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Title

AS 1668.3-2001 The use of ventilation and airconditioning in buildings - Smoke control systems for large single compartments or smoke reservoirs

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The use of ventilation and airconditioning in buildings

Part 3: Smoke control systems for large single compartments or smoke reservoirs

Standards Australia

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The following interests are represented on Committee ME-062:

Airconditioning and Mechanical Contractors Association of Australia

Air-conditioning and Refrigeration Equipment Manufacturers Association of Australia

Australian Fire Authorities Council

Australian Buildings Code Board

Australian Industry Group

Australian Institute of Building

Australian Institute of Building Surveyors

Australian Institute of Refrigeration Air conditioning and Heating

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Australian Standard™

The use of ventilation and airconditioning in buildings

Part 3: Smoke control systems for large single compartments or smoke reservoirs

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee ME-062, Ventilation and Airconditioning.

The Standard does not identify those buildings in which smoke control systems are required. This is covered in the Building Code of Australia (BCA).

The objective of this document is to provide a standardized methodology for the design of smoke control systems, utilizing exhaust from above the hot layer, for use by system owners, regulators, designers and installers.

In the preparation of this Standard, consideration has been given to the following—

(a) British Standard Institute, Draft for development DD 240: Part 1:1997, Fire safety engineering in buildings, Part 1: Guide to the application of fire safety engineering principles.

(b) BS 7346 Parts 1–3 inclusive, Performance of fans, vents and smoke curtains commensurate with likely fire impact (consolidated into this Standard).

(c) CIBSE, Technical Memoranda TM19, Relationships for Smoke Control Calculations (1995).

(d) Building Research Establishment Report, Design principles for smoke ventilation in enclosed shopping centres (1990).

(e) Building Research Establishment Report: Sprinkler Operation and the Effect of Venting: Studies Using a Zone Model.

(f) Building Research Establishment Report: Design Principles for Smoke Ventilation in Enclosed Shopping Centres.

(g) Building Control Commission, Smoke Management in Large Spaces in Buildings.

(h) Fire Brigade Intervention Model, pre-publication version 2.1, November 1997, Australasian Fire Authorities Council.

(i) Micro-economic Reform, Fire Regulation—Building Regulation Review Task Force May 1991. The concept of a 'Time Line' and the impact of resources to combat a fire has been considered.

(j) Fire Code Reform Centre, Fire Engineering Guidelines.

(k) The N.F.P.A. 92B, 'T' squared fire concept has also been utilized in the development of this Standard.

(j) Adelaide University, C.S.I.R.O. and South Australian Metropolitan Fire Service Data: recorded whilst fire and smoke testing within Australian buildings.

The term 'informative' has been used in this Standard to define the application of the appendix to which they apply. An 'informative' appendix is only for information and guidance.

This Standard incorporates a Commentary on some clauses. The Commentary directly follows the relevant Clause, is designated by 'C' preceding the clause number and is printed in italics in a panel. The Commentary is for information only and does not need to be followed for compliance with the Standard.

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FOREWORD

The intent of this Standard is to provide a structured prescriptive method for the design of smoke control systems in large single compartments or smoke reservoirs. Systems designed in accordance with this Standard are required to have a performance graded to the characteristics of a particular risk.

The outcome of the methodology employed by this Standard will be a relative grading of the interactions of fire load, building characteristics and fire intervention systems. As with other fire Standards (e.g. AS 1530 series of Standards) this Standard does not predict system performance under actual building fire conditions.

Systems are designed to operate under prescribed interior fire conditions influenced by such factors as enclosure volume, fire growth rate and active suppression systems. The period of time the system is required to operate is affected by the safety risk and resources available to fight the fire.

STANDARDS AUSTRALIA

Australian Standard

The use of ventilation and airconditioning in buildings

Part 3: Smoke control systems for large single compartments or smoke reservoirs

SECTION 1 GENERAL

1.1 SCOPE

This Standard sets minimum requirements for the design of smoke control systems in large single compartments in which smoke accumulates in a smoke reservoir. It sets minimum requirements considered necessary to meet the system design objectives in terms of continuous operation over a specified time period under a specified fire condition.

The design information given in this Standard is based on axisymmetric plumes. Compartments and smoke reservoirs are designed separately and spill plumes between compartments/reservoirs are not considered.

This Standard is not appropriate in situations where a stable buoyant hot layer does not exist.

NOTES:

1 Smoke control in multi-compartment buildings is covered in AS/NZS 1668.1.

2 This Standard should only be applied to areas with greater than 3 m floor to ceiling or upper bounding layer height.

3 AS 1851.5 and AS/NZS 1851.6 outline management procedures for maintaining smoke and heat vents and the fire and smoke control features of air-handling systems.

1.2 DESIGN PARAMETERS

This Standard specifies minimum requirements for the design of mechanical and buoyancy-driven smoke control systems relying on the removal of smoke from a buoyant hot layer within a smoke reservoir. The method of system design is based on key input design parameters. These key input design parameters include —

(i) total fire heat output $(\dot{Q}_c)$;

(ii) volumetric exhaust flow rate $(\dot{V})$;

(iii) hot layer temperature (T_L);

(iv) hot layer depth (d); and

(v) system duration time (t_d).

Such design parameters are required before system design is undertaken. They may be developed for a particular building from consideration of a Fire Engineering Design Brief (FEDB) or from the application of the information and calculations contained in this Standard. Design parameters will vary depending on the objectives of the smoke control system.

NOTE: Guidance on the selection/development of these design parameters is provided in the Fire Engineering Guidelines or in Appendix A.

C1.2 *System design parameters need to be developed so that the detailed system design can be completed.*

Design parameters will depend on design objectives which may include the following:

(a) Maintenance of a tenable atmosphere within the smoke zone during the time required for occupant evacuation.

(b) Provision of conditions within and without the smoke zone to aid fire brigade search and rescue operations.

(c) Limitation of fire and smoke spread and heat radiation to reduce building structural damage.

(d) Control and reduction of smoke migration between the smoke zone and adjacent areas.

(e) Limitation of fire and smoke spread and heat radiation to reduce damage to contents.

(f) Limitation of fire and smoke spread and heat radiation to reduce damage to adjoining buildings.

Specific design objectives or parameters for smoke control systems may be established through other Standards or Regulations.

1.3 PRINCIPLES

Smoke control systems are designed on the basis of the specified design parameters. Removal of smoke is from the hot layer by either mechanical means or by buoyancy driven flow through openings in the upper bounding surfaces (roof or high level of walls). Make-up air is provided below the hot layer to balance the flow into the layer to maintain the design hot layer height. The maximum hot layer temperatures are considered with respect to the performance of fans, vent openings, smoke curtains and other system components.

This Standard is based upon a two-zone model concept comprising a buoyant upper hot ceiling layer of smoky gases at average temperature (T_L) and a layer of air beneath the ceiling layer at average temperature (T_a).

C1.3 *The requirements of this Standard do not address in-depth issues such as the properties of the burning material (e.g. density, moisture content, surface area and texture, flame retardant treatment), ventilation conditions, radiation feedback from the burning material itself as well as that from the compartment walls and the hot layer, fuel arrangement (e.g. how close are the fuel packages, are there bridges between fuel packages), fuel geometry (e.g. a sofa with a straight back compared with one with an inclined back), presence of flying embers or the effect of operation of fire suppression systems on hot layer temperatures.*

1.4 APPLICATION

For the purposes of this Standard a two-layer principle for smoke movement analysis may be applied to large single compartments. It is not intended that this Standard be applied to areas of a low floor to ceiling height of less than 3 m or to road tunnels.

This Standard may be applied to the design of smoke exhaust systems where smoke control is to be achieved by exhaust from a ceiling smoke reservoir satisfying the following:

(a) The compartment or smoke reservoir has a floor to ceiling height of not less than 3.0 m.

(b) The smoke control zone forms a single smoke reservoir capable of containing the hot smoke.

(c) Smoke reservoirs are formed by non-combustible walls or screens that retain their integrity for the system duration time (t_d) when exposed to the maximum expected hot layer temperature (T_L).

(d) Interconnected compartments within one smoke reservoir have a minimum cross-sectioned area within compartments above the design hot layer height not less than the design volumetric exhaust flow rate ($\dot{V}$) divided by 2 m/s.

(e) Smoke reservoirs have a minimum depth of one-fifth enclosure height.

(f) Smoke reservoirs have a maximum area of 2000 m^2.

(g) Smoke reservoirs have a minimum dimension of $\sqrt{(\text{Area of Compartment}/5)}$

(h) Smoke reservoirs have a minimum volume of 10 times the design volumetric exhaust flow rate ($\dot{V}$).

C1.4 *The following examples of large single compartments or smoke reservoirs may be helpful:*

(a) Factories, warehouses, shops, enclosed atria, sporting venues, ten-pin bowling alleys, indoor cricket, netball multi-function halls.

(b) Shopping complexes, open atria and enclosed shopping malls.

(c) Entertainment centres and other large auditoriums, aircraft hangars, automotive manufacturers or factories and warehouses.

The difficulties experienced in effectively maintaining a smoke layer above head height, necessary to enable occupant escape or efficient fire intervention, will proportionally increase as the available room height decreases. Smoke layer depth in the order of less than one-sixth of ceiling height should not be considered a practical option and a safety margin should always be provided in a design to accommodate variations in the predicted layer depth. This Standard recommends that the designed smoke layer height should not be less than 2000 mm above the highest occupied level in the volume within which smoke control is proposed and should not have a design depth greater than 80% of the depth of a smoke curtain or other bounding element of a smoke reservoir.

The smoke reservoirs need to be capable of confining the hot smoke for the required duration. The construction forming the reservoir needs to withstand the maximum likely hot layer temperatures.

When walls and partitions or other structural elements subdivide the smoke layer, there should be sufficient space above the design hot layer interface height to permit the flow of smoke from any point in the reservoir to the extraction/vent points. If inadequate flow paths exist, it may be necessary to subdivide the smoke reservoir.

When smoke reservoirs become very narrow smoke flow is impeded and the reservoir boundaries channel the smoke rather than accumulate the smoke to permit efficient extraction/venting from the smoke reservoir. Reservoirs with an aspect ratio of greater than 5:1 should be avoided.

Limits on the maximum hot layer temperature may be required so that the area beneath the hot layer does not become untenable due to excessive thermal radiation. Generally the hot layer temperature should not be greater than 180^{o}C unless all occupants have left the building.

1.5 REFERENCED DOCUMENTS

The following are documents referred to in this Standard:

AS		
1170	Minimum design loads on structures	
1170.1	Part 1:	Dead and live loads and load combinations
1170.2	Part 2:	Wind loads
1170.3	Part 3:	Snow loads
1530	Methods for fire tests on building materials, components and structures	
1530.1	Part 1:	Combustibility test for materials
1530.2	Part 2:	Test for flammability of materials
1530.3	Part 3:	Simultaneous determination of ignitability, flame propagation, heat release and smoke release
1562	Design and installation of metal roofing (all parts)	
1670	Automatic fire detection, warning, control and intercom systems—System design, installation and commissioning	
1670.1	Part 1:	Fire
1851	Maintenance of fire protection equipment	
1851.5	Part 5:	Automatic smoke/heat venting systems
1851.6	Part 6:	Management procedures for maintaining the fire and smoke control features of air-handling systems
2047	Aluminium windows for buildings	
2118	Automatic fire sprinkler systems	
2118.1	Part 1:	Standard
2220	Emergency warning and intercommunication systems in buildings	
2220.2	Part 2:	System design, installation and commissioning
2419	Fire hydrant installations	
2419.1	Part 1:	System design, installation and commissioning
2427	Smoke/heat release vents	
2428	Methods of testing smoke/heat release vents	
2428.5	Part 5:	Determination of discharge coefficient and effective aerodynamic area
2484	Fire—Glossary of terms	
2484.1	Part 1:	Fire tests
4391	Smoke management—Hot smoke test	
4429	Methods of test and rating requirements for smoke-spill fans	
AS/NZS		
1668	The use of mechanical ventilation and air-conditioning in building	
1668.1	Part 1:	Fire and smoke control in multi-compartment buildings
1668.2	Part 2:	Mechanical ventilation for acceptable indoor-air quality
3000	Electrical installations (known as the Australian/New Zealand Wiring Rules)	
3013	Electrical installations—Classification of the fire and mechanical performance of wiring systems	
ABCB		
BCA	Building Code of Australia	
ASHRAE		
Handbook	Fundamentals	
ANSI/NFPA		
92B	Smoke management systems in malls, atria and large areas	

Australasian Fire Authorities Council Fire Brigade Intervention Model (FBIM)

BS	
7346	Components for smoke and heat control systems
7346.3	Part 3: Specification of smoke curtains
prEN	
12101	Smoke and heat control systems
12101-1	Part 1: Specification for smoke curtains requirements and test methods

1.6 DEFINITIONS

For the purpose of this Standard, the definitions in AS/NZS 1668.1, AS 2484.1, the Building Code of Australia and those below apply.

1.6.1 Alarm time

The time taken from the initiation of a fire, to the time a fire alarm is transmitted either manually or automatically to a fire monitoring service. This time includes the time to identify the existence of the fire, operate the detection device, any alarm verification time, the time taken by an independent monitoring company to notify the fire brigade and, where sprinklers are installed, the time taken for the system pressure to drop to a level where an alarm is activated.

1.6.2 Alarm verification

The delay between the time of fire detection by an automatic system and the time of transmission of an alarm to a monitoring service.

NOTE: AS 1670.1 specifies maximum alarm verification times.

1.6.3 Automatic suppression system

A system which, when activated by the heat of a fire or its products of combustion, will actively have an impact on the rate of growth of the fire and which may contain the size of the fire, reduce or extinguish it. Active systems include fire sprinklers, inert gas flooding, deluge and water spray systems.

1.6.4 Automatic smoke/heat release vent

A vent complying with AS 2427.

NOTE: The term ‘vent’, when used in this Standard, is synonymous with ‘automatic smoke/heat release vent’.

1.6.5 Buoyancy-driven

A smoke control system that uses non-mechanical means of smoke and heat venting, where flow through the vent is caused by the pressure created due to the difference in density between the hot gases and the surrounding air.

1.6.6 Fire growth rate

The rate of increase of heat output of a fire with respect to time.

1.6.7 Fire load

The heat energy potential of the whole contents contained in a space, including the facings of the walls, partitions, floors, and ceilings.

NOTE: Fire load is expressed in joules.

1.6.8 Fire load density

The fire load divided by floor area.

NOTE: In this Standard, fire load density is expressed in megajoules per square metre (MJ/m^2).

1.6.9 Hot layer

A buoyant layer of hot smoky gases contained by a ceiling or roof above it, and characterized by a relatively clear smoke-free zone beneath it.

1.6.10 Interconnected volume

More than one single smoke control zone or reservoir with an opening joining them. An example of this is a large department store (volume 1) opening onto a pedestrian mall or atrium (volume 2) in a shopping centre.

1.6.11 Local alarm

An automatic warning of fire, for the occupants of a building, initiated by a fire detection or suppression system, which is not connected to a fire brigade or other monitoring service.

1.6.12 Mains pressure feed hydrants

An above-ground hydrant, connected to a water supply authority street reticulation system, located so that a fire brigade pump appliance can be sited to within a 20 m length of laid hose connected to it.

1.6.13 Mains pressure feed plugs

An underground hydrant, connected to a water supply authority street reticulation system, located such that a fire brigade pump appliance can be sited to within a 20 m length of laid hose connected to a standpipe screwed into the hydrant.

1.6.14 Manual fire suppression

The application of a suitable fire suppressant by trained firefighting personnel.

1.6.15 Make-up air

Replacement air for mechanical or buoyancy-driven smoke exhaust systems introduced below the hot layer, usually at ambient temperature/density.

1.6.16 Non-complying hydrant system

A fire hydrant system that does not comply with the requirements of AS 2419.1.

1.6.17 On-site storage tank

A static water storage vessel located on the site, for the purpose of providing water for firefighting, with fittings and access suitable for the connection of a fire brigade pump appliance, generally in accordance with AS 2419.1.

1.6.18 Pumped hydrant system

A hydrant system, in accordance with AS 2419.1, installed within a building that incorporates automatically operated fixed on-site pumps, which will provide sufficient flow and pressure for the equipment connected to it by the firefighters.

1.6.19 Response time

The time taken by firefighters to arrive at the fire scene from the time of notification of fire via an automatic or manual system.

1.6.20 Set-up time

The time taken from time of arrival at the fire scene to reach the area, or floor level, where the fire is located, connect all necessary fire hoses and commence application of water on the fire. Where the system depends upon a fire brigade booster to achieve necessary operating conditions for the firefighting equipment connected to the system, then the longest of either the time to access the fire area and apply water or the time taken to connect to the booster is used.

1.6.21 Smoke curtain

A vertical smoke-resistant, non-shatterable curtain or screen fitted internally to divide a roof or ceiling space into smoke reservoirs, to contain smoke and hot gases from a fire.

NOTE: Plasterboard or non-combustible materials are generally acceptable.

1.6.22 Smoke control zone

A smoke-resistant area or volume as determined for smoke management which, where applicable, is—

(a) a smoke compartment within a building;

(b) a fire compartment;

(c) a smoke reservoir contained between smoke curtains; or

(d) where specifically prescribed, a designated smoke reservoir that is not physically separated by smoke curtains.

1.6.23 Smoke reservoir

A volume contained within the upper portion of a smoke control zone, which forms the collection and containment point for hot smoke, and with a depth that is not—

(a) less than $^1/_5$ of enclosure height from underside of the ceiling, roof or slab;

(b) lower than any smoke curtain;

(c) lower than the top of any openings interconnecting different smoke control zones; or

(d) lower than 2000 mm from the highest occupied level.

1.6.24 Smoke-resistant

Construction able to withstand the hot layer temperature for the system duration time.

1.6.25 Sprinkler response time

The time, in seconds, prescribed by this Standard, taken for a sprinkler head to operate when exposed to the specified fire conditions.

1.6.26 Wiring system

An arrangement of cables, busways, fittings, supports, fixings and enclosure, all of which are part of the wiring system.

1.6.27 Volume

The volume bounded by smoke-resistant floors, walls and ceiling or roof.

1.7 NEW DESIGNS AND INNOVATIONS

Any alternative materials, designs, methods of assembly and procedures that do not comply with the specific requirements of this Standard or are not mentioned in it, but give equivalent results to those specified, are not necessarily prohibited.

SECTION 2 SEQUENTIAL DESIGN PROCESS

2.1 SCOPE OF SECTION

This Section details a prescriptive design process for smoke control systems in accordance with this Standard.

NOTE: Figure 2.1 outlines the logic flow of the system design process.

2.2 KEY INPUT DESIGN PARAMATERS

The key input design parameters are:

(i) total fire heat output $(\dot{Q}_c)$;

(ii) volumetric exhaust flow rate $(\dot{V})$;

(iii) hot layer temperature (T_L);

(iv) hot layer depth (d); and

(v) system duration time (t_d).

These design parameters are required before the system design is undertaken. They may be developed for a particular building from consideration of a Fire Engineering Design Brief (FEDB) or from the application of the information and calculations contained in this Standard. Design parameters will vary depending on the objectives of the smoke control system.

NOTE: Guidance on the selection/development of these design parameters is provided in the Fire Engineering Guidelines or in Appendix A.

2.3 SYSTEM SELECTION

The type of system, i.e., mechanical or buoyancy-driven, shall be selected as appropriate for the required volume flows and building configuration.

NOTE: Guidance on calculating hot layer parameters is provided in Appendix C.

2.4 EQUIPMENT SIZING

Mechanical exhaust fans shall be sized in accordance with Section 3 and buoyancy-driven ventilators in accordance with Section 4 on the basis of the required volumetric exhaust flow rate.

2.5 MAKE-UP AIR

Provisions for make-up air shall be in accordance with Section 6.

2.6 DETAILED DESIGN

Systems shall comply with the detailed design requirements of Section 7.

2.7 CONTROL AND ACTUATION

Systems shall be controlled and actuated in accordance with Section 8.

SECTION 3 MECHANICAL SMOKE CONTROL

3.1 SCOPE OF SECTION

This Section sets out requirements for the design of mechanical smoke control systems. Smoke exhaust fans are selected for the required duty.

3.2 GENERAL

Extraction points shall be located, taking into account the depth and temperature of the hot layer and the likelihood of plugholing, in accordance with Clause 5.7.

3.3 EXHAUST CAPACITY

The minimum exhaust capacity of the smoke-spill fan(s) shall be equal to the maximum design flow into the hot layer at the plume/layer interface. The minimum exhaust opening perimeter shall be in accordance with Clause 5.7.

3.4 TEMPERATURE/DURATION OF OPERATION

The temperature of the hot gases to be exhausted shall be based on the maximum hot layer temperature. The required minimum duration of system operation (t_d) shall be determined. The system shall operate to exhaust the hot gases for the required duration, which shall be not less than 30 min.

3.5 SMOKE EXHAUST FANS

Smoke exhaust fans complete with motor, drive, flexible connections, control gear and wiring shall be constructed and installed so that they are capable of continuous operation at the required temperature for the required duration.

Smoke exhaust fans shall be selected to handle the design volumetric airflow rate (calculated at the hot layer temperature) at the installed system resistance under ambient temperature conditions. The fan motor shall be selected such that it will not overload during testing at ambient conditions.

Where smoke exhaust fans are used for normal ventilation purposes, any installed high temperature overload devices shall be automatically overridden during fire mode. Apart from fuses and circuit breakers used for the protection of circuits, all safety devices intended for the protection of smoke exhaust fans and their ancillaries shall be automatically overridden during the fire mode to ensure continued operation.

The smoke exhaust fan shall be type-tested for these rating requirements in accordance with AS 4429. Fans shall be selected and installed so that the structural adequacy of the roof is not impaired, the possibility of galvanic corrosion is minimized, and the fan is capable of operating under the wind and snow loading characteristics of the building and region (see AS 1170.1 and AS 1170.3).

Non-return discharge gravity dampers, installed on smoke-spill systems, need not mechanically latch open or be arranged to fail open during system operation

> ***C3.4*** *Allowing non-return dampers to close on system failure is a departure from the requirements for* AS/NZS 1668.1 *smoke control systems. Such systems are based on pressure differences and the need to keep the smoke-spill path open on smoke spill fan failure is critical. Systems designed in accordance with this Standard are based on flow movements and the maintenance of open smoke spill paths on system failure provide less benefits and the provision of latching dampers represents a significantly more onerous requirement.*

SECTION 4 BUOYANCY-DRIVEN SMOKE CONTROL

4.1 SCOPE OF SECTION

This Section sets out specific requirements for the design of buoyancy-driven smoke control systems.

4.2 SYSTEM COMPONENTS

A smoke/heat venting system shall comprise—

(a) smoke and heat ventilators;

(b) smoke reservoirs and zones (refer Section 5); and

(c) inlet ventilation (refer Section 6).

4.3 VENT SELECTION

The vent shall be selected to operate for the required time (t_d) and the required smoke exhaust volume ($\dot{V}$) at the hot layer temperature (T_L).

4.4 VENTS

4.4.1 General

Vents shall be either fixed (permanently open) or operable and shall comply with AS 2427. Permanently open vents shall comply with all relevant construction and performance requirements of AS 2427. Vents shall be suitable for the building in which they are to be installed and to the geographic location of the building, as follows:

(a) *Rain leakage wind velocity* Each vent shall have a rain leakage wind velocity v_r (see AS 2427) not less than 45% of the structural design wind velocity with a 50 year mean return period, as determined from AS 1170.2, but, in any case, not less than 16 m/s.

NOTE: The wind velocity test requirements are based on those used in AS 2047 and also take account of the rainfall intensities in cyclonic areas (see AS 1170.2).

(b) *Maximum wind velocity for operation* Each vent shall be capable of operating (see AS 2427) at wind velocities not less than 100% of the structural design wind velocity with a 5 year mean return period, as determined from AS 1170.2.

(c) *Structural adequacy* Vents shall be selected and installed so that the structural adequacy of the roof is not impaired.

