The Use of Impulse Fan Systems in Enclosed Carparks

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1. PURPOSE

This guideline is principally concerned with the design, construction and commissioning of enclosed carpark buildings and carparks forming part of a building, which utilise multiple impulse fans as an alternative means of satisfying the general provisions of Clause E2.2 Table E2.2a for Class 7a buildings and ventilation requirements of Clause F4.11 of the relevant National Construction Code (NCC).

The purpose of this guideline is to provide industry with a means of guidance in relation to Fire Rescue Victoria's (FRV) position on the use of multiple impulse fan systems, in addition to the requirements outlined in the Australasian Fire and Emergency Services Authorities Council (AFAC) guideline *Fire safety for impulse (jet) fans in carparks*. This guideline must therefore be read in conjunction with the AFAC guideline to ensure all considerations are included in the proposed design and associated Performance Solution.

The target audience includes engineers (mechanical and fire safety), building surveyors, commercial builders, installers and property developers.

Although this guideline provides design recommendations and considerations, the responsibility remains with the relevant building surveyor (RBS), mechanical and fire safety engineers and design team to ensure compliance with all applicable performance requirements of the Building Code of Australia (BCA).

2. SCOPE

This guideline relates to all fire sprinkler protected and enclosed Class 7a carpark building, or part of a building, that are located within the FRV fire district that are provided with multiple impulse fans.

Note: the terms **"impulse fans"** and **"jet fans"** refer to the same type of fans and are used interchangeably within this document.

3. ABBREVIATIONS

AFAC	Australasian Fire and Emergency Services Authorities Council
ASD	Aspirated Smoke Detection
BAB	Building Appeals Board
BCA	National Construction Code Series–Volume 1–Building Code of Australia 2013
CSIRO	Commonwealth Scientific and Industrial Research Organisation
FEB	Fire Engineering Brief

FER	Fire Engineering Report
FRV	Fire Rescue Victoria
IFEG	International Fire Engineering Guidelines
RBS	relevant building surveyor
DTS	Deemed to Satisfy provisions of the BCA
FBIM	Fire Brigade Intervention Model
RECEO	Rescue, Exposure, Confinement, Extinguishment and Overhaul (Refers to FRV operational process)

4. BACKGROUND

Impulse fans are high speed fans that are typically installed within enclosed carparks where sufficient access to the open air is not possible.

Where impulse fans have been installed, it is generally within carparks that have low ceiling heights or significant beam obstructions, which do not lend themselves to a typical ducted ventilation system. Their purpose is to move vehicle exhaust emissions from one (1) zone of a carpark to another zone, ultimately ensuring that the vehicle emissions are expelled via an exhaust system or to the outside.

Furthermore, the design intent and objective of impulse fans in Europe is typically to cease fan operation immediately upon fire detection, in order to ensure conditions are suitable for occupant evacuation and to provide responding firefighters with a means to create an environment by using the impulse fans that would enable access to the seat of the fire and suppression activities.

Since their inception and use in metropolitan Melbourne, FRV have observed that some developers are providing impulse fan systems as an alternative to the typical ducted ventilation arrangement permitted under AS1668.2 and not necessarily with the intended use as described above.

The strict controls imposed by AS1668.2 also means that designers who do not design to the DTS are required to formulate a Performance Solution to satisfy the requirements of Part E and Part F of the BCA, i.e. the air quality requirement, by way of compliance with the respective Performance Requirements.

Based on a literature review and the results of hot smoke tests conducted in several carpark building configurations, the following common observations were made:

- the operating velocity of an impulse fan has the potential to move hot smoke away from the nearest group of sprinklers/detectors and promote the activation of sprinkler heads/detectors in areas further away for a fire
- a fire in a carpark containing an impulse fan system can grow to a larger size before the appropriate sprinkler (or group of sprinklers) activates, which may over-run the installed sprinkler system. Similarly, delayed activation of heat detectors is also of concern
- turbulent mixing of the smoke layer due to continued jet fan operations after fire initiation impacts on occupant visibility, and thus evacuation
- the immediate shut down of impulse fan systems upon initiation will increase the efficiency and effectiveness of sprinkler system activation and controlling of a fire.

