DHL - Canon
Lot 1A, Oakdale Central
Horsley Park NSW 2175

Prime Constructions Pty Ltd
394 – 396 Pacific Highway
Lane Cove NSW 2066

25 March 2013 | Final Issue: Rev 01 | Report No. s121073_FER_03

Fire Engineering Report

DHL - Canon

Lot 1A, Oakdale Central, Horsley Park

RAWFIRE
Fire Safety Engineering

Sydney
Suite 401, Grafton Bond Building,
201 Kent Street, Sydney NSW 2000
Phone | +61 2 9299 6605
Fax | +61 2 9299 6615
Email | sydney@rawfire.com

Melbourne
Suite 123, 757 Bourke Street
Docklands VIC 3008
Phone | +61 3 8616 0686
Fax | +61 3 8616 0690
Email | melbourne@rawfire.com

London
32 Hallings Wharf
1 Channelsea Road
London, E15 2SX
Phone | +44 (0) 203 384 0050
Email | london@rawfire.com

www.rawfire.com

RAW Fire Safety Engineering
ABN 73 746 163 281

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REV	DATE ISSUED	COMMENT	PREPARED BY	REVIEWED BY	VERIFIED BY
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02	05/03/13	Final Issue			**Sandro Razzi** *BE (Building)* *Grad Dip (Performance Based Building & Fire Codes)* *Accredited Fire Engineer* *BPB 0501* *MIEAust* *CPEng 2180287*
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EXECUTIVE SUMMARY

RAWFire Safety Engineering has been engaged by Prime Constructions Pty Ltd to develop an Alternative Solution for the development at Lot 1A, Oakdale Central, Horsley Park in NSW. The development comprises of a storage and dispatch facility with two ancillary offices for use by logistics company DHL.

This Fire Engineering Report (FER) highlights areas of non-compliance with the Building Code of Australia 2012 (BCA) [1] Deemed-to-Satisfy (DTS) provisions for the project.

The FER outlines the scope of work for the Fire Engineering Analysis, sets down the basis on which the analysis has been undertaken (as agreed by the stakeholders), the necessary acceptance criteria and specifies a Fire Safety Strategy and work schedule for compliance.

The following table lists the departures from the DTS provisions of the BCA for the works and those Fire Engineering requirements formulated as part of the evaluation. The procedures outlined in BCA clause A0.10 have been used to identify the BCA DTS Provisions and Performance Requirements that are relevant to the Alternative Solutions. The assessment methodology for the Fire Engineering Assessment has been prepared in accordance with the International Fire Engineering Guidelines (IFEG) [3].

Due to the size of the development a fully prescriptive approach that complies with the BCA DTS provisions for occupant egress, fire brigade access and smoke hazard management would not satisfy the desired architectural and client aspirations. As such, an Alternative Solution has been developed to account for the provision of extended travel distances through the warehouse, altered fire brigade perimeter access and smoke hazard management design.

As detailed within this report evaluation of these Alternative Solutions has identified that the project will comply with the Performance Requirements of the BCA.

Table 1-1: Summary of Alternative Solutions

BCA DTS VARIATIONS	BCA PROCESS FOR REVIEW OF BUILDING SOLUTIONS
BCA DTS Provisions Clause D1.4: Distance to the nearest exit. Clause D1.5: Distance between alternative exits. Clause E2.2: Smoke hazard management **Performance Requirement** DP4 & EP2.2	***BCA DTS Provision*** Clause D1.4: the travel distance to the nearest exit must not exceed 40-metres. Clause D1.5: the travel distance between alternative exits must not exceed 60-metres. Clause E2.2 *(Table E2.2a)*: the building requires an automatic smoke exhaust system. ***DTS Non-Conformance*** The following DTS non-compliances have been identified in the warehouse. ▪ Travel distances of up to 73m to the nearest exit and 145m between alternative exits; and ▪ A manually operated smoke clearance system shall be provided in the warehouse lieu of the DTS required automatic smoke exhaust. ***Alternative Solution*** The Alternative Solution will rely upon the volume of the warehouse enclosure to act as a smoke reservoir for hot combustion products with significant reserve so as to provide the population with adequate time to safely evacuate the building prior to the onset of untenable conditions. ***Assessment Methodology*** The assessment methodology will adhere to Clauses A0.5(b)(i), A0.9(b)(ii), and A0.10 of the BCA. The analysis will be absolute and quantitative where the results of the deterministic assessment are measured directly against the agreed acceptance criteria, with a supporting qualitative argument. Computational Fluid Dynamic (CFD) programs will be used to simulate the fire development and smoke spread in the warehouse with these results utilised in an

<table>
<tr><th>BCA DTS VARIATIONS</th><th>BCA PROCESS FOR REVIEW OF BUILDING SOLUTIONS</th></tr>
<tr><td></td><td>ASET/RSET time-line analysis.
Acceptance Criteria
The Alternative Solution is deemed acceptable when demonstrated:-
▪ ASET calculated is greater than, or at least equivalent to, the RSET for the worst credible scenarios incorporating a safety factor of 1.5:
$ASET_{WC} \geq 1.5 \times RSET_{WC}$
▪ ASET calculated is greater than, or at least equivalent to, the RSET for the sensitivity and redundancy scenarios:
$ASET_{Sen/Red} \geq RSET_{Sen/Red}$
NB: Occupant tenability criteria are in accordance with CIBSE Guide E [14], the International Fire Engineering Guidelines [3] and the Fire Brigade Intervention Model [6] as listed in APPENDIX A.</td></tr>
<tr><td>BCA DTS Provisions

Clause E4.6 – Direction signs
(inter alia AS2293.1: 2005)

Performance Requirement
EP4.2</td><td>BCA DTS Provision
<u>Clause E4.6 (NSW)</u> states that if an exit is not readily apparent, then exit signs must be appropriately provided in accordance with AS2293.1.
<u>AS2293.1 (Clause 6.8.1)</u> requires exit signs be mounted not less than 2m and not more than 2.7 above floor level.
DTS Non-Conformance
The exit lighting design shall incorporate signage in the warehouse parts that are positioned above a height of 2.7m to permit the passage of picking machinery below.
Alternative Solution
The Alternative Solution shall rely upon the volume of the warehouse enclosure to provide adequate time to evacuate prior to the directional exit signs becoming compromised by the hot smoke layer. Further to this, the simplicity of the racking layouts and the familiarity of the occupants within the building shall provide for a rapid evacuation along familiar egress routes.
Assessment Methodology
The assessment methodology will adhere to Clauses A0.5(b)(i), A0.9(b)(ii), and A0.10 of the BCA. The analysis will consist of a qualitative discussion to demonstrate compliance with the relevant Performance Requirements.
Further to the above the deterministic results of the CFD modelling shall demonstrate that the directional exit signage will not be obscured by the descending smoke layer prior to the completion of occupant evacuation, thereby permitting adequate and sufficient way-finding provisions to complete an evacuation.
Acceptance Criteria
During an evacuation occupants have clear visibility of the directional exit signs when navigating to an exit.</td></tr>
</table>

As a result of the identified building and occupant characteristics, fire safety objectives, identified fire hazards, BCA DTS non-compliances the Fire Safety Strategy (Trial Design) has been formulated.

In this instance the following is put forward as a summary of the fire safety measures required by the Fire Engineering Assessment in ensuring the Alternative Solutions assessed herein comply with the relevant Performance Requirements of the Building Code of Australia. Where not commented on herein it is expected that all other relevant fire safety requirements either through the BCA and Australian Standards are to comply.

Table 1-2: Summary of Fire Engineering Requirements

FIRE ENGINEERING REQUIREMENT	DETAILS	STANDARD OF COMPLIANCE
Fire Resistance		
Type of construction	The development shall be built in accordance with the prescriptive requirements of the BCA for Type C construction.	BCA Spec C1.1 (Table 5)
Access and Egress		
Perimeter vehicular access	A compliant vehicular access path shall be provided around the building in all-weather surface capable of supporting all FRNSW appliances (maximum weight of 27,500kgs) in accordance with '*Guidelines for emergency vehicle access*', available from www.fire.nsw.gov.au. To ensure access for fire brigade vehicles around the site the boom gates at the entry and exit shall open on fire alarm. All gates or security fencing that blocks fire brigade entry must be openable with 003 keys or with a master key provided to the two nearest fire brigade stations. If the gates are motor driven they must be openable by the fire brigade (by key, swipe card or manually).	BCA clause C2.3
Exit travel distance	Travel distances to an exit, between alternate exits and to a point of choice are to comply with the following exceptions permitted within the central parts of the warehouse; ▪ Up to 73m to the nearest exit; and ▪ Up to 145m between alternative exits	BCA clause D1.4, D1.5 and Alternative Solution
Doorways and doors	Doorways serving as required exits must not be fitted with a sliding door unless it leads directly to a road or open space and is manually openable under a force of 110N. If power operated it must be manually openable under a force of 110N or open automatically upon detector activation.	BCA clause D2.19
Door swings	A swinging door in a required exit must swing in the direction of egress unless it serves a building (or part) less than 200m^2 and is the only required exit.	BCA clause D2.20
Operation of latch	Door hardware on all required exits, including main entrance doors, shall be in accordance with current regulations such that all required exits will be available for emergency egress.	BCA clause D2.21
Services and Equipment		
Fire Indicator Panel & Fire Fan Control Panel	The Main Fire Indicator Panel (FIP) and main smoke clearance fan controls shall be located in the entry lobby of the main office, where the fire control centre is located. ▪ The panel shall include clear signalling of the operational status of the fans with override controls for the smoke clearance fans. The sprinkler and smoke detection systems are to be interfaced with the FIP. The FIP shall be connected to a direct monitoring station via alarm signalling equipment to initiate a signal to the fire brigade upon sprinkler and smoke detector activation.	AS3013:1995, AS4428.6:1997, AS/NZS 1668.1:1998 and Alternative Solution

FIRE ENGINEERING REQUIREMENT	DETAILS	STANDARD OF COMPLIANCE
Smoke detection	Automatic smoke detection system shall be provided throughout the warehouse parts (i.e. not required in the office parts). The detection system shall activate the building occupant warning system and direct brigade alarm upon detection of a fire. The system shall be designed in accordance with AS1670.1:2004 with detector head spacing in accordance with Clause 5 of Specification E2.2a (i.e. 20m x 20m grids).	BCA Specification E2.2a, AS1670.1:2004 *(spacing per AS/NZ1668.1: 1998)* and Alternative Solution
Sprinklers	An automatic fire sprinkler system is required to be fitted throughout the building. ■ The sprinkler system shall activate the building occupant warning system and direct brigade alarm upon detection of a fire. ■ In the offices, Eco run-up rooms and beneath the warehouse awnings the system shall comply with BCA Specification E1.5 and AS2118.1:1999. ■ In the warehouses a storage mode system shall be provided in accordance with BCA Specification E1.5, AS2118.1:1999 with head spacing, discharge pressures and flows per Factory Mutual Guidelines 2-0 and 8-9. The warehouse sprinkler system shall meet the following minimum performance requirements; ■ Sprinkler activation temperature no greater than 101°C. ■ Sprinkler response time index (RTI) of less than $50m^{1/2}s^{1/2}$ (i.e. fast response type)	BCA Specification E1.5, AS2118.1:1999, FM Global Data Sheets FM2-0 & FM8-9, and Alternative Solution.
Smoke Hazard Management	A manually operated smoke clearance system shall be installed to the warehouse areas in lieu of a DTS required automatic smoke exhaust system. The smoke clearance system shall meet the following minimum performance requirements: ■ Initiation switches shall be located on or adjacent to the main FIP. ■ Signs alerting the Fire Brigade to the operation of the smoke clearance system must be provided. ■ Fire rated fans and fire rated cabling shall be used and designed to operate at 200°C for a period of 60 minutes. ■ System capacity must be capable of one enclosure air change per hour. ■ It is recommended that multiple fans be provided and be evenly distributed to otherwise comply with the requirements of Specification E2.2b Clause 5 of the BCA. ■ Adequate make-up air shall be provided via permanently open or mechanically driven louvers that open upon initiation of the fans at the FIP (not on fire alarm). ○ All motors and cabling required to open the mechanical louvers must be fire rated to operate at 200°C for a period of 60 minutes. ■ If used for general ventilation, the air flow rate at any sprinkler head must be less than 1.5m/s and the system must shut down automatically upon any fire alarm, with manual override available to fire fighters.	BCA Clause E2.2, Table E2.2a, AS/NZ1668.1: 1998 and Alternative Solution

FIRE ENGINEERING REQUIREMENT	DETAILS	STANDARD OF COMPLIANCE
Occupant warning system	A building occupant warning system must be provided throughout. The alarm tone shall be initiated throughout the building upon fire detection by the smoke detection and sprinkler systems	BCA clause E1.5, E2.2 (Clause 6) and AS1670.1:2004
Fire hydrants	A fire hydrant system must be installed in accordance with the regulatory requirements. ▪ Hydrant booster assembly location and design shall be fully compliant. ▪ The hydrant ring main shall be fitted with isolation valves external to the building with the valves numbered and the corresponding numbers indicated on the hydrant block plan. ▪ External hydrant connections shall be provided with the heat shields per the requirements of AS2419.1 (i.e. FRL 90/90/90 2m either side and 3m above the hydrant connection point) or be setback more than 10m from the building. ▪ All connection points must be fitted with Storz hose couplings which comply with Clause 7.1 and 8.5.11 of AS2419.1:2005. Further information is available from the FRNSW Guide Sheet No.4 '*Hydrant system connectors*' available at www.fire.nsw.gov.au. ▪ Clear block plans (not less than A3 in size) shall be provided at the booster assembly. Further at the entries to the warehouse where an internal hydrant is to be located, a basic block plan is to be placed adjacent to the nearest exit door indicating the location of the internal and intermediate hydrants. ▪ As far as possible external hydrants shall be provided to achieve coverage of the building, where not possible additional fall-back hydrant(s) shall be provided.	BCA clause E1.3, AS2419.1:2005
Fire hose reels	Fire hose reels must be provided throughout all areas in accordance with the prescriptive provisions of the regulatory requirements.	BCA clause E1.4 and AS2441:2005
Fire extinguishers	Portable fire extinguishers must be provided throughout all areas with their location and selection relevant to the risk class in accordance with the relevant regulatory requirements.	BCA clause E1.6 and AS2444:2001
Emergency lighting	Emergency lighting must be installed throughout all areas in accordance with the relevant regulatory requirements.	BCA clause E4.2, E4.4 and AS2293.1:2005
Exit signs	Exit signs and direction signs to exits must be provided throughout all areas in accordance with the relevant regulatory requirements with the following exceptions. ▪ Directional exit signs located on the eastern end of the racking aisles may be installed up to 4m above floor level.	BCA clause E4.5,E4.6,E4.8, AS2293.1:2005

FIRE ENGINEERING REQUIREMENT	DETAILS	STANDARD OF COMPLIANCE
Fire Brigade intervention		
Notification	An automatic link shall be provided directly to an approved monitoring centre on activation of the smoke detection and sprinkler systems.	Specification E2.2a Clause 7 & Clause 3.2 of AS2118.1:1999 and AS1670.3:2004
Block plans	Block plans shall be provided for use by the fire brigade adjacent to the any Fire Indicator Panel, hydrant booster assembly and at the entry/exit doors accessing internal hydrant points.	AS1670.1:2004 AS2419.1:2005 and Alternative Solution
Building Management Requirements		
Smoking policy	No smoking policy throughout all public areas of the building.	Note
Fuel load control	Keep unnecessary combustible loads to a minimum in public areas via regular housekeeping, including the removal of random storage and accumulated debris.	Note
Renovation or new works	The recommended fire safety systems must be replaced with equivalent systems in all future works and the recommended fire safety systems must be applied to any renovations or new works.	Note
Inspection, testing and maintenance	Periodic inspection, testing and maintenance of all fire safety systems, fire hydrants, fire hose reels (where provided), emergency lighting, exit signage, doors, fire resistance, portable fire extinguishers, etc. should be implemented. ■ As there is no set testing specification for the manual smoke clearance system, this system shall be tested in accordance with the regime in AS1851 for automatic smoke exhaust where applicable.	AS1851:2005 and Alternative Solution
Operation	Under all circumstances it is important to keep as much of the system fully operational as is practical. Should any building works extend over a number of days, the system must be re-instated as far as practical at the end of each day.	Note
During construction	Scaffolding, wire fencing, barricades and the like must not prevent fire brigade access for vehicles or personnel to essential fire safety components (hydrants, boosters, FIP, etc.) or prevent fire brigade personnel from intervening in the event of a fire.	BCA clause E1.9
Annual fire safety certificate	The Alternative Solutions assessed herein shall be listed on the building's annual fire safety certificate such that the systems are inspected and tested annually and fire brigade are provided with accurate information to undertake fire intervention activities.	Alternative Solution

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1 INTRODUCTION

1.1 OVERVIEW

This Fire Engineering Report has been undertaken to nominate proposed Alternative Solutions for assessing compliance with the nominated Performance Requirements of the BCA [1] in accordance with the methodologies defined in the IFEG [3] and provide a workable and safe Fire Safety Strategy through a trial design. In order to develop and assess the nominated non-compliances the following flowchart process is to be adopted.

Project Scope	• Provides details of the project team • Provides information to be utilised • Provides limitations of the assessment	
Principal Building Characteristics	• Defines particular construction details of the development applicable to fire safety management	Each characteristic can affect the outcome of the fire strategy when assessed in conjunction with each other i.e. occupants requiring assistance may require increased passive and active fire protection.
Dominant Occupant Characteristics	• Defines occupant characteristics which may affect their ability to respond and evacuate in fire conditions	
Fire Brigade Characteristics	• Defines fire brigade characteristics which may affect their ability to undertake search and rescue and fire attack in fire conditions	
Fire Hazards and Protective Measures	• Establishes the likely risks for occupant and brigade life safety and suitable measures to address those risks	
BCA DTS Non-Compliance Assessment and Acceptance Criteria	• Details non-compliance/s for the building and relevant BCA clauses • Provides methods for justifying the above risks • Defines methods proposed for assessing the performance of the Alternative Solutions and objectives	
Fire Engineering Assessment	• Provides assessment of the BCA non-compliances utilising the methodology and acceptance criteria to confirm compliance with the required performance Provisions	
Fire Engineering Requirements	• Details likely passive, active and management requirements to confirm the trial design assesses the nominated non compliances	

Figure 1-1: Fire Engineering Report Process

1.2 FIRE SAFETY OBJECTIVES

The objective of this Fire Engineering Assessment is to develop a Fire Safety System, which satisfies the performance requirements of the BCA whilst maintaining an acceptable level of life safety, protection of adjacent property and adequate provisions for Fire Brigade intervention. At a community level, fire safety objectives are met if the relevant legislation and regulations are complied with. As stated in the BCA, "*A Building Solution will comply with the BCA if it satisfies the Performance Requirements*". In addition to this certain non-regulatory objectives exist as detailed below.

1.2.1 Building regulatory objectives

The following items are a summary of the fire and life safety objectives of the BCA:

- **Life safety of occupants -** the occupants must be able to leave the building (or remain in a safe refuge) without being subject to hazardous or untenable conditions. The objective of the Fire Engineering Assessment is to demonstrate that the proposed building design and fire safety systems would minimise the risk of exposing building occupants to hazardous or untenable conditions in an event of a fire.
- **Life safety of fire fighters -** fire fighters must be given a reasonable time to rescue any remaining occupants before hazardous conditions or building collapse occurs. The objective of the Fire Engineering Assessment is to demonstrate that the proposed building design and fire safety systems would facilitate fire brigade intervention and minimise the risk of exposing fire fighters to hazardous or untenable conditions in an event of a fire.
- **Protection of adjoining buildings** - structures must not collapse onto adjacent property and fire spread by radiation should not occur. The objective of the Fire Engineering Assessment is to demonstrate that the proposed building design and fire safety systems would minimise the risk of fire spreading from one building to another.

1.2.2 Fire Brigade objectives

The overall philosophical Fire Brigade objectives throughout Australia are to protect life, property and the environment from fire according to the Fire Brigade Intervention Model (FBIM) [6] as per the Fire Services State and Territory Acts and Regulations.

Over and above the requirements of the BCA, the Fire Brigade has functions with regard to property and environmental protection and considerations regarding occupational health and safety for its employees.

1.2.3 Non-prescribed objectives

Fire Engineering has an overarching benefit to many facets of the built environment where non-prescribed objectives can have an influence on the Fire Safety Strategy adopted. Although not assessed within, the following can be considered if requested.

- **Business continuity -** will the loss of a particular facility due to fire / smoke damage result in excessive financial impact on the client? For example, is the facility critical to business continuity?
- **Public perception -** should a fire occur within the facility is there likely to be questionable public perception about the safety and operation of the facility?
- **Environmental protection -** fires of excessive sizes can have significant effects on the environment which may require a detailed risk assessment to minimise such outcomes.
- **Heritage salvation -** buildings can have a heritage value for both cultural and educational purposes which can be destroyed by insufficient fire protection.
- **Risk mitigation / insurance limitations -** are there specific limitations on insurance with respect to risk mitigation and fire safety design? i.e. Does the relevant insurer have concerns with respect to open voids through the building?
- **Future proofing (isolation of systems) -** what flexibility is required in the overall design to allow for future development or changes in building layout?
- **Occupational Health and Safety (OHS) requirements -** buildings may have specific fire safety requirements pertaining to OHS requirements.

1.3 REGULATORY FRAMEWORK OF THE FIRE ENGINEERING ASSESSMENT

1.3.1 Building Code of Australia

One of the goals of the BCA is the achievement and maintenance of acceptable standards of safety from fire for the benefit of the community. This goal extends no further than is necessary in the public interest and is considered to be cost effective and not needlessly onerous in its application.

Section A0.5 of the BCA [1] outlines how compliance with the Performance Requirements can be achieved. These are as follows:

(a) complying with the Deemed-to-Satisfy Provisions; or

(b) formulating an Alternative Solution which –

(i) complies with the Performance Requirements; or

(ii) is shown to be at least equivalent to the Deemed-to-Satisfy Provisions or

(c) a combination of (a) and (b).

Section A0.9 of the BCA provides several different methods for assessing that an Alternate Solution complies with the Performance Requirements. These methods are summarised as follows:

(a) Evidence to support that the use of a material, form of construction or design meets a Performance Requirement or a Deemed-to-Satisfy Provision.

(b) Verification Methods such as:

(i) the Verifications Methods in the BCA; or

(ii) such other Verification Methods as the appropriate authority accepts for determining compliance with the Performance Requirements.

(c) Comparison with the Deemed-to-Satisfy Provisions.

(d) Expert Judgment.

Section A0.10 of the BCA provides methods for complying with provisions A1.5 (to comply with Sections A to J of the BCA inclusive). The following method must be used to determine the Performance Requirements relevant to the Alternative Solution: These methods are summarised as follows:

(a) Identify the relevant Deemed-to-Satisfy Provision of each Section or Part that is to be the subject of the Alternative Solution.

(b) Identify the Performance Requirements from the same Section or Part that are relevant to the identified Deemed-to-Satisfy Provisions.

(c) Identify Performance Requirements from the other Sections and Parts that are relevant to any aspects of the Alternative Solution proposed or that are affected by the application of the Deemed-to-Satisfy Provisions that are the subject of the Alternative Solution.

1.3.2 International Fire Engineering Guidelines

The IFEG [3] document has been developed for use in fire safety design and assessment of buildings and reflects world's best practice. The document is intended to provide guidance for fire engineers as they work to develop and assess strategies that provide acceptable levels of safety.

The document is particularly useful in providing guidance in the design and assessment of Alternative Solutions against the Performance Requirements of the BCA. The prescribed methodology set out in the IFEG has been generally adopted in the Fire Engineering Report.

2 PROJECT SCOPE

2.1 OVERVIEW

Project Scope

RAWFire Safety Engineering has been engaged by Prime Constructions to provide a Fire Engineered Alternative Solution for the storage and dispatch development at Lot 1A, Oakdale Central, Horsley Park. The Alternative Solutions relate specifically to the following areas of non-conformance with the BCA 2012.

- Occupant travel distances
- Smoke hazard management
- Exit signage

2.2 RELEVANT STAKEHOLDERS

This Alternative Solution has been developed collaboratively with the relevant stakeholders as identified below:

Table 2-1: Relevant Stakeholders

ROLE	NAME	ORGANISATION
Developer	Adrian Tesoriero Michael Ossitt	Goodman
Construction Manager	Daniel Swinnerton	Prime Constructions
Principal Certifying Authority BCA Consultant	Dean Goldsmith Tony Heaslip	Blackett Maguire + Goldsmith
Fire Authority	TBA	Fire and Rescue NSW
Architect	Greg Baird	SBA Architects
Fire Services	Garey Sparks	Sparks & Partners
Fire Safety Consultant	Thomas Newton Trent De Maria	RAWFire Safety Engineering
Fire Safety Engineer	Sandro Razzi	

It should be noted that at times some parties may have a vested interest in the outcome of the Fire Engineering assessment. Such parties can include local fire brigades, insurers, Environmental Protection Authority (EPA), project control groups, end users and community representatives. Although not always a legislative requirement, the design team should give due consideration to their inclusion in the Fire Engineering process. Where not required by legislation it is the client's decision to involve such parties, especially local fire brigade, to ensure a transparent and adequate fire safety solution for all. Where we are not notified of the inclusion of such parties it is assumed the client / representative has given due consideration to the above.