(d) *Corrosion resistance* Each vent shall be made of materials that will prevent the possibility of galvanic corrosion between the vent and the roof.

NOTE: AS 1562 provides guidance on the selection of metals and alloys between which direct contact is acceptable as good practice. (See also AS 2427.)

(e) *Operation under snow loading* In geographic locations where snowfalls are registered, vents shall be capable of operating under snow loading.

4.4.2 Effective aerodynamic area

The effective aerodynamic area of vents provided for the required smoke exhaust, shall be calculated in accordance with the following equation:

$$A_{\mathrm{f}} = \frac{M T_1^{1/2}\left[T_1 + \left(\frac{1}{r}\right)^2 T_{\mathrm{a}}\right]^{1/2}}{\varrho_1\left[2gd\left(T_1 - T_{\mathrm{a}}\right)T_{\mathrm{a}}\right]^{1/2}} \qquad \ldots (4.4)1$$

where

A_{f} = effective aerodynamic area of vent outlet required, in square metres

M = mass flow into/out of the hot layer in kilogram per second (smoke exhaust)

T_1 = average temperature of the hot layer, in Kelvins

r = ratio of the effective aerodynamic inlet vent area to the effective aerodynamic outlet vent area, never less than 1.25

NOTE: The ratio of inlet to outlet areas is a design parameter which influences the effective aerodynamic vent area required for the system. r should never be selected at less than 1.25. Historically a ratio of 2 has been used however an acceptable system performance can be obtained with ratios as low as 1.25.

T_{a} = ambient temperature, in Kelvins

ϱ_1 = average density of the hot layer, in kilograms per cubic metre

g = gravitational constant, in metres per square second

d = depth of hot layer, in metre

4.4.3 Vent outlet area

The required roof vent outlet area for the effective aerodynamic area determined in accordance with Clause 4.4.2 shall be calculated in accordance with the following equation:

$$A_{\mathrm{vo}} = \frac{A_{\mathrm{f}}}{Cd_{\mathrm{vo}}} \qquad \ldots (4.4)2$$

where

A_{vo} = actual throat area of vent outlet required, in square metres

A_{f} = effective aerodynamic area of vent outlet required, in square metres

Cd_{vo} = coefficient of discharge of vent outlet

4.4.4 Vent inlet area

The required low level vent inlet area shall be calculated in accordance with Equation 4.3:

$$A_{\mathrm{vi}} = \frac{r \times A_{\mathrm{f}}}{Cd_{\mathrm{vi}}} \qquad \ldots (4.4)3$$

where

A_{vi} = actual throat area of vent inlet required, in square metre

r = ratio of the effective aerodynamic inlet vent area to the effective aerodynamic outlet vent area, used in Equation (4.4)1

A_{f} = effective aerodynamic area of vent outlet required, in square metre

Cd_{vi} = coefficient of discharge of vent inlet

4.4.5 Coefficient of discharge

For all low level inlet and roof outlet vents, the coefficient of discharge shall be determined in accordance with AS 2428.5. Where differing vents are used with differing coefficients of discharge, the weighted mean value shall be used for calculation purposes.

NOTE: Figure 4.1 provides typical coefficients of discharge of simple vents.

4.4.6 Vent spacing

Roof vents shall be located, taking into account the depth and temperature of the hot layer and the likelihood of plugholing, in accordance with Clause 5.7.

4.4.7 Location of vents

Vents should be located such that the discharge openings are not subject to positive air pressure from prevailing winds.

NOTE: Location of vents, complying with AS 2427, near the ridge will satisfy these requirements.

Vents in walls may need to be protected from the influence of wind.

4.4.8 Vents in a roof having a ceiling

Where an imperforate ceiling (see Clause 5.6) is installed below a roof, the vent shall be ducted from the ceiling to the roof. The duct cross-sectional area at any part shall be not less than the throat area of the vent.

4.4.9 Installation

4.4.9.1 *General*

Vents shall be installed so that the design and performance requirements of AS 2427 are not infringed.

4.4.9.2 *Pitch angle*

Each vent shall be installed at a pitch angle within the maximum and minimum values specified for that particular vent (see AS 2427).

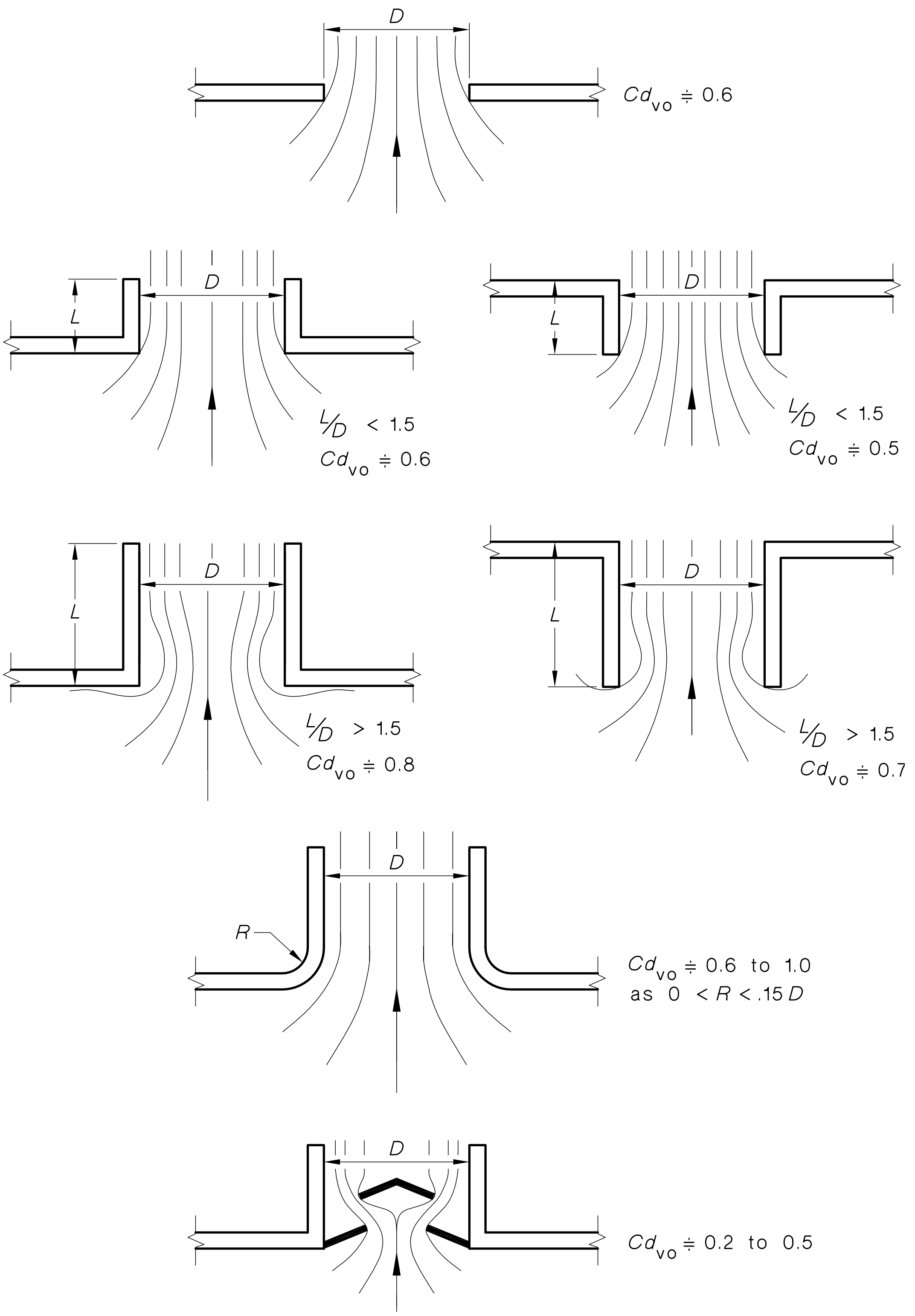
4.4.9.3 *Water from sprinklers*

Where it is necessary to prevent water from sprinklers wetting the thermally released link of a vent, the link shall be shielded rather than have a baffle plate provided near the sprinkler head.

NOTE: A sprinkler baffle plate could interfere with the water distribution pattern from the sprinkler head.

4.4.9.4 *Security devices*

Security devices, other than those that have been considered in the determination of the coefficient of discharge of the vent, shall not be fitted.



NOTE: Actual discharge coefficients of vents should be sourced from the manufacturer or supplier.

FIGURE 4.1 TYPICAL COEFFICIENTS OF DISCHARGE (Cd_{vo}) OF SIMPLE VENTS

SECTION 5 SMOKE RESERVOIRS AND EXHAUST OPENING PERIMETER

5.1 SCOPE OF SECTION

This Section outlines requirements for smoke reservoirs created by smoke curtains or walls and ceilings and their fixing systems forming smoke-resistant bounding layers.

NOTE: Information on building geometry is given in Appendix D.

5.2 SIZE OF SMOKE RESERVOIRS

The horizontal area of smoke reservoirs shall not exceed 2000 m^2. The maximum distance between any two points within the smoke reservoir measured on a horizontal plane shall not exceed 60 m.

5.3 DEPTH

5.3.1 General

Smoke reservoirs shall extend downwards, not less than one-fifth of the floor to imperforate ceiling/roof height, below the lowest edge of an opening in a vent or extract point (see Table 5.1).

NOTE: To maximize system performance, smoke reservoirs should be as deep as practicable.

Only one-sixth of the floor to ceiling height (reservoir depth) may be considered for the purpose of containing the hot layer.

NOTES:

1 Where a high fire load area is involved, smoke reservoirs should extend to the maximum practicable depth, ideally to within 3 m of the floor.

2 For calculation purposes, smoke reservoir depth is one-sixth of floor to ceiling height. A 20% safety factor is applied to this value, to arrive at the minimum depths of Table 5.1.

TABLE 5.1

MINIMUM SMOKE RESERVOIR DEPTH

metres

Depth (d)	Ceiling height (h)
0.6	3.0
0.8	4.0
1.0	5.0
2.0	10.0
3.0	15.0
4.0	20.0

5.3.2 Vertically interconnected smoke control zones

Within a multistorey volume, a smoke curtain should be provided around the perimeter of any floor penetration opening into a building void, to minimize the spread of smoke to other storeys. The smoke curtain should be set back from the opening perimeter by a minimum distance of 1 m or one-third of the floor to ceiling height whichever is the greater.

Where a smoke zone extends over more than one floor (such as an atrium shown in Figure G3, Appendix G) the atrium well, should be separated from any open floor by smoke curtains around the perimeter of the well, to minimize smoke entry onto intermediate floors. Smoke curtains should be set back from the well edge by a minimum distance of 1 m or one-third of the floor to ceiling height, whichever is the greater.

> ***C5.3.2*** *Smoke control zones are treated separately and this Standard does not consider the effect of smoke spill plumes from one smoke reservoir into another, because the temperature and entrainment characteristics of such a plume is very complex. Where such a smoke spill plume occurs, the smoke control system has failed to contain and exhaust the smoke developed.*

5.4 CONSTRUCTION

5.4.1 Materials

Smoke curtains and their fixing systems shall be non-shatterable and smoke-resistant, i.e., construction able to withstand the maximum design hot layer temperature for the required system duration time.

NOTE: Guidance on possible smoke-resistant materials of construction is given in Table H2, Appendix H.

5.4.2 Bottom edges

The bottom edges of smoke reservoirs shall, where practicable, be horizontal. (See Figure 5.1.)

5.4.3 Leakage

Smoke curtains or bounding layers shall butt up to the roof in a manner that will minimize leakage of smoke between the edge of the curtain or wall and the upper surface of the smoke reservoir. The penetration of smoke curtains or bounding layers for the accommodation of structural elements, fasteners, pipes, ducts or wiring is permissible. The gaps between the penetrating service or member and the smoke curtain shall be sealed. Sealant material shall be flexible to allow for any expansion or contraction and shall be smoke-resistant.

5.4.4 Expansion

Some smoke curtain materials will change shape with temperature and an allowance for expansion shall be included in the design.

5.4.5 Smoke curtains in sprinklered buildings

Smoke curtains in sprinklered buildings shall be located so that the requirements of AS 2118.1 are not infringed.

5.5 RETRACTABLE SMOKE CURTAINS

5.5.1 Design

Retractable smoke curtains should operate automatically upon receipt of a control signal from the smoke detection system, FIP or alarm system. Retractable smoke curtains should be type tested to ensure that they will —

(a) operate repetitively for the life expectancy of the system;

(b) operate in a fail safe manner in the event of a power failure;

(c) not deflect by more than 20° when subjected to a 3 m/s air velocity applied perpendicularly to the smoke curtain; and

(d) be fully deployed within 30 s of receipt of the control signal.

NOTE: At the time of publication there was no Australian Standard relating to the construction and reliability of these products. Publicly available Standards include BS 7346.3 and prEN 12101-1.

5.5.2 Installation

Retractable smoke curtains should be installed so that—

(a) sectional components of a continuous run of smoke curtain overlap by a minimum of 100 mm;

(b) fully deployed curtains do not extend beyond 2000 mm above an occupied floor level; and

(c) curtains adjacent to walls are installed to minimize any gap between the curtain edge and the wall.

Smoke reservoirs created by corner to corner retractable smoke curtains are not recommended unless the corner edges are adequately sealed.

5.6 CEILINGS

5.6.1 Ceiling plenum for mechanical smoke extract

The ceiling space may be used as a plenum, providing the ceiling is well sealed to minimize direct infiltration of outdoor air and the required system capacity is increased to account for any leakage.

5.6.2 Ceiling space reservoir

Where openings in the ceiling have a free area of 25% or more, the ceiling is considered porous to smoke and to form part of the smoke reservoir. Smoke extract points located above the ceiling may be based on the depth of the hot layer measured from the underside of the smoke layer to the underside of the smoke extract points above the ceiling.

5.6.3 Ceiling acting as vent

Where openings in the ceiling have a free area less than 25%, the ceiling is not considered porous to smoke and the smoke inlet points located in the ceiling should be based on the depth of the hot layer measured from the underside of the smoke layer to the lowest point of the smoke inlet points in the ceiling. The smoke extract points located above the ceiling should be based on the depth of the hot layer measured from the ceiling to the underside of the smoke extract points. Smoke extract points above the ceiling should be located not more than 25 m apart and the cross-sectional free area of the ceiling space should be greater than twice the free area of the smoke inlet points in the ceiling, to minimize any pressure loss between the smoke inlet and extract points and achieve a balanced extract over the entire smoke reservoir.

5.7 MINIMUM EXHAUST OPENING PERIMETER

The minimum required total perimeter (L) of exhaust vents, fans and extraction points shall be calculated, based on the minimum required volumetric exhaust flowrate ($\dot{V}$), in accordance with the following equation:

$$L = \frac{\dot{V}}{\sqrt{\frac{8}{27} d^3 g \left(\frac{T_L}{T_a} - 1 \right)}} \qquad \ldots (5.7)$$

where

L = minimum required total perimeter of exhaust vents, fans and extraction points, in metres

$\dot{V}$ = minimum required volumetric exhaust flowrate, in cubic metres per second

T_L = hot layer temperature, in Kelvins

T_a = ambient temperature, in Kelvins

d = design hot layer depth, in metres

The calculated minimum required exhaust point perimeter (L) shall be provided by exhaust vents, fans and extraction points with an effective opening perimeter determined in accordance with Table 5.1.

When openings are located less than:

(a) one quarter of the design hot layer depth (d) from a wall; or

(b) one half of the design hot layer depth (d) apart,

the effective perimeter shall be based upon the perimeter of the enclosing boundary in accordance with Table 5.1. The effective dimension of the opening shall be increased by one-quarter of the hot layer depth (d) in each dimensions before constructing the bounding line. In any case, the length of the bounding line shall never exceed the effective perimeter given in Table 5.1 for an opening remote from a wall.

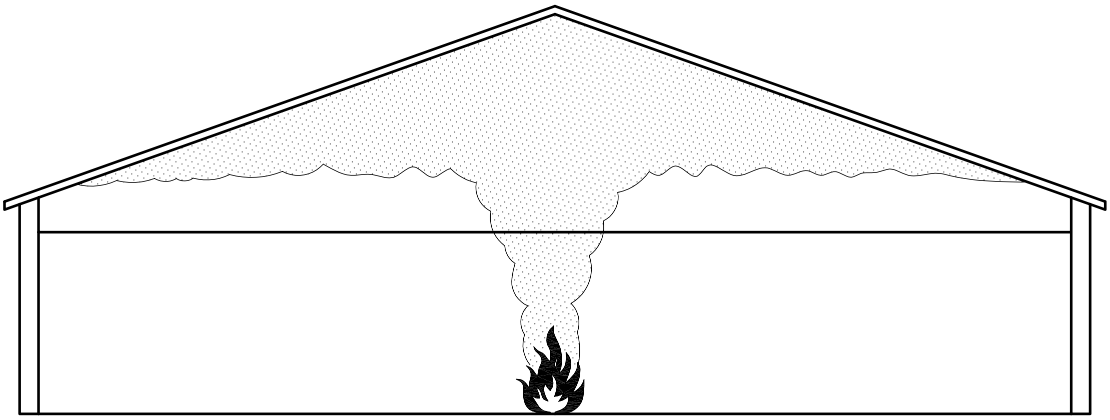
TABLE 5.1

EFFECTIVE PERIMETER OF EXHAUST OPENING

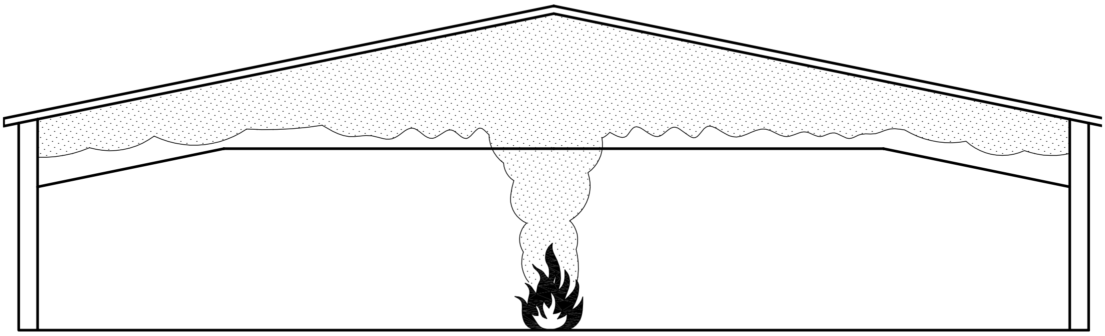
Opening type	Condition	Effective perimeter (L)
Circular opening diameter (D)	More than one quarter the design hot layer depth from a wall and more than half the design hot lay depth from other exhaust openings.	$L=\pi\left(D+\frac{d}{2}\right)$ Refer Figure 5.2, (a), (b) and (d).
Circular opening diameter (D)	Less than one quarter the design hot layer depth from a wall or less than half the design hot layer depth from other exhaust openings.	Perimeter of enclosing boundary line. Refer Figure 5.2(c) and (e) for determination of L.
Rectangular opening length (a) and breadth (b)	More than one quarter the design hot layer depth from a wall and more than half the design hot layer depth from other exhaust openings.	$L = 2\left(\mathrm{a} + \mathrm{b} + \mathrm{d}\right)$ Refer Figure 5.2(f), (g) and (I).
Rectangular opening length (a) and breadth (b)	Less than one quarter the design hot layer depth from a wall or less than half the design hot layer depth from other exhaust openings.	Perimeter of enclosing boundary line. Refer Figure 5.2(h), (j) and (k) for determination of L.

C5.7 *The minimum required total perimeter (L) of exhaust vents, fans and extraction point openings is dependent on the depth of the hot layer and the location of exhaust openings. For a given hot layer depth, there is a maximum rate at which smoke can be extracted from a single inlet and any increase in exhaust capacity above this maximum rate will only serve to draw air from below the hot layer (plugholing) reducing overall system exhaust capacity. Similarly, openings that interact with each other or with walls and other obstructions will have a reduced performance, while this Standard requires that the effective perimeter of a proposed system be calculated to ensure that the minimum required total perimeter (L) is provided.*

Where proposed systems do not achieve the minimum required effective perimeter, baffle plates or ducts may be applied to increase the effective perimeter achieved, see Figure 5.3. It should be noted that the effective hot layer depth is reduced in these solutions.

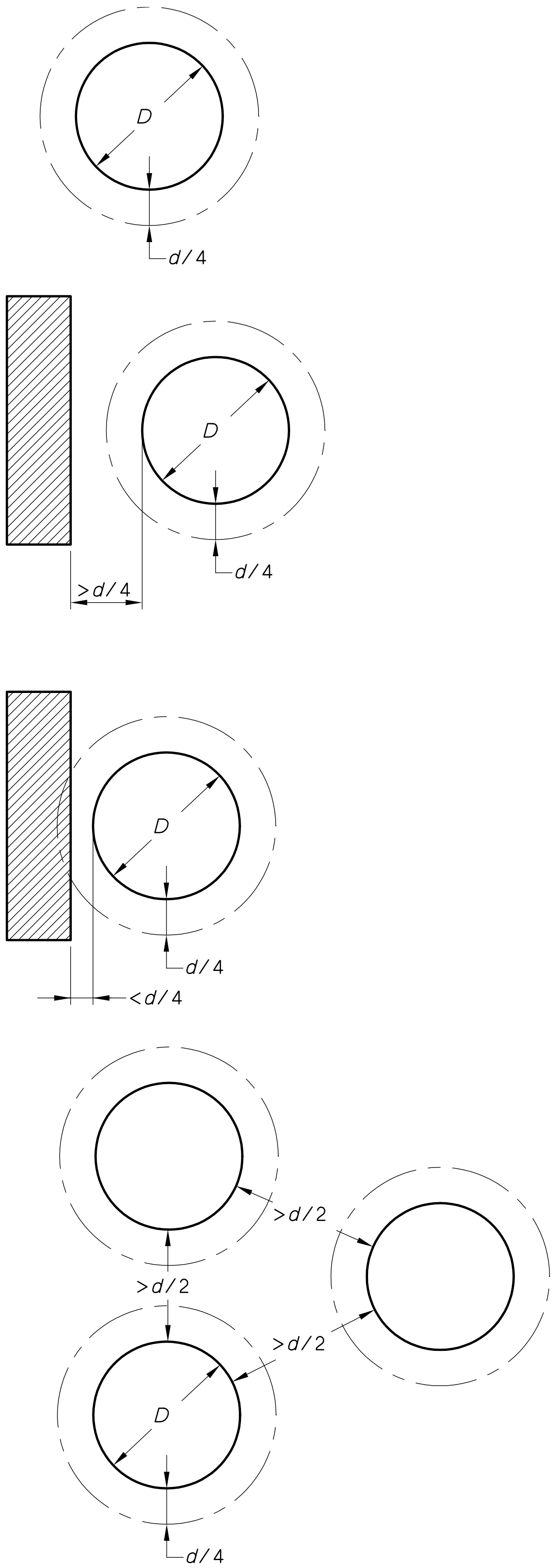


(a) Smoke reservoirs in pitched roof—preferred



(b) Smoke reservoirs in pitched roof—possible alternative

FIGURE 5.1 SMOKE RESERVOIR BOTTOM EDGES



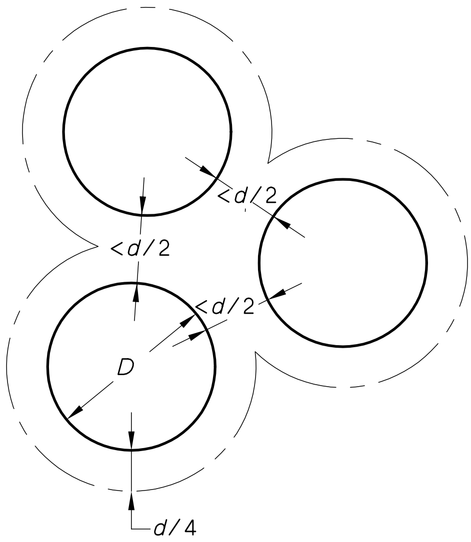
(a) Effective perimeter = $\pi(D + d/2)$

(b) A circular exhaust opening greater than one quarter the design smoke layer depth from a wall.
Therefore the effective perimeter is the full effective perimeter of the circular opening.
Effective perimeter = $\pi(D + d/2)$

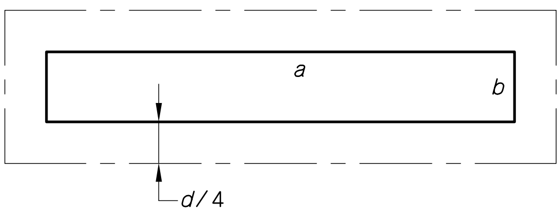
(c) A circular exhaust opening less than one quarter the design smoke layer depth from a wall will achieve a reduced effective perimeter.
No effective exhaust at point of overlap.