5. ISSUES OF CONCERN

The use of impulse fans presents the following issues of concern for FRV:

- delays in sprinklers and/or detector activation are likely to be experienced due to their close proximity to high velocity impulse fans. Delaying the activation of sprinklers has the potential to result in larger fires and greater smoke development, which in turn results in fire brigade operations becoming significantly more hazardous. In addition, high velocity air streams from a fan may result in sprinkler skipping and interference with the water discharge pattern that reduces sprinkler efficiency
- an operating impulse fan can de-stratify a hot smoke layer which reduces tenability for occupants during the early stages of a fire's development. Without impulse fans, the smoke remains in a well-defined layer close to the ceiling until sprinkler activation
- egress paths can become untenable in a fire due to low visibility, where air flow from a fan directs the de-stratified smoke layer towards the egress stairs and nearby egress paths.

6. PERFORMANCE REQUIREMENTS

In accordance with the DTS provisions of the BCA, the fire hazard in enclosed carparks is managed by the requirements for increased Fire Resistance Levels (FRL) and the installation of an automatic fire sprinkler or heat detection system. The other hazard in an enclosed carpark is air quality. Carbon Monoxide (CO) and other vehicle emissions are managed by a mechanical ventilation system. Traditionally, this has involved the use of a ducted exhaust system; however impulse fans and supply/return air systems have also been identified as an alternative ventilation system.

The intent of the BCA is to provide a mechanical ventilation system in a carpark to address the amenity and air quality, where this cannot be achieved through natural means. The following identifies the requirements of the BCA and relevant standards for mechanical ventilation systems, smoke control and impulse fans in carparks:

- F4.11 of the BCA requires an enclosed car park to have mechanical ventilation complying with AS 1668.2- 2012
- AS 1668.2-2012 allows for the provision of impulse fans for movement of air from dead air spaces
- Table E2.2a also requires carparks that have a mechanical ventilation system in accordance with AS 1668.2-2012 to meet specific requirements of clause 5.5 of AS/NZS 1668.1-2015.

AS/NZS 1668.1:2015 does not allow jet fans in series, and it incorporates the below specific design requirements where jet fans are installed as part of mechanical ventilation systems:

- Clause 5.5.1(c) outlines a number of installation requirements, including the position of jet fans with respect to sprinkler heads and detectors
- Clause 5.5.3 prescribed measures for switches to be provided to enable restart and manual control by attending emergency services personnel, e.g. on auto-off controls and interactions with the fire fan control panel (FFCP) and FDCIE
- Clause 5.5.5 requires fans to be shut down upon initiation of fire mode or activation of a sprinkler system in the car park

- Clause 5.5.4 of AS 1668.1:2015 requires that detection for car park ventilation systems and impulse fans comply with the requirements of AS 1670.1-2015.

AS 1670.1-2015 requires the following:

- Clause 7.1 prescribes requirements for smoke detection, initiation and control for car park ventilation systems
- Clause 7.4 and Table 7.4 summarises smoke control systems that shall be automatically initiated by fire, smoke detectors or suppression systems, included are 'Shutdown systems'
- Clause 7.5.2.2 requires smoke detection provided to initiate car park ventilation in fire mode to be provided throughout circulation spaces
- additional smoke detection measures are prescribed in clause 7.7 for supply air systems associated with car park ventilation.

Australian Standard AS1668.2-2012 is the relevant mechanical ventilation standard applicable to managing atmospheric contaminants produced by vehicles in carparks. This standard does permit the use of impulse fans in carparks; however this is restricted to the provision of a single (1) impulse fan serving a dead spot in the carpark. Where the installation exceeds this provision, the system is considered to be beyond the scope of DTS and a Performance Solution would be necessary.

Section 5.5 of AS1668.1 is the relevant section that is referenced by Table E2.2a of the BCA that a carpark must satisfy from a fire safety perspective. This section of the standard advocates the need for firefighters to be provided with controls to turn the ventilation system on or off. It also advises that smoke detectors need to be present in supply air systems, which in turn shut down the supply air and set the exhaust capacity of the system to full extraction.

