stated intention is to have fire suppression fitted to all new vehicles purchased regardless of fuel type or emissions standard. Further, STA has expressed the view that the supply and fitting of fire suppression systems should be included as part of the standard specifications for buses.

The fire suppression system fitted to STA Volvo buses consists of two cylinders located towards the rear of the bus. One cylinder contains compressed nitrogen gas which is distributed in two plastic pressurised detector tubes to the engine bay and transmission. The other cylinder contains water with a foaming additive which is distributed along two metal sprinkler pipes, also to the engine bay and transmission.

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 container. A pressure switch on the detection gas bottle indicator gives both an audible and a visual alarm to the bus driver via a display panel installed above the driver's side 'A' pillar. The system operates independently of the bus power supply.

When the system is activated, the water in the metal piping is discharged under pressure as a mist from small nozzles along the sprinkler pipe throughout the engine bay and over the transmission, directed into areas of known heat sources. The water mist provides a cooling effect and interrupts the supply of oxygen to the fire. The water mist also deposits a layer of foam over flammable oil products that tend to collect in depressions on and around the engine.

However, fire suppression systems do not constitute the 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, different agent dispersal technologies and different extinguishing agents available, each with their own specific performance characteristics:

> … there are many different types of systems on the market with different extinguishing agents, including water mist, dry agent, aerosols, and gas.

> These systems all behave differently in terms of their firefighting performance and they all have their pros and cons when it comes to their mode of extinguishment.
>
> Certain types have challenges concerning re-ignition protection while others may have difficulty with suppression of large or small hidden fires.
>
> Most systems work well in confined spaces where the concentration of the extinguishing agent remains high for a long period of time but have difficulty maintaining performance under high airflow conditions often present in bus engine compartments.[14]

Some manufacturers have begun to fit fire suppression systems voluntarily as a standard inclusion. Some operators are retrofitting systems to existing fleets and/or are requiring systems to be fitted in new purchases. There is also impetus through the insurance industry to fit systems. For example, from 2004 Swedish insurance companies have required all buses insured with them to be fitted with fire suppression systems in their engine compartments. No bus in Sweden insured with an insurance company has been reported as destroyed by a fire in the engine compartment since then.

There are no national or international standards pertaining to bus fire suppression systems. However, since 2005 the Department of Fire Technology at the SP Technical Research Institute of Sweden has been at the forefront in conducting research aimed at improving bus fire safety. Recent work has culminated in the development of a standard for testing bus engine compartment fire suppression systems, '*SP Method 4912*'.[15] 'The objective has been to construct a model of an engine compartment where stakeholders can evaluate the fire fighting performance of different suppression systems in a well-defined and objective way.'[16] It is intended to submit the standard for acceptance by the UNECE Working Group on General Safety Provisions (GRSG) in 2013. This would result in the revision and updating of UNECE Regulation 107 *Uniform provisions concerning the approval of category M2*

---

14 Fredrik Rosén, 'Burning ambition', *Australasian Bus and Coach*, January 2012.

15 Transperth was an invited member of the Reference Group for the development of the standard and continues involvement with the project through commenting on the P-mark.

16 SP Technical Research Institute of Sweden, *New standard for fire suppression systems in engine compartments of buses and coaches finally published*, media release, Borås, Sweden, 10 October 2012.

or M3 vehicles with regard to their general construction and make the installation of fire suppression systems in the engine compartments of buses compulsory.[17]

The Institute has established a voluntary certification/quality mark - the P-mark - for industry use until the Standard is adopted by the UNECE. To obtain a P-mark, a system needs to fulfil the requirements of SP Method 4912. In addition, performance testing of all components of the system is required under a range of harsh environmental conditions. One large North American transit authority has adopted the P-mark into their procurement specifications and a leading German bus manufacturer has also adopted it.[18]

SP Technical Research Institute is looking to commence work early in 2013 on developing a standard for testing fire detection, a project expected to run for some two years.[19]

A leading manufacturer of fire safety products based in the United States has constructed and trialled an apparatus for evaluating 'the fire extinguishing performance of current in-house fire protection systems installed on commercial vehicles' and acquiring data for future benchmarking purposes.[20]

Maritime Approach. In the commercial maritime industry all engine rooms must be constructed with fire retardant materials, and air and fuel supplies must have cut-offs operable from outside the engine room. Fire suppression systems and alarms activated by heat and smoke detectors are also installed in all areas of high fire risk such as engine rooms and galleys. Smaller commercial vessels operating in sheltered waters which have compact engine bays without adequate space for an automatic fire suppression system are fitted with a peephole with a spring loaded cover in the engine room bulkhead. These peepholes allow for a fire extinguisher nozzle to be inserted and discharged directly over the top of the engine.

---

[17] M2 and M3 vehicles are those used for the carriage of passengers and comprise more than eight seats in addition to the driver's seat.

[18] Fredrik Rosén, email, 20 December 2012.

[19] ibid.

[20] Chattaway, A, Dunster, R, Weller, P & Peoples, J 2012, 'The Development of a Standard Test for Assessing the Effectiveness of Transit Vehicle Fire Extinguishing Systems', *Proceedings from 2nd International Conference on Fires in Vehicles – FIVE 2012*, Chicago, USA, p.281.

Rail Approach. Because of the risks associated with fires in passenger trains capable of carrying in excess of 1000 passengers, national standards and guidelines have been developed over time to mitigate against the spread and severity of fires initiated both accidentally and deliberately. They have evolved with the advent of new and improved materials used in vehicle construction. The standards and guidelines are also designed to maximise the time available for the safe evacuation of passengers and crew.