(d) Circular exhaust openings greater than half the design smoke layer depth apart. Therefor the effective perimeter is the full effective perimeter of the three circular openings.
Effective perimeter = $3\pi(D + d/2)$

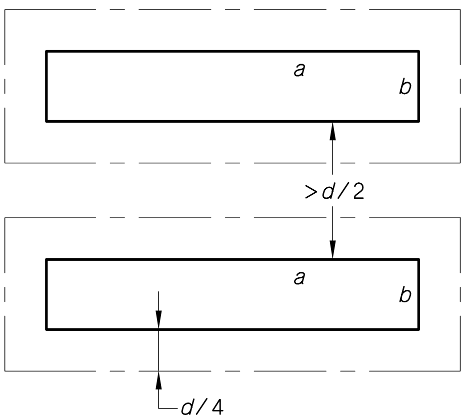
FIGURE 5.2 (in part) EFFECTIVE PERIMETER OF OPENINGS



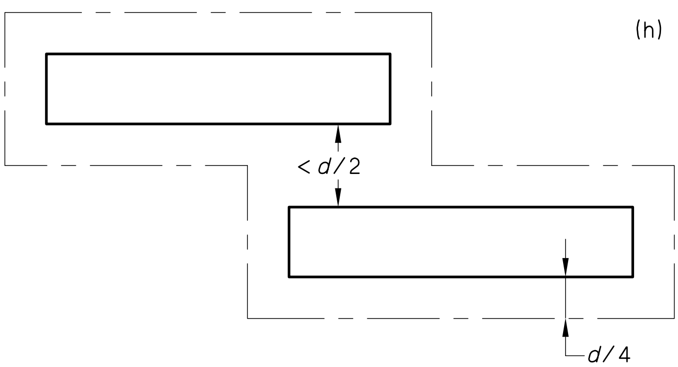
(e) Circular exhaust openings less than half the design smoke layer depth apart achieve a reduced effective perimeter (no effective exhaust at points of overlap).



(f) Effective perimeter $= 2(a + d/2) + 2(b + d/2)$
$= 2(a + b + d)$

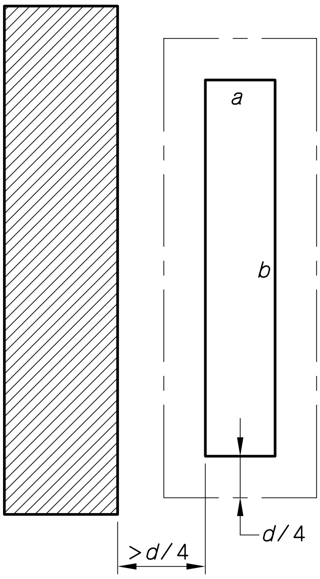


(g) Spacing between slots greater than half the design smoke layer depth. Therefore effective perimeter equals the full effective perimeter of both slots. Effective perimeter $= 4(a + b + d)$ for two identical slots.

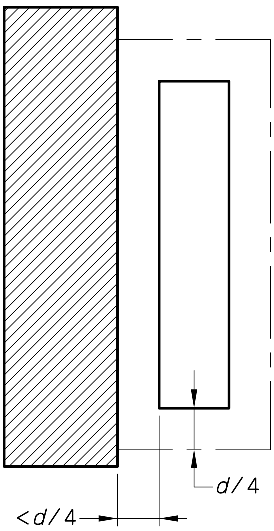


(h) Effective perimeter is less than the effective perimeter of both slots due to spacing between slots being less than half the design depth of the smoke layer.

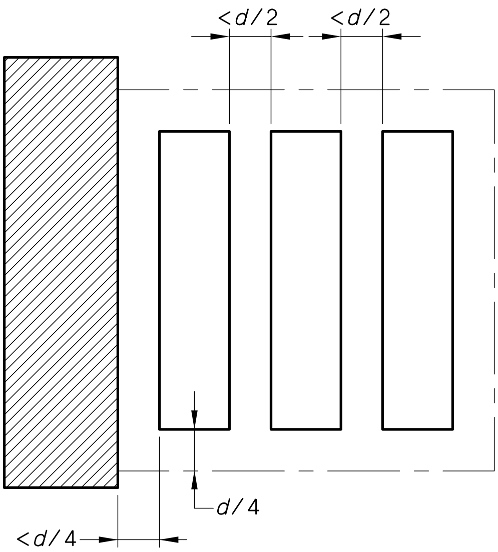
FIGURE 5.2 (in part) EFFECTIVE PERIMETER OF OPENINGS



(i) A rectangular exhaust opening greater than one quarter the design smoke layer depth from a wall.
Therefore the effective perimeter is the full effective perimeter of the rectangular opening.
Effective perimeter = $2(a + b + d)$

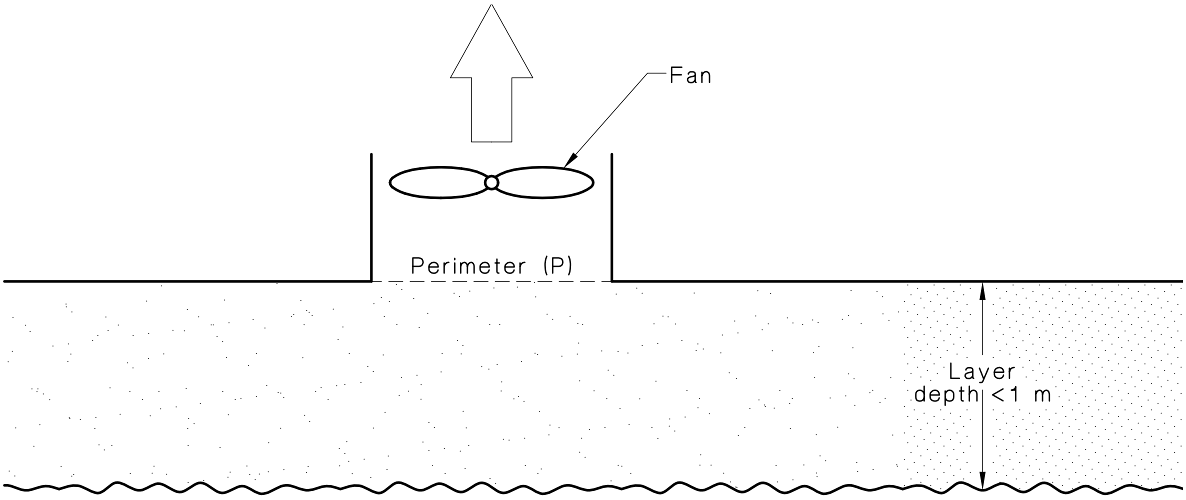


(j) A rectangular exhaust opening less than one quarter the design smoke layer depth from a wall will achieve a reduced effective perimeter.

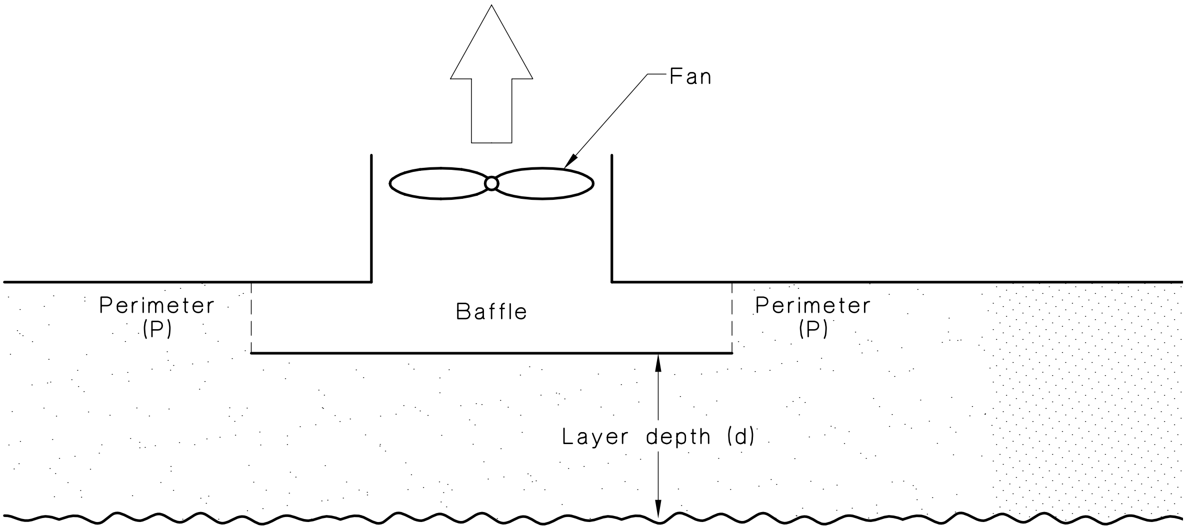


(k) A series of rectangular exhaust openings spaced less than half the design smoke layer depth apart and less than one quarter the design smoke layer depth from a wall will achieve a reduced effective perimeter.

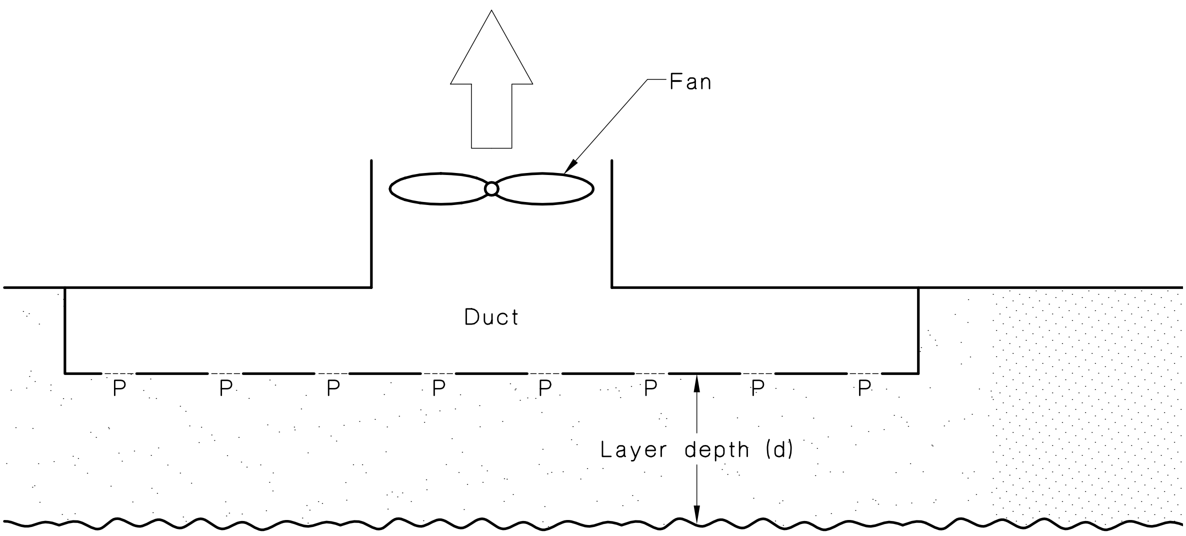
FIGURE 5.2 (in part) EFFECTIVE PERIMETER OF OPENINGS



(a) Single extract point



(b) Baffle at extract point increases extract perimeter and reduces layer depth



(c) Multiple extract points increase extract perimeter and reduce layer depth

FIGURE 5.3 EXTRACTION POINT PERIMETER VARIED BY BAFFLE PLATES AND DUCTS

SECTION 6 MAKE-UP AIR REQUIREMENTS

6.1 SCOPE OF SECTION

This Section sets out design requirements for make-up air (inlet ventilation) systems.

6.2 GENERAL

Inlet ventilation provided as make-up air is required from a source external to each smoke reservoir. Make-up air shall be uncontaminated from any other possible smoke source and shall be introduced below the design hot layer interface height.

6.3 BUOYANCY-DRIVEN SYSTEMS

6.3.1 Method of make-up air

Make-up air ventilation for these systems shall be through natural ventilation, wherever possible. The required vent inlet area shall be calculated in accordance with Section 4. The use of fan assisted make-up needs careful consideration and is not recommended.

6.3.2 Air inlet provisions

Reservoir make-up air inlet ventilation area shall be provided at low level by—

(a) permanent openings;

(b) automatically operated inlet opening vents (operating simultaneously with outlet vents);

(c) automatically operated doors, windows or roller shutters (operating simultaneously with smoke vents), the latter limited to an opening height below two-thirds of the design hot layer interface height;

(d) natural leakage/infiltration; or

(e) a combination of Items (a) to (d).

6.3.3 Inlet vent distribution

Make-up air inlet ventilation shall be distributed as evenly as practicable to the smoke control zone perimeter and shall be unobstructed for the passage of air within a surrounding area of not less than the smallest dimension of the opening, both internally and externally.

6.3.4 Multiple smoke reservoirs

Where multiple smoke reservoirs are provided in sprinkler protected buildings, inlet ventilation may be introduced either at low level or alternatively at high level from opening smoke vents in adjacent unaffected smoke reservoirs (see Figure 6.1), based on a single fire event located at the intersection of the maximum possible number of smoke reservoirs which could be affected by the fire.

NOTE: It is considered that in sprinklered buildings fire growth will be controlled, whilst in unsprinklered buildings this may not occur until manual intervention occurs.

The required inlet ventilation area is achieved through one of the following:

(a) Outlet vents located in unaffected adjoining smoke reservoirs.

(b) Low level inlet vents in accordance with Clause 6.3.2; or

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

6.4 MECHANICAL SMOKE EXHAUST SYSTEMS

6.4.1 Method of make-up air

Make-up air ventilation shall be provided for these systems and may be by natural means or be introduced by a mechanical system. In both cases, the requirements of Clause 6.4.2 shall be complied with.

6.4.2 Air inlet provisions

The air inlet provisions for make-up air systems shall be as follows:

(a) The air inlet velocity shall not exceed 1.0 m/s.

(b) The air inlet shall be located below two-thirds of the design hot layer interface height to minimize any disturbance of the hot layer due to turbulence created by the make-up air.

(c) In the case of natural make-up air systems, the requirements of Clauses 6.3.2 and 6.3.3 with an inlet air velocity of less than or equal to 1.0 m/s shall apply.

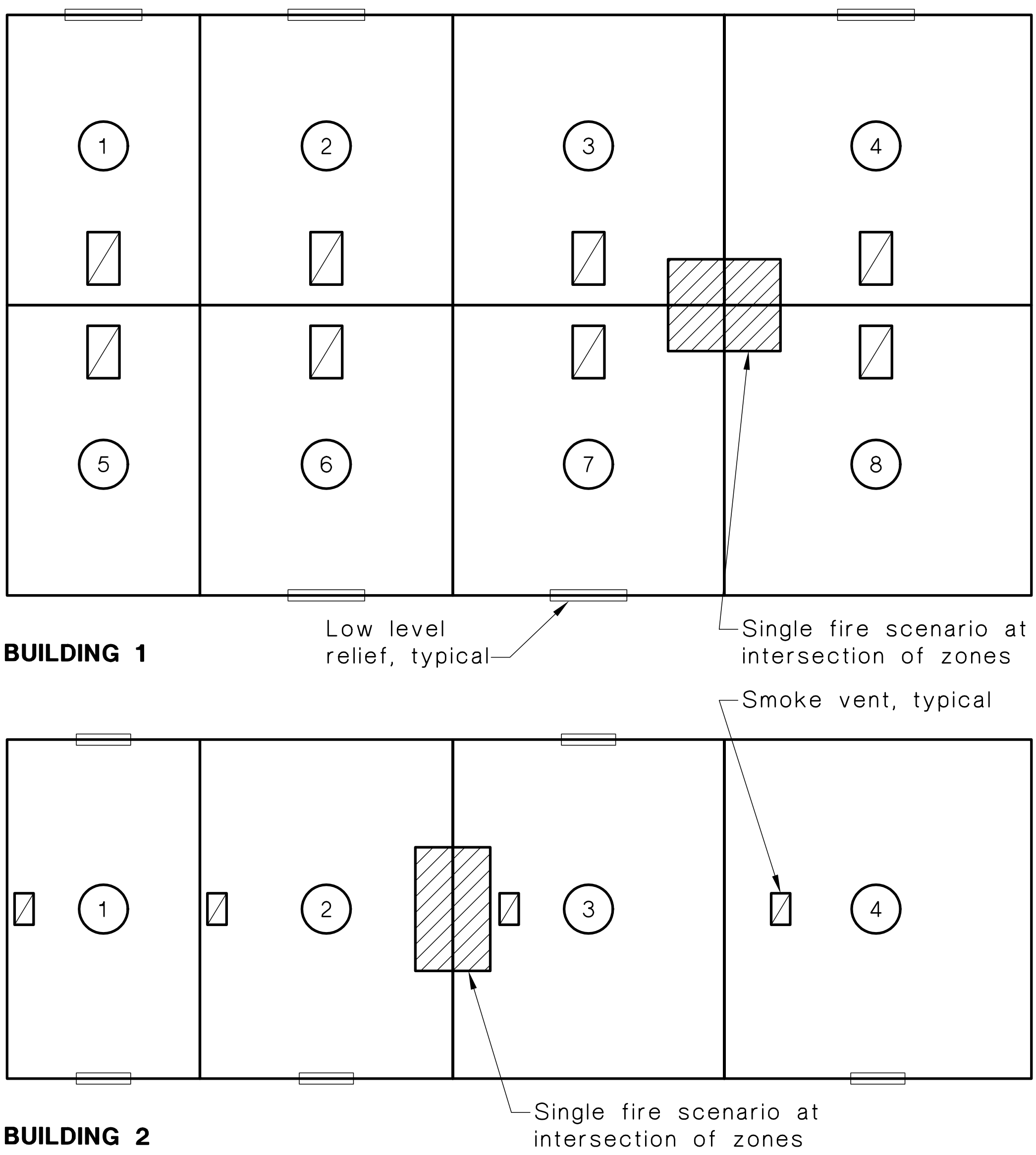
(d) In the case of mechanical make-up air systems, such systems shall not create a positive pressure within the fire-affected compartment relative to adjoining compartments.

NOTE: Make-up air velocity through air inlets, open doorways and the like should ideally be in the order of 0.5 m/s.

6.5 MAKE-UP AIR FROM INTERCONNECTED VOLUMES

Make-up air to a fire-affected smoke reservoir may be supplied through open interconnected spaces provided that the make-up air velocity does not disturb the smoke layer.

NOTE: In these instances, it may be necessary to limit the make-up to a lower level to comply with Clause 6.2.



Air Inlet Options:

Option A: low level make-up air

Option B: high level make-up air (from roof vents in adjacent smoke reservoirs)

Option C: combination of Option A and Option B

Comments

(a) Building 1 make-up air area criteria for Option A may be obtained from low level air inlets in smoke reservoirs 1, 2, 4, 6 and 7.

(b) Building 2 make-up air area criteria for Option A may be obtained from low level air inlets in smoke reservoirs 1 to 4.

(c) Building 1 make-up air area criteria for Option B may be obtained from roof vents in smoke reservoirs 1, 2, 5 and 6.

(d) Building 2 make-up air area criteria for Option C may be obtained from roof vents in smoke reservoirs 1 and 4 and from low level air inlets in smoke reservoirs 2 and 3.

FIGURE 6.1 MULTIPLE SMOKE RESERVOIRS—SPRINKLERED BUILDINGS

SECTION 7 GENERAL SYSTEM REQUIREMENTS

7.1 SCOPE OF SECTION

This Section sets out general requirements for smoke control systems.

7.2 WIRING

7.2.1 General

Where equipment is required to operate, or indicate status during fire mode and where exposure of the wiring systems to the design fire conditions would interfere with the fire mode function, the associated wiring system shall be fire rated. The fire resistance level for circuit integrity shall not be less than the system duration time (t_d).

7.2.2 Power wiring

Wiring systems supplying power to equipment required to operate in the fire mode shall be supplied from the live side of the incoming mains power supply switch to the building and shall—

(a) be suitable for the elevated temperatures to which the system will be exposed at least equal to the hot layer temperature.

(b) be located remote from the smoke control zone; or

(c) be a system complying with AS/NZS 3013 which achieves the requirement of Item (a).

7.2.3 Control wiring

Wiring systems for smoke detection, control and indication shall be in accordance with AS/NZS 1668.1.

7.2.4 Mechanical damage

All power and control wiring systems required to operate in the fire mode shall be protected from mechanical damage in accordance with Appendix J.

7.2.5 Hosing

All power and control wiring systems required to operate in the fire mode in an unsprinklered building shall be protected against hosing with water in accordance with Appendix J.

7.3 SYSTEM COMPONENTS

Ductwork, plenums and air duct dampers shall comply with AS/NZS 1668.1.

7.4 VIBRATION

Where vibration mounts are incorporated to support smoke exhaust fans their failure due to heat or other stress shall not cause equipment collapse. This may be achieved by employing captive supports around rubber and other such isolators.

7.5 NOISE

In fire mode, the noise levels due to operation of the smoke control systems shall not exceed 80 dB(A) or 5 dB(A) above ambient, whichever is the greater when measured at 1200 to 1500 mm above the occupied floor level.

C7.5 *Where practicable it is recommended that noise levels do not exceed the local ambient levels provided in Appendix H. Specific attention is drawn to the white noise effect of smoke control fans that have the tendency to mask the audio frequency spectrum employed by E.W.I.S. and other audio communication systems. Equipment noise should not interfere with the effective operation of E.W.I.S. systems or be likely to frighten the building occupants.*

7.6 NON-ELECTRICAL CONTROL EQUIPMENT

Non-electrical control equipment shall comply with the requirements of AS/NZS 1668.1.

C7.6 The most commonly used non-electrical systems are pneumatic controls or remote cable-operated systems. To maintain integrity during a fire, equivalent to that required for electrical controls, such systems should be constructed from materials that do not melt or otherwise break down during a fire.

The following is a useful guide for designers and installers:

(a) Essential tubing or cables should be constructed in steel or copper.

(b) Central pneumatic air system (compressors, pressure reducing sets, dryers and receivers) should be considered essential services which are supplied from the essential electrical power supply and which are protected to maintain integrity in the event of —

  (i) inadvertent isolation during normal operation or in fire mode; or

  (ii) fire in a remote compartment.

(c) Actuators whose failure would not affect the operation of the smoke control system need not maintain the specified integrity under fire conditions.

(d) Tubing or cables whose failure would not affect the operation of the smoke control system need not maintain integrity under fire conditions.

(e) Pneumatic tubing serving non-essential or fail-safe components may be polyethylene (or other plastic material), provided that loss of the non-essential part of the system does not cause the whole system to fail, through loss of pneumatic pressure.

(f) Where added security of pneumatic systems requires stand-by, remote compressed air bottles may be a design option worthy of consideration.

7.7 LOCATION OF EXTERNAL OPENINGS AND VENTS

Outdoor air intakes, air inlets and discharge openings and air outlets for smoke exhaust air shall be appropriately located to minimize the possibility of smoke contamination of the incoming air.

NOTE: See requirements for air-inlet and air-discharge locations in AS/NZS 1668.1 and AS 1668.2.