2.3 SOURCES OF INFORMATION

The following sources of information have been provided by the design team:

- Building BCA assessment report produced by Tony Heaslip of Blackett Maguire + Goldsmith. Project No. 120336, Revision 0, dated 13 August 2012.
- Architectural Plans provided by Greg Baird of SBA Architects as indicated in Table 2-2 below.
- Fire hydrant plans provide by Garry Sparks or Sparks and Partners as indicated in Table 2-2 below

Table 2-2: Drawings

DRAWING NO.	DESCRIPTION	ISSUE	DATE
GA-102	Site Plan	G	10.12.2012
GA-201	Part Plan Ground South	P	14.03.2013
GA-202	Part Pan Ground North	B	19.11.2012
GA-301	Elevation North East	B	05.11.2012
GA-302	Elevation South West	B	05.11.2012
GA-305	Sections	F	14.03.2013
H-07	Hydraulic Services Site Plan – Water Layout	E	28.02.2013
H-08	Hydraulic Services Ground Floor South	A	17.12.2012
H-09	Hydraulic Services Ground Floor South	E	28.02.2013

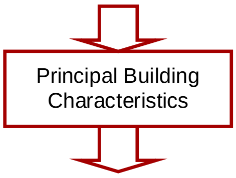
2.4 LIMITATIONS AND ASSUMPTIONS

In this instance the Fire Engineering Report is developed based on applicable limitations and assumptions for the development which are listed as follows:

- The report is specifically limited to the project described in Section 3.
- The report is based on the information provided by the team as listed above in Section 2.3.
- Building and occupant characteristics are as per Section 3 and 4 respectively of this report. Variations to these assumptions may affect the Fire Engineering Strategy and therefore they should be reviewed by a suitably qualified Fire Engineer should they differ.
- As per any building design, DTS or otherwise, the report is limited to the fire hazards and fuel loads as prescribed in Section 6.2 and 6.5 respectively. The report does not provide guidance in respect of areas, which are used for processing of flammable liquids, explosive materials, multiple fire ignitions or sabotage of fire safety systems.
- The development complies with the DTS provisions of the BCA [1] with all aspects unless otherwise specifically stated in this report. Where not specifically mentioned, the design is expected to meet the BCA DTS requirements of all relevant codes and legislation at the time of construction and / or at the time of issue of this report.
- The assessment is limited to the objectives of the BCA and does not consider property damage such as building and contents damage caused by fire, potential increased insurance liability and loss of business continuity.
- Malicious acts or arson with respect to fire ignition and safety systems are limited in nature and are outside the objectives of the BCA. Such acts can potentially overwhelm fire safety systems and therefore further strategies such as security, housekeeping and management procedures may better mitigate such risks.
- This report is prepared in good faith and with due care for information purposes only, and should not be relied upon as providing any warranty or guarantee that ignition or a fire will not occur.
- The Fire Engineering Report is only applicable to the completed building. This report is not suitable, unless approved otherwise, to the building in a staged handover.
- Where parties nominated in Section 2.2 have not been consulted or legislatively are not required to be, this report does not take into account, nor warrant, that fire safety requirements specific to their needs have been complied with.

3 PRINCIPAL BUILDING CHARACTERISTICS

3.1 OVERVIEW



Building characteristics are assessed as part of the Fire Engineering Review due to the following:

1. The location can affect the time for fire brigade intervention and potential external fire exposure issues.
2. The structure will impact on the building's ability to resist a developing fire and support conditions to allow occupants to escape the building and the fire brigade to undertake fire fighting to the degree necessary.
3. The floor area determines the potential fire size and area required to be evacuated in the event of a fire.
4. BCA details such as Type of Construction, Classification and height will dictate passive and active fire safety systems.

3.2 BUILDING DESCRIPTION

The site is located in Horsley Park approximately 40km west of Sydney City. The site is bound by Old Wallgrove Road to the east and Estate Road to the South. The two nearest fire brigade stations that are provided with permanent staff are located in Huntingwood and Mount Druitt approximately 8km and 11km from the site respectively.

Figure 3-1: Site location

The main portion of the development is occupied by a large warehouse with a length and breadth of 206m and 97m respectively. The warehouse is provided with a high level awning extending 15m over the loading bays on the eastern side of the warehouse, with the central loading bays provided with a recessed dock.

The building has a rise in storeys of two (2) and an effective height of approximately 4m *(applicable to the dock office)*. The structure is considered for building certification compliance to be a Large Isolated Building requiring Type C construction and perimeter access for emergency vehicles. Subsequently the building is constructed as a single fire compartment with the bounding structure consisting of steel columns, beams and purlins supporting sheet metal roofing.

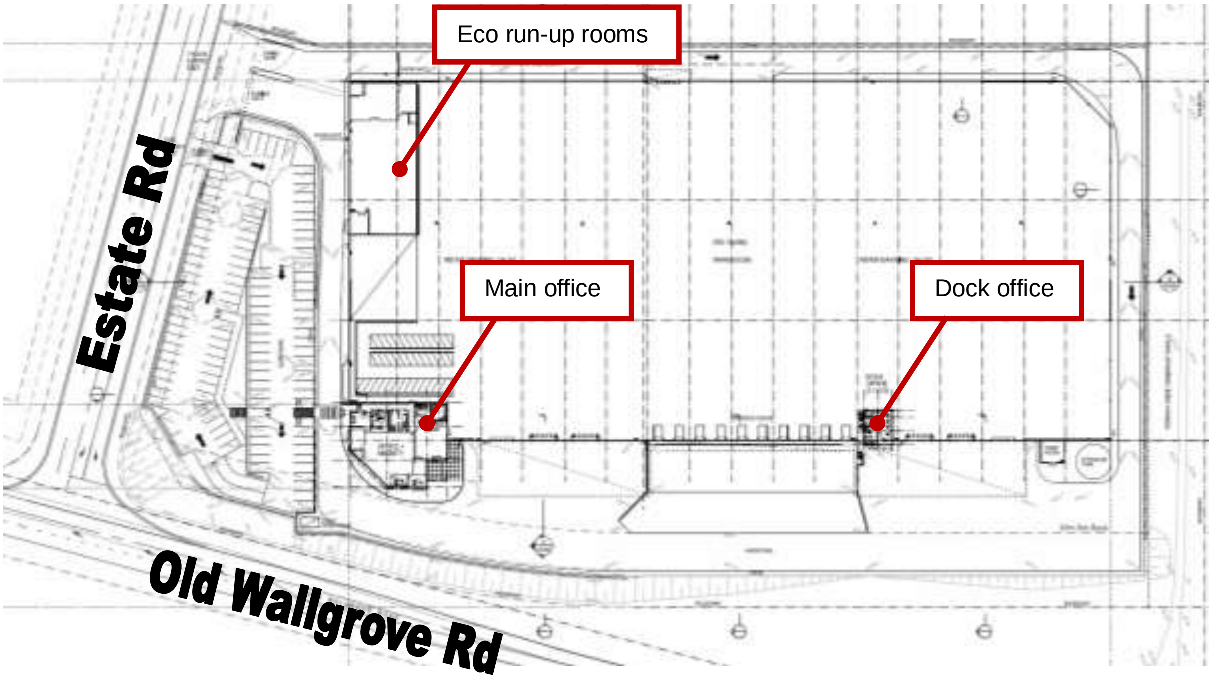


Figure 3-2: Development layout

Within the warehouse high-bay racking will extend in the east-west direction through the majority of the space. At the southern end of the warehouse is the 'Eco run-up room' and associated office space that is used for the servicing of copiers, cameras and other stock. The Eco rooms encompass an area of approximately 680m^2 with a suspended ceiling above the space located at 3m above FFL.

Further to this, a ground floor office is provided at the building's entry encompassing approximately 500m^2, with a smaller 2-storey (150m^2) dock office adjacent to the warehouse loading docks.

The fitout of the space is illustrated in Figure 3-3 over two drawings.

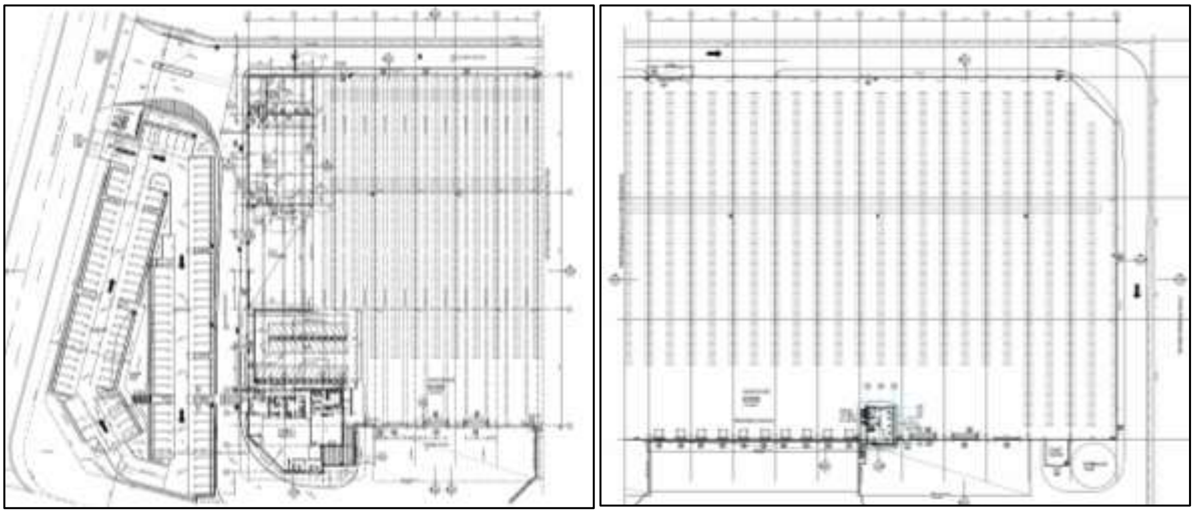


Figure 3-3: Indicative fitout showing the Eco Room, high-bay racking and offices

3.3 BUILDING CHARACTERISTIC ASSESSMENT

Table 3-1: Building Characteristics Assessment

<table>
<tr><th>CHARACTERISTIC</th><th colspan="2">DESCRIPTION</th></tr>
<tr><td>Location</td><td colspan="2">The site is located within the industrial area of Horsley Park. The two nearest fire brigade stations are located within 11km of the site.

The building site influences the likely fire brigade intervention times, and given the close proximity to the nearest fire station is expected to facilitate a relatively convenient and expedient fire brigade response.

Furthermore being located within a major city outer suburb the development is provided with the services and facilities expected in an urban setting.</td></tr>
<tr><td>Layout</td><td colspan="2">The development shall be constructed as a single fire compartment and is intended to be utilised for the temporary storage of stock prior to final dispatch by the logistic company DHL.

The warehouse parts shall have high-bay racking running east to west permitting a clear line of sight along the racking aisles that will assist in occupant evacuation in a fire emergency. Conversely occupant's line of sight will be highly obstructed in the north south direction creating a barrier in determining the safest path of egress in a fire emergency.

Exit doors are situated around the building perimeter providing occupants with multiple egress opportunities in the event of a fire emergency.</td></tr>
<tr><td>Structure</td><td colspan="2">Materials and finishes shall be in accordance with the DTS requirements for Type C construction. Construction materials will include masonry and steel construction, with external steel sheeting.

Materials used in construction will conform with the testing methodology outlined in the DTS provisions so as to avoid the spread of smoke and fire and minimise the risk to occupants and fire fighters.</td></tr>
<tr><td>Total Floor area</td><td colspan="2">The total floor area and volume of the building are approximately 20,170m^2 and 190,000m^3 respectively; with the following floor area breakdown:-

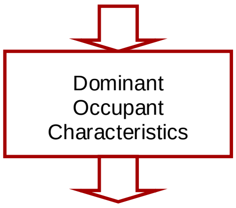
■ Warehouse: 18,840m^2
■ Eco run-up: 680m^2
■ Main office: 500m^2
■ Dock office: 150m^2</td></tr>
<tr><td rowspan="4">BCA Assessment</td><td>Classification</td><td>Class 5 - Offices

Class 7b - Storage facility</td></tr>
<tr><td>Construction Type</td><td>Type C Construction (Large Isolated Building)</td></tr>
<tr><td>Rise in Storeys</td><td>The building has a rise in storeys of two (2) (as applied to the dock office).

NB: Increasing the number of floors in a building increases the building population, placing more occupants at risk in the event of a fire, and allowing for overcrowding in stairways and other pinch points in the path of egress to a final exit.</td></tr>
<tr><td>Effective Height</td><td>The building has an effective height of less than 12m (as applied to the dock office).</td></tr>
</table>

4 DOMINANT OCCUPANT CHARACTERISTICS

4.1 OVERVIEW



The occupant characteristics are assessed within the Fire Engineering Report due to the following:

1. Population numbers can dictate the time required to evacuate the building and the required life safety systems to be provided due to evacuation times.
2. Physical and mental attribute affects the occupant's capacity to respond to various fire cues and react accordingly.
3. Familiarity of occupants can affect the time taken to evacuate the building and subsequent active / passive requirements.

4.2 DOMINANT OCCUPANT CHARACTERISTICS

Table 4-1: Occupant Characteristics

CHARACTERISTIC	DESCRIPTION
Population numbers	Due to the type of works being undertaken in the facility the number of occupants expected within the subject building is considered to be generally less than that assumed in the BCA Table D1.13 [1]. The BCA assumes the following densities: ▪ 1 person per 30 square metres in plant, carpark and warehouse areas. ▪ 1 person per 10 square metres in the office areas. Occupant following population has been calculated based on the above densities. **Warehouse:** 628 occupants **Eco run-up:** 22 occupants **Main office:** 50 occupants **Dock office:** 15 occupants ***Note:*** *The population above is greater than those expected in the building at any one time and form a conservative basis for fire engineering in the assessments herein. In that respect these numbers are expected to be greater than those utilised for certification purposes.*
Population location	The population is expected to be distributed throughout the building. The office is considered to 'on average' be more densely populated than the warehouse and plant areas, however the building's function and use may dictate an overall lower occupant number in the office areas.
Physical and mental attributes	Occupants in the building may be of mixed age, although the elderly and children are generally not expected to be present. The population is therefore expected to be that of the general working public and be adults between the ages of 16 to 70. Due to the nature of the work conducted the majority of occupants are assumed to be able bodied people with a small number of less mobile occupants requiring assistance during an evacuation. All occupants are expected to be awake and alert adults or in the direct company of an adult, capable of entering and leaving the building under their own volition. Occupants in all of these areas are not expected to be adversely impaired by drugs, alcohol, fatigue or other adverse conditions to degrees greater than in other warehouse and office buildings.

CHARACTERISTIC	DESCRIPTION
	■ ***Staff and Security*** – are expected to be mobile with normal hearing and visual abilities, and occupants in this group are considered to take and implement decisions independently, and require minimal assistance during evacuation in a fire emergency. This occupant group is expected to be awake and fully conscious at all times when inside the building; and ■ ***Clients / Visitors*** – are expected to be mobile with normal hearing and visual abilities, this occupant group are expected to be capable of making and implementing decisions independently however may require assistance in locating the nearest and safest egress path in an emergency; and ■ ***External Maintenance Contractors*** – are expected to be mobile with normal hearing and visual abilities and occupants in this group are considered to take and implement decisions independently and require minimal assistance during evacuation in a fire emergency. The contractors are expected to be awake and aware of their surroundings at all times when inside the building; and ■ ***Fire & Rescue NSW*** – are expected to be equipped with safety equipment and will be educated in fire fighting activities and the dangers associated with fire incidents. This occupant group would be expected to be in a position to assist other occupants requiring assistance to evacuate. It is not expected that this occupant group would be present in the building at the time of fire ignition; however, they are expected to enter the building at a later stage to assist with the evacuation of occupants, if required, and to undertake fire suppression activities.
Familiarity with the building	■ ***Warehouse Staff and Security*** – can be expected to have a good familiarity with the building and the fire safety systems provided and may be trained in emergency procedures; and ■ ***Office Staff*** – can be expected to have a good familiarity with the administration areas and the means of exits from these parts. General familiarity of the building as a whole and the location of main exits; and ■ ***Clients / visitors*** – may or may not be familiar with the layout of the building and may require assistance in locating the exits; and ■ ***External Maintenance Contractors*** – this occupant group is expected to have a reasonable familiarity with the building as they would have to undergo site specific induction prior to commencement of work on site; and ■ ***Fire & Rescue NSW*** – are not expected to have any familiarity of the building layout, however are assumed to obtain the required information from the site block plans and tactical fire plans available prior to entering the building. Notwithstanding this they will be equipped with breathing apparatus and specialist equipment to prevent them from being adversely affected by fire hazards.
Travel speeds	SFPE Handbook [15] indicates that individuals will move under their own volition at a speed of between 0.8-1.2m/s. Given the function of the carpark and warehouse this range is considered applicable and reasonable for egress approximations, and thus a mean value of 1m/s shall be used in these locations.

5 FIRE BRIGADE CHARACTERISTICS

5.1 OVERVIEW

The fire brigade characteristics are assessed within the Fire Engineering Report due to the following:

1. Fire Brigade characteristics can dictate the time required for fire brigade intervention including search and rescue and fire attack.

5.2 FIRE BRIGADE ASSESSMENT

In order to assess fire brigade response times and requirements additional to those normally presented within a DTS design an indicative assessment of fire brigade intervention has been undertaken based on the methods defined in the Fire Brigade Intervention Model (FBIM) [6].

The following Figure illustrates the building layout with the entry points to the building and the allotment, with the perimeter access outlined. Hydrants are located externally on the southern, western and northern sides with additional internal hydrants as required to achieve compliant coverage of the floor area.

It is noted that the hydrant design was unable to achieve coverage through the use of external hydrant points along the eastern side of the building without significant impact on the vehicular access path. Subsequently an additional fall-back hydrant is provided to allow fire fighters to attend to a fire on the eastern parts of the site.

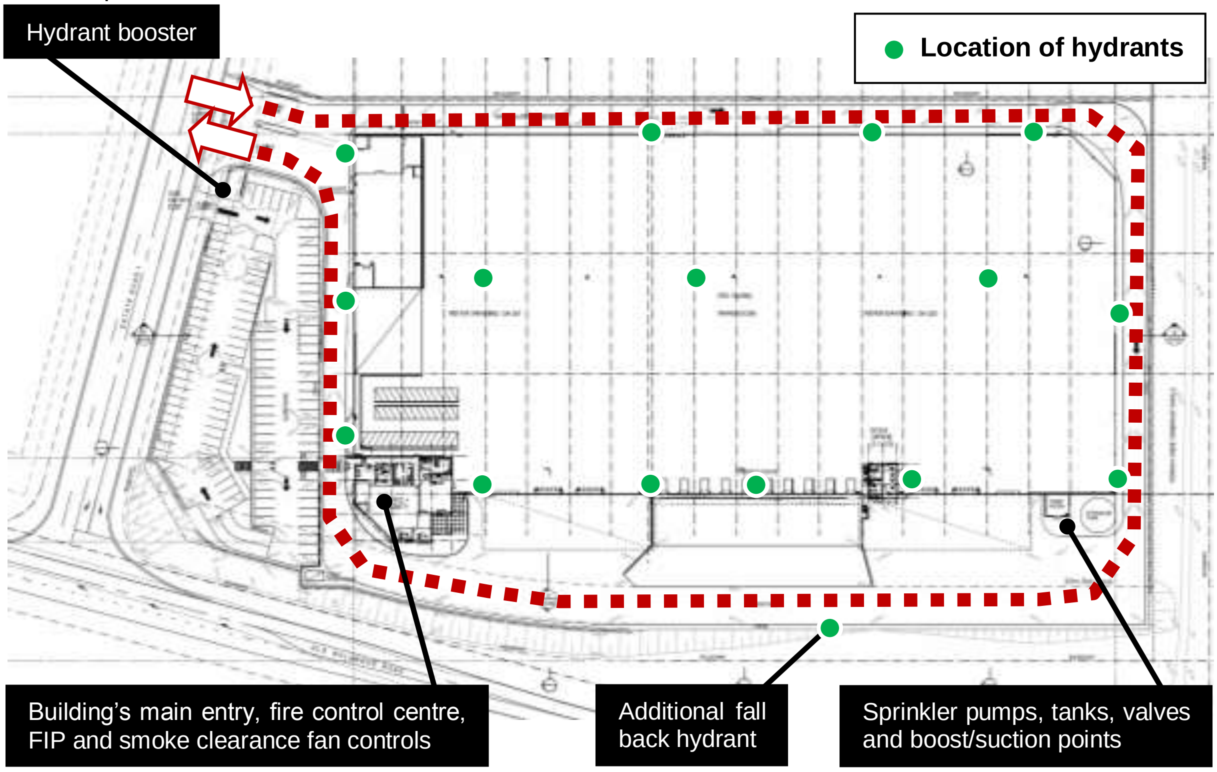


Figure 5-1: Fire Brigade Access and Site Facilities

The two nearest fire brigade stations that are provided with permanent staff are located in Huntingwood and Mount Druitt approximately 8km and 11km from the site respectively. illustrates the expected route to be taken in the event of a fire.

Figure 5-2: Route from the two nearest fire stations

Due to the nature of the FBIM, it is necessary to justify the results through the inclusion of assumptions. The accuracy of results weighs heavily upon the measure of which assumptions are made and the sources from which they are derived.

The model produced details the time it will take for brigade personnel within the aforementioned location to receive notification of a fire, time to respond and dispatch resources, time for resources to reach the fire scene, time for the initial determination of the fire location, time to assess the fire, time for fire fighter travel to location of fire, and time for water setup such that suppression of the fire can commence. The following are details of the assumptions utilised in this FBIM:

Location of Fire

- This FBIM will only be an indicative model of one fire scenario within the building. For conservative purposes, the FBIM considers a fire in the furthest habitable room from the point of entry. In this case entry is through the office areas and the fire located in the north-western corner of the warehouse.

Time between Ignition and Detection

- Based on calculations using the Alpert's Correlations (Figure 5-3) the initial brigade notification is via the activation of the warehouse sprinkler system.

  The alarm time calculated has considered a fire with an Ultra-Fast t-squared fire growth rate, which is expected to be indicative of the type of fire in the high bay racking area. The alarm time following fire ignition was calculated to occur at 191 seconds.

Input data required		
The ambient temperature of the room, T_∞ =	20	(°C)
Fire Category =	Ultrafast	
Output time step =	20	(s)
The distance of the detector from the fire, r =	2.12	(m)
The height of the ceiling above the fire, H =	12	(m)
The Response Time Index of the detector, RTI =	50	($m^{1/2}s^{1/2}$)
Sprinkler density of discharge =	5	mm / min
Detector activation temperature =	101	(°C)
Calculated quantities at detector activation		
The gas temperature at sprinkler activation, T =	112.79	(°C)
HRR at sprinkler activation =	6417.78	(kW)
The gas velocity, U =	6.71	(m/s)
Time at detector activation =	191	(s)
Time to reach 10% of peak HRR =	877	(s)
Ratio, r / H =	0.18	

Fire Type:	α =
Ultrafast	0.178
Fast	0.044
Medium	0.011
Slow	0.003
Custom	0.011

Figure 5-3: Sprinkler activation

Time for Initial Brigade Notification

- Fire brigade notification is expected to occur via a direct monitored alarm.
- A time for alarms/fire verification and any notification delay is 20 seconds based on Table B of the Fire Brigade Intervention Model. Therefore the time after ignition at which the fire brigade receive the alarm is (191+20) = 211 seconds.

Time to Dispatch Resources

- The two fire stations are assumed to be manned at the time of the fire as they are permanently staffed stations.

Time for fire fighters to respond to dispatch call and leave fire station is included in the travel time for fire brigade in NSW (Fire Brigade Intervention Model [6]).

Time to Travel to Scene

Table 5-1: FBIM data for the FRNSW (Table F2 FBIM)

GRAPH	REGION CLASSIFICATION	SPEED (KM/H)	
		μ	σ
F2.1	Major city central business district	26.6	11.3
F2.2	Major city inner suburb	26.3	11.9
F2.3	**Major city outer suburb**	**29.5**	**12.2**
F2.4	Rural town centre	21.6	11.0
F2.5	Rural country	40.5	15.6
	Travel speed through site	8	-

Based on speed data provided by the Fire Brigade Intervention Model (FBIM) [6], this travel speed assumes the brigade is travelling at a mean speed of 29.5km/h (major city outer suburb) with a standard deviation of 12.2km/h. Since the mean speed would result in this particular travel speed occurring 50% of the time, there is an equal likelihood that the travel speed would take longer. Hence, it is desirable to introduce a margin of safety of using a greater percentile of 90%.

In order for the speed to be within the 90% percentile value, a safety factor of 1.28 is applied to the standard deviation as noted in Table 4.3 of Fire Brigade Intervention Model V2.2 [6].

Hence, a mean travel speed will be taken at a much slower travel speed at 29.5 – (12.2 x 1.28) = 13.9km/h which is conservative.

- Appliance travel speeds of 13.9km/h have been adopted for the purposes of modelling, and as such the following travel times are expected:-

Table 5-2: Fire Brigade Arrival Times

STATION	TRAVEL SPEED (km/h)	DISTANCE (km)	TRAVEL TIME (sec)
Huntingwood	13.9 km/h	8 km	2072
Mount Druitt		11 km	2849

Time for Initial Determination of Fire Location

- On arrival, the fire location is not visible to the approaching brigade personnel, thus requiring information to be obtained from the Fire Indicator Panel (FIP) and evacuating occupants.
- Fire brigade personnel assemble at the FIP in the office building's main entry.
- Fire brigade tactical fire plans will be provided.
- Security procedures are expected to be minimal as brigade personnel will be issued with a key for the site. As such, forced entry into the building is not required.