The standards and guidelines govern both the design of the passenger carriages and the materials used in their construction. To ensure compliance with the standards, manufacturers are required to rigorously assess the hazards of the materials used, the rates for the spread of fire on the materials and the toxicity of the ensuing gases. Further, passenger carriages are required to be fitted with modern fire alarm and suppression systems. These systems include:

- establishing fire barrier systems using fire-rated partitions and flooring to protect passenger compartments;
- limiting the size and sealing of the apertures in the barriers to ensure integrity is maintained;
- installing sensing systems on propulsion and electrical generation/control equipment which automatically warn the train crew when fire is detected and release gas or chemical type extinguishers;
- installing shut-offs within air conditioning systems to prevent the recirculation of smoke and gaseous combustion products within passenger areas, and
- positioning of manual alarms and portable fire extinguishers in each carriage for passenger use in cases of emergency.

It is of interest to note that the engines used in diesel passenger trains nowadays are often the same “off-the-shelf” basic engines fitted to many models of buses and trucks simply converted to serve the rail application. Anecdotally, there are far fewer fires in and around train engines than there are in buses.

Passenger Evacuation

Two major concerns in bus fires are the speed at which the fire engulfs the vehicle once it enters the interior and the toxic gases generated when the flammable materials used in the interior fit-out catch fire. In a full scale test to study fire development, smoke spread, visibility and concentration of toxic gases in the passenger compartment from an engine compartment fire, the SP Institute found:

> … that the time for evacuation of the passengers was 4 – 5 minutes at a maximum. After this time the concentration of toxic gases reached dangerous levels. The visibility in the passenger compartment decreased rapidly. After 5 – 6 minutes the visibility was just a few meters.[21]

Thus, rapid evacuation of bus occupants, especially any that may be elderly or infirm, is critical. In addition to the number and mobility of passengers, the speed and efficiency of evacuation will be influenced by design factors such as number, size, location and operation of exits, and any damage interfering with the operation of doors such as distortion suffered in a collision. [Bus fires associated with collisions appear to be rare and OTSI has not experienced any to date.]

Most of the standard public passenger buses operating on regular short routes around cities and towns are fitted with two entry/exit doors, as well as emergency exits. In NSW, the two-door city buses, which have experienced the majority of fires, require approximately two minutes to unload in normal in-service operations. Additionally, provision is made for elderly or wheelchair-bound passengers to be seated in the front section and so furthest away from the engine and rear wheel arches where the majority of fires start.

Coaches in Australia differ in configuration in that there is usually only one entry/exit door and the centre aisle may be narrower,[22] which has the potential to slow down the progress of evacuation. Luggage compartments below the floor provide a passage for the rapid spread of fire from around the rear of a coach to the front where the entry/exit door is located. The materials used for the interior fit-out of coaches are similar to those used in commuter style buses but additional furnishings such as curtaining increase the fuel load.

Evacuation though emergency exit windows as an alternative to vehicle doors is arguably only viable for the most agile of passengers given their height above

---

21 Hammarström, R, Axelsson, J, Försth, M, Johansson, P & Sundström, B, 'Bus Fire Safety SP Report 2008:41', *SP Fire Technology*, Borås, Sweden, 2008.

22 ADR 58/00 Clause 58.4: *Aisle Requirements*.

ground level. Rear emergency exit windows, and those mounted in the sides of the rear half of a bus, are not likely to be suitable if a fire is well underway or may be potentially dangerous to use if a fire at the rear is in the development stage.

Driver Training

There appears to be a lack of detail and consistency among operators in relation to instructions and provision of training to drivers, and other crew members who may be onboard, for the handling of fire-related emergencies. They cannot be expected to be expert in fire fighting but, if a fire is detected and can be attacked at its seat in its early stages of development, they may be successful in saving their vehicle from further damage or in suppressing development of the fire while awaiting the arrival of fire fighting appliances.

Regardless of the nature of instructions and training provided to drivers by operators, it is important to conduct ongoing refresher training programs to reinforce the requirements and aid retention of learning. It is equally important to ensure ‘conversion’ training is conducted when drivers are assigned to a make or model of vehicle with which they are unfamiliar or have not driven for some considerable time.

Australian Standard 5062—2006

AS 5062—2006 *Fire protection for mobile and transportable equipment* has the stated objective ‘to formalize current good practice in reducing the incidence and severity of fires and to provide a consistent approach to fire risk reduction …’. It advocates a risk management approach and specifies fire risk management procedures in detail. It sets out minimum requirements for fire protection system design, installation, commissioning and maintenance.

It appears that hazard identification and risk assessments, if they were undertaken in accordance with the Standard within the first few years of its release, did not result in the identification of a need to specify fire suppression systems for new vehicles or retro-fitting to existing vehicles. The impetus for action in some instances in Australian and overseas has been a significant event or series of events, or realisation of a significant emerging trend.

Industry Response

The BIC is currently leading the industry response in addressing bus fire safety issues. It has been successful in gaining funding jointly from New South Wales, Queensland and Western Australian state governments to facilitate industry-wide consultation, negotiation and subsequent development and publication of an 'Industry Advisory on Fire Mitigation'. The work commenced early April 2013. Their industry advisories (industry based codes of practice) are designed to complement existing regulations and are intended to describe and explain in detail a safety or potential safety issue, its possible effects, the process to address it and, if applicable, how to achieve compliance with existing legislation.