C7.7 *This Standard does not seek to lay down firm rules for the location of openings in the exterior walls of buildings as each opening for each building requires individual consideration. Factors to be taken into account include the purpose of the opening, its proximity to other openings and to external hazards, the effect of wind and the effect of surrounding buildings on airflow.*

Ideally, smoke-spill discharge openings should be located on the leeward side of the building. Intake openings for supply air should be located on the windward side at a level below that of the smoke-spill opening. It may be desirable to carry out model studies of the building and its environs to select the optimum locations of openings.

Chapter 15 of the 1997 ASHRAE Fundamentals Handbook contains comprehensive information on airflow around buildings, dispersion of building exhaust gases and designs to minimize re-entry. Particularly critical cases may warrant wind tunnel testing of models.

SECTION 8 CONTROL

8.1 SCOPE OF SECTION

This Section outlines the requirements for the initiation and operation of smoke control systems.

8.2 AUTOMATIC INITIATION OF SMOKE CONTROL

Automatic initiation of systems shall be arranged through one of the following methods:

(a) A smoke detection system in accordance with AS 1670.1, arranged in zones to match each smoke reservoir.

(b) A smoke detection system generally in accordance with AS 1670.1, with an extended grid spacing of detectors at not more than 21.6 m apart and not more than 10 m from any wall, bulkhead or smoke curtain, and arranged to match each smoke control zone.

For buoyancy-driven systems only, in addition to (a) or (b), fusible links connected to all ventilators such that the operation of any single fusible link will cause all ventilators in the smoke reservoir to operate simultaneously. The operating temperature of the thermally released mechanism of a vent should be no greater than 68°C unless required by reason of elevated temperatures associated with a process conducted in the building, geographical location or the like, to be a higher operating temperature.

C8.2 *Smoke detectors provide earlier warning and faster response to control smoke within a compartment. Generally, smoke detection systems, installed solely for smoke control system initiation, are installed on an extended grid basis.*

For some specialized sprinkler systems, activation of venting prior to sprinkler operation is not permitted.

Control activation of smoke compartments using mechanical venting is more important than for buoyancy venting. Incorrect zone operation will cause migration of smoke from one zone to another, thus negating the objective for minimizing smoke spread through the building and provision of smoke control zones/reservoirs.

In extra high hazard buildings, such as industrial warehouse buildings incorporating high piled storage, smoke control system activation by fast response sprinklers may be considered if the system is not required for life safety. The fast response sprinklers (RTI ≤50) would need to be zoned to match each smoke reservoir, and be operated by a dedicated pressure switch and individual sprinkler valve set per reservoir

8.3 OPERATION OF SMOKE CONTROL

8.3.1 General

The operation of smoke control systems shall facilitate the venting of smoke from the smoke reservoir(s) of fire origin and the provision of make-up air.

Control systems for air duct dampers and vents shall be arranged for fail-safe operation to the venting mode.

8.3.2 Buoyancy-driven systems

Vents shall be operated by electrical, pneumatic, fusible link or mechanical means. All vents within the smoke reservoir of origin shall operate simultaneously. Vents shall be provided with remote manual operation in accordance with Clause 8.4.

NOTE: In the event of fire, all air inlet and smoke relief vents within a fire compartment should operate simultaneously.

C8.3.2 Pneumatic control, employed for operation of vents, is usually arranged such that loss of control air pressure opens the vents. It is usual for reserve bottle supplies or an air compressor to be provided, to minimize the consequences of system failure (e.g. rain damage).

Where security or stock loss due to rain penetration through open vents is of a concern, low pressure alarm devices should be incorporated in the design and linked to a security/fire monitoring service. A leak within the pneumatic system will cause an air compressor to run frequently or bottles to run dry, the latter causing opening of vents. On this basis, pneumatic design should consider arranging the vents in groups that control valves, to assist in maintenance and leak analysis.

Fusible link operation of one roof vent can initiate other vents by a cord/pulley system. This is an acceptable alternative, provided cord routes are not hindered and regular testing is employed. Breakage of the cord tension should allow activation of all required vents.

8.3.3 Mechanical systems

The exhaust fan and any associated make-up air system serving the reservoir of fire origin shall be initiated via one of the systems detailed in Clause 8.2. Where smoke detection is utilized for system control, each fan shall be individually activated by smoke detectors located within the reservoir served by the fan. Spread of smoke due to an uncontrolled fire shall allow other smoke zones to operate as the smoke spreads to these locations.

Where control dampers are affected by system pressure such that the torque of the damper actuator may not be adequate to operate the damper, fan operation shall be delayed until damper operation is completed. Therefore, the damper operation time shall be included in the time line of the system. Fans and dampers shall be provided with remote manual operation in accordance with Clause 8.4.

Control components and methods of installation shall provide for reliable operation under expected fire conditions and shall be in accordance with AS/NZS 1668.1.

Systems not required to operate in the fire mode shall shut down.

8.4 MANUAL OVERRIDE FACILITY

A manual override facility shall be provided for the use of the attending fire brigade, to control and provide indication of the automatic smoke control system. The facility shall be provided adjacent to, or be incorporated in, any FIP or, where no FIP is installed, in an appropriate location. This facility shall also operate all equipment associated with the operation of the smoke control system.

For mechanical systems, control and indication of fans and associated equipment shall generally be in accordance with AS/NZS 1668.1.

For buoyancy-driven systems, a manual override switch (OPEN-AUTO) shall be provided such that in the open position the system operates in fire mode and in the auto position the system shall be operable in accordance with Clause 8.2. Where more than one smoke control zone is provided, then a separate switch shall be provided for each zone.

NOTE: All fire-brigade-related manual control equipment should be located together in one appropriate position.

8.5 SYSTEM PLAN

A permanent schematic plan of the smoke control system shall be mounted in a secure position within the building adjacent to the manual override facility, clearly visible and readily accessible from the main entrance or other suitable location.

The following minimum information shall be included on the plan:

(a) Location of all vents/fans, smoke reservoirs and manual controls.

(b) The method of manual operation of the system.

(c) Name and telephone number of a responsible person to be contacted in the event of operation of the system.

SECTION 9 COMMISSIONING

9.1 SCOPE OF SECTION

This Section specifies requirements for the commissioning of smoke control systems. Methods for smoke control systems verification and performance testing are provided.

9.2 GENERAL

Each smoke control system shall be tested to verify that it operates and performs in accordance with the design specification and the requirements of this Standard.

> ***C9.2*** *Testing requirements form a very important part of any smoke control system to ensure that it will function as intended during a fire. As system designs vary to match building configurations, test procedures need to be developed to encompass the specifics of individual systems.*

9.3 PRE-COMMISSIONING PROCEDURES

Prior to commissioning, the party responsible for the tests shall verify the completeness of the building construction.

9.4 COMMISSIONING

The commissioning of mechanical smoke exhaust systems shall be carried out in three stages as follows:

(a) *Stage 1* Every component of the smoke control system shall be tested to prove their correct operation. When the operation of every component has been satisfactorily proven, proceed to Stage 2.

(b) *Stage 2* Test each smoke reservoir in turn. Where detectors are installed for system control they shall be artificially initiated to establish a fire mode alarm. Each test shall be recorded, together with the response of all associated components being checked for integration with the total system via the control matrix, under normal power supply. When proof is obtained that all systems will act in concert as part of a total smoke control system, proceed to Stage 3.

(c) *Stage 3* For buoyancy-driven smoke control systems, vents shall be activated and checked for satisfactory operation. The certified effective aerodynamic area of each installed vent type shall be determined (by reference to the installed model number and manufacturer's literature) and assessed against the design requirements of Section 4.

    For mechanical smoke control systems, the exhaust air flow rate and air inlet velocities shall be determined and assessed against the design requirements of Section 5 and Section 6, as appropriate. With the system in operation, noise levels shall be measured at 1200 to 1500 mm above each occupied floor level to determine that it does not exceed the requirements of Clause 7.5.

C9.4

(a) *Stage 1 This stage would include smoke extraction systems, make-up air supply, smoke detectors and alarms, HVAC components where appropriate, automatic door closers, door hold-open devices if any, pressurization systems, and emergency power supply where installed.*

(b) *Stage 2 This stage checks the integration of all system components to ensure that each component is correctly controlled.*

(c) *Stage 3 Not only should each system be seen to operate as designed, but also the design parameters need checking.*

For a complex life-safety system such as that covered by this Standard, it is vital to ascertain that the entire system will operate satisfactorily and to verify system completion. Operational testing of individual systems rarely provides sufficient proof that the whole system will operate correctly during fire mode. It is seldom feasible during testing to produce the heat and smoke for which the installation is designed, i.e., the 'design fire'. Tests can be undertaken without any damage to surface finishes whatsoever, using the hot smoke test methodology of AS 4391.

9.5 EMERGENCY POWER

Where emergency power supply has been provided for the smoke control systems, additional commissioning tests should only be carried out to demonstrate that the system operates and the provided electrical capacity is adequate. The systems should be continuously operated for a minimum of 30 mins.

APPENDIX A

DEVELOPMENT OF KEY INPUT DESIGN PARAMETERS

(Informative)

A1 GENERAL

This Appendix provides guidance on the development of the essential input design parameters required for smoke control system design. Such design parameters may also be nominated for system design in accordance with the building fire engineering design brief (FEDB).

A2 DESIGN METHODOLOGY

A design fire curve is selected in accordance with Appendix B as the primary design parameter.

The hot layer parameters generated by the fire are established by using a selected fire heat output curve determined by the compartment fire load characteristics. A heat output point is selected on this curve at time of fire control or where control does not occur, at the peak heat output of the curve. From this time, the heat output is considered steady and the smoke volume entering the layer can be calculated.

Fundamental conservation of mass principles are applied, i.e., mass flows into and out of the hot layer are generally balanced. Thermal losses due to radiation and conduction are not considered.

Before using this design fire heat output, a check has to be made to establish if the heat output has exceeded that necessary to cause flashover. If flashover has occurred, then the system/building needs to be redesigned. Smoke control systems are not designed to vent a fire at flashover.

For hand calculations, this selected heat output may be utilized as a fixed fire size. Where a computer is used, the growth curve up to the fixed heat output may be incorporated in the calculations. A 3 min incipient phase is added to the time of occurrence of the maximum heat output, which will generate early warning from smoke detectors.

Time-dependent prescriptive parameters are given in Appendix B for growing fires, the rate of growth being dependent on the contents and use of the building. The likely maximum fire size is calculated according to the elapsed time from fire start until the maximum fire heat output occurs for the selected growing fire. For the purposes of smoke control, the fire is assumed to reach a steady state condition. At this time (to a maximum of 1020 s). The calculated fire size is then used to determine the steady state volumetric flow rate of hot smoky gases into the hot layer. A corresponding exhaust volume is then required to maintain steady state conditions within the layer.

In accordance with this methodology the maximum size of the fire will be influenced by many factors including the contents and use of the building, firefighter response times or the effect of fire suppression activities (automatic and manual including firefighting response times).

A3 MAXIMUM SIZE OF DESIGN FIRE

A3.1 Default maximum design fire

The default maximum size of the design fire, for the purposes of system design, should be selected from the design fire curve at the maximum fire growth time event (t_m) equal to 1020 s, unless modified in accordance with Paragraph A3.2. In no case should the maximum fire growth time event (t_m) exceed 1020 s. The system design should be based on the heat output of the design fire curve at t_m.

The peak heat release rates for the family of design fire curves adopted in this Standard occur at 1020 s, and this value is adopted as the maximum fire growth period. It is also considered that such a period is a reasonable time limit over which an installed system is expected to cope with an unrestrained fire. This default maximum fire growth time limit may be modified in accordance with Paragraph A3.2.

A3.2 Modified maximum design fire

If the fire is to be controlled, the maximum design fire heat output may be altered by the modification of the maximum fire growth time event (t_m). The modified maximum fire growth time event (t_m) should be based on the time for fire control, calculated in accordance with Appendix C. In no case should t_m be selected as greater than 1020 s.

A3.3 Check for flashover

In all cases, a check calculation needs to be carried out to ensure that a flashover has not occurred. The time to reach flashover, i.e., when the hot layer reaches 600°C, is calculated in accordance with Appendix C. If flashover has occurred before the calculated maximum fire growth time event (t_m), the smoke control system cannot be designed in accordance with this Standard, as steady state conditions within the hot layer cannot be achieved.

The maximum default time limit may be modified in line with the design objectives of the system or because of installed systems or processes, which will act to control the fire growth and modify the maximum design fire curve peak.

Time for fire control, either by automatic fire suppression systems (sprinklers) or manual intervention (trained in-house firefighters or fire brigade intervention) may be calculated in accordance with Appendix C.

Regardless of whether the maximum default time limit has been modified it is necessary to ensure that flashover has not occurred before the maximum fire growth time limit.

The time to reach flashover may be calculated in accordance with Appendix B.

If flashover has occurred, the design options need to be reviewed. The system or building design may need to be modified to achieve reduced hot layer temperatures by measures such as increasing building height to increase the clear height below the hot layer (which increases the required exhaust or vented air quantity), provision of a detection system or upgrading to a pumped hydrant system to reduce the fire control time (which reduces the maximum design fire size), or provision of a sprinkler system (to reduce the fire control time). Higher hot layer temperatures may increase the cost of the building and smoke control system components.

It is expected that others provide occupant evacuation times and that tenability has to be maintained for that time. This Standard does not contain requirements for tenability criteria.

A4 HOT LAYER DEPTH

The required hot layer depth should be defined with consideration of the building geometry and any required clear height beneath the layer for occupant evacuation or firefighter access.

The hot layer depth should be selected as the required height above the highest occupied floor or level within a smoke control zone plus a safety factor. Some minimum heights above floor levels may be specified in regulation.

A5 HOT LAYER TEMPERATURE

The temperature of the hot layer should be calculated, at the maximum layer depth, as set out in Appendix D.

A6 SMOKE GENERATION RATE

The flow rate of the smoke entering the defined hot layer should be calculated in accordance with Appendix D.

A7 EXHAUST FLOW RATE

The exhaust flow rate required to maintain a steady state layer depth at time (t_m) should be calculated.

A8 DESIGN EXAMPLE

An example of the application of the sequential design process is given in Appendix G.

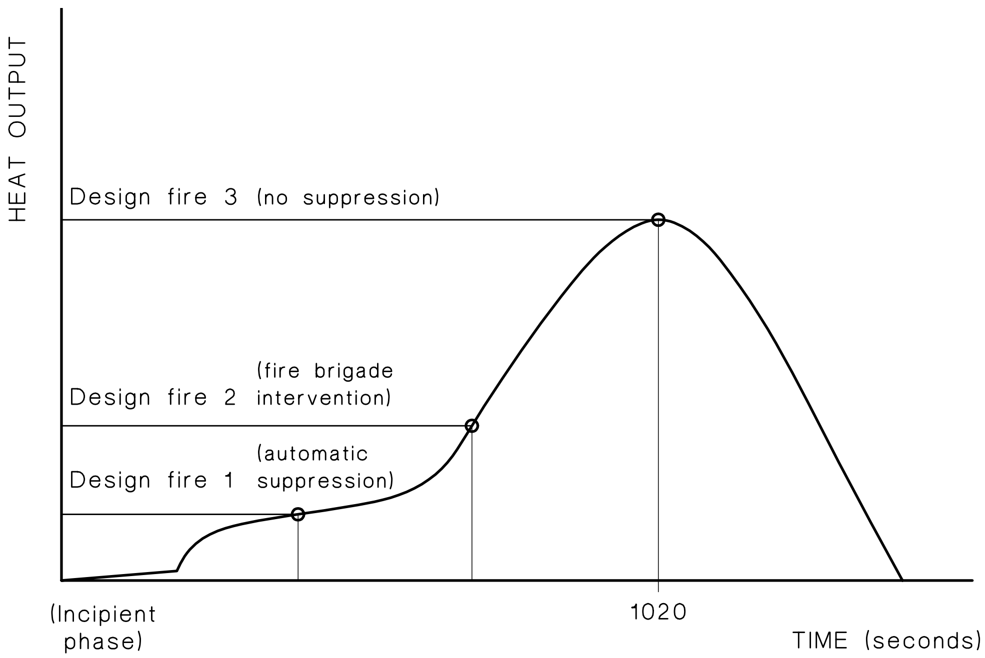


FIGURE A1 HEAT OUTPUT OF DESIGN FIRE DEPENDENT UPON FIRE GROWTH EVENTS

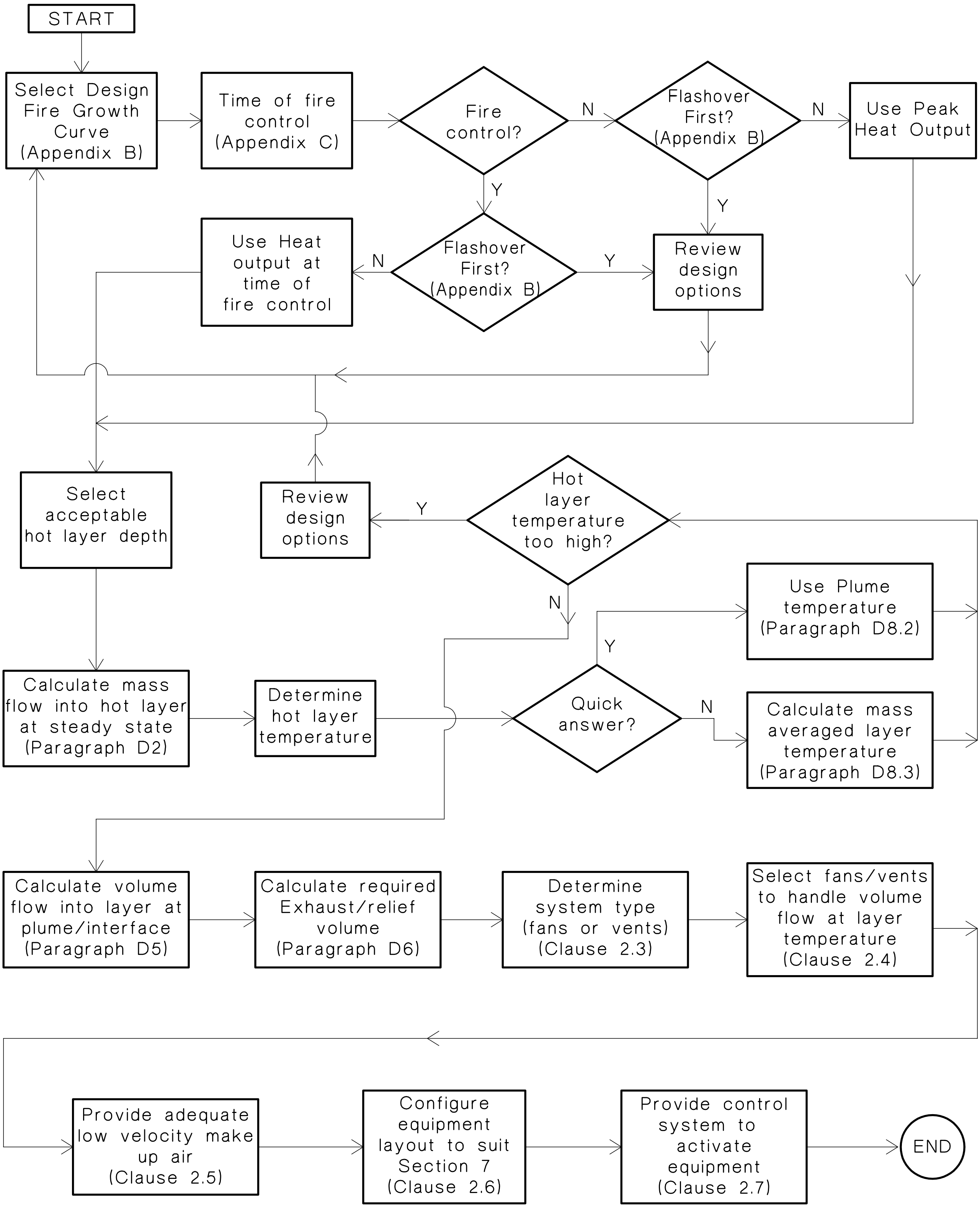


FIGURE A2 METHODOLOGY FOR DEVELOPMENT OF KEY INPUT DESIGN PARAMETERS

APPENDIX B

DESIGN FIRE

(Informative)

B1 GENERAL

A polynomial fire curve, developed in accordance with Paragraph B2, preceded by an incipient period of 3 min (smouldering fire), comprises the convective heat output of the design fire employed by this Appendix for the design of smoke control systems.

CB1 *The cornerstone of any fire engineering design solution is the specification of the fire size. The Building Code of Australia (BCA) uses an arbitrary fixed fire size and perimeter to predict the rate of smoke production, based upon Thomas's equations. NFPA 92B uses an alpha tee-squared fire growth curve to specify fire size at any given time. It also uses different equations to the BCA.*

This Appendix requires that a growing fire be utilized. An approximation of equating a fire load to an appropriate fire curve has been used to establish a simple prescription.

Initially, a condition determined to be a medium fire load was selected and considered, to comprise a plane of stored energy at floor level. Next a radial rate of increase in area through the stored energy was calculated so that the alpha coefficient of a medium alpha tee-squared fire was matched.

This Appendix recognizes that the alpha tee-squared fire curve does not adequately represent real fire growth during its early stages. The alpha tee-squared curve cannot represent the incipient or smouldering stages of a fire, where the advantages of early detection systems may be realized, and may not represent the burning rate of the first item to ignite. The alpha tee-squared fire can generate unrealistically small fire sizes if very early intervention methods are proposed.

This Appendix uses a modified fire curve (a sixth-order polynomial function) initially generating a parabolic curve, which falls back onto the alpha tee-squared fire curve for a time before it peaks and decays. After initial alignment with the selected medium fire load and medium alpha tee-squared curve, the rate of radial increase is adjusted so that the relationship of the family of curves generated more appropriately relates to the likely range of fire loads which will be encountered (see Figure B1).

For the purposes of this Appendix methodology $\dot{Q}_c$ *represents the total heat output of the fire which may traditionally incorporate radiation outputs and be conservative.*

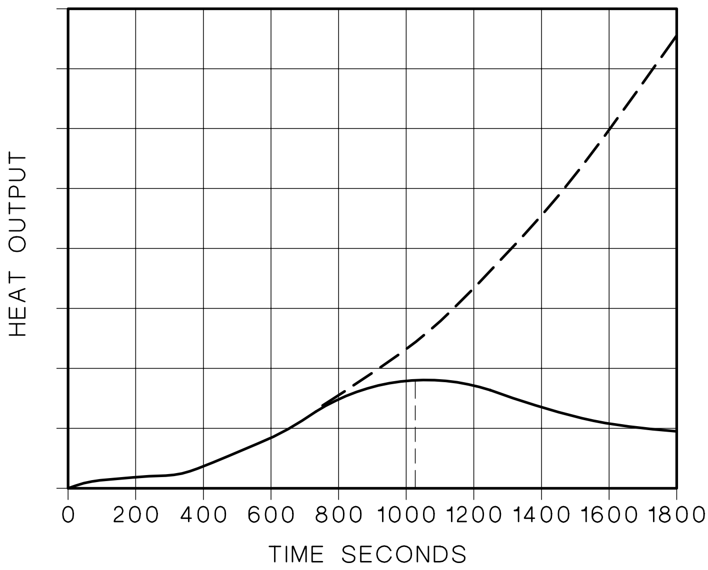


FIGURE B1 RELATIONSHIP BETWEEN A TYPICAL ALPHA TEE-SQUARED FIRE (DOTTED LINE) AND THE EQUATION (B2)1 POLYNOMIAL (SOLID LINE)

B2 SPECIFICATION OF A DESIGN FIRE

B2.1 General

The design fire curve used to determine the maximum fire size is based on the following polynomial equation:

$$\dot{Q}_c = \frac{\alpha(a_0 + a_1 t_m + a_2 t_m^2 + a_3 t_m^3 + a_4 t_m^4 + a_5 t_m^5 + a_6 t_m^6)}{0.0117} \qquad \ldots \text{(B2)1}$$

where

$\dot{Q}_c$ = the convective heat output of the fire, in kilowatts

α = a coefficient governing the fire growth rate, calculated in accordance with Paragraph B3

a_0 = 0

a_1 = 16.08587

a_2 = –0.1007277

a_3 = 0.2791618×10^{-3}

a_4 = $-0.3026714 \times 10^{-6}$

a_5 = 0.1411789×10^{-9}

a_6 = $-0.2400561 \times 10^{-13}$

t_m = maximum fire growth time event, (s), selected in accordance with Appendix A and never greater than 1020 s

For the appropriate contents and risk, a coefficient of fire growth rate (α) is calculated in accordance with Paragraph B3 where α is based upon the fire load density and, where appropriate, the fire load configuration factor.

