Fire Safety Guideline
Car Stackers

MFS Fire Safety Guideline for Car Stackers

Adelaide Station
99 Wakefield Street
Adelaide SA 5000

Enquiries 8204 3611
samfscommunitysafety@sa.gov.au
www.mfs.sa.gov.au

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Author: SO Kubler
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Whole document	Format update References updated
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Adelaide Station
99 Wakefield Street
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GLOSSARY

AS	Australian Standard
BES	MFS Built Environment Section
DtS	Deemed to Satisfy (refer Definitions)
FDCIE	fire detection control and indicating equipment
MFS	South Australian Metropolitan Fire Service
NCC	National Construction Code

REFERENCED DOCUMENTS

The following documents are referred to in this Guideline:

AS 1657 Australian Standard 1657 – *Fixed platforms, walkways, stairways and ladders - Design, construction and installation*

AS 1668.1 Australian Standard 1668.1 – *The use of ventilation and air conditioning in buildings – Part 1: Fire and smoke control in buildings*

AS 1670.1 Australian Standard 1670.1 – *Fire detection, warning, control and intercom systems – System design, installation and commissioning – Part 1: Fire*

AS 2118.1 Australian Standard 2118 – *Automatic fire sprinkler systems, Part 1: General systems*

AS 2419.1 Australian Standard 2419 – *Fire hydrant installations, Part 1: System design, installation and commissioning*

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

Australian Building Codes Board, *National Construction Code, Volume One, Building Code of Australia,* (Edition applicable at the time of Development Approval), Australian Building Codes Board, Canberra.

BRE Global, 2009, *Sprinkler protected car stacker fire test*, client report number 256618, BRE Fire and Security, Watford.

National Fire Protection Association, 2020, *Modern vehicle hazards in parking structures and vehicle carriers*, report number FPRF-2020-07, Fire Protection Research Foundation, NFPA, Maryland, USA.

Planning, Development and Infrastructure (General) Regulations 2017 (SA)

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www.mfs.sa.gov.au

DEFINITIONS

Deemed-to-Satisfy (DtS) Provisions has the meaning as defined in the National Construction Code.

Performance Requirement has the meaning as defined in the National Construction Code.

Performance Solution has the meaning as defined in the National Construction Code.

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1 WHAT IS A CAR STACKER?

A car stacker is a mechanical system that allows vertical parking of vehicles with reduced spacing between vehicles.

The stacker system may be manually controlled or even partially or fully automatic and is generally an electro-hydraulically operated system.

Car stackers are growing in popularity across all Australian capital cities as an option, typically for increasing maximum permissible occupancy numbers within apartment complexes with limited off-street parking.

Car stackers can also be used for showroom display of vehicles (vertical stacking) due to the small building footprint.

From an MFS operational perspective, car stackers have been classified (by the MFS Built Environment Section (BES)) into three types of systems:-

Type 1 – Simple system or single movement hoist or ramp type system

Type 2 – Medium complexity system - 2-3 levels, up to semi-automatic

Type 3 – Complex system – fully automatic, multi-level.

These are outlined in more detail below:-

1.1 Type 1 – Simple Systems

- Part-ramp or hoist type suspension system.
- Allows one car to be moved over an already parked car
- Lower car is parked on car park floor slab.
- Majority external above ground application or retrofit to conventional carparks.
- Manual operation via individual key switched controls.
- Driver must drive onto platform.

Figure 1: Examples of Simple Systems.

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1.2 Type 2 – Medium Complexity Systems

- Two or three levels of vehicles on platforms – requires a pit for the overrun to allow upper platform access to ground level.
- Manual operation via grouped or individual key switched controls.
- May be semi-automatic.
- May be within an enclosed space.
- Driver must park car onto tray and alight vehicle.
- Cars typically remain parked on tray.

