Australian Building Codes Board

Provision of Fire Hose Reels in Class 5 Buildings

Fire Risk Assessment

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1 Introduction

1.1 The Project

The National Construction Code, Volume One Building Code of Australia (BCA) [1] Deemed-to-Satisfy (DTS) provisions require fire hose reels (FHR's) to be installed to serve Class 5 buildings where one or more internal fire hydrants are installed or where internal fire hydrants are not installed, to serve any fire compartment with a floor area greater than 500 m².

Fire hose reels in the past were seen as a key piece of first aid fighting equipment for use by occupants to tackle the early stages of fire. However, in more recent times, a change in approach and attitude, driven substantially by workplace OH&S considerations, has been for occupants of buildings to require evacuation as a first priority, and leave fire-fighting to the arriving fire services. This has led to many organizations no longer training staff in the use of hose reels, but if any training is undertaken, restricting to use of portable fire extinguishers.

Another factor has been the more extensive use of automatic sprinklers and sometimes faster acting smoke detectors in office buildings to enable improved response of responding fire services and better overall fire protection of Class 5 offices and other buildings. At the same time, fire statistics in Australia and other countries confirm that the rate of fire fatalities and injuries in office buildings is low and has reduced over the past 15 years.

Therefore the Australian Building Codes Board (ABCB) have appointed Arup for this study to examine the life safety risks if fire hose reels are retained or removed from new Class 5 buildings, and if changes are made whether other alternative fire measures should be considered.

1.2 Purpose of Report

The purpose of this report is to evaluate the change in risk level which could result from two potential changes to the BCA:

1. To no longer require fire hose reels in new Class 5 buildings; or
2. To replace the requirement for fire hose reels with portable fire extinguishers.

1.3 Scope

The scope of services provided by Arup is based on the fee proposal e-mail dated 27 November 2015 and the acceptance by Arup's client, Australian Buildings Codes Board, dated 18 December 2015.

This report does not consider the level of property protection, business interruption, or environmental protection associated with the provision of fire hose reels, or insurance issues.

2 Project Description

2.1 Assessment methodologies

This report documents two assessment methodologies undertaken to analyse the relative fire risk levels within office buildings, with specific regard to the provision of first aid fire fighting – i.e. fire hose reels and fire extinguishers.

The first methodology follows an epidemiological approach and is described in Section 4. This assessment focusses on statistical data for offices, for example the rate of fire starts, the rates of injuries and fatalities and the rates of usage for first aid fire fighting equipment.

The second methodology follows an engineering approach, which uses the concept of a quantitative risk assessment (QRA) to analyse the relative risk levels. Likelihood data is estimated using an event tree, while consequence data is calculated using the computational fluid dynamics software package Fire Dynamics Simulator (FDS). The relative risk levels are then calculated in terms of fatalities per year.

2.1.1 Methodology for hose reel deletion

The deletion of hose reels (without replacement by other measures), has been assessed using both the epidemiological and engineering methodologies.

This option lends itself to the engineering methodology as there is no ambiguity about the provision of first aid fire fighting. Furthermore, as the removal of fire hose reels is expected to demonstrate a slight increase in risk level, it is considered necessary to quantify that increase such that an informed decision can be made with regards to the implications of deleting the requirement for fire hose reels from offices.

2.1.2 Methodology for replacement of hose reels with extinguishers

The replacement of fire hose reels with portable fire extinguishers has been assessed using only the epidemiological methodology. As is apparent in Section 4.3, if the engineering methodology were to be applied to the portable extinguishers, it would show an overall risk reduction.

However, portable extinguishers could be provided to differing extents. For example, hose reels could be replaced on a like-for-like basis whereby extinguishers are provided with the same frequency – i.e. replace one hose reel with one set of extinguishers.

Alternatively, compliance with AS2444 could be designed for, in which case there could be more extinguishers provided across an office floor than there were previously fire hose reels (depending on the factors such as compartment size, distribution of electrical equipment etc.). The extent of extinguisher provision is subject to further variables, based on the size of the extinguisher selected and whether or not fixed fire suppression (i.e. sprinklers) are provided. The analysis undertaken in this report suggests that even a one-for-one replacement of hose reels with appropriate extinguishers would result in an overall life safety benefit. Refer to Section 4.3 and Section 6 for further discussion.

Given the significantly varying potential levels of extinguisher provision and the scope of this project as a “Regulation Reduction”, it has not been considered necessary to quantify the overall risk benefit that would be incurred through the replacement of fire hose reels with extinguishers. As the risk level goes down, it is considered that an informed decision can be made about the potential change to the BCA – although the extent to which portable extinguishers might be provided in the future would need to be determined.

2.2 Building Characterisation

The typical buildings to be considered in this fire risk assessment are Class 5 buildings. A Class 5 building is defined in the BCA as an office building used for professional or commercial purposes, excluding buildings of Class 6, 7, 8 or 9.

The general BCA DTS requirements for fire safety provisions vary for offices in buildings with an effective height above or below 25m as summarised below:

<table>
<tr><th rowspan="2">Fire Measure</th><th rowspan="2">Office building > 25m high</th><th colspan="2">Office building < 25 m high</th></tr>
<tr><th>Rise in storeys > 3</th><th>Rise in storeys < 3</th></tr>
<tr><td>Smoke Management</td><td>Zone smoke control to AS1668.1</td><td rowspan="4">Zone Smoke Control to AS1668.1, OR
Smoke Detection to AS1670.1, OR
Pressurisation in fire isolated exits, OR
Sprinkler protection to AS2118.1.</td><td>No requirement</td></tr>
<tr><td>Smoke Detection</td><td>To AS1668.1</td><td>No requirement</td></tr>
<tr><td>Stair Pressurisation</td><td>To AS1668.1</td><td>No requirement</td></tr>
<tr><td>Sprinklers</td><td>To AS2118.1</td><td>No requirement</td></tr>
<tr><td>Exits</td><td>At least two exits</td><td>At least one exit</td><td>At least one exit</td></tr>
</table>

2.3 Occupant Characterisation

Full populations are only expected during operating hours, however small numbers of staff may be present out of hours.

Based on the building classification above, occupants in the Class 5 buildings would be largely awake, alert and familiar with the escape routes.

For the purposes of analysis in this report, occupant numbers have been calculated in accordance with BCA Table D1.13.

Most of the occupants may not have received basic fire safety training or training to use first aid fire-fighting equipment such as fire hose reels and portable fire extinguishers.

Fire wardens are expected to be present as required by the various OH&S legislation enforced by the States and Territories, which generally refers to AS 3745. Wardens are expected to have received at least some level of fire safety training which may include the use of first aid fire fighting equipment.

3 Fire Safety Objectives

This risk assessment addresses fire safety objectives only as required in the BCA, i.e. occupant life safety, protection of adjacent buildings and facilitating fire brigade intervention, and does not consider other potential fire safety objectives such as property protection, business interruption and minimisation of insurance premiums.

The Productivity Commission [5] has indicated the following regarding BCA fire safety objectives:

"The ABCB Chairman submitted that the BCA's goal in the area of fire safety is:

…to protect the lives of building occupants, facilitate fire brigade intervention in the event of emergency, and protect adjacent property from the spread of fire and physical damage caused by structural failure.

It would appear to be generally accepted that the property protection of a building that is on fire is not a primary objective of the Code (although a level of property protection would often be an indirect consequence of fire safety measures directed at protecting building occupants). Provided the BCA's spread of fire criteria have been satisfied, a building may burn down and technically still have complied with the performance requirements of the Code."

Given that fire hose reels and portable extinguishers are intended for primary use by building occupants and not by fire brigades, and play little, if any, role in protecting adjacent buildings, the only objective specifically addressed by this risk assessment is the life safety of occupants, however the potential for fire fighters to use first aid fire fighting equipment is discussed further in Section 4.4.

4 Epidemiological approach

4.1 General

This approach looks at the total population of people in Class 5 office buildings, and examines the best available national and international statistical data and research to broadly examine the risks arising from a fire.

4.1.1 Amount of office space in Australia

Data available from the Property Council of Australia [6]indicates that there is a total of approximately 2.5m square metres of office space in Australia currently.

As any changes to the BCA will only affect future buildings rather than being applied retrospectively, the amount of office space currently under construction has been analysed instead, in order to give an indication of the future risk levels that may result from changes to the DTS provisions of the BCA.

Research undertaken by Savills[7][8][9][10][11]] indicates that across the capital cities of Sydney, Perth, Brisbane, Adelaide and Melbourne, there are a total of approximately 1.1m square metres of new (or refurbished) office space due for completion prior to 2019.

4.2 Relevant fire incident statistics for office buildings

4.2.1 Fire Starts

The rate of fire starts in office buildings is generally a useful statistic as it can be used to predict the likelihood of a fire occurring in an office space.

Statistics, such as those in the Warren Centre report have reported $1.6x10^{-5}$ fire starts per year per m^2 in Sydney Offices (over the period 1986-1988) [6]

A report published by BHP Research in 1992 regarding a quantitative risk assessment of a building at 140 Williams St [13] derived a value of $8.9x10^{-6}$ fire starts per year per m^2 based on fire brigade responses to office fires in Sydney CBD.

However, the most complete data available is that of the Australasian Fire Authorities Council's (AFAC's) national incident database which showed 2,355 fires had occurred in offices from 1998-2004[14]. From this the rate of fire starts was derived as $2.19x10^{-5}$ fire starts per year per m^2 (based on 2007 office space data from the Property Council of Australia). This is the figure selected for all further analysis in this study, as it is considered the most relevant and covers the whole of Australia rather than specific areas or capital cities.

