Ministry of Business, Innovation & Employment

C/VM2

Verification Method: Framework for Fire Safety Design

For New Zealand Building Code Clauses C1-C6 Protection from Fire

ARCHIVED

C

BUILDING CODE

Using this Verification Method

The Ministry of Business, Innovation and Employment may amend parts of this Verification Method at any time. People using this Verification Method should check on a regular basis whether new versions have been published. The current version can be downloaded from www.dbh.govt.nz/compliance-documents

Users should make themselves familiar with the preface to the New Zealand Building Code Handbook, which describes the status of Verification Methods and explains other ways of achieving compliance.

Defined words (italicised in the text) are explained in the Building Code Clause A2 and in the Definitions section of this Verification Method. Classified uses of buildings are explained in the Building Code Clause A1. Importance levels of building are buildings (italicised in the text) are explained in the Building Code Clause A3.

Enquiries about the content of this document should be directed to:

Ministry of Business, Innovation & Employment

The Ministry of Business, Innovation and Employment
PO Box 10-729, Wellington.
Telephone 0800 242 243
Fax 04 494 0290
Email: info@dbh.govt.nz

ISBN: 978-0-478-38164-1 (print)
ISBN: 978-0-478-38165-8 (electronic)

Acceptable Solutions and Verification Methods are available from www.dbh.govt.nz/compliance-documents

New Zealand Government

Status of C/VM2

This Verification Method C/VM2, Framework for Fire Safety Design, provides a means of compliance with the New Zealand Building Code Clauses C1-C6 Protection from Fire. It is issued under section 22 of the Building Act 2004 as a compliance document.

This Verification Method is one way that can be used to show compliance with the New Zealand Building Code Clauses C1-C6 Protection from Fire. Other ways of complying with the Building Code are described, in general terms, in the preface of the New Zealand Building Code Handbook.

When can you use C/VM2

The Building Code Clauses C1-C6 Protection from Fire take effect on 10 April 2012. The Building Code Clauses C1-C6 Protection from Fire replaces the Building Code Clauses C1-C4 Fire Safety on 9 April 2013.

This Verification Method is effective from 15 February 2013. It can be used to show compliance with the Building Code Clauses C1-C6 Protection from Fire. It does not apply to building consents issued before 15 February 2013.

The Compliance Document for Fire Safety Amendment 9 may be used to show compliance with the Building Code Clauses C1-C4 Fire Safety for building consent applications made before 10 April 2013.

From 10 April 2013, the Compliance Document for Fire Safety Amendment 9 ceases to have effect.

Document History

	Date	Alterations	
New document	Effective from 10 April 2012	C/VM2 is a new publication that can be used to show compliance with the Building Code Clauses C1-C6 Protection from Fire.	
Errata 1	Effective from 30 April 2012	p. 11, 1.2 p. 13, Figure 1.1 a) p. 19, Figure 1.1 g)	p. 32, Table 2.3 p. 39, Table 3.3 p. 59, 4.9
Errata 2	Effective from 15 February 2013	p. 9 Definitions pp. 25–26 2.2.1 p. 33 Table 2.4 p. 40 3.2.4 p. 41 3.2.7	p. 58 4.8 p. 59 4.9 p. 61 4.10 p. 64 Index

Contents

References

For the purposes of New Zealand Building Code (NZBC) compliance, the Standards and documents referenced in this Compliance Document (primary reference documents) must be the editions, along with their specific amendments, listed below. Where these primary reference documents refer to other Standards or documents (secondary reference documents), which in turn may also refer to other Standards or documents, and so on (lower-order reference documents), then the version in effect at the date of publication of this Compliance Document must be used.

Standards New Zealand		
NZS 4510: 2008	Fire hydrant systems for buildings *Amend: 1*	4.8
NZS 4512: 2010	Fire detection and alarm systems in buildings	3.4
NZS 4515: 2009	Fire sprinkler systems for life safety in sleeping occupancies (up to 2000 m^2)	Definitions
NZS 4541: 2007	Automatic fire sprinkler systems *Amend: 1*	Definitions
AS/NZS 3837: 1998	Method of test for heat and smoke release rates for materials and products using an oxygen consumption calorimeter	4.6
Standards Australia		
AS 1366:-	Rigid cellular plastics sheets for thermal insulation	
Part 1: 1992	Rigid cellular polyurethane (RC/PUR) *Amend: 1*	4.7
Part 2: 1992	Rigid cellular polyisocyanurate (RC/PIR)	4.7
Part 3: 1992	Rigid cellular polystyrene – moulded (RC/PS-M) *Amend: 1*	4.7
Part 4: 1989	Rigid cellular polystyrene – extruded (RC/PS-E)	4.7
AS 1530:-	Methods for fire tests on building materials, components and structures	
Part 1: 1994	Combustibility test for materials	4.7
Part 2: 1993	Test for flammability of materials	4.7
Part 4: 2005	Fire resistance tests for elements of construction	2.4
British Standards Institution		
BS 7273:-	Code of practice for the operation of fire protection measures	
Part 4: 2007	Actuation of release mechanisms for doors	4.10
International Standards Organisation		
ISO 1182: 2010	Reaction to fire tests for products – Non-combustibility test	4.7
ISO 5660:-	Reaction-to-fire tests	
Part 1: 2002	Heat release, smoke production and mass loss rate	4.6, 4.7, A1.1, A1.2, A1.3
Part 2: 2002	Smoke production rate (dynamic measurement)	A1.1
ISO 9239:-	Reaction to fire tests for floorings	
Part 1: 2010	Determination of the burning behaviour using a radiant heat source	4.7 Figure 1.1 h)

ISO 9705: 1993	Fire tests – Full-scale room test for surface products	4.7, A1.1, A1.2 Figure 1.1 h)
ISO 13571: 2007	Life-threatening components of fire Guidelines for the estimation of time available for escape using fire data.	2.2.1
ISO 13784:-	Reaction-to-fire tests for sandwich panel building systems	
Part 1: 2002	Test method for small rooms	A1.1
ISO 13785:-	Reaction-to-fire tests for façades	
Part 1: 2002	Intermediate-scale test	4.6

European Committee for Standardisation

Eurocode DD ENV 1991:-	Eurocode 1: basis of design and actions on structures,	
Part 2.2: 1996	Actions on structures exposed to fire	2.4 Comment, 2.4.4

National Fire Protection Association of America

NFPA 285: 1998	Standard method of test for the evaluation of flammability characteristics of exterior non-load-bearing wall assemblies containing components using the intermediate scale, multi-storey test apparatus	4.6

BRANZ Ltd

BRANZ Study Report No. 137: 2005 Development of the Vertical Channel Test Method for Regulatory Control of Combustible Exterior Cladding Systems, Whiting, P. N.	4.6

Australian Building Codes Board

International Fire Engineering Guidelines (IFEG): 2005	1.3

Society of Fire Protection Engineers

The Handbook of Fire Protection Engineering, 4th Edition, National Fire Protection Association, Quincy, M.A, USA, 2008.	
Gwynne, S.M.V, and Rosenbaum, E.R, "Employing the Hydraulic Model in Assessing Emergency Movement", Section 3 Chapter 13.	3.2 Comment 3.2.6 Comment
SFPE Engineering Guide to Predicting 1st and 2nd Degree Skin Burns from Thermal Radiation, 2000	3.6.1

General publications

Fire Engineering Design Guide (Centre for Advanced Engineering, 2008)	2.4.4 Comment

Definitions

The full list of definitions for italicised words may be found in the New Zealand Building Code Handbook.

Available safe egress time (ASET) Time available for escape for an individual occupant. This is the calculated time interval between the time of ignition of a fire and the time at which conditions become such that the occupant is estimated to be incapacitated (ie, unable to take effective action to escape to a *place of safety*).

Burnout Means exposure to fire for a time that includes fire growth, full development, and decay in the absence of intervention or automatic suppression, beyond which the fire is no longer a threat to building elements intended to perform loadbearing or fire separation functions, or both.

Computational fluid dynamics (CFD) Calculation method that solves equations to represent the movement of fluids in an environment.

Design fire Quantitative description of assumed *fire* characteristics within the *design scenario*.

Design scenario Specific scenario on which a deterministic *fire safety engineering* analysis is conducted.

Detection time Time interval between ignition of a *fire* and its detection by an automatic or manual system.

Evacuation time Time interval between the time of warning of a *fire* being transmitted to the occupants and the time at which the occupants of a specified part of a *building* or all of the *building* are able to enter a *place of safety*.

Fire decay Stage of *fire* development after a *fire* has reached its maximum intensity and during which the *heat release rate* and the temperature of the *fire* are decreasing.

Fire growth Stage of *fire* development during which the *heat release rate* and the temperature of the *fire* are increasing.

Fire load Quantity of heat which can be released by the complete combustion of all the *combustible* materials in a volume, including the facings of all bounding surfaces (Joules).

Fire load energy density (FLED) *Fire load* per unit area (MJ/M^2).

Fire safety engineering Application of engineering methods based on scientific principles to the development or assessment of designs in the built environment through the analysis of specific *design scenarios* or through the quantification of risk for a group of *design scenarios*.

Flashover Stage of *fire* transition to a state of total surface involvement in a *fire* of *combustible* materials within an enclosure.

Fractional effective dose (FED) The fraction of the dose (of carbon monoxide (CO) or thermal effects) that would render a person of average susceptibility incapable of escape.

Comment:
The definition for FED has been modified from the ISO definition to be made specific for this Verification Method. The ISO definition is "Ratio of the exposure dose for an insult to that exposure dose of the insult expected to produce a specified effect on an exposed subject of average susceptibility."

Fully developed fire State of total involvement of *combustible* materials in a *fire*.

Heat of combustion Thermal energy produced by combustion of unit mass of a given substance (kJ/g).

Heat release Thermal energy produced by combustion (Joules).

Heat release rate (HRR) Rate of thermal energy production generated by combustion (kW or MW).

Importance level As specified in Clause A3 of the *Building Code*.

Incapacitated State of physical inability to accomplish a specific task. Errata 2 Feb 2013

Insulation In the context of *fire* protection, the time in minutes for which a prototype specimen of a *fire separation*, when subjected to the *standard test* for *fire* resistance, has limited the transmission of heat through the specimen.

Integrity In the context of *fire* protection, the time in minutes for which a prototype specimen of a *fire separation*, when subjected to the *standard test* for *fire* resistance, has prevented the passage of flame or hot gases.

Comment:
The precise meaning of *integrity* depends on the type of *building elements* being treated and how it is defined in the *standard test* being used.

Optical density of smoke Measure of the attenuation of a light beam passing through smoke expressed as the logarithm to the base 10 of the opacity of smoke.

Opacity of smoke Ratio of incident light intensity to transmitted light intensity through smoke under specified conditions.

Place of safety means either—

a) a *safe place*; or

b) a place that is inside a *building* and meets the following requirements:

  i) the place is constructed with *fire separations* that have *fire* resistance sufficient to withstand *burnout* at the point of the *fire source*; and

  ii) the place is in a *building* that is protected by an automatic fire sprinkler system that complies with NZS 4541 or NZS 4515 as appropriate to the *building's* use; and

  iii) the place is designed to accommodate the intended number of persons; and

  iv) the place is provided with sufficient means of escape to enable the intended number of persons to escape to a *safe place* that is outside a *building*.

Pre-travel activity time Time period after an alarm or *fire* cue is transmitted and before occupants first travel towards an exit.

Required safe egress time (RSET) Time required for escape. This is the calculated time period required for an individual occupant to travel from their location at the time of ignition to a *place of safety*.

Response Time Index (RTI) The measure of the reaction time to a *fire* phenomenon of the sensing element of a *fire safety system*.

Safe place A place, outside of and in the vicinity of a single *building* unit, from which people may safely disperse after escaping the effects of a *fire*. It may be a place such as a street, *open space*, public space or an *adjacent building* unit.

Comment:
The Fire Safety and Evacuation of Buildings Regulations 2006 use the term *'place of safety'* and allow the *place of safety* to be within the *building* provided that it is protected with a sprinkler system.

Separating element Barrier that exhibits fire *integrity*, *structural adequacy*, thermal *insulation*, or a combination of these for a period of time under specified conditions (in a fire resistance test).

Smoke production rate Amount of smoke produced per unit time in a *fire* or *fire* test.

Specific extinction area of smoke Extinction area of smoke produced by a test specimen in a given time period, divided by the mass lost from the test specimen in the same time period.

Structural adequacy In the context of the *standard test* for *fire* resistance, is the time in minutes for which a prototype specimen has continued to carry its applied load within defined deflection limits.

Surface spread of flame Flame spread away from the source of ignition across the surface of a liquid or a solid.

Travel distance Distance that is necessary for a person to travel from any point within a built environment to the nearest exit, taking into account the layout of walls, partitions and fittings.

Visibility Maximum distance at which an object of defined size, brightness and contrast can be seen and recognised.

Yield Mass of a combustion product generated during combustion divided by the mass loss of the test specimen.

1 Introduction and scope

CONTENTS

1.1 Purpose

This is a Verification Method for the specific design of *buildings* to demonstrate compliance with NZBC C1 to C6 Protection from Fire. It is suitable for use by professional fire engineers who are proficient in the use of fire engineering modelling methods.

1.2 Scope

This Verification Method can be applied to *fire* designs for all *buildings*.

Comment:
This Verification Method will usually be used for *fire* designs that, for whatever reason, cannot be shown to comply with NZBC C: Protection from Fire using the relevant Acceptable Solutions C/AS1 to C/AS7. However, a designer may opt to use this Verification Method even if the building could be designed using the Acceptable Solutions.

Errata 1 Apr 2012

There are some minor exceptions to 'all *buildings*', for example tunnels.

1.3 How to use this Verification Method

This Verification Method sets out 10 *design scenarios* that must each be considered and designed for, where appropriate, in order to achieve compliance with NZBC C: Protection from Fire.

Trial the *fire* design based on the requirements ascertained via the Fire Engineering Brief (FEB) as described in the International Fire Engineering Guidelines and other *fire* engineering process documents.

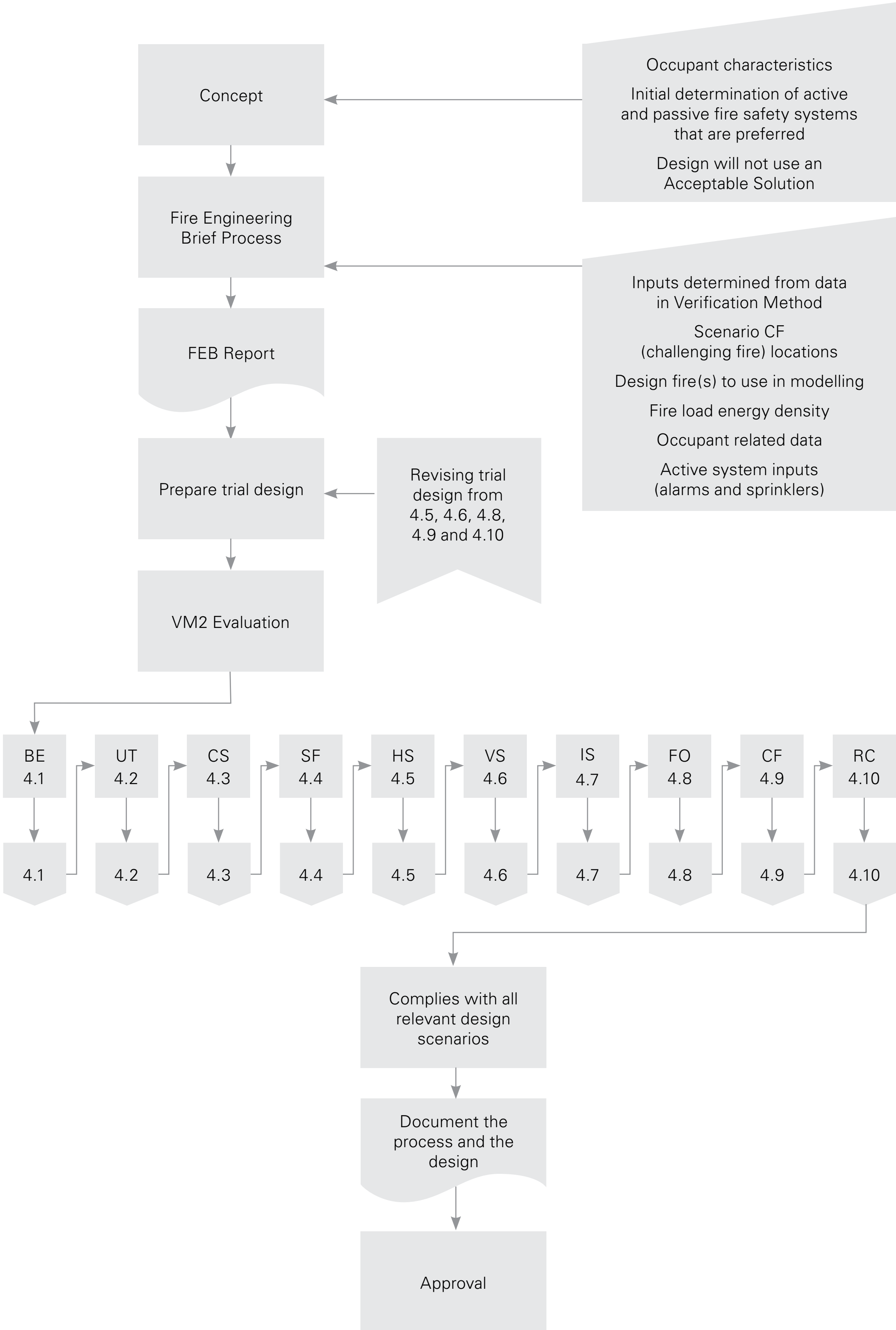
Follow the process shown in Figure 1.1 as appropriate, analysing or testing the *fire* design against the *design scenarios* as applicable and modelling the *design scenario*: CF Challenging Fire (see Paragraph 4.9) a number of times with the *design fire* positioned in the most challenging locations.