Time for Water Setup

- The first appliance would be expected to commence the initial attack on the fire.
- Time taken to connect and charge hoses from onsite hydrants to the fire area is based on V3 on Table V of the Fire Brigade Intervention Model Guidelines, which indicates an average time of 18.4 seconds, and a standard deviation of 10.2 seconds. Therefore allowing for 5 connections, the time utilised in this FBIM is 5*[18.4+(1.28x10.2)]* = 155 seconds.

Time for Fire Fighters to Travel to Fire Location

- Time for fire fighters to travel from the FIP to the fire affected area; in this case conservatively assumed to be the furthest point from the FIP in the eastern end of the warehouse.

Table 5-3: FBIM data for horizontal travel speeds (Table Q FBIM)

GRAPH	TRAVEL CONDITIONS	SPEED (KM/H)	
		μ	σ
Q1	Dressed in turnout uniform	2.3	1.4
Q2	Dressed in turnout uniform with equipment	1.9	1.3
Q3	**Dressed in turnout uniform in BA with or without equipment**	**1.4**	**0.6**
Q4	Dressed in full hazardous incident suit in BA	0.8	0.5

Horizontal egress speeds have been based on fire brigade personnel dressed in turnout uniform in BA. An average travel speed of 1.4m/s with a standard deviation of 0.6m/s are utilised. As such, for the purposes of the calculations, a horizontal travel speed of 1.40-(1.28x0.6) = 0.63m/s is utilised.

- Horizontal travel distances (not including travel via lifts or stairs) will include the following:
  - Travel from the curb to the Main FIP in the office foyer and finally to the north-western corner of the warehouse is approximately 300m.
  - Based on the above, the total horizontal travel distance of 300m coupled with an egress speed of 0.63m/s results in a horizontal travel time of up to 476 seconds.

Search and Rescue

- Search and rescue will consist of a perimeter search of the warehouse; due to the size of the warehouse in comparison to the office it is assumed that a second team will conduct a search of the office in the time required to cover the warehouse. Thus, this will provide fire fighting personnel with an additional 600m of travel. At a speed of 0.63m/s, this will take fire fighting personnel approximately 953 seconds.

Table 5-4 Summary of the Fire Brigade Intervention Model (FBIM)

FIRE STATION	TIME OF ALARM	TRAVEL TIME TO SCENE	ASSUMED SET UP TIME	TIME TO REACH THE FIRE BASE	TIME OF ATTACK	PERIMETER SEARCH & RESCUE
Huntingwood	211	2072	155	476	2914 sec (49 min)	3867 sec
Mount Druitt		2849			3691 sec (62 min)	4644 sec

The FBIM indicates that the arrival time of the brigade from the nearest two fire stations is approximately 38 and 51 minutes respectively after fire ignition. It is estimated that it takes another 11 minutes for the fire brigade to carry out activities including determination of fire location, preparation of fire fighting equipment and travel on foot to the fire base. As such, fire fighting activities are expected to commence between approximately 49 and 62 minutes, with preliminary search and rescue completed at 65-78 minutes.

6 FIRE HAZARDS AND PROTECTIVE MEASURES

6.1 OVERVIEW

The fire hazard analysis forms the basis for the review of non-compliances within the building. In assessing expected and statistically validated hazards, preventative and protective measures are developed commensurate with those expected risks. The following section reviews applicable hazards and recommends possible measures to address those risks. Furthermore, hazards identified can form a justified basis for selected scenarios.

6.2 FIRE STATISTICS

In order to assess the most likely fire hazards within the building, and subsequently the risk presented by these hazards it is necessary to develop an understanding of the factors that have an influence on the fire safety of building occupants. The best method in doing so is to review existing statistical data.

Existing data is an invaluable tool in providing an overview of the situations in which occupant deaths have, and are likely to occur, and factors that contribute to more severe fires. This aids in understanding, and helps evaluate the effectiveness of, and the need for various fire safety systems. Reference is made to the American database as it is significantly larger than Australian data sets, but is generally considered to be representative of the Australian situation.

Table 6-1: Fire statistics in all building types [62]

Structure Use	Fires per Year	Civilian Fatalities per Year	Civilian Fatalities per 1000 Fires
Public assembly	15,050	5	0.33
Health Care, Detention and Correction	7,090	6	0.85
Manufacturing	5,670	5	0.88
Business offices	3,020	4	1.32
Parking garage	4,760	8	1.68
Warehouse	1,290	4	3.10
Hotels or motels	3,700	12	3.24
Apartments	108,530	422	3.89
Homes	263,150	2163	8.22

Based on the National Fire Protection Association, the statistics are based upon recorded fire events occurring between:

- 2003 – 2007 Structure fires in Warehouses (excluding cold storage)

Note that the statistics below have been compiled from U.S. fires reported to U.S. municipal fire departments between 2003 and 2007, and do not include fires where private or government fire brigades responded or fires that were not reported. Further, it should be noted that cold storage, residential storage and self-storage are excluded. Despite the fact that cold storage is not reported within the statistics it is considered that they still provide a reasonable basis for the general understanding of the risk presented by a high storage warehouse, cold storage or otherwise.

It is a common misconception that fires do not occur in cold store. However, factors such as an ultra dry atmosphere and the highly combustible nature of polyurethane or polystyrene foam insulation, wooden pallets and plastic wrapping present a high fire risk in these environments. Electrical faults from conveyor/transport equipment, lighting, or hot spots caused by maintenance operation can also contribute to this risk. Additionally the holding capacity of a cold store demands specialized high volume storage racking which can affect the airflow and impede the detection and response to a fire event.

These statistics represent a much greater number of events than Australian statistics and therefore have a greater statistical reliability. Building construction types and fire hazards are estimated to be sufficiently similar between Australia and the U.S. for the following results to be applicable.

Warehouse (excluding cold storage) Fire Statistics

A total of 1,350 structure fires occurred in warehouses. The fires recorded resulted in 5 occupant fatalities, 21 occupant injuries and $124 million in direct property damage per year. The leading cause of fires in Warehouses (excluding cold storage) is from electrical distribution or lighting resulting in 17% civilian injuries. The leading area of fire origin in warehouses comes from an unclassified storage area resulting in 21% civilian injuries.

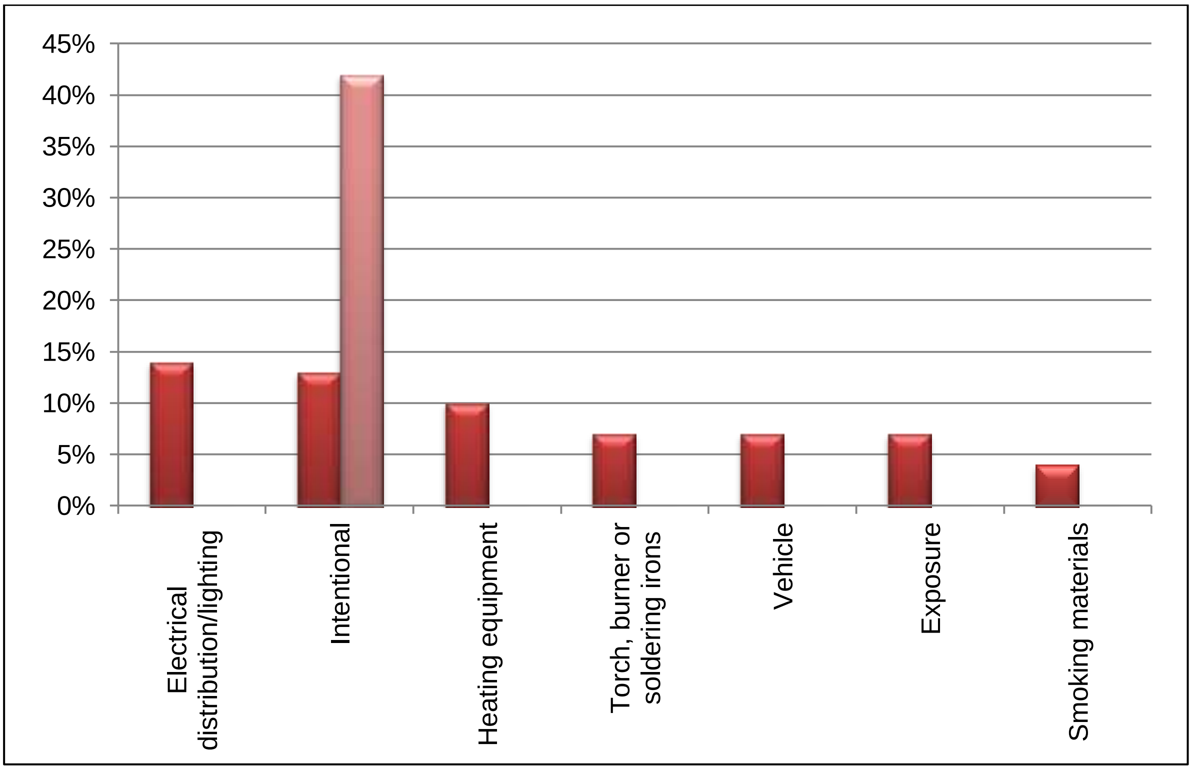


Figure 6-1 Leading causes of fires in warehouse (excluding cold storage) structures

The potential fire hazards (inclusive of the leading causes, as well as area of origin of a fire) identified throughout the development are illustrated in the graphs below. The statistics as illustrated in the figures below have been obtained from the National Fire Protection Association (NFPA) website (www.nfpa.com).

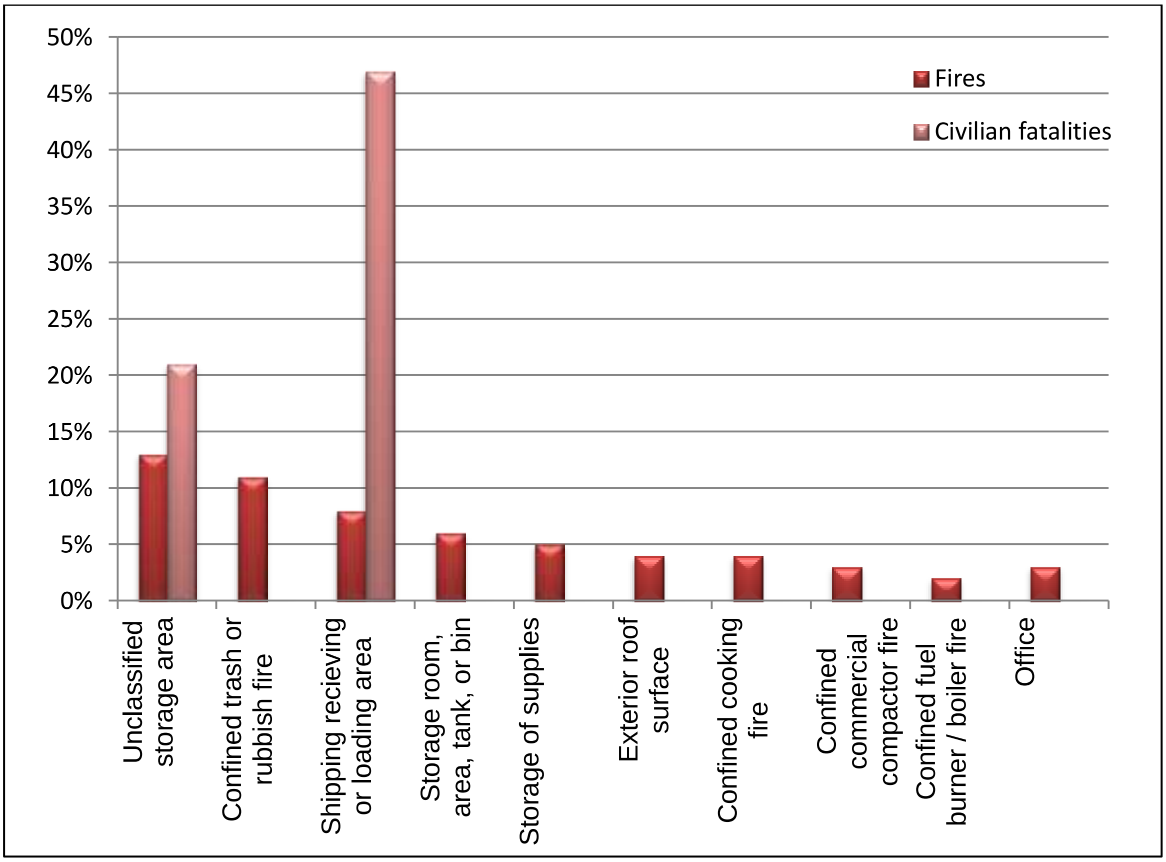


Figure 6-2 Structure fires in warehouse (excluding cold storage) structures by area of origin

Office Facilities

Fire statistics for offices in Australia as reported in Technical Report 96-02 [40] show that the most common cause of fires in these types of buildings are attributed to faults in electrical equipment, with lighting fixtures being the equipment most often cited.

Table 6-2: Office fire statistics by cause of ignition

CAUSE OF FIRE	FIRES	CIVILIAN FATALITIES
Electrical Distribution	21.1%	51.6%
Other Equipment; motors, generator, elevators, office equipment etc.	17.0%	21.4%
Incendiary or suspicious	15.7%	26.9%
Smoking Materials	8.6%	0.0%
Heating equipment	8.1%	0.0%
Appliance, tool or air conditioning	7.5%	0.0%
Open flame or torch	7.3%	0.0%
Cooking equipment	5.7%	0.0%
Other, less than 6% of fires per area	9.0%	0.0%
Total:	**100%** **5,800 fires per year**	**100.0%** **1 fatality per year**

Ahrens (2001) [42] reports that fire statistics from the U.S. confirm the same key ignition sources. It should be noted that with so few fire fatalities in office fires, the data for fatalities should be considered holistically, representing a low likelihood of fatalities overall in offices. The identification of the comparative risk of fatality within different areas or by different ignition sources is lacking in accuracy by virtue of a limited data set of 1 fatality per year.

Table 6-3: Office fire statistics by area of fire origin

AREA OF FIRE ORIGIN	FIRES	CIVILIAN FATALITIES
Office	17.7%	40.7%
Kitchen	6.0%	0.0%
Exterior wall surface	5.6%	0.0%
Attic or ceiling/roof assembly or concealed space	5.2%	0.0%
Heating equipment room	5.1%	0.0%
Hallway, Corridor or Mall	3.5%	21.2%
Crawl space or substructure space	1.6%	21.2%
Other, less than 5% of fires per area	55.3%	16.9%
Total:	**100%** **5,800 fires per year**	**100.0%** **1 fatality per year**

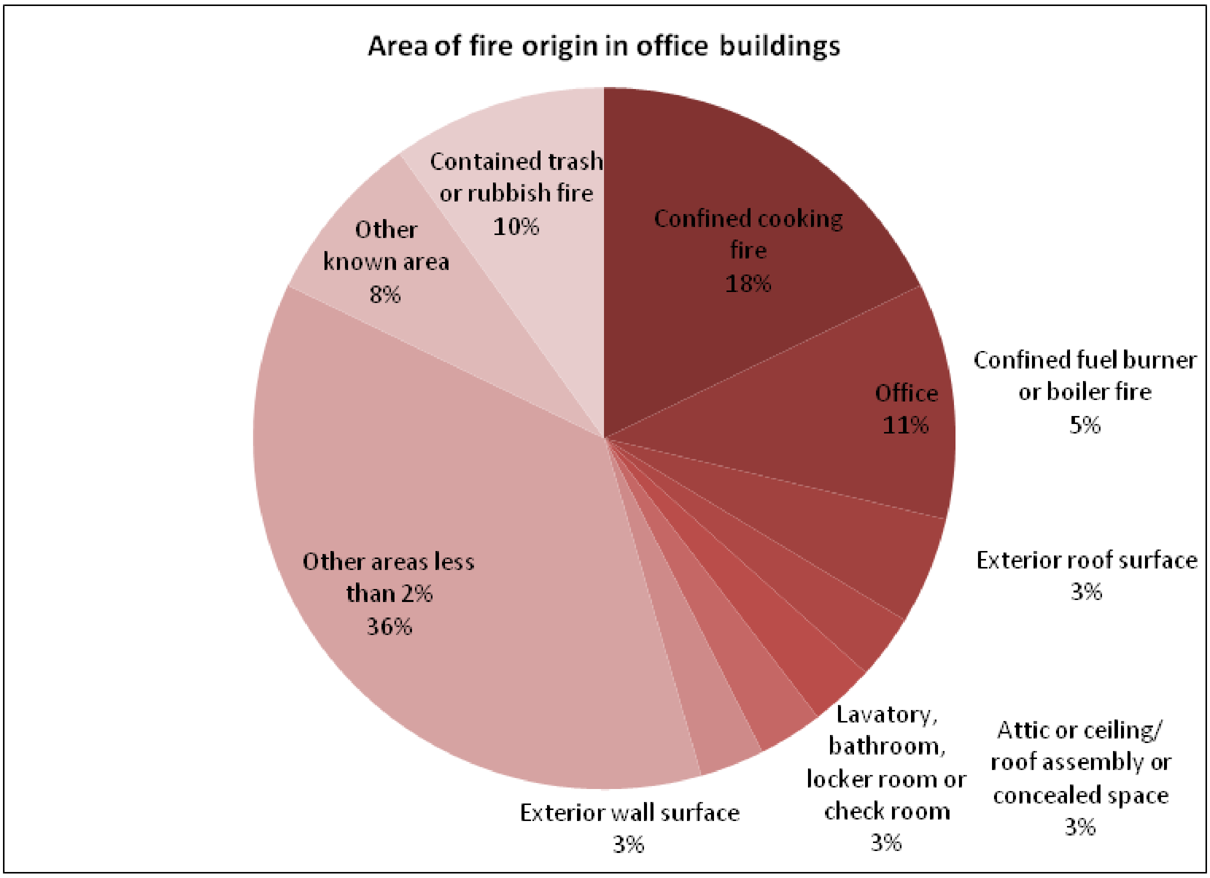


Figure 6-3: Area of fire origin in office buildings

Ahrens also indicates that 17.7% of all recorded office fires occur within the specific office area. This figure is likely to be highest by virtue of the proportion of the buildings which the general office space occupies and as such may not actually represent the high ignition risk of the office space but the risk of fire resulting from the application of a minor risk over the majority of the floor space. The next four most frequent areas of ignition are grouped around 5% each and include kitchens, exterior walls, concealed spaces and heating equipment rooms. Any correlation between the area of ignition and the likelihood of fatalities is likely to be misrepresentative due to the low number of fatalities relied upon to draw such conclusions.

Statistics shown in Figure 6-3 are published in the document 'U.S Structure fires in office properties' by Flynn (2007) [41]. A total of 5,800 fires were considered in the statistical data and had recorded one civilian fatality in these fires. It can be seen from the above figure that office, cooking and rubbish areas are the most common areas for fire origins within office buildings, which is consistent with the findings of Ahrens.

6.3 SPRINKLER EFFECTIVENESS & RELIABILITY

The effectiveness of automatic fire sprinklers in general in limiting fire spread and growth is supported by statistics and studies undertaken into the effects of automatic fire sprinklers within buildings. These studies show that fire sprinkler systems operate and control fires in 81% to 99.5% of fire occurrences [3]. The lower reliability estimates of 81.3% [23] as well as some of the higher values of 87.6% [36] appear to reflect significant bias in data in terms of the small number of fire incidents and the lack of differentiation between fire sprinklers and other fire suppression systems. A number of the lower figures are results of dated studies.

It must be noted that the higher reliability of fire sprinklers reported by Marryatt [25] of 99.5% reflect fire sprinkler systems where inspections, testing and maintenance exceeded normal expectations and applies to installations specifically in Australia and New Zealand. The statistical data indicate that sprinklers with appropriate maintenance are highly effective in reducing the loss of life and limiting fire spread and in particular the storage (ESFR) system has an exemplary record.

With reference to FM Global data sheet (2-2) as of 2002 [21] there had been six known fires involving suppression mode sprinkler protection.

In all of these incidents, the sprinkler system was successful in suppressing the fire and no more than four sprinkler heads operated. Therefore it is a relevant assumption that on the activation of the ESFR fire sprinkler system, the fire growth is considered to be suppressed within the area of activation.

FM Global Data Sheet 2-0 states that, FM Global loss history over the past twenty years indicates that approximately 25% of the time, the operation of a single sprinkler will control or suppress a fire if the sprinkler system has been properly designed and installed. This percentage increases to approximately 50% of the time with the operation of 3 or fewer sprinklers, and 75% of the time with the operation of nine or fewer sprinklers.

In addition analysis of the likelihood of sprinkler failure shows that most sprinkler system failures are due to impaired water supplies such as closed valves, blocked pipes, impaired sources, etc., which tend to affect sections of or the entire system [36]. As such, system reliability can be increased by active monitoring of water supplies and controls. The general consensus within the fire protection industry is that problems with individual sprinkler heads are rare. This information combined with sprinkler reliability data is favourable when compared with the reliability of fire compartmentation [3].

Moinuddin and Thomas [36] have found that masonry fire rated construction had a reliability of 81-95%, and gypsum 69-95%, with the upper level in both instances having been reported within the IFEG [3]. Both reported ranges are considered to be less than that offered by automatic sprinkler systems. Table 6-4 lists the effectiveness of sprinkler systems in the event of a fire growing to a size that facilitates sprinkler head activation [36].

Table 6-4: Effectiveness of sprinkler systems

PROPERTY TYPE	EFFECTIVENESS OF SPRINKLERS IN EVENTS WHERE SPRINKLERS OPERATE
Public Assembly	90%
Educational	93%
Health care / Correctional Centre	95%
Residential (average)	97%
Office / Retail	91%
Manufacturing	93%
Storage	86%
Cold Storage	89%

Statistics for general sprinkler effectiveness in storage properties is provided in the table below which is drawn from the research of Rohr [39]. The data indicates over 77% of storage fires and 84% of manufacturing facility fires are confined to the area of fire origin where sprinklers are fitted.

Table 6-5: Effectiveness of sprinkler in storage facilities

EXTENT OF FLAME DAMAGE	FIRES WITH SPRINKLER PROTECTION	FIRES WITHOUT SPRINKLER PROTECTION
Confined to object of origin	50.0%	19.9%
Confined to area of origin	27.8%	14.1%
Confined to room of origin	6.7%	4.9%
Confined to fire-rated compartment of origin	1.1%	0.6%
Confined to floor of origin	2.4%	1.1%
Confined to structure of origin	10.0%	45.0%
Extended beyond structure of fire origin	2.2%	14.3%
Total:	900 fires	29,330 fires

According to the tests undertaken by FM Global Property Loss Prevention Data Sheets [21], automatic smoke exhaust systems would operate prior to an installed sprinkler system. This would result in the removal of hot smoke from the ceiling causing a critical delay in sprinkler operation. As such, FM Global recommends that a sprinkler system should not be installed in conjunction with automatic smoke exhaust systems.

It is considered likely that the BCA DTS smoke management would hinder and prevent the activation of the sprinkler system as discussed in the FM Global Property Loss Prevention Data Sheets. The failure of the sprinkler system would allow fire development and cause uncontrolled spread throughout the building leading to a more rapid onset of untenable conditions, significant property loss, and restriction of fire fighter access into the building.

Furthermore, rapid fire development and spread could eventually overrun the sprinkler system by resulting in the activation of several fast response sprinkler heads, over and above the system design requirement, potentially depleting the water supply. In this instance, the system may be rendered ineffective and unable to hydraulically perform as intended. As such, it is recommended that the removal of the BCA DTS smoke management system would allow hot smoke to build up in the ceiling leading to the activation of the sprinkler system as intended by design parameters which are based on tested systems and therefore improving the likelihood of fire control and/or suppression.

6.4 FIRE LOAD

The fire load within a room or compartment will influence the duration and severity of a fire and resultant hazard to occupants. The effective fire load for the building has been estimated by consideration of the typical spaces within the building.

The following fire loads have been extracted from Chapter 3.4 of the International Fire Engineering Guidelines [3] and are listed in Table 6-6. This data is derived from Switzerland, however is also deemed applicable to buildings in Australia of similar use.

The warehouses is considered to generally contain mixed types of commodities, where in some cases cellulosic materials are mixed with plastics and non-combustible materials on the same racks. There is a large amount of data concerning the burning rates of items and materials; however, this information is not often presented such that it is sufficiently generic to be universally adopted.

Also, while the current occupants within the buildings may be known during the design stages of the development the length of their occupancy can not be definitively identified. Therefore while what can be representative of the current fuel loadings for the enclosure, these may not be the case in the future use of the building. Therefore, it would be a rare assessment in which the specific items forming the fuel load had been tested to provide the fire heat release data. As such it is considered that the application of generic burning rates, translated through simplified mathematical expression (time squared growth rates) is a suitable means of estimating fire development.

Table 6-6: Fire load densities

TYPE OF OCCUPANCY	AVERAGE FIRE LOAD
Office, Business	300 MJ/m^2
Forwarding facility dealing in; Beverages, food, furniture, glassware, plastic product, printed goods, varnish/polish.	Range from; 200 MJ/m^2 - 1700 MJ/m^2
Storage of rubber products	5000 $MJ/m^2/m$
Storage of paper	1000 $MJ/m^2/m$

6.5 FIRE GROWTH RATE AND INTENSITY

As the fire increases in size, the rate of fire growth accelerates. The growth rate of a fire can result in various hazards for occupants due to the following:

- Protective and preventative measures may not be adequate.
- Occupants may have insufficient time to evacuate.
- Occupants may perceive a reduced threat from slow growing fires.