4.2.2 Ignition Hazards

Dowling and Ramsay [15] used data from the Australian Fire Incident Reporting System (AFIRS) in its first four years and reported the most common scenarios for fires in office buildings (see Table 1), for the period between 1989 and 1993. This indicates that the main fire hazard is an electrical fault.

Table 1: Most common scenarios for fires in offices, 1989-1993 (adopted from Table 13 in [15])

A. By area of fire origin and equipment involved in ignition		
Area of fire origin	Equipment involved in ignition	Fires
All	Electrical distribution equipment (4)	392
Office (27)	Lighting fixture, ballast, sign (46)	60
All	All	1,606
B. By ignition factor and form of material ignited first		
Ignition factor	Form of material ignited first	Fires
Short circuit, ground fault (54), other electrical failure (55)	All	468
Incendiary (1) or suspicious (2)	All	383
Abandoned, discarded material, incl. cigarettes etc. (31)	Rubbish, trash, waste (75)	74
All	All	1,606

[a] Fixed Property Use = 59 (offices).

Data from the national incident database[14], summarised in Figure 1, confirms that the majority of office property fires originate in functional areas such as cooking areas, cafeterias, performance areas, electronic equipment rooms, printing rooms, or process areas.

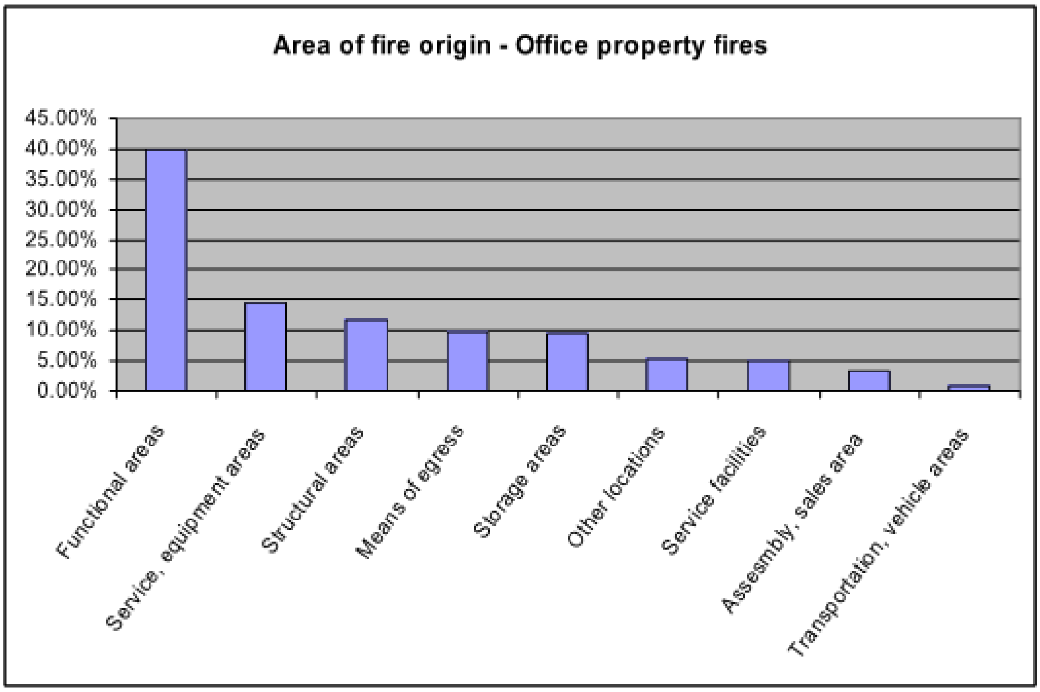


Figure 1: AFAC data – All non-domestic building fires: fire of origin

The ignition factors are detailed below in Figure 2 with the most likely being mechanical failure or malfunction. It is noted that 58% of the ignition factor category ‘Mechanical failure, malfunction’ was directly related to short circuits or other electrical failures, which equates to a total of approximately 20%.

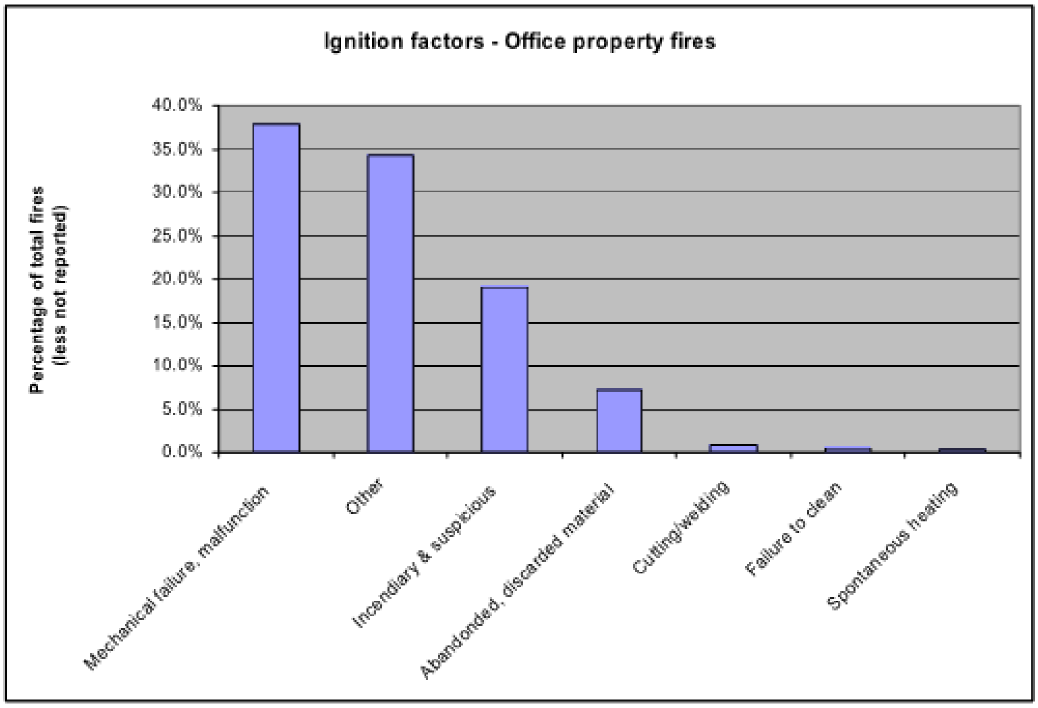


Figure 2: AFAC data – All non-domestic building fires: Ignition factors

73% of the ignition factor category 'Abandoned, discarded material' was directly related to smoker's material such as cigarettes, cigars and pipes, or approximately 2% of the overall data. It is therefore presumed that fire start rates have not changed significantly due to recent smoking regulations.

Figure 3 shows the distribution of ignition times with a marked increase in ignition during office hours – i.e. when populations are at their highest.

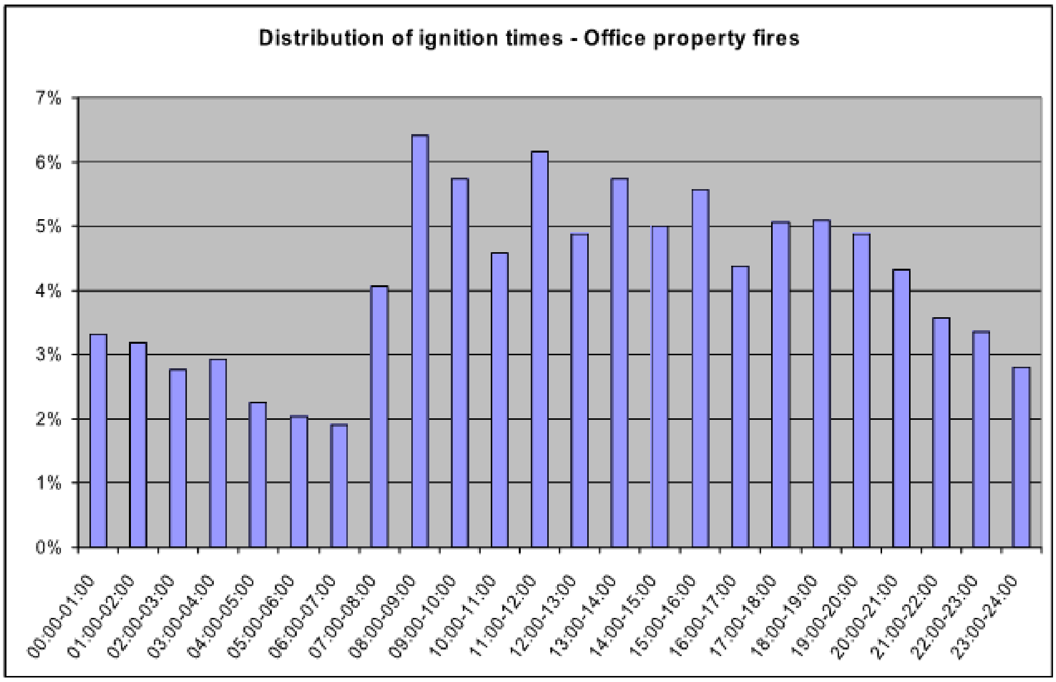


Figure 3: AFAC data – Office: Distribution of times of ignition

It can be seen from the figure above that the majority of fires occur during normal office hours, meaning that occupants would be expected to be present and therefore have the option to undertake first aid fire fighting.

It is noted that another hazard of an office is the large amount of fire load in the form of paper and plastics that, if ignited, may produce large volumes of toxic smoke.

4.2.3 Deaths in Office Fires

A review of the relevant literature and statistics [14][16][17][18] does not provide evidence of a fatality in a sprinkler protected office building in Australia.