Comment:
ASET/RSET and other computational modelling is only required for a few of the *design scenarios*. Many can be satisfied by inspection or by providing certain features (eg, *fire separations* or smoke detection systems).

In many cases the location that is the most challenging (that which will provide the shortest *ASET/RSET*) will be easily determined.

In all parts of Figure 1, the numbered references are to paragraph numbers in this Verification Method.

Figure 1.1 a): The design process for C/VM2



Errata 1
Apr 2012

Figure 1.1 b): Design scenario BE – Blocked exit

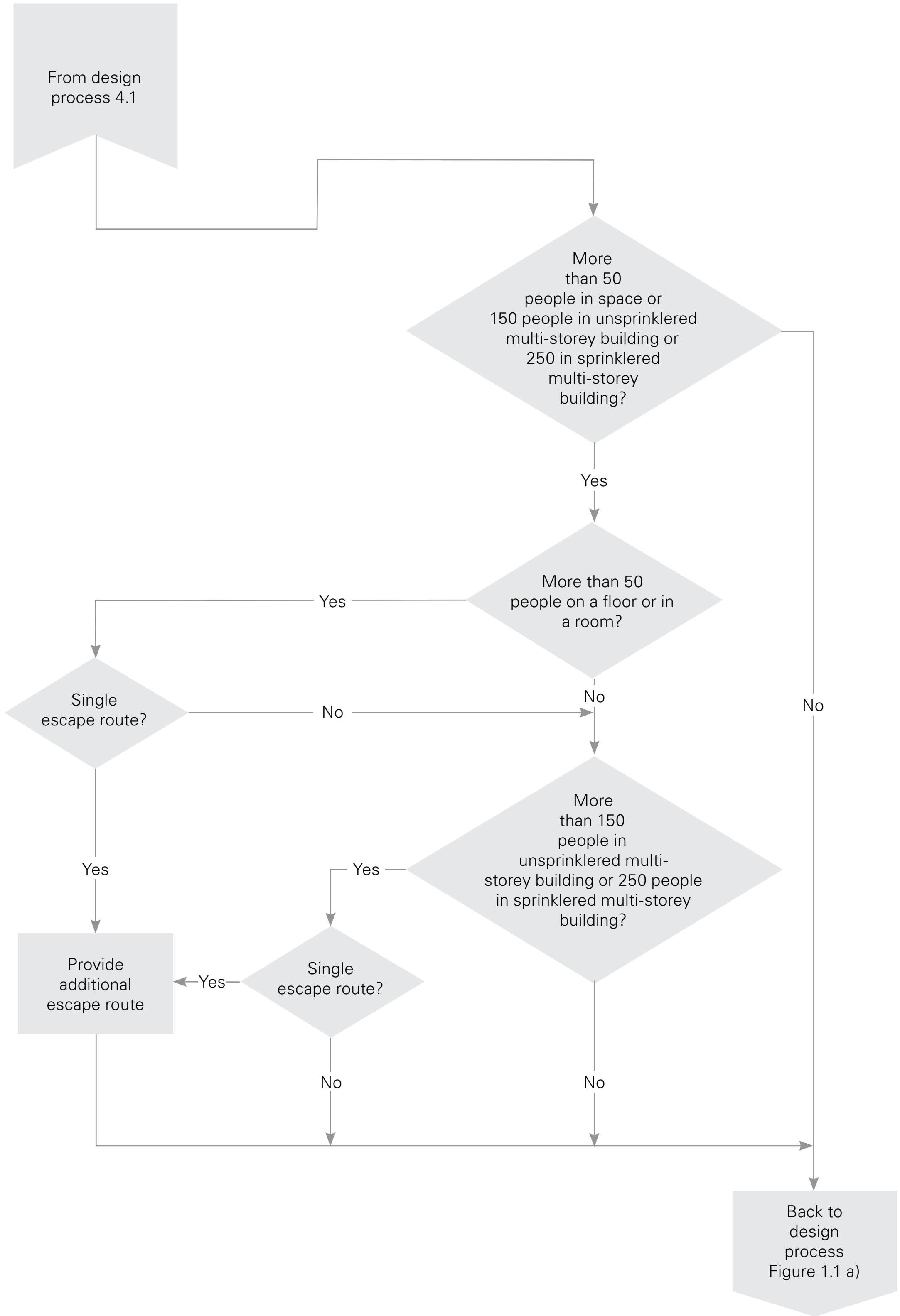


Figure 1.1 c): Design scenario UT – Unknown threat in unoccupied room

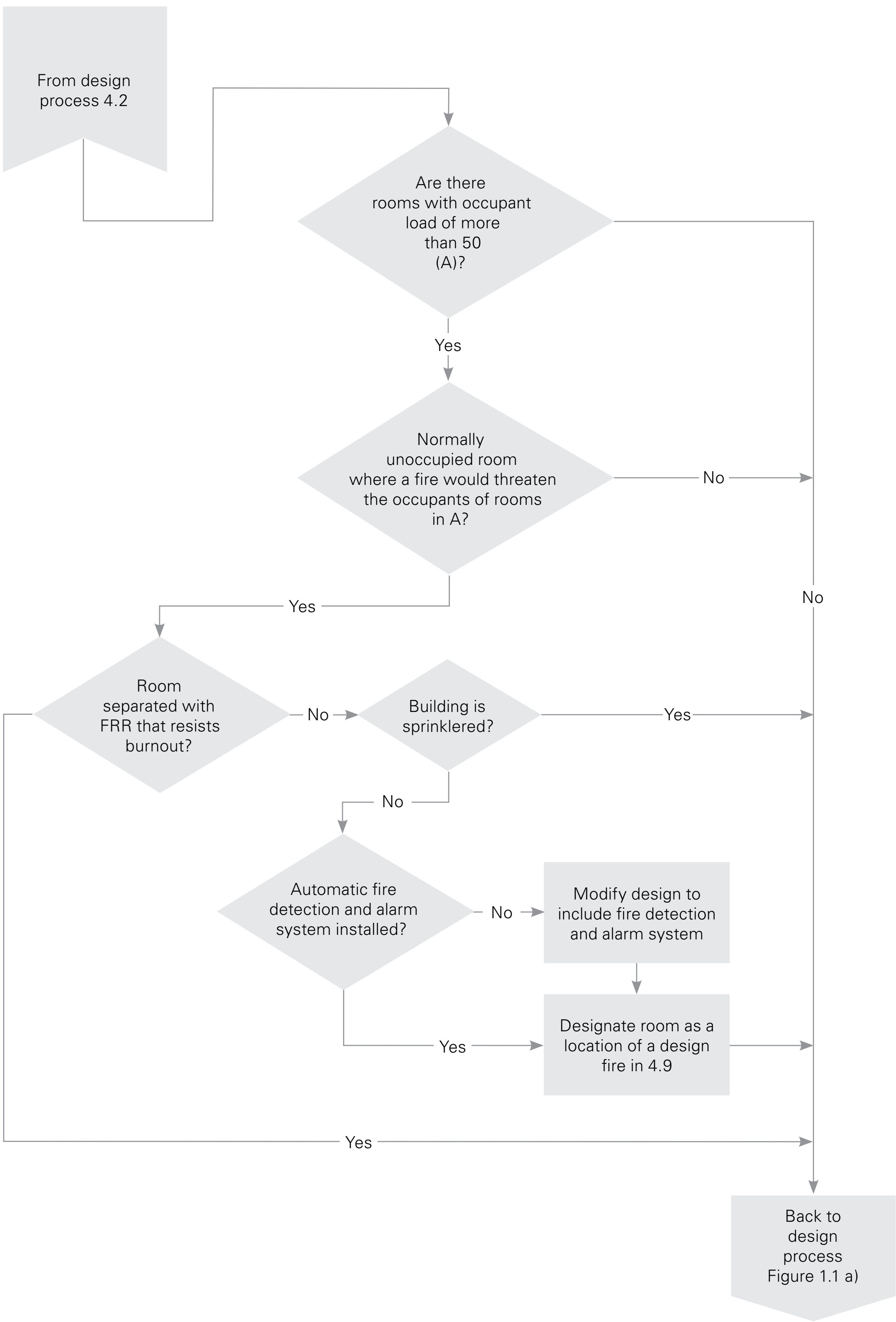


Figure 1.1 d): Design scenario CS – Concealed space

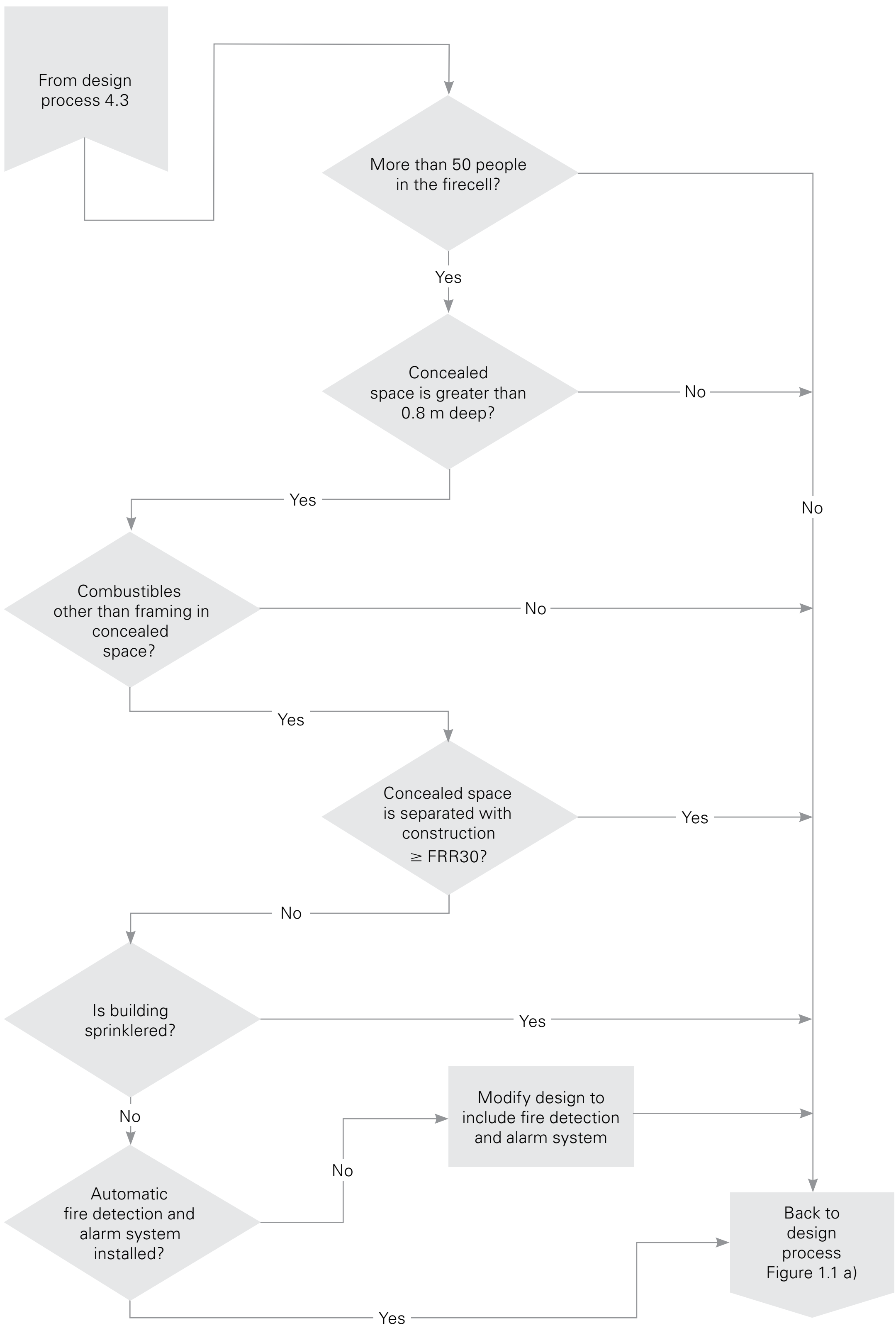


Figure 1.1 e): Design scenario SF – Smouldering fire

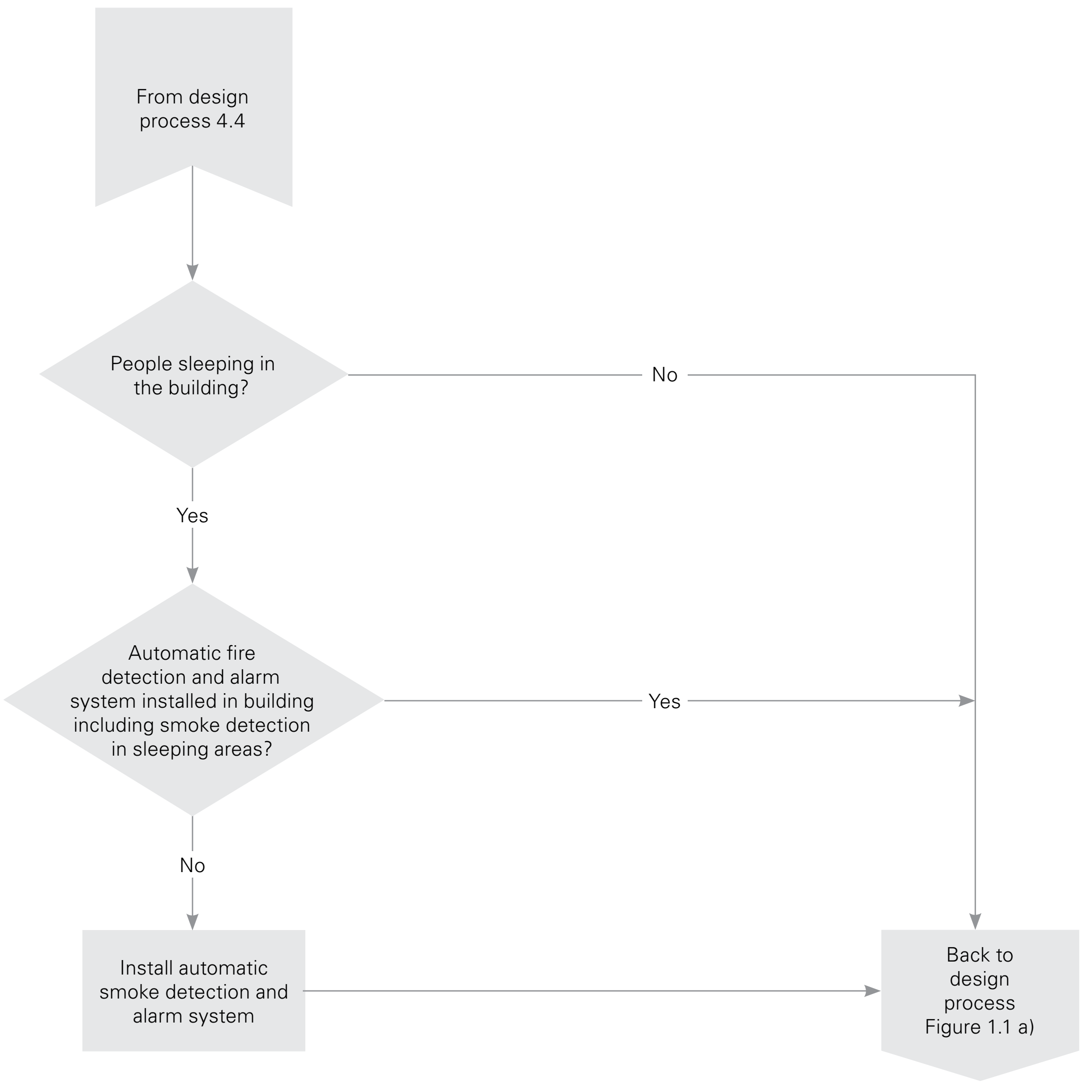
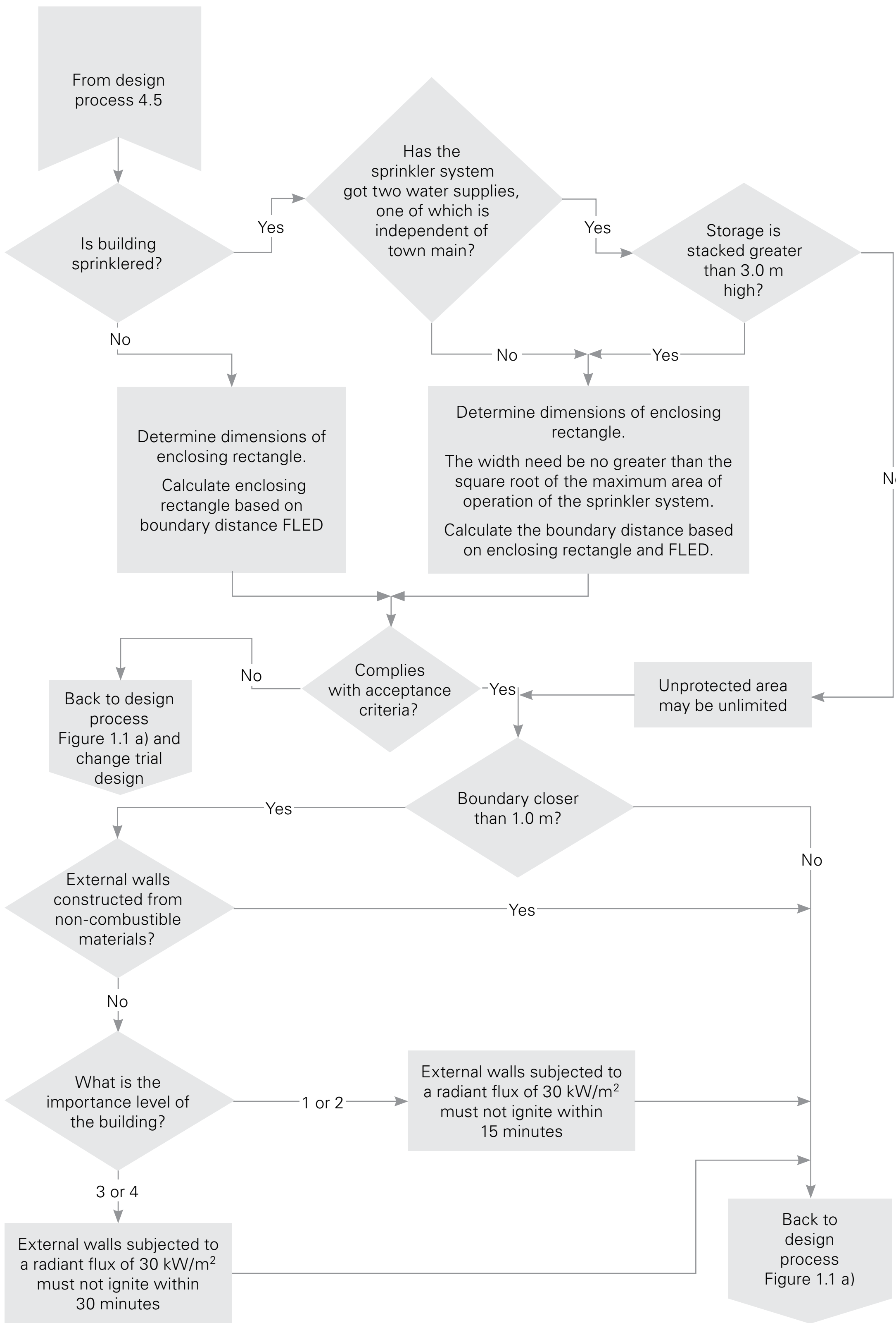