As a basis for discussion, the Confederation is advocating operators adopt a risk-based approach to establishing the most appropriate level of fire protection for their vehicles. Three levels of fire mitigation systems are proposed:

- Basic systems:
    - thorough maintenance and inspection programs
    - robust thermal insulation and encapsulation of the engine bay
    - potential ignition sources correctly designed and installed
    - appropriately sized portable extinguishers
    - drivers trained to deal with fires (includes evacuation)
    - fire alarms in the engine bay and, where fitted, the luggage bay and toilet
- Intermediate systems – add to basic systems:
    - a second fire extinguisher
    - separate fuel isolation valving
    - a driver activated engine bay fire protection system[23]
- Advanced systems – add to intermediate systems:
    - A fully automatic engine bay fire protection system
    - for high speed coach operations, a tyre pressure monitoring system on the rear axle/s.[24]

In the interim, BusNSW[25] has published a Member Information sheet recommending operators:

[23] This could be installed sophisticated proprietary equipment or simply a peep hole through which to direct a portable fire extinguisher.

[24] Hardy L, op.cit.

1. Undertake a risk analysis on the potential of fires on buses as part of their Safety Management System under the Bus Operator Accreditation Scheme (BOAS).
2. Develop a maintenance plan to minimise these risks.
3. Provide employees with training in the event of a fire as well as provide a consistent employee procedure in the bus driver manual.[26]

Australian Design Rules

Under the *Motor Vehicle Standards Act 1989* road vehicles are required to comply with the Australian Design Rules which are national standards for vehicle safety, anti-theft and emissions.

ADRs are administered on behalf of the Australian Government by the Department of Infrastructure and Transport (DIT). Where possible, ADRs are subject to a full review every 10 years. Considerable consultation is undertaken as part of the review process and is also the case in the development of draft new ADRs and amendment of existing ADRs. In addition to public comment being an important part of the process -

> Much of the consultation takes place within institutional arrangements established for this purpose. The analysis needed, and the bodies consulted, depends on the degree of impact the new or amended ADR is expected to have on industry or road users. Consultation may involve some or all of the following groups: the Strategic Vehicle Safety and Environment Group (SVSEG), Australian Motor Vehicle Certification Board (AMVCB) which includes the Technical Liaison Group (TLG); the Transport and Infrastructure Senior Officials' Committee (TISOC), and the Standing Council on Transport and Infrastructure (SCOTI).[27]

State and Territory governments are represented on the SVEG and AMVCB. Membership also includes representation from manufacturing, operational, consumer and road user sectors. For example, the Bus Industry Confederation has

---

[25] BusNSW is the peak industry body representing over 700 private bus and coach operators in NSW.

[26] BusNSW, *Bus Fire Mitigation*, Member Information Sheet, Sydney, 21 January 2013. BusNSW website accessed on 1 February 2013, <http://www.busnsw.com.au>.

[27] Department of Infrastructure and Transport website accessed on 21 March 2013, <http://www.infrastructure.gov.au/roads/motor/design/index.aspx>.

representation on both the SVSEG and the TLG. Heads of State and Territory departments make up the TISOC and Ministers make up the SCOTI.

Australia has a policy of harmonisation with international standards where possible. This is facilitated though participation in the UNECE World Forum for Harmonization of Vehicle Regulations (WP 29). WP 29 provides a framework for member countries "to establish regulatory instruments concerning motor vehicles and motor vehicle equipment".[28] Australian representation is provided from within DIT.

WP 29 functions through a number of discrete working parties. The working party on General Safety Provisions is responsible for standards relating to fire safety of vehicles such as Regulation No.118.

In 2008, the Victorian Government initiated an inquiry into the "process of development, adoption and implementation of Australian design rules" including consideration of "other worldwide practices with a focus on improving vehicle safety".[29] VicRoads presented a detailed submission which supported adoption of internationally agreed standards and alignment in their implementation. Two of VicRoads' recommendations were adopted by the Inquiry:

> That Australia strengthens its international voice and increases its contribution to the United Nations Economic Commission for Europe (UNECE) technical Working Party 29 (WP29).
>
> That Australia contributes more actively to international vehicle safety research programs with the aim of accelerating development of international standards.[30]

Road Safety Strategies

Both NSW and the Australian Government have comprehensive current 10 year road safety strategies. As evidenced by their targets and performance indicators, their focus is on reducing road fatalities and associated trauma, and material costs. There is scant mention of buses apart from their being included in the category

28 UNECE website accessed on 21 March 2013, <http://www.unece.org/trans/main/wp29/introduction.html>.

29 Parliament of Victoria website accessed on 28 March 2013, <http://www.parliament.vic.gov.au/rsc/inquiries/article/242>.

30 VicRoads Submission to the Parliamentary Road Safety Committee Inquiry into the Australian Design Rules, February 2009, p.2.

'heavy vehicles', probably due to the very fortunate situation of there having been comparatively few fatalities as a result of bus accidents in recent years. However, important aspects of the strategies could readily be applied to bus (fire) safety without amendment. This is so for four of the fourteen key vehicle safety initiatives set out in the NSW Strategy:[31]

- Investigate improvements to the safety standards for new vehicles.
- Work with industry to improve safer vehicles and technology availability.
- Work with the Federal Government and other jurisdictions to continue improving vehicle standards.
- Undertake further research in the areas of vehicle design … and occupant protection.

Likewise, there are equally applicable aspects in the National Strategy.[32] In relation to strategy interventions associated with safer vehicles, these include:

- Improved vehicle safety standards.
- Increased uptake of … occupant protection measures.
- Improve the ADR process to ensure that minor changes to UNECE regulations are accepted automatically, timely consideration is given to new and amended UNECE regulations and GTRs (*Global Technical Regulations*), and priority is given to implementing new and amended ADRs that can deliver the greatest safety benefits.
- Encourage vehicle manufacturers to develop industry codes of practice committing to incorporation of vehicle safety features, while ensuring that safety features are not packaged only with luxury or comfort features.
- Work with the motor vehicle industry to advance the safety of Australia's vehicle fleet.