B2.2 Flashover — Check step

B2.2.1 *General*

The heat output of the design fire ($\dot{Q}$) is assumed to increase according to the Equation (B2)1 until flashover is deemed to occur at time t_f given by the following equation:

$$t_f = \sqrt{(\dot{Q}/\alpha)} \qquad \text{. . . (B2)2}$$

where

$\dot{Q}$ = the total heat output of the fire given by Equation (B2)3

t_f = time to flashover, (s), never greater than 1020 s

α = a constant governing the fire growth rate, calculated in accordance with Paragraph B3

The area of openings is taken as 0 before flashover, unless the openings are permanently open or can be activated before this event.

CB2.2.1 *This Standard requires that the system designer undertakes a design check-step to ensure that the smoke control system has not been designed to vent a fire that has flashed over. It is essential that smoke control systems be based on a pre-flashover design fire heat output. When a fire flashes over it is unlikely that any smoke control system would be able to cope with the resultant hot layer temperatures and smoke development.*

There is a tendency to regard flashover as a final event. A better definition of flashover would be 'the time when flames cease to be localized and flaming can be observed throughout the whole compartment volume, i.e., the burning activity changes from being a surface phenomenon to a volume process. Flashover is, in fact, the transition from the growth period to the fully-developed stage in fire development (refer to Figure B2). It is used as the demarcation point between two stages of a compartment fire, i.e., pre-flashover and post-flashover.

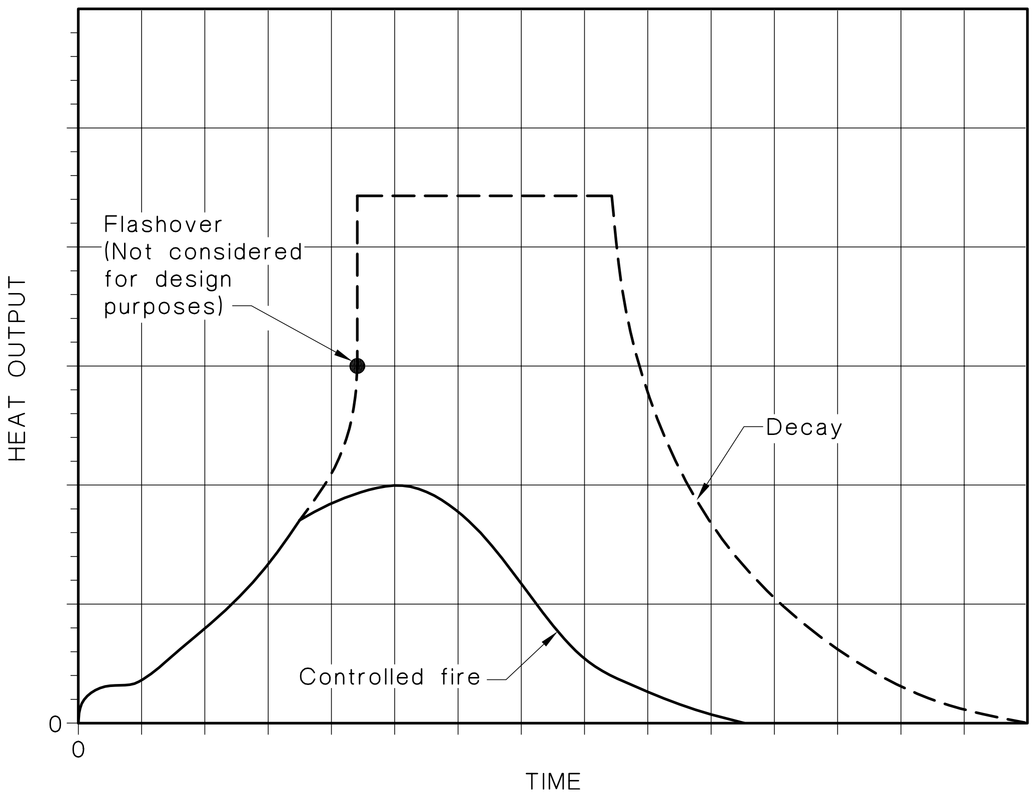


FIGURE B2 HYPOTHETICAL DIAGRAM OF THE PHASES OF A FIRE

B2.2.2 *General flashover*

Equation B.3 is based upon the assumption that flashover occurs at an upper layer temperature of 600°C. The heat output at flashover is given by the following equation:

$$\dot{Q} = 11.15A_t + 540A_w\, h_w^{1/2} \qquad \text{. . . (B2)3}$$

where

$\dot{Q}$ = the total heat output at flashover, in kilowatts

A_t = the total surface area of the compartment, in square metres (includes walls, floors, ceilings and openings)

A_w = the total area of ventilation openings, in square metres

h_w = the vertical dimension of ventilation openings, in metres

NOTE: Where more than one opening is being considered, h_w should be proportionally adjusted based on the area of each opening.

B2.3 Design fire—Sprinklered

The heat output of the design fire ($\dot{Q}_c$) is assumed to increase according to Equation (B2)1 until sprinkler operation is deemed to occur at time (t_m) (see Appendix C). Following sprinkler operation, the heat output of the fire is considered to remain constant. The fire growth constant (α) is determined in accordance with Paragraph B3.

B2.4 Design fire—Manual suppression

The heat output of the design fire ($\dot{Q}_c$) is assumed to increase according to Equation (B2)1 until manual fire suppression is deemed to occur at time (t_m) (see Appendix C). Following manual fire suppression operations, the heat output of the fire is considered to remain constant. The fire growth coefficient (α) is determined in accordance with Paragraph B3.

B3 FIRE GROWTH RATE

B3.1 Coefficient of fire growth

For the purposes of this Appendix methodology the fire growth rate coefficient (α) is determined from the following equation:

$$\alpha = 0.00002\, q_f\, c_f \qquad \text{. . . (B2)4}$$

where

α = a coefficient governing the fire growth rate

0.00002 = a constant

q_f = fire load density, in megajoules per square metre, see Table B1

c_f = a factor for configuration of the fire load, see Table B2

CB3.1 *An αt^2 fire can be expressed as a growing fire where the rate of radial expansion generates the α coefficient used. This Appendix uses a constant radial expansion rate through the design fire load thus generating coefficients which are in proportion to the fire load. The configuration factor (c_f) has been included, as a first approach, to address the fire growth which will vary due to the methods and materials of storage.*

B3.2 Fire load densities

For the purposes of this Appendix, the fire load density should be selected, according to the building use, from Table B1.

B3.3 Fire load configuration

For the purposes of this Appendix, the fire load configuration factor should be selected, according to storage type, from Table B3.

Generally a configuration factor of 1.0 will be applied, except for those occupancies where storage of materials occurs, in which case the configuration factor should be in accordance with Table B2. Where no configuration factor is given, select a similar use, or use a configuration factor of 1.0.

TABLE B1

FIRE LOAD DENSITY (MJ/m^2)

BUILDING USE	Fire load density (q_f)
Rubber storage	6000
Paint manufacturing	5000
Foam plastics (fabrication/storage)	3000
Cardboard box storage	2500
Health care storage	2000
Libraries	1500
Manufacturing and storage (see Note 1)	1180
Liqueur storage	800
Furniture storage	600
Retail	600
Exhibition hall	500
Office general	420
Manufacturing	300
Theatre/Cinema	300
Restaurant	300
Museum	300
Schools	285
Health care (hospital)	230
Storage of mixed combustibles (shops, warehouses, libraries, transport depots, etc.)	1000/m (see Note 2)

NOTES:

1 Storage of combustible materials at less than 150 kg/m^2.

2 MJ/m^2 for each metre height stored.

3 The values given in this Table include only the variable fire loads (i.e., building contents). If significant quantities of combustible materials are used in the building construction, this should be added to the variable fire load to give the total fire load.

TABLE B2

FIRE LOAD CONFIGURATION FACTOR

Occupancy/Storage	Configuration factor(c_f)
Storage >2.5 m	1.5
Office (Drawing, Legal government)	1.5
Storage ≤2.5 m	1.0
Storage with horizontal shelving between goods	0.75
Storage Block Stacking	0.5
Storage encapsulated in metal filing cabinets compactus or shipping containers	0.25
Other than listed above	1.0

B4 FIRE PERIMETER

The perimeter of the fire is used to determine the mass flow of hot smoky gases at any given height above a floor. The following equation is used to calculate the fire perimeter for a square fire of equal sides.

$$P = 4\left(\frac{\dot{Q}_c}{\ddot{Q}_c}\right)^{1/2} \quad \ldots \text{(B4)1}$$

where

P = fire perimeter, in metres

$\dot{Q}_c$ = heat output of fire, in kilowatts

$\ddot{Q}_c$ = heat release rate of fire, in kilowatts per square metre, see Table B3

Where elongated storage configurations such as racking or shelving are used, the fire perimeter is determined between the parallel sides of the stored goods using the following equation:

$$P = 2\frac{\dot{Q}_c}{\ddot{Q}_c \times d} \quad \ldots \text{(B4)2}$$

where

$\dot{Q}_c$ = the convective heat output of fire, in kilowatts

$\ddot{Q}_c$ = heat release rate of fire, in kilowatts per square metre, see Table B3

d = depth of rack, in metres

For the purpose of calculating the fire perimeter for use in Appendix D, the values for $\ddot{Q}_c$ given in Table B3 are used.

Equations (B4)1 and (B4)2 are used to calculate a prescribed fire perimeter based upon the heat release rate of the fire and the heat output of the fire as calculated by Equation (B2)1.

TABLE B3
MAXIMUM HEAT RELEASE RATES

Building use	Heat release rate ($\ddot{Q}_c$) kW/m^2
Industrial/retail storage > 4 m	1 500
Industrial/retail storage > 2 ≤ 4 m	1 000
Industrial/retail storage ≤ 2 m	500
Others	250

NOTE: Combustible storage includes non-combustible items in cardboard and other combustible cartons.

APPENDIX C

FIRE CONTROL TIME

(Informative)

C1 FIRE CONTROL TIME

Fire control time (t_c) is selected on the basis of the time required to initiate fire suppression (application of water on the fire) by any one of the following:

(a) Automatic fire suppression system.

(b) Manual fire suppression.

(c) Fire brigade intervention.

The result is calculated in accordance with Paragraph C5. The calculated fire control time (t_c) can then be used as the maximum fire growth time event (t_m) in accordance with Paragraph C6 and Appendix A.

> ***CC1*** *The interaction between the egress time of occupants and how this may affect the set-up time of the attending firefighters has not been addressed in this Appendix (e.g. occupants descending from a fire stair whilst firefighters attempt to ascend the same stair to reach the fire floor). There are many other aspects such as falling glass and inoperative or unsafe lifts, which may adversely affect the set-up period in a multistorey building. For example, water could not be applied to a large fire on the 11th floor of the 1st Interstate Bank Building in Los Angeles until 20 min after the alarm had been received, even though many firefighters and appliances had reached the fire scene after the first 5 min from receipt of the alarm call.*

C2 AUTOMATIC FIRE-SUPPRESSANT SYSTEMS

The operation of an automatic fire sprinkler system in accordance with AS 2118.1 is based on the sprinkler response times index (RTI). Sprinkler response times given in Tables C1.1 and C1.2 may be used according to the temperature rating of the heads.

C3 MANUAL CONTROL

The operation of manual fire suppression systems such as fire hydrants used by trained firefighters is based on the local alarm times given in Table C2 and the set-up times given in Table C3, C4, and C5. Table C3 is dependent on site water supplies, site access and system design complying with the requirements of AS 2419.1

C4 FIRE BRIGADE INTERVENTION TIME

C4.1 Time of alarm

The fire brigade notification time (FBNT) is the time of alarm, in seconds, that initiates a fire brigade response, calculated in accordance with this Appendix, which is based upon the fire growth curve, method of detection, detector characteristics, distance of detector from the fire and inbuilt scanning and alarm verification delays. The values given in Table C2 may be used. Where no detection system is provided, the notification time is always taken as a minimum of 480 s.

TABLE C1.1

TIME OF SPRINKLER OPERATION (68°C HEADS)

Ceiling height, m	Sprinkler response time (s)															
	α >0 ≤0.0029				α >0.0029 ≤0.0117				α >0.0117 ≤0.0469				α >0.0470 ≤0.188			
	S	M	F	Q	S	M	F	Q	S	M	F	Q	S	M	F	Q
2.4	582	509	448	412	331	284	240	212	189	159	135	118	130	109	89	74
4.0	736	671	620	590	405	355	311	283	236	195	161	143	154	131	108	92
6.0	907	842	795	771	481	432	390	367	293	243	199	173	177	151	128	112
8.0			984	964	550	500	463	444	340	299	252	227	197	170	145	129
10.0					619	569	532	513	372	340	315	302	214	187	161	145
15.0					809	766	736	721	455	422	397	382	260	230	207	194
25.0									754	718	693	680	405	375	353	340
50.0													849	818	796	785

NOTES:

1 Based on: 24°C ambient
68°C activation temperature
2.45 m axis from fire

2 Sprinkler range:

AVG	RTI
50 = quick (Q)	30 – 60
80 = fast (F)	60 – 100
150 = medium (M)	100 – 200
300 = standard (S)	200 – 300

3 Table C1.1 has been generated using building height and considering a pool fire at floor level. Whilst climbing fires in high-piled storage will give a faster sprinkler response, a shorter time line and a smaller indicated smoke exhaust capacity, it cannot be assumed that the fire will be climbing, it may be a low level fire needing greater smoke relief/exhaust.

4 Linear interpolation between fire sizes is permitted.

5 For information on fire growth rates (α), see Appendix B.

TABLE C1.2

TIME OF SPRINKLER OPERATION (93°C HEADS)

Ceiling height, m	Sprinkler response times (s)															
	α >0 ≤0.0029				α >0.0029 ≤0.0117				α >0.0117 ≤0.0469				α >0.047 ≤0.188			
	S	M	F	Q	S	M	F	Q	S	M	F	Q	S	M	F	Q
2.4	734	663	603	567	408	355	308	278	239	197	162	142	156	132	109	92
4.0	949	878	826	799	504	451	408	382	313	260	212	183	187	159	134	117
6.0	1210	1152	1112	1091	612	558	517	495	373	337	306	282	216	188	160	144
8.0					712	665	630	613	418	383	357	343	241	211	186	169
10.0					810	764	731	714	460	424	396	381	264	233	208	194
15.0					1081	1046	1022	1010	583	545	518	504	329	298	271	258
25.0									1016	985	962	951	528	495	471	460
50.0									2234	2207	2188	2179	1148	1123	1104	1095

NOTES:

1 Based on: 24°C ambient
93°C activation temperature
2.45 m axis from fire

2 Sprinkler range:

AVG	RTI
50 = quick (Q)	30 – 60
80 = fast (F)	60 – 100
150 = medium (M)	100 – 200
300 = standard (S)	200 – 300

3 Table C1.2 has been generated using building height and considering a pool fire at floor level. Whilst climbing fires in high-piled storage will give a faster sprinkler response, a shorter time line and a smaller indicated smoke exhaust capacity, it cannot be assumed that the fire will be climbing, it may be a low level fire needing greater smoke relief/exhaust.

4 Linear interpolation between fire sizes is permitted.

5 For information on fire growth rates (α), see Appendix B.

TABLE C2

TIME OF ALARM/FIRE BRIGADE NOTIFICATION

seconds

Detection system	Alarm connected directly to the fire brigade or indirectly via a monitoring service complying with AS 1670.1	Local alarms and alarms connected to a monitoring service not complying with AS 1670.1
Multipoint Aspirated Smoke Detection System (AS 1670.1 and set to 0 s delay)	20 – 180 = (–120)	90 – 180= (–90)
Smoke detectors (AS 1670.1)	50 – 180 = (–130)	120 – 180 = (–60)
Heat detectors (AS 1670.1)	80	150
Sprinklers (AS 2118)	See Table B1	See Table B1
Smoke detectors (Clause 8.2(b))	80 – 180 = (–100)	150 – 180 = (–30)
No detection system	480	480

NOTES:

1 Smoke detector time of alarm is calculated from the start of the 3 minute (180 s) incipient phase. This equates to a negative time with respect to the fire growth curve as shown in brackets.

2 The Table includes an allowance of 20 s for alarm verification, system scanning delays and fire indicator panel (FIP) scanning by the fire brigade or monitoring service

TABLE C3

TIME TO CONNECT A FIRE APPLIANCE TO A WATER SOURCE

seconds

Water source	Set-up time
Above-ground fire hydrant	+100
Below-ground fire hydrant	+150
On-site storage tank for firefighting purposes	+250
Draughting from open water (lake, dam, etc.)	+300

TABLE C4

TIME TO LAY HOSE OUTSIDE A BUILDING

seconds

Connection point*	Each 30 m hose length	Each 60 m hose length	Each 90 m hose length
Above ground hydrant	75	135	195
Below ground hydrant	120	180	240
Other	180	240	300

* Includes for drawing water from tanks, lakes, rivers and dams and applies to the complete hose system from the water source to the fire fighting stream.

NOTE: An allowance for adaptor or strainer at an above-ground hydrant is included in these values.

TABLE C5

TIME TO LAY HOSE INSIDE A BUILDING

seconds

Travel direction	Each 30 m hose length	Each 60 m hose length
Horizontal/vertical	120	240

C4.2 Fire brigade response time

The fire appliance response time is calculated as the sum of dispatch time, turnout time, and travel time based on travel speed in accordance with Table C6.

TABLE C6

FIRE BRIGADE RESPONSE TIMES

Location	Dispatch time, s	Turnout time, s	Travel speed km/h (see Note)
Inner city	10	45	25
Inner suburb	12	60	30
Outer suburb	20	60	40
Rural town	30	240	30
Rural country	30	360	50

NOTE: Travel distance along a known route from the fire station is divided by the appropriate travel speed and converted into seconds to provide the travel time. Where the exact route is not known, the radial distance from the fire station is divided by the travel speed, multiplied by a factor of 1.5 and converted into seconds.

C4.3 Manual application of fire suppressant

C4.3.1 *General*

The time taken to apply water on a fire is equal to the sum of the times taken from Tables C3 to C6 inclusive plus times taken to don and check safety equipment and any time firefighters will take to travel to the fire location as given in Table C7. Table C3 is dependent on site water supplies, site access and system design complying with the requirements of AS 2419.1.

TABLE C7

FIREFIGHTER TRAVEL TIMES

Gather, don and check safety equipment*	120 s
Horizontal travel speeds (see Note)	1.0 m/s
Vertical travel speeds (see Note)	0.3 m/s

* Includes breathing apparatus.

NOTE: Travel distance (in metres) is divided by the appropriate travel speed to calculate the travel time.

C4.3.2 *Time to apply water to the fire.*

The time required to lay water supply hose depends on the building configuration and design. Basic firefighting strategies are outlined in Figure C1 while Figure C2 clarifies how water is supplied to a fire.

In some buildings this time will be the time taken to lay hose from the water supply/source to the firefighting appliance plus the time taken to gather, don and check safety equipment, plus the time taken to lay hose from the firefighting appliance to the seat of the fire.

Where the building is equipped with a booster connection, in addition to the time taken to lay hose from the water supply/source to the firefighting appliance and the time taken to gather, don and check safety equipment, the time taken to connect to the booster must be added, plus the time taken for firefighters to travel to a remote (boosted) hydrant, and lay hose from that hydrant to the fire

Where the building has pumps, then the time will comprise the time taken by fire fighters to gather, don and check safety equipment, travel to a remote hydrant and lay hose from that hydrant to the fire. Hose laying from the water source to the fire appliance is usually undertaken simultaneously with hose laying from the fire appliance to the fire. In such cases the greatest time is used.

Thirty-metre hose lengths are used in Australia. The number of hose lengths required is equal to the distance layed, in metres, divided by 30. One additional hose length is necessary for any remaining distance, except that a hose stream of 10 m issuing from a nozzle at the end of the hose line may be taken into account when laying to the fire.

For the purpose of this Appendix, fire location is taken as the furthest point from the main entry to the building to the uppermost floor. Further, all firefighters are considered to respond from this location to undertake their allotted tasks.

C5 CALCULATION OF t_c

C5.1 Automatic fire suppression system

The fire control time (t_c) is equivalent to the automatic fire suppression system response time (see Tables C1.1 and C1.2)

C5.2 Manual/Fire brigade intervention

The fire control time (t_c) is the sum of the alarm time (see Table C2), hose laying times (see Tables C3 to C5), fire brigade response time (see Table C6) and the firefighter set up time (see Table C7).

C6 DETERMINATION OF t_m FROM t_c

Where t_c occurs due to automatic or manual fire suppression, or fire brigade intervention, prior to the design fire curve reaching its maximum heat release rate, then t_m may be selected as $\geq t_c$.