Figure 1.1 f): Design scenario HS – Horizontal spread of fire



Errata 1
Apr 2012

Figure 1.1 g): Design scenario VS – Vertical spread of fire

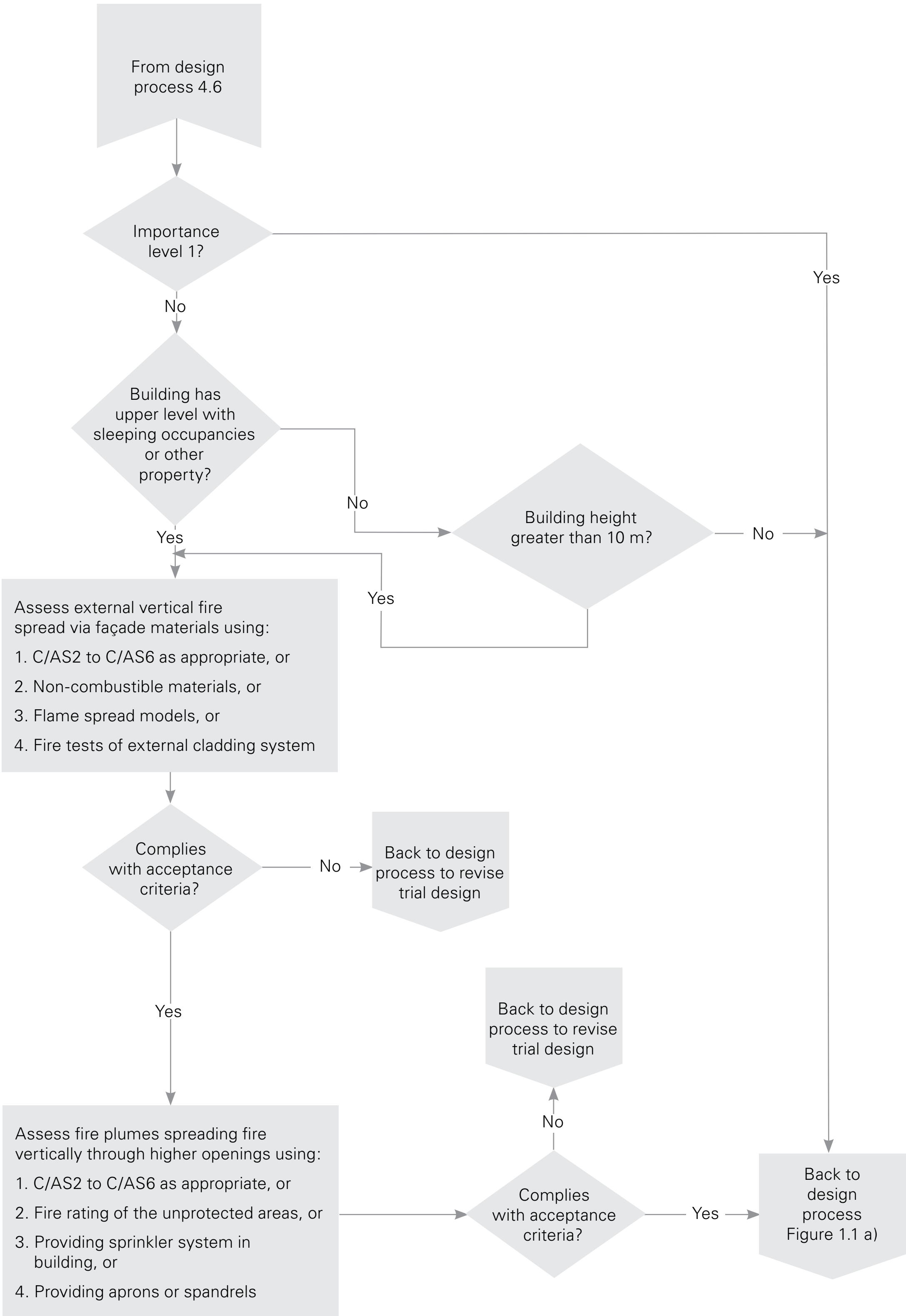
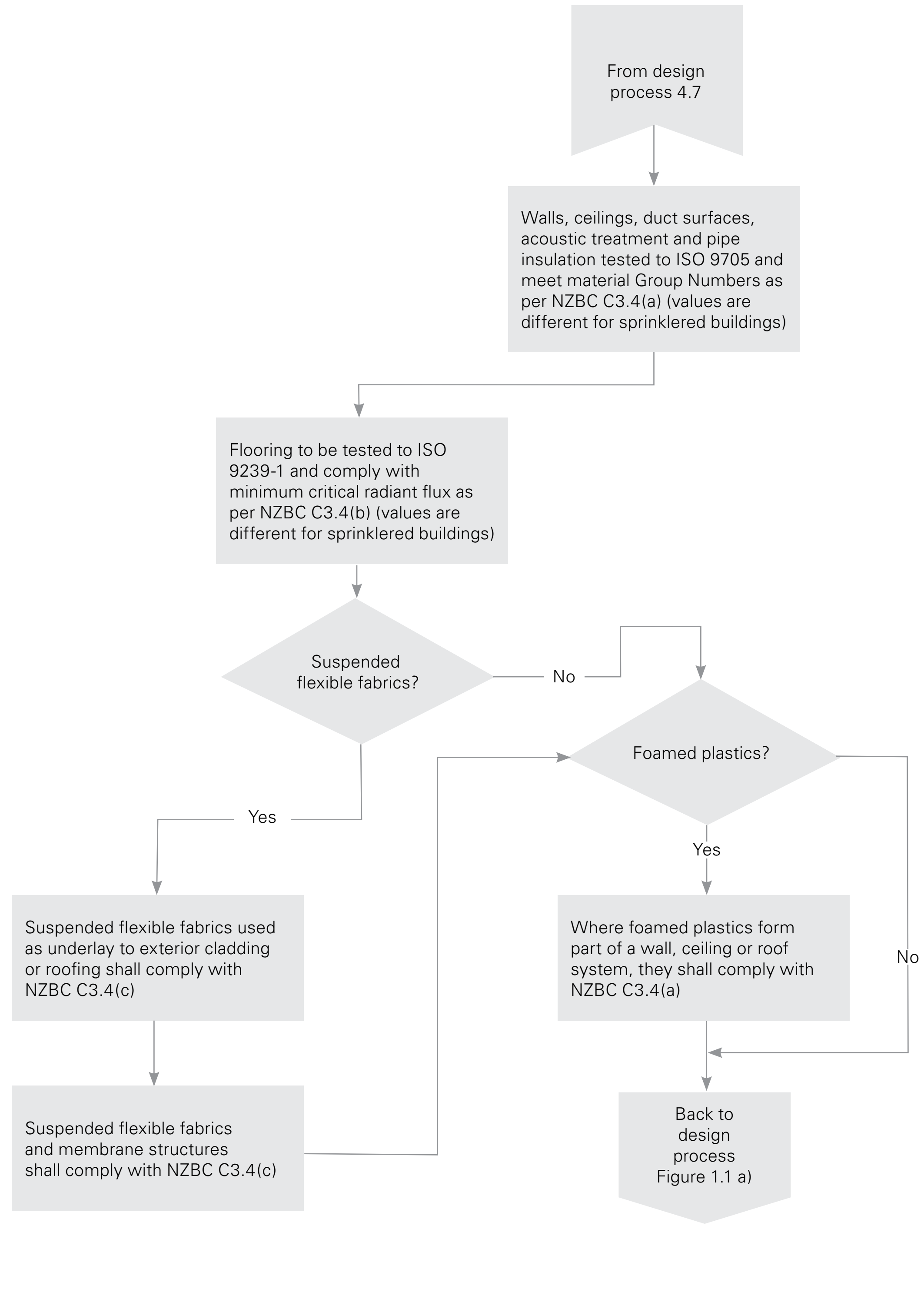


Figure 1.1 h): Design scenario IS – Surface finishes



Errata 1
Apr 2012

Figure 1.1 i): Design scenario FO – Firefighting operations

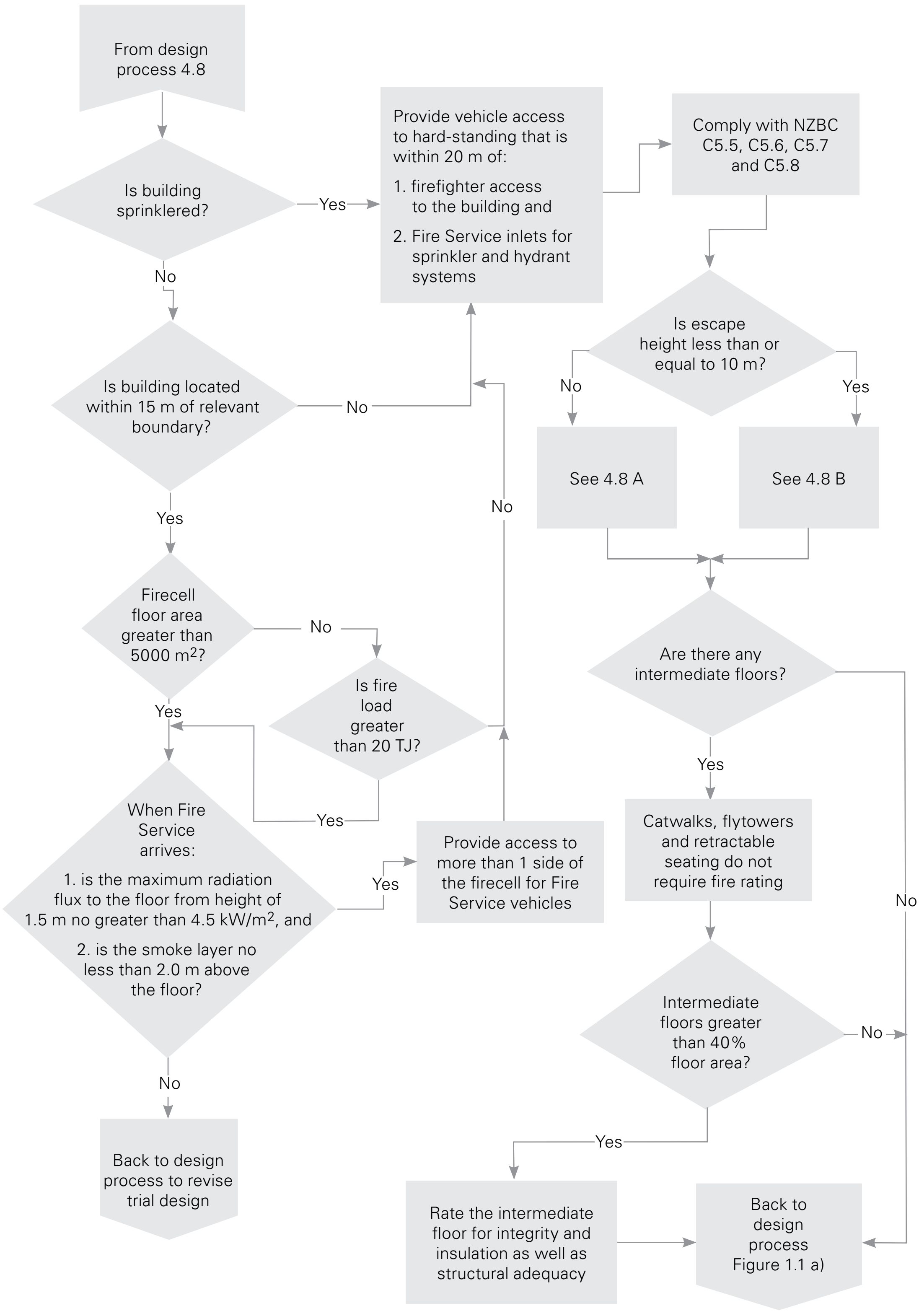


Figure 1.1 j): Design scenario CF – Challenging fire

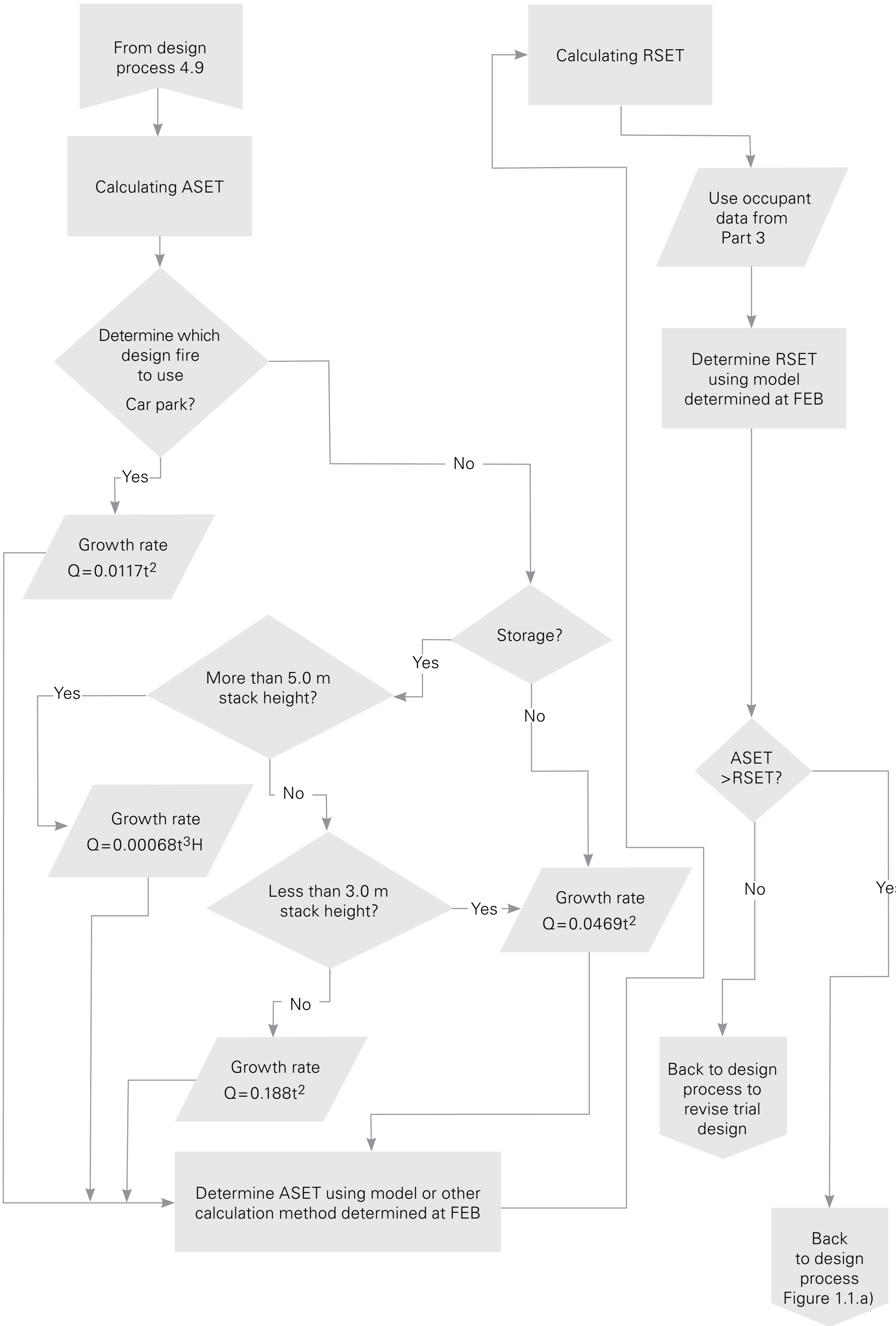
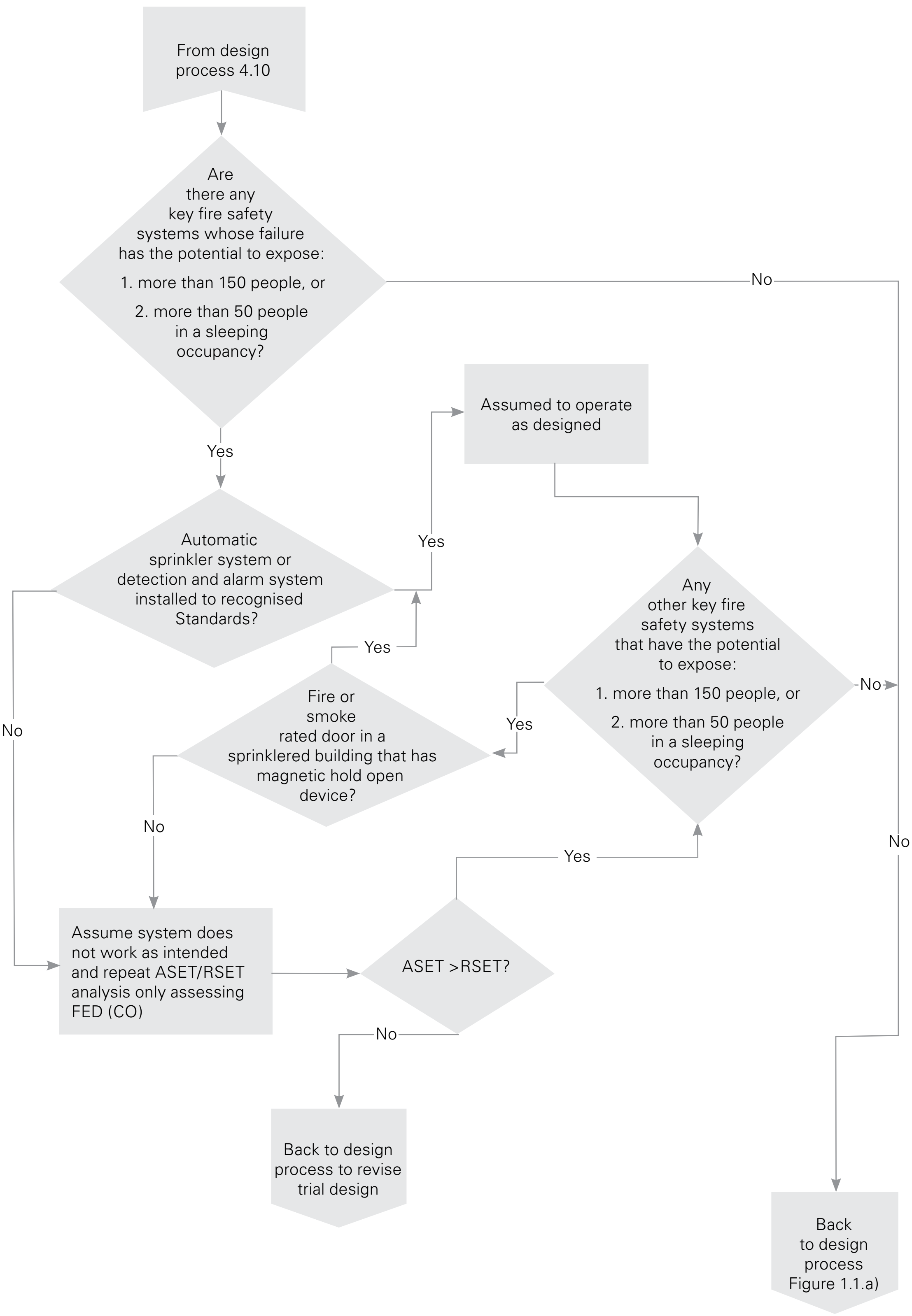