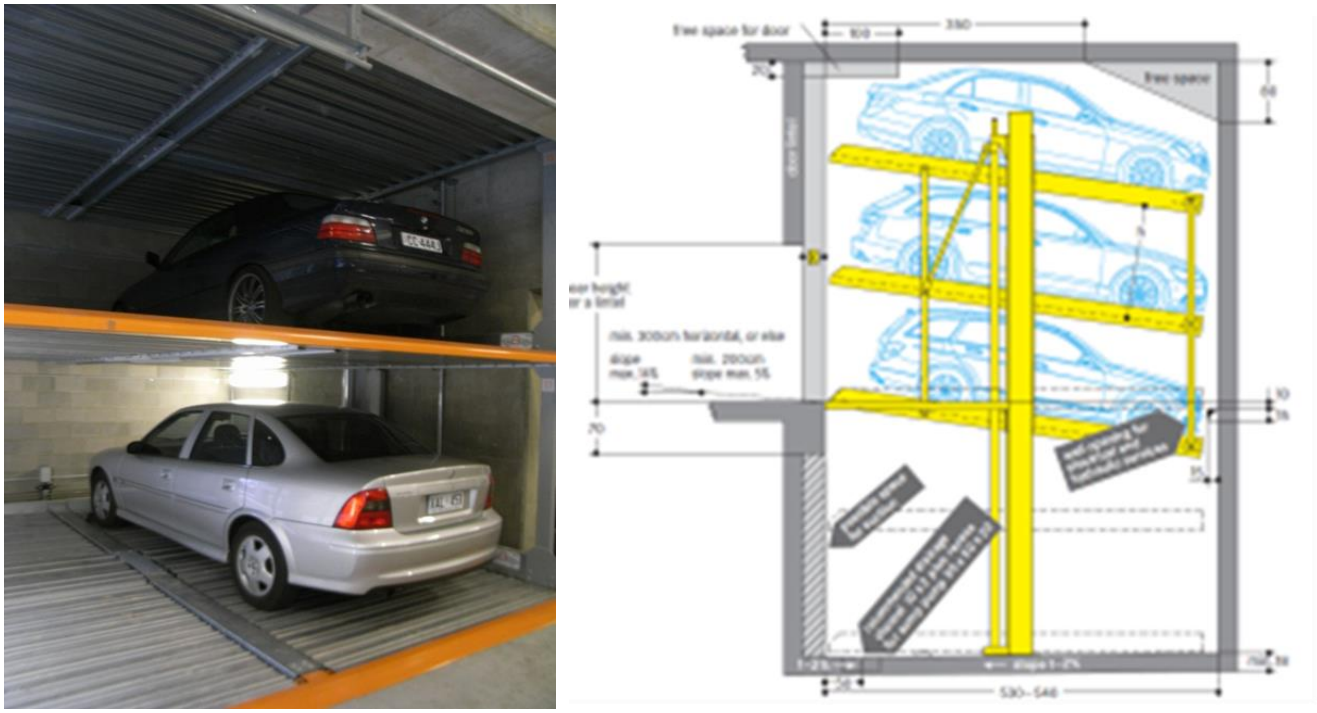

Figure 2: Examples of Medium Complexity Systems.

1.3 Type 3 – Complex Systems

- Fully automated – park car in a receiving bay and walk away
- Cars travel on a dedicated tray within the system and may not have a fixed address within the car parking system, i.e the trays keep moving as the system stores and retrieves cars.
- Infinite permutations for system layout
- Car retrieval can take some time
- Control via a central system, users have swipe card type access to the system

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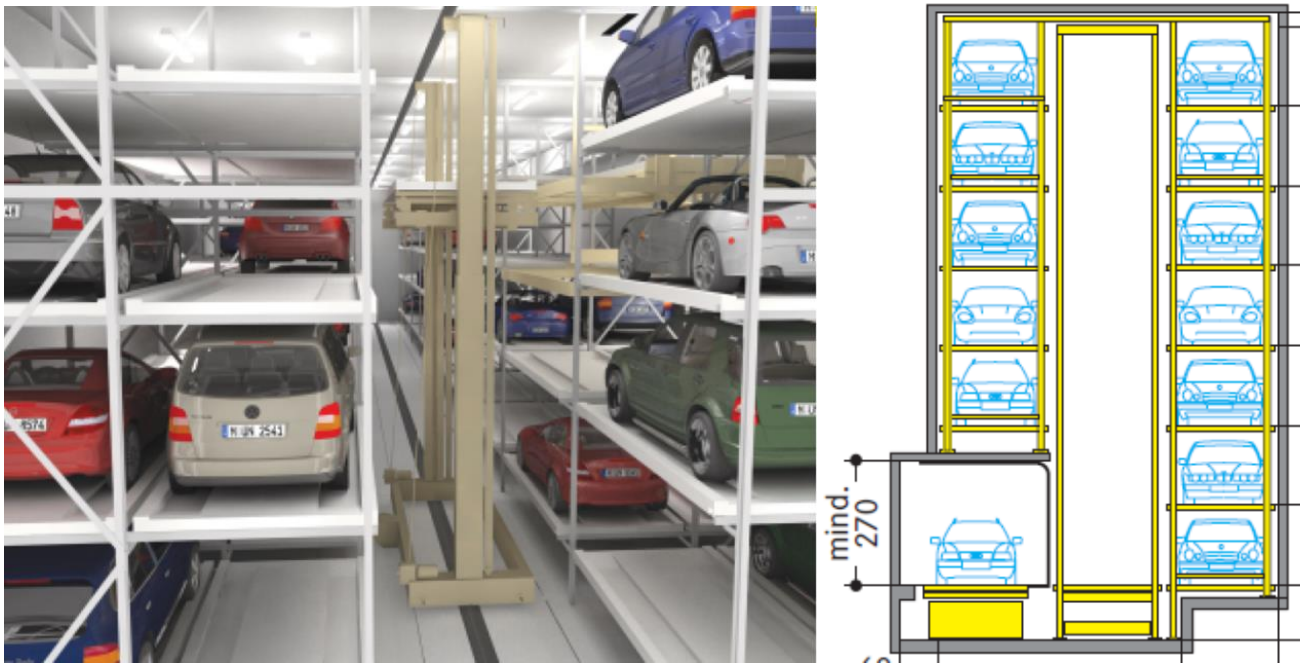