The design and operation of the system is to be discussed with FRV during the design stages. The review undertaken during the design stages will provide an opportunity for early comment in relation to fire brigade concerns that may affect fire-fighting operations, e.g. the location of carpark exhaust outlets. The Performance Solution should contain detailed engineering justification to demonstrate that the jet fan system will not have a significant detrimental effect on the safe egress of occupants, operation of the sprinkler system or impact fire fighting operations. The Performance Solution will need to:

- demonstrate that the jet fan system will not have a significant detrimental effect on the safe egress of occupants, operation of the sprinkler system or impact fire fighting operations
- identify the expected impact of the jet fan system on the air flow conditions within the carpark
- demonstrate that potential smoke movement within the carpark will not impede the occupant egress strategy
- identify the expected activation time of the detection system during a fire, when jet fans are operating
- identify the expected activation time of the sprinkler system during a fire, when jet fans are not operating
- demonstrate that, regardless of fire location, the fire detection system will shut down all jet fans earlier than the anticipated operation of the sprinkler system if no jet fans were operating.

Further, the need for hot smoke tests in enclosed carparks with impulse fans is to be discussed with FRV during the early stages of a project. When a hot smoke test is required, the test set up (essentially smoke generation locations) is to be agreed in consultation with FRV.

The criterion for the performance of a detection system in a hot smoke test is that it will initiate fan shutdown before fire sprinkler operation. In the context of a car fire in a typical carpark, acceptable performance is considered to occur if the initial response of a detector occurs within a suitable timeframe (90 seconds) that effectively identifies a fire condition in the early stages of development.

It is essential that the detection system be robust and be able to operate effectively in a typical carpark environment, without requiring excessive maintenance. Detection systems with a proven performance in carpark environments are recommended.

It is acknowledged that the BCA and Australian Standard AS1688.1 do not have requirements for smoke control in carparks in the event of a fire. However the BCA and Australian Standard do require the ventilation system to be operated in full exhaust mode upon detection to assist with smoke exhaust. Through the application of Part A2 of the BCA, Performance Requirements FP4.4, EP2.2, EP1.4, DP4, DP5 and DP6 are all considered to be equally applicable to the installation of multiple impulse fans. The associated deemed to satisfy references to the Performance Requirements are F4.11, E2.2, E1.5, D1.2, D1.3, D1.4, D1.5 and CP4.

It is recommended that the Performance Solution be developed through a collaborative stakeholder approach in accordance with the FEB process, as outlined in the IFEG.

7. THE POSITION OF FIRE RESCUE VICTORIA

It is the opinion of FRV that the design team should demonstrate that the provision of impulse fans, and the manner in which they are controlled, provides a satisfactory level of fire safety compliance with Part E of the BCA, and effectively address the significant concerns raised in Section 6 above.

FRV's position encompasses the provision of a reliable and suitable smoke detection system, such as Aspirated Smoke Detection (ASD), duct probe smoke detector, or other approved detection system to be installed to shut down all the impulse fans in the very early stages of fire development and prior to sprinkler activation, avoiding conditions that would impact on the visibility of evacuating occupants.

The design needs to be supported by a performance design utilising CFD modelling, and if not already validated to FRV's satisfaction, the design should also be supported by a range of experimental hot smoke tests or other appropriate tests which have been agreed upon by the stakeholders.

8. FIRE SAFETY DESIGN CONSIDERATIONS AND RECOMMENDATIONS

FRV recommends that the following issues be considered:

- when designing a ventilation system utilising impulse fans, the performance of the system should design against any adverse impact on evacuating occupants, any adverse impact on any automatic or detection system due to interference and reducing any adverse impact on fire brigade intervention
- impulse fans should be located in driveways and access ways, and not above car spaces/stagnant fire load locations. Furthermore, fans should also be located away from sprinkler heads, in order to eliminate the risk of high velocities impacting on sprinkler activation times and spray patterns. Operating impulse fans may disperse and interrupt a developing smoke layer from a growing fire. This dispersion and turbulent mixing of smoke, may impact detrimentally on sprinkler activation and occupant evacuation early in the fire's development
- the operation of impulse fans should be ceased automatically in the early stages of fire development, prior to sprinkler operation, so as to limit the impact on the developing smoke layer. This should be conducted via a reliable and proven means of detection within carpark environments
- exhaust points should be located away from egress paths and points. Onsite tests have shown that continued operation of impulse fans may induce airflow and smoke distribution towards egress paths. As a result, a quantitative analysis should be conducted to ensure tenability is maintained for occupants
- for detection systems which are yet to be tried and proven to deactivate impulse fans early in a fire development and prior to the time for sprinkler operation, FRV recommends that in addition to CFD modelling, the system be validated with appropriate onsite testing. Such testing should be determined as appropriate by the stakeholders. The onsite testing should also be consistent in relation to the heat release rate of the design fire as well as the smoke properties and production rates used for the CFD modelling
- smoke detectors and alarms primarily rely upon a ceiling jet to drive the smoke through the smoke detection chamber. Due to the turbulence created by the impulse fans, these detectors may not be capable of early detection in these situations due to a disturbed ceiling jet. It is a common and validated understanding that smoke detectors are not suitable for carpark environments, causing spurious alarms within a carpark environment. Issues associated with reliability and long term maintenance should also be considered when choosing a suitable detection system. The reliability and effectiveness of CO detectors to deactivate impulse fans is also questioned without evidence based testing
- the FEB and FER should identify the fire modelling parameters and assessment methodology, which includes the proposed method of validation at commissioning phase
- manual controls should be put in place at the Fire Indicator Panel (FIP) to enable fire fighter use of impulse fans to clear smoke after the fire is under control. The design and control requirements for the fans should be checked with the fire brigade
- design solutions that do not incorporate a reliable detection strategy will not be supported without further support from the Building Appeals Board, either via appeal or via a Section 160A determination