Overseas Experience

United States of America

A particularly tragic coach fire which occurred near Wilmer in Texas in 2005 exemplifies issues associated with the process of recognition of a fire, its development and the difficulties that can be encountered with vehicle evacuation.

[31] Transport for NSW, *Road Safety Strategy for New South Wales 2012-2021*, December 2012.

[32] Australian Transport Council, *National Road Safety Strategy 2011-2020*, 20 May 2011.

The coach was conveying persons being evacuated from a nursing home to safety ahead of Hurricane Rita. The fire was caused by a locked brake resulting in a fire in the rear tyre which then spread from the wheel arch area into the coach. The coach driver was alerted to there being a problem by a passing motorist who noticed the right rear tyre hub was glowing red.

The incident was investigated by the National Transportation Safety Board (NTSB) which concluded that the fire had spread from the tyre up the side of the coach and burnt through the fibreglass sidewall above and then entered the cabin through the windows.[33] This lead to a recommendation that a standard be developed 'to provide fire-hardening of exterior fire-prone materials, such as those around wheel wells'. The Board also recorded advice given to it that:

> ... it is extremely difficult, and beyond the capacity of any practical, currently available hand-held chemical extinguisher or automatic fire suppression system, to completely extinguish a burning tyre.

The passengers were elderly with special needs and were unable to self-evacuate from the coach through the emergency windows and the front door within the limited time available before the vehicle was engulfed by the fire. As a result, 23 passengers sustained fatal injuries attributable to both smoke inhalation and thermal exposure.

In investigating this and other coach accidents, the NTSB identified that emergency responders and bystanders had difficulty rescuing passengers due to the height from the ground and the (hinge) design of emergency exit windows. Only very agile passengers are likely to be able to quickly and successfully exit through bus windows and descend unassisted in excess of two metres to the ground.

The NTSB report also identified that there was no accurate recording of incidents between agencies as:

> … reporting systems are different and do not allow correlation of comprehensive and statistically accurate data on motor coach fires.

---

33 National Transportation Safety Board, *Motorcoach Fire on Interstate 45 During Hurricane Rita Evacuation, Near Wilmer, Texas, September 23, 2005*, Accident Report NTSB/HAR 07/01 PB2007-916202, adopted February 21, 2007.

It also found:

> Each DOT agency defines bus and motor coach differently for data collection and analysis.

Prompted by the NTSB report into the Wilmer coach fire, the Federal Motor Carrier Safety Administration commissioned a study to examine the causes, frequency and severity of motorcoach fires in the United States from available data for the period between 1995 and 2008.[34] A database was created with records from 899 fires of mechanical or electrical origin. Common to other studies examined, it was considered this number could be far less than the actual number of fires because 'reporting criteria for motorcoach fires are less clear and less enforceable compared with the criteria for other types of roadway incident reporting'.

Three of the key findings from the study were:

- The engine compartment was found to be most frequently the location of origin of fire followed closely by the wheel wells, together representing about 70% of the total instances. Only 1% were in the fuel system and 3% in the bus interior.
- The most frequent points of ignition were the turbocharger, electrical system, brakes, tyres, and wheel/hub bearings. Comparatively very few were associated with fuel lines and a negligible number with the fuel system.
- Approximately 4% of fires resulted in direct casualties. Aside from the Wilmer fire, there was only one other fatality; each of the other instances resulted in between one and three injuries.

The study identifies the following as providing areas for potential risk reduction measures:

> … data quality and reporting; compliance inspection and review standards; vehicle inspection, repair, and maintenance; and vehicle design, equipment development, and operational training.

Further, it recommends:

> … the development of wheel-well fire detection/suppression systems, and methods to enhance fire-response equipment, fire safety procedures, and training requirements.

---

34 Meltzer, N, Ayres, G & Truong, M 2012, 'Motorcoach Fire Safety Analysis: The causes, Frequency, and Severity of Motorcoach Fires in the United States', *Proceedings from 2nd International Conference on Fires in Vehicles – FIVE 2012*, Chicago, USA, p.111.

A review by a leading US insurance company of some 150 claims resulting from bus fires from 2007 to 2011 found that approximately 60% started in the engine compartment and approximately 20% in the wheel wells.[35] The 'most typical' cause of the engine compartment fires was fuel leaks from hoses, loose fittings, seals and fuel lines. The next most significant cause was from electrical shorts.

The review strongly advocated:

- Driver training that included use of fire extinguishers, installed safety systems and passenger evacuation;
- Sound maintenance, inspection and engine cleaning regimes including careful attention to electrical wiring, turbochargers, fuel lines, tyres and wheel wells, and
- Purchasing buses with fire suppression and tyre pressure monitoring systems.

Although it did not provide any data or detailed information, the review stated that:

> Personal injury claims resulting from bus fires are rarely caused by burns; most injuries result from smoke inhalation and injuries sustained as passengers attempt to exit the vehicle through doors, windows or roof hatches.

The United States National Fire Protection Association has reported that, over the five years from 2003 to 2007, fire departments attended on average 2,400 bus fires per year (includes 'trackless trolleys').[36] Data collected on bus fires showed 62% of fires being due to 'mechanical failure or malfunction' and 24% due to various electrical faults. Fires originating in the engine bay, wheel area and running gear area accounted for 70% of the fires while 12% started in the operator or passenger area. Significant among the list of 'items first ignited' is electrical wire or cable insulation (29%), flammable or combustible liquids or gases or associated parts (27%), tyres (11%) and upholstered furniture or vehicle seat (3%). Approximately 1.1% of fires on average resulted in a 'civilian' casualty.