Figure 3: Examples of Complex Systems.

2 DESIGN OBJECTIVES

Car stackers present unique challenges in terms of building fire safety and operational firefighting response, primarily due to the following factors:-

- increased fuel load per unit area,
- the vehicles (fuel load) are configured for fast vertical fire spread,
- car stackers present difficulties for safe and effective firefighter access and firefighting
- internal conditions for fire fighters may be hazardous due to smoke and heat retention.

Car stackers present a significant fire hazard in terms of fire severity and duration, and when coupled with a potential for restricted effectiveness of fire services intervention, may lead to significant structural impact on the entire building. Thus adequate facilities should be provided to ensure that:-

1. **A vehicle fire is limited in its potential to impact on the structure, and**
2. **A vehicle fire can be safely extinguished by fire fighters.**

The MFS considers these two points to be the primary Design Objectives that any Building Solution incorporating car stackers shall be based upon.

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3 BUILDING CODE AND REGULATIONS

3.1 National Construction Code

At present, multi-level car stackers are not specifically addressed within the current National Construction Code (NCC 2019) with respect to Deemed-to-Satisfy (DtS) prescriptive Provisions or Performance Requirements.

3.2 Australian Standards

The current relevant Australian Standards for firefighting services and equipment for fire hydrant systems (AS 2419.1-2005) and fire detection and alarms systems (AS 1670.1-2018) do not contain specific design criteria for car stackers.

The Australian Standard 2118.1-2017 now includes specific design criteria for sprinkler systems serving car stackers.

Australian Standard 5124:2017 has specific considerations with respect to fires in car stackers and offers guidance in this regard.

3.3 SA Planning, Development and Infrastructure (PDI) Regulations

Under the South Australian *Planning, Development and Infrastructure (General) Regulations 2017*, the MFS is empowered under Regulation 45 to review Performance Solutions with respect to fire brigade intervention, including firefighting equipment.

3.4 General

With respect to car stackers, the MFS does not accept that automatic fire sprinklers systems are only required for carparks containing more than 40 vehicles (NCC Table E1.5). This position is on the basis that car stackers present a significantly more complex and severe fire hazard than conventional car parks.

NCC Clauses E1.10 *Provision for special hazards – problems for firefighting* and/or **E2.3 *Provision for special hazards – smoke hazard management*** are deemed relevant in relation to car stackers to achieve Building Rules Consent and may be resolved through applying fire engineered performance-based design principles.

4 CAR STACKERS AND BUILDING CHARACTERISTICS

The following items/factors are deemed to impact on building fire safety and effective operational response. Consideration of these items/factors should form the basis of any design assessment when determining the required active and passive fire protection measures as well as fire services access into a car stacker structure.

4.1 Fire and Smoke Spread

- Vehicles are located in close proximity both horizontally and vertically, with a high potential for rapid fire spread.
- Often the entire car stacker potion of the building is a single fire compartment containing a large number of vehicles (very high fire load).
- Potential for total smoke filling and smoke containment of the compartment, limiting ability for access and intervention as well as leading to extensive property damage.
- Considered to be a challenging environment for fire services operations due to heat, smoke and access difficulties.

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- Car stacking spaces may be totally or partially installed below ground, leading to severe smoke logging and access issues, and hazardous firefighting conditions.

