Buildings Incorporating Automated Vehicle Parking Systems (AVPS)

Approval level: Fire Safety
First issued: May 2017
Review date: May 2019
Version number: 1

Fire Rescue Victoria

Guideline No. 32

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1. PURPOSE

The primary objectives of this guideline are to:

- describe the specific issues affecting occupant life safety and fire brigade intervention within buildings incorporating **automated vehicle parking systems (AVPS)** due to an alternative method of vehicle storage
- identify the limitations of the relevant building regulations in relation to building solutions that specify the use of AVPS, specifically the deemed to satisfy (DTS) Clause E1.5 of the Building Code of Australia (BCA)
- identify Clause E1.10 as a relevant DTS clause when designing for AVPS, due to the special fire hazards produced
- provide guidance to practicioners who design and certify building solutions that specify the use of AVPS.

2. SCOPE

The scope of this guideline relates to all classes of buildings that incorporate AVPS.

3. DEFINITONS

The following definitions apply for the purpose of this guideline.

Automatic Vehicle Parking System/s (AVPS): a mechanical device that is generally powered by electric motors or hydraulic pumps that move vehicles into storage positions. Systems can be ***fully-automated*** or ***semi-automated***; they commonly store cars but can also be designed to store motorcycles and trucks. They can range from a storage capacity of one vehicle and up to over 1000 vehicles. Vehicles may be stored in a horizontal configuration, vertical configuration or a combination of both.

BCA: refers to the Building Code of Australia 2016 and includes any amendment or replacement of the BCA as incorporated in the National Construction Code (NCC) series.

Carpark: has the same meaning as Clause A1.1 of the BCA.

Compliant: the AVPS complies with the Australian Standard AS 1524 or its European equivalent, EN 14010. Compliance is evidenced through certification from a recognised third party from the country of origin and would be required by a building certifier.

Enclosed Carpark: a carpark, other than an open-deck carpark, as defined in Clause A1.1 of the BCA. Carpark has the same meaning as **vehicle park** throughout this document.

Fire Compartment: has the same meaning as Clause A1.1 of the BCA.

Fire Hazard: has the same meaning as Clause A1.1 of the BCA.

Fire Resistance Level (FRL): has the same meaning as Clause A1.1 of the BCA.

Fully-Automated VPS: an AVPS that requires the driver to drive the vehicle into an entry/transfer area. When the driver and passengers have exited the vehicle and left the transfer area, the mechanical system transports the vehicle to a pre-determined parking space within the storage area/building. These systems are also commonly referred to as; **Automated Car Storage Systems, Fully-Automated Car Storage Systems** or **Parking Towers.**

Heat Release Rate: the rate in which heat is released by a fire.

Open-Deck Carpark: has the same meaning as Clause A1.1 of the BCA.

Safe, Well Considered Access: refers to the firefighter access provisions provided with regards to an AVPS. Detailed planning and design is required to ensure firefighters have safe access, various access options and a means of safe retreat.

Storage Area: the area where the vehicles are transported to and stored until they are required again by the driver, at which point they are retrieved and subsequently removed from storage.

Semi-Automated VPS: an AVPS that is typically less sophisticated than a Fully-Automated VPS. Semi-automated systems usually involve the driver having to drive the vehicle into or onto the storage system before exiting the vehicle. Once the driver has exited the vehicle, these systems typically require the driver to operate a control panel and monitor the system until the vehicle is secured or housed in the storage position. The following systems typically fall into this category:

- shifting pallet/platform systems
- stackers
- shufflers
- lift and slide systems
- park and lift systems.

Transfer/Entry Area: the area where the driver and passengers exit their vehicle and remove their applicable belongings, prior to the vehicle being automatically moved into the storage area. This area may also be referred to the as the loading area or drop-off /pick-up area.

Traverser: a component of an AVPS that has the ability to move vehicles both horizontally and vertically within the storage area. These components are also commonly referred to as:

- storage and retrieval units (SRU)
- shuttles
- transfer carriers
- travelling towers
- robots
- sliding lifts.

Vehicle Lift: a lift that transfers vehicles between carpark levels or storage areas/levels. In a traditional carpark a lift may be provided in the absence of a vehicular ramp, in these circumstances the driver usually drives the vehicle into the lift and remains within the vehicle while the lift moves between levels. Alternatively a vehicle lift may be incorporated into an AVPS to move vehicles between storage areas and transfer areas. In this case the driver is not permitted to travel within the vehicle.

Vehicle Storage Arrangement: the vehicle storage configuration in relation to vehicle fuel loading and access. For example, horizontal vehicle storage arrangements or vertical storage arrangements, as is the case where multi-tiered vehicle parking systems are utilised.

4. ABBREVIATIONS

AVPS	Automated Vehicle Parking System/s
AFAC	Australasian Fire and Emergency Services Authorities Council
AHJ	Authority Having Jurisdiction
BCA	Building Code of Australia
FBIM	Fire Brigade Intervention Model

FRL	Fire Resistance Level
FRV	Fire Rescue Victoria
FSE	Fire Safety Engineer
GFA	General Fire Alarm
NCC	National Construction Code
RBS	Relevant Building Surveyor
SSISEP	Sound System and Intercom System for Emergency Purposes
VWA	WorkSafe Victoria

5. BACKGROUND

Traditionally, vehicles stored in carparks have typically been parked in a horizontal configuration, meaning that only one vehicle is stored in a single parking space. However, the majority of AVPS allow for multiple vehicles to be stored in a vertical configuration within a traditional single vehicle storage space.

Australian fire incident statistics reveal that stationary vehicle fires are considered likely events. The probability of fire spreading to more than one vehicle is also considered likely when vehicles are stored in a vertical configuration. The presence of fire in these instances results in the generation of dense toxic smoke and reduced visibility. This has the potential to significantly impact on the safe evacuation of occupants and quickly reduce firefighter access as well as impacting on fire control and extinguishment effectiveness.

In recent decades, a number of factors have led to the increasing use of AVPS. These reasons include, but are not limited to, the following:

- the scarcity of land available for developing has resulted in developers/designers having to look at alternative solutions in regards to how vehicles are stored
- to maximise the use of the physical space/land area available within a designated vehicle parking area
- to satisfy off-street parking requirements that may be imposed by local government planning permits
- to satisfy local or state government planning policies/initiatives
- in many instances, AVPS are more cost effective to construct per vehicle space than it would be to construct in a traditional carpark
- developers are able to offer more than a single vehicle parking space as part of a property sale/lease, or offer additional parking spaces for sale
- in some areas, increased traffic congestion and social trends have seen an increase in public transport use and a decrease in owner vehicle use. In these instances, the off street security and vehicle storage convenience of AVPS may be appealing to those wanting to live close to public transport or inner city areas.

6. CARPARK FIRE SAFETY RESEARCH INITIATIVES

In 1998, BHP Steel published the first edition of *Economical Carparks – A Design Guide*. In developing the guide, BHP Steel conducted a series of full scale fire tests. The purpose of the tests was to gain a better understanding of the effects of fire associated within carpark buildings. The document indicated that the series of fire tests BHP Steel had conducted, consistently demonstrated that when fire spread between vehicles occurred, large quantities of dense toxic smoke was generated and that occupants within a building would experience a significant degree of reduced visibility.

As a result of these tests, regulations in Australia began to prescribe that closed carparks are to be afforded sprinkler protection where more than 40 cars are proposed to be accommodated.

One of the most significant aspects of the BHP Steel publication is that the research itself was based on full scale fire tests where vehicles stored within a horizontal configuration only (i.e. cars parked next to one another). Cars stored in a vertical arrangement however, were not considered in the BHP Steel test.

In October 2009, BRE Research published a research project titled *Fires in Enclosed Car Parks* on behalf of the UK Department of Communities and Local Government. The aim of the research project was to gather information on the nature of fires involving recent model cars for inclusion into existing guidance on fire safety strategies for closed carparks. The project involved eleven full scale tests, including tests on single cars, multiple cars (horizontal configuration) and two cars stored in a vertical configuration, as found in most Carpark Storage Systems (Test 11).