The development and effects of tyre fires have been further examined through experiments conducted by the United States National Institute of Standards and Technology (NIST). The experiments were concerned with fire penetration into the

---

[35] Crescenzo, RA 2012, 'Bus Fires in the United States: Statistics, Causes and Prevention', *Proceedings from 2nd International Conference on Fires in Vehicles – FIVE 2012*, Chicago, USA, p.13.

[36] Ahrens, Marty. *U.S. Vehicle Fire Trends and Patterns,* National Fire Protection Association, Quincy, MA, June 2010.

passenger compartment, fire-hardening against tyre fire penetration and fire growth within the passenger compartment. The results were published as a NIST Technical Note in 2011.[37]

It was found that an established tyre fire could spread to adjacent combustible fibreglass panels within two minutes, then gain entry to the passenger compartment through broken windows above as quickly as within five minutes. A combination of environmental conditions and the nature of materials of bus construction would affect the time taken between initiation of a fire in a wheel well and its penetration into the passenger compartment.

Three methods for fire-hardening to delay tyre fire penetration were investigated:

- replacing the exterior glass-reinforced plastic side panel below the windows and plastic fender with sheet steel;
- applying an intumescent[38] coating to the panel and fender, and
- Installing a fire plume deflector between the two components.

Steel sheeting was found to be the most effective followed by the intumescent coating.

An experiment to ascertain the approximate time for conditions to become untenable in a passenger compartment revealed that thermally untenable conditions were reached within about 6 to 11 minutes depending on the location within the motorcoach. Toxic, irritant and asphyxiant conditions and oxygen vitiation occurred between about 9 and 11 minutes. The report notes that these conditions were attained with a very limited fuel loading. It was also observed that:

> Visibility conditions (evaluated 1.5 m from the floor) deteriorated significantly prior to fire penetration of the motorcoach. Within 30 s after penetration, visibility decreased to less than 2 m. Poor visibility could have made egress from this motorcoach difficult several minutes before conditions became untenable.

---

37 National Institute of Standards and Technology, *Motorcoach Flammability Project Final Report: Tire Fires – Passenger Compartment Penetration, Tenability, Mitigation, and Material Performance*, U.S. Department of Commerce, July 2011.

38 Oxford Dictionary On-line: *swelling up when heated, thus protecting the material underneath or sealing a gap in the event of a fire*.

A representative sample of motorcoach interior components were selected for flammability testing against the requirements of Federal Motor Vehicle Safety Standard (FMVSS) 302 *Flammability of Interior Materials*, the Federal Aviation Administration (FAA) and the Federal Railroad Administration (FRA). All passed the FMVSS 302 requirement except the back of the seat backrest. All failed both FAA and FRA requirements with one exception, being the interior wall panel which met FAA requirements.

The experiments resulted in the following recommendations:

> Based on the particular interior motorcoach components tested … and the limited experiments conducted, the following recommendations for possible solutions and future research are made, but pertinence and application to other motorcoach models must be considered as well as cost-benefit analyses which have not been conducted:
>
> - A simple temperature measurement device such as a thermocouple located near the wheel could be investigated as a source for early warning to motorcoach drivers of adverse heating and an impending tire fire.
> - It is recommended that fire hardening of external components above the wheel wells be considered as part of a holistic fire safety performance analysis. Designs utilizing replacement of combustible materials with metal should consider the potential of heat from a tire fire to conduct through the metal to combustible materials in the motorcoach wall structure.
> - To potentially lead to additional design options for hardening a motorcoach exterior against tire fires, *exterior* components should be flammability tested to examine ignition and flame spread behaviour due to impinging flames or substantial radiative heat flux.
> - To potentially reduce fire spread and increase time to untenable conditions in the passenger compartment, it is recommended that further research be conducted to quantify the impact of improved flammability performance (such as that required by FRA and/or FAA for analogous components) of the seats and parcel rack doors on fire spread and time to untenable conditions.
> - Flammability testing (beyond FMVSS 302) of interior components vulnerable to early ignition by tire fire and not examined in the current study is recommended, including combustible coverings of window posts and

> window shades. Additional research is needed to quantify their role in early fire spread immediately after tire fire penetration.

Finnish Studies

In 2000, the Accident Investigation Board of Finland initiated a project to collect data on bus fires, report on the causes of the fires and associated safety issues, and make safety recommendations. The study was subsequently extended to include 2001 and resulted in 71 incidents being examined, 33 from 2000 and 38 from 2001. 'Regional emergency services' and insurance inspectors were the sources of notification of the fires to the Board.

The report on the study observed that a fire that begins outside the passenger compartment may spread into the passenger compartment very quickly and, in the worst case, prevent passenger egress.[39] However, passengers were evacuated safely in all the incidents studied, although it was acknowledged that:

> …the situation could change significantly if, for example, there are disabled passengers in the vehicle.

It was observed that:

> Normally the fire moves into the passenger compartment from outside after the flames have broken either the rear window or the side window next to the engine.

Drivers used their portable fire extinguishers in 55 of the 71 incidents and succeeded in preventing severe fire damage on 39 of these occasions. However, the study concluded that a 2kg capacity portable extinguisher was too small to defeat or fully suppress a fire in many cases. Response times for emergency services were examined but it was concluded that:

> ... if the driver has not extinguished the fire, or has not prevented it from spreading, and the fire-fighters' arrival time is more than 10 minutes, then the fire will already have moved to the passenger compartment.