Figure 1.1 k): Design scenario RC – Robustness check



1.4 Design scenarios: Building Code objectives and performance criteria

The *design scenarios* specified in Part 4 are summarised in Table 1.1 (with paragraph numbers given in brackets for ease of reference). Each scenario must be considered separately to achieve the *Building Code* objectives and to satisfy the performance criteria of the *Building Code* clauses shown.

Table 1.1 Key features of design scenarios

Design scenario		*Building Code* objectives	*Building Code* criteria	Expected method
Keeping people safe				
BE	*Fire* blocks exit (4.1)	C1(a)	C4.5	Solved by inspection
UT	*Fire* in a normally unoccupied room threatening occupants of other rooms (4.2)	C1(a)	C4.3, C4.4	*ASET/RSET* analysis or provide *separating elements*/suppression complying with a recognised Standard
CS	*Fire* starts in a *concealed space* (4.3)	C1(a)	C4.3	Provide *separating elements*/suppression or automatic detection complying with a recognised Standard
SF	Smouldering *fire* (4.4)	C1(a)	C4.3	Provide automatic detection and alarm system complying with a recognised Standard
IS	Rapid *fire* spread involving internal surface linings (4.7)	C1(b)	C3.4	Suitable materials used (proven by testing)
CF	Challenging *fire* (4.9)	C1(a)	C4.3, C4.4	*ASET/RSET* analysis
RC	Robustness check (4.10)	C1(a), C1(b), C1(c)	C3.9, C4.5, C5.8, C6.2(d)	Modified *ASET/RSET* analysis
Protecting other property				
HS	Horizontal *fire* spread (4.5)	C1(b), C1(a)	C3.6, C3.7, C4.2	Calculate radiation from *unprotected areas* as specified
VS	Vertical *fire* spread involving external cladding (4.6)	C1(a), C1(b)	C3.5	Suitable materials used (proven by testing) and *construction* features specified (eg, aprons/spandrels/sprinklers) as required to limit vertical *fire* spread
Firefighting operations				
FO	Firefighting operations (4.8)	C1(b), C1(c)	C3.8, C5.3, C5.4, C5.5, C5.6, C5.7, C5.8, C6.3	Demonstrate firefighter safety

Part 2: Rules and parameters for the design scenarios

CONTENTS

2.1 Applying the design scenarios

This Verification Method sets out 10 *design scenarios* that must each be considered and designed for, where appropriate, in order to achieve compliance with NZBC C1-C6: Protection from Fire.

This section sets out the *fire* modelling rules, *design fire* characteristics and other parameters to be used in calculations required by the *design scenarios*. Occupancy criteria and calculations for the movement of people are provided in Part 3.

2.2 Fire modelling rules

The *fire* modelling rules in Paragraphs 2.2.1 and 2.2.2 shall be applied to the *design scenarios* as appropriate.

2.2.1 Fire modelling rules for life safety design

Fire modelling rules for life safety design shall be as follows:

a) Warning systems in accordance with Paragraph 3.4 shall be installed.

b) *Fire* and *smoke control doors* with self-closers complying with a recognised national or international Standard are assumed closed unless being used by occupants. During egress, when *occupant load* is low, doors are assumed to be open for three seconds per occupant. However, when the *occupant load* is high and queuing is expected, the door is considered to be open for the duration of queuing.

c) All doors not described in 2.2.1 b) shall be considered to be open during the analysis.

d) Doors being used for egress, when in the open position, are assumed to be half-width for smoke flow calculations.

e) Where zone modelling is used, leakage through non *fire*-rated walls shall be calculated according to Paragraph 2.2.1 g) and modelled as a tall narrow slot from floor to ceiling with the width of the vent determined by the calculated area. A single slot may be used to represent the total wall leakage in the compartment. Errata 2 Feb 2013

Errata 2 Feb 2013

f) Where *CFD* modelling is used, leakage area shall be calculated according to Paragraph 2.2.1 g) and modelled either as a vertical slot as in zone modelling or as two vents, one at floor level and one at ceiling level, to fit within the computational grid.

g) Leakage areas assumed for modelling shall be as follows:

   i) *smoke separations* and *smoke control doors* that comply with a recognised national or international Standard (including doors that have both *fire* and smoke control capability complying with a recognised national or international Standard) are assumed to have zero leakage area, except for a 10 mm gap under doors

   ii) *fire* doors that are not *smoke control doors* are assumed to have a 10 mm gap over the height of the door

   iii) *construction* having a *fire resistance rating* (excluding doors) is considered to have no leakage, and

   iv) non *fire*-rated internal and *external walls* are assumed to have leakage areas that are proportional to the surface area of the walls. Leakage area is equal to the wall area multiplied by 0.001 m^2/m^2 (ie, 0.1%) for lined internal and *external walls* and 0.005 m^2/m^2 for unlined *external walls*.

Errata 2 Feb 2013

h) *Smoke separations* including glazing that comply with recognised national or international Standards for use as a smoke barrier are assumed to remain in place up to the rated temperature or the time at which *flashover* occurs, whichever is sooner.

i) *Smoke separations* that are not tested (eg, non *fire* rated but imperforate *construction*) are assumed to remain in place until the average upper layer smoke temperature reaches 200°C.

Errata 2 Feb 2013

j) Exterior windows that are not *fire resisting glazing* are assumed to break (ie, glass falls out to become completely open) at the sooner of either average upper layer temperature reaching 500°C or when the *fire* becomes limited by ventilation. Windows that are *fire resisting glazing* may be assumed to remain in place up to the rated time.

k) The *fire* shall be located away from walls and corners to maximise entrainment of air into the fire plume. The base of the *fire* shall be located at a height of no more than 0.5 m above floor level.

l) *Fractional Effective Dose (FED)* for CO and thermal effects shall be calculated using the procedures described in ISO 13571. FED_{CO} shall include contributions from CO, CO_2 and O_2 gases. $FED_{thermal}$ shall include radiative and convective effects.

Also refer to Paragraph 2.3.3 for guidance on modelling post-*flashover fires* when evaluating life safety on *escape routes* that are not in the room of *fire* origin.

2.2.2 Fire modelling rules for resistance of fire separations and structural design

a) *Fire* modelling rules shall be as specified in Paragraphs 2.3.2 and 2.3.3 for *fires* reaching full *burnout*, for structural design and for assessing *fire* resistance required of *separating elements*.

b) The *design fire* severity for car parking areas incorporating a vehicle stacking system shall use the *FLED* specified in Table 2.2.

c) The *design fire* severity for car parking areas with overlapping interconnected floors shall be based on the worst case (floor area and effective openings available for ventilation) for one of the overlapping floors or for the worst combination of two adjacent (overlapping) floors.

d) For car parking areas, the area of vertical opening ventilation available to the *fire* shall be the area available via permanent openings to the outside environment in the perimeter walls and access ramps to a car parking level above. Access ramp area shall be taken as the projection on the vertical plane at the point where the ramp meets the floor of the car park at the level under consideration.

e) For effective openings:

i) Only those areas of openings in *external walls* and roofs which can dependably provide airflow to the *fire* shall be used in calculating the *fire* severity. Such opening areas include windows containing non-*fire resisting glazing* and horizontal parts of a roof which are specifically designed to open or to melt rapidly in the event of exposure to *fully developed fire*.

ii) An allowance can be made for air leakage through the *external wall* of the *building* envelope. The allowance for inclusion in the vertical openings area shall be no greater than 0.1% of the *external wall* area where the wall is lined internally and 0.5% where the *external wall* is unlined.

iii) For single storey *buildings* or the top floor of multi-storey *buildings* where the structural system supporting the roof is exposed to view and has no dependable *fire* resistance (eg, less than 10 minutes), the ratio of A_h/A_f can be taken as 0.2.

2.3 Design fire characteristics

Analysis for a number of the *design scenarios* is based on the use of '*design fires*'. These are defined by one or more of the following parameters:

a) *Fire* growth rate

b) Peak *heat release rate*

c) *Fire load energy density*

d) Species production (CO, CO_2, water, soot)

e) Heat flux, and

f) Time.

Parameters and modelling instructions are given below for:

a) Pre-*flashover design fires*

b) Post-*flashover design fires*, and

c) Full *burnout design fires*.

The individual *design scenarios* in Part 4 specify where these *design fires* are to be used.

2.3.1 Pre-flashover design fires

The characteristics of the pre-*flashover design fire* are given in Table 2.1. In most cases (ie, for all *buildings*, including storage *buildings*, that are capable of storage to a height of less than 3.0 m) the *fire* is assumed to grow as a fast t^2 *fire* up to *flashover* or until the *HRR* reaches the peak given in Table 2.1 or becomes ventilation limited.

For life safety analysis in sprinklered *buildings*, the *fire* is assumed to be controlled (ie, with a constant *HRR*) after the sprinkler activates based on *RTI*, C-factor and activation temperature as specified in Table 3.2.

Table 2.1	Pre-flashover design fire characteristics			
Building use	*Fire* growth rate (kW)	Species	Radiative fraction	Peak *HRR*
All *buildings* including storage with a stack height of less than 3.0 m	$0.0469\ t^2$	Y_{soot} = 0.07 kg/kg Y_{CO} = 0.04 kg/kg ΔH_C = 20 MJ/kg Y_{CO_2} = 1.5 kg/kg Y_{H_2O} = 1.0 kg/kg	0.35	20 MW
Carparks (no stacking)	$0.0117\ t^2$		0.35	
Storage with a stack height of between 3.0 m and 5.0 m above the floor	$0.188\ t^2$		0.35	50 MW
Storage with a stack height of more than 5.0 m above the floor and car parks with stacking systems	$0.00068\ t^3\ H$		0.35	

NOTE:
t = time in seconds
H = height of storage in m
Y = *yield* kg/kg
ΔH_C = heat of combustion

2.3.2 Post-flashover design fires

Flashover is assumed to occur when the average upper layer temperature first reaches 500°C.

For uncontrolled *fires*, the burning rate is assumed to be governed by the ventilation limit or the peak *HRR*, whichever is less.

2.3.3 Modelling post-flashover fires

For life safety calculations (ie, *ASET*), modelling the *fire* into the post-*flashover* phase is unlikely to be required for sprinklered *buildings*. The *fire* is expected to be controlled (ie, with a constant *HRR*) after the sprinkler activates based on *RTI*, C-factor and activation temperature, and therefore *flashover* is not expected to occur. Sprinkler response calculations would be expected to confirm that this is the case.

However, note that for the full *burnout design fire* (see Paragraph 2.4), calculations of *fire* resistance shall be based on *burnout* without sprinkler or other intervention, except that the design *FLED* may be modified as described in Paragraph 2.4.1 where sprinklers are installed.

The following parameters shall apply:

a) Post-*flashover* species *yield* for soot is Y_{soot} = 0.14 kg/kg_{fuel}

b) Post-*flashover* species *yield* for CO is Y_{CO} = 0.40 kg/kg_{fuel}, and

c) Design *FLEDs* shall be as specified in Table 2.2 for activities within *buildings*.

The three steps for modelling the *fire* shall be as follows:

Step 1: Determine initial pre-*flashover fire growth* rate from Table 2.1; typically $q=0.0469t^2$.

Step 2: Run the *fire* model and determine which of the following five cases apply. If necessary adjust the input *HRR* to the model as described below and rerun the model.

Case 1 *Fire growth* reaches the peak *HRR* from Table 2.1 before T_{UL}=500°C

Fast *fire growth* to the peak *HRR* from Table 2.1

Species as given for pre-*flashover*

Case 2 Sprinklers activate before *fire growth* reaches the peak *HRR* from Table 2.1

Fast *fire growth* to sprinkler activation

Species as given for pre-*flashover*

Case 3 T_{UL}=500°C before *HRR* reaches the peak from Table 2.1 and *fire* is not ventilation limited

Fast *fire growth* to T_{UL}=500°C

Species as given for pre-*flashover*

At T_{UL}=500°C ramp up the *HRR* to the peak *HRR* from Table 2.1 over a period of 15s

Species as given for post-*flashover*

Case 4 T_{UL}=500°C before *HRR* reaches the peak from Table 2.1 and *fire* is ventilation limited

Fire growth to T_{UL}=500°C

Species as given for pre-*flashover*

At T_{UL}=500°C (or ventilation limit, whichever occurs first) ramp up the *HRR* to 1.5 times the ventilation limit over a period of 15s

Species as given for post-*flashover*

Case 5 T_{UL}<500°C and *fire* is ventilation limited

Fast *fire growth* to ventilation limit

Species as given for pre-*flashover*

At ventilation limit ramp up the *HRR* to 1.5 times the ventilation limit over a period of 15s

Species as given for post-*flashover*.

For modelling purposes, the ventilation limit shall be taken as the *HRR* at the time when the predicted energy release first diverges from the *design fire* (given in Table 2.1) due to the lack of sufficient oxygen for complete combustion.

Comment:
Ventilation limit is determined by *fire* modelling. See the commentary document for this Verification Method for a calculation example.

T_{UL} is the average temperature of the upper layer.

Step 3: Allow the *fire* to burn until all the fuel is exhausted, based on the design *FLED*. Use the design *FLEDs* provided in Table 2.2.

Table 2.2 Design FLEDs for use in modelling fires in C/VM2

Design *FLED* (MJ/m²)	Activities in the space or room	Examples
400	1. Display or other large open spaces; or other spaces of low *fire hazard* where the occupants are awake but may be unfamiliar with the *building*.	1. Art galleries, auditoriums, bowling alleys, churches, clubs, community halls, court rooms, day care centres, gymnasiums, indoor swimming pools
	2. Seating areas without upholstered furniture	2. School classrooms, lecture halls, museums, eating places without cooking facilities
	3. All spaces where occupants sleep	3. *Household units*, motels, hotels, hospitals, residential care institutions
	4. Working spaces and where low *fire hazard* materials are stored	4. Wineries, meat processing plants, manufacturing plants
	5. Support activities of low *fire hazard*	5. Car parks, locker rooms, toilets and amenities, service rooms
800	1. Spaces for business	1. Banks, personal or professional services, police stations (without detention)
	2. Seating areas with upholstered furniture, or spaces of moderate *fire hazard* where the occupants are awake but may be unfamiliar with the *building*	2. Nightclubs, restaurants and eating places, *early childhood centres*, cinemas, *theatres*, libraries
	3. Spaces for display of goods for sale (retail, non-bulk)	3. Exhibition halls, shops and other retail (non bulk)
1200	1. Spaces for working or storage with moderate *fire hazard*	1. Manufacturing and processing moderate *fire load* 2. Storage up to 3.0 m high other than *foamed plastics*
	2. Workshops and support activities of moderate *fire hazard*	3. Maintenance workshops, plant and boiler rooms
400/tier of car storage	Spaces for multi-level car storage	Car stacking systems. The design floor area over which the design *FLED* applies is the total actual car parking area
800/m height, with a minimum of 2400	1. Spaces for working or storage with high *fire hazard*	1. Chemical manufacturing and processing, feed mills, flour mills 2. Storage over 3.0 m high of *combustible* materials, including climate controlled storage
	2. Spaces for display and sale of goods (bulk retail)	3. Bulk retail (over 3.0 m high)

2.4 Full burnout design fires

Comment:
Design fire characteristics include parameters for *FLED, fire growth* rate and heat of combustion. This means a post-*flashover* 'full *burnout design fire*' can be defined.