The following is an extract from the findings of the BRE - Department for Communities and Local Government as stated in their document titled *BD2552 - Fire Spread in Car Parks* (December 2010):

“The additional test that was carried out on a stacker with two cars showed that, in the absence of any fire suppression, fire would spread very quickly from the lower car to the upper car, developing into a very extensive and severe fire which might be expected to readily spread laterally to nearby cars. The test deliberately did not allow for any collapse of the stacker structure due to failure of the hydraulics or due to steel weakening but this might happen in practice. The potential risks from car stackers are clearly a concern. Such innovations also have implications for fire fighters due to the very rapid development of fire in the second car. The complexity of stacker structures may also cause difficulties in the application of firefighting water”.

The results of BRE Test 11 confirmed the suspected fire behavior and spread characteristics associated with this vehicle storage configuration. Accelerated fire spread and development were recorded along with the associated effects.

The current DTS fire safety solution does not consider the fire behavior demonstrated in Test 11. Therefore, occupant life safety and fire brigade intervention is potentially compromised, with respect to adequate time for safe egress in an emergency and time for search, rescue, control and extinguishment activities.

7. OCCUPATIONAL HEALTH AND SAFETY LEGISLATION

Section 28 of the *Occupational Health and Safety Act 2004* (OHS Act 2004 (Vic)). imposes a duty on designers of buildings and structures, in order to ensure that hazards and risks that may exist in a workplace are eliminated or controlled at the design stage, so far as is reasonable practicable. It is therefore important that designers recognize that in the context of a fire incident at a building or structure, the building or structure becomes the firefighters' workplace.

Fire Rescue Victoria (FRV) believes that by complying with this guideline, designers are minimizing their exposure to being held accountable against Section 28 of the OHS Act 2004 (Vic).

8. PLANNING COMPLIANCE WITH THE BCA

8.1 BCA PERFORMANCE REQUIREMENTS

The relevant performance requirements applicable to carparks incorporating AVPS have generally been determined in accordance with the principles of Clause A0.7 of the BCA.

8.2 RELEVANT DEEMED-TO-SATISFY PROVISIONS

The following deemed-to-satisfy provisions are generally considered to be applicable:

- E1.5 – Sprinklers (inter-alia Table E1.5 and Specification E1.5)
- E1.10 – Provision for special hazards
- E2.3 – Provision for special hazards.

8.3 DIRECTLY RELATED PERFORMANCE REQUIREMENT

Performance Requirement EP1.4 is considered to be directly relevant to the deemed-to-satisfy provisions identified above.

8.4 INDIRECTLY RELATED PERFORMANCE REQUIREMENT

Performance Requirements CP1, CP2, EP1.1, EP1.2, EP1.3, EP1.5, EP1.6 and EP2.2 are considered to be relevant to any aspects of a performance based design applying to the construction of closed carparks/vehicular storage areas.

8.5 FIRE ENGINEERING ANALYSIS CONSIDERATIONS

FRV believes that the current DTS provisions pertaining to carpark buildings do not correctly distinguish between the risk of vehicles stored in both a vertical and horizontal storage arrangement. In this context, an AVPS that store vehicles in a vertical array is firmly outside the scope of Clause E1.5 of the BCA and must therefore be considered as a performance solution that is supported by suitably justified fire engineering analysis.

Vehicle fires in buildings, where vehicles are stored in a vertical arrangement, are likely to generate a larger **heat release rate**, potentially promoting untenable conditions in a shorter period of time (i.e. reduced time for occupant evacuation and fire brigade access and setup).

A multiple vehicle design fire scenario should be considered (fire development and spread), as the potential exists for fire spread to occur both horizontally and vertically. Therefore, a deterministic or probabilistic analysis should be utilised in the fire engineering analysis that is consistent with the principles of the International Fire Engineering Guidelines.

In addition to the above considerations, suitable factors of safety should be adopted to satisfy the relevant acceptance criteria for occupant life safety and

firefighter tenability (refer to Section 6 from FRV *Fire Safety Guideline GL-17*: *Fire Brigade Intervention Model (FBIM) – General Provisions*).

From a structural perspective, consideration should be given to the following issues when quantifying an appropriate duration for fire brigade intervention:

- local collapse of the building
- structural failure of the AVPS structure
- spalling of concrete elements
- the applied fire resistance levels (FRL) to structural members.

9. OPERATIONAL FIREFIGHTING CONCERNS

The following section highlights some of the hazards involved with fighting vehicle fires within AVPS, so that designers can better understand the importance of providing **safe, well considered access** in addition to enhanced fire safety systems:

- accelerated horizontal and vertical fire spread within the carpark/storage area potentially compromises fire brigade intervention times for search, rescue, control and extinguishment activities
- more rapid development of heat and dense toxic smoke, subsequently limiting firefighting operations prior to the onset of fire-fighter tenability limits
- difficulties in applying effective firefighting medium to the seat of a fire that may be shielded by other vehicles, the AVPS structural/mechanical components and building structural elements such as columns. At least two access points to the storage area should be considered, allowing firefighters an alternate means of attack when combating a shielded fire in a dense load storage configuration
- due to the nature of vehicle design and construction, a fire in a vehicle is typically very well shielded by body panels. During a fire, boot, bonnet and door release mechanisms are commonly damaged or unable to be accessed. This results in firefighters having to manually force boots, bonnets and doors and panels open with hand tools and hydraulic spreaders. Even in open areas, such as a roadway, where access is excellent these actions can easily result in injury due to the forces being applied. These risks are greatly exacerbated in an AVPS where vehicles are stored extremely close to one another, blocked by structural elements and stored at heights above or below the pedestrian level of egress
- it is common for firefighting hoses to get caught under the tires of the vehicle that is being extinguished and other surrounding vehicles. This can result in sprains, strains and trips. These risks are compounded in AVPS, as firefighters are required to drag hoses and negotiate their way around other stored vehicles, through doors, around pillars, corners and the structure/components of the AVPS itself
- components containing liquid or gas under pressure, such as shock absorbers, air conditioning systems and gas struts can explode or rupture violently when exposed to fire
- a fire can result in the failure of park brake systems. In these instances, a vehicle may become mobile

- a vehicles' fuel source is often the greatest risk to responding firefighters. In modern petrol fuelled vehicles, fuel tanks are most commonly made from high-density polyethylene (HDPE) plastic. These tanks can be quickly compromised under fire conditions resulting in free flowing liquid fuel fires, thus not only increasing the fire intensity but also spreading the fire to other areas
- a fire involving a LPG (liquid petroleum gas) fueled vehicle or a liquid hydrogen (fuel cell) fueled vehicle can result in a boiling liquid expanding vapour explosion (BLEVE). This is a violent explosion caused by the rupture of a vessel containing a pressurized flammable liquid. A failure of either of these fuel systems can also result in a highly flammable gas leak
- electric/hybrid vehicles have the ability to significantly increase the fire intensity due to their large storage batteries; they require significantly more water to extinguish and are capable of reigniting hours later. There is also a real risk of electrocution to firefighters.

In addition to the above items, FRV is concerned that AVPS structures supporting the vehicles may fail and a vehicle may more or fall from its storage position.

10. DESIGN CONSIDERATIONS

10.1 COMPLIANT WITH AS 5124 – SAFETY OF MACHINERY

A broad range of AVPS are available from local and international suppliers. Along with such variation in suppliers and products comes differing levels of safety considered in the design, manufacture and erection of these systems. Compliance with Australian Standard AS 5124 is a prerequisite for this guideline. This standard covers a list of hazards such as mechanical, electrical, thermal and noise and should be read alongside this Fire Safety Guideline. Evidence of compliance with AS 5124 or its European equivalent is required by FRV for consideration of firefighter safety.

In regards to Appendix ZX5 of AS 5124, whilst this section of the standard is informative, FRV believe that it should be considered with equal regard to the body of the standard.

10.2 FIRE SPRINKLER SYSTEM DESIGN

FRV believe that **all** buildings incorporating AVPS should be provided with an automatic fire sprinkler system, complying with AS 2118.1-2006 (Part 1: General Systems) to serve the entire carpark/storage area.

An Ordinary Hazard 2 category sprinkler system as prescribed by AS 2118.1 has not necessarily been tested in association with the vertical storage of vehicles. The increased fire load may reduce the performance of the Ordinary Hazard 2 category sprinkler system (i.e. 5 mm/m over 144 m^2). Therefore, the appropriateness of the sprinkler system, in terms of the schematic design, sprinkler spacing and locations, sprinkler spray technology and hydraulic requirements must be designed for the specific vehicle storage arrangement.