The rate of fire growth is generally expressed in terms of an energy release rate. The most commonly used relationship is what is commonly referred to as a quadratic time-squared fire. The basis of the time squared fire arises from the fact that the growth during the flaming stage can be approximated by a smooth curve that can be expressed mathematically. The rate of heat release is given by the expression:

$$Q = \left({}^{t}/_{k} \right)^2$$

Where; t is time from ignition of the fire (seconds) and k is the growth time (seconds) for the fire to reach a heat output of 1.055 MW.

Studies of actual fires have led to the adoption of five (5) standard fire growth rates covering a wide range of potential fire scenarios and fuel loads. It should be noted, the times of fire incubation are not included in the time-squared growth fire models. National Fire Protection Association Standard NFPA 92B [36] provides information on the relevance of time-squared approximation to real fire as depicted in the figure below.

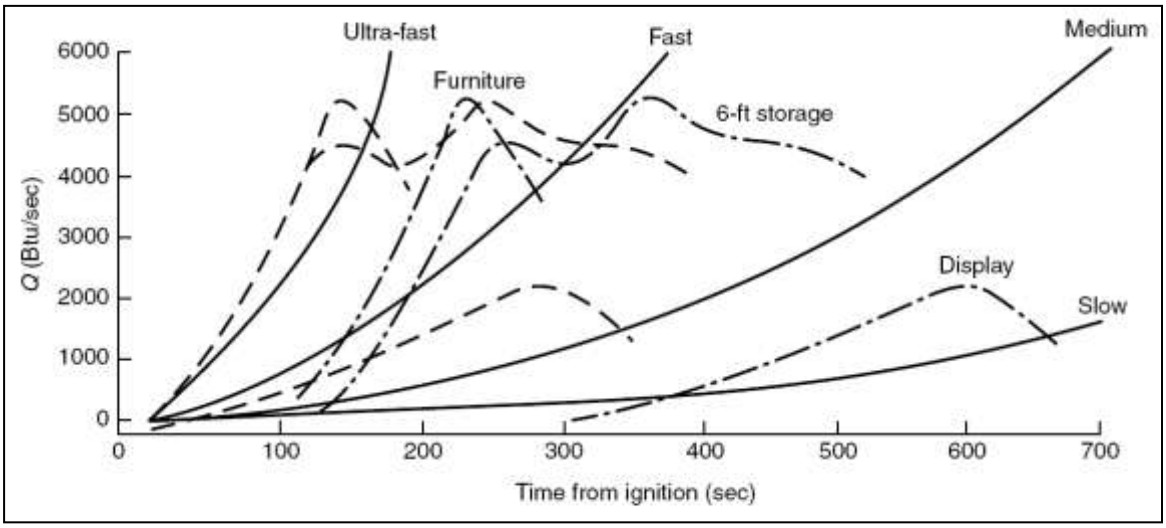


Figure 6-4: NFPA 92B: T-squared fire, rates of energy release

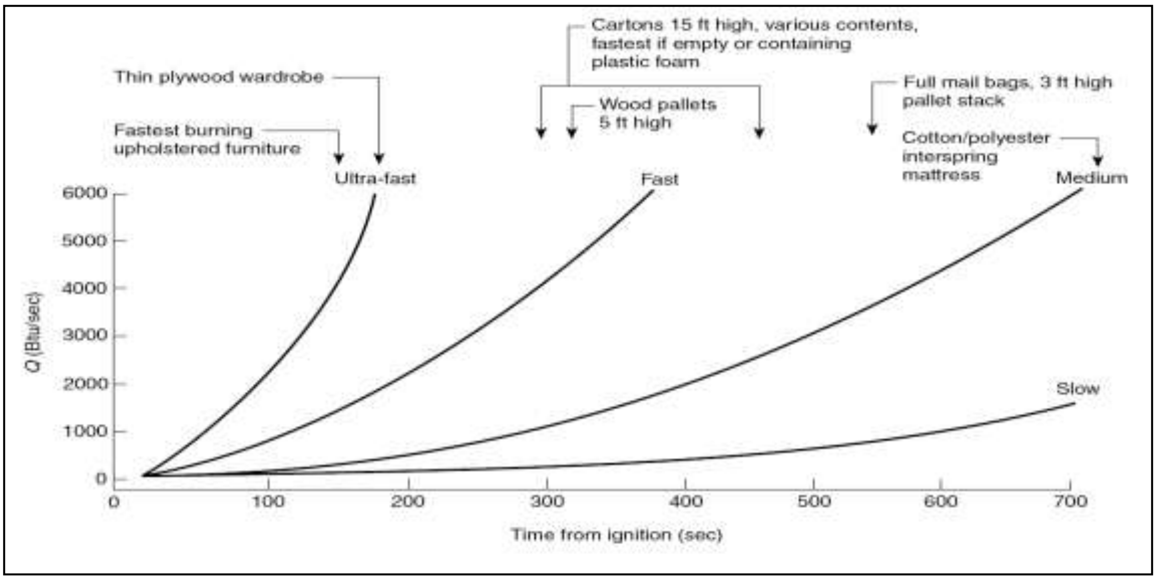


Figure 6-5: NFPA 92B: Relation of t-squared fires to some fire tests

The rate of fire growth can also be estimated from data published in British Standard (BS) 9999:2008 [5] as shown below in Table 6-7, and Table 6-8.

Table 6-7: Summary of fire growth rates per building type

BUILDING AREA PROVIDING FUEL	GROWTH RATE	BUILDING AREA PROVIDING FUEL	GROWTH RATE
Reception area	Slow	Restaurant/Canteen	Medium
Office	**Medium**	Teaching Laboratories	Fast
Shop	Fast	Meeting Room	Medium
Warehouse	**Medium/Fast/Ultra-Fast**	Waiting Room	slow

The variation in warehouse growth rates can be understood from the following table illustrating the types of stored items.

Table 6-8: Fire growth rates as described in BS 9999:2008

FIRE GROWTH RATE	STORED MATERIALS
Slow t^2	Banking hall, limited combustible materials.
Medium t^2	Stacked cardboard boxes, wooden pallets.
Fast t^2	**Baled thermoplastic chips, stacked plastic products, and baled clothing.**
Ultra-Fast t^2	**Flammable liquids, expanded cellular plastics and foam.**

From the above tables (and figures) it is concluded that the likely fire scenarios in the high bay racking may be approximated by an Ultra-Fast standard time-squared fire growth rate curve, while the office areas can be approximated with a Medium time-squared fire growth rate.

6.6 FIRE SOOT YIELD

The materials that make up the fuel load will determine the soot yield of a fire. The fire soot yield should be assessed with respect to hazard due to the following:

- Soot yield can affect visibility for occupants trying to escape a fire.
- Soot yield can be directly related to other products of combustion which may cause untenable conditions.

The fire load materials within an office is likely to involve plastics in the form of computer equipment and telephones etc and large quantities of cellulosic materials in the form of chip board desks, paper and general office stationary. Generally cellulosic materials have far lower smoke yields than plastics. A common plastic is polyurethane which has a soot yield of 0.1 kg/kg as referenced from Babrauskas in the NFPA Handbook. As a conservative input to the computer modelling all material involved in the fire has therefore assumed to be plastic.

6.7 FIRE HAZARD SUMMARY

Subsequent to a review of the relevant fire statistics the fire hazards for the building are listed in Table 6-9.

Hazards due to functions or characteristics are reviewed based on the building in question and relevant statistics; and

1. A description is provided on the nominated hazards; and
2. Relevant preventative / protective measures are provided to address the nominated hazards.

Table 6-9: Building Hazard Assessment

POTENTIAL HAZARDS DUE TO:		DESCRIPTION / DETAILS	PREVENTATIVE & PROTECTIVE MEASURES TO ADDRESS HAZARDS
Building layout		Exits are provided around the building perimeter to allow for multiple alternative egress opportunities. Areas within the warehouse have limited dead end travel routes to exits. Due to the size of the building, extended travel distances to the nearest exit and between alternative exits exist from the central warehouse areas. Within the subject building it is not expected that there will be any greater exposure to fire as a result of the Alternative Solution. No fire hazards to adjoining buildings have been identified, fire hazards generally relate to any internal exposures. Occupants in the area of fire origin are expected to be aware of fire and commence evacuation.	Fire Hydrants, BCA Clause E1.3 & AS2419.1:2005 Fire Hose Reels, BCA Clause E1.4 & AS24441:2005. Fire Extinguishers, BCA Clause E1.6, & AS2444:2004. Automatic Suppression System, BCA E1.5, AS2118.1:1999, FM2-0, FM8-9 and Alternative Solution. Occupant Warning System, AS1670.1:2004 Clause 3.22. Smoke Clearance System, Alternative Solution in lieu of BCA Spec E2.2b smoke exhaust system. Smoke Detection System, BCA E2.2a, AS1670.1:2004 & Alternative Solution Automatic Link to Fire Brigade, BCA Spec E1.5. Emergency Lighting, BCA Clause E4.2/E4.4 & AS2293.1:2005 Exit Signage, BCA Clause E4.5, NSW E4.6, NSW E4.8 & AS2293.1:2005 and Alternative Solution.
Activities		The development is a storage and dispatch facility containing a large number of high piled and racking storage containing combustibles. These items are only stored temporarily before being dispatched onward, thus there is no degradation of old stock. Notwithstanding the assumed turnover, the storage is assumed to be constantly filled to capacity due to the constant rolling stock. ■ Corridors, stairs and lobbies will generally be used only for transient purposes, occupants travelling to and from the various parts of the building.	
Ignition sources		Based on the statistical review contained above the ignition sources relevant to this site, in order of occurrence and likelihood ■ Electrical equipment / lighting ■ Intentional fire starts ■ Stored waste or rubbish ■ Heating equipment / freezer units	
Fuel sources	Quantity of materials	Dangerous goods may be present in the building however they are only expected to be ever be in small quantities. Where they are present they shall be stored in accordance with AS1940:2004 and Workcover requirements.	
	Location of materials	Products in high storage racking, store room, waste and rubbish containers. The lobbies, stairways and corridors are to be maintained clear of furniture, stored items and the like and constructed with materials and assemblies in accordance with C1.10 to reduce fire spread and smoke production in the event of fire in common areas. Significant fuel loads will therefore be generally limited to the warehouse.	
	Fire behaviour	Fire growth rates will vary with fuel type and conditions of ventilation and compartmentation. The most likely outcome of any fire outbreak within the building is	

POTENTIAL HAZARDS DUE TO:	DESCRIPTION / DETAILS		PREVENTATIVE & PROTECTIVE MEASURES TO ADDRESS HAZARDS
		expected to be sprinkler controlled fire. This would be expected to grow at an Ultra-Fast time squared fire growth rate until sprinkler activation. An office fire would likely be smaller in size due to the limited fuel density and would be expected to grow at a Medium time squared fire growth rate.	
Fire origins	Refer to previous charts whereby fires are likely to occur in the following origins: ■ High storage racking areas. ■ Waste and rubbish containers. ■ Store room. ■ Office workstation.		

7 BCA DTS NON-COMPLIANCE ASSESSMENT AND ACCEPTANCE CRITERIA

7.1 OVERVIEW

BCA DTS Non-Compliance Assessment and Acceptance Criteria

In this instance the BCA DTS non-compliances have been formulated based on the regulatory review as provided by the project building surveyor and / or design team. Where not listed herein the building is required to achieve compliance with relevant DTS provisions or if existing, comply with relevant codes, reports and / or Standards approved at the time of consideration.

The following table lists the departures from the DTS provisions of the BCA for the proposed building and the analysis methodology proposed for the Fire Engineering assessment, which is to be generally in accordance with the IFEG [3].

7.2 BCA DTS NON-COMPLIANCE ASSESSMENT AND ACCEPTANCE CRITERIA

Table 7-1: Summary of Alternative Solutions

BCA DTS VARIATIONS	BCA PROCESS FOR REVIEW OF BUILDING SOLUTIONS
BCA DTS Provisions Clause D1.4: Distance to the nearest exit. Clause D1.5: Distance between alternative exits. Clause E2.2: Smoke hazard management **Performance Requirement** DP4 & EP2.2	***BCA DTS Provision*** Clause D1.4: the travel distance to the nearest exit must not exceed 40-metres. Clause D1.5: the travel distance between alternative exits must not exceed 60-metres. Clause E2.2 *(Table E2.2a)*: the building requires an automatic smoke exhaust system. ***DTS Non-Conformance*** The following DTS non-compliances have been identified in the warehouse. ■ Travel distances of up to 73m to the nearest exit and 145m between alternative exits; and ■ A manually operated smoke clearance system shall be provided in the warehouse lieu of the DTS required automatic smoke exhaust. ***Alternative Solution*** The Alternative Solution will rely upon the volume of the warehouse enclosure to act as a smoke reservoir for hot combustion products with significant reserve so as to provide the population with adequate time to safely evacuate the building prior to the onset of untenable conditions. ***Assessment Methodology*** The assessment methodology will adhere to Clauses A0.5(b)(i), A0.9(b)(ii), and A0.10 of the BCA. The analysis will be absolute and quantitative where the results of the deterministic assessment are measured directly against the agreed acceptance criteria, with a supporting qualitative argument. Computational Fluid Dynamic (CFD) programs will be used to simulate the fire development and smoke spread in the warehouse with these results utilised in an ASET/RSET time-line analysis. ***Acceptance Criteria*** The Alternative Solution is deemed acceptable when demonstrated:- ■ ASET calculated is greater than, or at least equivalent to, the RSET for the worst credible scenarios incorporating a safety factor of 1.5: $ASET_{WC} \geq 1.5 \times RSET_{WC}$ ■ ASET calculated is greater than, or at least equivalent to, the RSET for the

BCA DTS VARIATIONS	BCA PROCESS FOR REVIEW OF BUILDING SOLUTIONS
	sensitivity and redundancy scenarios: $ASET_{Sen/Red} \geq RSET_{Sen/Red}$ **NB:** Occupant tenability criteria are in accordance with CIBSE Guide E [14], the International Fire Engineering Guidelines [3] and the Fire Brigade Intervention Model [6] as listed in APPENDIX A.
BCA DTS Provisions Clause E4.6 – Direction signs (inter alia AS2293.1: 2005) **Performance Requirement** EP4.2	***BCA DTS Provision*** Clause E4.6 (NSW) states that if an exit is not readily apparent, then exit signs must be appropriately provided in accordance with AS2293.1. AS2293.1 *(Clause 6.8.1)* requires exit signs be mounted not less than 2m and not more than 2.7 above floor level. ***DTS Non-Conformance*** The exit lighting design shall incorporate signage in the warehouse parts that are positioned above a height of 2.7m to permit the passage of picking machinery below. ***Alternative Solution*** The Alternative Solution shall rely upon the volume of the warehouse enclosure to provide adequate time to evacuate prior to the directional exit signs becoming compromised by the hot smoke layer. Further to this, the simplicity of the racking layouts and the familiarity of the occupants within the building shall provide for a rapid evacuation along familiar egress routes. ***Assessment Methodology*** The assessment methodology will adhere to Clauses A0.5(b)(i), A0.9(b)(ii), and A0.10 of the BCA. The analysis will consist of a qualitative discussion to demonstrate compliance with the relevant Performance Requirements. Further to the above the deterministic results of the CFD modelling shall demonstrate that the directional exit signage will not be obscured by the descending smoke layer prior to the completion of occupant evacuation, thereby permitting adequate and sufficient way-finding provisions to complete an evacuation. ***Acceptance Criteria*** During an evacuation occupants have clear visibility of the directional exit signs when navigating to an exit.

8 FIRE ENGINEERING ASSESSMENT

8.1 OVERVIEW

In order to establish that the required BCA Performance Requirements have been adequately assessed the following section details the results of the analysis and compares those results to each applicable Performance Requirement. The results of the analysis are collated and evaluated taking into consideration the DTS requirements, assessment methodology, and acceptance criteria.

8.2 EGRESS PROVISIONS AND SMOKE HAZARD MANAGEMENT

8.2.1 Regulatory assessment

In order to assess the non-compliance of the relevant BCA DTS clause(s) the following table is provided to outline the relevant regulatory requirements and assessment methods.

Table 8-1: Regulatory Assessment

REGULATORY REQUIREMENT	DESCRIPTION / DETAILS
BCA DTS provisions:	Clause D1.4: the travel distance to the nearest exit must not exceed 40-metres. Clause D1.5: the travel distance between alternative exits must not exceed 60-metres. Clause E2.2 *(Table E2.2a)*: the building requires an automatic smoke exhaust system.
Non-compliance with DTS provisions:	The following DTS non-compliances have been identified in the warehouse. ■ Travel distances of up to 73m to the nearest exit and 145m between alternative exits; and ■ A manually operated smoke clearance system shall be provided in the warehouse in lieu of the DTS required automatic smoke exhaust system.
Relevant Performance Requirements(s):	DP4 and EP2.2
Assessment methodology:	The assessment methodology will adhere to Clauses A0.5(b)(i), A0.9(b)(ii), and A0.10 of the BCA. The analysis will be absolute and quantitative where the results of the deterministic assessment are measured directly against the agreed acceptance criteria, with a supporting qualitative argument. Computational Fluid Dynamic (CFD) programs will be used to simulate the fire development and smoke spread in the warehouse with these results utilised in an ASET/RSET time-line analysis.
Acceptance criteria:	ASET calculated is greater than, or at least equivalent to, the RSET for the worst credible scenarios incorporating a safety factor of 1.5: $ASET_{WC} \geq 1.5 \times RSET_{WC}$ ASET calculated is greater than, or at least equivalent to, the RSET for the sensitivity and redundancy scenarios: $ASET_{Sen/Red} \geq RSET_{Sen/Red}$

8.2.2 Introduction

BCA DTS clause D1.4 states that the distance to a final exit must not exceed 40m where two or more exits are available and no greater than 20m to a single exit, while clause D1.5 deals with the distance between alternative exits and requires that this distance does not exceed 60m.

BCA DTS clause E2.2 (BCA Table E2.2a) requires large isolated buildings with a ceiling height of more than 12-metres to be equipped with an automatic smoke exhaust system.

Occupant travel distances and smoke hazard management systems in the building do not strictly meet the above listed DTS provisions, and subsequently an Alternative Solution has been developed to address the following areas of non-conformance;

- A manually operated smoke clearance system shall be provided in lieu of the DTS required automatic smoke exhaust system; and
- Travel distances of up to 73m to the nearest exit and 145m between alternative exits have been identified in the central parts of the warehouse.

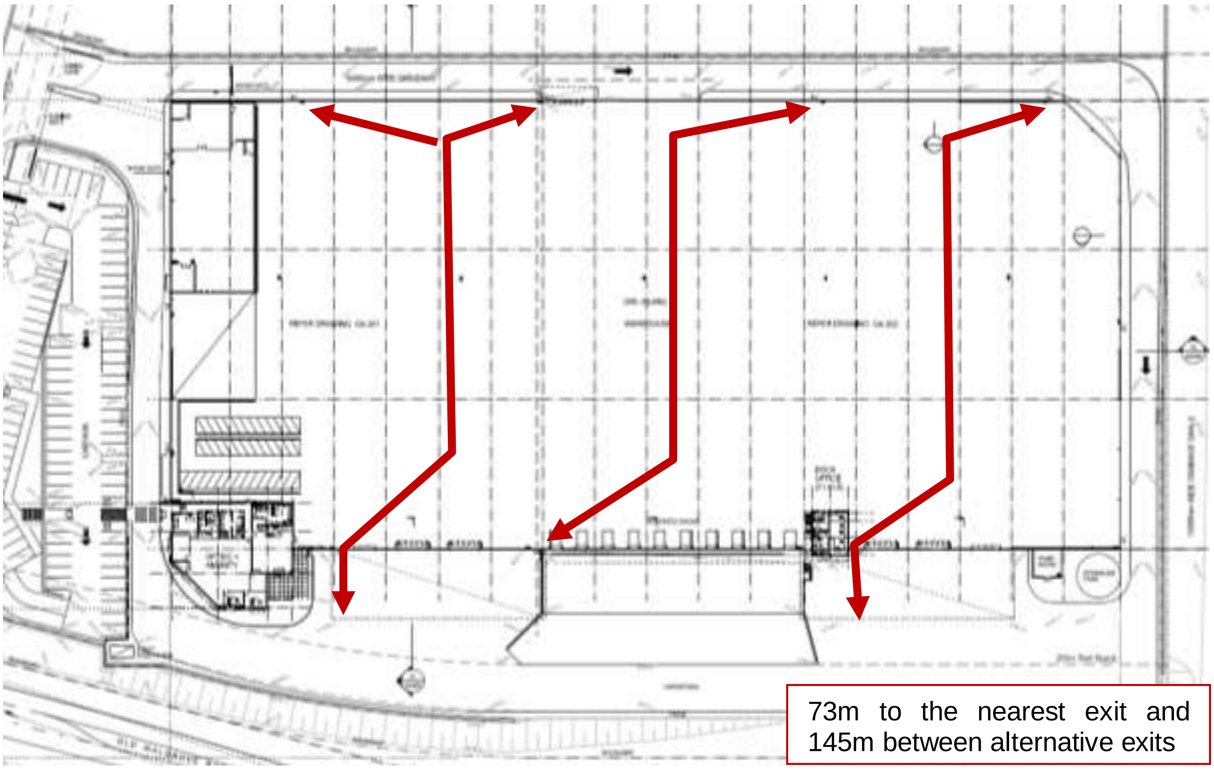


Figure 8-1: Warehouse non-conformant travel distances

8.2.3 Intent of the BCA

The Guide to the BCA [2] states that DP4 is designed to take into account, the distance travelled; the number of occupants and their characteristics in order to determine what is an acceptable travel time having regard to the function of the building and its likely fuel load; its height and whether the exit is from above or below ground level. Similarly, EP2.2 is required to consider a number of comparable elements in demonstrating that suitable conditions exist within the fire enclosure to facilitate the safe evacuation of all occupants from the building.

The criteria that need be satisfied to demonstrate compliance with Performance Requirement DP4 and EP2.2 is for the total movement time of occupants, and the subsequent conditions during that time being maintained to an agreed standard. In other words the assessment must demonstrate whether the building design is capable of satisfying the following nominated fire safety objectives:-

- *Safe evacuation of building occupants in the event of fire*; and
- *Internal Fire & Rescue NSW intervention in the event of fire*.

8.2.4 Alternative Solution

In the warehouse the Alternative Solution relies upon the volume of the enclosure to act as a smoke reservoir for hot combustion products with significant reserve so as to provide the population with adequate time to safely evacuate the building prior to untenable conditions forming.

Provided conditions for occupants and fire brigade are acceptable, it will be demonstrated that a smoke exhaust system is not warranted, and thus a manually operated smoke clearance system shall be installed for post fire operations.

8.2.5 Fire Engineering Assessment

Design fire location

An important factor of a fire safety engineering assessment is identifying appropriate fire scenarios. These scenarios are identified by considering fire hazards present and their potential consequences. The process of fire scenario selection is based around identifying those fire scenarios which might be considered “worst credible” that is having the following aspects:

a) The location of the most likely ignition source; and

b) The location of the densest or most flammable fuel load; and

c) Having the worst impact or consequence; and

d) Highlighting the performance of the identified areas of non-compliance during a fire emergency.

The warehouse is spread over an area of approximately 19,520m^2. Within the warehouse there are smaller enclosures at the southern end of the facility and a central dock office, however in the event of a fire in one of these enclosures occupants are able to exit directly to outside via compliant travel distances or into the main warehouse where they will be provided with the benefit of a large enclosure volume (with diluted fire hazards). Accordingly for the CFD modelling undertaken no individual fires have been modelled within the smaller enclosures in the warehouse.

Due to the rectangular shape of the warehouse two Design Fire locations have been selected within the main warehouse, namely a corner racking fire (DF1) and a central racking fire (DF2).

1) **DF1:** An initial design fire is located centrally within the high bay racking area in the centre of the warehouse. This is due to the combination of the dense fuel load located within the storage arrangement and late sprinkler activation due to the fire being under the ceiling ridgeline.
2) **DF2:** A second fire location is considered in the south-western corner of the warehouse as this blocks exits in the area and conversely to the central design fire, the corner fire will provide for an uneven smoke spread over the warehouse roof dropping at different locations due to the interaction with the bounding walls.

Design fire scenarios

The warehouse is considered to generally contain mixed types of commodities, where in some cases cellulosic materials are mixed with plastics and non-combustible materials on the same racks. There is a large amount of data concerning the burning rates of items and materials; however, this information is not often presented such that it is sufficiently generic to be universally adopted. Also, what can be representative of current fuel loadings for the enclosure may not be the case in the future use of the building. Therefore, it would be a rare assessment in which the specific items forming the fuel load had been tested to provide the fire heat release data. As such it is considered that the application of generic burning rates, translated through simplified mathematical expression (t-squared growth rates) is a suitable means of estimating fire development. The unpredictable incubation phase of the fires development is not included, therefore providing a conservative approximation of the time to peak heat release rate.

Based on the fire hazard assessment in Section 6; Densely stored combustibles are expected to create the worst credible fire scenario with a Medium or Fast fire growth rate with a possibility of an Ultra-Fast fire growth rate under high-bay storage arrangements. Further statistics suggest that a storage mode sprinkler system will likely control and/or suppress a fire with the activation of the inner row of sprinklers.

- **Worst credible design fires:** An Ultra-Fast t-squared fire growth rate has been selected to represent an assumption of rapid fire development in the high bay racking as suggested by the statistic review in Section 6. Upon activation of the inner row of sprinkler heads the fire is expected to be suppressed/controlled, however the heat release rate is maintained constant to simulate fire spread through the stock in areas protected from water discharge.