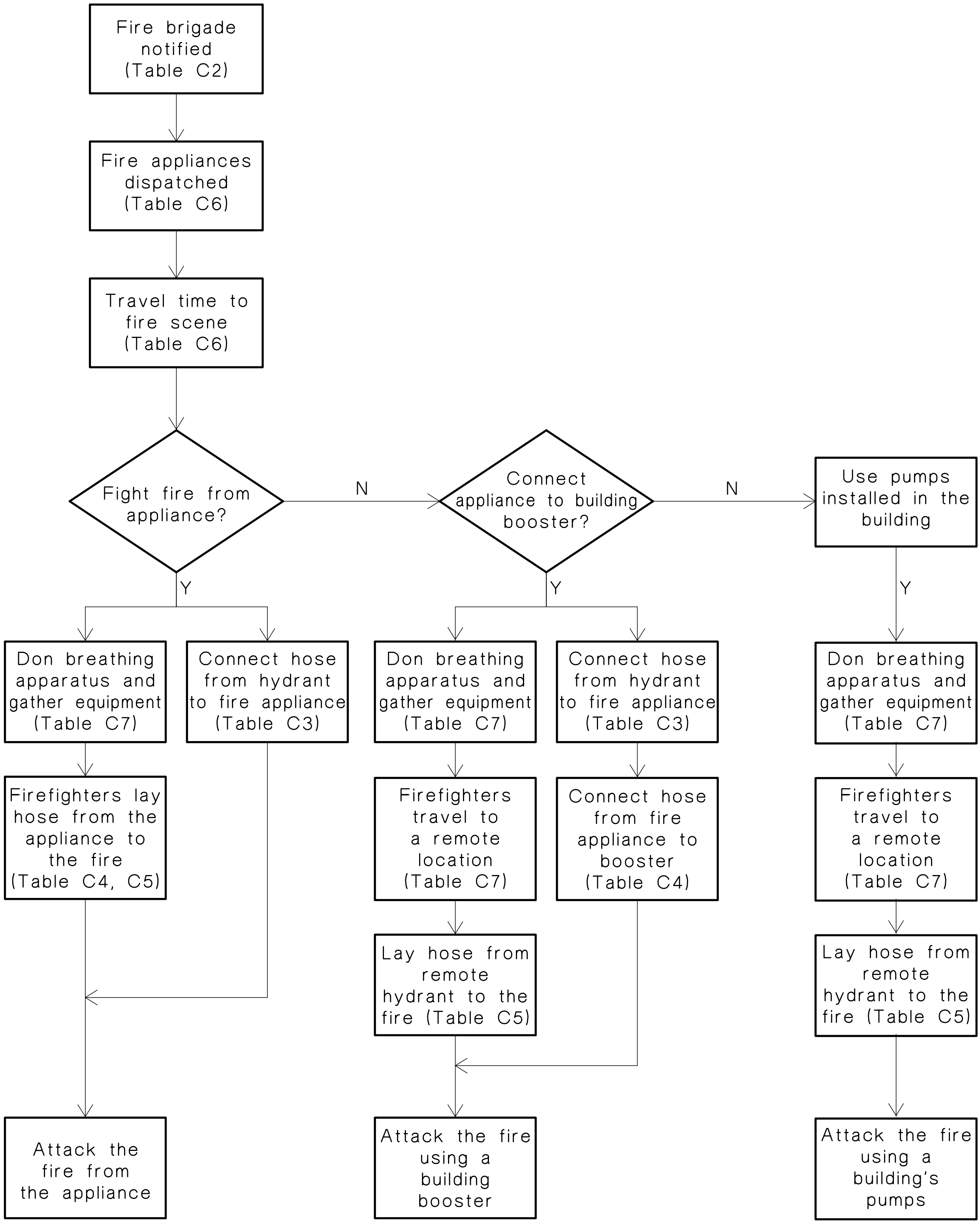
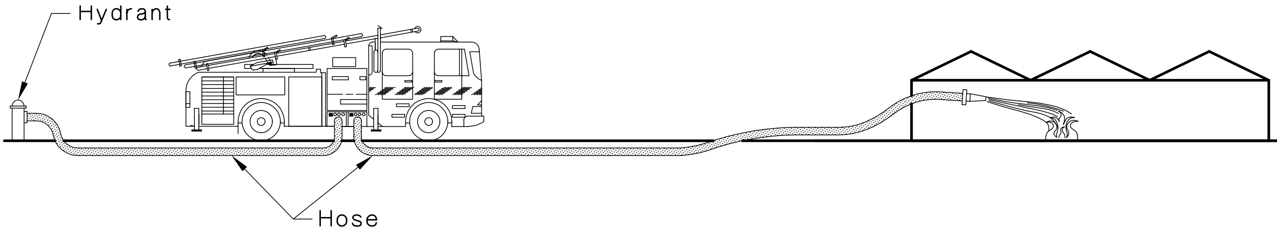
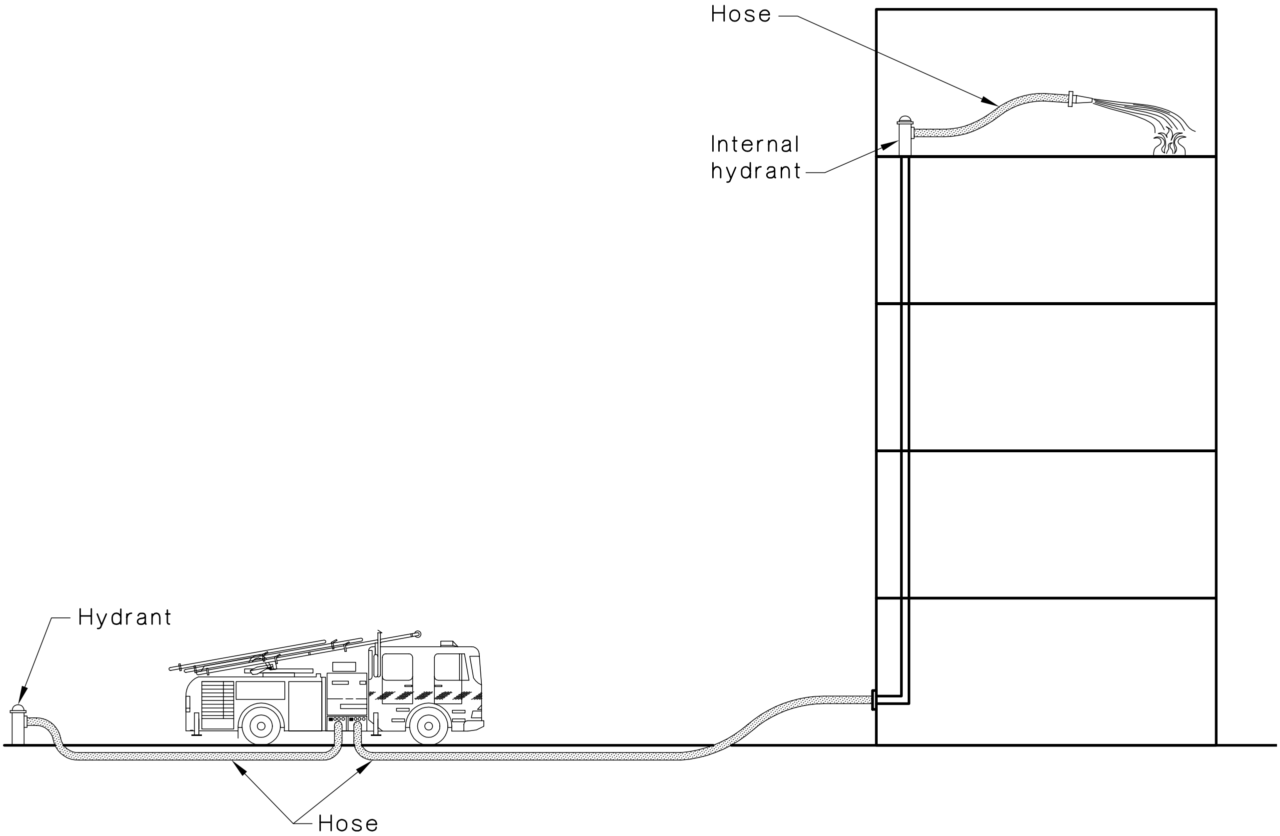


FIGURE C1 BASIC FIREFIGHTING STRATEGIES



(a) Hose laid from hydrant to appliance then appliance to fire



(b) Hose laid from hydrant to appliance then appliance to booster, then firefighters ascend to use internal hydrant

FIGURE C2 SUPPLYING WATER TO A FIRE

APPENDIX D
HOT LAYER PARAMETERS
(Informative)

D1 GENERAL

This Appendix details methods for calculating the layer depth and maximum ceiling temperature likely to be achieved by the design fire so that materials exposed to this temperature, such as the structure, smoke control equipment and smoke reservoir materials, can be designed to withstand this event. A methodology is also provided to calculate the average temperature of the hot layer so that its effect can be determined where buoyancy-driven smoke and heat vents are employed. The terminology used for hot layer parameters is illustrated in Figure D1.

D2 MASS FLOW INTO HOT LAYER

The perimeter of the fire is used to determine the mass flow of hot smoky gases at any given height (y) above a floor. The critical height considered is the underside of the buoyant hot layer, above which point the mass flow is considered to remain steady. Mass flow is calculated by the following equation:

$$\dot{M} = 0.096\, \rho_a\, P y^{3/2} \left(g T_a / T_f \right)^{1/2} \quad \text{. . . (D2)}$$

where

$\dot{M}$ = mass of air entrained into plume, in kilograms per second

ρ_a = density of air entrained into plume, in kilograms per cubic metre

P = perimeter of fire, in metres

y = height from floor to underside of hot layer, in metres

g = acceleration due to gravity, in metres per square second

T_a = temperature of ambient air entrained into plume, in Kelvins

T_f = temperature of flame, in Kelvins

NOTE: For the purposes of these calculations T_f may be taken as 1173 K (900°C).

D3 AMBIENT AIR DENSITY

The volumetric flow rate into the hot layer is determined by the density (ϱ_a) of the air in the layer beneath it, i.e., the temperature of the ambient air entrained into the hot rising plume.

At an air temperature of 17°C the ambient air density (ϱ_a) = 1.22 kg/m^2, at any other air temperature (T_a) the air density at that temperature (ϱ_a) may be calculated from the following equation:

$$\varrho_a \frac{353.8}{(T_a + 273)} \quad \text{. . . (D3)}$$

where

ϱ_a = air density, in kilograms per cubic metre

T_a = air temperature, in degrees Celsius

D4 TEMPERATURE RISE IN PLUME

The heat input from the fire will cause a temperature rise (ΔT) that can be calculated at height y, knowing the mass and the specific heat of the entrained air by the following equation:

$$\Delta T = \frac{\dot{Q}_c}{\dot{M} \times C_p} \qquad \text{. . . (D4)}$$

where

ΔT = temperature rise in plume at the interface of the hot layer, in Kelvins

$\dot{Q}_c$ = convective heat output of fire, in kilojoules per second

$\dot{M}$ = mass of air entrained into plume, in kilograms per second

C_p = specific heat of air, in kilojoules per kilogram Kelvin (kJ/kg.K)

NOTE: For the purposes of these calculations C_p may be taken as 1.005 kJ/kg.K.

The hot layer temperature (T_L) can be calculated as the ambient (make-up) air temperature increased by ΔT.

D5 VOLUME OF SMOKE FLOW INTO HOT LAYER

The volumetric flow into the hot layer can be calculated from the mass entrainment rate using the universal gas law (ideal gas), as follows:

$$\dot{V} = \frac{\dot{M} \times (T_a + 273 + \Delta T)}{\varrho_a \times (T_a + 273)} \qquad \text{. . . (D5)}$$

where

$\dot{V}$ = volumetric flow rate of smoke, in cubic metres per second

$\dot{M}$ = mass of air entrained into plume, in kilograms per second

T_a = temperature of ambient air, in degrees Celsius

ΔT = temperature rise in plume, in degrees Celsius

ϱ_a = ambient air density, in kilograms per cubic metres

D6 EXHAUST QUANTITY REQUIRED

The exhaust rate from the reservoir should be equal to or greater than the flow rate of hot gases into the reservoir due to the design fire if steady state conditions are to be maintained so that the hot layer interface position remains constant at the design height.

For mechanical smoke control systems, the flow at the plume/layer interface needs to be expressed as a volume in metres cubed per second which is matched by the fan performance at the calculated hot layer temperature, in accordance with Section 3.

For buoyancy-driven smoke and heat vents, the flow at the plume/layer interface needs to be expressed as a mass flow in kilograms per second, which is matched by the vent performance at the calculated hot layer temperature, in accordance with Section 4.

D7 LAYER DEPTH

Layer depth is the selected layer depth to suit the geometry of the building and reservoir configuration. The flow of hot gases into the reservoir from the selected design fire, at the interface of the rising plume and the underside of the hot smoke layer, has to be at least equal to the flow of hot gasses from the reservoir if steady state conditions are to exist so that the layer depth remains constant.

D8 HOT LAYER TEMPERATURE

D8.1 General

The temperature of the hot layer affects the selection of mechanical extract fans in terms of temperature resistance and non-overload characteristics at ambient conditions, and directly affects the performance of buoyancy-driven smoke and heat ventilators. As shown in Figure D1, the temperature of the hot layer will vary according to its depth and the correct temperature needs to be applied. Two solutions are provided, a conservative steady state layer temperature solution is given in Paragraph D8.2 or a more complex time-dependent option is given in Paragraph D8.3. Both solutions rely on the design fire characteristics calculated in accordance with Paragraphs D1 to D6.

D8.2 Steady state solution

D8.2.1 *Buoyancy-driven systems*

The simplest, albeit conservative, layer temperature solution is to calculate the plume temperature at the full room height and select this temperature as the layer temperature; however, in practice, for a given $\dot{Q}_c$, as the layer deepens, its temperature will increase and the performance of the ventilators will improve because of a deepened layer and increased buoyancy. If the temperature at the plume/layer interface is calculated for the full layer depth, this may be averaged with the temperature at full ceiling height (with no layer) for ventilator performance purposes.

D8.2.2 *Mechanical exhaust systems*

The simplest, albeit most conservative, layer temperature solution is to use the calculated plume temperature at the plume/layer interface for the full layer depth. In practice, the maximum temperature encountered by a roof fan, directly over the fire, will be less than that calculated temperature. How much less will depend upon the temperature of the smoke layer, the gases of which will be entrained into the rising plume continuing up through the hot layer.

D8.3 Time-dependent solution

The mass averaged layer temperature may be calculated and used for the determination of both mechanical and buoyancy-driven system performance.

For each second, the condition of the plume/layer interface is calculated in terms of temperature, mass and interface height. The temperature of the layer needs to be calculated each second, by adding the new mass flowing at the new (higher) temperature in Kelvins into the layer mass at the layer temperature in Kelvins. The layer temperature in Kelvins is increased in proportion to the mass flowing into the layer, divided by the mass contained within the layer, multiplied by the temperature difference between the plume and layer, i.e., the layer temperature is revised each second.

To calculate the plume interface temperature it is also necessary to carry out volume calculations each second to establish the incremental depth of the layer for each mass and temperature calculation. The layer depth used to determine the interface height will change according to volume flow into the layer, volume flow out of the layer, the rate of removal of gases and volume/area of the reservoir. A growing fire and delayed system operation adds further complexities to the calculations.

NOTE: To facilitate this method, due to the iterative nature of this calculation the use of a computer is recommended.

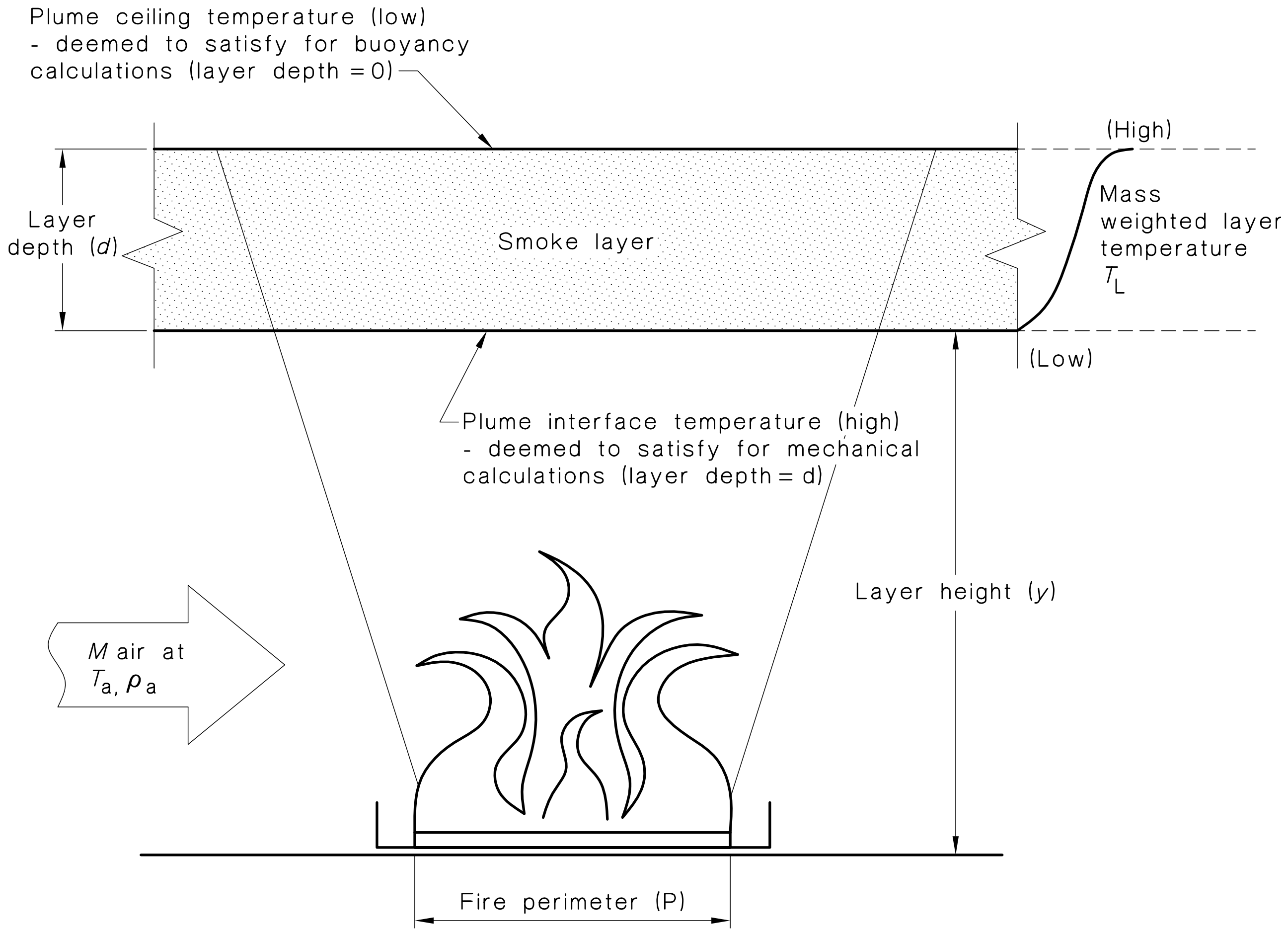


FIGURE D1 HOT LAYER PARAMETERS

APPENDIX E

PRINCIPLES OF SMOKE CONTROL AND SYSTEM SELECTION

(Informative)

E1 GENERAL

Smoke control systems are installed in a building to reduce the impact of a fire by discharging the generated heat and smoke. The rate of combustion varies considerably depending on the nature, shape, size and packaging of combustible material, the size and height of the storage/piling and other factors; hence, the volume of heat and smoke to be vented varies accordingly.

E2 REMOVAL OF HEAT

The removal of heat from the building will assist in the prevention of the horizontal spread of fire and reduce the damage caused by heat.

If severe damage to exposed structural steel is to be avoided, the temperature of the vented heat should not be so high as to overheat the steel to a point where its strength is reduced.

E3 REMOVAL OF SMOKE

The removal of smoke can assist in—

(a) reducing the impact of smoke inhalation on evacuating occupants;

(b) preventing personnel evacuating the building from becoming disoriented;

(c) locating the seat of the fire by firefighting personnel;

(d) reducing smoke damage within the building; and

(e) drawing attention to a fire in an unoccupied building.

E4 SMOKE CONTROL SYSTEMS

Smoke control systems in this Standard consist of automatic exhaust fans or vents installed in association with smoke reservoirs. The operation of the fans/vents removes heat and smoke. The smoke reservoirs prevent the horizontal spread of heat and smoke within the building. Smoke reservoirs enable hot gases to bank up and provide a deep layer of hot gas, which causes a buoyancy pressure to drive smoke through the vent or fan.

The localized deep layer of hot gases, contained by the smoke reservoirs, causes smoke control systems, detectors and sprinklers to operate earlier than would be the case with a widespread thin layer of gases.

To permit the system to operate satisfactorily, it is necessary to make provision for air to enter the building. For buoyancy-driven systems the area of inlet is ideally twice the total effective aerodynamic area of the vents in the largest compartment bounded by smoke curtains. When the required inlet area is being assessed, natural leakage provided in the building construction may be included in calculations. Inlets may be designed to open automatically in conjunction with automatic system operation.

Under certain conditions, a layer of hot air can form under a completely sealed roof. This inversion layer can delay the products of combustion in reaching detectors or sprinklers until a fire is well established. Leakage through closed vents or non-operating mechanical systems will allow this heated air to escape, thus preventing the formation of an inversion layer, and so assisting in the earlier operation of fire detection devices.

E5 SYSTEM SELECTION

E5.1 Mechanical systems

A mechanical exhaust system is usually appropriate where the temperature of the gases in the hot layer are relatively low. The cost of a fan may increase because of the following:

(a) Fan construction to withstand high temperatures will be proportional to the temperature of the gases passing through the fan. This is particularly critical for fan drives located within the smoke-spill stream.

(b) The higher the gas temperature the lower the gas density; hence, a fan will require a higher volume flow to maintain the required mass flow.

Mechanical systems are ideally suited to buildings in areas where public utility power interruption is rare (e.g. metropolitan area), or of little consequence (e.g. stand-by generator on site) and where layer temperatures are likely to be low (e.g. a sprinklered building, or one with contents of low fire load). Such buildings include but are not limited to, shopping centres, atriums, indoor sporting complexes, auditoriums, schools, health care buildings, low fire load sprinklered industrial buildings, and the like.

E5.2 Buoyancy-driven systems

Natural buoyancy-driven ventilators, which depend upon the temperature of the hot gases to do the work, have the following characteristics:

(a) They improve in performance as the hot layer temperature increases;

(b) They improve in performance as the smoke layer deepens; and

(c) For a given flow rate, they proportionally increase in cost as layer temperatures reduce.

Other factors to be considered in the overall design strategy include the following:

(i) What process or comfort systems are there within the building which can be adapted to cope with or augment a proposed system?

(ii) What building facilities, in terms of configuration or natural ventilation, can be used to advantage?

(iii) How should the system operation be controlled if indeed such control is considered necessary?

Whilst buoyancy-driven systems can be designed for any circumstance they are ideally suited to high fire load buildings where high layer temperatures are expected. These include shopping complexes (especially stock areas) and high fire load warehouses and factories (even if such incorporate sprinklers in their design). Consideration should be given to using such systems where the smoke layer will be deep due to ceiling or building geometry and may include some atria.

E6 THE INTEGRATION OF MECHANICAL AND BUOYANCY-DRIVEN SYSTEMS

Whilst it is possible to combine the performance of a mechanical process extract system in a factory with that of roof-mounted extract fans, or even consider the performance of some fixed ventilation openings in a building which utilizes a mechanical smoke extract system, the interaction between mechanical and buoyancy-driven systems should be closely scrutinized.

If restricted air inlets are provided for such a combined system, then the building may become depressurized by the mechanical exhaust system to such an extent that air is drawn in through the high level smoke vents. The minimum effect will be that the volume of the smoke layer will increase at a rate equal to the air drawn in. In practice, 'jetting' is likely to occur and the incoming air will quickly bring smoke down to floor level. Air inlet vent area must be increased to overcome the depressurization problem.

In extreme cases, where no other design options exist, a solution to this dilemma is to convert all required smoke relief achieved by fans and vents, to a total mass flow and then, using the appropriate equations, select the necessary low-level air intake size needed to achieve this fictitious performance where the total flow is considered to be handled by buoyancy-driven openings. Fans could then be substituted for smoke and heat vents on an equivalent mass flow selection basis.

It is important to verify by commissioning tests that the installed fan performance does not exceed design parameters to ensure that depressurization of the building is prevented.

E7 EXTERNAL WIND EFFECTS

Any design, be it buoyancy-driven or mechanically assisted, should take account of external wind conditions. Wind profiles over building roofs and impinging upon building facades is a specialized subject and the designer may need to seek professional advice in this regard. Selection of fan equipment should allow for reduced performance due to wind pressure, especially if located on the prevailing windward side of a building or at the ridge of a roof where turbulent flow will affect the outlet performance.

APPENDIX F
APPLICATION OF STANDARD
(Informative)

F1 SCOPE

This Appendix provides some background information on smoke control systems, to guide the designer in the application of the design methodology of this Standard to common building types.

F2 WAREHOUSES

Buoyancy-driven smoke and heat ventilation systems were primarily developed for control of the hot products of combustion within warehouses and factories, for the purpose of asset protection. These systems were designed to minimize lateral fire spread through the building by limiting the hot smoky gases to areas often defined by smoke curtains forming smoke reservoirs. The performance of these systems also allowed firefighters to locate and extinguish a fire.

The original concept of this type of system employed natural ventilators, which sequentially opened by fusible links and relied upon the buoyancy of the hot gases to drive the smoke through the opening. Today, mechanical extract fans are often employed to replace the natural ventilators; however, generally, they will not be a cost-effective option unless the hot layer temperature is modified by the cooling spray of a sprinkler system. Historically, low temperature fans of 200°C performance have been inappropriately selected for use in unsprinklered buildings with high fire loads where the layer temperature is likely to reach more than 600°C.

Changes in the concept of natural ventilator operation from individually opened vents to every vent opening at once as early as possible has resulted from the outcome of research by the Building Research Establishment in the U.K. This concept is still challenged by Factory Mutual in the U.S. This may be because they do not have the facilities to test ventilators in the configurations they are likely to be installed.