However, the national incident database does record one civilian death in an unsprinklered office in 2000 and two civilian deaths in an office in 2002. Further details of each incident are as follows:

1. One civilian death recorded in a fire in Toowoomba in 2000. A review of press archives indicate that this fire occurred in a timber framed home that had been converted into a dentist's office. The cause of the fire was apparently a malfunctioning fridge that subsequently exploded. The casualty was able to dial 000 however was unable to escape the building. The press cutting describes the casualty's escape route as being blocked by "flames" and "security bars".
2. Two civilian deaths recorded in a fire in Meekatharra in 2002. The AFAC data indicates that this may have been a suspicious fire however no further details have been found.

In the two cases described above it is not possible to determine whether the occupants had access to fire aid fire fighting, or whether it would have assisted them, however in case 1 above it seems plausible that access to an appropriate fire extinguisher may have assisted the occupant in what appears to have started as an electrical fire.

It is also considered relevant that neither of the above incidents are likely to have taken place in a building with Type A construction (incident 1 was in a converted timber home and incident 2 was in a small country town with very few multi-storey buildings.

Considering there were 2,355 office fires recorded over the period of 1998-2004, this suggests a fatality rate of 0.0013 fatalities per fire however given the small sample size, this may not be statistically significant.

Despite these two events the likelihood of a fatality is very low, a conclusion supported by various studies.[16][17][18]

4.3 Discussion of the relative merits of fire extinguishers

As an alternative to removing all first attack firefighting equipment, it has been considered that provision of fire extinguishers in lieu of fire hose reels may be of benefit. A discussion of the qualitative reasoning is presented below:

- According to national incidents data [14] of the office premises with Fire Hose Reels installed, they were only used in 5% of cases whereas Fire Extinguishers were used in 11% of cases, indicating that people are more than twice as likely to make use of an extinguisher than a hose reel.
- In the event that an occupant has decided to fight the fire, the time required to reach a fire hose reel is expected to be longer statistically than that to reach a portable fire extinguisher if provision and location of portable extinguishers complies with AS 2444. This is because the maximum coverage of a hose reel according to AS 2441 is 40m (36m hose length plus 4m hose stream); whereas the maximum travel distance to a portable fire extinguisher for Class A fire risks is 15m.
- The time required to retrieve a fire hose reel and then reach the fire site is expected to be longer than a portable fire extinguisher because the occupant needs to open the stop valve before the nozzle can be disengaged from the nozzle interlock, to roll out the hose, and to negotiate the hose around bends and corners.
- Accordingly the fire is likely to be relatively larger when water is discharged from a fire hose reel compared to when a portable extinguisher is discharged due to the longer time required for bring a fire hose to the fire site.
- An occupant is more likely to retreat to safety from the room of fire origin earlier when using a portable fire extinguisher for fire fighting because the extinguishing agent will eventually run out, whereas a fire hose reel has a continuous water supply.
- An occupant is more likely to retreat to safety from the room of fire origin earlier when there is no expectation that they should fight the fire.
- As a result, an occupant who fights a fire with a fire hose reel is more likely to be exposed to a hazardous condition than with a portable fire extinguisher because of the longer dwell time at the fire site.
- Whilst it is recognised that theoretically fire hose reels have greater extinguishing power than portable fire extinguishers due to cooling effect by the continuous water spray (with virtually unlimited supply) for some fire scenarios, the most significant source of fires scenarios in office buildings revealed in the past fire incident statistics is associated with electrical faults for which using water as a fire extinguishing agent is not appropriate and a more appropriate fire extinguisher (e.g. ABE, CO2, AFFF) would likely provide a greater level of protection to occupants.
- According to national incidents data of the office premises with Fire Hose Reels installed, they were the major method of extinguishment in 1.5% of fires whereas Fire Extinguishers were the major method in 6% of cases. This suggests that not only are people more likely to use an extinguisher, they are also more likely to be successful with one than with a hose reel.
- Fewer occupants are expected to be familiar with the use or operation of hose reels since many workplaces no longer provide training on their use and may actively discourage training or their use on the ground of OH&S concerns and potential fire exposure (an informal survey of four training

companies showed that none provided hose reel training as part of warden training and that the focus was on extinguishers).

Hence, it is considered that fire extinguishers may provide an equivalent or better chance of successful fire fighting and expose occupants to less risk during the process.

4.4 Fire Brigade use of Fire Hose Reels

The national data analysed suggests that fire brigades do sometimes use fire hose reels in buildings. However, the use of fire hose reels by brigades is rarely the "main method of extinguishment".

According to BCA Performance Requirement EP1.1, hose reels are installed *"to the degree necessary to allow occupants to safely undertake initial attack on a fire"*. This clearly indicates that the provision of fire hose reels is not intended for use by fire fighters.

While fire hose reels may provide a convenient means of fighting some fires, they are not considered to be an essential measure for fire fighters. Fire fighter equipment is provided under Performance Requirement EP1.3, via the provision of a fire hydrant system.

5 Engineering Approach

5.1 General

Further to the epidemiological assessment carried out above, quantitative analysis of representative fire scenarios has also been carried out in order to provide an estimate of the actual risk level changes that may occur as a result of changes to fire hose reel provisions in office buildings.

The concept of Quantitative Risk Assessment (QRA) has been used, which in its simplest form can be represented as:

Risk = Likelihood x Consequence

The likelihood of relevant fire scenarios has been estimated by developing event trees and statistical analysis (much of which formed part of the epidemiological analysis), while the consequence has been determined by using the Computational Fluid Dynamics (CFD) package, Fire Dynamics Simulator (FDS) (refer to Appendix B).

The analysis described in this section addressed two design cases:

1. The current DTS provisions – i.e. hose reels provided
2. Option to delete fire hose reels

The potential to replace fire hose reels with extinguishers is addressed in Section 4.3.

Throughout this section of the report, there are a number of assumptions that have been made, mostly as a result of having insufficient data on the likelihood of use and efficacy of fire hose reels. Where assumptions have been made, they have been made in order to maximise the benefit demonstrated by fire hose reels. This approach leads to a conservative analysis that is likely to overestimate the risk increase as a result of deleting hose reels. As a result of this methodology, many of the assumptions have not been subjected to sensitivity testing as this is not considered necessary.

5.2 Representative building layouts

The assessments have been undertaken for two representative building layouts:

1. A building with effective height greater than 25m in effective height
2. A building with effective height less than 25m in effective height (rise in storeys not more than 3)

The two representative layouts have been selected as there are significant difference in the required fire safety measures for buildings with effective height greater than 25m. For the representative building with effective height less than 25m, a building with not more than 3 storeys has been selected for analysis, as there are fewer fire safety measures required and it is therefore expected that first aid fire fighting may play a more significant role in the overall safety levels in these buildings.

The fire safety measures for each building have been selected according to the DTS Provisions, as per Section 2.2.

The building geometries have been developed as follows:

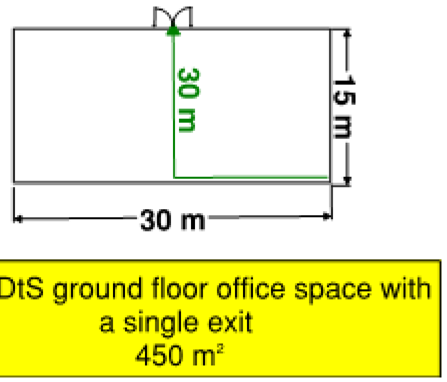


Figure 4 Layout for <25m high building

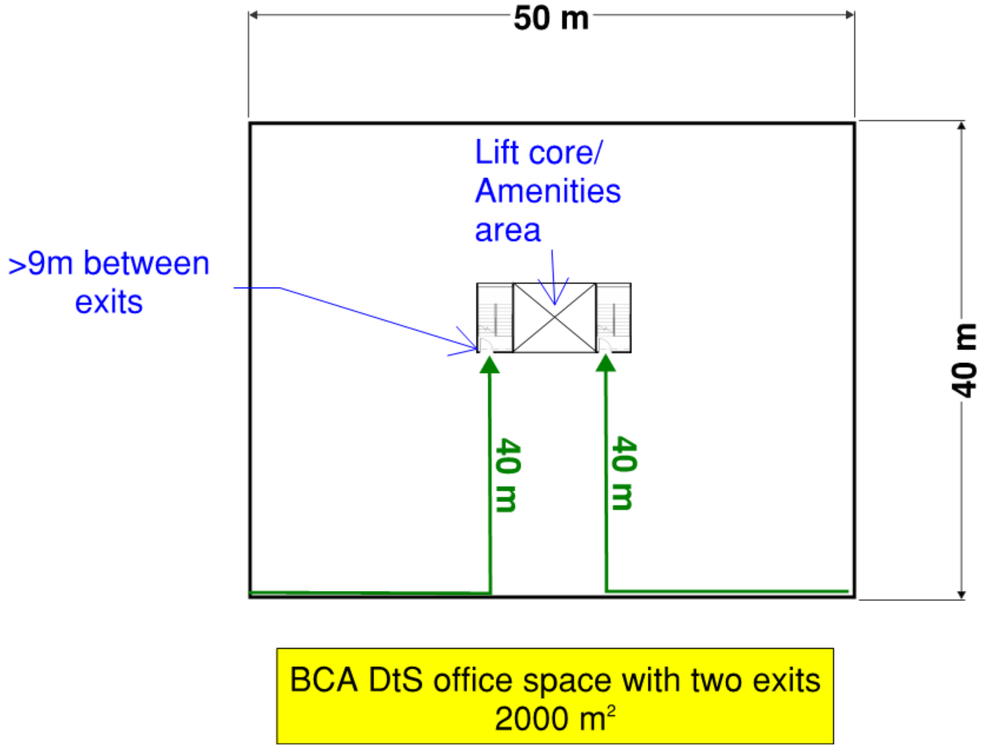


Figure 5 Layout for >25m high building

The layouts above (in particular the method of measuring travel distance) has been selected in order to provide a realistic overall building size, taking into account the total distance that an occupant may need to travel in order to avoid obstacles such as furniture or partition walls.