- **Sensitivity design fires:** The fire is also designed to grow at an Ultra-Fast rate, however the maximum heat release rate is permitted to be larger as the fire is not controlled until the second array of sprinkler heads.

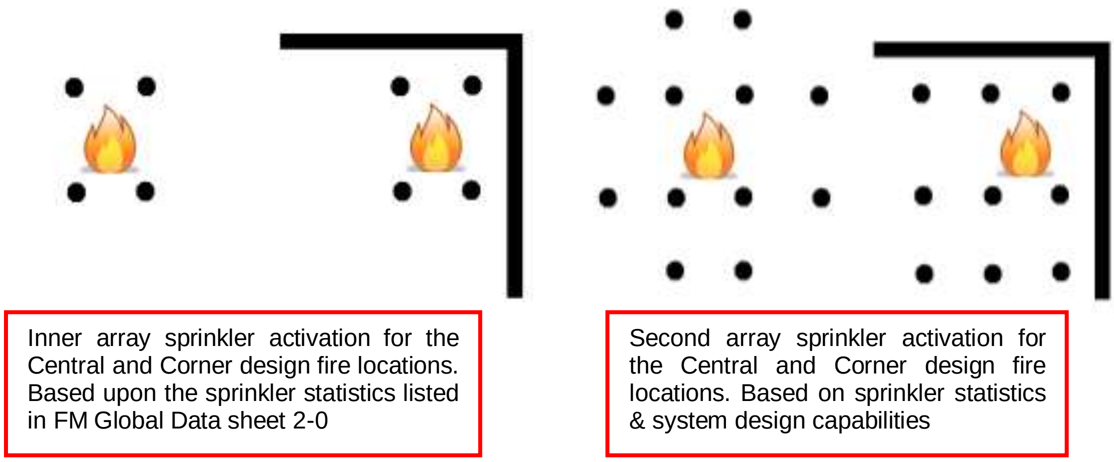


Figure 8-2: Sprinkler head activation *(assumed to control fire growth)*

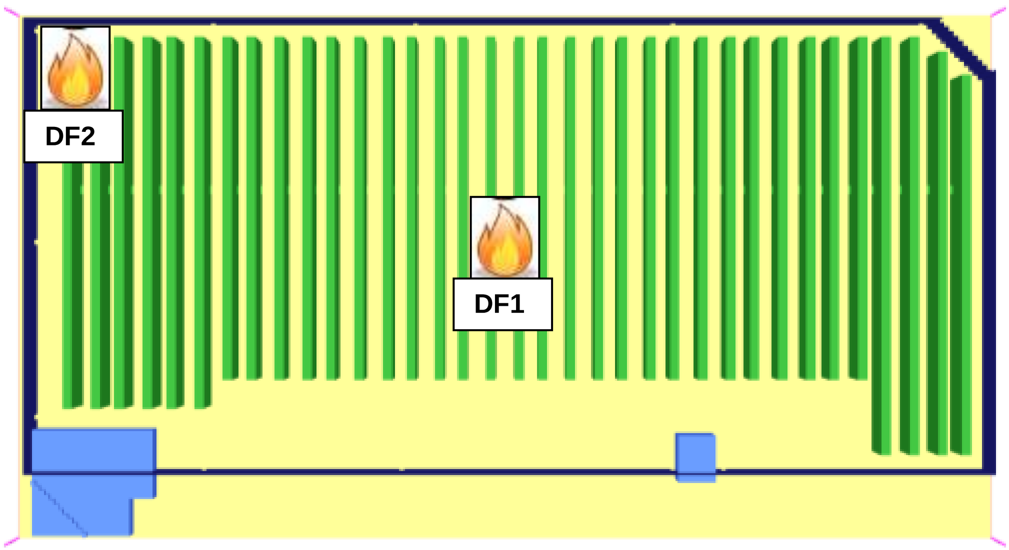


Figure 8-3: Computational domain and fire locations

It should be noted that the southern Eco run-up room and associated office space has not been considered in the fire modelling due to the low level of the space. As a conservative assumption and to allow for future tenants the high bay racking is considered to extend throughout the warehouse. This will create a smaller volume of space at high level, which is expected to cause the hot smoke layer to descend at a more rapid rate when compared to the low level Eco run-up room enclosures.

<u>ASET Calculation</u>

This assessment uses computational fluid dynamics (CFD) modelling to predict the time period during which tenable conditions are likely to be maintained in the escape routes under differing design fire scenarios, thereby permitting the calculation of the ASET.

The NIST Fire Dynamics Simulator (FDS) is a CFD model of fire-driven fluid flow. It solves a form of the Navier-Stokes equations appropriate for low-speed, thermally driven flow with an emphasis on smoke and heat transport from fires [3]. A companion software program, Smokeview, allows for the simulation results to be easily displayed. FDS has been through extensive validation in fire engineering on modelling heat transfer, gas movement and combustion phenomena, etc. [53, 54]. It has also been used widely to assess untenable conditions such as the upper hot layer temperature and visibility in a fire scenario. Complete descriptions of the FDS model and Smokeview, as well as the technical references which support the model, are given in references [53, 56, 57].

Inputs required by FDS include the geometry of the structure, the computational cell size, the location of the fire source, the energy release rate of the fire source, the mass, geometry and thermal properties of walls, ceilings, floors, and furnishings, and the size, location, and timing of door and window openings to the outside of the structure. The selection of thermo physical properties and dimensions for the input parameters can have a significant impact on the outcome of the simulation, and because considerable uncertainty exists in the values of these parameters, a range of values is used.

For a specific set of inputs, FDS calculates the fire-spread and smoke movement within the building. The results of the simulation including the spread of fire and smoke throughout the various rooms, enclosures and fire compartments are then assessed to determine the expected conditions within the building.

Design Fire Summary

Table 8-2: Fire scenario summary: Warehouse fire scenarios

FIRE SCENARIO CHARACTERISTIC				
FIRE SCENARIO	**DF1** Worst Credible	**DF1** Sensitivity	**DF2** Worst Credible	**DF2** Sensitivity
Fire growth rate	Ultra-Fast t-squared fire growth rate			
Suppression by automatic equipment	Worst credible scenario assumes the fire is controlled by the inner array of sprinkler heads. Sensitivity scenario assumes the fire is controlled by the second radial row of sprinklers heads.			
Maximum heat release rate	8.6 MW	16 MW	8.6 MW	16 MW
Material soot yield	Polyurethane equivalent 0.1g/g.			
Simulation time	Model is run until steady state conditions or the time of fire brigade attack, whichever occurs first			
Ventilation conditions due to natural smoke relief	No mechanical exhaust is provided. Natural leakage through the enclosure walls and doors can be expected, along with any dispatch roller doors that may be open at the time of fire ignition. To allow for natural ventilation into the building and ensure complete combustion of the design fire and the most onerous conditions in regards to smoke and heat production all required exit doors are modelled as being open 100%.			
Active fire system parameters	Sprinkler activation temperature and response time index (RTI) are no greater than 101°C and $50m^{1/2}s^{1/2}$ respectively.			

Computational Fluid Dynamic Modelling Results

The results of the computer modelling for the fire scenarios are illustrated in APPENDIX G. The modelling indicates that the smoke reaches the ceiling of the warehouse quickly, even at a maximum height of over 13m, and spreads laterally across the ceiling before descending when it reaches the enclosure's bounding walls. Typically the upper ridge of the roofing provides a channel for smoke spread in a north-south direction before descending out across the floor plate.

In all simulations visibility is deemed to be the limiting factor in relation to occupant tenability. The final ASET results are provided in APPENDIX G.

RSET Calculation

To establish the RSET a time-line analysis has been employed, with the general assumptions that occupants use the exits proportionally in the optimum balance, that all occupants are familiar with their place of employment and the layout of the warehouse such that minimum way finding is required during an evacuation. The full calculations in regard to travel times, queuing times at exit doors, general assumptions including travel speeds, occupant locations, and pre-movement times are detailed in full in APPENDIX D.

Table 8-3: Evacuation scenario summary

EVACUATION SCENARIO	EXIT WIDTH	EXIT FLOW RATE	TOTAL POPULATION	TRAVEL DISTANCE	TRAVEL SPEED
EV-WC *Worst credible*	13m [a]	1.3 people per metre of effective width per second	715	73 metres [c]	1.0 metre per second
EV-RED *Redundancy*	6m [b]			218 metres [d]	

[a] *All 13 exits are available (each assumed to be 1m in width).*

[b] *Half of the exits considered compromised by fire hazards or otherwise (6 exits available for egress).*

[c] *All occupants must traverse the furthest travel distance (73m) to reach a final exit.*

[d] *On route to the initial exit of choice it is registered that the exit is blocked due to smoke/fire requiring egress to an alternative exit (73m + 145m).*

Table 8-3 illustrates the two egress scenarios incorporated into each analysis, with the final RSET calculations completed in Table 8-4 based on the assumptions and calculations listed in APPENDIX D.

Table 8-4: Required Safe Egress Time Calculations (RSET)

FIRE SCENARIO	EVACUATION SCENARIO	SMOKE DETECTION	PRE-MOVEMENT	TRAVEL TIME	RSET
DF1-WC	EV-WC	55 sec	180 sec	73 sec	308 sec / 5.1 min
DF1-SEN	EV-WC				
DF1-WC	EV-RED			218 sec	453 sec / 7.6 min
DF2-WC	EV-WC			73 sec	308 sec / 5.1 min
DF2-SEN	EV-WC				
DF2-WC	EV-RED			218 sec	453 sec / 7.6 min

Comparative ASET / RSET Analysis

In determining the onset of untenable conditions, the ASET is calculated according to the set of criteria governing conditions once the smoke layer descends below 2-metres. Namely this relates to:-

- Smoke Temperature exceeding 60°C; or
- Visibility falling below 10 m (optical density < 0.1 m^{-1}); or
- The CO toxicity rising above 1,400ppm.

From the FDS simulation results, the combination of visibility, smoke layer temperature and CO levels are obtained over time. Based on the abovementioned criteria the ASET for each scenario is found to be governed by the visibility limit once the smoke layer descends to within 2 metres of the floor. The results of the assessment and the summarised *available safe egress time* for each design scenario are compared against the *required safe egress time*.

The analysis demonstrates the Alternative Solution provides adequate levels of safety for occupants to safety evacuate in the event of a fire in the warehouse.

Table 8-5: Comparison of ASET and RSET: *Worst Credible Scenarios*

DESIGN FIRE SCENARIOS	Worst Credible Scenarios	
	DF1	DF2
RSET	308 sec	308 sec
Temperature*(>60°C)*	>1800 sec	>1800 sec
Visibility *(<10m)*	890 sec	620 sec
CO *(>1400ppm)*	>1800 sec	>1800 sec
ASET	890 sec	620 sec
Margin of Safety	582 sec	312 sec
Factor of Safety	***2.9 (>1.5 required)***	***2.0 (>1.5 required)***
Conforms with Acceptance Criteria	✓	✓

Table 8-6: Comparison of ASET and RSET: *Sensitivity and Redundancy Scenarios*

DESIGN FIRE SCENARIOS	Redundancy and Sensitivity Scenarios			
	DF1 *Sensitivity*	DF1 *Redundancy*	DF2 *Sensitivity*	DF2 *Redundancy*
RSET	308 sec	453 sec	308 sec	453 sec
Temperature*(>60°C)*	>1800 sec	>1800 sec	>1800 sec	>1800 sec
Visibility *(<10m)*	680 sec	890 sec	575 sec	620 sec
CO *(>1400ppm)*	>1800 sec	>1800 sec	>1800 sec	>1800 sec
ASET	680 sec	890 sec	575 sec	575 sec
Margin of Safety	372 sec	437 sec	267 sec	167 sec
Factor of Safety	***2.2 (>1.0 required)***	***2.0 (>1.0 required)***	***1.9 (>1.0 required)***	***1.4 (>1.0 required)***
Conforms with Acceptance Criteria	✓	✓	✓	✓

Fire Brigade Intervention

In considering the impact of removing smoke exhaust on fire fighting personnel, reference has been made to the Fire Brigade Intervention Model [6]. The following fire-fighter tenability limits are applied during routine conditions as the most onerous conditions with all conditions being relative to a height of 1.5 m above the finished floor level.

Routine Conditions

Elevated temperatures, but not direct thermal radiation

- Maximum Time: 25 minutes
- Maximum Air Temperature: 100°C (in the lower layer)
- Maximum Radiation: 1kW/m^2

As indicated above, air temperature and thermal radiation are the two factors used to determine the tenable conditions for fire fighters. It should be noted that visibility and toxicity have not been listed to determine the tenable conditions for fire fighters. Fire brigade personnel are expected to encounter smoke conditions in any significant fire event.

The temperature at 2m above FFL did not reach 60°C throughout the modelling period in all of the design fire scenarios modelled. A conservative temperature of 60°C has been used in a radiant heat calculation for the determination of occupant and fire brigade tenability in relation to radiant heat impingement. The calculations in APPENDIX C have determined that the maximum radiant heat that fire brigade will be exposed to will not exceed $1kW/m^2$, i.e. below the tenability criteria of $3kW/m^2$.

8.2.6 Performance Requirement Assessment

The following tables provide assessments of each relevant BCA Performance Requirement, thereby achieving compliance with the BCA.

Table 8-7: Performance Requirement Assessment (DP4)

DP4	CONCLUSION
Exits must be provided from a building to allow occupants to evacuate safely, with their number, location, and dimensions being appropriate to -	
(a) the travel distance; and	The assessment has illustrated that the occupants are provided with adequate time to safely evacuate the building prior to the onset of untenable conditions. Therefore it is considered that the travel distance provided in the Alternative Solution is appropriate to allow for the safe evacuation of the building population.
(b) the number, mobility, and other characteristics of occupants; and	The ASET/RSET calculations have incorporated various conservative parameters to allow for any occupants that have ambulatory disabilities however the population are not expected to have additional requirements above that of the common public.
(c) the function or use of the building; and	The building's function leads to a population that are familiar with the building layout and egress provisions, it is deemed that the building function provides for minimal hazard to occupants and further assists the implementation of the Alternative Solution provided.
(d) the height of the building; and	The development has a rise in storeys of two. This demonstrates the limited amount of risk possessed in the building to occupant entrapment, and allows fire brigade personnel to easily access all level of the building with minimal obstructions.
(e) whether the exit is from above or below ground level.	The development has no basement level and has a rise in storeys of two, therefore it is deemed that this sub-clause shall not adversely affect the implementation of the Alternative Solution provided.

Table 8-8: Performance Requirement Assessment (EP2.2)

EP2.2	CONCLUSION
(a) In the event of a fire in a building the conditions in any evacuation route must be maintained for the period of time occupants take to evacuate the part of the building so that-	
(ii) The temperature will not endanger human life; and	The temperature is shown to remain below a tenability limit of 60°C remote from the fire plume for the duration of the CFD modelling.
(iii) The level of visibility will enable the evacuation route to be determined; and	Visibility is shown to remain above 10-metres, at a height of 2m remote from the fire plume for the period it takes occupants to evacuate in all simulated scenarios. Carbon monoxide levels are shown to remain below the tenability concentration, at a height of 2m remote from the fire plume for the duration of the CFD modelling.
(iv) The level of toxicity will not endanger human life.	The warehouse will have extended sprinkler activation times due to the high roofed areas allowing smoke dilution and dissipation.
(b) The period of time occupants take to evacuate referred to in (a) must be appropriate to:-	
(i) The number, mobility and other characteristics of the occupants; and	The number of staff within the warehouse is considerably less than that permitted within a DTS building and the calculation undertaken, thereby illustrating a high level of conservatism in the analysis. Furthermore the low occupant numbers are not anticipated to cause considerable queuing. Occupants are expected to have reasonable mobility due to the type of work being undertaken in the facility. Other characteristics of the occupants are not expected to influence their ability to egress from the building by their own volition.
(ii) The function or use of the building; and	High level staff supervision and monitoring will be provided to the building by virtue of the nature and use.
(iii) The travel distances and other characteristics of the building; and	Distances of travel to exits and between exits are increased within the warehouse. However despite the increased travel distance, occupants are able to reach an exit in acceptable enclosure conditions as demonstrated by in the assessment.
(iv) The fire load; and	The Ultra-Fast fire growth rates included in the design fires consider the most hazardous fuel load that would be expected in the warehouse.
(v) The potential fire intensity; and	The fires have been modelled to reach differing maximum peak heat release rates so as to allow for any uncertainty in the fire simulations.
(vi) The fire hazard; and	The use of CFD modelling ascertains the likely hazards associated with a fire occurring in the building and determining relevant acceptance criteria for occupants and fire fighters. The Ultra-Fast fire growth rate considers the fire hazard expected in the building.

EP2.2	CONCLUSION
(vii) any active fire safety systems installed in the building; and	The modelling demonstrates that the removal of smoke exhaust does not adversely impact on occupant evacuation. Storage mode sprinklers will act to reduce fire sizes.
(viii) fire brigade intervention	Fire brigade intervention is not expected to be hindered by the removal of smoke exhaust. The storage mode sprinkler system and smoke clearance system will aid in fire brigades intervention. Furthermore, temperature levels are well within fire fighter tenability limits outside the fire plume and enclosure of fire origin.

8.2.7 Conclusion

Within the building the following fire safety strategies are relied upon so as to permit the rationalisation of the smoke exhaust system and travel distances in excess of the BCA DTS requirements:-

- Early alarm activation from the smoke detection system.
- Increased probability of fire suppression through the installation of a storage mode sprinkler system.
- Increased likelihood of prolonged tenable conditions for occupants and fire fighters associated with the large building volume.

The Alternative Solution described herein has been assessed in accordance with A0.5(b)(i), A0.9(b)(ii) and A0.9(c) and therefore complies with the requirements of A0.8, A0.10 and Performance Requirements **DP4** and **EP2.2**.

8.3 LOCATION OF EXIT SIGNAGE

8.3.1 Regulatory assessment

In order to assess the non-compliance of the relevant BCA DTS clause(s) the following table is provided to outline the relevant regulatory requirements and assessment methods.

Table 8-9: Regulatory Assessment

REGULATORY REQUIREMENT	DESCRIPTION / DETAILS
BCA DTS provisions:	Clause E4.6 (NSW) states that if an exit is not readily apparent to persons occupying or visiting the building, then directional exit signs must be provided in accordance with AS2293.1. AS2293.1 (*Clause 6.8.1*) requires exit signs be mounted not less than 2m and not more than 2.7 above floor level.
Non-compliance with DTS provisions:	Directional exit signs are installed at 4m to allow the uninhibited passage of forklifts and other picking machinery.
Relevant Performance Requirements(s):	EP4.2
Assessment methodology:	The assessment methodology adheres to Clauses A0.5(b)(i), A0.9(b)(ii), and A0.10 of the BCA. The analysis consists of a quantitative analysis where the deterministic results of the CFD modelling demonstrate that the directional exit signage will not be obscured by the descending smoke layer prior to the completion of occupant evacuation.
Acceptance criteria:	During an evacuation occupants have clear visibility of the directional exits signs when navigating to an exit.

8.3.2 Introduction

Buildings are provided with directional way finding signage to direct occupants to an exit in the event of a fire. According to the literature reviews by the Society of Fire Protection Engineers (SFPE) into human behaviour in a fire [14], the familiarity of occupants within the building and its fire safety systems is an important factor in analysing the occupant response and use of route in evacuating a building. Based on these research studies, the frequent users of a building may have a complete knowledge of the nearest and alternative egress routes and warning systems, whereas visitors and infrequent users are more reliant upon directional signage and instructions from authority figures, i.e. staff, security, management and the like.

Directional exit signs are required where final exits are not readily apparent. They are generally installed in hallways, foyers, aisles and the like and as such AS2293.1 requires that exit signs be "*mounted not less than 2m and not more than 2.7 above floor level, or immediately above the doorway if the doorway is higher than 2.7m.*" Further to this, the standard states that a variation to these heights shall be allowed when specifically agreed upon by the relevant regulatory authority.

8.3.3 Intent of the BCA and Australian Standards

The Guide to the BCA [2] states that the requirement for the identification of exits is to, *"Provide occupants with clear and concise information on what route to take to evacuating a building in an emergency. This may require the installation of emergency signage or other suitable means to identify egress routes and exits and assist in an orderly evacuation."*

The Guide to the BCA further requires egress information to be easily obtainable, despite the reduced lighting conditions that may be expected in a fire situation, highlighting the situation whereby smoke produced by a fire creates a thick dense layer covering the high level lighting in the enclosure and reducing visibility at ground level.

AS2293.1 states that, *"The intent of Clause 6.8.1 is to ensure that each exit sign is in the field of view of a person in the applicable viewing distance and looking at the relevant door or along the relevant exit path."* This is to provide occupants sufficient time to travel the required distance while making informed decisions on the route that must be taken to arrive at a safe place outside the building.

8.3.4 Warehouse floor layout and enclosure volume

The central warehouse layout provides for long racking rows running in the east west direction as illustrated in Figure 8-4. As such the directional exit signs at the end of the racking aisles sit above the picking machineries access path these signs are located 4m above FFL.

Figure 8-4: Warehouse floor layout & non-compliant exit sign locations

As illustrated, there are four (4) exits located along the eastern wall with and additional exits through the warehouse office. These have compliant exit signs above the final exit doors which can be relied upon in an evacuation to provide guidance to unfamiliar occupants.

Occupants in the racking aisles have a choice of two directions, both of which lead to an exit. Once exiting the racking aisles occupants are provided with a clear line of sight to the final exit signs located above the exit doors as well as the doors themselves. Therefore occupants should be able to locate an exit at all times.

8.3.5 Building occupant characteristics

Occupants within the building are expected to be primarily staff members that are present in the building on a daily basis. Staff will be working throughout the warehouse providing them with a high level familiarity of the warehouse layout and egress provisions available. Therefore it is assumed that their reliance upon directional signage in the event of an evacuation would be limited.

Visitors and contractors are not expected to have this level of familiarity, however they will be in low numbers in proportion to staff numbers. Due to the building safety requirements, and security reasons, visitors are expected to be in the direct company of employees whenever present in the warehouse. Therefore although visitors may not have a similar level of familiarity as staff, they would be aware of the path by which they entered the building and are expected to be directed by staff in the event of an evacuation; thereby also limiting their reliance upon the directional exit signage.

8.3.6 Fire Engineering Analysis

The BCA and Australian Standards are designed to be suitable for a large range of building stock in an ever changing built environment. This requires assumptions to be made, and to knowingly omit rare situations for a common band of provisions that apply to a majority of circumstances.

One of these such provisions is AS2293.1 Clause 6.8.1 which requires exits signs to be located between 2.0 and 2.7 meters above floor level, as most buildings are provided with ceiling heights between 3 and 4 meters the provisions ensures that the egress signage is not located at such a height that it is quickly engulfed in the hot smoke layer created by a fire.

The warehouse has a ridge height of approximately 13m; clearly demonstrating the conservatism of the AS2293.1 requirement, as the warehouse is provided with a ceiling height up to 10m higher than common buildings and the extent of the non-compliance is no more than 2m.

The motive behind the upper limit of 2.7m is due to two reasons:-

- Occupants should not be expected to look over the entire room for a sign that will assist them in determining the route to an exit. A sign located in a central position and slightly above 2m is deemed to be in the focal area of occupants traversing down a corridor, hallway or the like; and
- The codes assume an exit sign located above 2.7m will have an increased probability of being consumed by the hot smoke layer during fire obscuring visibility of the sign. This situation is illustrated in Figure 8-5.

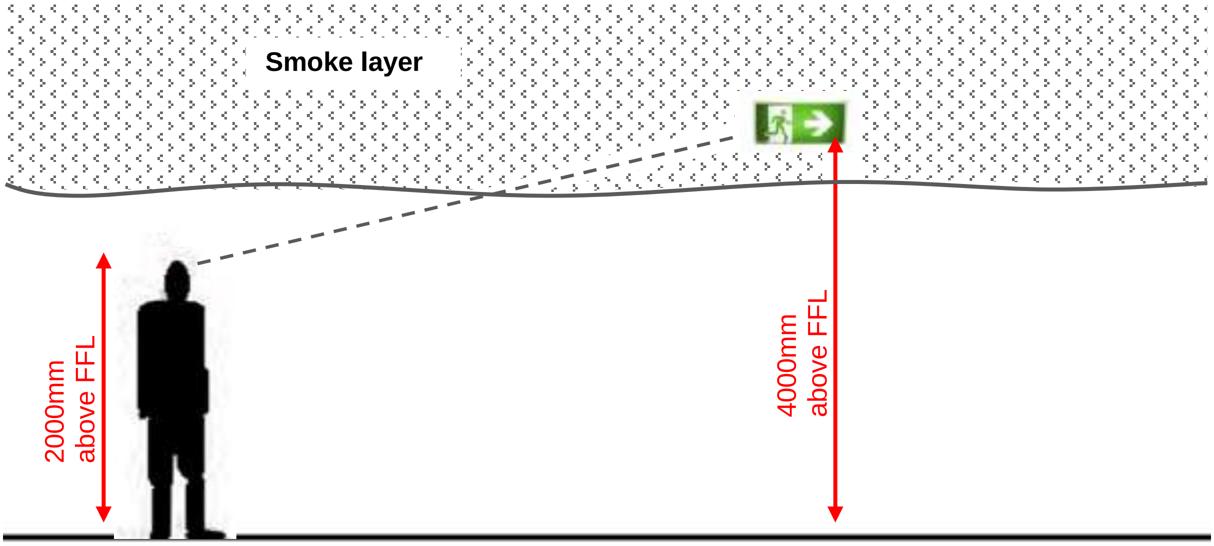


Figure 8-5: Possible scenario whereby the exit signage is obscured by the hot smoke layer

Field of view

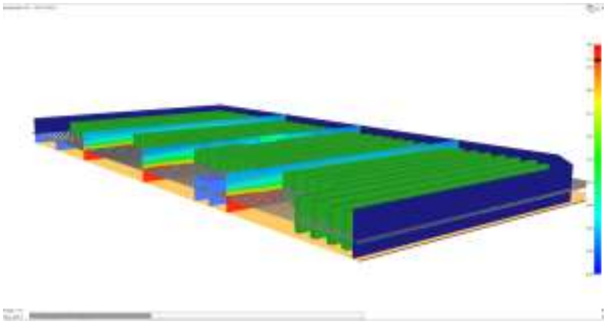
The upper focal view point from the human eye is approximately 60° from the horizontal. Therefore, for a sign located 4m above FFL (approx. 2m above the average human eye) an occupant must be located less than 1m away from the sign for it to be out of the field of view.