Important Note: sprinkler systems are designed to control a fire, they may extinguish it but this is not the intent of the AS 2118.1. It is expected that firefighters extinguish the fire after sprinklers have controlled the fire and the heat release rate. The reason for this is that typically, a vehicle fire involves significant shielding from sprinklers. For example, a fire in the engine compartment of a vehicle will be shielded by the bonnet, guards and radiator.

FRV believe the best practice to limit exposure and maximize containment through the use of sprinklers. FRV is of the opinion that the following design requirements should be implemented as an absolute **minimum**:

- sprinkler heads should be provided at the ceiling level and be designed as per OH2
- in addition to the sprinklers provided in the point above, additional sprinkler heads should be incorporated within the vehicle storage bays (including pits). The design of these additional sprinklers should be based on a minimum of eight sprinkler heads operating. Hydraulic calculations should to be based on these eight sprinkler heads discharging simultaneously with the OH2 ceiling sprinklers. Thus a minimum total of 20 heads discharging simultaneously is suggested
- sprinklers incorporated within the storage bays should be positioned so that every corner of each vehicle space/bay is covered. These sprinkler heads should also be positioned at a height that is not heavily shielded or obstructed by the vehicle itself (refer to Figures 1 and 2 for suggested placement positions and spray directions). The intent of these sprinkler heads is to contain the heat and flame from a burning vehicle and prevent fire spread sideways and upwards, this should be considered when designing head placement and direction
- Sprinklers should include fast response heads.

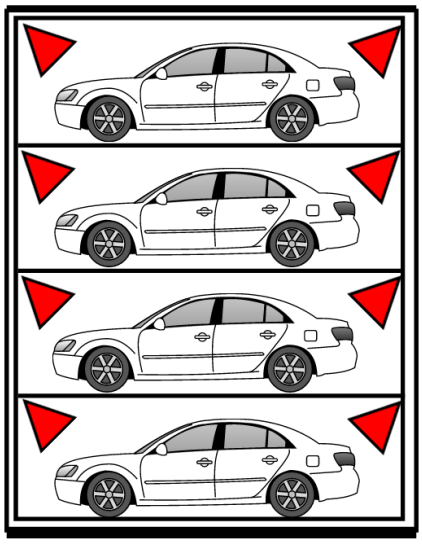


Figure 1 – sprinkler placement example

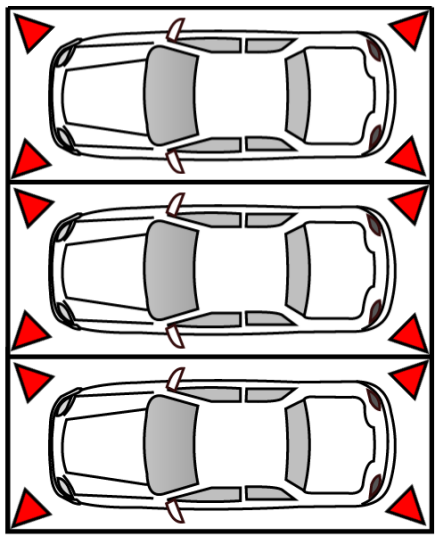


Figure 2 – sprinkler placement example

Consideration should also be given to zoning the sprinkler system in conjunction with firefighter access points. With the use of strategically placed flow switch, the system should be able to identify a certain point within the vehicle storage area where the sprinkler has activated. This should then in turn identify what level or area of the building firefighters should gain access to. For example, an activated sprinkler flow switch may indicate at the FIP that firefighters should respond to the *"Southern Vehicle Storage Access Point on Building Level 4".*

10.3 ALTERNATIVE METHODS OF FIRE SUPRESSION AND DETECTION

FRV will consider supporting the proposed use of alternative suppression mediums such as foam, mist, gas, etc. Support will be dependent upon research and design.

FRV encourages designers to investigate alternative methods of detection that increases detection times and assists in pinpointing the area within an AVPS where the detection has occurred.

10.4 FIRE COMPARTMENTATION AND BUILDING STRUCTURAL STABILITY

In instances where a **fully-automated VPS** is proposed, FRV believe that due to the potential fire loads and intervention issues involved the compartment containing the fully-automated VPS/storage area should be separated from the remainder of the building by barriers to fire such as walls and/or floors that achieve a minimum 240 minute resistance to the spread of fire, with any openings adequately protected.

All penetrations through building elements that are required by the BCA to achieve a specific FRL should be protected with fire collars and assemblies that have been tested in accordance with AS 4072.1 and AS 1530.4. Additionally, any ductwork and associated system componentry that is required to function in fire mode should not reduce the fire resistance of the construction element through which the duct(s) may pass.

The effects of fire loads on the structural adequacy of the building must also be considered (structural stability of the building).

10.5 AVPS STRUCTURAL STABILITY

With limited structural/thermal protection afforded to the AVPS under fire conditions, the likely fire intensity may cause structural failure of the AVPS or its supporting frame. In this instance the vehicle may roll or drop into other areas promoting further fire spread.

Calculations indicating the structural adequacy of the steel structure are required and need to be compared to Fire Brigade Intervention Model (FBIM).

FRV encourage the provision of engineering controls that eliminate this issue from occurring.

10.6 LININGS WITHIN THE VEHICLE STORAGE AREA

Any internal linings and the like fitted to walls and the underside of ceilings within the vehicle storage area must be successfully tested to AS 9705 in accordance with AS 5637.1. The lining material must be fixed in accordance with the tested prototype.

An example of an internal lining would be a product fitted to the underside of the vehicle storage area ceiling for the purpose of insulation.

10.7 CONTROLLED AUTOMATIC SHUTDOWN OF AVPS

Upon activation of a GFA, it is expected that the control and indicating equipment (or the FIP) will automatically initiate a controlled shutdown of the AVPS. This will assist with firefighter investigation and intervention, as well as reducing the potential for the system to move a vehicle that may be on fire.

In this context, building designers and the technicians who program the FIP and AVPS are to implement the following system controls and enhancements:

- visual signals should be provided at the designated firefighter access points to the carpark/storage area and the fire indicator panel (FIP). These visual signals should indicate the status of the system, e.g. "*vehicle parking system operating"* or *"vehicle parking system isolated*"
- the AVPS should **not** automatically start back up when the fire panel has been reset. FRV's concern is that a firefighter may be in the storage area when the fire panel is reset and that firefighter faces the risk of being crushed when the AVPS reactivates. Designers should consider a separate process for the reactivation of the AVPS that is undertaken by a trained authorized person.

In regards to a **fully-automated VPS**, it is recommended that designers incorporate the following additional functions upon activation of a GFA:

- if the system is moving a vehicle at the time of a GFA then the vehicle should be automatically moved as a priority to an enhanced sprinkler protected area prior to the system shutting down
- vehicle lifts should return to predetermined levels to act as void fall protection for firefighters potentially entering the area. For example in buildings where a vehicle lift passed through a number of levels then the lift should return to the fire level where firefighters will be responding to protect/cover the lift void. See further discussion on this issue in Section 10.12.10
- consideration must still be given to accessibility and safety. FRV would be concerned if a traverser or lift stopped in an area where it obstructed firefighter access.

10.8 POWER ISOLATION TO AN AVPS (AND IDENTIFICATION/STATUS)

Signage indicating the power isolation procedure and isolation locations should be provided at the FIP and designated firefighter access points to the carpark/storage area. Isolation points/breakers should also be clearly identified.

Considerations should be given to providing signals at the designated firefighter access points to the carpark/storage area and the fire indicator panel (FIP). These visual signals should indicate the status of the electrical systems within the AVPS area/storage area, e.g. "*electrical systems live"* or *"electrical systems isolated*".

10.9 FIRE HYDRANT DESIGN

Compliant fire hydrant coverage should be achieved within the AVPS and storage areas in accordance with the BCA and AS 2419.

If compliant coverage is not achieved, then depending on the final design and fire-fighter accessibility, additional fire hydrants may be required to be installed within the vehicle storage area. This is not FRV's preference and would require significant consultation with FRV to determine the site specific 'operational requirements'. Clause 3.2.3.3 of AS 2419 reiterates that additional hydrants are only acceptable if they suit the 'operational requirements' of the fire brigade. The 'operational requirements' of FRV will be determined on a case by case basis.