The number of persons accommodated within each layout is based upon Table D1.13 of the BCA the following populations have been calculated:

Layout	Floor Area	m^2 per person	Population
< 25m tall building (Figure 4)	$450m^2$	10	45
> 25m tall building (Figure 5)	$2000m^2$	10	200

5.3 Likelihoods

In order to determine the change in risk level, the relevant fire scenarios for analysis have been identified by developing an event tree.

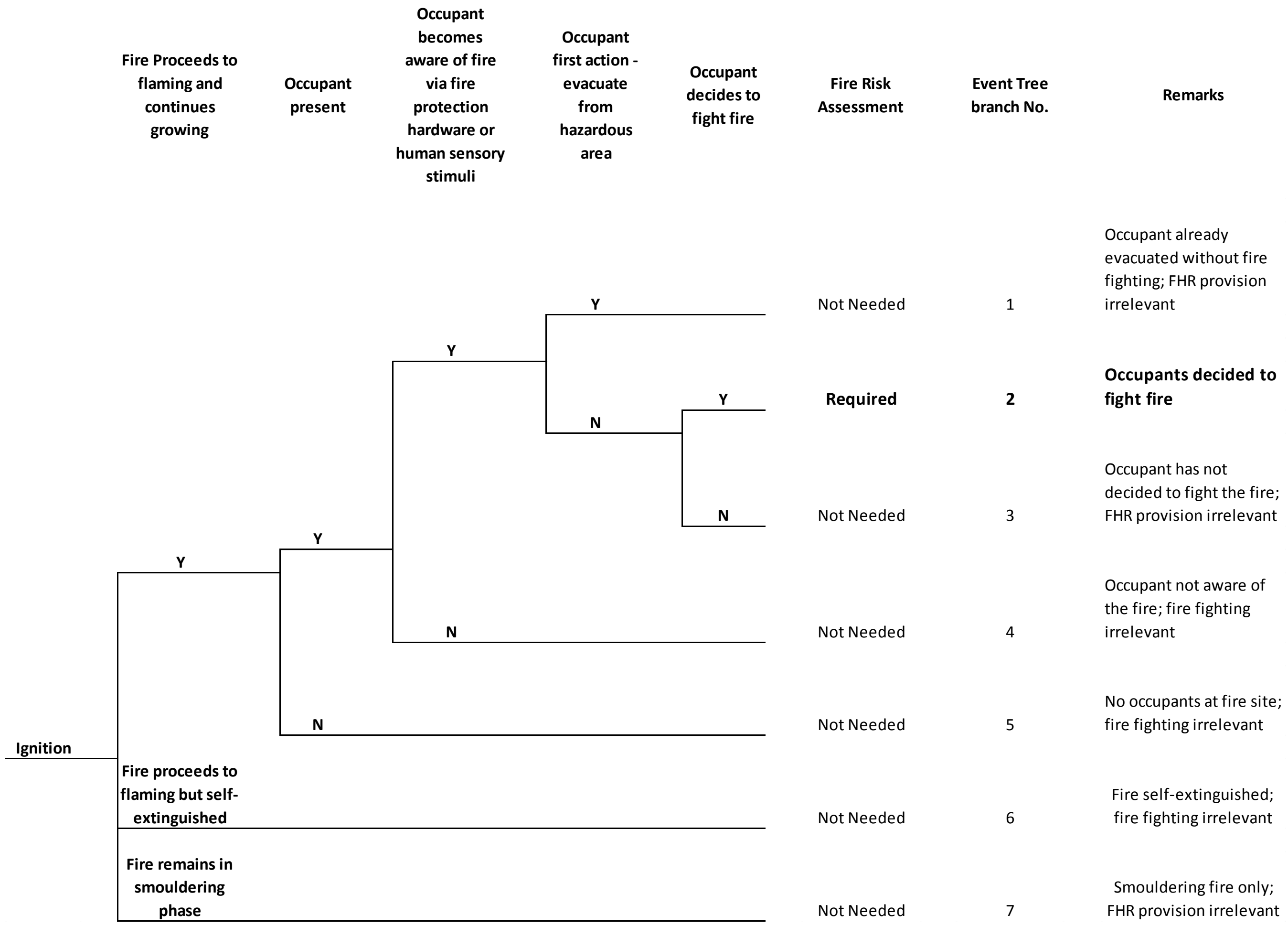


Figure 6: Event Tree for Identification of Fire Scenarios

The fire scenarios and their associated probabilities of occurrence apply equally to each design case. As a result, the differences in the level of risk (or its inverse - the level of life safety) can be determined by evaluating the relative risk of the identified fire scenario 2, i.e. branch 2 in the Event Tree above. All other scenarios do not involve the use of first aid fire fighting equipment.

Event tree branch 2 is further expanded to include the likelihood of success with each extinguishing method (i.e. hose reels or extinguishers).

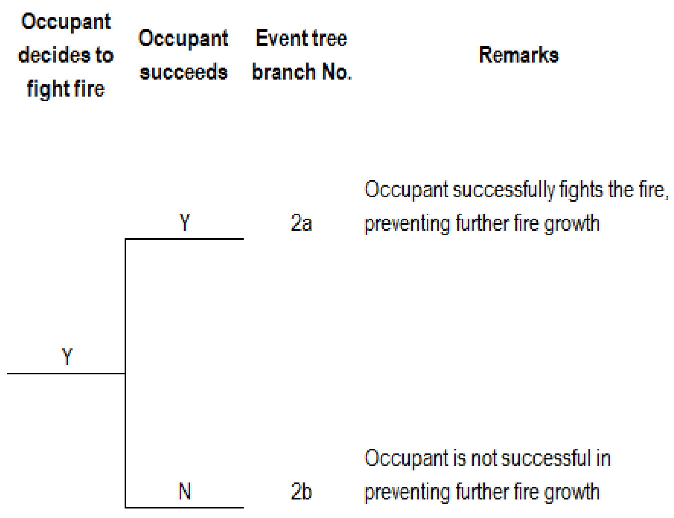


Figure 7 - Event tree 2 expansion

Based on the above, the scenarios for analysis are as follows:

Building height	**Design case**	**Event tree branch**	**Scenario number**
>25m	1 – hose reels	2a	T1a
		2b	T1b
	2 – delete hose reels	2a	N/A
		2b	T2b
<25m	1 – hose reels	2a	S1a
		2b	S1b
	2 – delete hose reels	2a	N/A
		2b	S2b

5.3.1 Likelihood data

The relevant likelihoods for the event tree above have been estimated as follows:

Measure	**Probability of use**	**Probability of success**
Hose reels	11%	93%

Extinguishers	11%	93%

Notes on table:

- Probability of use of extinguisher is taken from SFPE Handbook 4th Edition and is consistent with the data presented in Section 4.3.
- Probability of success for extinguishers is taken from studies by Charters and Smith[24][25].
- Probabilities of use and success of hose reels have been assumed to be the same as for fire extinguishers. This is considered to be a conservative assumption, as it is considered that people are generally more likely to use extinguishers than hose reels, and extinguishers are appropriate for use on more fire types than hose reels, as described in Section 4.3. Overestimating the effectiveness of fire hose reels will in turn overestimate the risk increase deleting hose reels.

5.3.2 Likelihood results

Based on the above, the scenario likelihoods for each event tree branch under consideration are as follows:

- Event tree branch 2a = 0.11 x 0.93 = 10.2%
- Event tree branch 2b = 0.11 x 0.07 = 0.8%

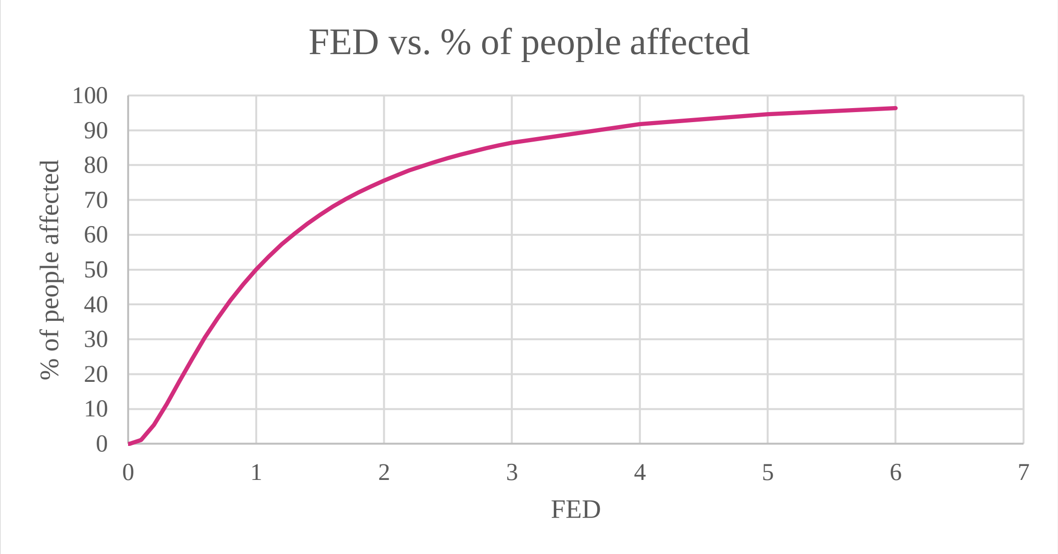
The approach taken in this section, by only considering the likelihood of events past a certain point on the event tree is deterministic up that point (i.e. all branches leading up to that point are assumed to have happened). This approach is conservative, as it will overestimate the likelihoods of the analysed scenarios and therefore overestimate the total risk increase associated with deleting hose reels.