Once occupants are located within 1m of the non-conformant signs, they are approximately 20m from the bounding wall where further directional and final exit signs are located therefore occupants will always be in sight of an exit or directional sign.

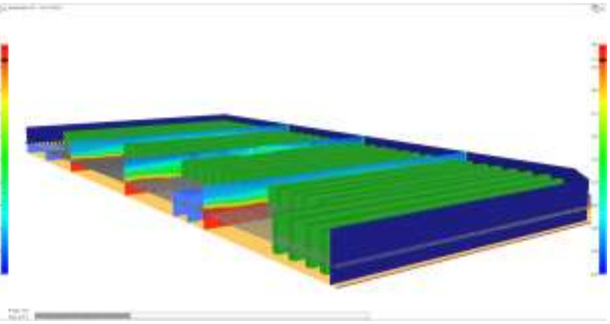
Obscuration due to smoke assessment

The final exits are located up to 56m apart along the eastern side of the warehouse. Assessing a minimum amount of directional signs, i.e. one adjacent each exit, an occupant standing at the end of the racking aisle would have a line of sight no more than 28m to a directional sign.

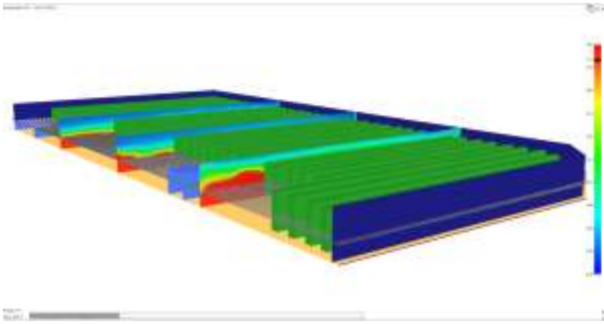
Using the fire modeling completed in Section 8.1, the following images demonstrate the point in time where visibility is reduced to less than 28m at a height of 4m above floor level. This is a conservative assumption as occupant will be looking through improved conditions and not along the horizontal plane at 4m as depicted in the slice files used in the assessment.



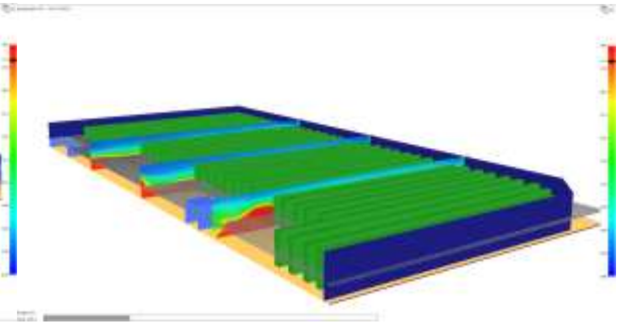
Fire Scenario 1A: 655 seconds



Fire Scenario 1B: 515 seconds



Fire Scenario 2A: 485 seconds



Fire Scenario 2B: 465 seconds

Figure 8-6: Illustrating 28m visibility at a height of 4m above FFL

Table 8-10 provides a comparative assessment of the time to obscuration of the directional signs and the time required for occupant evacuation. The results demonstrate that occupants evacuating from the racking aisles have adequate time to not only pass under the directional signs but evacuate entirely from the building prior to the signs being compromised by smoke.

Table 8-10: Comparative analysis of RSET and Obscuration

Time	Fire/Evacuation Scenarios					
	1A WC	1A RED	1B WC	2A WC	2A RED	2B WC
28m Visibility at 4m above FFL	655-sec	655-sec	515-sec	485-sec	485-sec	465-sec
Occupant evacuation completed	308-sec	453-sec	308-sec	308-sec	453-sec	308-sec
Compliant	✓	✓	✓	✓	✓	✓

8.3.7 Performance Requirement Assessment

The following table provides assessment of each relevant BCA Performance requirement thereby achieving compliance with the BCA.

Table 8-11: Performance Requirement EP4.2 Assessment

EP4.2	CONCLUSION
To facilitate evacuation, suitable signs or other means of identification must, to the degree necessary:-	
(a) Be provided to identify the location of exits; and	The assessment has demonstrated that the building is provided with sufficient directional and final exit signage to provide occupants with adequate information to determine the path of egress to the location of an exit.
(b) Guide occupants to an exit; and	Signs are provided in accordance with AS2293.1 with the exception of the installation height.
(c) Be clearly visible to occupants; and	The assessment concludes that the exit sign heights are appropriate to the enclosure dimensions and human field of view. The smoke layer is shown to have adequate visibility for the duration of occupant evacuation.
(d) Operate in the event of a power failure of the main lighting system for sufficient time for occupants to safely evacuate.	The exit signs provided shall be illuminated signs with a battery back-up as per the requirements of AS2293.1.

8.3.8Conclusion

Within the building the following fire safety strategies are relied upon so as to permit the location of the directional exit signs:-

- A high ceiling height and increased enclosure volume *(acting as a smoke reservoir, thereby extending the time between ignition and obscuration of the exit signs by the hot smoke layer)*; and
- The building population's high level of familiarity of the building layout and available egress provisions *(this will facilitate in a quick and efficient egress from the building that would be expected to have a low reliance upon directional and exit location signage)*.

The Alternative Solution described herein has been assessed in accordance with A0.9(b)(i) and A0.9(b)(ii), and therefore complies with the requirements of A0.5, A0.10 and the Performance Requirement **EP1.3** in offering a solution that complies with the relevant Performance Requirements.

9 FIRE ENGINEERING REQUIREMENTS

Fire Engineering Requirements

The following are the design requirements, to be undertaken by others, to achieve the nominated fire safety objectives of this report.

All other items not specifically addressed are to be in accordance with DTS provisions of the BCA or as accepted by the relevant authorities. Any change in this information to suit future building works or re-organisation will require further analysis to confirm compliance with the regulations and this Fire Engineering Report.

Table 9-1: Fire Engineering Requirements

FIRE ENGINEERING REQUIREMENT	DETAILS	STANDARD OF COMPLIANCE
Fire Resistance		
Type of construction	The development shall be built in accordance with the prescriptive requirements of the BCA for Type C construction.	BCA Spec C1.1 (Table 5)
Access and Egress		
Perimeter vehicular access	A compliant vehicular access path shall be provided around the building in all-weather surface capable of supporting all FRNSW appliances (maximum weight of 27,500kgs) in accordance with '*Guidelines for emergency vehicle access*', available from www.fire.nsw.gov.au. To ensure access for fire brigade vehicles around the site the boom gates at the entry and exit shall open on fire alarm. All gates or security fencing that blocks fire brigade entry must be openable with 003 keys or with a master key provided to the two nearest fire brigade stations. If the gates are motor driven they must be openable by the fire brigade (by key, swipe card or manually).	BCA clause C2.3
Exit travel distance	Travel distances to an exit, between alternate exits and to a point of choice are to comply with the following exceptions permitted within the central parts of the warehouse; ▪ Up to 73m to the nearest exit; and ▪ Up to 145m between alternative exits	BCA clause D1.4, D1.5 and Alternative Solution
Doorways and doors	Doorways serving as required exits must not be fitted with a sliding door unless it leads directly to a road or open space and is manually openable under a force of 110N. If power operated it must be manually openable under a force of 110N or open automatically upon detector activation.	BCA clause D2.19
Door swings	A swinging door in a required exit must swing in the direction of egress unless it serves a building (or part) less than 200m^2 and is the only required exit.	BCA clause D2.20
Operation of latch	Door hardware on all required exits, including main entrance doors, shall be in accordance with current regulations such that all required exits will be available for emergency egress.	BCA clause D2.21

FIRE ENGINEERING REQUIREMENT	DETAILS	STANDARD OF COMPLIANCE
Services and Equipment		
Fire Indicator Panel & Fire Fan Control Panel	The Main Fire Indicator Panel (FIP) and main smoke clearance fan controls shall be located in the entry lobby of the main office, where the fire control centre is located. ■ The panel shall include clear signalling of the operational status of the fans with override controls for the smoke clearance fans. The sprinkler and smoke detection systems are to be interfaced with the FIP. The FIP shall be connected to a direct monitoring station via alarm signalling equipment to initiate a signal to the fire brigade upon sprinkler and smoke detector activation.	AS3013:1995, AS4428.6:1997, AS/NZS 1668.1:1998 and Alternative Solution
Smoke detection	Automatic smoke detection system shall be provided throughout the warehouse parts (i.e. not required in the office parts). The detection system shall activate the building occupant warning system and direct brigade alarm upon detection of a fire. The system shall be designed in accordance with AS1670.1:2004 with detector head spacing in accordance with Clause 5 of Specification E2.2a (i.e. 20m x 20m grids).	BCA Specification E2.2a, AS1670.1:2004 *(spacing per AS/NZ1668.1: 1998)* and Alternative Solution
Sprinklers	An automatic fire sprinkler system is required to be fitted throughout the building. ■ The sprinkler system shall activate the building occupant warning system and direct brigade alarm upon detection of a fire. ■ In the offices, Eco run-up rooms and beneath the warehouse awnings the system shall comply with BCA Specification E1.5 and AS2118.1:1999. ■ In the warehouses a storage mode system shall be provided in accordance with BCA Specification E1.5, AS2118.1:1999 with head spacing, discharge pressures and flows per Factory Mutual Guidelines 2-0 and 8-9. The warehouse sprinkler system shall meet the following minimum performance requirements; ■ Sprinkler activation temperature no greater than 101°C. ■ Sprinkler response time index (RTI) of less than $50m^{1/2}s^{1/2}$ (i.e. fast response type)	BCA Specification E1.5, AS2118.1:1999, FM Global Data Sheets FM2-0 & FM8-9, and Alternative Solution.
Smoke Hazard Management	A manually operated smoke clearance system shall be installed to the warehouse areas in lieu of a DTS required automatic smoke exhaust system. The smoke clearance system shall meet the following minimum performance requirements: ■ Initiation switches shall be located on or adjacent to the main FIP. ■ Signs alerting the Fire Brigade to the operation of the smoke clearance system must be provided. ■ Fire rated fans and fire rated cabling shall be used and designed to operate at 200°C for a period of 60 minutes.	BCA Clause E2.2, Table E2.2a, AS/NZ1668.1: 1998 and Alternative Solution

FIRE ENGINEERING REQUIREMENT	DETAILS	STANDARD OF COMPLIANCE
	■ System capacity must be capable of one enclosure air change per hour. ■ It is recommended that multiple fans be provided and be evenly distributed to otherwise comply with the requirements of Specification E2.2b Clause 5 of the BCA. ■ Adequate make-up air shall be provided via permanently open or mechanically driven louvers that open upon initiation of the fans at the FIP (not on fire alarm). ○ All motors and cabling required to open the mechanical louvers must be fire rated to operate at 200°C for a period of 60 minutes. ■ If used for general ventilation, the air flow rate at any sprinkler head must be less than 1.5m/s and the system must shut down automatically upon any fire alarm, with manual override available to fire fighters.	
Occupant warning system	A building occupant warning system must be provided throughout. The alarm tone shall be initiated throughout the building upon fire detection by the smoke detection and sprinkler systems	BCA clause E1.5, E2.2 (Clause 6) and AS1670.1:2004
Fire hydrants	A fire hydrant system must be installed in accordance with the regulatory requirements. ■ Hydrant booster assembly location and design shall be fully compliant. ■ The hydrant ring main shall be fitted with isolation valves external to the building with the valves numbered and the corresponding numbers indicated on the hydrant block plan. ■ External hydrant connections shall be provided with the heat shields per the requirements of AS2419.1 (i.e. FRL 90/90/90 2m either side and 3m above the hydrant connection point) or be setback more than 10m from the building. ■ All connection points must be fitted with Storz hose couplings which comply with Clause 7.1 and 8.5.11 of AS2419.1:2005. Further information is available from the FRNSW Guide Sheet No.4 '*Hydrant system connectors*' available at www.fire.nsw.gov.au. ■ Clear block plans (not less than A3 in size) shall be provided at the booster assembly. Further at the entries to the warehouse where an internal hydrant is to be located, a basic block plan is to be placed adjacent to the nearest exit door indicating the location of the internal and intermediate hydrants. ■ As far as possible external hydrants shall be provided to achieve coverage of the building, where not possible additional fall-back hydrant(s) shall be provided.	BCA clause E1.3, AS2419.1:2005
Fire hose reels	Fire hose reels must be provided throughout all areas in accordance with the prescriptive provisions of the regulatory requirements.	BCA clause E1.4 and AS2441:2005

FIRE ENGINEERING REQUIREMENT	DETAILS	STANDARD OF COMPLIANCE
Fire extinguishers	Portable fire extinguishers must be provided throughout all areas with their location and selection relevant to the risk class in accordance with the relevant regulatory requirements.	BCA clause E1.6 and AS2444:2001
Emergency lighting	Emergency lighting must be installed throughout all areas in accordance with the relevant regulatory requirements.	BCA clause E4.2, E4.4 and AS2293.1:2005
Exit signs	Exit signs and direction signs to exits must be provided throughout all areas in accordance with the relevant regulatory requirements with the following exceptions. ▪ Directional exit signs located on the eastern end of the racking aisles may be installed up to 4m above floor level.	BCA clause E4.5,E4.6,E4.8, AS2293.1:2005
Fire Brigade intervention		
Notification	An automatic link shall be provided directly to an approved monitoring centre on activation of the smoke detection and sprinkler systems.	Specification E2.2a Clause 7 & Clause 3.2 of AS2118.1:1999 and AS1670.3:2004
Block plans	Block plans shall be provided for use by the fire brigade adjacent to the any Fire Indicator Panel, hydrant booster assembly and at the entry/exit doors accessing internal hydrant points.	AS1670.1:2004 AS2419.1:2005 and Alternative Solution
Building Management Requirements		
Smoking policy	No smoking policy throughout all public areas of the building.	Note
Fuel load control	Keep unnecessary combustible loads to a minimum in public areas via regular housekeeping, including the removal of random storage and accumulated debris.	Note
Renovation or new works	The recommended fire safety systems must be replaced with equivalent systems in all future works and the recommended fire safety systems must be applied to any renovations or new works.	Note
Inspection, testing and maintenance	Periodic inspection, testing and maintenance of all fire safety systems, fire hydrants, fire hose reels (where provided), emergency lighting, exit signage, doors, fire resistance, portable fire extinguishers, etc. should be implemented. ▪ As there is no set testing specification for the manual smoke clearance system, this system shall be tested in accordance with the regime in AS1851 for automatic smoke exhaust where applicable.	AS1851:2005 and Alternative Solution
Operation	Under all circumstances it is important to keep as much of the system fully operational as is practical. Should any building works extend over a number of days, the system must be re-instated as far as practical at the end of each day.	Note

FIRE ENGINEERING REQUIREMENT	DETAILS	STANDARD OF COMPLIANCE
During construction	Scaffolding, wire fencing, barricades and the like must not prevent fire brigade access for vehicles or personnel to essential fire safety components (hydrants, boosters, FIP, etc.) or prevent fire brigade personnel from intervening in the event of a fire.	BCA clause E1.9
Annual fire safety certificate	The Alternative Solutions assessed herein shall be listed on the building's annual fire safety certificate such that the systems are inspected and tested annually and fire brigade are provided with accurate information to undertake fire intervention activities.	Alternative Solution

10 REFERENCES

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APPENDIX A ACCEPTANCE REQUIREMENTS

Occupant Life Safety Criteria

The tenability criteria for occupant life safety is based on the SFPE Handbook of Fire Protection Engineering and CIBSE Guide E – Fire Safety Engineering [17], which requires temperature, visibility and toxicity conditions to be maintained so that they do not endanger human life, by satisfying either one of the following criteria:

Criteria 1 – Smoke layer above 2.1 m

The limiting condition for tenable condition with radiant heat from a hot layer or other fire condition is 2.5 kW/m^2. This radiant heat level generally occurs when temperatures are approximately 200°C in small enclosures with relatively low ceiling heights. Therefore, the acceptance criteria are when the smoke layer height is greater than 2.1 m and the smoke temperature is less than 200°C.

Criteria 2 – Smoke layer below 2.1 m

Untenable conditions are considered to occur if the smoke layer drops below 2.1 m and any of the following temperature, visibility and toxicity limits are exceeded:

- Smoke Temperature > 60^{O}C
- Visibility < 10 m (optical density < 0.1 m^{-1})
- CO Toxicity > 1,400 ppm

Toxicity is generally considered to be acceptable if the visibility criterion is satisfied.

Fire Brigade Life Safety Criteria

The Fire Engineering Assessment considers fire-fighter life safety where occupant tenability limits have been exceeded and intervention is required by the Fire Brigade.

Search and rescue operations require enclosure to be safe for fire fighters. According to the Fire Brigade Intervention Model V2.2 the following criteria are used to determine the tenable conditions for fire fighters relative to height of 1.5m above floor level:

Routine Condition

Elevated temperatures, but not direct thermal radiation

- Maximum Time: 25 minutes
- Maximum Air Temperature: 100^{o}C (in lower layer)
- Maximum Radiation: 1kW/m^2

Hazardous Condition

Where firefighters would be expected to operate for a short period of time in high temperatures in combination with direct thermal radiation

- Maximum Time: 10 minutes
- Maximum Air Temperature: 120^{o}C (in lower layer)
- Maximum Radiation: 3kW/m^2

Extreme Condition

These conditions would be encountered in a snatch rescue situation or a retreat from a flashover

- Maximum Time: 1 minutes
- Maximum Air Temperature: 160^{o}C (in lower layer)
- Maximum Air Temperature: 280^{o}C (in upper layer)
- Maximum Radiation: 4-4.5kW/m^2

Critical Conditions

These conditions have not been considered as the FBIM states that firefighters would noted be expected to operate in such conditions.

Routine conditions for 25 minutes	Hazardous conditions for 10 minutes.	Extreme conditions for less than 1 minute.

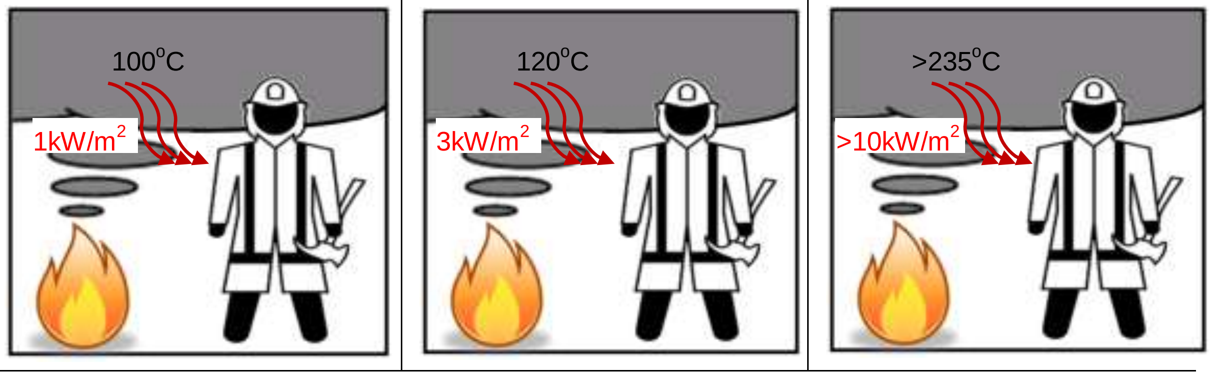


Figure 10-1: Fire brigade acceptance for brigade intervention

APPENDIX B ALPERTS CORRELATIONS

Alarm Time

Alpert correlation calculations are used to determine the activation time of the smoke detectors [19]. The basic response equation for a heat sensing device (whether heat detector or sprinkler head) is given by the lumped mass heat transfer equation as follows:

Detector temperature:

$$\frac{dT_d}{dt} = \frac{\sqrt{u} \times (T_g - T_d)}{RTI} \qquad \text{Eqn. 1}$$

where;

T_d	=	detector temperature	(^{O}C)
u	=	velocity of gases surround the detector	(m/s)
T_g	=	temperature of gases surround the detector	(^{O}C)
RTI	=	Response Time Index of the detector	(m$^{1/2}$s$^{1/2}$)
t	=	time	(s)

The first step in calculating the time to detector activation is to establish which of Alpert's correlation's for gas temperature are to be used. To undertake this, the user divides the distance of the detector from the fire over the height of the ceiling above the fire. In the question prescribed, the relevant equation required is determined as follows:

$$\frac{r}{H} = \frac{2.5}{13.7} = 0.182 \; i.e > 0.18$$

Therefore, Equation 3 is to be utilised in this instance.

To determine the response time of a detector the temperature and gas velocity at the detector are determined as follows:

Gas temperature across the detector:

$$T - T_\infty = \frac{16.9 \times \dot{Q}^{2/3}}{H^{5/3}} \quad \text{for } \frac{r}{H} \le 0.18 \qquad \text{Eqn. 2}$$

$$T - T_\infty = \frac{5.38 \times (\dot{Q}/r)^{2/3}}{H} \quad \text{for } \frac{r}{H} \ge 0.18 \qquad \text{Eqn. 3}$$

Gas velocity across the detector:

$$u = 0.96\left(\frac{\dot{Q}}{H}\right)^{1/3} \quad \text{for } \frac{r}{H} \leq 0.15 \qquad \text{Eqn. 4}$$

$$u = \frac{0.196 \times \dot{Q}^{1/3}\sqrt{H}}{r^{5/6}} \quad \text{for } \frac{r}{H} \geq 0.15 \qquad \text{Eqn. 5}$$

where;

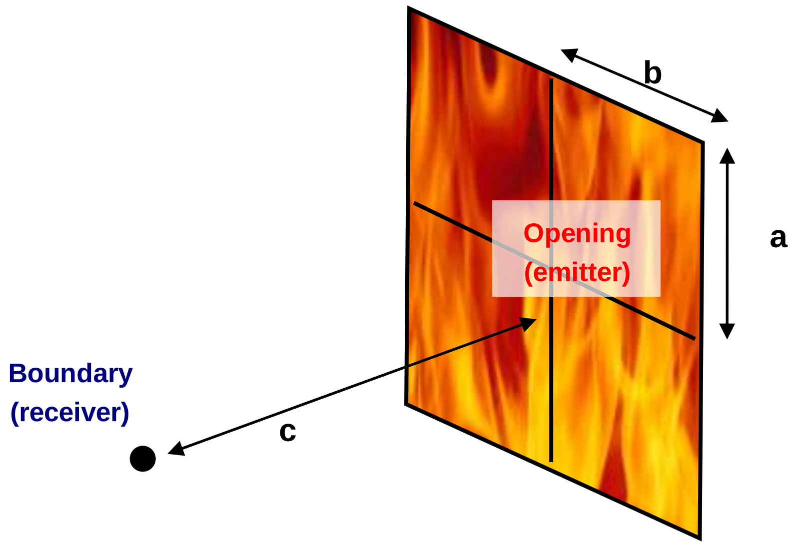
T	=	The gas temperature	(^{O}C)
T∞	=	The ambient temperature of the room	(^{O}C)
$\dot{Q}$	=	The heat release rate	(kW)
r	=	The distance of the detector from the fire	(m)
H	=	The height of the ceiling above the fire	(m)
u	=	The gas velocity	(m/s)

The detector temperature is proportionate to the temperature differential of the detector, the gas velocity across the detector and the Response Time Index of the detector. Hence the detector temperature is calculated as per equation 1. In order to calculate the temperature of the detector the user must integrate the detector temperature over time, i.e. calculate the rate of change of detector temperature.

APPENDIX C RADIANT HEAT CALCULATIONS

To calculate the heat transfer to the building property line across the right of way, we must first consider the 'configuration factor', $F_{d1\text{-}2}$. This value accounts for the size of the emitter, the distance between the receiving target and the emitter, and the angle of the emitter with regards to the target. To obtain the 'configuration factor' we can use Table 1-4.1 of the SFPE Handbook of Fire Protection Engineering 2nd Edition.

The standardised radiant heat transfer calculations are based on radiant heat transfer from a corner of a rectangle to a dimensionless target. In calculating the 'configuration factor', we consider only one quadrant of the opening. As such, the height and length of the emitter must be halved. As only a quadrant of the emitter is utilised in calculating the 'configuration factor' it is multiplied by a factor of four.



Configuration factor

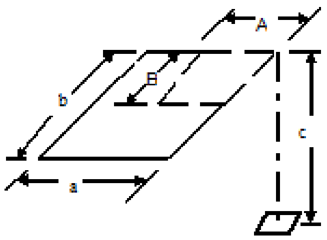
The radiation emitted by a body is related through the Stefan-Boltzmann equation to the temperature of the emitting element. When calculating flame radiation it is normally assumed that the flame radiates as a surface with an emissivity of 1 (i.e. a blackbody). This is accurate when the flame is thick enough to provide a continuous wall of luminous radiating carbon particles.