Furthermore, as per AS 2419, the fire hydrant system performance should also be validated given the potential for a multiple vehicle fire.

10.10 OCCUPANT WARNING SYSTEM

As per Specification E1.5 of the BCA, the sprinkler system must be interfaced to initiate the operation of an occupant warning throughout all areas of the building or SSISEP, where it is installed.

10.11 VENTILATION DESIGN

Smoke exhaust/natural venting will also need to be provided at the highest level and/or along the façade of the vehicle storage system. Ventilation is required to ensure visibility is maintained in the event of fire. Preference would be for natural venting as it may also be utilised for fighting a fire from the outside of the building depending on the site access.

The performance criteria and fan selection of any mechanical system should meet the smoke exhaust system requirements under Specification E2.2b of the BCA and adhere to relevant standard AS 1668.1, with consideration of the system having fire rated fans, cabling and controls that do not hinder sprinkler activation. With respect to any metal ductwork, and the likelihood of that ductwork deforming, suitable passive protection should be provided (e.g. fire rated board material) to encase the entire metal ductwork. Additional protection of the ductwork will increase the reliability and robustness of the overall smoke exhaust system.

Natural ventilation should encourage designs that have cross flow on opposite walls of the vehicle storage compartment, with at least 50% openings. Mechanical ventilation should be encouraged to adhere to the relevant AS 1668.1 standard with consideration of the system having fire rated or fire separated fans, cabling and controls that do not hinder sprinkler activation.

The design must demonstrate that:

- the conditions within the carpark/storage area permit firefighers to undertake search and rescue
- firefighters must be able to locate the seat of a fire and commence primary containment and extinguishment operations
- firefighters must be provided with appropriate controls to operate a mechanical exhaust or ventilation system.

10.12 ACCESS AND EGRESS REQUIREMENTS FOR FIREFIGHTERS

Section 10.12 and its subsequent sub sections relate to the provision of access and egress requirements for firefighters.

Scenarios requiring the response of emergency services personnel and potential access into the AVPS/storage area may include:

- rescue of persons or animals trapper within a transferred vehicle
- rescue of staff members or maintenance workers trapped or suffering a medical emergency within the AVPS/storage area
- emergency situation (fire/fuel leak, chemical leak, structural collapse, etc.)
- investigation of activation of FIP (accidental false alarms)
- fire investigation analysis (post fire).

Furthermore, it is for the reasons highlighted in Section 9 (Operational Firefighting Concerns) that FRV highlight the need for safe, well considered access. Designers should implement the following recommendations as a minimum, as well as consult with FRV in regards to access plans/proposals.

As discussed previously, even with enhanced sprinkler systems, at some stage firefighters will need to access the seat of the fire to ensure complete extinguishment has occurred and to be able to investigate the cause of the fire.

10.12.1 ACCESSING THE STORAGE AREA

Two separate firefighter access points into the vehicle storage area should be provided at each pedestrian access level (refer to Figures 3 and 4). This provides an egress contingency and assists in firefighter access and intervention.

Any door leading into the vehicle storage area should achieve a fire rating of -/240/30 and be provided with smoke seals.

Each doorway must permit entry by a firefighter wearing a breathing apparatus and carrying a telescopic “jumbo” ladder or other firefighting equipment.

In regards to fully-automated VPS, any doors leading into vehicle storage areas should be locked and be only accessible by attending fire brigade and maintenance personnel.

10.12.2 STORAGE DEPTH RESTRICTIONS

Vehicles should be stored no deeper (horizontally) than three vehicles deep from the safe pedestrian access area (refer to Figure 3). This restriction relates to the following:

- the limitations of a standard water spray from a fire hose
- the amount that a vehicle shields/blocks a water spray from the safe pedestrian access area to the furthest most vehicle
- the amount of manoeuvring required by a firefighter to physically access the furthest most vehicles and the associated evacuation from this confined area.

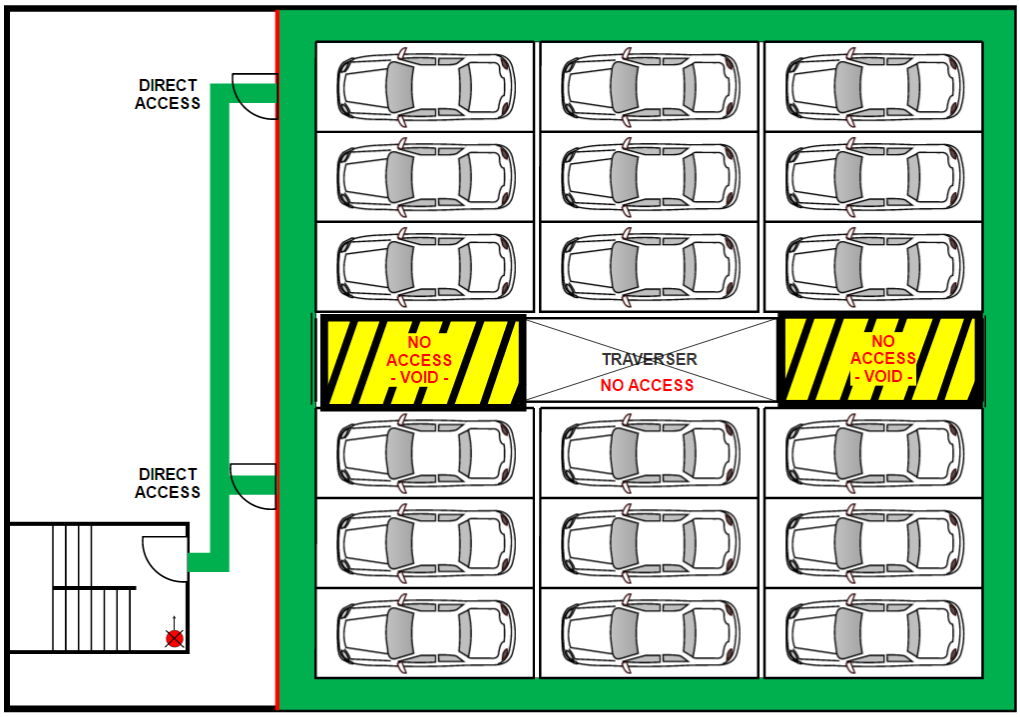


Figure 3 - vehicles stored no greater than three vehicles deep from the safe pedestrian access area.

10.12.3 STORAGE LEVEL RESTRICTIONS

FRV's preference is for safe pedestrian access to be provided to every vehicle storage level. However, at an absolute minimum, safe pedestrian access must be provided to every third vehicle level (vertically) of the vehicle storage area. In designs which incorporate higher vehicles, such as SUV's being stored on top of each other, then pedestrian access should be provided to every second vehicle level in these areas (refer to Figure 4).

FRV's preference is for a concrete slab floor to be provided at this pedestrian access level. However, if this is unachievable then access must be provided by way of a compliant gantry system. FRV discourages the use of gantry systems to provide access solutions, however acknowledges that due to the complexities involved with building design a gantry system may be the only practical means of providing access.

Note: when used, gantries should be galvanised for reliability and longevity. ChemSet style anchoring systems should not be used due to the tendency for these products to fail under fire conditions (AS 1735 should be used when specifying anchoring requirements).