The 'full *burnout design fire*' for structural design and for assessing *fire* resistance of *separating elements* shall be based on complete *burnout* of the *firecell* with no intervention. However, the maximum *fire resistance rating* for a sprinklered *firecell* need not exceed 240/240/240 determined using AS 1530.4.

There are three choices for modelling the full *burnout design fire*:

a) Use a time-equivalent formula to calculate the equivalent *fire* severity and specify *building elements* with a *fire resistance rating* not less than the calculated *fire* severity. In this case, an equivalent *fire* severity of 20 minutes shall be used, if the calculated value is less.

b) Use a parametric time versus gas temperature formula to calculate the thermal boundary conditions (time/temperature) for input to a structural response model, or

c) Construct an *HRR* versus time structural *design fire* as described in Paragraph 2.3.3. Then, taking into account the ventilation conditions, use a *fire* model or energy conservation equations to determine suitable thermal boundary conditions (time/temperature/flux) for input to a structural response model.

Comment:
A common approach to use with this Verification Method is the 'equivalent fire severity' method described in Eurocode 1 Actions on structures, Part 2-2. This allows the equivalent time of exposure to the *standard test* for *fire* resistance to be estimated based on the compartment properties, *FLED* and available ventilation given complete *burnout* of the *firecell* with no intervention.

2.4.1 Modifications to the design FLED

For assessing the *fire* resistance of structural and non-structural elements, the design *FLED* from Table 2.2 used for the *design fire* shall be modified by multiplying the *FLED* by the applicable F_m factor from Table 2.3.

For assessing *fire* duration for life safety calculations the design *FLED* from Table 2.2 shall be modified by multiplying the *FLED* by the applicable F_m factor from Table 2.3.

Table 2.3 F_m **factors to be applied to FLED**

	Sprinklered *firecell*	Unsprinklered *firecell*
Fire resistance of primary structural elements in any structural system which is unable to develop dependable deformation capacity under post-*flashover fire* conditions[1]	1.00	1.25
Fire resistance of primary structural elements whose failure would consequently lead to disproportionate extent of collapse [2]	1.00	1.25
All other structural and non-structural elements or for life safety calculations of *fire* duration.	0.50	1.00

Errata 1 Apr 2012

Notes

1. This factor accounts for non-uniformity of *fire load* and/or ventilation and hence local structural *fire* severity. The structural system comprises the individual members and the connections between these members. The dependable deformation capacity shall have been established by rational analysis supported by evidence from experimental testing. One example is composite floor systems comprising concrete slab on steel deck supported on steel beams.
2. Guidance on an extent of collapse which would be regarded as disproportionate is given in the commentary document for this Verification Method. One example is isolated columns near the base of a tall, multi-storey structure where the column would suffer sudden and complete loss of load-carrying capacity if subjected to the deformations expected in a severe *fire*.

2.4.2 Openings for full burnout fires

For the purposes of calculating A_v (the total area (m²) of vertical windows and doors) in full *burnout design fire* calculations it shall be assumed that doors in *external walls* are closed. Wall areas clad in sheet metal shall not be included in the area A_v.

Comment:
Also refer to the *fire* modelling rules for full *burnout fires* in Paragraph 2.2.2 for effective openings.

2.4.3 Structural fire severity for interconnected floors

Where a space contains interconnected floors, separate calculations shall be made to determine the structural *fire* severity, first by considering the total floor area of the space and then by considering the interconnected floor at each level. The greatest magnitude of structural *fire* severity shall be applied to all levels, unless the structural system supporting floors is designed to dependably prevent collapse during the *fire*.

2.4.4 Time equivalence formula

The time equivalence formula shall be taken from Annex E of Eurocode DD ENV 1991-2-2.

Comment:
Further discussion can be found in the Fire Engineering Design Guide.

The required *fire resistance rating* must be greater than the time equivalence (t_e) value calculated using the equations 2.1 and 2.2:

$$t_e = e_f \, k_b \, k_m \, w_f \qquad \text{Equation 2.1}$$

where:

e_f = *FLED* given in Table 2.2 and as modified by Table 2.3.

k_b = conversion factor to account for the thermal properties of the material, as specified in Table 2.4

k_m = modification factor for the structural material.

and

w_f = ventilation factor.

$$w_f = \left(\frac{6.0}{H}\right)^{0.3} \left[0.62 + \frac{90(0.4 - \alpha_v)^4}{1 + b_v \alpha_h}\right] \geq 0.5$$

Equation 2.2

where

$\alpha_v = A_v / A_f \qquad 0.025 \leq \alpha_v \leq 0.25$

$b_v = 12.5\left(1 + 10\alpha_v - \alpha_v^2\right) \geq 10.0$

A_f = floor area of the *space*

A_v = area of vertical window and door openings (m^2)

A_h = area of horizontal openings in the roof (m^2), and

H = height of the space (m) (for pitched roofs, use the smallest value for H).

If $A_v < 0.025A_f$ then $A_v = 0.025A_f$ shall be used for the purpose of this calculation.

If $A_v > 0.25A_f$ then $A_v = 0.25A_f$ shall be used for the purpose of this calculation.

When $W_f < 0.5$ then use $W_f = 0.5$

When there are multiple vertical openings, the weighted average height (h_{eq}) of all of the openings is used.

For pitched roofs use the smallest value for H.

k_m = 1.0 for reinforced concrete, protected steel, timber, and a mix of unprotected and protected steel. For unprotected steel:

$$k_m = 13.7\, A_v \sqrt{h_{eq}} / A_t \geq 1.0$$

applicable over the range:

$$0.02 \leq A_v \sqrt{h_{eq}} / A_t \leq 0.20$$

Table 2.4 Conversion factor k_b for various lining materials

Errata 2 Feb 2013

Typical values for $\sqrt{k\rho c}$ $J/m^2s^{0.5}K$	*Construction* materials	K_b
400	Very light highly insulating materials	0.10
700	Plasterboard ceilings and walls, timber floors	0.09
1100	Light weight concrete ceilings and floors	0.08
1700	Normal weight concrete ceilings and floors	0.065
>2500	Thin sheet steel roof and wall systems	0.04

NOTE:
k=thermal conductivity (W/m K)
ρ=density (kg/m^3)
c=specific heat (J/kg K)

Part 3: Movement of people

CONTENTS

3.1 Occupant numbers

The occupancy of any space in a *building* shall be calculated using the occupant densities provided in Table 3.1.

Table 3.1 Occupant densities

Activity	Occupant density (m^2/person)
Area without seating or aisles	1.0
Art galleries, museums	4
Bar sitting areas	1.0
Bar standing areas	0.5
Bleachers, pews or bench type seating	0.45 linear m per person
Classrooms	2
Consulting rooms (doctors, dentists, beauty therapy)	5
Dance floors	0.6
Day care centres	4
Dining, beverage and cafeteria spaces	1.25
Early childhood centres	Based on Education (Early Childhood Services) Regulations 2008 plus the number of staff
Exhibition areas, trade fairs	1.4
Fitness centres	5
Gaming and casino areas	1
Indoor games areas, bowling alleys	10
Libraries – stack areas	10
Libraries other areas	7
Lobbies and foyers	1
Mall areas used for assembly uses	1
Reading or writing rooms and lounges	2
Restaurants, dining rooms	1.1
Shop spaces and pedestrian circulation areas including malls and arcades	3
Shop spaces for furniture, floor coverings, large appliances, building supplies and Manchester	10
Showrooms	5
Spaces with fixed seating	As number of seats
Spaces with loose seating	0.8
Spaces with loose seating and tables	1.1
Sports halls	3
Stadiums and grandstands	0.6
Staffrooms and lunch rooms	5
Stages for theatrical performances	0.8
Standing spaces	0.4
Swimming pools: water surface area	5

Table 3.1	Occupant densities (continued)
Activity	**Occupant density (m^2/person)**
Swimming pools: surrounds and seating	3
Teaching laboratories	5
Vocational training rooms in schools	10
Bedrooms	As number of bed spaces and staff when appropriate
Bunkrooms	
Dormitories, hostels	
Halls and *wharenui*	
Wards in hospitals, operating theatres and similar	
Detention quarters	
Aircraft hangars	50
Bulk storage including racks and shelves (warehouses etc)	100
Retail and trading (storage >3.0 m high)	5
Call centres	7
Commercial laboratories, laundries	10
Computer server rooms	25
Heavy industry	30
Interview rooms	5
Commercial kitchens	10
Manufacturing and process areas	10
Meeting rooms	2.5
Offices	10
Personal service facilities	5
Reception areas	10
Staffrooms and lunchrooms	5
Workrooms, workshops	5
Boiler rooms, plant rooms	30
Parking *buildings*, garages	50

3.2 Required safe egress time (RSET)

The *required safe egress time* (*RSET*), is the calculated time available between ignition of the *design fire* and the time when all the occupants in the specified room/location have left that room/location.

The *RSET* in a simple hydraulic model for evacuation (see Comment below) is:

$$RSET = (t_d + t_n + t_{pre}) + (t_{trav} \text{ or } t_{flow})$$

Equation 3.1

where:

t_d = detection time determined from deterministic modelling

t_n = time from detection to notification of the occupants

t_{pre} = time from notification until evacuation begins

t_{trav} = time spent moving toward a *place of safety*, and

t_{flow} = time spent in congestion controlled by flow characteristics.

The requirements for establishing each of these times are set out in Paragraphs 3.2.1 to 3.2.5.

When calculating the flow from the room of origin, the occupants are assumed to be evenly distributed in the space. Therefore, the egress time is determined by the greater of the queuing time and the travel time to the exit.

Comment:
This Verification Method defines the minimum analysis required to demonstrate that the *fire* engineer's design meets the required performance criteria.
For more information on how to calculate *RSET*, refer to the SFPE Handbook of Fire Protection Engineering, Section 3 Chapter 13.

3.2.1 Detection time

The *fire* engineer shall establish the detection time from deterministic modelling or as described in Paragraph 3.4 for a manually activated warning system. It is expected that the model used to calculate the detection time for an automatic warning system will use an appropriate algorithm that includes at least a ceiling jet correlation or a *CFD* model code that solves for the velocity and temperature (and smoke/soot concentration) directly.

Regardless of the actual make/model and installation parameters of the detection device specified to be installed in the *building*, the values given in Table 3.2 for the detector shall be used in this analysis.

Table 3.2 Detector criteria

Heat detectors RTI = 30 $m^{1/2}s^{1/2}$ T_{act} = 57°C Radial distance = 4.2 m Distance below ceiling not less than 25 mm	**Extended coverage (sprinkler)** RTI = 50 $m^{1/2}s^{1/2}$ C = 0.65 $m^{1/2}s^{1/2}$ T_{act} = 68°C Radial distance = 4.3 m (maximum) Distance below ceiling not less than 25 mm
Standard response (sprinkler) RTI = 135 $m^{1/2}s^{1/2}$ C = 0.85 $m^{1/2}s^{1/2}$ T_{act} = 68°C Radial distance = 3.25 m Distance below ceiling not less than 25 mm	**Quick response (sprinkler)** RTI = 50 $m^{1/2}s^{1/2}$ C = 0.65 $m^{1/2}s^{1/2}$ T_{act} = 68°C Radial distance = 3.25 m Distance below ceiling not less than 25 mm
Spot/point smoke detectors Optical density at alarm = 0.097 m^{-1} Radial distance = 7 m Distance below ceiling not less than 25 mm	**Projected beam smoke detectors** Optical density at alarm to be determined based on beam path length and the design setting for the total obscuration for alarm[1]

NOTE:

1. The commentary document for this Verification Method provides a method for calculating the optical density for projected beam smoke detectors.

3.2.1.1 Smoke detection optical density criteria for spot detectors

The optical density at alarm criteria in Table 3.2 shall apply to spot detectors (ionisation and photoelectric).

3.2.1.2 Criteria for very high sensitivity air sampling smoke detectors

This type of detector requires specialised design, and the response depends on a range of factors including air flow rates, sampling tube length and alarm threshold levels. The response criteria in Table 3.2 shall be used in the analysis.

3.2.2 Notification time

For standard evacuation strategies, take the notification time as 30 seconds.

For non-standard evacuation strategies (for example, management investigating sole activation), take account of the extended notification time.

3.2.3 Pre-travel activity time

Use the values in Table 3.3 for *pre-travel activity times*.

Comment:
The incipient phase of the *fire growth* has not been considered in the *design fire*. This provides an implicit safety factor for the *pre-travel activity time*.

Table 3.3	**Pre-travel activity times**
Description of *building* use	*Pre-travel activity time(s)*
Buildings where the occupants are considered awake, alert and **familiar** with the *building* (eg, offices, warehouses **not** open to the public)	
Enclosure of origin	30
Remote from the enclosure of origin	60
Buildings where the occupants are considered awake, alert and **unfamiliar** with the *building* (eg, retail shops, exhibition spaces, restaurants)	
Enclosure of origin (standard alarm signal)	60
Remote from the enclosure of origin (standard alarm signal)	120
Enclosure of origin (voice alarm signal)	30
Remote from the enclosure of origin (voice alarm signal)	60
Buildings where the occupants are considered sleeping and **familiar** with the *building* (eg, apartments)	
Enclosure of origin (standard alarm signal)	60
Remote from the enclosure of origin (standard alarm signal)	300
Buildings where the occupants are considered sleeping and **unfamiliar** with the *building* (eg, hotels and motels)	
Enclosure of origin	60
Remote from the enclosure of origin (standard alarm signal)	600
Remote from the enclosure of origin (voice alarm signal)	300
Buildings where the occupants are considered awake and under the care of trained staff (eg, day care, dental office, clinic)	
Enclosure of origin (independent of alarm signal)	60
Remote from the enclosure of origin (independent of alarm signal)	120
Buildings where the occupants are considered sleeping and under the care of trained staff (eg, hospitals and rest homes)	
Enclosure of origin (assume staff will respond to room of origin first)	60 s for staff to respond to alarm then 120 s (per patient per 2 staff)[1]
Remote from the enclosure of origin (independent of alarm signal)	1800
Errata 1 Apr 2012 Remote from the enclosure of origin (independent of alarm signal) where occupants are unable to be moved due to the procedure or other factor	1800 or as per specific requirements, whichever is the greater
Spaces within *buildings* which have only focused activities (eg, cinemas, *theatres* and stadiums)	
Space of origin (occupants assumed to start evacuation travel immediately after detection and notification time or when *fire* in their space reaches 500 kW, whichever occurs first)	0

NOTE:

1. This allows 120 s to move each patient from their room to the next adjacent *firecell*. This includes time for staff to prepare the patient and transport them to the adjacent *firecell*, and then to return to evacuate another patient. The commentary document for this Verification Method gives details of staff to patient ratios.

3.2.4 Travel time

Travel time within a space is governed by:

a) The time taken to travel to the doorway (t_{trav}), or

b) The flow time (ie, the time taken for all the occupants to flow through a restriction, typically a doorway, when queueing is necessary).

The greater of these two times is the evacuation time from the space.

For **horizontal travel**, the travel time shall be calculated based on the estimated walking speed. Horizontal travel speed shall be calculated using equation 3.2 with a maximum travel speed of 1.2 m/s.

Errata 2 Feb 2013

$$S = k - akD \qquad \text{Equation 3.2}$$

where:

S= horizontal travel speed (m/s)

D= occupant density of the space (persons/m^2)

k = 1.4 for horizontal travel, and

a =0.266.

Travel time (t_{trav}) is calculated by using equation 3.3:

$$t_{trav} = L_{trav} / S \qquad \text{Equation 3.3}$$

where:

t_{trav} = travel time (s), and

L_{trav} = travel distance (m).

The maximum horizontal travel distance (L_{trav}) shall be determined by either:

a) The measured length around furniture if this is known, or

b) Adding together the length and width measurements of the room.

For **vertical travel**, equation 3.2 applies but the values used for k are a function of the stair riser and tread size as given in Table 3.4.

Table 3.4 Maximum flow rates for use in equation 3.2 for horizontal and vertical travel speeds

Exit route elements		k	Speed m/s
Corridor, aisle, ramp, doorway		1.40	1.19
Stair riser (mm)	Stair tread (mm)		
191	254	1.00	0.85
178	279	1.08	0.95
165	305	1.16	1.00
165	330	1.23	1.05

3.2.5 Time if flow governs

Flow rate shall be calculated using equation 3.4:

$$F_c = (1 - aD)kDW_e \qquad \text{Equation 3.4}$$

where:

F_c = calculated flow (persons/sec), and

D = occupant density near flow constriction (ie, for doors, use 1.9 persons/m^2)

W_e = effective width of component being traversed in metres.

The effective width is equal to the measured width minus the boundary layer, where the thickness of the boundary layer is given in Table 3.5.

Comment:
Equation 3.4 is most commonly used for doorway flows to estimate the queuing times. However, it is useful in many situations, as shown by the variety of exit route elements listed in Table 3.5.

Table 3.5 Boundary layer width for calculating the effective width of an exit component

Exit route element	Boundary layer on each side (m)
Stairway – walls or side tread	0.15
Railing or *handrail*	0.09
Theatre chairs, stadium bench	0.00
Corridor wall and ramp wall	0.20
Obstacle	0.10
Wide concourse, passageway	0.46
Door, archway	0.15

For doorway flows, the maximum flow rate is limited to 50 people per minute for each standard door leaf that has a self-closing device fitted. If there is no self-closing device, equation 3.4 shall be used with no upper limit on the flow rate.

Comment:
This requirement applies to standard, manual, self-closing side-hinged doors and not to automatic sliding doors. In the case of automatic sliding doors, the effective width of the opening may be used in equation 3.4 from the time when the doors are opened and remain open. The same applies to manual sliding doors. They may be assumed to remain fully open once the first occupant has passed through the door.