5.4 Consequence

In order to calculate the life safety consequence of each scenario, the concept of Fractional Effective Dose (FED) has been applied. This method, as described by Purser in the SFPE Handbook, is a cumulative measure of toxicity received over time.

The impact of that dosage on a person is estimated using a log-normal distribution[26] to account for the varying vulnerabilities of the general population.

The log-normal distribution is shown below.



Example data points from the distribution are as follows:

- FED = 0.3 equates to 11% of people affected
- FED = 1.0 equates to 50% of people affected
- FED = 3.0 equates to 86% of people affected

5.4.1 Evacuation analysis

The Required Safe Egress Time (RSET) can be expressed in the following equation:

$$RSET = t_{alm} + t_{pre} + t_{flow}$$

Where:

t_{alm}	is the alarm / detection time
t_{pre}	is the pre-movement time
t_{flow}	is the flow / movement time

5.4.1.1 Alarm time

Sprinkler and Smoke Detector activation times have been calculated using the FPE Sprinkler Activation Tool.

The RTI range for standard response sprinklers is 80 $m^{1/2}s^{1/2}$ to 350 $m^{1/2}s^{1/2}$, according to AS 4118.1. For the purposes of comparison, an RTI value of 150 $m^{1/2}$ $s^{1/2}$ is considered appropriately conservative.

Parameter	**Sprinkler activation**	**Detector Activation**
RTI	150 $m^{-1/2}s^{-1/2}$	0.5 $m^{-1/2}s^{-1/2}$
Activation Temperature	68°C	33°C [19]
Ceiling Height	2.8m	2.8m
Spacing	12m² area of operation*	20m grid (AS1668.1)
Ambient Temperature	20°C	20°C
Fire growth rate	Medium	Medium
Fire Size	907.5 kW	219 kW
Activation time	275 s	135 s

* Sprinkler system details based on Ordinary Hazard spacing rather than Light Hazard spacing, in order to maximise the demonstrated benefit of the first aid fire fighting measures.

For the building with effective height less than 25m, there would not necessarily be any automatic detection system. In this case, visual detection by occupants has been assumed to occur when the smoke fills down to 5% of the ceiling height [21].

5.4.1.2 Pre-movement time

The pre-movement time depends on two parts; coping time and recognition time. During the coping time, occupants will become aware of the situation and in the recognition time they will decide how to react.

For the scenarios in a building over 25m in effective height, the provision of a SSISEP is assumed to provide a reduced pre-movement time, compared to the building under 25m which may not be provided with any alarm system, as occupants are expected to react more quickly to voice messaging than to simple alarm tones.

Pre-movement times have been selected based on the guidance available in PD7976-6 [20].

5.4.1.3 Flow time

Flow time is the time needed for all of the occupants in a specified part of the building to move to an exit and pass through that exit (either to a road or open space, or into a fire isolated exit). The flow time can be divided into two parts:

- The time taken for occupants to move to an exit (i.e. travel time); and
- The time taken for occupants to pass through an exit (i.e. queuing time).

Flow times have been calculated based on the hydraulic flow model described in the SFPE Handbook, primarily that a single door leaf is likely to provide egress capacity for 50 people per minute [23].

5.4.1.4 Evacuation results

Based on the above, the following RSET has been calculated for each representative building type:

Building type	Alarm time	Pre movement time	Travel time	Queuing time	RSET
>25m	135	30-60	40*	120	285* (135+30+120)
<25m	85	60-120	30	54**	235** (85+120+30)

* Flow time dominates travel time and pre-movement time therefore 1st percentile pre-movement time selected and travel time is discounted (i.e. queuing at the exit)

** Pre-movement time and travel time dominate the flow time therefore 99th percentile pre-movement selected and flow time is discounted (i.e. no queuing at the exit)

Note that varying walking speeds to account for elderly, disabled or the like have not been considered. A walking speed of 1m/s has been selected as reasonably representative of typical office populations, most of whom are expected to walk faster than this and a minority of whom may travel slower.

5.4.2 Smoke modelling

Based on the evacuation results above, smoke modelling has been undertaken to determine the FED received by occupants of each representative building layout over the respective evacuation periods. Refer to Appendix B for more details.

5.4.2.1 Fire growth rate

Where fires occur in sprinkler protected areas, activation of the sprinklers or application of first aid fire fighting is assumed to control, but not to reduce the heat release rate. The fires are assumed to follow a ‘t-squared’ fire growth rate, ignoring any incipient period.

The following table from the Fire Engineering Design Guide 4.3 presents typical growth rates comparatively associated with various fuels.

Fire growth rate	**Fire growth rate α/ kWs²**	**Typical real fire examples**	**Building area providing fuel**
Slow	0.00293	Densely packed wood products	Picture gallery
Slow-medium	-	-	Display area
Medium	0.0117	Solid wooden furniture such as desks. Individual furniture items with small amounts of plastic	Dwelling Office Hotel bedroom Hotel reception
Medium-fast	-	-	Assembly hall seating
Fast	0.0469	High stacked wood pallets, cartons on pallets, some upholstered furniture	Shop
Ultra-fast	0.1874	Upholstered furniture (poor performing), high stacked plastic materials, thin wood furniture such as wardrobes.	Warehouse

For the office areas the 'base case' design fires are based upon a medium growth rate t-squared fire originating at a desk. The fire grows at the nominal t-squared rate until either the predicted time of sprinkler activation. Following this brief delay period, the sprinkler system is assumed to control further fire growth and to maintain steady state conditions.

The fire size is considered to be conservative, as it is likely that a sprinkler would reduce the fire size and possibly extinguish the fire over time. The assumed heat release rate curve is depicted in the figure below.

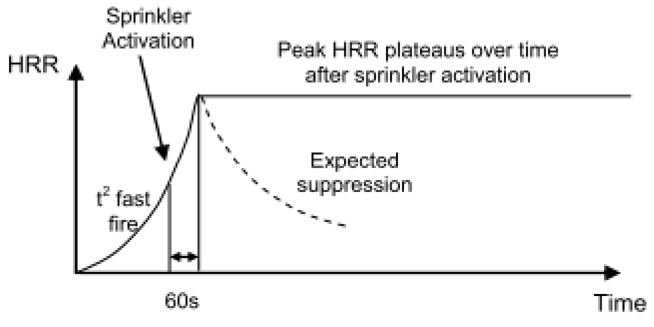


Figure 8: Heat release rate curve for base case design fires

Further details on the typical fire hazards expected in office buildings is provided in Appendix A.

5.4.2.2 First aid fire fighting intervention time

In the smoke modelling carried out, it has been assumed that the fire growth rate is capped at the point at which first aid fire fighting begins. This time has been estimated as follows:

$$t_{int} = t_{alm} + travel\ distance$$

This approximation is based on the average distance that would need to be travelled to reach the first aid fire fighting equipment and a 1m/s walking speed[23].

This approach makes no account of time taken to make a decision to fight the fire, nor of the time it would take to operate the first aid fire fighting. As such, this approach is expected to overestimate the benefit of using hose reels and provide conservative results of the increased risk associated with deleting hose reels.

5.4.2.3 Modelling Parameters

Modelling of the representative building layouts has been undertaken using the CFD software package Fire Dynamic Simulator (FDS), developed by the National Institute of Standards and Technology (NIST). FDS 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. To visualise the FDS results with animations, the Smokeview programme is used.

Inputs	**Comments**	
Model geometry	As above	
Ambient temperature	20^0C	
Mesh size(s)	Near field (adjacent fire)	0.2m x 0.2m x 0.2m
	Far field (remote from fire)	0.2m x 0.2m x 0.2m
Simulation time	300 seconds	
Ventilation	Leakage air paths simulated	
Devices	FED sampled 2m above floor height on a 5m grid	
Design Fire Characteristics	All of the fire scenarios were analysed with the fuel properties of ‘polyurethane’* which has the following parameters: • Soot yield - 0.1 kg_{soot} / kg_{fuel} • Chemical reaction – $C_{6.3}H_{7.1}NO_{2.2}+7.025O_2 \rightarrow 0.5N_2+6.3CO^2+3.55H^2O$ • Heat of combustion – 21,500kJ/kg	

* Polyurethane has been selected in order to conservatively calculate the amount of smoke that people may be exposed to.

Further details on the modelling inputs and parameters are provided in Appendix B.

FDS calculates the fractional effective dose (FED) at points in space, over time, according to the following equation (adapted from the FDS User Guide)

$$FED_{tot} = FED_{CO} \times HV_{CO_2} + FED_{O_2}$$

Which can be described as the total dose being equal to the dose of carbon monoxide multiplied by the hyperventilation effect of carbon dioxide, added to the dose of oxygen depletion.

5.4.2.4 Modelling Results

The fatality results of the smoke modelling are as follows:

Building type	With hose reels	Without hose reels
>25m	4.12E-09	1.91E-08
<25m	5.43E-08	4.62E-07

5.5 Risk Assessment

Taking the likelihood data from Section 5.3 and the consequence results from Section 5.4, the risk levels associated with the relevant fire scenarios are as follows:

Scenario	Description	Likelihood	Consequence	Risk (Fatalities/Year)
T1a	>25m with hose reels Successful first attack fire fighting	10.20%	4.12E-09	4.20E-10
T1b	>25m with hose reels Unsuccessful first attack fire fighting	0.80%	1.91E-08	1.53E-10
T2a	>25m without hose reels Successful first attack fire fighting	0.00%	1.91E-08	0.00E+00
T2b	>25m without hose reels Unsuccessful first attack fire fighting	11.00%	1.91E-08	2.10E-09
S1a	<25m with hose reels Successful first attack fire fighting	10.20%	5.43E-08	5.54E-09
S1b	<25m with hose reels Unsuccessful first attack fire fighting	0.80%	4.62E-07	3.69E-09

S2a	<25m without hose reels Successful first attack fire fighting	0.00%	4.62E-07	0.00E+00
S2b	<25m without hose reels Unsuccessful first attack fire fighting	11.00%	4.62E-07	5.08E-08

The table above shows the relative risk levels per fire event. In order to present the risk results in terms of fatalities per year across Australia, it is necessary to multiply the results by the likelihood of a fire in an office.