4.2 Fire Services

- Studies indicate that automatic fire sprinklers can control but not extinguish vehicle fires in open framed, vertically stacked car parking arrangements (BRE Global, 2009). Thus firefighter intervention is required for full extinguishment.
- Fire services require access to vehicle bonnets/boots and other enclosed spaces for fire extinguishment and hazard isolations or removals (e.g. LPG cylinders, battery, SRS systems, etc.).
- Fire crews require hoseline access to all areas of the car stacker.

4.3 Construction and Access

- Construction of the building envelope (pre-cast panelling, steel or concrete structure - open sided, glazed, louvred, etc.).
- Below grade pits may be present and have vehicles within. Consideration needs to be given to effective sub-grade access for extinguishment/intervention. This access requirement may be avoidable through control system programming of a “return to grade” facility.
- Exposure of unprotected structural steelwork to prolonged fire impingement has the potential to impact the structural adequacy of load bearing members.
- Number of cars contained.
- Number of above ground levels and internal heights.
- Number of levels below ground.
- Internal layout of the car stacking system.
- Fire crew access provisions (fire stairs, ramps internal walkways, etc.).

5 FIRE SAFETY SYSTEM DESIGN CONSIDERATIONS

To achieve the **Design Objectives** (see Section 2), it is expected that multi-level car stackers will be provided with all, or a combination of, the firefighting and fire protection measures discussed in the following sections.

Where electric vehicles are to be accommodated in a car stacker system, particularly in systems which enable charging, particular consideration must be given to the specific behaviour and hazards associated with electric vehicle fires. The design operational duration of various fire safety systems and/or additional fire safety provisions may be required.

5.1 Fire Separation

It is considered that the multi-level car stacker shall be fire separated from the remainder of the building by:-

1. a fire wall having an FRL applicable to a Class 7a “Common Wall or Fire Wall” in line with the Type of Construction applicable as per the NCC; and
2. floors in accordance with NCC Clause C2.9; and
3. the concessions available for sprinkler protected (conventional layout) carparks are not applicable.

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5.2 Automatic Fire Sprinklers

Automatic fire sprinkler systems are expected to form an integral part of most car stacker fire protection systems.

Achieving complying sprinkler coverage and minimising obstruction of spray patterns is difficult to achieve within a car stacker space and consideration needs to be given to location of sprinkler heads, water shielding and utilisation of side wall heads where appropriate.

AS 2118-2017 Section 10 details the requirements for sprinkler protection within the car stacker, including Ordinary Hazard II protection at roof level as well as intermediate sprinklers within the car stacker.

Sprinkler protection will limit the maximum fire size, reduce temperatures and thus the impact of fire exposure to structural steel members and other load bearing parts.

The sprinkler control valve should be located adjacent the main loading bay entry point or the primary entry point for fire service access to the car stacker. This control valve will serve the car stacker installation only, be clearly labelled and shall have boosting provisions.

5.3 Fire Hydrant Systems and Firefighter Access

Fire hydrant systems shall be installed in accordance with AS 2419 and hoseline coverage to the internal stacking space is required to enable extinguishment of any vehicle fire.

1. Type 1 and 2 systems (as outlined in Section 1) located on the ground floors may achieve satisfactory hydrant coverage from external hydrants adjacent the main entry points.
2. Type 3 Systems (Complex, as outlined in Section 1) with multiple internal levels provide challenges for hoseline access and internal hydrants with dedicated access to the stacker from fire stairs may be required.
3. Open grate style metal walkways are typically required to access the internal perimeter of the car stacker space. Walkways may be accessible from internal or external stairs or from a fire stair contained within the primary building.
4. Given that the internal tiers or levels of the car stacker are in the order of 1.8 metres, it is not expected that walkways can be provided to serve every tier. However, provision shall be made that a hose stream can access every parking space.
5. Where walkway access is provided from a stair, that stair will be provided with a hydrant riser, fed from the main building's fire hydrant or combined fire system. Walkways and the like must be in accordance with AS 1657.
6. Preliminary layouts of internal access ways shall be discussed in detail with the BES.
7. Vertical ladder ways are to be avoided due to the requirement for firefighters to carry equipment and wear breathing apparatus.
8. Any roller doors/shutters shall open in fire alarm to provide additional means of firefighter entry and aid in natural ventilation.

5.4 Automatic Fire Detection Systems

Where the car stacker bounding construction does not permit appropriate levels of natural ventilation, a smoke detection system (in accordance with AS 1670) may be installed to provide early detection of a fire and shall be utilised for control of any automatic smoke exhaust system.