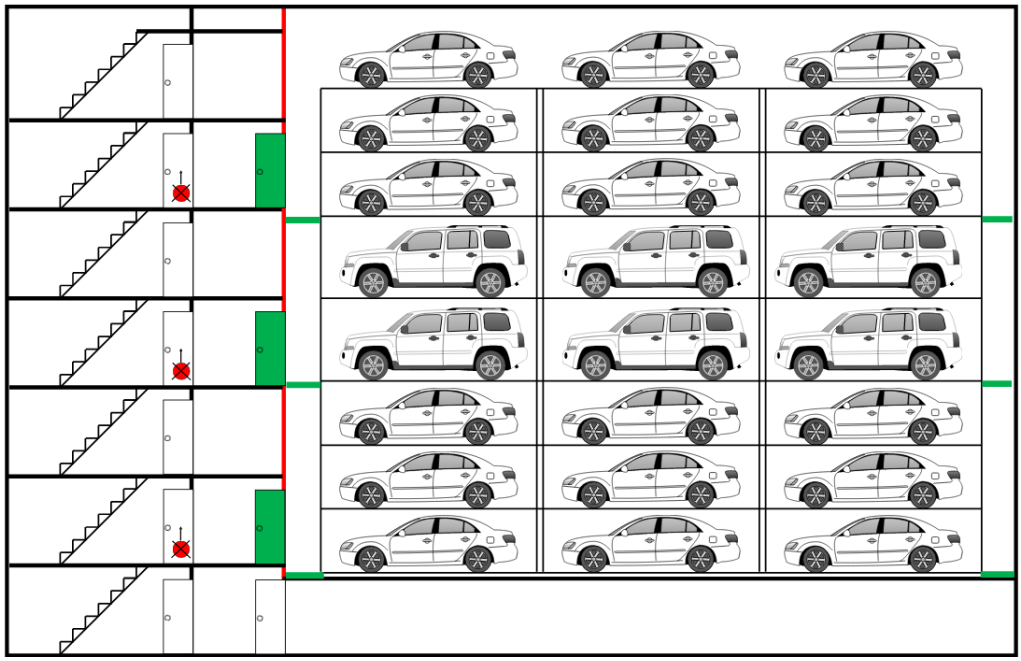


Figure 4 – pedestrian access at minimum every third vehicle level for “sedan” vehicles and at least every second vehicle level for “SUV” vehicles.

10.12.4 ACCESSING A GANTRY LEVEL

Where a design includes an internal gantry system, it is FRV’s preference that the gantry level is accessed **directly** off an adjacent building floor level.

If it is not achievable to provide access to a gantry level off an adjacent building floor level, and all design options have been exhausted, then access between the access level and the internal gantry level may be provided by way of a permanent safety ladder, compliant to AS 1657 (refer to additional clearance requirements in the following section). Depending on the length of these ladders they may be caged or uncaged, as detailed in AS 1657.

This type of design restricts intervention and does not offer an evacuation contingency, as such this design should only be considered as a last resort and is FRV’s least preferred access solution (refer to Figures 5A, B and C).

Pedestrian access must be provided from the entry door to the permanent ladder. “Pedestrian Access” is to be interpreted as the ability to walk up to the ladder without obstruction.

Note 1: a permanent ladder can only be used in an access design to ascend from a direct pedestrian access level to a gantry level above. It cannot be used to descend to a lower level.

Note 2: ladders should be galvanised for reliability and longevity. ChemSet style anchoring systems should not be used due to the tendency for these products to fail under fire conditions (AS 1735 should be used when specifying anchoring requirements).

Note 3: the provision of on-site portable ladders is **not** considered as an acceptable means of firefighter access.

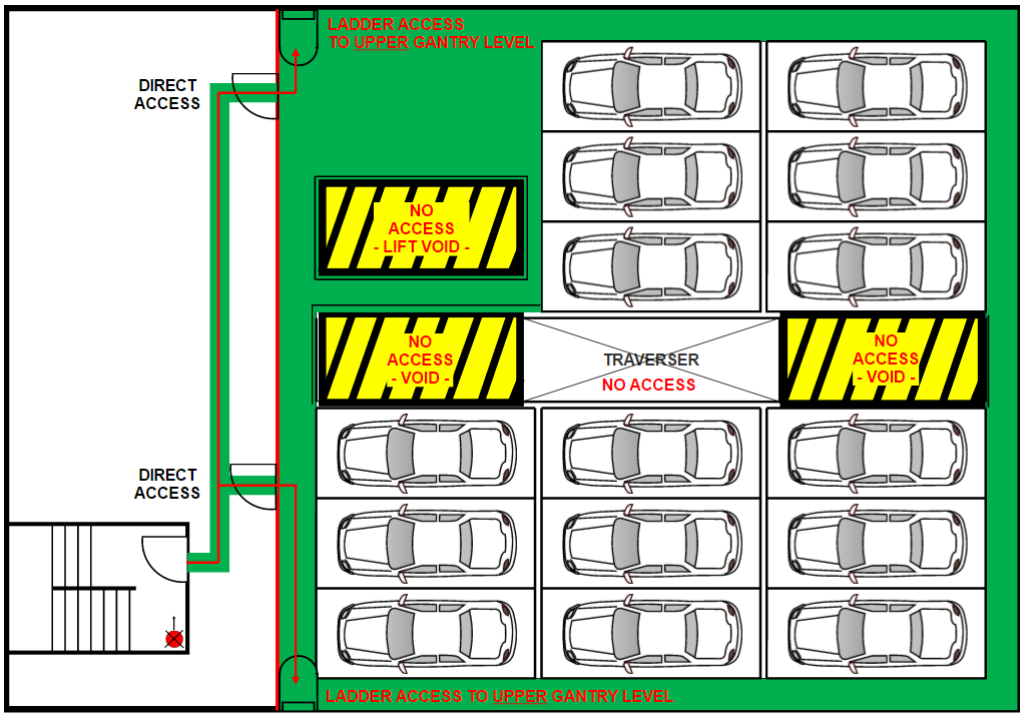


Figure 5A - AVPS level with direct pedestrian access, showing access to higher levels by permanently attached ladder.
Note: this is FRV's least preferred access solution and can only be considered once all other design options have been exhausted.

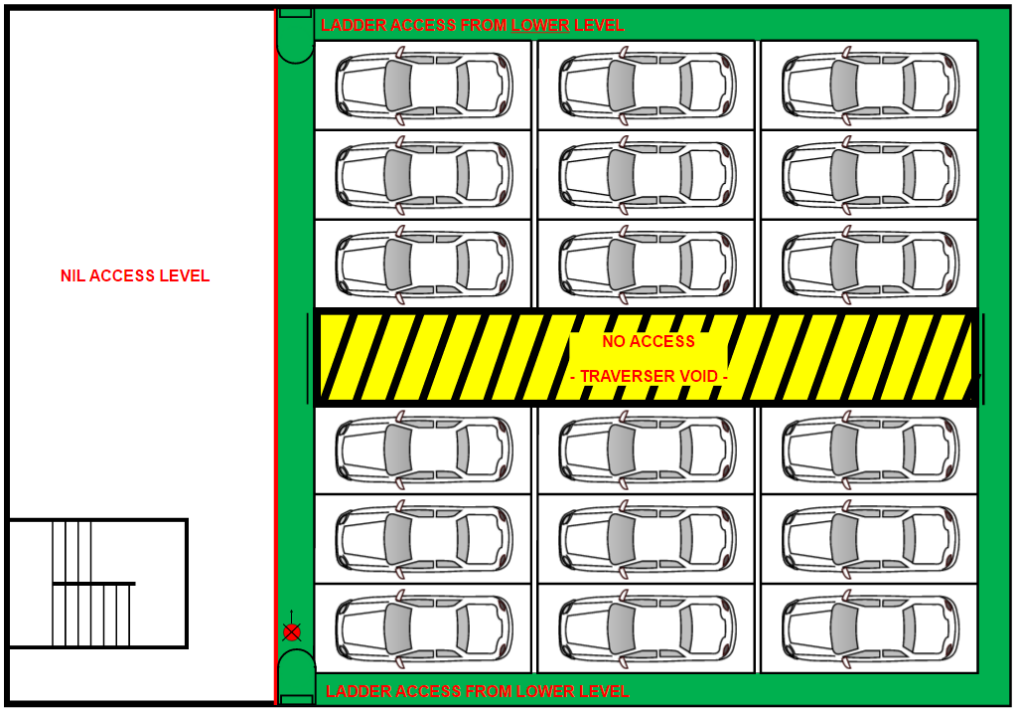


Figure 5B - AVPS level inaccessible by stairs or other external means, access via permanently attached ladder from access level below.
Note: this is FRV's least preferred access solution and can only be considered once all other design options have been exhausted.