According to research by Savills, there is approximately 1.15 million square metres of office space being built in Australia, due for completion not later than 2019. Based on a fire start rate per square metre of 2.19×10^{-5}, the final risk change results, for the office space currently under construction are as follows:

Building height	**Risk level with hose reels**	**Risk level without hose reels**	**Change in risk level (fatalities per year)**	**Change in safety level (years per fatality)**
>25m	1.44E-08 (T1a + T1b)	5.29E-08 (T2a + T2b)	3.85E-08	2.60E+07
<25m	2.33E-07 (S1a + S1b)	1.28E-06 (S2a + S2b)	1.05E-06	9.55E+05

Commentary on results

The very small numbers are considered representative of real fire statistics. In sprinklered offices, data indicates there have been zero fatalities in Australia and New Zealand in sprinklered offices in over 100 years.

The change in safety level in office buildings with effective height less than 25m has been calculated as being two orders of magnitude greater than in buildings with effective height greater than 25m. This suggests that first aid fire fighting plays a more significant role in low rise office buildings. Relevant factors in this could be that low rise offices tend to have smaller floor plates, leading to greater exposure of occupants to smoke and that everyone typically has to move towards a single exit, with no opportunity to move away from or avoid the fire. Furthermore, as buildings less than 25m effective height may not be provided with sprinklers, the impact of first aid fire fighting is more pronounced.

In unsprinklered offices, there have been fatalities recorded. However with the limited data available from AFAC it is not possible to draw meaningful conclusions about whether the provision of first aid fire fighting played a role in the outcome of fires in unsprinklered buildings.

Only the occupants of the fire affected floor have been considered. Life safety benefit afforded to occupants elsewhere in the building by systems such as stair pressurisation and zone pressurisation has not been considered in the relative analysis. Assumptions and simplifications made during this analysis have tended to be conservative, leading to higher risk results and meaning the increase in risk as a results of deleting hose reels is at the upper limits of conservatism.

6 Conclusion

Data has shown that people are more likely to use a portable extinguisher than a fire hose reel, and that they are more likely to be successful in fighting a fire with an extinguisher than with a hose reel. As both the likelihood of use and the likelihood of success indicated by the epidemiological assessment are considered higher for extinguishers than for hose reels, the risk level is therefore expected to be lower in buildings provided with fire extinguishers in lieu of fire hose reels.

Notwithstanding the above, the analysis in this report shows that the anticipated risk increase for Class 5 buildings, as a result of deleting hose reels, is expected to be very small.

The quantitative analysis conducted as part of this study indicated that deleting hose reels would result in a risk increase of 0.000004% for buildings with effective height greater than 25m and of 0.000105% for buildings with effective height less than 25m. These very low risk increases are due to the small number of scenarios whereby fire hose reels are of use, and also that by the time they are of use the majority of people are expected to have exited the floor of fire origin.

Where there is only one exit, the potential for that exit to be blocked by a fire is a scenario in which the use of first aid fire fighting could provide significant benefit (and that benefit was not quantified in the engineering analysis undertaken in this study). Where there is more than one exit, this scenario becomes less important.

Therefore, in buildings that have sprinkler systems installed and where there are at least two exits available from each floor, the benefit afforded to occupants by fire hose reels is considered negligible. In buildings without sprinklers and with only a single exit, the potential for that exit to be blocked makes the benefit of first aid fire fighting more significant.

The qualitative assessment undertaken in this study has shown clear evidence that fire extinguishers would be a more appropriate means of first aid fire fighting by occupants of office buildings as they are more accessible, more appropriate to the source of ignition and less likely to delay evacuation. Compliance with AS2444 in sprinklered buildings typically results in the provision of a CO_2 extinguisher located alongside each fire hose reel. Deletion of fire hose reels would likely result in an additional extinguisher being required to address Class A fires and to complement the CO_2 extinguisher. In unsprinklered buildings, it is likely that more extinguishers would be required to meet AS2444 compliance however, as discussed above, more onerous requirements for extinguishers in buildings without sprinklers and/or with only one fire exit available, are considered appropriate.

Where assumptions or simplifications have been made in this report, they have been made in order to provide higher risk results and to provide results at the upper limits of conservatism resulting in a greater risk change. Despite this, the numbers produced are extremely small. It is likely that the analysis undertaken is sensitive to a number of the inputs and assumptions, however considering conservatism adopted and the order of magnitude of the results, the analysis is considered reasonable.

7 References

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Appendix A

Fire hazard assessment

A1 Office fire hazard assessment

Typical ignition sources in the offices may include cooking facilities in kitchens or tea rooms and electrical faults. Other reasons for fires are known to be smoking and external fires. If a fire begins, it is likely to first go through an incubation period or incipient stage. Figure 9 is adapted from NFPA 92B and shows a typical time-based illustration of the heat release rate of a continuously growing fire, known as t^2 fire. The incubation period may range from seconds to hours, however it is very difficult predict.

Tests carried out by NIST for work station fires showed that a typical work station fire develops as a slow or medium t^2 fire, see figure below, hence in the assessment carried out in this study a conservative medium growth rate t^2 fire has been used. A fast growth rate t^2 fire may be used for sensitivity cases, if the required.

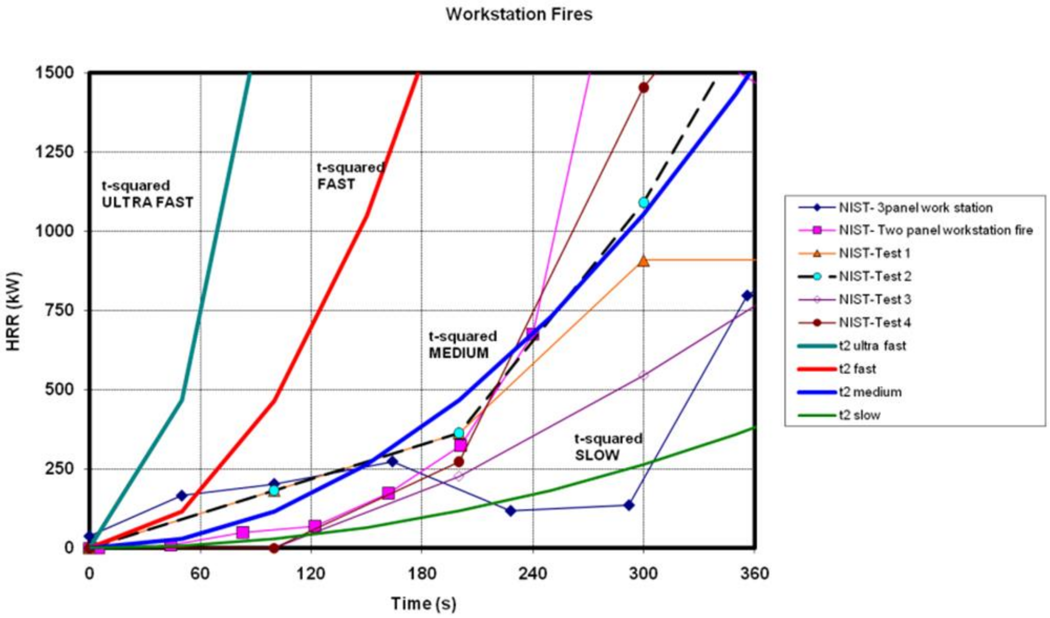

Figure 9: Work station fires showing typical fire growth rate of slow or medium t^2 fire.

The conditions of the occupants in offices, such as alertness and mobility, is not expected to typically pose a specific risk associated with achieving safe evacuation from a building. There is a small risk that some occupants are present after normal working hours; however they are likely to have faster evacuation times as the population density would be lower.

Appendix B

FDS modelling details

B1 Smoke modelling assessment

This appendix presents the details of the computational fluid dynamics (CFD) modelling undertaken for fires occurring in Class 5 buildings both above and below 25m in effective height.

The intent of this CFD modelling is to determine the fractional effective dose (FED) within the offices during a fire event. This information was then used to calculate the consequence for the risk assessment. The inputs for various parts of these models are summarised below.

B1.1 CFD Software and Set-up

B1.1.1 FDS

Fire Dynamics Simulator (FDS) version 6.1.1 has been used in this study to simulate three-dimensional air velocity, temperature and smoke distributions within the shopping centre. FDS is a CFD analysis program that has been developed specifically for fire and smoke spread modelling. The user guide contains technical documentation including verification and validation documents [27][28][29][30].

FDS allows the space to be defined in a three-dimensional environment with rectangular grid dividing the space into multiple numbers of cells. A fire source is then placed within this model acting as a source for heat and smoke to simulate the buoyancy driven smoke flow within the simulated space. Critical modelling outputs can be monitored with devices, such as the FED device

FDS allows the simulation of smoke spread to be carried out in a transient (time-based) manner under a fire situation.

B1.1.2 Mesh Resolution

At near field (i.e. around the area of fire origin), cell sizes were chosen with consideration of the fire phenomenon (i.e. the fire plume). Therefore, a uniform grid cell size of 0.2m × 0.2m × 0.2m (length × width × height, FDS grid IJK dimension) was adopted.

B1.1.3 Design Fuel Properties

For modelling purposes, it is necessary to have a design fire with fuel properties that are representative of the actual fuel considered, as this will have an impact on the amount of soot produced, thus affecting the conditions (i.e. visibility) calculated within the space.