The maximum flow rate corresponds to a door of 0.95 m wide with a boundary layer each side of 0.15 m and a total effective width of 0.65 m.

3.2.6 Direction of opening

Doors on *escape routes* shall be hung to open in the direction of escape and, where escape may be in either direction, doors shall swing both ways. These requirements need not apply where the number of occupants of spaces with egress using the door is no greater than 50. Manual sliding doors are permitted where the relevant number of occupants is no more than 20.

Comment:
This Verification Method does not provide a comprehensive guide to egress analysis, but highlights the level of rigour expected in the egress calculations. Refer to the SFPE Handbook of Fire Protection Engineering, Section 3 Chapter 13, for further details regarding egress calculation procedures, including flow transitions.

3.2.7 Exit doors

Where a primary entrance can be identified the primary entrance shall be designed to egress 50% of the total *occupant load* of the space and the remaining occupants are evenly distributed in proportion to the number of exits.

Where there is no primary entrance the *occupant load* shall be distributed to the available exits with no more than 50% to one exit.

Errata 2
Feb 2013

3.3 Requirements for delayed evacuation strategies

Buildings and parts of *buildings* that have occupants that are required to stay in place or where evacuation is to a *place of safety* inside the *building* (eg, where occupants may either be detained or undergoing treatment such as in an operating theatre or delivery suite) must comply with the definition of '*place of safety*'.

Comment:
As these spaces usually have a climate controlled environment, special care should be taken with the design of smoke detection and air handling system smoke control.

3.4 Alerting people with warning systems

There must be warning systems installed to NZS 4512 to alert the occupants of a *fire*.

Manual activation of a warning system shall only be premitted in a space where the average ceiling height $\geq$5 m, the occupants are awake and familiar with their surroundings, and where the occupant density calculation results in an *occupant load* of fewer than 50 persons. In all other situations automatic detection is required.

Where only manual systems are installed occupants are assumed to be aware of the *fire* when the ceiling jet flow has traversed the entire length of the space from a *fire* at the opposite end of the space. No additional pre-evacuation time need be included. The time required for the ceiling jet to completely traverse the ceiling can either be determined using *CFD* modelling or by the following relationship if zone modelling is used:

For storage height $\leq$ 5.0 m (ultrafast fire growth):

t_d=10 + 2.4 L when L $\leq$ 1.4 w, and

t_d=10 + w + 1.7 L when 1.4 w < L $\leq$ 4 w, and

For storage height >5 m (rack growth):

t_d=25 + 1.7 L when L$\leq$1.4 w, and

t_d=25 + w + L when 1.4 w<L$\leq$4 w,

where:

w = width of the space in metres (shortest dimension)

L = length of the space in metres (longest dimension).

3.5 Fire modelling to determine ASET

For the *design scenario*: CF Challenging fire (see Paragraph 4.9), the designer must demonstrate that the occupants have sufficient time to evacuate the *building* before being overcome by the effects of *fire*.

In *fire* engineering terms, the *available safe egress time* (*ASET*) shall be greater than the *required safe egress time* (*RSET*).

ASET is defined as the time between ignition of the *design fire* and the time when the first tenability criterion is exceeded in a specified room within the *building*. The tenability parameters measured at a height of 2.0 m above floor level, as specified in NZBC C4.3, are:

a) Visibility

b) $FED_{(thermal)}$, and

c) $FED_{(CO)}$.

Exceptions can be applied, as outlined in NZBC C4.4 (a *building* with an automatic sprinkler system and more than 1000 people cannot be exposed to conditions exceeding the *visibility* limits or $FED_{thermal}$ limits).

Comment:
Visibility will generally be the first tenability criterion exceeded in the calculations unless any exception is applied.

Calculate the *ASET* by choosing a *fire* model and using the *design fire* as specified in Part 2.

In most cases there will be a number of locations for the *fire* that could produce the lowest *ASET* for a given *escape route*. Check a number of rooms to determine the limiting case.

3.6 Exposure to radiation along egress routes

3.6.1 General

When occupants located within an *exitway* or on an external *escape route* must egress past a window opening or glazed panel, they must not be exposed to a radiation level which will cause pain while evacuating. Therefore, the time to onset of pain (t_p) must be longer than the exposure time (t_{exp}).

The limitations for the analysis are as follows:

a) The analysis requires that all occupants must have evacuated past the window opening or glazed panel within 10 minutes after ignition unless *fire resisting glazing* tested to a recognised national or international Standard is used.

b) The maximum allowable radiation level that an occupant can be exposed to is 10 kW/m².

c) The analysis described here is only applicable for a single window. Multiple windows require more detailed analysis on the time to pain calculations where the time-dependent cumulative effect of the radiation can be accounted for (such procedures can be found in the SFPE Engineering Guide – Predicting 1st and 2nd Degree Skin Burns from Thermal Radiation).

d) Analysis is not appropriate where occupants are likely to be mobility-impaired.

e) Radiation through uninsulated *fire resisting glazing* can be reduced by 50% (see k=0.5 in equation 3.6 below).

f) Analysis is not required where an alternative *escape route* is available.

g) Analysis is not required where insulated glazing with *fire* resistance of not less than -/30/30 is used.

h) Analysis is not required for sprinklered *buildings* with window wetting sprinklers located on the same side of the window as the *fire* and designed and installed for that specific purpose.

i) Analysis is not required during the period prior to *ASET* for the room of fire origin.

j) Any part of the window or glazed panel that is openable must be fitted with a self-closer or other device that automatically closes the opening on detecting smoke or heat.

3.6.2 Time to onset of pain

The time to onset of pain shall be determined using equation 3.5.

$$t_p = \left(\frac{35}{\dot{q}''_r}\right)^{1.33} \quad \text{Equation 3.5}$$

where:

t_p = time required for pain (s), and

$\dot{q}''_r$ = maximum incident thermal radiation (kW/m²)

3.6.3 Radiation from a window to an egressing occupant

The maximum incident thermal radiation occurs opposite the centre of the window or glazing, at a height of 2.0 m or mid-height of the glazing whichever is the lower height, and can be calculated using equation 3.6:

$$\dot{q}''_r = F_W \varepsilon k \dot{q}''_w \quad \text{Equation 3.6}$$

where:

$\dot{q}''_w$ = design emitted heat flux from the window. This shall be taken as:

a) 83 kW/m² for *FLED* (from Table 2.3) 400 MJ/m²

b) 103 kW/m² for *FLED* (from Table 2.3) between 400 and 800 MJ/m², and

c) 144 kW/m² for *FLED* (from Table 2.3) greater than 800 MJ/m².

and

ε = emissivity of the *fire* gases (shall be taken as 1.0)

k = glazing factor (=0.5 for *fire resisting glazing*; =1.0 for all other glazing)

F_W = view factor from a window or glazing to a point opposite the centre of the window or glazing, at a height of 2.0 m or mid-height of the glazing whichever is the lower height, and at a distance corresponding to the nearest part of the required *escape route*.

3.6.4 Exposure time

The exposure time (t_{exp}) is determined by calculating the distance (D) the occupant must travel while exposed to radiation from the window or glazed panel and assuming a travel speed of 1.0 m/s. The occupant is assumed to be exposed as long as their exposure to the incident thermal radiation is greater than 2.5 kW/m^2. The exposure time for the occupant is the *travel distance* required to pass the window, divided by the walking speed as shown in equation 3.7, below:

$$t_{exp} = \frac{D}{V} \qquad \text{Equation 3.7}$$

where:

t_{exp} = the time an occupant is exposed to the radiation (s)

V = travel speed (=1 m/s), and

D = the distance the occupant must travel while exposed to incident thermal radiation of at least 2.5 kW/m^2 from the window or glazing (m).

3.7 Egress past a burning object

3.7.1 Radiation from a burning object to an egressing occupant

Radiation calculations from a burning object can be approximated using the point source model with fixed radiation fraction as given in equation 3.8:

$$\dot{q}''_r = \frac{0.45\,\dot{q}_{Fire}}{4\pi r^2} \qquad \text{Equation 3.8}$$

where:

$\dot{q}''_r$ = radiation flux at a distance r from the fire occupant (kW/m^2)

$\dot{q}_{Fire}$ = total *heat release rate* from the fire (kw)

and

r = radial distance from the *fire* to the egressing occupant (m).

Limitation:

Average upper layer temperature within the *fire* compartment must not have exceeded 150˚C.

Part 4: Design scenarios

CONTENTS

Comment:
References in the *design scenarios* to C1(a), C4.5 etc are to clauses within NZBC C1 to C6: Protection from Fire. The relevant *Building Code* clauses are included in full in *italic* at the start of each scenario for ease of reference.

4.1 Design scenario (BE): Fire blocks exit

Scenario in brief	A *fire* starts in an *escape route* and can potentially block an exit.
Code objective	***C1(a)*** *Safeguard people from an unacceptable risk of injury or illness caused by fire.*
What you must satisfy	C4.5 by providing a viable *escape route* or routes for *building* occupants in the event of *fire*. ***C4.5*** *Means of escape to a place of safety in buildings must be designed and constructed with regard to the likelihood and consequence of failure of any fire safety systems.*
Outcome required	Demonstrate that a viable *escape route* (or multiple routes where necessary) has been provided for *building* occupants.

Scenario description

This scenario addresses the concern that an *escape route* may be blocked due to proximity of the *fire source*. In this event, the number of exits and total exit width must be sufficient for occupants to escape before *ASET* is reached.

This scenario applies to *escape routes* serving more than 50 people.

Exception: this scenario does not apply to vertical stair enclosures serving not more than 150 people *fire separated* from all other parts of a *building* or, if the *building* is sprinkler protected, serving not more than 250 people.

Single *escape routes* are permitted to serve up to 50 people.

For each room/space within the *building* (accommodating more than 50 people), assume that the *fire source* is located near the primary *escape route* or exit and that it prevents occupants from leaving the *building* by that route. *Fire* in *escape routes* can be the result of a deliberately lit *fire* or accidental. *Fire* originating within an *escape route* will be considered to be a severe *fire* applicable to the particular *building* use as described in the *design scenario*: CF Challenging fire (see Paragraph 4.9).

In order to be regarded as alternative *escape routes*, the routes shall be separated from each other and shall remain separated until reaching a *final exit*. Separation shall be achieved by diverging (from the point where two *escape routes* are required) at an angle of no less than 90° until separated by:

a) a distance of at least 8.0 m when up to 250 occupants are required to use the *escape routes* or at least 20 m when more than 250 occupants are required to use the *escape routes*; or

b) *Smoke separations* and *smoke control doors.*

Active and passive *fire safety systems* in the *building* shall be assumed to perform as intended by the design.

Comment:
The engineer needs to consider *fire source* locations that prevent the use of exits in *escape routes*.

Fire characteristics (eg, *HRR*) and analysis need not be considered in this scenario, as the *fire* is assumed to physically block the exit. It may be assumed that occupant tenability criteria cannot be met where *fire* plumes and flame block an exit.

Method

The requirements of this scenario can be demonstrated by analysis that is limited to checking whether or not a second exit is required.

4.2 Design scenario (UT): Fire in normally unoccupied room threatening occupants of other rooms

Scenario in brief	A *fire* starts in a normally unoccupied room and can potentially endanger a large number of occupants in another room.
Code objective	***C1(a)*** *Safeguard people from an unacceptable risk of injury or illness caused by fire.*
What you must satisfy	The performance criteria of C4.3 and C4.4 for any *buildings* with rooms or spaces that can hold more than 50 people. This may require analysis. ***C4.3*** *The evacuation time must allow occupants of a building to move to a place of safety in the event of fire so that occupants are not exposed to any of the following:* *a) a fractional effective dose of carbon monoxide greater than 0.3;* *b) a fractional effective dose of thermal effects greater than 0.3;* *c) conditions where, due to smoke obstruction, visibility is less than 10 m except in rooms of less than 100 m^2 where visibility may fall to 5.0 m.* ***C4.4*** *Clause C4.3 (b) and (c) do not apply where it is not possible to expose more than 1,000 occupants in a firecell protected with an automatic fire sprinkler system.*
Required outcome	Demonstrate *ASET>RSET* for any rooms or spaces that can hold more than 50 people given a *fire* occurs in the normally unoccupied space. Solutions might include the use of *separating elements* or *fire* suppression to confine the *fire* to the room of origin.

Scenario description

This *design scenario* only applies to *buildings* with rooms or spaces that can hold more than 50 occupants that could be threatened by a *fire* occurring in another normally unoccupied space. It does not need to be satisfied for any other rooms or spaces in the *building*.

A *fire* starting in an unoccupied space can grow to a significant size undetected and then spread to other areas where large numbers of people may be present. This scenario is intended to address the concern regarding a *fire* starting in a normally unoccupied room and then migrating into the space(s) that can potentially hold large numbers of occupants in the *building*.

The analysis shall assume that the target space containing the people is filled to capacity under normal use. For analysis, select a *design fire* as described in Part 2 for the applicable occupancy.

Active and passive *fire safety systems* in the *building* shall be assumed to perform as intended by the design.

Method

Either:

a) Carry out *ASET/RSET* analysis to show that the occupants within target spaces are not exposed to untenable conditions, or

b) Include *separating elements* or *fire* suppression to confine the *fire* to the room of origin. If *separating elements* are used the *FRR* shall be based on the following design criteria.

   i) If no automatic *fire* detection is installed in the space of *fire* origin, separating elements shall have *fire* resistance to withstand a full *burnout fire* (see Paragraph 2.4).

   ii) If automatic *fire* detection is installed in the space of *fire* origin, *separating elements* shall either:

      A) Have a *fire resistance rating* of not less than 60 minutes (-/60/60), or

      B) Demonstrate the *separating elements* will be effective for the period from ignition to the time when the *occupied space* (target space) is evacuated.

4.3 Design scenario (CS): Fire starts in a concealed space

Scenario in brief	A *fire* starts in a *concealed space* that can potentially endanger a large number of people in another room.
Code objective	***C1(a)*** *Safeguard people from an unacceptable risk of injury or illness caused by fire.*
What you must satisfy	For any *buildings* with rooms holding more than 50 people and with *concealed spaces*, ensure that *fire* spread via *concealed spaces* will not endanger the *building* occupants. This will not require analysis.
Required outcome	Demonstrate that *fire* spread via *concealed spaces* will not endanger occupants located in rooms/spaces holding more than 50 people. This scenario is deemed to be satisfied by the use of *separating elements*, automatic detection or suppression.

Scenario description

This *design scenario* only applies to *buildings* with rooms holding more than 50 occupants and with *concealed spaces*. It does not apply if the *concealed space* has no *combustibles* (other than timber framing) and no more than two dimensions (length, width or depth) greater than 0.8 m.

A *fire* starting in a *concealed space* can develop undetected and spread to endanger a large number of occupants in another room. This scenario addresses a concern regarding a *fire*, originating in a non-separated *concealed space* without either a detection system or suppression system, and spreading into any room within the *building* that can, potentially, hold a large number of occupants.

Assume that active and passive *fire safety systems* in the *building* perform as intended by the design.

Comment:
Fire spreading in *concealed spaces* may also compromise the ability of firefighters to assess the threat to themselves whilst undertaking rescue and firefighting operations.

Method

Due to the difficulty in modelling *fire* spread within *concealed spaces*, it is expected that traditional solutions will apply here (ie, containment, detection or suppression.)

The expected methodology is to either:

a) Use *separating elements* (*cavity barriers*) or suppression to confine *fire* to the *concealed space*, or

b) Include automatic detection of heat or smoke to provide early warning of *fire* within a *concealed space*.

Separating elements (*cavity barriers*) in *concealed spaces* without a means of automatic *fire* detection shall have a *fire resistance rating* of not less than 30 minutes (-/30/30) and the *concealed space* shall not have an area greater than 500 m^2.

4.4 Design scenario (SF): Smouldering fire

Scenario in brief	A fire is smouldering in close proximity to a sleeping area.
Code objective	*C1(a) Safeguard people from an unacceptable risk of injury or illness caused by fire.*
What you must satisfy	For *buildings* with a sleeping use, ensure that there are automatic means of smoke detection and alarm complying with a recognised national or international Standard for occupants who may be sleeping.
Required outcome	Provide an automatic smoke detection and alarm system throughout the *building* that has been designed and installed to a recognised national or international Standard.

Scenario description

This scenario addresses the concern regarding a slow, smouldering *fire* that causes a threat to sleeping occupants. Assume that active and passive *fire safety systems* in the *building* perform as intended by the design.

Method

Provide an automatic smoke detection and alarm system throughout the sleeping spaces, designed and installed to a recognised national or international Standard. No further analysis is expected.

4.5 Design scenario (HS): Horizontal fire spread

Scenario in brief	A fully developed *fire* in a *building* exposes the *external walls* of a neighbouring *building* or *firecell.*
Code objectives	***C1(b)*** *Protect other property from damage caused by fire.*
What you must satisfy	The performance criteria in C3.6 and C3.7. This will require calculation. C4.2 is to be considered in relation to horizontal *fire* spread across a *notional boundary* to sleeping occupancies and *exitways* in *buildings* under the same *ownership.* ***C3.6*** *Buildings must be designed and constructed so that in the event of fire in the building the received radiation at the relevant boundary of the property does not exceed 30 kW/m² and at a distance of 1 m beyond the relevant boundary of the property does not exceed 16 kW/m².* ***C3.7*** *External walls of buildings that are located closer than 1 m to the relevant boundary of the property on which the building stands must either:* *a) be constructed from materials which are not combustible building materials, or* *b) for buildings in Importance levels 3 and 4 be constructed from materials that, when subjected to a radiant flux of 30 kW/m², do not ignite for 30 minutes, or* *c) for buildings in Importance levels 1 and 2, be constructed from materials that, when subjected to a radiant flux of 30 kW/m², do not ignite for 15 minutes.* ***C4.2*** *Buildings must be provided with means of escape to ensure that there is a low probability of occupants of those buildings being unreasonably delayed or impeded from moving to a place of safety and that those occupants will not suffer injury or illness as a result.*
Required outcome	Demonstrate that the criteria in C3.6 and C3.7 are not exceeded by calculating the radiation from *unprotected areas* in the *external wall* to the closest point on an adjacent *boundary* and at 1.0 m beyond an adjacent *boundary*, and specifying exterior cladding materials with adequate resistance to ignition Control horizontal *fire* spread across a *notional boundary* to sleeping occupancies and *exitways* in *buildings* under the same *ownership.*

Comment:
NZBC C3.6 applies to all *buildings* except those with an automatic sprinkler system with two independent water supplies, one of which is not dependent on town mains and not used for storage above 3.0 m.