Other findings included:

- 52% of the fires started in the engine compartment;
- only one of the buses had an automatic fire extinguishing system installed;

---

[39] Accident Investigation Board of Finland, *Bus Fires in Finland during 2001*, Incident Report D 1/2001 Y, Shortened Version, Helsinki, 2002 [Translation]

- to install an automatic fire extinguishing system in a new vehicle or retrofit a suppression system costs approximately 1% of the vehicle's purchase price, and
- no fire alarm sensors had been correctly located.

The report of the findings of the study made a number of recommendations, the key ones of which are reproduced at Appendix B. Many of the recommendations remain unfulfilled.

Another study of bus fires in Finland was initiated in 2009 by the Transport Safety Agency, TraFi, to investigate all bus fires in 2010. The study was subsequently extended to cover 2011 and 2012, with an interim report being published in 2012 to cover 2010 and 2011.[40] A total of 126 bus fires were reported; 57 in 2010 and 69 from 2011.

A comparison of some basic data from the two Finnish studies is shown in Table 2:

BUS FIRE DATA	2000/2001	2010/2011
Started Inside Cabin	10 (14%)	10 (8%)
Started Outside Cabin	61 (86%)	113 (90%)
Progressed into Cabin	9 (15%)	10 (9%)
Vehicle Destroyed	8 (11%)	7 (6%)
Portable Extinguisher Used	55 (77%)	91 (72%)
Extinguisher Used Effectively	39 (71%)	78 (86%)

Table 2: Basic data comparison

The reports contain insufficient information from which to draw conclusions about fires which started inside the cabin. Fires progressing into the cabin were reported as normally coming through the windows above the fire when they broke due to the heat.

[40] Kokki, E, *Bus Fires in Finland 2010-2011*, Trafi Publications 11/2012, 2012

The more effective use of handheld/portable fire extinguishers – in successfully extinguishing or suppressing the fire – may be attributable to the availability of larger capacity equipment and/or driver training. The 2000/2001 report explains:

> The most common reason for the failure was early exhaustion of the fire-extinguisher contents.

The 2010/2011 report notes that:

> Extinguishers in buses were usually (67%) over 6 kg (13 lb) in weight.

It also explains that, in many cases, portable extinguishers carried in vehicles were not used because the fire had 'escalated too widely'. The report also notes that fixed extinguishing systems are not common as they are not mandatory, and that no fires were extinguished by an installed system.

A trend to larger installed fire extinguishers can be seen in the 10 years between the studies as the capacity of installed extinguishers in the 2000/2001 study was recorded as 63% being 2 kg, 10% being 3 kg and 27% being 6 kg. The regulatory requirement remains as only 2 kg but many bus companies are voluntarily equipping their buses with higher capacity equipment.[41]

The extent of installation of fire detection and alarm systems is not recorded but it is noted that, of the 126 fires in 2010/2011, only on three occasions was the fire first detected by a fire alarm system.

Two passengers suffered from smoke inhalation on one occasion, two others were injured in connection with a garage fire that destroyed six buses and two fire fighters were injured.

An accurate comparison between the two sets of reported data in relation to the nature and origin of the fires is not possible but the following indicative statistics are of interest:

- fire initiated in the engine compartment in approximately 50% of the occasions in both studies;
- fire initiated in the wheel area roughly around 25% of the occasions, primarily due to overheating of brakes;
- fire was initiated by electrical 'faults' on roughly 25% of the occasions, and

[41] Kai Valonen, email, 13 December 2012.

- fuel and oil leaks were the cause of about 27% of the fires in 2000/2001 but only about 12% in 2010/2011.

The only notable change, then, is the significant reduction in the number and proportion of fires attributable to fuel and oil related problems. This could be due to a number or combination of reasons – improved technology, design, materials, and maintenance.

Most of the report's recommendations to improve bus fire safety mirror those made in the 2000/2001 study (see *Appendix B* for the comparison).

Scandinavian Experience

A 2006 report by the SP Swedish National Testing and Research Institute describes the results of a project to produce a survey of the number, causes and consequences of bus and coach fires in Norway and Sweden in the period 1996 – 2004.[42] During the period, on average 49 fires were reported annually in Norway, while in Sweden the average was 122. However, it was stated that 'the actual number of fires is considerably higher than this, as a large number of fires are not reported' (perhaps in the order of roughly 40%). This is despite both countries having a central government agency holding 'official statistics' on bus and coach fires.

Both countries recorded 54% of fires as being caused by 'Technical Fault' – electrical, leakage, friction or unspecified – and approximately 40% due to unknown causes. The remainder were attributed to arson. The difficulties experienced in comparing and analysing information and data reflects the Australian experience:

> Information on the causes of fires differs very considerably between Norway and Sweden, particularly for the category of 'Technical Fault'.

The report observed that, while the number of fires was high and noticeably increased over the period, injuries were 'very few', although 'the potential risk of a catastrophe is high'. The report identified two possible reasons for the increase in the number of fires as being the reduction in permissible noise levels and new emission requirements. Both resulted in higher engine operating temperatures.