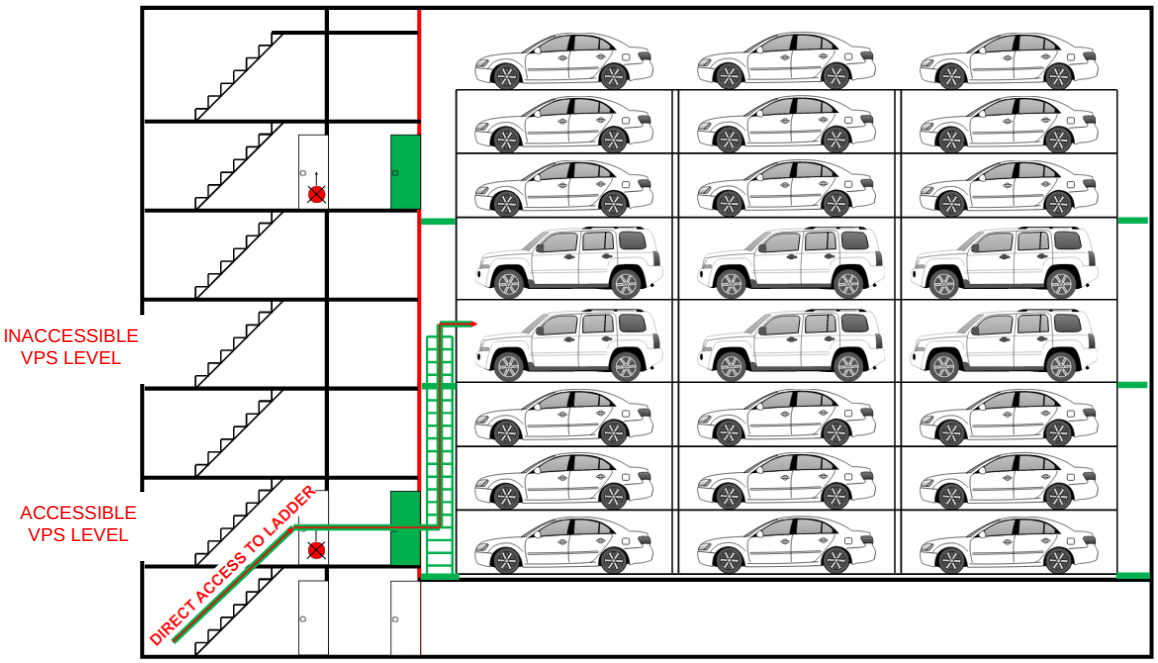


Figure 5C - elevation view of figures 5A and 5B.
Note: this is FRV's least preferred access solution and can only be considered once all other design options have been exhausted.

10.12.5 ACCESSING AREAS/LEVELS BELOW PEDESTRIAN ACCESS LEVEL

When it is proposed to build an AVPS that extends more than one car level below the main pedestrian access level or ground level, safe access to the lowest level within the storage area must be provided. This access must be provided via a compliant fire isolated stair, extending to the lowest most point of the storage area (refer to figures 6A, B and C).

Note 1: all other access provisions detailed above must also be provided.

Note 2: the use of permanent ladders for access below ground level is not supported by FRV.

Note 3: compliant fire hydrant coverage must be provided to these levels in accordance with AS 2419, as in many instances a fire hydrant will need to be located within this fire isolated access stair.

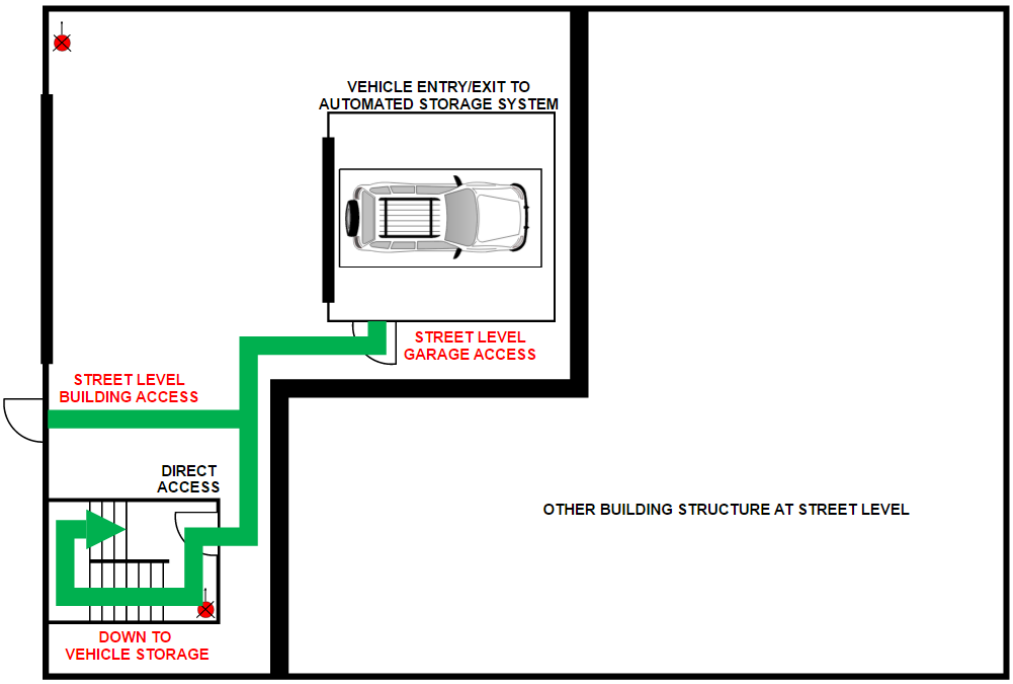


Figure 6A - street level entry point to below ground storage.

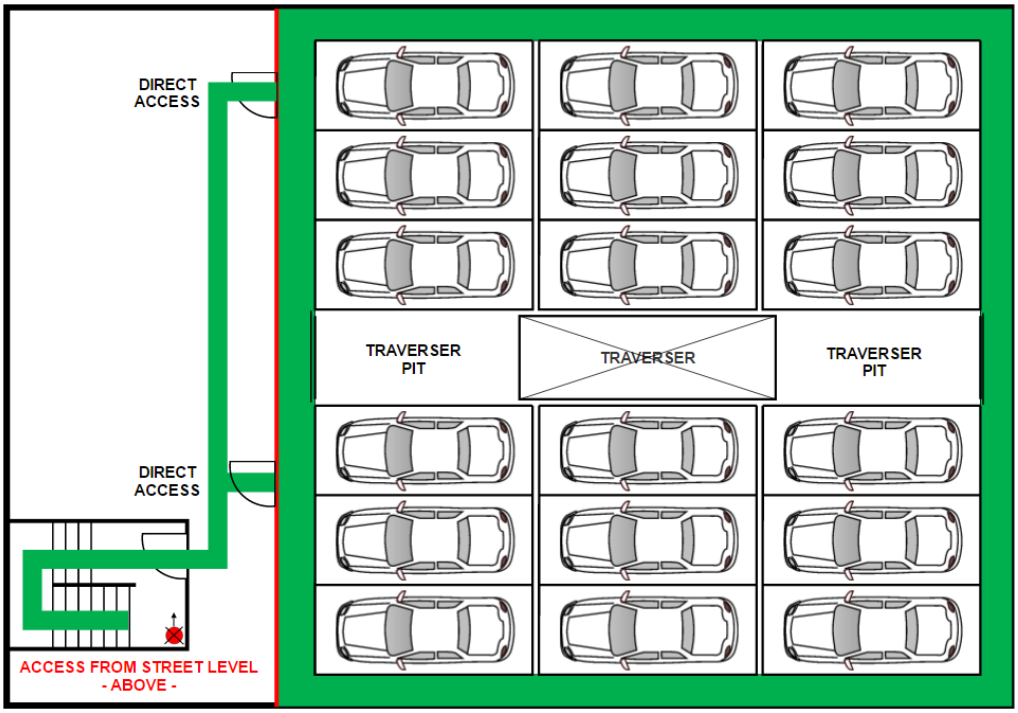


Figure 6B - access to AVPS storage area from fire isolated stair.