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5.5 Automatic Smoke Exhaust

Due to the risk posed from smoke filling of large compartments with respect to firefighter internal access it is expected that mechanical smoke exhaust will be provided where reliance upon natural ventilation is deemed to be insufficient or ineffective.

1. The extent of open façade and type of louvers/mesh panelling (where provided) shall be taken into consideration when assessing firefighter access provisions.
2. The smoke exhaust fans may be activated off the detection system or, where deemed appropriate, off the sprinkler pressure switch signal.
3. Manual controls (AS 1668.1) of any installed mechanical exhaust shall be provided at the main car stacker entry point and/or on the fire indicator panel as appropriate.
4. Make-up air provisions will need to be carefully assessed with respect to below ground installations and the extent of openings in the building façade.

6 ELECTRIC VEHICLES

Electric vehicles are a relatively recent and rapidly growing market for passenger vehicles. The lithium-ion battery systems are typically found in the floor pan of the vehicles, comprising thousands of individual cylindrical lithium-ion battery cells, and presenting a very high-density fuel source. Lithium-ion batteries typically ignite due to a chemical reaction referred to as thermal runaway. The challenge with these types of battery fires is that they continue to burn until the compounds contributing to the chemical reaction are exhausted and these fires cannot simply be extinguished by “usual” means. There is also a high risk of explosion during these reactions, which occur unpredictably. As these battery systems are made up of many individual battery cells, once the system starts to burn and break apart, individual burning cells can be ejected from the floor pan of the vehicle, starting fires elsewhere.

On top of the prolonged fire and explosion risks, the reactions involved produce a variety of toxic gasses, such as hydrogen fluoride, which present a significant risk to firefighters and others in the vicinity of the resultant smoke products. Some of the toxic gasses (e.g. hydrogen fluoride) can be water soluble, meaning that any fire water runoff also becomes contaminated and must be managed.

Internationally, electric vehicle fires are proving to be challenging to extinguish. Recommended firefighting response is for the application of very large amounts of water directly to the outside of the battery pack, potentially for several hours (NFPA, 2020). Anecdotally, current experience appears to be that electric vehicle fires are taking around four (4) to six (6) hours to control, with firefighting operations limited to cooling of the vehicle and batteries and exposure protection rather than direct or effective extinguishment.

The MFS is aware of car stacker system manufacturers that are developing their systems to incorporate the ability to connect and charge electric vehicles when stored in the car stacker system. Given the challenges and prolonged nature of electric vehicle fires, there is significant concern around the resultant impacts on the surrounding building structure as well as the ability of the installed firefighting systems to operate for the likely duration of an electric vehicle fire.

The MFS may request additional assessments and fire safety provisions not detailed in this Guideline be included in buildings where the storage and/or charging of electric vehicles is reasonably anticipated to occur.

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7 DESIGN SUMMARY

Designers and Certifying Authorities are actively encouraged to meet with the BES to discuss building developments involving car stackers to ensure a practicable and safe solution is developed.

The BES reinforces that the Design Objectives can be achieved by reviewing the proposed building against the criteria as below.

1. A vehicle fire is limited in its potential to impact on the structure by:-
   a. Assess car stacker potential fire size, given that single vehicle in the order of 5-8MW peak heat release rate;
   b. Review bounding construction and potential to contain heat and smoke;
   c. Automatic fire suppression best solution;
   d. Automatic fire sprinklers most commonly applied, however, other systems may suit specific enclosure geometries.
2. A vehicle fire can generally be safely extinguished by firefighters through:-
   a. Providing means of safe access;
   b. Adequate ventilation and smoke hazard management;
   c. Provision of a fire hydrant system (internal/external as required);
   d. Readily accessible and identifiable sprinkler control and boosting facilities.
3. The presence of electric vehicles within a car stacker require particular and specific design consideration to address the potential associated fire hazards.

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8 COMMISSIONING CHECKLIST

The following is a checklist of items that may be incorporated within the car stacker design as agreed with the BES and as documented within the submitted project documentation and the MFS Regulation 45 Fire Authority Referral Comment and Report.

ITEM / FACILITY	Y	N
Return-to-Ground function (vertical multi-tier stackers)		
Emergency stop switch on stacker main control panel		
Entry roller shutter manual control at FDCIE		
Local key/fob safe (where master key control unavoidable)		
Internal access ways – AS 1657		
Fire rated access points for fire fighters		
Hydrant coverage		
Automatic fire detection		
Automatic fire sprinklers		
Local sprinkler isolation valve – safe and accessible location		
Smoke hazard management – fire fan control at FDCIE		

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