42 SP Swedish National Testing and Research Institute, *Bus and coach fires in Sweden and Norway*, SP Report 2006:26.

In 2008, the SP Technical Research Institute of Sweden reported on a project managed by its Department of Fire Technology, a major component of which involved testing of materials typically used in bus interiors in terms of fire performance.[43] It included using a 49-passenger conventional coach to test the effects of fire in the engine compartment and in a tyre, and on the entire coach in a full scale fire. The report's conclusion commences with the following observations:

> The full scale test showed that smoke and toxic gases reached lethal levels in the passenger area within a few minutes, despite the fact that the fire started outside of the passenger area, in the rear compartment. This indicates a number of flaws which are characteristic of buses. The first is that the smoke was easily transported into the passenger area. Better partitions between different compartments are therefore desirable. The second is the rapid spread of the fire into the passenger area and the interior materials. This illustrates the need for stricter regulations regarding the fire performance of interior materials in buses. Bus fire safety is lagging behind that of other vehicles in terms of fire safety. Finally it is clear that the time available for escape is very limited. Thus a fire detection system will save very valuable time if it is installed in such a way that it gives early warning of fire or of overheating.

From the review of interior materials, it was also concluded most of the products would not meet all the relevant European requirements for use in passenger ships, public spaces, escape routes in buildings and passenger trains.

In addition to making a number of recommendations in relation to improving design, the report recommended improving 'routines' by:

- Ensuring quality of service and repairs through staff training, appropriate time allowance, and choosing the correct spare materials. Basic training concerning fire risks should be included in all training of the engineering staff
- Educating drivers in fire fighting and fire risks

and improving materials by:

- Imposing stricter requirements on interior materials
- Improving fire resistance of partitions, thereby reducing spread of smoke and fire

43 SP Technical Research Institute of Sweden, *Bus Fire Safety*, SP Report 2008:41

- Equipping the engine compartment with better detection system, in combination with fire extinguish system.

Postscript

In the six months to the end of 2012, OTSI received reports of another 11 bus fires (see *Appendix C* for brief details). Portable extinguishers were used on all occasions and were successful in all but two cases, only one of which resulted in the destruction of the vehicle. The locations of the source of the fires were markedly different from those of the previous 2½ years.

In December 2012, a Transperth CNG-powered bus was destroyed by fire despite it being fitted with fire suppression equipment and the driver using a portable extinguisher. Safety valves operated to vent fuel tanks as designed.

On 11 March 2013, it was reported that the Israeli Minister for Transportation, Road Safety and Infrastructure had announced that fire extinguishing systems, together with fire detectors in the engine and battery compartments, would be required to be installed on all the country's buses.[44]

Conclusions

Accurate, consolidated data on bus fires in New South Wales is not readily available as uniform, comprehensive records are not maintained by the various interested parties or necessarily provided by operators. The same situation generally applies both nationally and internationally. It is clear though, that there are more instances of bus fires than are reported to and recorded by any individual agency. While this makes rigorous analysis difficult, there has been an apparent upward trend in the number of fires in recent years coincidental with the adoption of stringent emission standards.

Available data indicates some overall consistency over time in relation to the causes of fires. The majority of fires originate in the engine compartment due mainly to flammable liquids and gases coming into contact with very hot engine components

---

[44] Israel National News website accessed on 25 March 2013, <http://www.israelnationalnews.com/News/Flash.aspx/264059#%2EUT7LhGt5mK0>.

because of loose fittings and/or damaged hoses/lines. Electrical fires account for around 20-25% of fires. Up to about 25% of fires originate in the wheel wells mainly due to brake problems. Comparatively few originate in the passenger compartment and those that do are often electrical fires behind the dashboard.

The primary concern in a bus fire is the amount of time available to evacuate passengers. Usually, fires that enter the passenger compartment do so by breaching the rear window or windows above wheel wells, having travelled up the outside of the bus. They may also enter through the floor around inspection hatches. Experiments indicate survivability in the passenger compartment once it has been breached may be as little as about five minutes in the best of circumstances. The main concern is the extensive fuel load provided by furnishings and fittings within the compartment and the possibility of 'flash over' occurring.

There is a high degree of consistency in the conclusions and recommendations of various overseas studies, experimentation and testing conducted in the United States, Scandinavia, Finland and Germany. The main themes are:

- installation of fixed fire suppression systems – given the greatest prominence
- detection and alarm systems
- improved fire resistance in and around wheel wells
- reduced flammability of materials used in body work and fit-out
- larger portable fire extinguishers
- driver training
- engine inspection, maintenance, and cleaning.

These are equally applicable in Australia and consistent with views expressed by industry representatives and findings from OTSI's investigations.

Relevant current Australian design rules and standards are very limited and have changed little over time, if at all. In this they mirror overseas experience. However, there is now momentum overseas, under the auspices of the United Nations Economic Commission for Europe, to develop and implement contemporary design rules and standards concerning bus fire safety. The SP Technical Research Institute of Sweden is taking a prominent lead in this, especially in relation to fire suppression systems. Nationally, the Bus Industry Confederation has taken the initiative and acquired funding to develop an industry based code of practice – a Bus Fire Mitigation Advisory.

Recommendations

In the interests of progressing bus fire safety, it is recommended that Transport for New South Wales undertake the following:

In consultation with and on behalf of all interested parties, establish a permanent resource dedicated to building a comprehensive State-wide bus fire reporting regime, maintaining the data base, and undertaking research and analysis of causes, effects and trends in bus fires within the State, nationally and internationally. Advocate for other states and territories to maintain data in the same format to facilitate improved monitoring and analysis.

As a matter of priority, advocate strongly for the development and implementation of new design rules and standards for bus fire warning and suppression systems and materials of construction and fit-out. Such rules and standards should draw on those approved by the United Nations Economic Commission for Europe. If this work does not attract high national priority, take the initiative to develop and implement design rules and standards for NSW as an interim safety measure.