Radiant heat transfer is then determined using the following formula for radiative heat transfer:

$q_{rad} = \sigma \times \varepsilon \times F_{d1-2} \times \left(T_2^4 - T_1^4\right)$	q_{rad}	=	Radiation heat transfer
	σ	=	Stefan – Boltzman constant
	ε	=	Emissivity factor
	F_{d1-2}	=	Configuration factor
	T_2	=	Temperature of emitter (K)
	T_1	=	Temperature of receiver (K)

- Conservatively the emissivity of the radiating hot smoke layer has been assumed to be 100%.
- The distance between occupants (the receiving surface) and the hot smoke layer is 0.001m (i.e. approaching direct contact).
- The hot smoke layer temperature of 60°C.
- The entire floor area of the warehouse has been considered as a radiant panel.
  - Approximately 19,520m^2 with a length of 205m and breadth of 96m.

		Input		
a	*Height of opening*	48.000	m	
b	*Length of opening*	102.500	m	
c	*Distance b/w opening and surface*	0.001	m	
A	*Height of non-opening*	0.000	m	
B	*Length of non-opening*	0.000	m	
	Number of quadrants	4		
ε_r	*Emissivity of the Surface*	1.00		
T_B	*Temperature of Radiator*	333	K	60 ºC
T_S	*Temperature of receiving surface*	293	K	20 ºC
σ	*Stefan Boltzman Constant*	5.67E-11	kW/m²K	
k_1	*Reduction factor for glass*	1.0		



$$X_1 = a/c,\ X_2 = A/c,\ Y_1 = b/c,\ Y_2 = B/c,\ F_{1-2} = F_{a\times b} - F_{A\times B}$$

$$F_{a\times b} = \frac{1}{2\pi}\left[\frac{X_1}{\sqrt{1+X_1^2}}\tan^{-1}\left(\frac{Y_1}{\sqrt{1+X_1^2}}\right) + \frac{Y_1}{\sqrt{1+Y_1^2}}\tan^{-1}\left(\frac{X_1}{\sqrt{1+Y_1^2}}\right)\right]$$

$$F_{A\times B} = \frac{1}{2\pi}\left[\frac{X_2}{\sqrt{1+X_2^2}}\tan^{-1}\left(\frac{Y_2}{\sqrt{1+X_2^2}}\right) + \frac{Y_2}{\sqrt{1+Y_2^2}}\tan^{-1}\left(\frac{X_2}{\sqrt{1+Y_2^2}}\right)\right]$$

X_1 = a / c	48000.000	X_2 = A / c	0.000
Y_1 = b / c	102500.000	Y_2 = B / c	0.000
$\sqrt{(1 + X_1^2)}$ =	48000.000	$\sqrt{(1 + X_2^2)}$ =	1.000
$\sqrt{(1 + Y_1^2)}$ =	102500.000	$\sqrt{(1 + Y_2^2)}$ =	1.000
$F_{a \times b}$ =	0.2500	$F_{A \times B}$ =	0.000
F_{1-2} =	0.2500	Quadrant adjustment:	1.000

Output

$q_r = k_1 \times F_{d1-2} \times \varepsilon_r \times \sigma \times (T_B^4 - T_S^4)$	**0.28**	**kW/m²**

Tenability Criteria	Allowable Heat Flux	Complies
Occupant tenability smoke layer above 2.1m	2.5 kW/m²	**Yes**
Occupant tenability smoke layer at/below 2.1m	1.5 kW/m²	**Yes**
Fire Brigade tenability	3 kW/m²	**Yes**

Fire Brigade Intervention Model (2004)
CIBSE Guide E - Fire Safety Engineering (Edition 3, 2010)

APPENDIX D EVACUATION CALCUALTION

To establish the RSET, **Equation 1** is used. In the first instance evacuation will be modelled using hydraulic flow calculations based on first principles. The egress analysis evaluates the time necessary to initiate occupant response to an alarm or cue of a fire and the required time for occupants to reach a safe place during evacuation. The RSET is measured from the same point in time as the initiation of ignition. The calculated RSET is the sum of times incurred during the following three stages of the evacuation process:

- ***Alarm time*** – Time taken from ignition to the receipt of a cue by the occupants regarding the awareness of a fire. In open plan areas occupants can also receive a cue upon development of a visible smoke layer under the ceiling.
- ***Response (pre-movement) time*** – Time which extends from the alarm or cue to the time when occupants decide to evacuate. The degree of training and familiarity with the surroundings, as well as the general nature of the population, has an impact on the response time, together with the type of cue received. This period covers the time for occupants to assimilate the cue, resolve any ambiguity, undertake pre-evacuation actions and commence evacuation.
- ***Egress time*** – Occupant evacuation time, which can be calculated on the basis of human walking speeds affected by crowding and occupant mobility.

The abovementioned elements are expressed through the following equation:

$$t_t = t_a + t_p + t_m \text{ (s)} \qquad \textbf{[Eqn. 1]}$$

Where: t_t = total egress time (s)

t_a = alarm time (s)

t_p = pre-movement time (s)

t_m = movement time (s)

Assumptions

- Occupants are awake and generally familiar with the areas of the building which they commonly access and use.
- Occupant density is likely to be very low to low and the complexity of the building is relatively simple.
- Occupant flows are treated like fluid flow.
- All occupants start egress at the same time, regardless of their location to the fire base.
- The population is expected to use all exits evenly.
- Exits which do not conform to the DTS requirements, such as roller shutters and the like are not included in egress calculations despite their ability (and likelihood) to be used to exit from the building in emergency.

Pre-Movement Time

Pre-movement time typically applies only to areas remote from the room of fire origin where they may receive only a single cue to the presence of a fire and where those cues do not present an immediate threat to their health and safety. An example is where an occupant remote from the fire origin may smell smoke however would be unsure of its origin and may take investigative action or rationalise that it is ‘normal’, e.g. someone burning off outside.

In assessing the likely response of the occupants, the issue of pre-movement time must be addressed. In the case of occupants who are awake and in the vicinity of the fire, the decision to evacuate is likely to be a function of the perceived threat associated with the fire. If the fire is not perceived as threatening, then the occupants may decide not to evacuate. However, if the opposite is true, evacuation will begin almost at once. It is assumed that most of the occupants will associate flaming fires and black smoke with a threatening situation. Thus, in undertaking calculations of evacuation, this can be assumed to commence once a threat is perceived.

In the situation where the occupants are intimate with the development of the fire (area of fire origin), it is reasonable to suggest that occupant avoidance will be immediate, as they will be presented with multiple fire cues and would include:

- Visual - smoke and flames
- Tactile - heat radiated and convected from fire
- Audible - sound generated by burning materials
- Olfactory - smell of smoke and other combustion products

The pre-movement time depends primarily upon the design behavioural scenario category and the fire safety management level, with some effect of building complexity. Although, it is possible to make an adequate estimation of evacuation times for most situations by considering two main criteria, the pre-movement times of the first few occupants in an enclosure to move (pre-movement time of the 1st percentile of occupants) and the pre-movement times of the last few occupants to move (99th percentile of occupants). However, data on pre-movement time distributions for different behavioural scenarios are currently limited. Some measured distributions exist with suggested default values for pre-movement time 1st and 99th percentiles for different design behavioural scenarios.

According to the British Standards PD 7974-6:2004 [12], the quantification of pre-movement time is highly influenced by aspects of occupant behaviour. The British Standards provide a method to draw general estimates of pre-movement times via the identification of design behavioural scenarios.

Based on Table 1 of the PD 7974-6:2004, the behavioural scenario applicable to the proposed development is provided in Table 10-1. Due to the nature of the occupancy, persons within the building are expected to be awake and relatively familiar with the area.

Table 10-1 – Design behavioural scenario based on PD 7974-6:2004

Areas of the development	Category	Occupant alertness	Occupant familiarity	Occupant density	Enclosures/complexity
Warehouse	**A**	Awake	Familiar	Low	One or few

The following variables have been identified in accordance with Clause 5.2 of PD 1974-6:2004 which are necessary in determining the pre-movement time:

- Level A1 alarm system: The building has a smoke detection and sprinkler system connected to a building occupant warning system; and
- Building Level B2: A simple multi-enclosure building; and
- Management Level M2: A well designed building with obvious and easy to use escape routes, with automatic detection and alarm system.

Based on Table C.1 of the PD 7974-6:2004 coupled with the identified design behavioural scenarios and variables, the adopted pre-movement times for the evacuation modelling are provided in Table 10-2.

Table 10-2 – Adopted pre-movement time based on Table C.1 of PD 7974-6:2004

Areas of the development	Scenario category	Pre-movement time
Warehouse	A: Managed occupancy M2 B2 A1 – A2	3 minutes or 180 seconds

Travel Time

Population

It is considered that the entire warehouse and office population are spread evenly throughout the warehouse floor area. The occupant numbers used for the calculations are based on the densities listed in BCA Table D1.13 as calculated in Table 4-1.

- Warehouse: 650 occupants
- Main office: 50 occupants
- Dock office: 15 occupants

Travel distance

Although only a portion of the occupants would actually have to travel the extended distances to an exit the calculations allow for all occupants to travel the maximum travel distance (73m).

Further a redundancy scenario has been included and assumes that 50% of the available exits doors are compromised by fire, smoke or otherwise unavailable for egress. This will result in occupants travelling the maximum distance to an exit (73m) then travel to an alternative exit (145m).

The following summarises the parameters used in the RSET calculations:-

Worst Credible Scenario (EV-WC)

- The population (715 occupants) use all exits equally
- All occupants must traverse the non-compliant travel distance (73m) to reach a final exit
- All exits are available; 13 single leaf exit doors leading directly to outside (13m total egress width)

Warehouse Redundancy Scenario (EV-RED)

- The population (715 occupants) use all the available exits equally
- 50% of the aggregate exit width is compromised (i.e. 6m egress available)
- All occupants must traverse up to 218m to reach an available exit.

TRAVEL TIME CALCULATIONS				
Harold Nelson & Frederick Mowrer, "SFPE Handbook – Emergency Movement", Chapter 3-14, 3rd Edition, 2002				
Inputs				
No. of Occupants	715	people		
Occupant Horizontal Travel Speed	1	m/sec		
Travel Distance to Stair/Exit Door	73			
Stair/exit Door Width	13	m		
Less Boundary Layer	3.9	m		
Calculations				
Travel time to exit door				
Calculated travel time	**73**	**sec**	**or**	**1.216667 minutes**
Flow capacity through door				
Effective width of door	**9.1**	**m**		
Maximum Specific Flow (Fs)	**1.3**	**persons/sec/m of effective width**		
Doorway Specific Flow (Fs)	**1.3**	**persons/sec/m of effective width**		
Doorway Calculated Flow (Fc)	**11.83**	**persons/sec**		
or	**709.8**	**persons/minutes**		
Outputs				
Travel time to exit door	**73**	**sec**		Critical time is the travel to an exit: 73 seconds
Travel time through exit door	**60**	**sec**		

Figure 10-2: Travel time calculations evacuation scenario EV-WC

TRAVEL TIME CALCULATIONS				
Harold Nelson & Frederick Mowrer, "SFPE Handbook – Emergency Movement", Chapter 3-14, 3rd Edition, 2002				
Inputs				
No. of Occupants	715	people		
Occupant Horizontal Travel Speed	1	m/sec		
Travel Distance to Stair/Exit Door	218			
Stair/exit Door Width	6	m		
Less Boundary Layer	1.8	m		
Calculations				
Travel time to exit door				
Calculated travel time	218	sec	or	3.633333 minutes
Flow capacity through door				
Effective width of door	4.2	m		
Maximum Specific Flow (Fs)	1.3	persons/sec/m of effective width		
Doorway Specific Flow (Fs)	1.3	persons/sec/m of effective width		
Doorway Calculated Flow (Fc)	5.46	persons/sec		
or	327.6	persons/minutes		
Outputs				
Travel time to exit door	218	sec		
Travel time through exit door	131	sec		

Critical time is the travel to an exit: 218 seconds

Figure 10-3: Travel time calculations evacuation scenario EV-RED

In all cases the time taken to travel to the exits is far greater than the time required to travel through the doors and considering the travel speed, and time queuing at exits due to congestion are mutually exclusive events (i.e. the congestion time is taken to include all occupants arriving at the exit at the same point in time). Therefore the total physical travel time is calculated by selecting the greater time period between the congestion time and the travel time to the exit.

APPENDIX E FIRE DYNAMICS SIMULATOR LIMITATIONS AND VERIFICATION

Fire dynamics simulator

Fire Dynamics Simulator (FDS) is a Computational Fluid Dynamics (CFD) model of fire-driven fluid flow that solves the governing equations of fluid dynamics with a particular emphasis on fire and smoke transport. The model solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally driven flow with an emphasis on smoke and heat transport from fires. The partial derivatives of the conservation equations of mass, momentum and energy are approximated as finite differences, and the solution is updated in time on a three-dimensional, rectilinear grid. Thermal radiation is computed using a finite volume technique on the same grid as the flow solver. Lagrangian particles are used to simulate smoke movement and sprinkler sprays.

FDS is documented by two publications, the Technical Reference Guide [29] and the FDS User's Guide [30]. The FDS User's Guide describes how to use the model and the Technical Reference Guide describes the underlying physical principles, provides a comparison with some experimental data and discusses the limitations of this model.

Smokeview is a companion program that produces images and animations of the FDS calculations. Smokeview is documented in the Smokeview User's Guide [31].

FDS and Smokeview have been developed and are currently maintained by the Fire Research Division in the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST). NIST has developed a public website to distribute FDS and Smokeview and support users of the programs. The website (http://fire.nist.gov/fds/) also includes documents that describe various parts of the model in detail.

Model Limitations and Assumptions

It is used for low speed flow with an emphasis on smoke and heat transport from fires and is not valid for modelling blasts or explosions. The use of rectilinear geometry although suitable for most buildings may require simplification. Sawtooth function can be used to lessen the effect of this simplification or the use of finer grids.

Prescribed heat release rate provides flow velocities and temperatures within 5 to 20% of experimental results. However, where heat release rate is predicted this uncertainty of the model is higher. This is due to the material properties being not fully known, physical process of combustion, radiation and solid phase heat transfer are more complicated than their mathematical representation in FDS and the results of the calculations are sensitive to numerical and physical parameters. It should be noted that the heat release rate in this analysis were prescribed and not predicted.

FDS uses a mixture fraction model for combustion where the reaction of fuel and oxygen is infinitely fast and is representative of a large scale well ventilated fire. For under-ventilated fires where fuel and oxygen may mix but not burn are complex phenomenon and not within the capability of the current model. There is no Reynolds-Averaged Navier-Stokes (RANS) capability in the current version of FDS Input Data Files.

As the FDS model requires high computing power a number of assumptions and simplifications have been made to the model as noted below:

- Multiple meshes have been used to represent the model in FDS where the cell quantity limits permit.
- Uniform grids with grid sizes smallest to largest from the mesh with fire plume to remote areas.
- The meshes abut each other such that there is one single computation domain for the FDS analysis.
- The burner size used was 4m x 4m for the worst credible and 4m x 4m for the Sensitivity scenarios. These burner sizes are based on the studies by Chitty [] that states that the heat release rate per unit area should be between 250-2000kW/m^2, and as such an approximate rate of 1000kW/m^2 is maintained for all modelling burner sizes.
- The heat release rate was prescribed and not predicted by the model.
- Reaction type – polyurethane with soot yield of 0.1. The fuel involved in the fire has been conservatively modelled as pure polyurethane with regards to production of smoke products.

APPENDIX F FIRE DYNAMICS SIMULATOR INPUTS

DF1 – WORST CREDIBLE

```
&HEAD CHID='31A_OAKDALE_1a', TITLE='31a Oakdale, Rack worst credible'/

&TIME T_END=0.0/
&DUMP DT_RESTART=25.0, NFRAMES=360,/

&MESH ID='Mesh A', IJK=212,114,15,   XB=-2,210,
        -2,112,    0,15, / 362k

 MESH ID='MESH 1', IJK=24,39,14,     XB=0,24, 73,112,
        0,15 / 1.0M  (13.1)
 MESH ID='MESH 2', IJK=80,78,28,     XB=24,64,
        73,112,    0,15 / 0.5M  (175)
 MESH ID='MESH 3', IJK=225,39,14,    XB=64,289,
        73,112,    0,15 / 1.0M  (123)
 MESH ID='MESH 4', IJK=289,73,14,    XB=0,289,
        0,73,      0,15 / 1.0M  (296)

&VENT XB=-2,210, -2,-2,              0,15,
        SURF_ID='OPEN'/
&VENT XB=-2,210, 112,112,  0,15,
        SURF_ID='OPEN'/
&VENT XB=-2,-2,            -2,112,        0,15,
        SURF_ID='OPEN'/
&VENT XB=210,210,          -2,112,        0,15,
        SURF_ID='OPEN'/
&VENT XB=-2,210, -2,112,             15,15,
        SURF_ID='OPEN'/

/ RACKING FIRE: 8.6MW First ROW SPRINKLER ACTIVATION (ULTRA-FAST T2)
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&OBST XB=102,105,47,50,0,1.5, SURF_IDS='FIRE','INERT','INERT', RGB=255,0,0, PERMIT_HOLE=.FALSE./ 3x3m
&SURF ID='FIRE',HRRPUA=956, RAMP_Q='FIRERAMP'/
Note: Fire base should be between 250-2000KWm2 (~1000KWm2)
&HOLE XB= 97,111,42,56,0,10 /

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        /
&RAMP ID='FIRERAMP',T=   20     ,F=     0.00826
        /
&RAMP ID='FIRERAMP',T=   40     ,F=     0.03306
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        /
&RAMP ID='FIRERAMP',T=   80     ,F=     0.13223
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&RAMP ID='FIRERAMP',T=   180    ,F=     0.66942
        /
&RAMP ID='FIRERAMP',T=   200    ,F=     0.82645
        /
&RAMP ID='FIRERAMP',T=   220    ,F=     1.00000
        /
&RAMP ID='FIRERAMP',T=   1800   ,F=     1.00000
        /

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&REAC ID      = 'POLYURETHANE',
   FYI        = 'C_6.3 H_7.1 N O_2.1, NFPA Handbook, Babrauskas',
   SOOT_YIELD = 0.10,
   N        = 1.0,
   C        = 6.3,
   H        = 7.1,
   O        = 2.1,
   CO_YIELD   = 0.05,
   MASS_EXTINCTION_COEFFICIENT=8100,
   VISIBILITY_FACTOR=8/

&MISC SURF_DEFAULT='INERT', TMPA=21./ AMBIENT TEMPERATURE 21C

--------
/ SPRINKLERS (3m x 3m SPACING) 101*C
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&PART ID='Water',
   WATER=.TRUE.,
   AGE=60.00,
   SPECIFIC_HEAT=4.18,
   MELTING_TEMPERATURE=0.00,
   VAPORIZATION_TEMPERATURE=100.00,
   HEAT_OF_VAPORIZATION=2.2590000E003/

&PROP ID='sprinkler',
   QUANTITY='SPRINKLER LINK TEMPERATURE',
   ACTIVATION_TEMPERATURE=101.00,
   RTI=50.00,
   PART_ID='Water',
   DROPLET_VELOCITY=10.00/

&DEVC ID='Spr_1', PROP_ID='sprinkler',
        XYZ=102,47,13.6/
&DEVC ID='Spr_2', PROP_ID='sprinkler',
        XYZ=102,50,13.6/
&DEVC ID='Spr_3', PROP_ID='sprinkler',
        XYZ=105,47,13.6/
&DEVC ID='Spr_4', PROP_ID='sprinkler',
        XYZ=105,50,13.6/

&DEVC ID='Spr_5', PROP_ID='sprinkler',
        XYZ=99,  47,13.6/
&DEVC ID='Spr_6', PROP_ID='sprinkler',
        XYZ=99, 50,13.6/
&DEVC ID='Spr_7', PROP_ID='sprinkler',
        XYZ=102,44,13.6/
&DEVC ID='Spr_8', PROP_ID='sprinkler',
        XYZ=102,53,13.6/
&DEVC ID='Spr_9', PROP_ID='sprinkler',
        XYZ=105,44,13.6/
&DEVC ID='Spr_10',        PROP_ID='sprinkler',
        XYZ=105,53,13.6/
&DEVC ID='Spr_11',        PROP_ID='sprinkler',
        XYZ=108,47,13.6/
&DEVC ID='Spr_11',        PROP_ID='sprinkler',
        XYZ=108,50,13.6/
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```
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/ Smoke detectors
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&PROP ID='Smoke Detector', QUANTITY='spot obscuration', LENGTH=1.8, ACTIVATION_OBSCURATION=12/

&DEVC ID='SD_1', PROP_ID='Smoke Detector', XYZ=93.5,38.5, 13.6 /
&DEVC ID='SD_2', PROP_ID='Smoke Detector', XYZ=93.5,58.5, 13.6 /
&DEVC ID='SD_3', PROP_ID='Smoke Detector', XYZ=113.5,38.5,13.6 /
&DEVC ID='SD_4', PROP_ID='Smoke Detector', XYZ=113.5,58.5,13.6 /

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/ CONCRETE
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&MATL ID          = 'CONCRETE',
    FYI           = 'Quintiere, Fire Behavior',
    SPECIFIC_HEAT = 0.88,
    DENSITY       = 2100,
    CONDUCTIVITY  = 1.0 /
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&SURF ID          = 'SLAB',
    RGB           = 156,102,31,
    MATL_ID       = 'CONCRETE',
    THICKNESS     = 0.15 / TRANSPARENCY 0.95

&SURF ID          = 'WALL 1',
    RGB           = 25,25,112,
    MATL_ID       = 'CONCRETE',
    THICKNESS     = 0.15 / TRANSPARENCY 0.5

&SURF ID          = 'WALL 2',
    RGB           = 65,105,225,
    MATL_ID       = 'CONCRETE',
    THICKNESS     = 0.15 / TRANSPARENCY 0.7

&SURF ID          = 'WALL TRANS',
    RGB           = 25,25,112,
    MATL_ID       = 'CONCRETE',
    THICKNESS     = 0.15,
    TRANSPARENCY  = 0.3 /
--------
/ GLASS
--------
&MATL ID          = 'GLASS',
    CONDUCTIVITY  = 0.76,
    SPECIFIC_HEAT = 0.84,
    DENSITY       = 2700 /
--------
&SURF ID          = 'GLASS',
    MATL_ID       = 'GLASS',
    FYI           = 'Quintiere, Fire Behavior',
    THICKNESS     = 0.005,
    BACKING       = 'EXPOSED',
    TRANSPARENCY  = 0.2 /
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/ GYPSUM PLASTER (GYPROCK)
--------
&MATL ID          = 'GYPSUM PLASTER',
    FYI           = 'Quintiere, Fire Behavior',
    CONDUCTIVITY  = 0.48,
    SPECIFIC_HEAT = 0.84,
    DENSITY       = 1440 /
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&SURF ID          = 'CEILING',
    RGB           = 184,184,184,
    MATL_ID       = 'GYPSUM PLASTER',
    THICKNESS     = 0.2,
    TRANSPARENCY  = 0.3 /
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/ STEEL
--------
&MATL ID          = 'STEEL',
    FYI           = 'Quintiere, Fire Behavior',
    EMISSIVITY    = 0.95,
    DENSITY       = 7850,
    CONDUCTIVITY  = 45.8,
    SPECIFIC_HEAT = 0.46 /
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&SURF ID          = 'SHEET METAL',
    MATL_ID       = 'STEEL',
    COLOR         = 'CYAN',
    BACKING       = 'EXPOSED',
    THICKNESS     = 0.03 / TRANSPARENCY 0.3

&SURF ID          = 'STAIR',
    MATL_ID       = 'STEEL',
    COLOR         = 'BLACK',
    BACKING       = 'EXPOSED',
    THICKNESS     = 0.2 /

&SURF ID          = 'PLANT',
    MATL_ID       = 'STEEL',
    RGB           = 34,139,34,
    BACKING       = 'EXPOSED',
    THICKNESS     = 0.2 / TRANSPARENCY 1

&SURF ID          = 'RACK',
    RGB           = 34,139,34,
    MATL_ID       = 'STEEL',
    THICKNESS     = 0.15,
    TRANSPARENCY  = 0.3
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DF2– WORST CREDIBLE

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&TIME T_END=0/
&DUMP DT_RESTART=25.0, NFRAMES=360,/


&MESH ID='Mesh A', IJK=212,114,15, XB=-2,210,
        -2,112, 0,15, / 362k

&VENT XB=-2,210, -2,-2, 0,15,
        SURF_ID='OPEN'/
&VENT XB=-2,210, 112,112, 0,15,
        SURF_ID='OPEN'/
&VENT XB=-2,-2, -2,112, 0,15,
        SURF_ID='OPEN'/
&VENT XB=210,210, -2,112, 0,15,
        SURF_ID='OPEN'/
&VENT XB=-2,210, -2,112, 15,15,
        SURF_ID='OPEN'/

/ CORNER FIRE: 8.6MW FIRST ROW SPRINKLER ACTIVATION (ULTRA-FAST T2)
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&OBST XB=200,204,1,5,0,1.5, SURF_IDS='FIRE','INERT','INERT', RGB=255,0,0/ 4x4m
&SURF ID='FIRE',HRRPUA=1000, RAMP_Q='FIRERAMP'/ Note: Fire base should be between 250-2000KWm2 (~1000KWm2)
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&RAMP ID='FIRERAMP',T=   0      ,F=    0.00000 /
&RAMP ID='FIRERAMP',T=   20     ,F=    0.00826 /
&RAMP ID='FIRERAMP',T=   40     ,F=    0.03306 /
&RAMP ID='FIRERAMP',T=   60     ,F=    0.07438 /
&RAMP ID='FIRERAMP',T=   80     ,F=    0.13223 /
&RAMP ID='FIRERAMP',T=   100    ,F=    0.20661 /
&RAMP ID='FIRERAMP',T=   120    ,F=    0.29752 /
&RAMP ID='FIRERAMP',T=   140    ,F=    0.40496 /
&RAMP ID='FIRERAMP',T=   160    ,F=    0.52893 /
&RAMP ID='FIRERAMP',T=   180    ,F=    0.66942 /
&RAMP ID='FIRERAMP',T=   200    ,F=    0.82645 /
&RAMP ID='FIRERAMP',T=   220    ,F=    1.00000 /
&RAMP ID='FIRERAMP',T=   1800   ,F=    1.00000 /


--------
&REAC ID      = 'POLYURETHANE',
    FYI       = 'C_6.3 H_7.1 N O_2.1, NFPA Handbook, Babrauskas',
    SOOT_YIELD = 0.10,
    N      = 1.0,
    C      = 6.3,
    H      = 7.1,
    O      = 2.1,
    CO_YIELD  = 0.05,
    MASS_EXTINCTION_COEFFICIENT=8100,
    VISIBILITY_FACTOR=8/

&MISC SURF_DEFAULT='INERT', TMPA=21./ AMBIENT TEMPERATURE 21C

--------
/ SPRINKLERS (3m x 3m SPACING) 101*C
--------
&PART ID='Water',
    WATER=.TRUE.,
    AGE=60.00,
    SPECIFIC_HEAT=4.18,
    MELTING_TEMPERATURE=0.00,
    VAPORIZATION_TEMPERATURE=100.00,
    HEAT_OF_VAPORIZATION=2.2590000E003/

&PROP ID='sprinkler',
    QUANTITY='SPRINKLER LINK TEMPERATURE',
    ACTIVATION_TEMPERATURE=101.00,
    RTI=50.00,
    PART_ID='Water',
    DROPLET_VELOCITY=10.00/

&DEVC ID='Spr_1', PROP_ID='sprinkler', XYZ=204.5, 0.1, 10.9 /
&DEVC ID='Spr_2', PROP_ID='sprinkler', XYZ=204.5, 3, 10.9 /
&DEVC ID='Spr_3', PROP_ID='sprinkler', XYZ=204.5, 6, 10.9 /
&DEVC ID='Spr_4', PROP_ID='sprinkler', XYZ=203, 0.1, 10.9 /
&DEVC ID='Spr_5', PROP_ID='sprinkler', XYZ=203, 3, 10.9 /
&DEVC ID='Spr_6', PROP_ID='sprinkler', XYZ=205.6, 3, 10.9 /
&DEVC ID='Spr_7', PROP_ID='sprinkler', XYZ=205.6, 6, 10.9 /
&DEVC ID='Spr_8', PROP_ID='sprinkler', XYZ=203, 6, 10.9 /


--------
/ Smoke detectors
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&PROP ID='Smoke Detector', QUANTITY='spot obscuration', LENGTH=1.8, ACTIVATION_OBSCURATION=12/


&DEVC ID='SD_1', PROP_ID='Smoke Detector', XYZ=195.7,0.1, 10.9 /
&DEVC ID='SD_2', PROP_ID='Smoke Detector', XYZ=195.7,10, 10.9 /
&DEVC ID='SD_3', PROP_ID='Smoke Detector', XYZ=205.6,10,10.9 /

--------
/ CONCRETE
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&MATL ID      = 'CONCRETE',
    FYI     = 'Quintiere, Fire Behavior',
    SPECIFIC_HEAT = 0.88,
    DENSITY    = 2100,
    CONDUCTIVITY  = 1.0 /
--------
&SURF ID          = 'SLAB',
    RGB           = 156,102,31,
    MATL_ID       = 'CONCRETE',
    THICKNESS     = 0.15 / TRANSPARENCY 0.95

&SURF ID          = 'WALL 1',
    RGB           = 25,25,112,
    MATL_ID       = 'CONCRETE',
    THICKNESS              = 0.15 / TRANSPARENCY 0.5

&SURF ID          = 'WALL 2',
    RGB           = 65,105,225,
    MATL_ID       = 'CONCRETE',
    THICKNESS     = 0.15 / TRANSPARENCY 0.7

&SURF ID          = 'WALL TRANS',
    RGB           = 25,25,112,
    MATL_ID       = 'CONCRETE',
    THICKNESS     = 0.15,
    TRANSPARENCY          = 0.3 /
--------
/ GLASS
--------
&MATL ID      = 'GLASS',
    CONDUCTIVITY  = 0.76,
    SPECIFIC_HEAT = 0.84,
    DENSITY    = 2700 /
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&SURF ID          = 'GLASS',
    MATL_ID       = 'GLASS',
    FYI          = 'Quintiere, Fire Behavior',
    THICKNESS              = 0.005,
    BACKING          = 'EXPOSED',
    TRANSPARENCY           = 0.2 /
--------
/ GYPSUM PLASTER (GYPROCK)
--------
&MATL ID      = 'GYPSUM PLASTER',
    FYI     = 'Quintiere, Fire Behavior',
    CONDUCTIVITY  = 0.48,
    SPECIFIC_HEAT = 0.84,
```