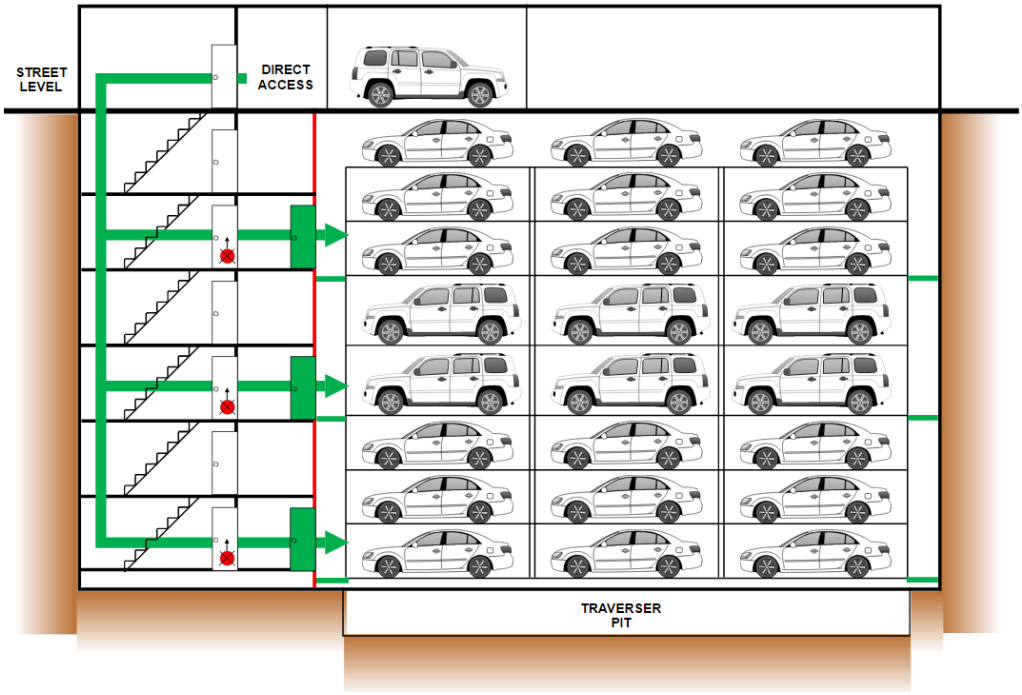


Figure 6C - elevation view of below ground storage area access.

10.12.6 FIREFIGHTER PEDESTRIAN ACCESS CLEARANCE

When designing firefighter pedestrian access paths, it should always be considered that firefighters will be wearing a breathing apparatus kit and carrying firefighting equipment. Therefore, pinch points and ladders accessing gantry systems must accommodate the additional size of an air cylinder worn on the back of a firefighter, as well as the equipment they are carrying.

Firefighter pedestrian access paths should be no less than 800mm wide. Pinch points should be no narrower than 700mm wide and for a length no more than 400mm (refer to Figure 7). An example of a pinch point would be passing a duct, pipe or other structural element. **Note:** the minimum 'effective' width of a pedestrian access path must not include the parking space/platform as part of calculation for the access path.

Permanent safety ladders must have an increased clearance to that detailed in AS 1657. The minimum clearance in front of the ladder between the ladder and all permanent objects that are not part of the ladder installation shall be as follows; from the nosing of the tread measured perpendicular to the slope of the ladder, 1200mm when the ladder is inclined at 70^{o} to the horizontal, increasing proportionally to 1300mm when the ladder is inclined at 60^{o} to the horizontal.

A minimum lateral clearance of permanently unobstructed space having a height above floor level of not less than 2000mm should be maintained. Where this figure cannot be achieved due to a beam, pipework or alike, a clearance of 1800mm lasting no longer laterally than 2000mm should be the absolute minimum clearance maintained. Where this scenario occurs, appropriate padded protection and hazard signage should be provided.

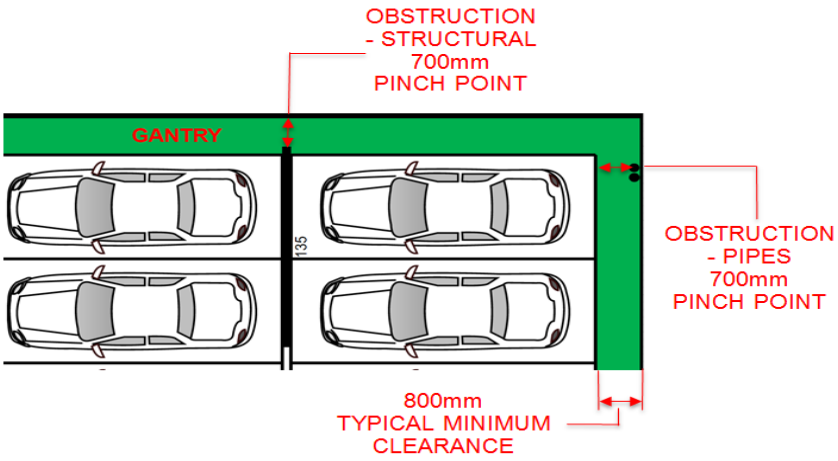


Figure 7 - minimum firefighter pedestrian access clearances.

10.12.7 SEPARATION OF AREAS CAUSED BY *TRAVERSER* AISLE

A traverser aisle can create a 2.8m separation between one side of a stack of stored vehicles to the other side which cannot be bridged. It is not acceptable to expect firefighters to bridge this separation by any temporary means. A permanent safe means of access must be provided.

10.12.8 ACCESSING THE STORAGE AREA VIA A MAINTENANCE PALLET

It has been identified by FRV that a number of fully-automatic VPS have “maintenance pallets” that effectively allow maintenance personnel to travel throughout the system/storage area, on a specially designed pallet, as a vehicle normally would.

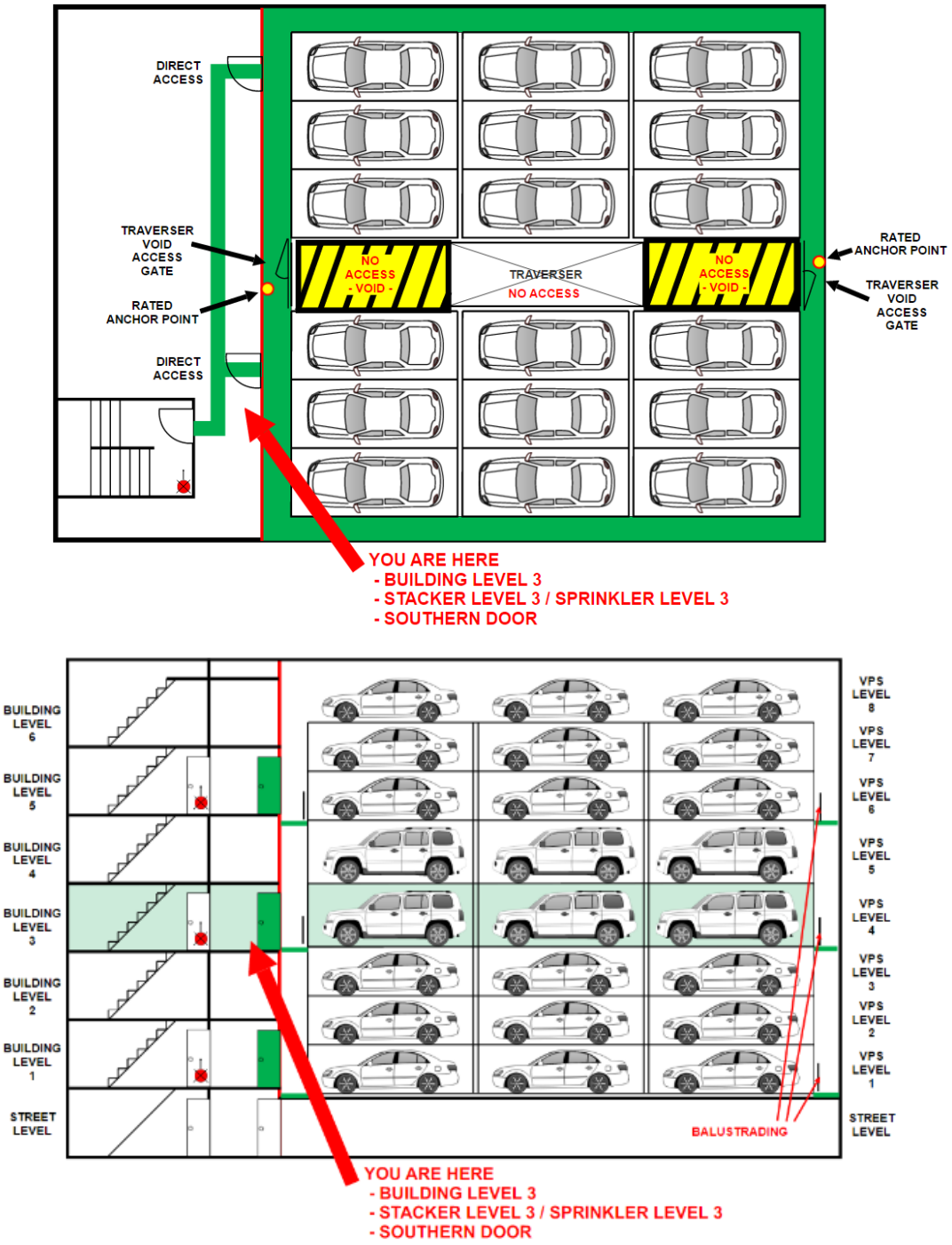
FRV can categorically confirm that this “maintenance pallet” would not be used to transport firefighters during a fire event or whilst investigating an alarm of fire. However, during a rescue/medical emergency firefighters may utilise this equipment. This would only occur after a thorough dynamic risk assessment and under the supervision of trained maintenance personnel.