The performance requirements of C3.6 are also to be applied to limit the radiation at the *notional boundary* to sleeping occupancies and *exitways* in *buildings* under the same *ownership*. This partially contributes to the achievement of the functional requirement C4.2.

Scenario description

A fully developed *fire* in a *building* exposes the *external walls* of a neighbouring *building* (*other property*) or *firecell* (sleeping occupancy or *exitway*).

This scenario addresses a *fire* in a *building* that leads to high levels of radiation heat exposure across a *relevant boundary*, potentially igniting the *external walls* of a neighbouring *building*.

The potential for any *firecell* to expose *other property* shall be evaluated. However, the area beneath a canopy roof does not need to be assessed as a source of external *fire* spread if all the following conditions apply:

a) The nearest distance between any part of the canopy and the *relevant boundary* is not less than 1.0 m, and

b) The average *FLED* applying to the area beneath the canopy is not greater than 400 MJ/ m², and

c) The canopy has at least 50% of the perimeter area open to the outside.

The *design fire* for this scenario comprises an assumed emitted radiation flux from *unprotected areas* in *external walls* of the *fire source building* (assuming no intervention). This shall be taken as:

d) 83 kW/m² for *FLED* $\leq$400 MJ/m²

e) 103 kW/m² for *FLED* between 400 and 800 MJ/m², and

f) 144 kW/m² for *FLED* greater than 800 MJ/m².

Emissivity of *fire* gases shall be taken as 1.0.

For unsprinklered *buildings*, the width of the enclosing rectangle need be no greater than 20 m for *FLED* up to and including 800 MJ/m^2, or no greater than 30 m for *FLED* greater than 800 MJ/m^2. The actual width of the enclosing rectangle shall be used if it is less than 20 m.

If a *firecell* is not used for storage above 3.0 m and with an automatic sprinkler system supplied by two independent water supplies, one of which is not dependent on town mains, there are no restrictions on the amount of *unprotected area* and the *fire* engineer does not need to assess the external *fire* spread to the *boundary*.

In other *firecells* with an automatic sprinkler system, the maximum *unprotected area* permitted for an unsprinklered *firecell* can be doubled. Alternatively, if the *firecell* is not used for storage, you can consider:

a) The height of the enclosing rectangle as the vertical distance between the floor and the ceiling level beneath which the sprinklers are installed in the area adjacent to the *external wall* facing the *relevant boundary*, and

b) The width of the enclosing rectangle as the square root of the design maximum area of sprinkler operation (the actual width of the enclosing rectangle may be used if it is less).

The *fire* engineer only needs to consider one *firecell* at a time as a potential source of thermal radiation.

Unprotected area shall include both unrated *external wall construction* as well as any unrated window/door assemblies and other openings. Areas of the *external wall* that are not designated as *unprotected area* shall have a *fire resistance rating* (meeting both *integrity* and *insulation* criteria) sufficient to resist the full *burnout design fire* described in Paragraph 2.4. Furthermore, the structural system supporting those parts of the *external wall* not permitted to be unprotected must also have sufficient *fire* resistance to resist the full *burnout design fire*, and keep the *external wall* in place.

Unprotected area is not permitted within 1.0 m of a *relevant boundary*, except for a combination of small *unprotected area* and/or *fire resisting glazing* as described in Acceptable Solutions C/AS2 to C/AS6 Paragraph 5.4 or in the commentary document for this Verification Method.

Method

Calculate radiation from *unprotected areas* in the *external wall* to the closest point on an adjacent *boundary* and at 1.0 m beyond an adjacent *boundary*. The calculations must take into account:

a) The distance to the *boundary*, and

b) The size/shape of the *unprotected area* in the *external walls*, assuming the emitted radiant heat flux specified above for the applicable *FLED* range.

Alternatively, use the tabulated values of the maximum percentage of permitted *unprotected area* directly from Acceptable Solutions C/AS2 to C/AS6 as appropriate, or as provided in the commentary for this Verification Method.

The tables in the commentary document along with additional tables for *fire resisting glazing* and return and/or wing walls have been produced in accordance with this Verification Method. These tables can be used directly for unsprinklered *firecells* as long as *external walls* are parallel to, or angled at no more than, 10° to the *relevant boundary* and are no closer than 1.0 m to the *relevant boundary*.

For *external walls* at greater angles to the *relevant boundary*, appropriate calculations shall be undertaken to demonstrate that the performance criteria are achieved and minimum dimensions shall be specified for return and/or wing walls as necessary or use tables as provided in the commentary document.

To demonstrate that NZBC C3.7 is achieved, it is expected that relevant *fire* test results for the selected cladding system will be provided. Engineers may also choose to comply with Paragraph 5.8 of the relevant Acceptable Solutions C/AS2 to C/AS6 to satisfy the performance criteria of this clause.

4.6 Design scenario (VS): Vertical fire spread involving external cladding

Scenario in brief	A *fire source* exposes the *external wall* and leads to significant vertical *fire* spread.
Code objectives	***C1(a)*** *Safeguard people from an unacceptable risk of injury or illness caused by fire.* ***C1(b)*** *Protect other property from damage caused by fire.*
What you must satisfy	The performance criteria of C3.5 (ie, if *buildings* are taller than 10 m or have upper floors that are *other property* or contain people sleeping, *fire* shall be prevented from spreading more than 3.5 m vertically) so that: • tenable conditions are maintained on *escape routes* until the occupants have evacuated, and • vertical *fire* spread does not compromise the safety of firefighters working in or around the *building*. ***C3.5*** *Buildings must be designed and constructed so that fire does not spread more than 3.5 m vertically from the fire source over the external cladding of multi-level buildings.*
Required outcome	Demonstrate that the *building's* external claddings do not contribute to excessive vertical *fire* spread using one of the methods described.

Scenario description

This *design scenario* applies to:

a) All *buildings* with a *building height* of more than 10 m, and

b) Any other *buildings* with upper floors where people sleep or are defined as *other property*.

Comment:
This scenario is not concerned with *building*-to-*building fire* spread across a *relevant boundary*, as this is addressed in the *design scenario*: HS (see Paragraph 4.5).

The *design fire* for this scenario shall be a *fire source* that is either:

a) In close contact with the façade (eg, in a rubbish container/skip) that could ignite and spread *fire* vertically to higher levels in the *building*, or

b) Adjacent to an *external wall*, such as a *fire* plume emerging from a window opening or from an *unprotected area* of the wall burning.

There are two considerations in this scenario:

Part A: External vertical *fire* spread over the façade materials, and

Part B: *Fire* plumes spreading *fire* vertically up the *external wall* via openings and *unprotected areas*.

Comment:
Part A addresses concerns regarding the contribution of *combustible* claddings to vertical *fire* spread, while Part B looks at the role of aprons, spandrels or sprinklers in preventing external *fire* spread (due to projecting window *fire* plumes) between openings at different levels in the *building*.

For Part A, the *design fire* exposure is:

a) Radiant flux of 50 kW/m² impinging on the façade for 15 minutes for *buildings* in *importance levels* 2 and 3, or

b) Radiant flux of 90 kW/m² impinging on the façade for 15 minutes for *buildings* in *importance level* 4.

The intention is to prevent façade cladding materials from contributing to significant flame spread propagation beyond the area initially exposed. Some damage to the area initially exposed is expected.

This can be achieved by:

a) Limiting the maximum *HRR* from a cladding material when exposed to the design event to no more than 100 kW/m², or

b) Limiting the extent of the vertical flame spread distance (on the façade) to no more than 3.5 m above the *fire source*. This accepts that *fire* spread via the façade materials may occur to the floor immediately above, but not two floors above.

For Part B, the *design fire* exposure is a *fire* plume projecting from openings or *unprotected areas* in the *external wall*, with characteristics determined from the *design fire* as described in Part 2 for the applicable occupancy. The intention is to prevent *fire* spread in unsprinklered *buildings* from projecting *fire* plumes to *unprotected areas* on upper floors where they are within 1.5 m vertically of a projecting plume *fire source*.

Method

For Part A, follow the requirements of Part 5: Control of external fire spread of the relevant Acceptable Solutions (C/AS2 to C/AS6) and use:

a) Large or medium-scale 'façade type' *fire* tests (eg, NFPA 285, ISO 13785-1 or Vertical Channel test) demonstrating the extent of vertical flame spread is no more than 3.5 m above the *fire source*, or

b) Small-scale testing using ISO 5660 or AS/NZS 3837 (cone calorimeter) for homogeneous materials, demonstrating the maximum *HRR* from a cladding material is no greater than 100 kW/m² when exposed to the design event to ensure propagating flame spread over its surface is unlikely, or

c) Use *non-combustible* materials.

Comment:
Validated flame spread models could be used for some materials.

The requirements given in Acceptable Solutions C/AS2 to C/AS6 Paragraph 5.8 for *fire* properties of external claddings are acceptable means of demonstrating compliance with Part A above for *buildings* with an *importance level* not higher than 3.

For Part B:

a) *Construction* features such as aprons and/or spandrels designed to the specifications given in C/AS2 to C/AS6 Part 5 or the installation of an automatic *fire* sprinkler system designed to a recognised national or international Standard can be used to satisfy the requirements of this scenario.

b) Should calculation methods be used instead, then *fire* plume characteristics and geometry shall be derived from the *design fires* as described in Part 2 for the applicable occupancy.

4.7 Design scenario (IS): Rapid fire spread involving internal surface linings

Scenario in brief	Interior surfaces are exposed to a growing *fire* that potentially endangers occupants.
Code objective	***C1(a)*** *Safeguard people from an unacceptable risk of injury or illness caused by fire.*
What you must satisfy	The performance criteria of C3.4 for materials used as internal surface linings in the relevant *building* areas, as also specified in C3.4. Where *foamed plastics* or combustible insulating materials form part of a wall, ceiling or roof system, the completed system shall achieve a *Group Number* as specified in C3.4(a) and the *foamed plastics* shall comply with the flame propagation criteria as specified in AS 1366 for the type of material being used. **Comment:** The completed system may or may not include a surface lining product enclosing any insulation material from any adjacent *occupied space*. If a surface lining is not included then the *foamed plastics* or combustible *insulating materials* when tested alone shall achieve a *Group Number* of 3. Otherwise a surface lining is also required such that the completed system achieves a *Group Number* of 3.

Walls and ceiling linings and ducts	*Limits on application*	
C3.4(a) *Materials used as internal surface linings in the following areas of buildings must meet the performance criteria specified below:*	*Clause C3.4 does not apply to detached dwellings, within household units in multi-unit dwellings, or outbuildings and ancillary buildings.*	
Area of building	*Performance determined under the conditions described in ISO 9705: 1993*	
	Buildings not protected with an automatic fire sprinkler system	*Buildings protected with an automatic fire sprinkler system*
Wall/ceiling materials in sleeping areas where care or detention is provided *Wall/ceiling materials in exitways* *Wall/ceiling materials in all occupied spaces in importance level 4 buildings* *Internal surfaces of ducts for HVAC systems*	*Material Group Number 1-S*	*Material Group Number 1 or 2*
Ceiling materials in crowd and sleeping uses but not household units or where care or detention is provided	*Material Group Number 1-S or 2-S.*	*Material Group Number 1 or 2*
Wall materials in crowd and sleeping uses except household units or where care or detention is provided	*Material Group Number 1-S or 2-S*	*Material Group Number 1, 2 or 3*
Wall/ceiling materials in occupied spaces in all other locations in buildings, including household units *External surfaces of ducts for HVAC systems* *Acoustic treatment and pipe insulation within air-handling plenums in sleeping uses*	*Material Group Number 1, 2 or 3*	*Material Group Number 1, 2 or 3*

	Floor surfaces suspended flexible fabrics and membrane structures		
	C3.4(b) Floor surface materials in the following areas of buildings must meet the performance criteria specified below:		
	Area of building	*Minimum critical radiant flux when tested to ISO 9239-1: 2010*	
		Buildings not protected with an automatic fire sprinkler system	*Buildings protected with an automatic fire sprinkler system*
	Sleeping areas and exitways in buildings where care or detention is provided	*4.5 kW/m²*	*2.2 kW/m²*
	Exitways in all other buildings	*2.2 kW/m²*	*2.2 kW/m²*
	Firecells accommodating more than 50 persons	*2.2 kW/m²*	*1.2 kW/m²*
	All other occupied spaces except household units	*1.2 kW/m²*	*1.2 kW/m²*
	C3.4(c) is to be satisfied by ensuring that: a) suspended flexible fabrics used as underlay to exterior cladding or roofing, when exposed to view in all *occupied spaces* excluding *household units*, shall have a *flammability index* of no greater than 5 when tested to AS 1530 Part 2 b) Suspended flexible fabrics and membrane structures shall have a *flammability index* of no greater than 12 when tested to AS 1530 Part 2 in the following locations: i) *exitways* from spaces where people sleep, and ii) all *occupied spaces* within crowd uses.		
Required outcome	Demonstrate that *surface finishes* comply with these performance requirements.		

Scenario description

The performance criteria required for lining materials will depend on their location within a *building*, the use of the *building* and its *importance level*.

The criteria in NZBC C3.4 shall be applied to lining materials, except in the following cases:

a) Small areas of non-conforming product within a space with a total aggregate surface area not more than 5.0 m²

b) Electrical switches, outlets, cover plates and similar small discontinuous areas

c) Pipes and cables used to distribute power or services

d) *Handrails* and general decorative trim such as architraves, skirtings and window components including reveals

e) *Damp-proof courses*, seals, caulking, flashings, thermal breaks and ground moisture barriers

f) Timber joinery and structural timber *building elements* constructed from solid wood, glulam or laminated veneer lumber. This includes heavy timber columns, beams, portals and shear walls not more than 3.0 m wide, but does not include exposed timber panels or permanent formwork on the underside of floor/ ceiling systems.

g) Individual *doorsets*, and

h) Continuous areas of permanently installed openable wall partitions not more than 3.0 m high and having a surface area of not more than 25% of the divided room floor area or 5.0 m², whichever is less.

The smoke production rate criteria do not need to apply for sprinklered *buildings*.

Material *Group Numbers* apply to the exposed surface of the interior wall or ceiling lining. They are determined by the *fire* testing laboratory using the procedure described in Appendix A. This is either to:

a) ISO 9705, which is a full-scale room corner test, or

b) ISO 5660, which is a bench-scale fire test on a small sample of the material.

A correlation is used that allows the ISO 9705 result to be predicted using data obtained in the ISO 5660 test.

If an 'S' is appended to the material *Group Number*, the material also is required to meet smoke production criteria. The limit for maximum smoke production is:

a) 5.0 m^2/s if the ISO 9705 test is used, or

b) 250 m^2/kg if the ISO 5660 test is used.

Materials that are classified *non-combustible* when tested to AS 1530.1 or ISO 1182 can be assigned a material *Group Number* of 1 or 1–S without further evaluation using Appendix A.

The minimum critical flux for a floor surface material or covering is determined by *fire* testing to ISO 9239 Part 1 (radiant panel test).

Method

The following tests should be applied to lining materials to achieve compliance with NZBC C3.4.

For wall/ceiling lining materials, external surface of ducts and pipe insulation:

a) Small scale testing to ISO 5660 (cone calorimeter test) provided it is appropriate for the type of material, or

b) Full scale testing to ISO 9705 (room corner test).

For floor surface materials:

a) *Fire* testing to ISO 9239 Part 1 (radiant panel test).

For suspended flexible fabrics and membrane structures:

a) *Fire* testing to AS 1530 Part 2 (flammability test).

4.8 Design scenario (FO): Firefighting operations

Scenario in brief	This scenario provides for the safe operation of firefighters in a *building*.
Code objectives	***C1 b)*** *Protect other property from damage caused by fire, and* ***C1(c)*** *Facilitate firefighting and rescue operations.*
What you must satisfy	The performance criteria in C3.8, C5.3, C5.4, C5.5, C5.6, C5.7, C5.8 and C6.3. ***C3.8*** *Firecells located within 15 m of a relevant boundary that are not protected by an automatic fire sprinkler system, and that contain a fire load greater than 20 TJ or that have a floor area greater than 5000 m*^{2} *must be designed and constructed so that at the time that firefighters first apply water to the fire, the maximum radiation flux at 1.5 m above the floor is no greater than 4.5 kW/m*^{2}*; and the smoke layer is no less than 2 m above the floor.*
	C5.3 *Buildings must be provided with access for fire service vehicles to a hard-standing from which there is an unobstructed path to the building within 20 m of:* *(a) the firefighter access into the building, and* *(b) the inlets to automatic fire sprinkler systems or fire hydrant systems, where these are installed.*
	C5.4 *Access for fire service vehicles in accordance with Clause C5.3 shall be provided to more than 1 side of firecells greater than 5 000 m*^{2} *in floor area that are not protected by an automatic fire sprinkler system.*
	C5.5 *Buildings must be provided with the means to deliver water for firefighting to all parts of the building.*
	C5.6 *Buildings must be designed and constructed in a manner that will allow firefighters, taking into account the firefighters' personal protective equipment and standard training, to:* *a) reach the floor of fire origin,* *b) search the general area of fire origin, and* *c) protect their means of egress.*
	C5.7 *Buildings must be provided with means of giving clear information to enable firefighters to:* *a) establish the general location of the fire,* *b) identify the fire safety systems available in the building, and* *c) establish the presence of hazardous substances or process in the building.*
	C5.8 *Means to provide access for and safety of firefighters in buildings must be designed and constructed with regard to the likelihood and consequence of failure of any fire safety systems.*
	C6.3 *Structural systems in buildings that are necessary to provide firefighters with safe access to floors for the purpose of conducting firefighting and rescue operations must be designed and constructed so that they remain stable during and after fire.*
Required outcome	Show that the performance requirements are satisfied.