F3 SHOPS AND SHOPPING COMPLEXES

Large, stand-alone shops such as supermarkets, including those located within shopping complexes, principally utilize a smoke control system to keep the smoke layer above the heads of shoppers. The pedestrian mall areas of a shopping complex are similarly treated. Because most premises of this size are protected by fire sprinkler systems, the use of mechanical exhaust systems is usually the most cost-effective design solution. Areas of smoke control and operation of smoke exhaust systems needs to be zoned by the use of smoke curtains which can be fixed screens (often toughened glass), drop-down motorized smoke curtains or architectural geometry, which will contain the smoke layer to a desired area thus restricting its lateral spread.

Smoke exhaust systems need to be sequentially activated by local smoke detectors as smoke spreads laterally. If all fans are started at once in a shopping complex, the resultant air movement will likely entrain smoke to all parts of the complex. Care needs to be exercised when designing make-up air paths for fresh air to replace the extracted smoke quantity. Opening of roller doors and other openings to supermarkets need careful consideration (not least, including the security of a premises for its owner) when using this method to provide make-up air to replace extracted air. The shutdown of airconditioning supply systems that supply air at a level above the hot layer is essential in the compartment of fire origin.

Multilevel malls pose special problems and are outside the Scope of this Standard. The concurrent lateral spread of smoke at more than one level needs to be considered. In some cases it will be necessary to provide smoke exhaust to individual specialty shops as a first option rather than rely upon the mall smoke exhaust system to handle the secondary smoke spill plume from a single shop on the perimeter of a multilevel shopping mall. Typical smoke control systems are shown in Figures F1 and F3.

F4 AUDITORIUMS AND THEATRES

Auditoriums and theatres exhibit two principal smoke management problems. A high life risk in the auditorium and often a high fire load (low life risk) on the stage. If a stage is incorporated in the auditorium (theatre in the round), then the smoke control system needs to cope with a large fire load for the purpose of life safety for the theatre patrons. If the theatre is a traditional structure with a proscenium wall and a fire curtain, then each compartment may be treated on its merits. Generally, auditoriums will utilize mechanical exhaust systems whilst stage areas may have the option of using either mechanical fans or buoyancy-driven ventilators. How to provide the necessary low level make-up air into stage and audience areas is often a problem, sometimes resolved by the ingenious use of low level airconditioning ducts normally used for other purposes.

F5 BUILDINGS THAT CONTAIN AN ATRIUM

Atriums can be categorized into three principal types:

(a) The sterile tube atrium, which principally comprises an external building facade to the perimeter of an internal court.

(b) The open atrium, where all floors open onto the atrium and there is no separation between the atrium void and the floor spaces that open off at the atrium.

(c) The hybrid atrium which comprises perimeter pedestrian access to rooms or shops on the perimeter of the atrium where such rooms or shops are ostensibly separated from the atrium void by construction, which may vary from shopfront glazing to fire-rated hotel walls and doors.

Irrespective as to type, the principal method of smoke management is to treat the atrium and perimeter areas separately.

Perimeter areas should have a form of smoke control system that inhibits the spread of smoke into the atrium. A zone pressurization system in accordance with AS/NZS 1668.1 is very effective for perimeter areas that are separated from the atrium void as in a sterile tube.

A similar application may work in an open atrium if the principles of AS/NZS 1668.1 are employed but the fire floor has a smoke exhaust system with an extract performance in accordance with this Standard. Air will flow from the non-fire floors, through the atrium void, to the fire floor thus further inhibiting smoke flow into the atrium because of entering air velocity through the perimeter openings of the fire floor.

Shops and hotel rooms leading to atriums with perimeter pedestrian access will need smoke management systems that address the needs of the perimeter compartments (in shops a ceiling extract plenum is often possible). Further consideration needs to be given with respect to the supply of fresh air to the perimeter pedestrian areas to move any intermittent smoke migration from the void back into that space.

Finally, if smoke does enter the atrium, a smoke exhaust system at the top of the atrium should be utilized to prevent the smoke layer from deepening to an unacceptable level which could spill into open upper floors or pedestrian areas, reach excessive temperatures likely to breach perimeter glazing or permeate through miscellaneous structural openings.

The smoke exhaust system in the atrium should operate in concert with any previously described floor system. For open atriums this system has been called a changeover system because initially for a fire on a floor, the floor is depressurized and the atrium is pressurized by air from non-fire floors. Once smoke enters the atrium, the atrium smoke exhaust fans operate. This will generally change the pressure in the atrium void from positive to negative. This changeover will then increase the velocity of air entering the void from the non-fire floors, hence further discouraging the flow of smoke from the atrium into those spaces. However, the changeover will also likely reduce the velocity of air onto the fire floor and the performance of the smoke exhaust fans serving that floor.

Considering that this is a second operational step of the system to cope with smoke entering the atrium from the fire floor, presumably because the initial step of exhausting the fire floor has failed to fully handle the situation, this is not considered to be detrimental to the overall performance of such systems. It is important that operation of the atrium fans are only initiated by a detection system within the atrium. A mechanical aspirated smoke detection system at the top of the atrium may be appropriate for detection. Typical smoke control systems are shown in Figures F2 and F4.

F6 FACTORIES

Factories are generally treated in a similar manner to warehouses (see Paragraph F2). However, the intent of a design in such buildings may shift from primarily asset protection toward life safety, depending upon the number of factory workers within the space. A factory could comprise a robotics-driven assembly plant with a single operative, or a clothing manufacturer with hundreds of machinists, the former would primarily present an asset management design problem, the latter a life safety problem.

Because of the processes employed, many factories can take advantage of industrial or process ventilation systems to supplement the needs of a smoke control system. Some factory designs incorporate combined buoyancy-driven and mechanical smoke exhaust systems; however, care needs to be exercised when mixing system types (see Paragraph F9).

F7 RECREATIONAL AND OTHER FACILITIES

There are no hard and fast rules regarding treatment of such premises. They may vary from indoor cricket stadiums which simply need an industrial type system, to entertainment venues which employ the same principles of smoke management as theatre in the round, but on a larger scale. Generally, such buildings are likely to utilize mechanical exhaust systems rather than smoke and heat vents.

F8 BUOYANCY-DRIVEN PRESSURE-ASSISTED ROOF VENTILATION SYSTEMS

This type of system employs the principle of natural ventilation. However, the area of the natural ventilation openings is choked because the energy generated to push the smoke through the ventilator is not provided by the hot smoke but by a mechanical pressurization system that supplies the pressurizing (make-up air) below the hot layer without disturbing it.

This method has been successfully tested in an atrium where low velocity relief air from all enclosed non-fire floors enters the atrium void below the designed smoke layer, pressurizing the void and expelling the smoke through the openings at high level.

F9 COMBINING BUOYANCY-DRIVEN AND MECHANICALLY ASSISTED SYSTEMS

Where mechanical exhaust systems are combined with buoyancy-driven relief openings, it is important that the mechanical system does not depressurize the building, because this will adversely affect the performance of the smoke relief openings. The correct design procedure is described in Paragraph F6.

F10 HIGH RISK AREAS IN A BUILDING

Where the fire load in a building varies and the areas of higher fire load are permanently located, e.g. a high fire load area in a manufacturing plant, such areas should be supplied with a venting system of higher capacity than the remainder of the building.

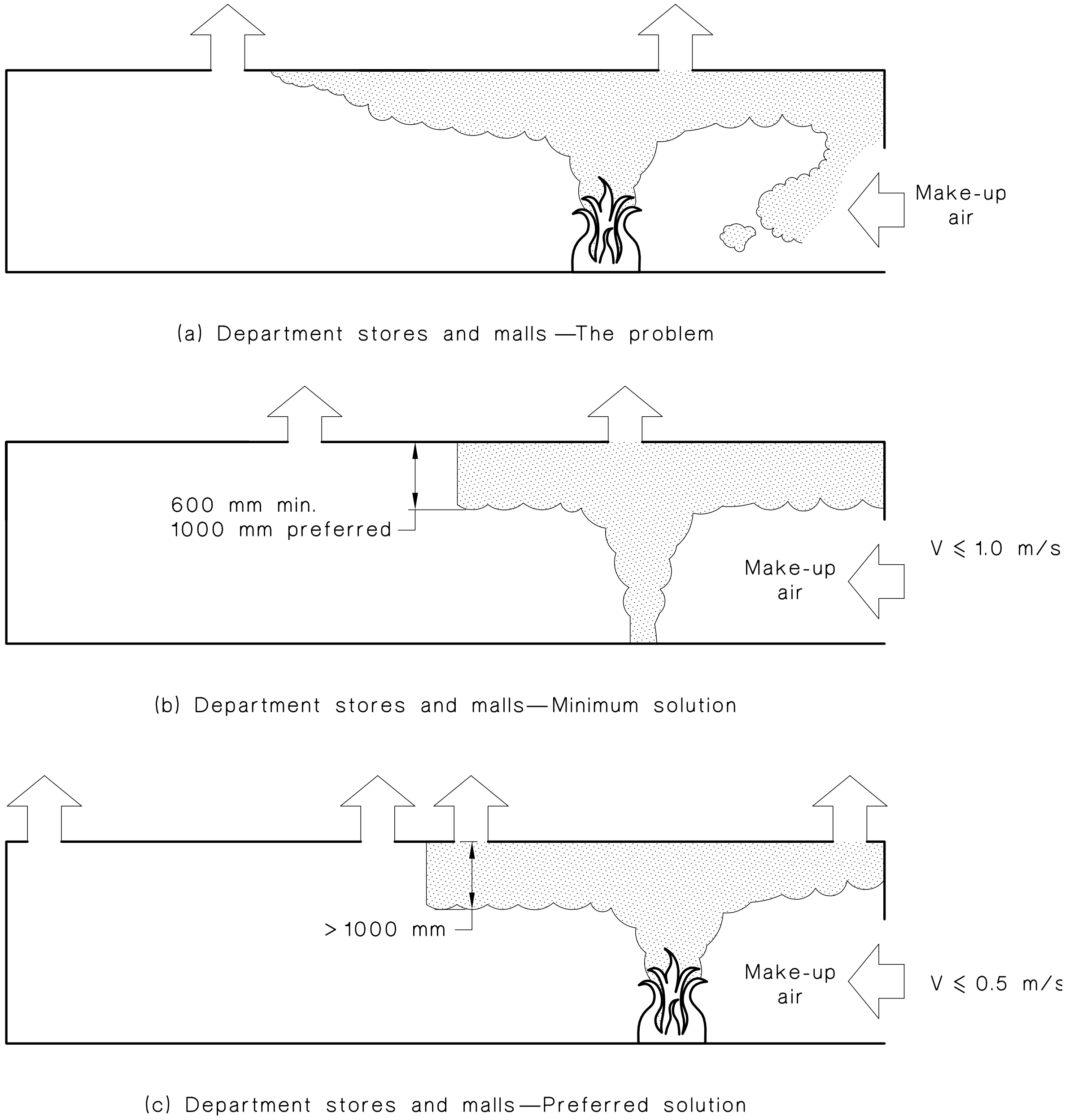


FIGURE F1 TYPICAL SMOKE CONTROL—STORES AND MALLS

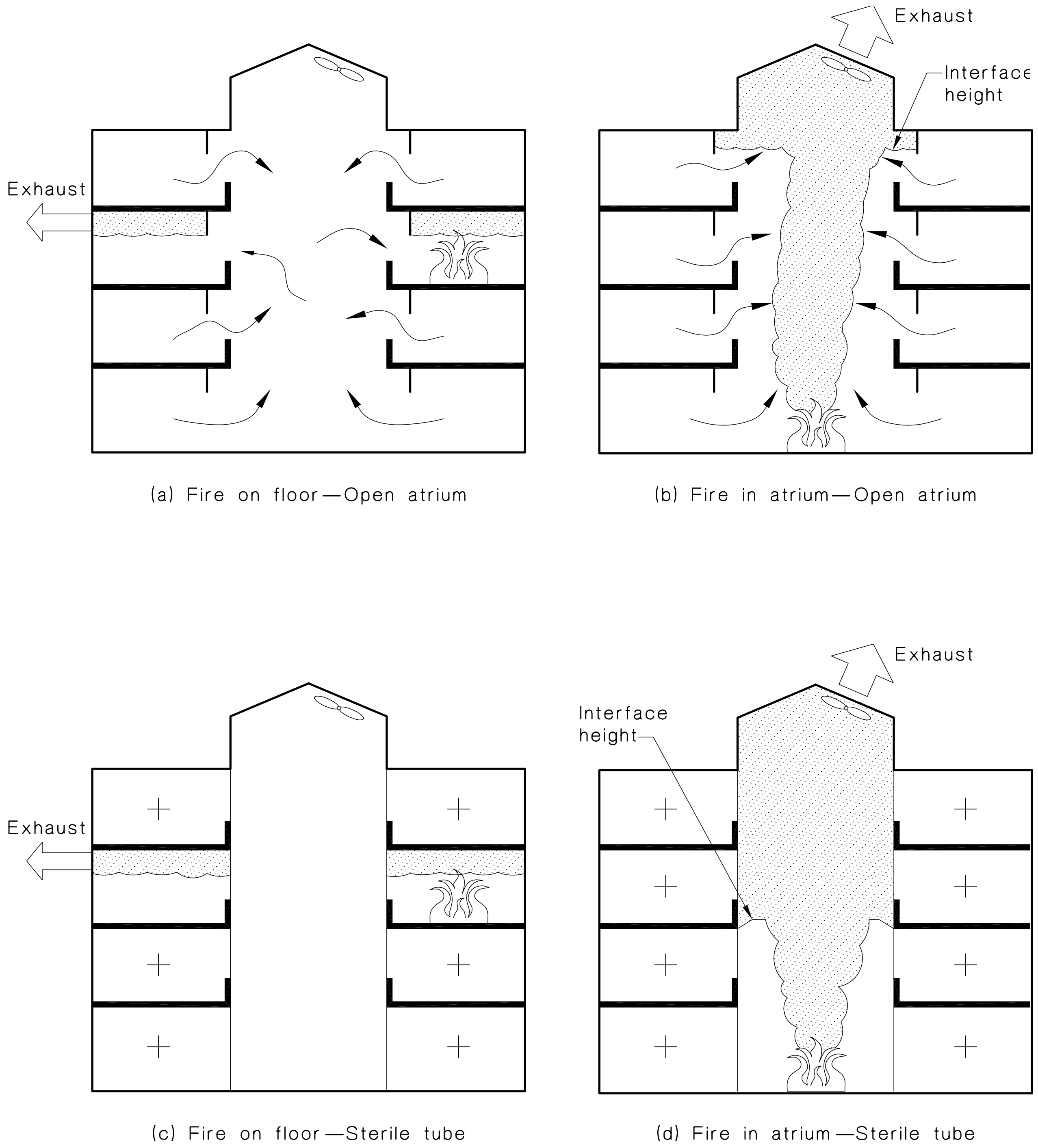
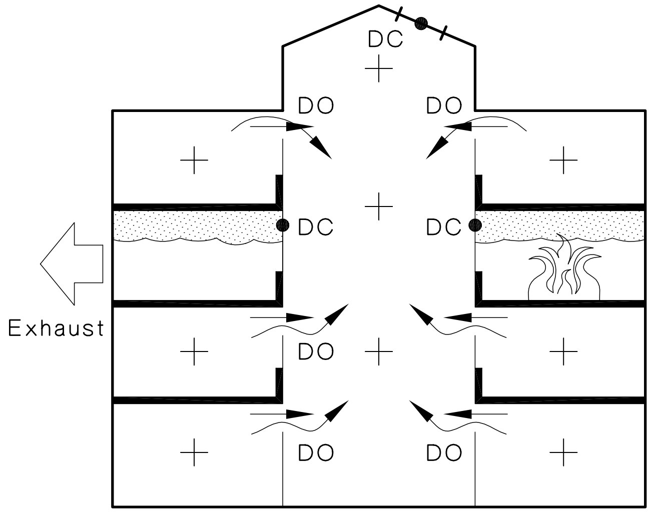
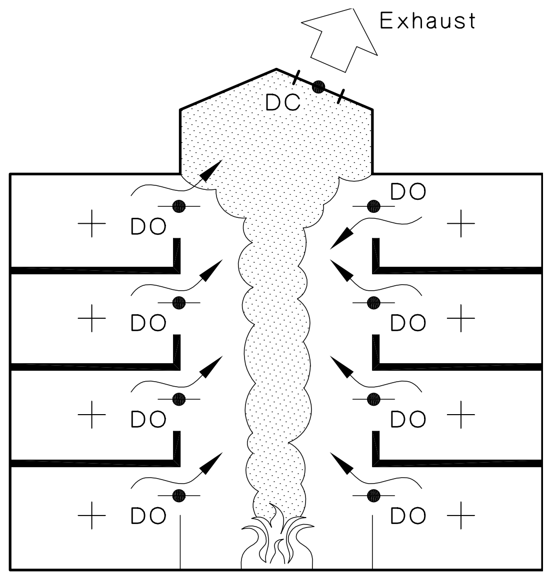


FIGURE F2 (in part) TYPICAL SMOKE CONTROL—ATRIA

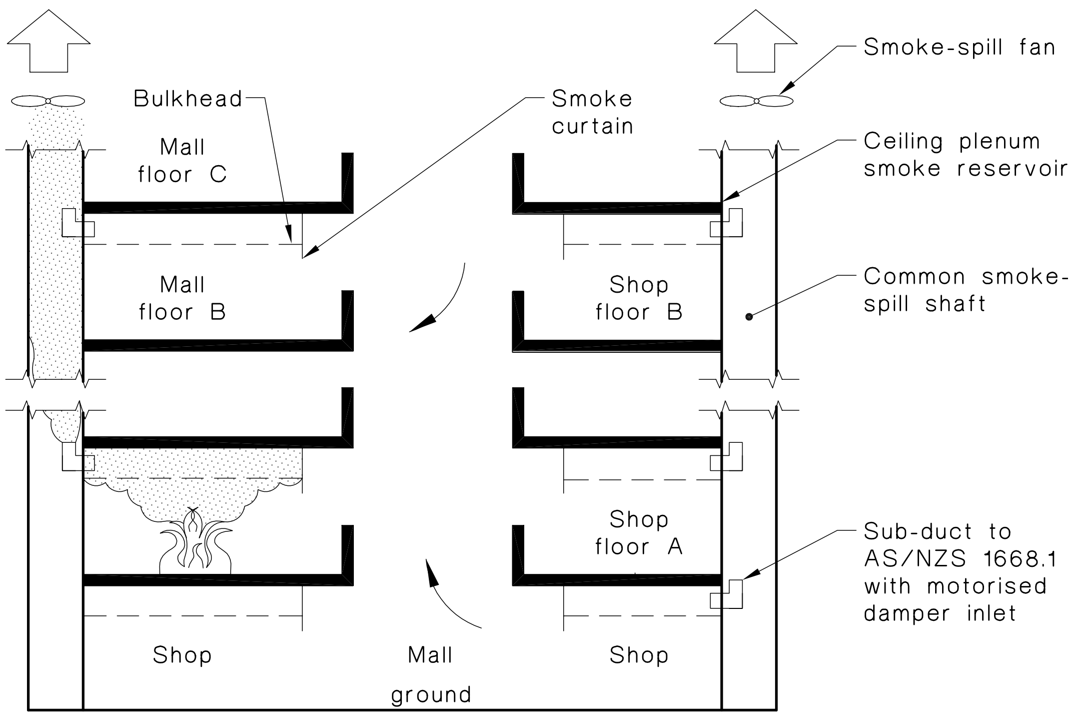


(e) Fire on floor—buoyancy driven purge assisted



(f) Fire in atrium—buoyancy driven purge assisted

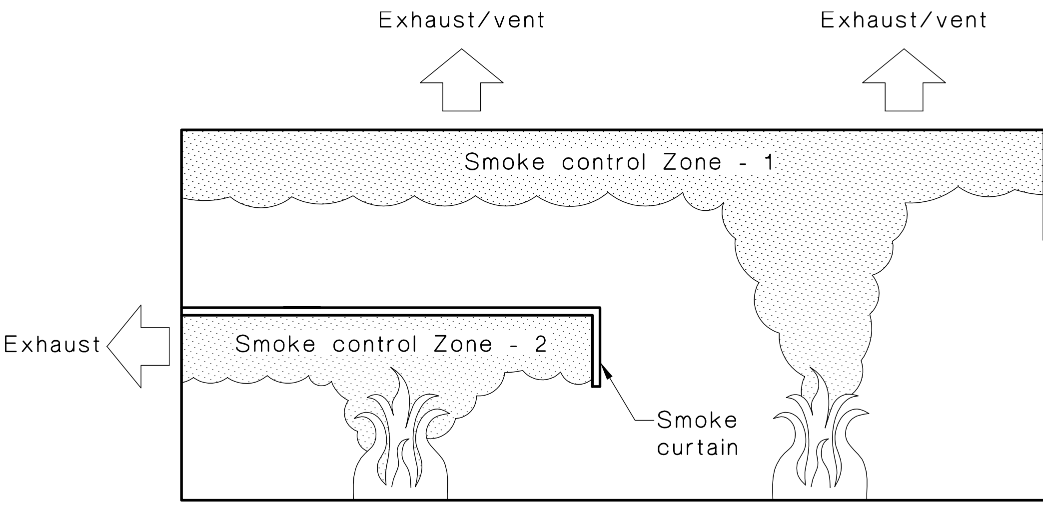
FIGURE F2 (in part) TYPICAL SMOKE CONTROL—ATRIA



Multistorey malls —Shop venting (plenum principle)

NOTE: For mall fires refer to ATRIA.

FIGURE F3 TYPICAL SMOKE CONTROL—MALLS



Large mezzanine floor—Separate system for below mezzanine.

FIGURE F4 TYPICAL SMOKE CONTROL—LARGE MEZZANINE FLOOR

APPENDIX G

EXAMPLE OF APPLIED DESIGN METHODOLOGY

(Informative)

G1 GENERAL

This Appendix sets out an example that demonstrates the intended application of the Standard, incorporating the development of key design input parameters, to compare different design options based on the same methodology.

A warehouse operator wishes to construct a new warehouse 50 m × 60 m × 6 m high in the outer suburbs of a major city. The warehouse will be used to store block-stacked cartons of combustible goods 3.6 m high. Because there will be a number of employees working in the warehouse, some form of comfort ventilation will be necessary.

The owner recognises that smoke ventilation will be necessary and favours a natural smoke and heat ventilation system for the dual uses of smoke management and comfort ventilation. The owner is also interested in asset protection and wishes the design team to investigate the installation of a sprinkler system as a form of asset protection, which will likely permit the economical installation of smoke exhaust fans, and which may also be used for comfort ventilation.

This building is located 2055 m from a fire station.

The purpose of this exercise is to establish the requirements for —

(a) a buoyancy-driven fire and smoke ventilation system, compared with that for;

(b) a sprinklered building employing mechanical exhaust;

so that a cost analysis of the two options can be undertaken.

G2 ATTRIBUTES COMMON TO BOTH SYSTEMS UNDER INVESTIGATION

Warehouse size = 50 m × 60 m = 3000 m^2.

Storage = 3.6 m block stacking.

Number of smoke reservoirs = 2 at 50 m × 30 m (see Clause 5.2).

Minimum smoke curtain depth = $^1/_5$ of building height (taken from springing line) = 1200 mm (see Clause 5.3.1 and Figure 5.1(a)).

Minimum smoke layer depth = $^1/_6$ of building height = 1000 mm (see Clause 5.3.1).

For the purpose of this exercise consider the 3 degree sloping roof as flat at 6.0 m from springing line.

Step 1 Selection of design fire curve

Determine the fire growth rate coefficient (α)

$$\alpha = 0.00002 \times q_f \times c_f \text{ (see Equation (B.2)4)}$$

where

q_f = 3.6 × 1000 = 3600 MJ/m^2 (see Table B1 'Storage of mixed combustibles')

c_f = 0.5 (see Table B2 'Storage Block Stacking')

α = 0.00002 × 3600 × 0.5 = 0.036

G3 CASE 1—BUOYANCY-DRIVEN OPTION

Step 2 Calculate t_m the maximum fire growth time event

This will be either—

(a) the time of fire brigade intervention if this is before 1020 seconds.