10.12.9 SIGNAGE

Appropriate signage should be provided on the outside of any door leading into the vehicle storage area. Signage should read: “***ACCESS TO VEHICLE STORAGE UNIT – WARNING: FALL HAZARD AUTHORISED PERSONNEL ONLY – CONSIDER IMPLEMENTING WORKING FROM HEIGHTS PROCEDURES”.***

Any door leading into the vehicle storage/carpark area should have a permanent **Firefighter Block Plan** displayed directly adjacent to it (refer to Figures 8A and B). These permanent plans should provide firefighters with a clear floor plan and cross section plan of the floor level and vehicle storage area and show features such as:

- safe pedestrian access routes within the vehicle storage area (shaded green)
- risk areas, such as voids or switchboards (shaded yellow for electrical risk and yellow with black diagonal lines for all other risks)
- additional safety provisions, such as anchor points, gates or balustrading
- installed firefighting equipment, including hydrants and isolation valves
- sprinkler zones (correlating to FIP data)
- building floor level
- fire walls/compartmentation (designated with red lines).



Figures 8A and 8B - example of a Firefighter Block Plan – plan and elevation view.

Consideration should also be given to signage identifying non-guarded machinery, electrical risks, pinch points, etc.

All safety signage must comply with AS 1319.

10.12.10 VOID/FALL FROM HEIGHT PROTECTION

Depending on the system design, a compliant balustrade to AS 1657 may be required to protect firefighters from falling into a lift or traverser void. If a balustrade cannot be provided to all voids at the pedestrian access levels, then as much of the pedestrian access path as possible must be protected by balustrading. At the point where the protected path ends, a latched self-closing gate displaying the following signage should be provided:

"ATTENTION: NO HANDRAILS ARE PROVIDED BEYOND THIS POINT – INITIATE WORKING FROM HEIGHTS PROCEDURES".

Where a vehicle lift void passes through a pedestrian access level, some designers have designed their system so that a balustrade can be installed around the void and the action of a traverser transferring a vehicle to or from a vehicle lift occurs over or above the balustrading (refer to Figure 9).

Where there is a risk of falls, then consideration should also be given to providing load rated anchor points (with appropriate signage) in these areas to AS 1891.

Safety/hazard line marking should be provided around voids, as well as fall and trip hazards.

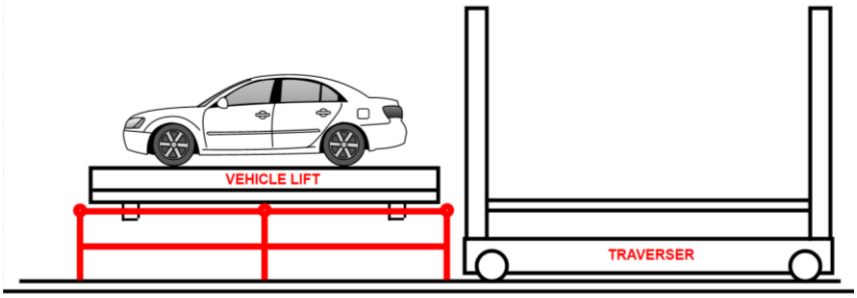


Figure 9 - example of a lift void being protected by balustrading.
The lift transfers the vehicle to the traverser over the balustrading.

10.12.11 LIGHTING

Exit, emergency lighting and non-emergency lighting should also be provided inside the vehicle storage area along the firefighter pedestrian access paths. This should also include any gantries. The lighting should be provided at a low height level (approximately 1500-2000mm) so that it is not greatly impacted by smoke in a fire situation. Exit and emergency lighting should be in accordance with relevant standard AS 2293.1; however the use of non-illuminated exits signs is discouraged.

10.12.12 EMERGENCY SERVICE COMMUNICATION

Where fully-automated VPS are proposed, a FRV emergency telephone system or leaky cable radio communications system should be provided in accordance with FRV *Fire Safety Guideline GL-01: The Installation of FRV Emergency Telephone and Leaky Cable Communication Systems*, to facilitate emergency service communications within the carpark/storage area.

11. ADDITIONAL CONSIDERATIONS

11.1 DEFINING AREAS AS CONFINED SPACES

Designers should define all vehicle storage areas as **confined spaces.** This will evoke Occupational Health and Safety legislation, which will require all future parties working within these areas to develop their own safety procedures in order to meet the requirements of Part 3.4 – Confined Spaces of the Occupational Health and Safety Regulations 2007. The Confined Space Compliance Code, developed by WorkSafe Victoria, identifies how to comply with those duties or obligations.

Along with other requirements, the Confined Space Compliance Code requires the following:

- a documented procedure which is particular to AVPS, its devices and the maintenance requirement. This document must also include hazard identification
- “Confined Space” placard adhered to and placed on each and every entry to the vehicle storage/AVPS areas (refer to Figure 10)
- confined space training for all maintenance crew by a Registered Training Organisation (RTO)
- a safety observer (spotter) must be present and not enter the confined space
- confined space permits issued each and every time that maintenance persons are entering the vehicle storage/transfer areas
- atmospheric air monitoring
- entry and exit procedures.

Compliance with the code should reduce the likelihood of staff members or maintenance workers becoming trapped or injured within the transfer/storage area. If an incident does occur, the procedures should support the response from emergency services personnel.

The employer of a maintenance crew attending an AVPS must satisfy the Confined Spaces Compliance Code or risk proceedings from WorkSafe for failure to meet duties under the OHS Act or Regulations.

Figure 10 - example of ‘Confined Space’ signage.

11.2 MACHINERY ISOLATION

Tag Out Lock Out systems should be installed on all systems/components within the vehicle storage area, as per Occupational Health and Safety Regulations 2007.

11.3 LPG (LIQUIFIED PETROLEUM GAS) AND HYDROGEN (FUEL CELL) FUELLED VEHICLES

Due to the elevated hazards presented with fires and leaks involving LPG and hydrogen fuelled vehicles, FRV recommends the LPG and hydrogen fuelled vehicles should not be stored or transported in AVPS.
Designers should explore possible ways in which this restriction can be enforced, monitored and managed throughout the life of the building.

11.4 ADDITIONAL HAZARD ABATEMENT MEASURES

In an effort to reduce fuel loads within the carpark/vehicle storage area, private resident storage areas within these areas potentially comprising combustible materials, flammable liquids, cleaning products and other general consumables should be avoided and stored within other fire separated areas of the building.

12. REFERENCES

ABCB, *International Fire Engineering Guidelines*, Canberra, Australia

AS 2118 Part 1, AS 2118 Part 4 and AS 2118 Part 6 – Sprinkler Systems

AS 1668 Part 2 – Ventilation requirements and systems for buildings in fire mode.

AS 2419 Part 1 – Fire hydrant system

AS 4072 Part 1 - Components for the Protection of Openings in Fire–Resistant Separating Elements Part 1 – Service Penetrations and Control Joints

AS 1530 Part 4 – Methods for Fire Tests on Building Materials, Components and Structures – Fire Resistance Test of Elements of Construction.

AS 5124 – Safety of Machinery – Equipment for power driven parking of motor vehicles – Safety and EMC requirements for design, manufacturing, erection and commissioning stages

AS 1657 – Fixed platforms, walkways, stairways and ladders – Design, construction and installation

BHP, March 1999, *Economical Carparks - A Guide to Fire Safety*

BRE Research, October 2009, *Fires in Enclosed Car Parks*

FRV Fire Safety Guideline *GL-01 – The Installation of Emergency Telephone and Leaky Cable Communications System*

FRV Fire Safety Guideline *GL-17 – Fire Brigade Intervention Model – General Provisions*