All of the fire scenarios were analysed with the following typical fuel properties:

- Heat of combustion, Δ_{hc}, of 26MJ/kg
- Soot yield of 0.1 g/g

B1.1.4 Assumptions and Limitations

The following assumptions and simplifications have been used in the analysis:

- 30% of the heat release rate from the fire was radiation and 70% was convective heat released [31].
- The fire began to grow immediately and the incubation period was ignored. The fire was assumed to be a single flat burner a medium t^2 growth rate (i.e. grows as a function of time squared until activation of the suppression system or end of the simulation).
- The fire was well-ventilated and hence fuel controlled, having sufficient air/oxygen to grow to its peak heat release rate.
- External ambient temperature and initial temperature within the mall were assumed to be 20°C.

B1.2 Model Geometry

The CFD modelling covered two geometries: a typical DtS office in a building greater than 25m and a typical DtS office in a building less than 25m. These were described in Section 5.2.

Make up air has been provided via low level vents in the wall most remote from the fire. This is to provide sufficient oxygen to the fire and allow it to grow uninhibited.

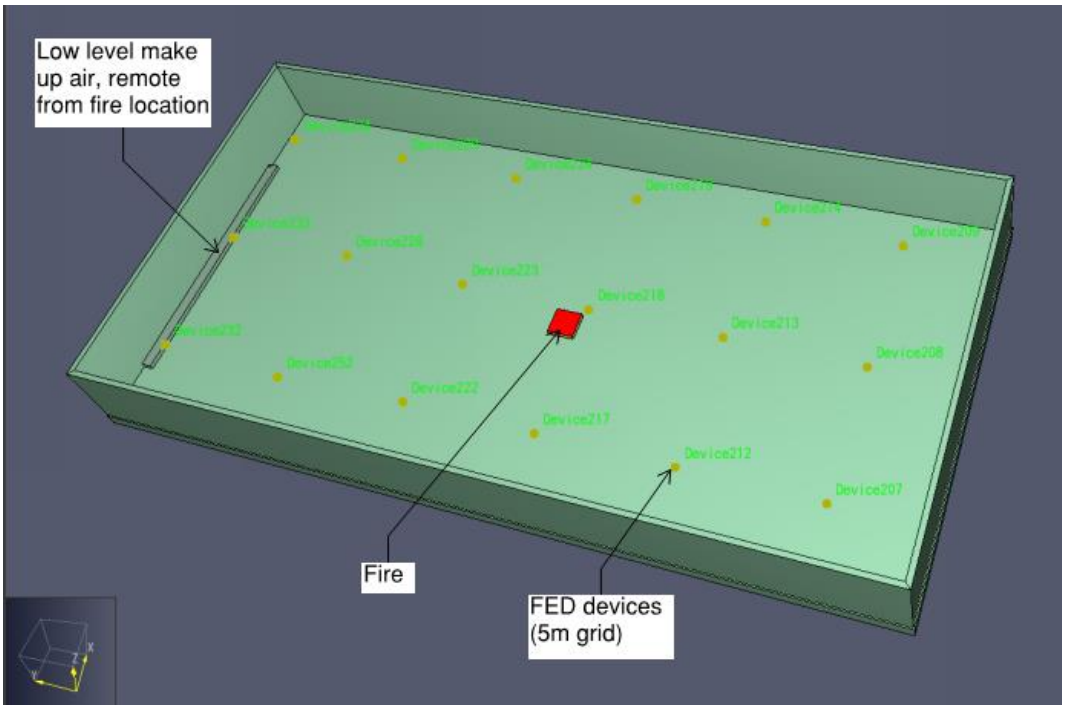

Figure 10 Model of <25m high building

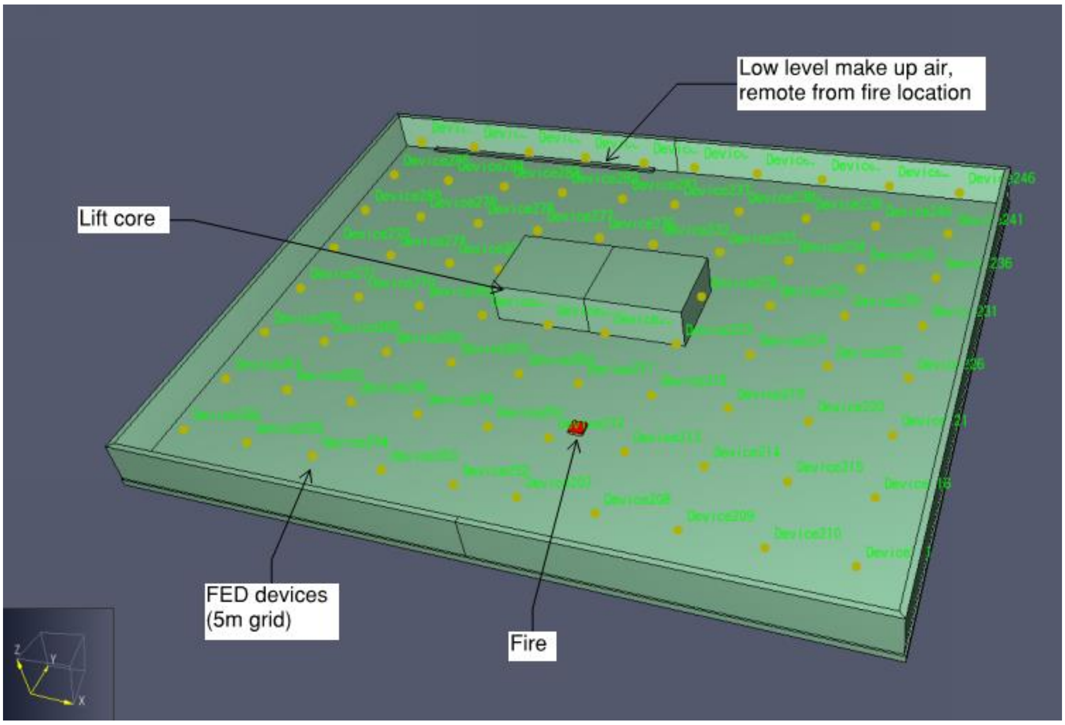

Figure 11 Model of >25m high building

B1.3 Fire Scenarios

The types of fires considered to be relevant have been identified in Appendix A of this report. Table 2 provides a summary of the fire scenarios that have been assessed.

B1.3.1 Determination of design fire sizes

For a fire occurring within the tall building (>25m), sprinklers would be expected to activate to control and limit the fire size when FHR are not present, or not used. The sprinkler activation time has been calculated using the computer program FPETool [32]. Use of FPETool tends to predict larger fire sizes than using FDS to predict the sprinkler activation time, hence this approach is conservative and consistent with the intent of all other assumptions in this study.