(b) the peak heat release rate at 1020 s if fire brigade intervention takes longer and flashover has not occurred.

An extended grid smoke detection system (see Clause 8.2(b)) is considered to be the most cost effective means of opening all vents in a smoke reservoir (see Clause 8.3.2). This will also call the fire brigade. The maximum fire size (t_m) will be established at their time of intervention.

Time of fire brigade intervention (t_m)

The smoke detection and alarm system calls the fire brigade during the 3 min incipient phase:

Time of smoke detection system alarm = −100 s (see Table C2).

Time of fire brigade notification = −100 s.

The dispatch time = 20 s, turnout time = 60 s and time to travel the 2055 m at 40 km/h = 184.95 s = 185 s (see Table C6, 'Outer suburb').

Time of arrival of fire brigade = −100 + 20 + 60 + 185 = + 165 s.

For the purposes of this example we assume that the fire hydrant layout complies with AS 2419. All parts of the building will be within reach of a 10 m stream of water issuing from a 60 m hose line connected to a boosted hydrant within 20 m distance of fire appliance access.

The two operations considered to occur simultaneously are the following:

(i) Firefighters gather, don and check safety equipment (e.g. breathing apparatus, fire hose and forced entry equipment), connect hose to the nearest attack hydrant and lay the hose (60 m) to the fire.

Gather, don and check safety equipment = 120 s (see Table C7) plus time to carry fire hose 20 m horizontally from fire appliance to fire hydrant = 20 s (see Table C7) plus time to lay 60 m hose from an above ground hydrant to the fire inside the building = 240 s (see Table C5).

= + 120 + 20 + 240+ 380 s

(ii) Other firefighters (possibly in another fire appliance) will connect hose from a hydrant to the fire appliance and from the fire appliance to a booster connection, so that operational fire pressures are available at the attack fire hydrant to which the attack fire hose is connected.

Gather, don and check safety equipment = 120 s (see Table C7) plus time to connect water source (mains pressure feed hydrant) to the fire appliance = 100 s (see Table C3) plus time to connect 30 m hose from the fire appliance to a booster inlet = 75 s (see Table C4).

= + 120 + 100 + 75 = + 295 s

Time at which water is applied, (t_m) = 165 + the greater of activity times for Items (i) and (ii), i.e.,

t_m = 165 + 380 = 545 s

NOTE: For an in depth analysis of the time of fire brigade intervention, refer to the Australasian Fire Authorities Council Fire Brigade Intervention Model (FBIM).

There is no need to use the fire size at the 1020 s mark (t_m) because fire brigade intervention has occurred prior to this time.

The time for flashover needs to be calculated to determine that flashover has not occurred.

This Standard will generally calculate smoke heat vents of a lower cross-sectional area than that required in the historic, deemed-to-satisfy provisions of building regulations. Therefore, flashover at a lower ventilation area should be checked. It is suggested that 1% of the floor area be used for roof vents and 2% for wall vents. The lower the ventilation area, the smaller the fire to cause flashover. This should be a conservative approach; however, if the final calculated area of the vents is less than this assumption, these calculations will need to be revisited.

Because some vents are in the roof and others are at low level, the mean vertical dimension of all openings will be used.

A_w = Roof openings + Wall openings

= 2 zones at (.01 × 1500) + (.02 × 1500)

= 60 m^2

A_t = Roof + Walls + Floor

= 3000 +(6 × 50 × 2) + (6 × 60 × 2) + 3000

= 3000 + 600 + 720 + 3000

= 7320 m^2

h_w = 3.0 m

$$\dot{Q} = (11.5 \times 7320) + ((550 \times 60) \times \sqrt{3.0}) \qquad \text{(Equation (B2)3)}$$

= 84,180 + (33,000 × 1.73)

= 84,180 + 57,090

= 141,270 kW

$$t_f = \sqrt{(\dot{Q}/\alpha)} \qquad \text{(Equation (B2)2)}$$

$$= \sqrt{141{,}270/0.036}$$

= 1981 s

Flashover time is later than the fire brigade intervention time of 545 s and will not occur for the design fire curve. Therefore we use the fire brigade intervention time to establish the maximum heat output of the fire.

t_m = 545 s

NOTE: It is important to revisit this calculation procedure if the design outcome achieves vent sizes substantially smaller than those used in this calculation. A further check on time of flashover will then be necessary to verify that the fire brigade intervention time used is still valid and flashover has not occurred before intervention can take place.

Step 3 Calculate heat output of fire at t_m

The heat output of the fire is calculated using Equation (B2)1:

$$\dot{Q}_c = \alpha(a_0 + a_1 t_m + a_2 t_m^2 + a_3 t_m^3 + a_4 t_m^4 + a_5 t_m^5 + a_6 t_m^6)/0.0117$$

$$= 0.036(0 + (16.08587 \times 545) + (-0.1007277 \times (545^2)) + (0.2791618 \times 10^{-3} \times (545^3)) + (-0.3026714 \times 10^{-6} \times (545^4)) + (0.1411789 \times 10^{-9} \times (545^5)) + (-0.2400561 \times 10\text{-}13 \times (545^6)) / .0117$$

Design fire size = $\dot{Q}_c$ = 10,753 kW (10.8 MW)

Step 4 Calculate the fire perimeter (P)

The fire perimeter is calculated using Equation (B4)1, where $\ddot{Q}_c$ is taken from Table B3 (Industrial/retail storage >2 ≤4 m).

$$P = 4\sqrt{(\dot{Q}_c / \ddot{Q}_c)}$$

$$= 4\sqrt{(10753/1000)}$$

$$= 13.1 \text{ m}$$

Step 5 Select depth of smoke layer based on building geometry

The smoke layer depth has been established at 1.0 m deep, i.e., the plume/layer interface height *y* will be 5.0 m above floor level.

NOTE: For buoyancy-driven systems this layer depth is minimal. 1.5 to 2.0 m is preferable because deeper layer depth means smaller vent openings. For consistency, this example will use the same layer depth as that for the mechanical exhaust system.

Step 6 Determine the smoke mass flow rate into the hot layer at the plume/layer interface height

The mass flow into the hot layer is calculated using Equation D2.

$$\dot{M} = 0.096\, \rho_a\, P \sqrt{y3}\ \sqrt{(gT_a / T_f)}$$

Ambient outside air conditions for Australian smoke control design is generally taken as 30°C (room ambient air is quickly replaced by outside air).

T_a = 30 + 273 = 303 K

ϱ = 353.8/303 = 1.168 kg/m^3 (from Equation D3)

P = 13.1 (from Step 4)

y = Building height – hot layer depth (Step 5) = 6 – 1 = 5 m

T_f = 1173 K

g = 9.81 m/s^2

$$\dot{M} = 0.096 \times 1.168 \times 13.1 \times \sqrt{5^3} \times \sqrt{(9.81 \times 303/1173)}$$

$$= 26.14 \text{ kg/s}$$

Step 7 Calculate the average hot layer temperature

For the purpose of this example, the centre-line plume temperature rise at the full ceiling height *y* is used in accordance with Paragraph D7.2.1.

This is calculated using Equation D5.

$$\Delta T = \dot{Q}_c / \dot{M} \times c_p = 10753/26.14 \times 1.005$$

$$= 413.4 \text{ K}$$

Layer temperature = $T_l = \Delta T + T_a$ = 413.9 + 303

T_L = 716.4 K

NOTE: An average layer temperature may be calculated using the centre line plume temperature at full ceiling height and plume/layer interface height. This will require a second calculation under Step 6. This calculation is required for the mechanical system and can be viewed under Step 6 of Section 2.

Step 8 Calculate the average density of the hot layer, kilograms per cubic metre

For the purposes of this example the centre line plume temperature rise at the full ceiling height y (as calculated in Step 7) is used to establish a conservative layer density ρ_x in accordance with Paragraph D7.2.1.

Using Equation D3:

$$\varrho_x = 353.8/(T_x + 273) = 353.8/716.4$$

$$= 0.49397\ \text{kg/m}^3 = 0.49\ \text{kg/m}^3$$

Step 9 Select the ratio of roof outlet vent area to inlet vent area

For the purpose of this exercise we will reduce the historic prescriptive requirement where A_{vi} is twice A_{vo} to a more economical value where A_{vi} is 1.25 times A_{vo} i.e., $\frac{1}{r} = A_{vo}/A_{vi} = 0.8$.

Step 10 Calculate the effective aerodynamic area of outlet vent required

The effective aerodynamic area of outlet vents is calculated using Equation (4.4)1

$$A_f = \frac{M\sqrt{T_1}\sqrt{\left[T_1 + \left(\frac{1}{r}\right)^2 T_a\right]}}{\varrho_1\sqrt{\left[2gd(T_1 - T_a)T_a\right]}}$$

$$= \left(26.14\times\sqrt{716.4}\times\sqrt{716.4 + \left([0.8]^2\times 303\right)}\right)/\left(0.49\times\sqrt{2\times 9.81\times 1\times(716.4-303)\times 303}\right)$$

$$= 27.48\ \text{m}^2$$

NOTE: This equates to a vent area of 1.8% of the smoke reservoir because the reservoir is 1500 m^2. If the reservoir were the maximum 2000 m^2 then the percentage effective aerodynamic area of the reservoir would be 1.4% which compares favourably to the historic 3% figure.

Step 11 Calculate the actual throat area of outlet vent required

The actual throat area of outlet vents required is calculated using Equation (4.4)2.

$$A_{vo} = A_f / Cd_{vo}$$

From manufacturer's data $Cd = 0.6$

$$A_{vo} = 27.48/0.6$$

$$= 45.8\ \text{m}^2$$

NOTE: The actual Cd used needs to supported by certified tests undertaken by the roof vent manufacturer

Step 12 Calculate the throat area of inlets required

The throat area of low level inlet vents required is calculated using Equation (4.4)3.

$$A_{vi} = r\times A_f / Cd_{vi}$$

Because the ratio of low level air inlet to roof vent area has been reduced to $r = 1.25$ we will select proprietary inlet vents that have a coefficient of discharge of 0.3.

$$A_{vi} = 1.25\times 27.48/0.6$$

$$= 114.5\ \text{m}^2$$

NOTE: Some weatherproof fixed grilles, which are also used as inlet openings, may have a *Cd* of less than 0.2; therefore, specific selection of grille type, based upon aerodynamic performance, has significant cost implications.

Step 13 Calculate the required spacing of the roof vents

The spacing between roof vents is determined in accordance with Clause 4.4.6.

$$d_{vo} \le (L \times W)/(5 \times A_{vo})$$

$$\le 50 \times 30/(5 \times 45.8)$$

$$\le 6.55 \text{ m}$$

If each roof vent has a gross throat area of 2.7 m^2, the following is required:

45.8/2.7 = 16.9 = 17 vents (for ease of layout use 18 vents)

Assuming the ridge runs across the short (30 m) dimension of the smoke reservoir, by placing one row of vents on the ridge and one row of vents on each side of the ridge (i.e., 3 rows of ventilators 6 in each row) the centre-line spacing will be 5.0 m.

NOTE: These calculations reinforce the comment in Step 5 that a layer depth of 1.0 m is inappropriate for buoyancy-driven smoke relief. If the layer is increased to 2.0 m (which for the design stack height can be achieved) then the required roof vent area will be significantly less than that calculated above. If the average layer temperature is calculated using plume centre line temperatures at the ceiling and at the layer interface, as a suggested alternative in Step 7, then further marginal reductions in vent area will be achieved.

G4 CASE 2—SPRINKLERED BUILDING OPTION

Step 1

The fire growth rate coefficient (α) = 0.036 as previously calculated.

Step 2 Calculate the maximum fire size to be used for the design

The maximum fire size will occur at the time of operation of the sprinklers. This will be before 1020 s and flashover will not occur.

Sprinkler heads having an RTI of 250 at 68°C have been selected. At their time of operation (t_m), the maximum fire size will be established.

This is a normal response sprinkler head, the fast response option can be pursued later to establish the cost impact of reducing fire size against the extra cost of fast response sprinkler heads, should the client wish to further refine this option.

Time of sprinkler operation (t_m).

For a ceiling height of 6.0 m and an α = 0.036 the Standard 68°C sprinkler head operation time = 293 s (see Table C1.1).

t_m = + 293 s

Step 3 Calculate heat output of fire at t_m

The heat output of the fire is calculated using Equation (B2)1:

$$\dot{Q}_c = \alpha(a0 + a1t_m + a2t_m^2 + a3t_m^3 + a4t_m^4 + a5t_m^5 + a6t_m^6)/0.0117$$

$$= 0.036(0 + (16.08587 \times 293) + (-0.1007277 \times (293^2)) + (0.2791618 \times 10^{-3} \times (293^3)) + (-0.3026714 \times 10^{-6} \times (293^4)) + (0.1411789 \times 10^{-9} \times (293^5)) + (-0.2400561 \times 10^{-13} \times (293^6)) /0.0117$$

Design fire size = $\dot{Q}_c$ = 2332.3 kW (2.3 MW)

Step 4 Calculate the fire perimeter (P)

The fire perimeter is calculated using Equation B.5 where $\ddot{Q}_c$ is taken from Table B3 (Industrial/retail storage > 2 ≤ 4 m)

$$P = 4\sqrt{\left(\dot{Q}_c / \ddot{Q}_c\right)}$$

$$= 4\sqrt{\left(2332.3/1000\right)}$$

$$= 6.1 \text{ m}$$

Step 5 Select depth of smoke layer based on building geometry

The smoke layer depth has been established at 1.0 m deep, i.e., the plume/layer interface height y will be 5.0 m above floor level.

Step 6 Determine the smoke mass flow rate into the hot layer at the plume/layer interface height

The mass flow into the hot layer is calculated using Equation D2.

$$\dot{M} = 0.096\,\rho_a\, P\sqrt{y^3}\sqrt{\left(g\,T_a / T_f\right)}$$

Ambient outside air conditions for Australian smoke control system design is generally taken as 30°C (room ambient air is quickly replaced by outside air)

T_a = 30 + 273 = 303 K

ϱ = 353.8/303 = 1.168 kg/m^3 (from Equation D3)

P = 6.1 (from Step 4)

y = Building height – hot layer depth (Step 5) = 6 – 1 = 5 m

T_f = 1173 K

g = 9.81 m/s^2

$\dot{M}$ = $0.096 \times 1.168 \times 6.1 \times \sqrt{5^3} \times \sqrt{(9.81 \times 303/1173)}$

= 12.17 kg/s

Step 7 Calculate the centre line plume temperature at the plume/hot layer interface height

For the purpose of this example, the centre-line plume temperature rise at the plume/hot layer interface height y is used in accordance with Paragraph D8.2.2.

This is calculated using Equation D4.

$$\Delta T = \dot{Q}_c / \left(\dot{M} \times c_p\right) = 2332.3 / \left(12.17 \times 1.005\right)$$

= 193 K

Step 8 Calculate the volumetric exhaust flow rate, correcting for expansion due to temperature increase (Step 7)

The exhaust flow rate required to maintain a steady state layer depth (flow into layer = exhaust flow out of layer) for the calculated hot layer parameter is now calculated using Equation D5

$$\dot{V} = \left(\dot{M} \times \left(T_a + 273 + \Delta T\right)\right) / \left(T_a + 273\right) \times \varrho_a$$

$$\varrho_a = \frac{353.8}{30 + 273} = 1.168$$

$$\dot{V} = \frac{12.17 \times (30 + 273 + 193)}{(30 + 273) \times 1.168}$$

$$\dot{V} = 17.1 \text{ m}^3/\text{s}$$

NOTE: The temperature at the plume/smoke layer interface must be used in this calculation, not an average layer temperature. Possibly due to turbulent mixing and diffusion, it has not been demonstrated that the volume of smoke reduces due to cooling by mixing in the layer.

Therefore, each smoke reservoir requires a fan capable of extracting 17.1 m^3/s of smoke. If the building were not sprinklered, then the conservative design temperature for the fan would be $\Delta T + T_a$ = 223°C for 30 min. Because the building is sprinklered, and the water spray will cool the smoke, a lower temperature fan will likely suffice (say 100 to 150°C). Bearing in mind the calculated temperature is not excessive, the conservative approach is to select fans for the calculated temperature as required by this Standard.

NOTE: For a less conservative approach, an average layer temperature calculated in accordance with Step 9, may be used for fan temperature specification.

APPENDIX H

GENERAL DESIGN INFORMATION

(Informative)

H1 SOUND LEVELS

Representative ambient sound levels of buildings in use are given in Table H1.

TABLE H1

REPRESENTATIVE AMBIENT SOUND LEVELS OF BUILDINGS IN USE

Area		Maximum sound level, dB(A)
Airport terminals:	check-in	75
	concourse	75
	customs	65
Atrium:	'dry'	65
Banking hall:	water feature	75
	small	75
	large	75
Bus station		80
Cafeteria		80
Cinema		N/A
Concert hall		N/A
Courtroom	light assembly	65
Exhibition hall	control rooms	80
Factory:	heavy engineering	85
		65
		N/A
Kitchen (commercial)		80
Library		65
Multipurpose hall		80
Museum, gallery		65
Railway station		85
Restaurant		75
Shop		70
Shopping mall		75
Sports hall		80
Swimming pool		90
Theatre		N/A
Warehouse		60

N/A = Not available

NOTES:

1 All levels quoted are typical values only and reference should be made to an acoustic specialist for actual ambient levels.

2 EWIS systems are required to operate at 10 dB(A) above expected ambient levels, see AS 2220.2.

H2 SMOKE CURTAIN MATERIALS

Information on smoke curtain materials is given in Table H2.

TABLE H2

TYPICAL MATERIAL MAXIMUM SERVICE TEMPERATURES

Material	Melting temp, °C
Steel	550
Masonry (brick or concrete)	1100
Aluminium	400
Glass—wired	750
Glass—toughened	250
Plasterboard—fire protective grade	900
Fabric—glass	650
Fabric—ceramic	1000

NOTE: Values given in Table H2 are indicative only and actual maximum smoke-resistant service temperatures should be sourced from the material manufacturer/supplier.

H3 OUTDOOR DESIGN CONDITIONS

Outdoor design conditions for many locations are provided in AIRAH Application Manual DA19*.

* Published by the Australian Institute of Refrigeration, Air Conditioning and Heating.

APPENDIX I
BUILDING GEOMETRY
(Informative)

I1 GENERAL

The geometry of the building can affect the efficient movement of smoke to a designated extraction location. Such geometry including beams, smoke curtains and ceiling gradients, can be effectively employed to collect or transport smoke to designed locations for improved system performance.

NOTE: Smoke flow is analogous to inverted water flow; in a single compartment the inverted bucket principle applies, i.e., water fills the bucket from bottom to top, smoke fills the inverted bucket from top to bottom.

Following this analogy further, the up gradient in a ceiling is akin to rapids in a river system and the smoke curtain is equivalent to a dam which when it overflows creates a waterfall. The only difference with smoke is that unlike waterfalls, smoke rising from the fire source or spilling from a curtain, or other 'edge', increases in volume due to turbulent mixing and hence decreases in temperature.

I2 FLOW-CONTAINING CONSTRUCTION

A construction that is intended to contain smoke should be impervious to the products of combustion at the temperature likely to be encountered. A construction that could be utilized to contain smoke includes the bounding elements of a volume, e.g. walls, beams, curtains, ceiling coffers, ducting and other obstructions.

Where reservoirs or curtains are designed to contain a layer of hot smoky gases they should be constructed in accordance with Section 5.

I3 FLOW ENHANCING CONSTRUCTION

Construction which enhances smoke flow, i.e., encourages smoke to move, includes ceiling gradients such as a sloping roof ceiling gradients and ceiling coffers.

Reservoirs, within which a deep layer of smoke can accumulate so that the buoyant effect of this layer will increase the flow through a roof vent or opening at the top of the layer, are also considered to be a flow-enhancing feature.

I4 GEOMETRY LIMITATIONS

Cooling smoke loses buoyancy. Travelling smoke will cool and may cause smoke control problems due to the lack of buoyancy. The distance smoke will travel before cooling is dependent upon the building construction characteristics, the area, configuration and depth of the smoke reservoir, the height of the plume and the heat output of the fire. Areas of smoke reservoirs should not exceed the requirements of Section 5.

APPENDIX J

WIRING SYSTEMS RATING

(Normative)

J1 PROTECTION AGAINST EXPOSURE TO FIRE

All wiring systems required to have a protection against exposure to fire shall have a rating of not less than the (design fire) calculated time and temperature to which the wiring will be exposed. Wiring systems shall be protected against mechanical and water damage, as appropriate to the installation, in accordance with Paragraphs J2 and J3.

J2 PROTECTION AGAINST MECHANICAL DAMAGE

J2.1 General

Protection against mechanical damage shall be provided as listed below. The areas indicated should not be considered as a rigid list to be adhered to with no deviations, rather they should be considered as a guide to the types of areas and causes of damage to be encountered. Details of ways to achieve the grade to protection can be found in AS/NZS 3013.

J2.2 WSX

Areas where physical damage is considered to be unlikely. Examples of these areas include—

(a) masonry riser shafts with strictly limited access;

(b) non-trafficable ceiling void areas;

(c) inaccessible underfloor areas;

(d) underground installation in accordance with AS/NZS 3000; and

(e) internal domestic and office situations where cabling is mounted on walls at heights above 1.5 m.

J2.3 WS1

Areas where physical damage by light impact is considered possible. Examples of these areas include—

(a) internal domestic or office situations where cable is mounted on walls at heights below 1.5 m; and

(b) trafficable ceiling void areas where access to building services for maintenance purposes is required.

J2.4 WS2

Areas where physical damage by impact from manually propelled vehicle is possible. Examples of these areas are—

(a) passageways and storerooms in domestic, office, health care and commercial locations where hand trucks and barrows may be used, and cables are mounted at a height of less than 1.5 m;

(b) plant rooms where only minor equipment is installed; and

(c) workshops where repair and maintenance, on small equipment and furniture or the like, is carried out, and cables are mounted at a height of less than 2.0 m.

J2.5 WS3

Areas where physical damage by impact from light vehicles is possible. Examples of these areas include—

(a) car parks and driveways where cars and other light vehicles are present and cables are mounted at a height of less than 2.0 m;

(b) storage areas where manually operated devices such as pallet trucks may be operated and cables are mounted at a height of less than 2.5 m.

J2.6 WS4

Areas where physical impact from vehicles with rigid frames or rigid objects, the weight of which does not exceed 2.0 t, is possible. Examples of these areas include—

(a) small delivery docks where the cabling is mounted below a height of 3.0 m;

(b) warehouses with pallet storage up to 3.0 m and use of forklift trucks; and

(c) heavy vehicle workshops.

J2.7 WS5

Areas were physical damage from impact by laden vehicles or objects the laden weight of which exceed 2.0 t. Examples of these areas include—

(a) loading and delivery docks;

(b) fabrication and maintenance areas for medium to heavy engineering; and

(c) large high pile storage warehouses with forklift trucks.

J2.8 Various protection

Where any WS cabling traverses areas of various protection requirements, and it is neither viable nor practicable to change the degree of protection at the transition points, the installed cabling shall comply with the highest requirement of protection.

J3 PROTECTION AGAINST HOSING WITH WATER

Where the wiring system is required to maintain its integrity after exposure to fire and subsequent hosing with water, it shall have the suffix W appended to its rating. For the purposes of this Standard this wiring requirement applies only to unsprinklered buildings.

NOTE: Where manual intervention (as opposed to automatic suppression) forms the basis of the design fire it is likely that wiring systems may be subjected to the pressure of hose water. Any wiring required to operate in the fire mode in an unsprinklered building needs to be protected against hosing with water.

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Standards Australia

GPO Box 5420 Sydney NSW 2001

Administration Phone (02) 8206 6000 Fax (02) 8206 6001 Email mail@standards.com.au

Customer Service Phone 1300 65 46 46 Fax 1300 65 49 49 Email sales@standards.com.au

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