- indicate positions of exit points on drawings
- impulse fan documentation should include an impact statement on fan positioning in regards to the installed sprinkler and detection systems, including the method of fan shut down on detection of smoke, redundancy shut down and manual control for firefighters.

9. MECHANISM FOR REFERRALS TO THE BUILDING APPEALS BOARD

Design Stage

A Section 160A determination from the BAB must be obtained where a carpark design solution that incorporates impulse fans does not demonstrate conclusive compliance with this guideline, for designs which have not been previously tested and designs with new aspects in relation to detection and layout, the Section 160A application may be lodged either concurrently or prior to seeking the Fire Rescue Commissioner's report and consent under Regulation 129. The BAB, upon receipt of an application for Section 160A determination, is likely to seek the Fire Rescue Commissioner's opinion prior to determining the matter.

Prospective report and consent applications should therefore be aware that the Fire Rescue Commission will not consider any report and consent application under Regulations 129 and 187 that do not comply with this guideline or have the written support of the BAB under Section 160A of *the Building Act 1993 (the Act)*, which addresses the relevant performance requirements.

Construction Stage

Non-compliant building work that cannot be remedied to achieve compliance with the approved building permit documentation and Building Regulations 2018 must also be referred to the BAB for a Section 160A determination where the Fire Rescue Commissioner was a reporting authority under Regulations 129 and 187.

10. REQUIREMENT TO OBTAIN A REPORT AND CONSENT

The requirement to obtain the report and consent of the Fire Rescue Commissioner in respect to Regulations 129 and 187 are not removed where a carpark building solution complies with the fire safety design requirements contained within this guideline. Similarly, compliance with this guideline does not obviate the need to obtain the Fire Rescue Commissioner's endorsement of the FEB and FER as identified in FRV fire safety guideline *GL-33 – Performance based design within the built environment.*

11. APPLICATION OF PRECEDENT

Applicants who seek the Fire Rescue Commissioner's report and consent under Regulations 129 and 187 need to be aware that a supporting decision for one building solution does not automatically infer support for another building solution. Every building solution that is referred to the Fire Rescue Commissioner will be reviewed on a case by case basis.

12. REFERENCES

- NSW Fire and Rescue Fire Safety Guideline – Guideline for Impulse Fans in Car Parks, Version 01 – 9 October 2014 Fire Safety Branch – Community Safety Directorate.

- Paper presented at the 10th International Conference on Performance based Codes and fire safety design methods; Working Together to introduce new technology in a performance environment 2014, by Dr. Jonathan Barnett FSFPE FIEAust, CPEng PE Technical Director RED Fire Engineers and Dr. Tony O'Meagher, Senior Fire Safety Engineer, Community Safety Technical Department, FRV (previously MFB).

- Paper presented at Fire Australia 2013; Hot Smoke Testing of Carpark Impulse Fan Ventilation Systems., by Nathan White and Alex Webb CSIRO, Dr. Tony O'Meagher, FRV (previously MFB), Michael Hart Xtralis and Garry Weir RAW Fire.

- Report commissioned by FRV: Use of Jet Fans in car parks Information report by Olsson Fire and Risk.