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    DENSITY      = 1440 /
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&SURF ID                      = 'CEILING',
    RGB               = 184,184,184,
    MATL_ID           = 'GYPSUM PLASTER',
    THICKNESS         = 0.2,
    TRANSPARENCY              = 0.3 /
--------
/ STEEL
--------
&MATL ID          = 'STEEL',
    FYI          = 'Quintiere, Fire Behavior',
    EMISSIVITY    = 0.95,
    DENSITY      = 7850,
    CONDUCTIVITY  = 45.8,
    SPECIFIC_HEAT = 0.46 /
--------
&SURF ID              = 'SHEET METAL',
    MATL_ID           = 'STEEL',
    COLOR             = 'CYAN',
    BACKING           = 'EXPOSED',
    THICKNESS                 =  0.03  /  TRANSPARENCY
          0.3

&SURF ID              = 'STAIR',
    MATL_ID           = 'STEEL',
    COLOR             = 'BLACK',
    BACKING           = 'EXPOSED',
    THICKNESS         = 0.2 /

&SURF ID              = 'PLANT',
    MATL_ID           = 'STEEL',
    RGB                       = 34,139,34,
    BACKING           = 'EXPOSED',
    THICKNESS         = 0.2 / TRANSPARENCY  1

&SURF ID              = 'RACK',
    RGB               = 34,139,34,
    MATL_ID           = 'STEEL',
    THICKNESS         = 0.15,
    TRANSPARENCY              = 0.3 /
```

APPENDIX G FIRE DYNAMICS SIMULATOR RESULTS

The following output results have been compiled from the Computational Fluid Dynamic Simulations completed. The results have been rendered by Smokeview to create visual illustrations for ease of reference by the viewer.

The results illustrate that for each of the scenarios modelled the limiting factor in terms of tenability was visibility, i.e. smoke layer at 2m with obscuration reduced to less than 10m.

It is noted that the visibility slices are calculated on the assumption that occupants are looking at an illuminated sign, hence the factor of 8 in the input file. Generally in smaller enclosures the initial areas to become compromised due to visibility are around the bounding walls due to the smoke layers interaction with these parts; these areas are also the location of illuminated exit signs, i.e. above final exit doors, and therefore for these locations the use of the factor of 8 is deemed appropriate.

Due to the large envelope of the enclosure the smoke layer was calculated to descend in the racking aisles prior to visibility at the exit signs being compromised. Subsequently as the FDS modelling incorporates a visibility factor for light emitting signs (c=8) the following images provide a visibility tenability criteria of 26.6m which represent 10m visibility to a non-light emitting sign (such as in the racking aisles). However it should be noted that occupants located in the racking aisles are expected to travel through smoke conditions, navigating by the narrow racking aisles that help direct them to a point where an exit sign is visible.

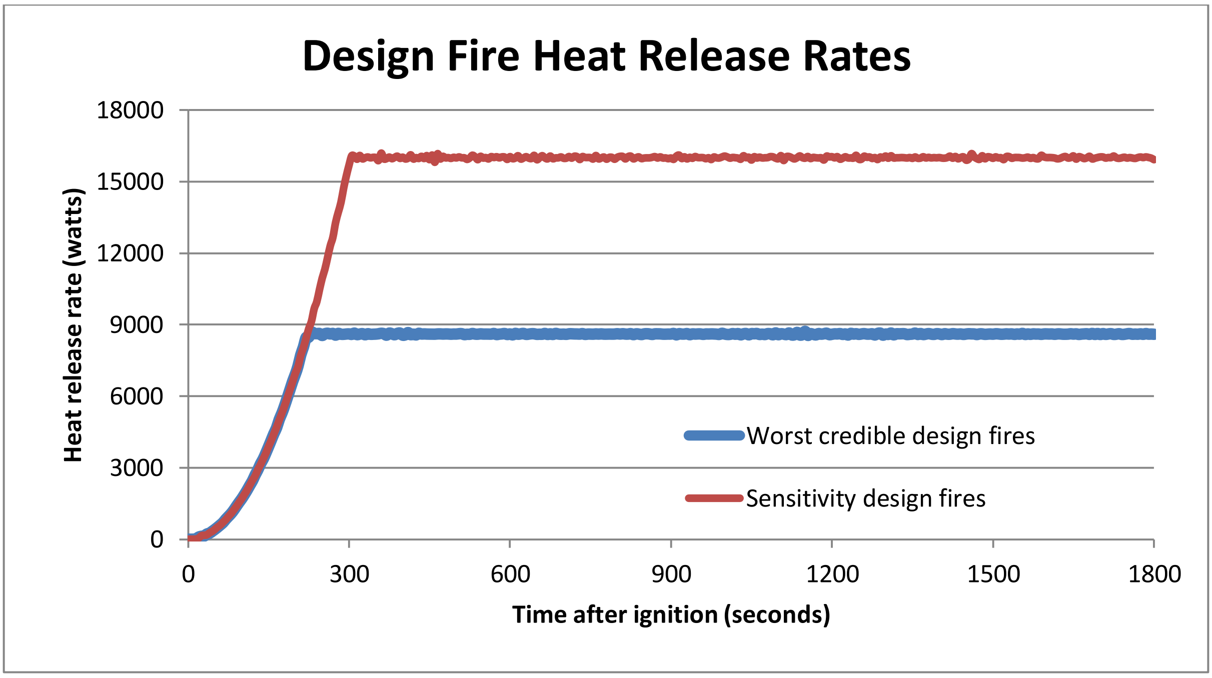

Figure 10-4: Design Fire Heat Release Rates

DESIGN FIRE 1 – Worst Credible Scenario

- **725 seconds:** The smoke layer loses buoyancy when interacting with the high bay racking and descends in the northern and southern aisles. At this stage occupants are expected to have moved out of the racking aisles, and as all exits are still available, tenability is deemed to be adequate for egress.
- **890 seconds:** Smoke concentration around the bounding walls increases at the northern and southern exits to compromise egress in these locations.
- **1800 seconds:** Temperature and toxicity conditions are maintained tenable for occupants with a steady state achieved. Entry into the building is available for fire brigade to undertake intervention activities.

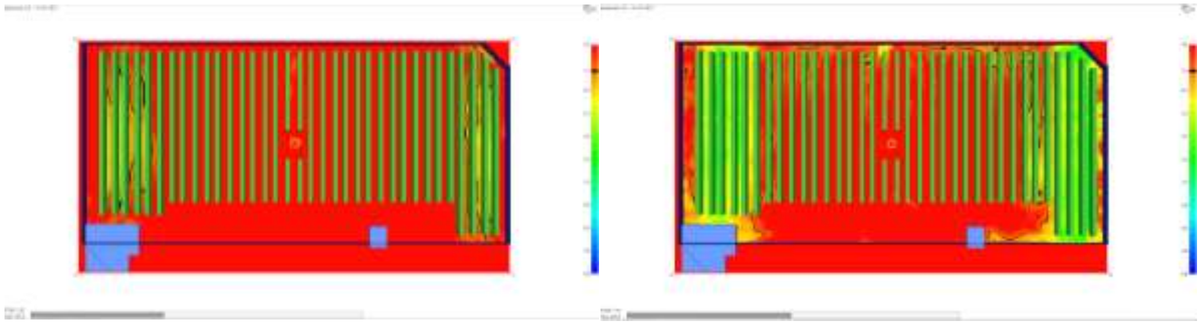

Figure 10-5: Visibility slice file illustrating 10m visibility at 2m above FFL | 725 and 890 seconds after ignition | Occupant tenability compromised at 890 seconds *Image rendered by Smokeview*

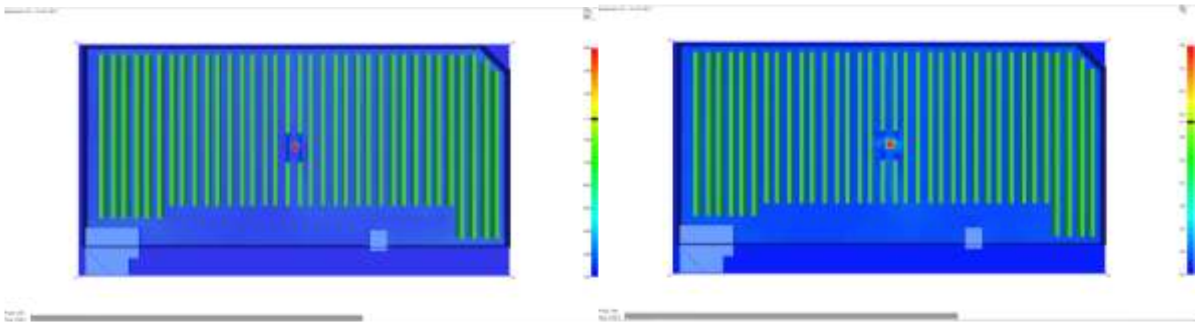

Figure 10-6: Carbon monoxide (illustrating 1400ppm) and Temperature (illustrating 60°C) at 2m above FFL | 1800-seconds | occupant tenability maintained *Image rendered by Smokeview*

DESIGN FIRE 1 – Sensitivity Scenario

Conditions in the Sensitivity scenario mimic that of the Worst Credible design fire until such time that the heat release rates exceeds 8.6MW. After this period the additional entrainment through the fire plume results in additional quantities of smoke filling the volume of the enclosure and significantly reducing the tenable area.

- **520 seconds:** The smoke layer loses buoyancy when interacting with the high bay racking and descends in the northern and southern aisles. At this stage occupants are expected to have moved out of the racking aisles, and as all exits are still available, tenability is deemed to be adequate for egress (applicable screen shot is based on non-illuminated signs – 26m on the side scale).
- **680 seconds:** Smoke concentration around the bounding walls increases at the northern and southern exits to compromise egress in these locations.
- **1800 seconds:** Temperature and toxicity conditions are maintained tenable for occupants with a steady state achieved. Entry into the building is available for fire brigade to undertake intervention activities.

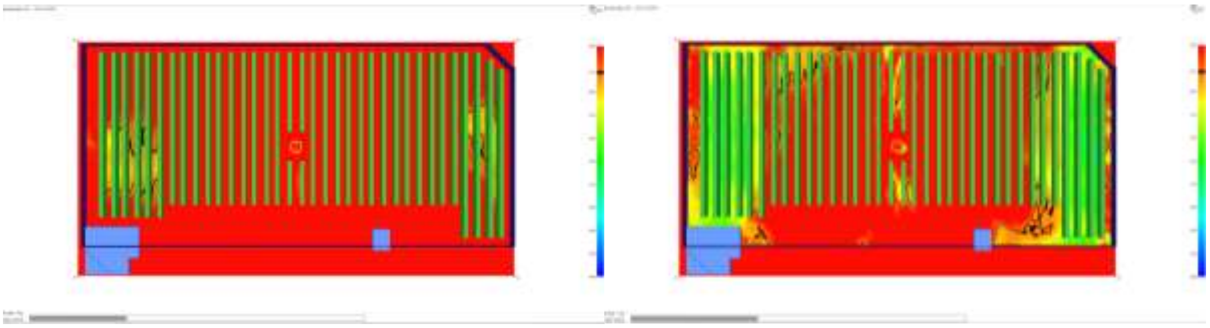

Figure 10-7: Visibility slice file illustrating 10m visibility at 2m above FFL | 520 and 680 seconds after ignition | Occupant tenability compromised at 680 seconds *Image rendered by Smokeview*

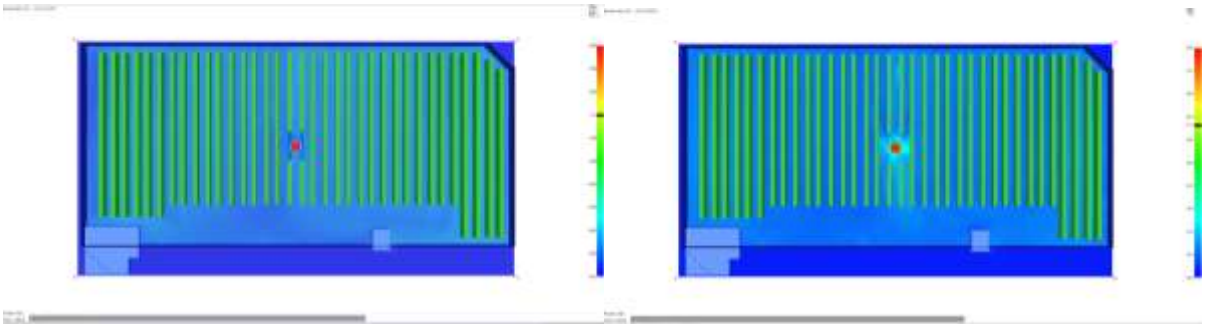

Figure 10-8: Carbon monoxide (illustrating 1400ppm) and Temperature (illustrating 60°C) at 2m above FFL | 1800-seconds | occupant tenability maintained *Image rendered by Smokeview*

DESIGN FIRE 2 – Worst Credible Scenario

- **550 seconds:** The smoke layer loses buoyancy when interacting with the south-eastern and north-eastern bounding walls. Visibility is reduced locally around these areas however at this stage all exits are tenable for occupant egress.
- **620 seconds:** Smoke concentration thickens and compromises egress at the south-eastern and western exits, as well as through the central racking aisles. Egress at this point is deemed to be compromised.
- **1800 seconds:** Temperature and toxicity conditions are maintained tenable for occupants with a steady state achieved. Entry into the building is available for fire brigade to undertake intervention activities.

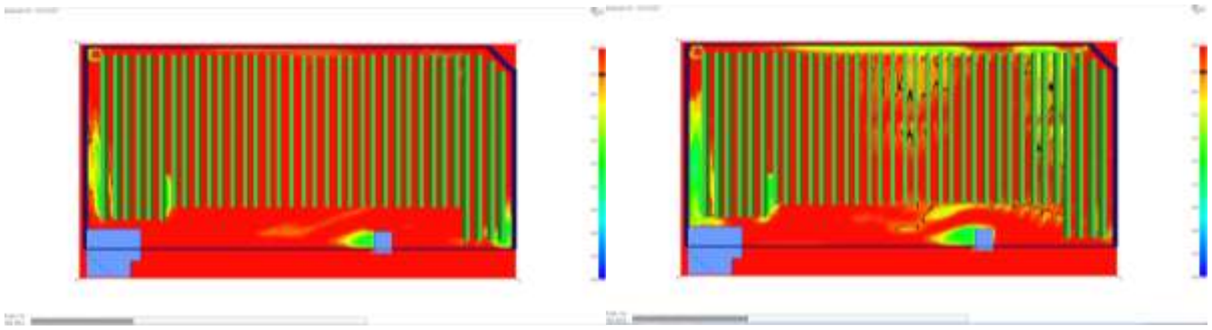

Figure 10-9: Visibility slice file illustrating 10m visibility at 2m above FFL | 550 and 620 seconds after ignition | Occupant tenability compromised at 620 seconds *Image rendered by Smokeview*

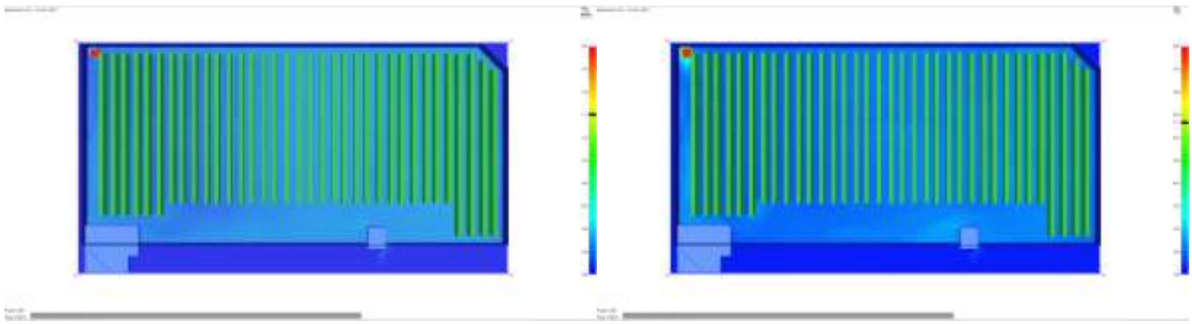

Figure 10-10: Carbon monoxide (illustrating 1400ppm) and Temperature (illustrating 60°C) at 2m above FFL | 1800-seconds | occupant tenability maintained *Image rendered by Smokeview*

DESIGN FIRE 2 – Sensitivity Scenario

Conditions in the Sensitivity fire scenario mimic that of the Worst Credible design fire until such time that the heat release rates exceeds 8.6MW. After this period the additional entrainment through the fire plume results in additional quantities of smoke filling the volume of the enclosure and significantly reducing the area of tenability.

- **445 seconds:** The smoke layer loses buoyancy when interacting with the south-eastern and north-eastern bounding walls. Visibility is reduced locally around these areas however at this stage all exits are tenable for occupant egress.
- **575 seconds:** Smoke concentration thickens and compromises egress at the south-eastern and western exits, as well as through the central racking aisles. Egress at this point is deemed to be compromised.
- **1800 seconds:** Temperature and toxicity conditions are maintained tenable for occupants with a steady state achieved. Entry into the building is available for fire brigade to undertake intervention activities.

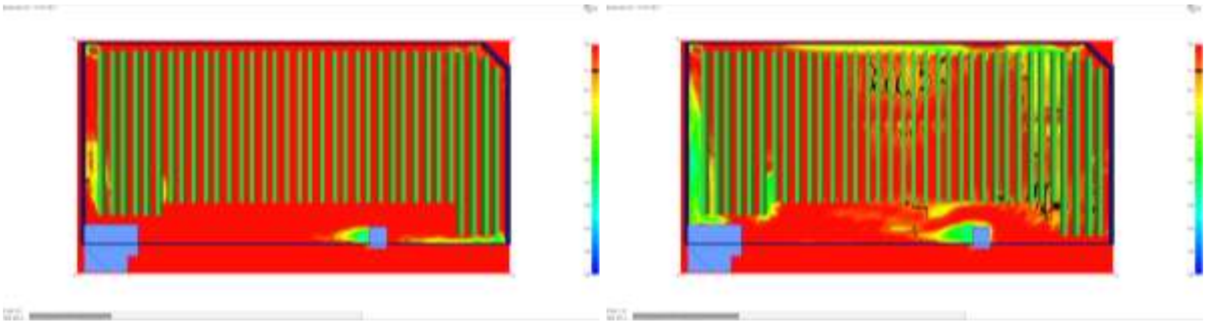

Figure 10-11: Visibility slice file illustrating 10m visibility at 2m above FFL: 445 and 575 seconds after ignition | Occupant tenability compromised at 575 seconds *Image rendered by Smokeview*

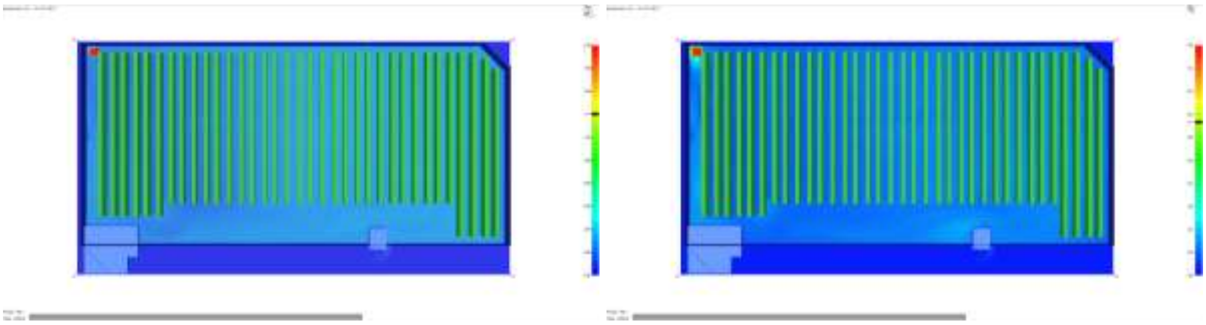

Figure 10-12: Carbon monoxide (illustrating 1400ppm) and Temperature (illustrating 60°C) at 2m above FFL | 1800-seconds | occupant tenability maintained *Image rendered by Smokeview*