Scenario description

This scenario has been designed to test the safe operation of firefighters in the event of a *fire* in the *building*.

For the purposes of NZBC C3.8, take the time that the Fire Service first applies water to the *fire* as either:

a) 1200 seconds, or

b) 1000 seconds if there is an automatic alarm and direct connection to the Fire Service, or

c) Some other time as determined and supported by the application of a *fire* brigade intervention model.

Use the *design fire* as described in Paragraph 2.3 for the applicable occupancy. This can be modified to account for ventilation conditions.

Where *fire separations* are specified to create *firecells* of area not more than 5000 m^2, the full *burnout design fire* defined in Paragraph 2.4 shall be used to determine the required *fire* resistance of the *fire separation*.

For the purposes of NZBC C5.5, water shall be provided from either:

a) A pumping appliance parked close to the *building* such that any point within the *building* may be reached within 75 m (~3 hose lengths) of the pumping appliance, or

b) An internal hydrant designed and installed to NZS 4510 or as approved by the National Commander of the New Zealand Fire Service.

In relation to NZBC C6.3, firefighters are provided with the means of conducting search and rescue operations by giving them safe access to the *fire* floor with *building construction* that will not collapse during the *fire*. Derive the *fire* resistance of the structure or separating *construction* needed to achieve this by reference to the full *burnout design fire* defined in Pararaph 2.4 and by meeting the requirements below.

A. For buildings with an escape height >10 m:

a) Provide firefighters with *safe paths* that are designed to resist *fire* spread until *burnout*, allowing them access to all floors within the *building* that are not directly accessible from street level, and

Comment:
In the case of *intermediate floors*, access to the *intermediate floor* can be taken as being achieved if:

a) The distance between the most remote point on the *intermediate floor* and a hydrant located within a *safe path* is no more than 40 m. This corresponds to ~2 hose lengths with some allowance for a non-direct path, or

b) The furthest point on the *intermediate floor* is able to be reached within 3 hose lengths to satisfy the requirement of NZBC C5.5 to provide water to all points of the *building*.

b) Protect firefighters and others at ground level and within the *building* by designing the load-carrying structure and floor systems (excluding *intermediate floors*) to resist collapse and prevent *fire* spread between floor levels until *burnout*, and

c) Design *intermediate floors* and supporting structure to resist collapse until *burnout*. This is unless the *intermediate floor* has an *occupant load* ≤100 people and an *escape height* ≤4.0 m and the area below the floor is open to the *firecell*; in which case the *intermediate floor* may be designed to resist collapse for not less than 30 minutes. Such collapse shall not cause consequent collapse of any other part of the structural system that is required to resist *burnout* in accordance with a) or b) above. Errata 2 Feb 2013

B. For buildings with an escape height ≤10 m:

a) Provide firefighters with *safe paths* allowing them access to all floors within the *building* that are not directly accessible from street level either for a period of 60 minutes (from ignition) or to resist collapse until *burnout*, whichever is less, and

b) Protect firefighters and others at ground level and within the *building* by designing the floor systems (excluding *intermediate floors*) and supporting structure to resist collapse and prevent *fire* spread between floor levels for a period of at least 30 minutes (provide them with an *FRR* of 30 minutes), and Errata 2 Feb 2013

c) Design *intermediate floors* and supporting structure to resist collapse by having an *FRR* of 30 minutes. Errata 2 Feb 2013

Comment:
These requirements permit search and rescue operations, and attempt to avoid unexpected or sudden collapse that would endanger Fire Service personnel within the *building*.

Intermediate floors – additional requirements:

If the total floor area of *intermediate floors* exceeds 40% of the floor area of the *firecell*, the *intermediate floor* shall be rated for *integrity* and *insulation* as well as *structural adequacy* to resist collapse.

Catwalks used intermittently in industrial plants, platforms for retractable seating, flytowers over stages, and similar structures do not need to be *fire* rated.

4.9 Design scenario (CF): Challenging fire

Scenario in brief	A *fire* starts in a normally *occupied space* and presents a challenge to the *building's fire safety systems*, threatening the safety of its occupants.
Code objective	***C1(a)*** *Safeguard people from an unacceptable risk of injury or illness caused by fire.*
What you must satisfy	The performance criteria of C4.3 and C4.4. This will require analysis. ***C4.3*** *The evacuation time must allow occupants of a building to move to a place of safety in the event of a fire so that occupants are not exposed to any of the following:* *(a) a fractional effective dose of carbon monoxide greater than 0.3;* *(b) a fractional effective dose of thermal effects greater than 0.3;* *(c) conditions where, due to smoke obscuration, visibility is less than 10 m except in rooms of less than 100 m^2 where the visibility may fall to 5 m.* ***C4.4*** *Clause C4.3 (b) and (c) do not apply where it is not possible to expose more than 1000 people in a firecell protected with an automatic fire sprinkler system.*
Required outcome	Demonstrate *ASET>RSET* for *design fires* in various locations within the *building*.

Scenario description

The challenging *fires* are intended to represent credible worst case scenarios in normally occupied spaces that will challenge the *fire* protection features of the *building*.

This scenario requires the use of *design fires* in various locations within the *building*. *ASET* need not be determined for occupants of the enclosure of *fire* origin for the following *fire* locations:

Errata 1 Apr 2012

a) Any room with a floor area less than 2.0 m^2, or

b) Sanitary facilities adjoining an *exitway*, or

c) Any room or space of *fire* origin other than sleeping areas where care or detention is provided, which has all of the following:

Errata 1 Apr 2012

  i) a total floor area, including *intermediate floors*, of less than 500 m^2, and

  ii) more than one direction of travel or a single direction of travel that is less than 25 m, and

  iii) an *occupant load* of less than 150 people for the room or less than 100 people for any *intermediate floor*.

For c), the *fire* engineer does not have to demonstrate that tenability is maintained for occupants within the enclosure of origin; however, they must demonstrate that the challenging *fire* in this space does not threaten occupants in the rest of the *building*. The *design fires* shall be characterised with a power law *HRR*, peak *HRR* and *FLED* as specified in Part 2. Design values for *yields* are specified for CO, CO_2 and soot/smoke. Hydrogen cyanide production need not be considered.

Errata 1 Apr 2012

The *design fires* are intended to represent 'free-burning' *fires*. However, they shall be modified during an analysis (depending on the methodology used) to account for *building* ventilation and the effects of automatic *fire* suppression systems (if any) on the *fire*. The *design scenario*: RC (see Paragraph 4.10) will require the overall robustness of the design to be examined separately.

The *fire* engineer shall:

a) For each location of the challenging *fire*, use a single *fire source* to evaluate the *building's* protection measures

b) Consider the impact on occupants who may be using *escape routes* external to the *building* as well as internal routes (see Paragraph 3.6.1), and Errata 2 Feb 2013

c) Assume that active and passive *fire safety systems* in the *building* will perform as intended by the design.

Method

This scenario requires the *ASET/RSET* analysis of the impact on all *building* occupants of *design fires* located in various locations within the *building*, except for those rooms or spaces excluded in the scenario description above.

The *fire* engineer is expected to calculate the *fire* environment in the *escape routes* over the period of time the occupants require to escape. Assess the *fire* environment based on the *fractional effective dose* and *visibility* at the location of the occupants.

The *fire* engineer will typically select a *fire* calculation model appropriate to the complexity and size of the *building*/space that allows the *fractional effective dose* and *visibility* to be determined.

4.10 Design scenario (RC): Robustness check

Scenario in brief	The *fire* design will be checked to ensure that the failure of a critical part of the *fire safety system* will not result in the design not meeting the objectives of the *Building Code*.
Code objectives	***C1(a)*** *Safeguard people from an unacceptable risk of injury or illness caused by fire.* ***C1(b)*** *Protect other property from damage caused by fire.* ***C1(c)*** *Facilitate firefighting and rescue operations.*
What you must satisfy	This scenario contributes to testing the performance criteria of C3.9, C4.5, C5.8 and C6.2d). Where tenability criteria are evaluated, these criteria only need to be assessed based on *FED* (CO). ***C3.9*** *Buildings must be designed and constructed with regard to the likelihood and consequence of failure of any fire safety system intended to control fire spread.* ***C4.5*** *Means of escape to a place of safety in buildings must be designed and constructed with regard to the likelihood and consequence of failure of any fire safety systems.* ***C5.8*** *Means to provide access for and safety of firefighters in buildings must be designed and constructed with regard to the likelihood and consequence of failure of any fire safety systems.* ***C6.2*** *Structural systems in buildings that are necessary for structural stability in fire must be designed and constructed so that they remain stable during fire and after fire when required to protect other property taking into account:* *(a) …* *(b) …* *(c) …* *(d) the likelihood and consequence of failure of any fire safety systems that affect the fire severity and its impact on structural stability.*
Required outcome	Demonstrate that if a single *fire safety system* fails, where that failure is statistically probable, the *building* as designed will allow people to escape and *fire* spread to *other property* will be limited.

Scenario description

This scenario applies where failure of a key *fire safety system* could potentially expose to untenable conditions:

a) More than 150 people, or

b) More than 50 people in a sleeping occupancy *firecell* where the occupants are neither detained or undergoing some treatment or care, or

c) People detained or undergoing treatment or care.

For this scenario, key *fire safety systems* include:

a) Smoke management systems (other than permanent natural/passive ventilation features that do not rely on the activation of any mechanical or electronic component)

b) *Fire* and/or *smoke control doors* or similar *fire* closures, and

c) Any other feature or system required as part of the *fire* safety design that relies on a mechanical or electronic component to be activated during the *fire*, except that:

i) *fire* sprinkler systems and automatic *fire* alarms installed to a recognised national or international Standard, can be considered to be sufficiently reliable that they are exempt from this robustness scenario, and

ii) in sprinklered *buildings*, *fire* and *smoke control doors* fitted with automatic *hold-open devices* that are designed and installed to BS 7273.4 or another recognised national or international Standard and are activated by the operation of the *fire* alarm system can be considered to be sufficiently reliable that they are exempt from this robustness scenario.

This particular scenario focuses on the *ASET/RSET* life safety calculations performed as part of the *design scenario*: CF Challenging fire (see Paragraph 4.9). The robustness of the design shall be tested by considering the *design fire* with each key *fire safety system* rendered ineffective in turn.

For this scenario, where tenability criteria are evaluated, the engineer needs to assess these based on *FED* (CO).

Comment:
Ideally, a comprehensive quantitative probabilistic risk assessment would be used to assess the safety of a design. However, the risk assessment tools and supporting data are currently not suitable for inclusion within this Verification Method. Therefore, the framework currently requires a deterministic *ASET/RSET* approach with additional checks and balances to meet *Building Code* objectives.

As a general rule, when calculating *ASET* times, *fire safety systems* may be assumed to operate as designed, provided they are manufactured and installed in accordance with recognised national or international Standards. However, in the situations defined above, additional *fire safety systems* are required to provide redundancy and robustness to the *fire* safety design.

Method

In the circumstances described in the scenario, assume the failure of each key *fire safety system* in turn. If *ASET* cannot be shown to be greater than *RSET* when each key system fails, then the design must be altered until the requirements of this scenario can be satisfied.

If a design does not require a key *fire safety system* for *ASET*>*RSET*, there is no system to fail and the further robustness test is not required.

Robustness check of vertical escape routes

In addition to the above, a robustness check applies to sprinklered sleeping occupancies as follows:

For a *building* served by a single vertical *escape route*, visibility in the vertical *escape route* shall not be less than 5.0 m for the period of the *RSET*.

Errata 2
Feb 2013

For a *building* where the vertical *escape routes* serve more than 250 people in a sleeping occupancy, visibility shall not be less than 5.0 m in more than one vertical *escape route* for the period of the *RSET*.

This check assumes that all *fire safety systems* are operating as designed.

Errata 2
Feb 2013

Appendix A (normative): Establishing Group Numbers for lining materials

A1.1 Tests for material Group Numbers

Materials shall be assigned a material *Group Number* when tested to either:

a) ISO 9705 Fire tests – full scale room test for surface products, or

b) ISO 5660 Reaction to fire tests (Heat release, smoke production and mass loss rate) Part 1: Heat release rate (cone calorimeter method); and ISO 5660 Reaction to fire tests (Heat release, smoke production and mass loss rate) Part 2: Smoke production rate (dynamic measurement).

This is except in the following cases:

a) Metal-skin panel assemblies with *combustible* core materials, which shall only be assessed using either the ISO 9705 or ISO 13784 Part 1 test method, or

b) Foil-faced *combustible* materials, which shall only be assessed using the ISO 9705 test method, or

c) Other products that an accredited test laboratory believes are not appropriate to be evaluated using the ISO 5660 test method due to the configuration or other characteristics of the product. Such products shall be assessed using either the ISO 9705 test or another large scale test if deemed to be appropriate.

Comment:
ISO 5660 is unsuitable in cases where the *fire* performance of the assembly is dominated by the *construction* details rather than the flammability characteristics of the surface material or in cases where, due to the configuration of the material in the test, significant mechanical damage occurs at full scale which does not occur with small, horizontal samples.

A1. 2 Determining a material's Group Number when tested to ISO 9705

For a material tested to ISO 9705, the material's *Group Number* shall be determined as follows:

Group Number 1 material has total heat release not greater than 1 MW following exposure to 100 kW for 10 minutes then 300 kW for 10 minutes

Group Number 1–S material has total heat release not greater than 1 MW following exposure to 100 kW for 10 minutes then 300 kW for 10 minutes and the average smoke production rate over the period 0–20 min is not greater than 5.0 m^2/s

Group Number 2 material has total heat release not greater than 1 MW following exposure to 100 kW for 10 minutes

Group Number 2–S material has total heat release not greater than 1 MW following exposure to 100 kW for 10 minutes and the average smoke production rate over the period 0–10 min is not greater than 5.0 m^2/s

Group Number 3 material has total heat release not greater than 1 MW following exposure to 100 kW for 2 minutes, and

Group Number 4 material has total heat release greater than 1 MW following exposure to 100 kW for 2 minutes.

The rate of total heat release determined in ISO 9705 includes contribution from both the internal lining and the exposure source (100 kW or 300 kW).

The *Group Number* of a material predicted in accordance with Paragraph A1.3 using data obtained by testing the material at 50 kW/m^2 irradiance in the horizontal orientation with edge frame in accordance with ISO 5660 is given by:

Group Number 1 material: as predicted in accordance with Paragraph A1.3

Group Number 1-S material: as predicted in accordance with Paragraph A1.3 and an average *specific extinction area* less than 250 m^2/kg

Group Number 2 material: as predicted in accordance with Paragraph A1.3

Group Number 2-S material: as predicted in accordance with Paragraph A1.3 and an average *specific extinction area* less than 250 m^2/kg

Group Number 3 material: as predicted in accordance with Paragraph A1.3, and

Group Number 4 material: as predicted in accordance with Paragraph A1.3.

A1. 3 Determining a material's Group Number when tested to ISO 5660

For a material tested to ISO 5660, the material's *Group Number* must be determined in accordance with the following:

a) Data must be in the form of time and *HRR* pairs for the duration of the test. The time interval between pairs should not be more than 5 seconds. The end of the test (t_f) is determined as defined in ISO 5660, and

b) At least three replicate specimens must be tested.

The following five steps must be applied separately to each specimen:

Step 1: Determine time to ignition (t_{ig}). This is defined as the time (in seconds) when the *HRR* reaches or first exceeds a value of 50 kW/m^2.

Step 2: Calculate the Ignitability Index (I_{ig}) expressed in reciprocal minutes.

$$I_{ig} = \frac{60}{t_{ig}}$$

Step 3: Calculate the following two *HRR* indices:

$$IQ_1 = \int_{t_{ir}}^{t_i} \left[\frac{q''(t)}{(t - t_{ig})^{0.34}} \right]$$

$$IQ_2 = \int_{t_{ir}}^{t_i} \left[\frac{q''(t)}{(t - t_{ig})^{0.93}} \right]$$

> **Comment:**
> These definite integral expressions represent the area under a curve from the ignition time until the end of the test, where the parameter is plotted on the vertical axis and time (t) is plotted on the horizontal axis.

Step 4: Calculate the following three integral limits:

$IQ_{,10\text{min}} = 6800 - 540I_{ig}$

$IQ_{,2\text{min}} = 2475 - 165I_{ig}$

$IQ_{,12\text{min}} = 1650 - 165I_{ig}$

Step 5: Classify the material in accordance with the following:

i) If $IQ_1 > IQ_{10}$ min and $IQ_2 > IQ_2$ min, the material is a *Group Number* 4 material

ii) If $IQ_1 > IQ_{10}$ min and $IQ_2 \leq IQ_2$ min, the material is a *Group Number* 3 material

iii) If $IQ_1 \leq IQ_{10}$ min and $IQ_2 > IQ_{12}$ min, the material is a *Group Number* 2 material

iv) If $IQ_1 \leq IQ_{10}$ min and $IQ_2 \leq IQ_{12}$ min, the material is a *Group Number* 1 material, or

v) If the ignition criterion in Step 1 above is not reached, the material is a *Group Number* 1 material.

Repeat steps 1 to 5 above for each replicate specimen tested. If a different classification group is obtained for different specimens tested, then the highest (worst) classification for any specimen must be taken as the final classification for that material.

> **Comment:**
> It is expected that the *fire* testing laboratory will determine the material *Group Number* as described in this section when reporting the *fire* test results.

Index

References are to the relevent paragraphs, figures or tables in **C/VM2** unless otherwise stated.
References to Appendices are prefixed by the Appendix letter.