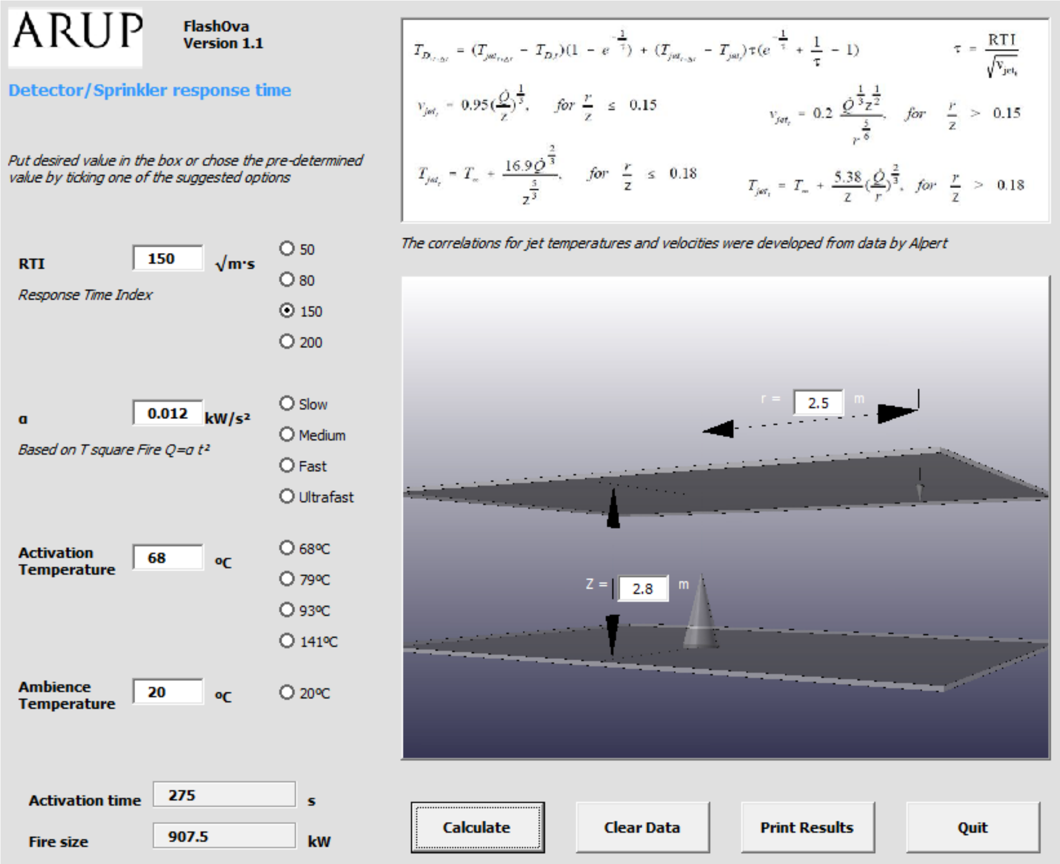

Figure 12 Sprinkler activation, Medium growth t^2 fire

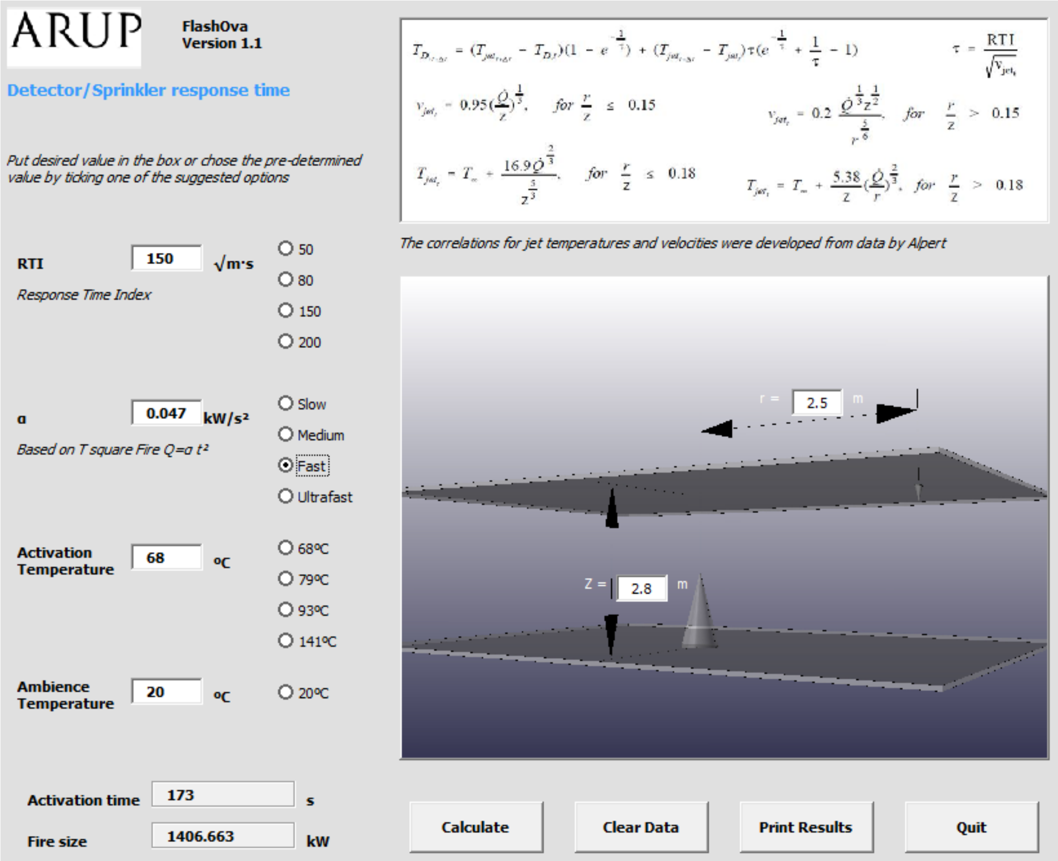

Figure 13 Sprinkler activation, Fast growth t² fire

For fires occurring in both buildings (above and below 25m effective height), detectors would be expected to activate and alert occupants to the fire and begin the evacuation and/or first attack fire-fighting process. The detector activation has been calculated using the computer program FPETool [32].

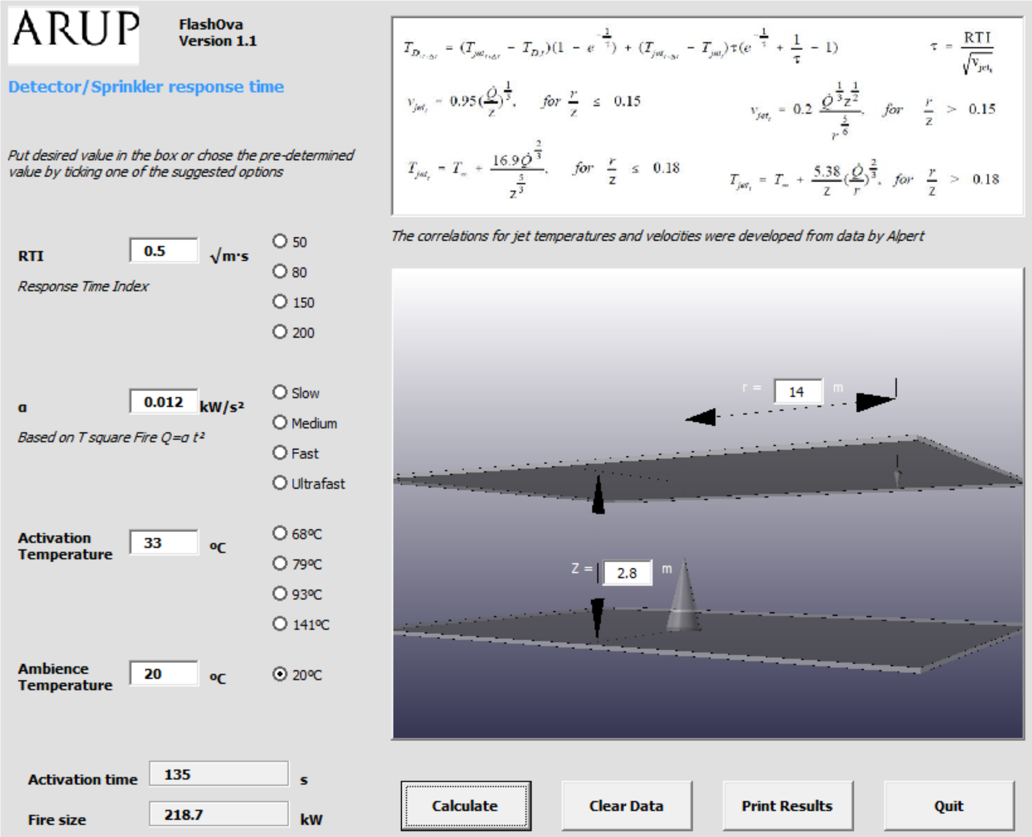

Figure 14 Detector activation, Medium growth t2 fire

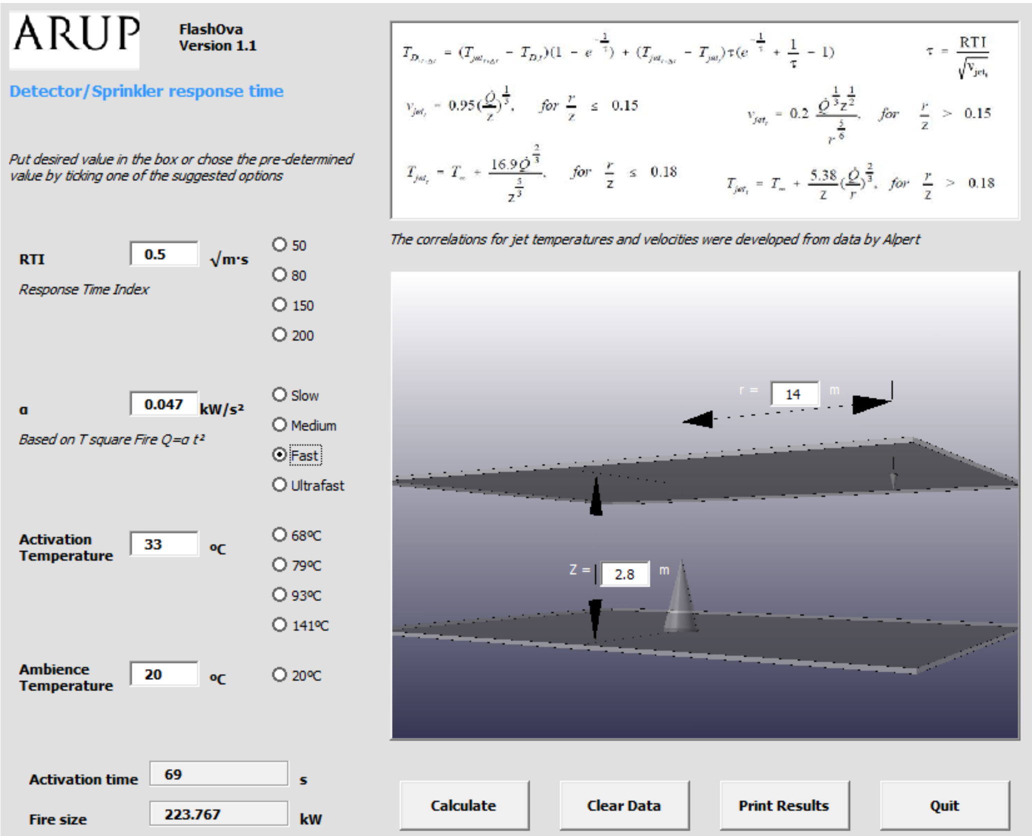

Figure 15 Detector activation, fast growth t2 fire

B1.3.2 Modelling Scenarios

Table 2 below lists the modelling scenarios being assessed in order to study the performance of the smoke exhaust system.

Table 2: Fire scenarios for assessment

Scenario	**Description**	**Fire Growth Rate**	**Fire Size**
T1_base	>25m building FHR controlled fire	Medium t^2	386kW
T2_base	>25m building Sprinkler controlled fire	Medium t^2	907kW
T1_sensitivity	>25m building FHR controlled fire	Fast t^2	557kW
T2_sensitivity	>25m building Sprinkler controlled fire	Fast t^2	1406kW
S1_base	<25m building FHR controlled fire	Medium t^2	168kW
S2_base	<25m building Uncontrolled fire	Medium t^2	1054kW at the end of the simulation
S1_sensitivity	<25m without hose reels FHR controlled fire	Fast t^2	396kW
S2_sensitivity	<25m without hose reels Uncontrolled fire	Fast t^2	4220kW at the end of the simulation

B2 Appendix C references

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