Continue to provide material support and assistance to industry initiatives consistent with the relevant strategies contained in both the State and Australian Government road safety strategies.

Provide support and assistance to the bus and coach industry in relation to the development and implementation of training of drivers in dealing with vehicle fires including the evacuation of passengers.

In addition, all bus and coach service operators are referred to the risk-based approach to fire mitigation systems advocated by the Bus Industry Confederation and BusNSW, particularly the implementation of thorough routine and scheduled inspection, maintenance and servicing plans and programs.

Appendices

Appendix A: Bus Fires Examined January 2010 – June 2012

DATE	VEHICLE TYPE	YEAR	LIKELY FIRE SOURCE LOCATION	LEVEL of DAMAGE	ONBOARD FIRE EQUIPMENT USED
Feb-10	Tour Coach	2005	Rear wheel arch	Destroyed	Portable extinguisher
Jul-10	Tour Coach	2005	Turbocharger	Destroyed	Nil
Aug-10	Tour Coach	1987	Rear brake drum	Destroyed	Portable extinguisher
Sep-10	Bus	2001	Alternator	Destroyed	Portable extinguisher
Mar-11	Articulated Bus	2010	Fuse box	Minor	Portable extinguisher Suppression system
Jul-11	Bus[1]	2008	Turbocharger (coolant)	Destroyed	Portable extinguisher
Sep-11	Tour Coach	2007	Turbocharger	Destroyed	Portable extinguisher
Dec-11	Bus	2011	? Turbocharger (oil line)[2]	Destroyed	Portable extinguisher
Jan-12	Tour Bus	1984	Alternator / vacuum pump	Destroyed	Nil
Feb-12	Bus	1994	Fuel injector pipe	Major	Portable extinguisher
Mar-12	Bus	1994	? Electrical[2]	Moderate	Portable extinguisher
Mar-12	Tour Coach	2006	Turbocharger (oil pipe)	Major	Portable extinguisher
May-12	Bus[1]	2000	Oil in air filter	Minor	Portable extinguisher
May-12	Bus[1]	2000	Electrical (aircon)	Moderate	Portable extinguisher
May-12	Bus	1998	Fuel line	Moderate	Portable extinguisher

Notes: 1. CNG fuelled vehicles. All other vehicles were diesel powered.
2. Cause not definitively established.

Appendix B: Key Recommendations from Finnish Reports

2000/2001. *All new buses should be equipped with an automatic or semi-automatic fixed fire extinguisher system.*

2010/2011. *Fixed extinguishing systems in the engine area … should be maintained in buses*.

2000/2001. *The Ministry of Transport and Communications should prescribe a fire extinguisher of at least 6 kg in buses instead of the current 2 kg hand extinguisher.*

2010/2011. *Buses should be furnished with two 6 kg (13 lb) fire extinguishers.* [One in the cab and one in the engine compartment.]

2000/2001. *Bus manufacturers should equip the engine compartment covers with holes for fire extinguisher nozzles, with a spring loaded lid that opens inwards. The location of the holes should be determined according to chassis and body so that the extinguisher contents may be freely directed to higher fire risk objects. The lid should be equipped with the picture of a hand extinguisher.*

2010/2011. *Hole for first extinguishing should be maintained in the engine area …*

2000/2001. *Bus company owners should give every driver training in the first-hand extinguishing and at regular intervals arrange practice in the use of fire extinguishers and passenger evacuation.*

2010/2011. *Bus and coach operators should arrange regular theoretical and practical training on identifying fire risks, first extinguishing and evacuation of passengers for their personnel.*

2010/2011. *Topics on fire safety should be included in all mandatory refresher courses of bus drivers.*

2000/2001. *Drivers should become conversant with the function, among others, of the vehicle's fire warning system and the indicators relating to it.*

2000/2001. *The vehicle user should take care of:*

- *maintaining cleanliness of the engine and engine compartment*
- *inspecting the condition of the fuel pipes and replacing them with new types of pipes if necessary*
- *undertaking fitting work, according to the instructions in the maintenance manual, by taking into account the correct torque in tightening and the support of pipes*
- *checking the fitting and condition of the battery and generator cables according to the scheduled maintenance service program.*

2010/2011. *Bus and coach operators should create and put in the operation the check lists on fire risk. Check list should cover at least: engine area, fuel and oil leaks, wire bundles, electric appliances, wheels, brakes, fire extinguishers and exits.*

2010/2011. The investigation of bus fires and the reporting of investigation should be improved.

Appendix C: OTSI Bus Fires Notifications July - December 2012

DATE	VEHICLE TYPE	LIKELY FIRE SOURCE LOCATION	LEVEL of DAMAGE	ONBOARD FIRE EQUIPMENT USED
Jul-12	Bus	Transmission (oil line)	Minor	Portable extinguisher
Aug-12	Bus	Brakes	Minor	Portable extinguisher Unsuccessful
Sep-12	Double Deck Bus	Turbocharger	Destroyed	Portable extinguisher Unsuccessful
Sep-12	Bus	Sticking brakes	Minor	Portable extinguisher
Oct-12	Articulated Bus	Overheated brakes	Minor	Portable extinguisher
Oct-12	Bus	Fuel injector return line	Moderate	Portable extinguisher Unsuccessful
Oct-12	Bus	Brakes	Minor	Portable extinguisher
Nov-12	Bus	Alternator	Minor	Portable extinguisher
Dec-12	Bus	Coolant leak (aircon pump)	Minor	No
Dec-12	Bus	Engine oil (cracked head)	Minor	Portable extinguisher
Dec-12	Bus	Alternator	Minor	Portable extinguisher