

Australian Standard™

**The use of ventilation and
airconditioning in buildings**

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



This Australian Standard was prepared by Committee ME-062, Ventilation and Airconditioning. It was approved on behalf of the Council of Standards Australia on 22 December 2000 and published on 17 December 2001.

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
Chartered Institution of Building Services Engineers
Department of Contract and Management Services, W.A.
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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 m².
- (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°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)

Documents



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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/m²).

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 $\frac{1}{5}$ 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 PARAMETERS

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:

$$A_f = \frac{MT_1^{1/2} \left[T_1 + \left(\frac{1}{r} \right)^2 T_a \right]^{1/2}}{\rho_1 [2gd(T_1 - T_a)T_a]^{1/2}} \quad \dots (4.4)1$$

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:

$$A_{vo} = \frac{A_f}{Cd_{vo}} \quad \dots (4.4)2$$

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:

$$A_{vi} = \frac{r \times A_f}{Cd_{vi}} \quad \dots (4.4)3$$

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).

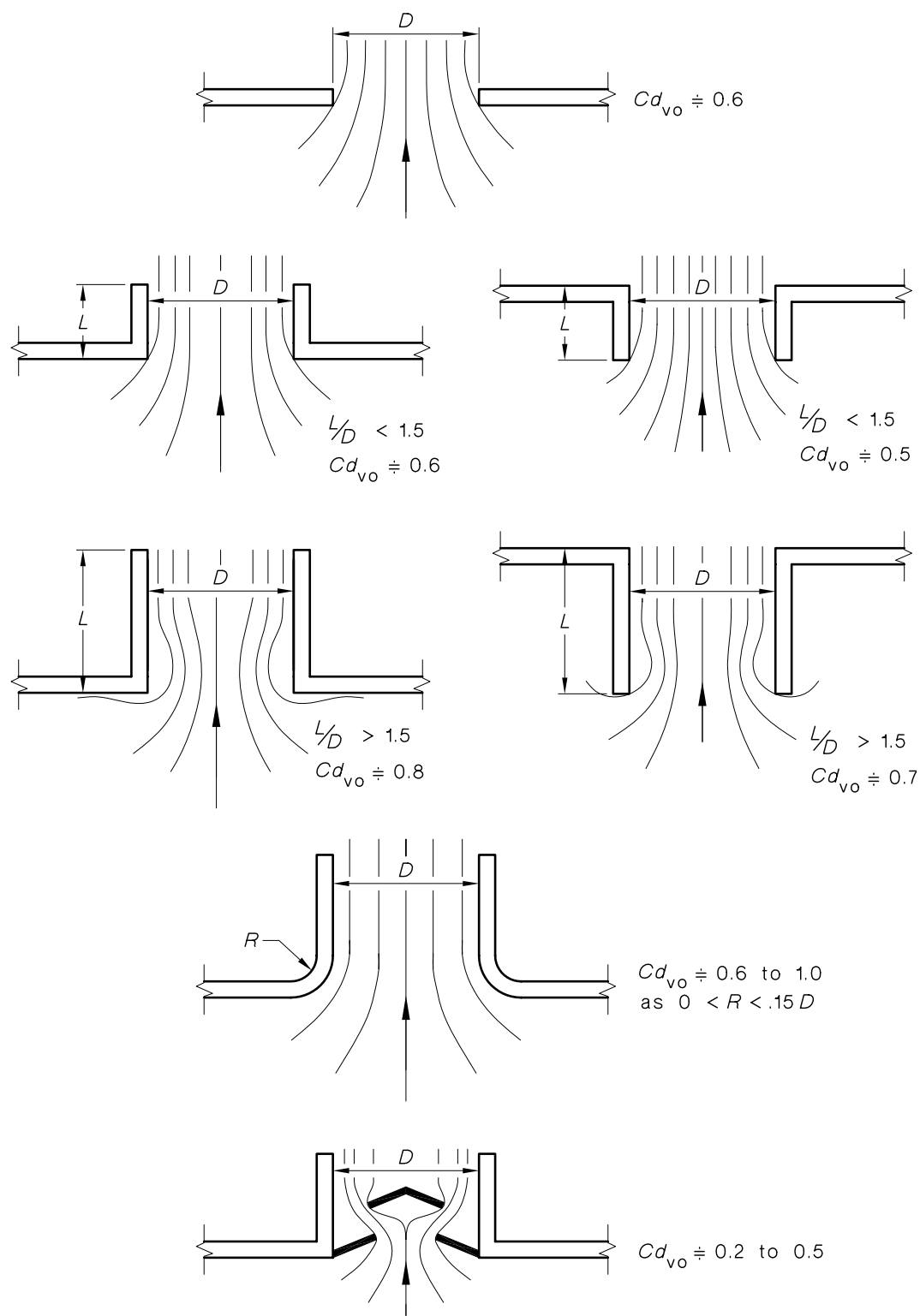
4.4.9.3 Water from sprinklers

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 m². 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 (<i>d</i>)	Ceiling height (<i>h</i>)
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:

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

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,

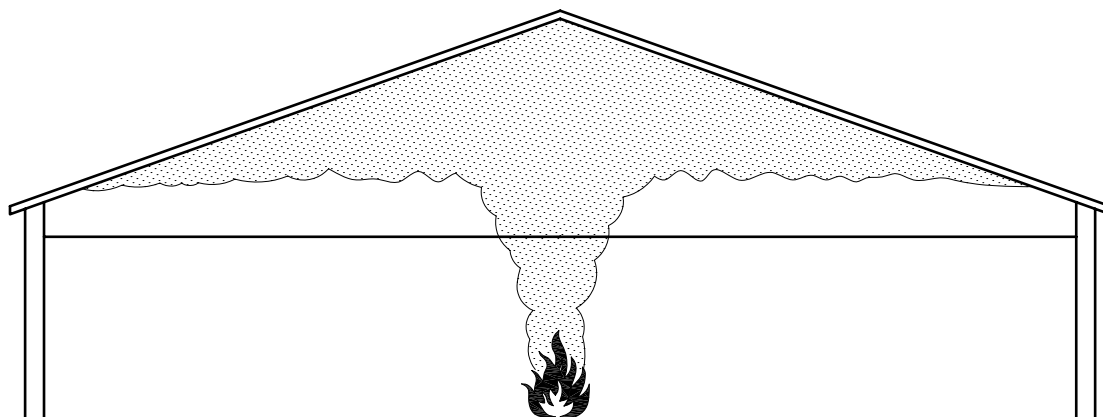
the effective perimeter shall be based upon the perimeter of the enclosing boundary in accordance with Table 5.1. The effective dimension of the opening shall be increased by one-quarter of the hot layer depth (d) in each dimensions before constructing the bounding line. In any case, the length of the 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

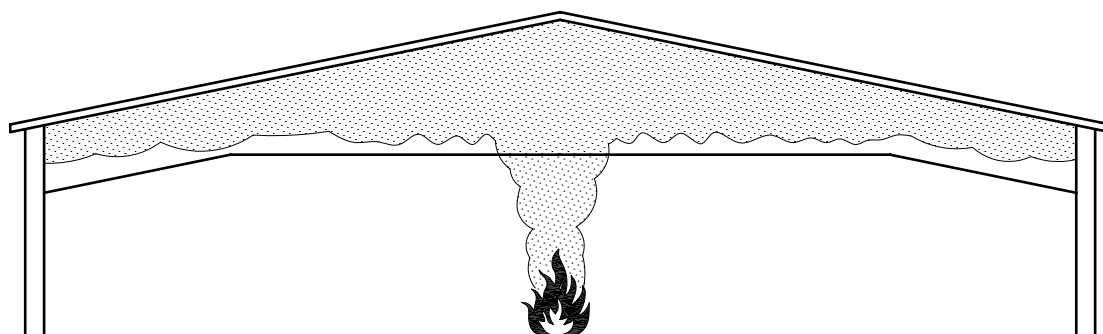
Opening type	Condition	Effective perimeter (L)
Circular opening diameter (D)	More than one quarter the design hot layer depth from a wall and more than half the design hot layer depth from other exhaust openings.	$L = \pi \left(D + \frac{d}{2} \right)$ Refer Figure 5.2, (a), (b) and (d).
Circular opening 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.	$L = 2(a + b + d)$ 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.

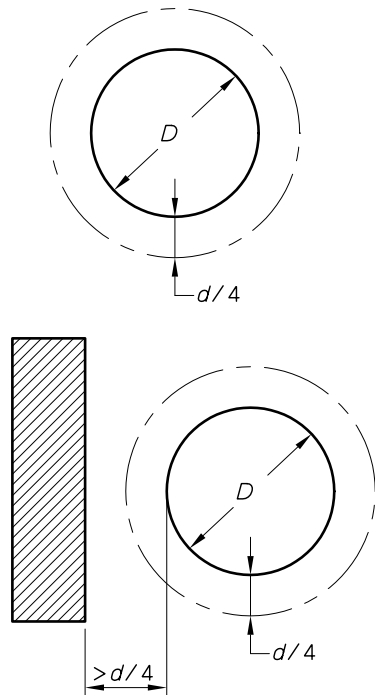


(a) Smoke reservoirs in pitched roof—preferred

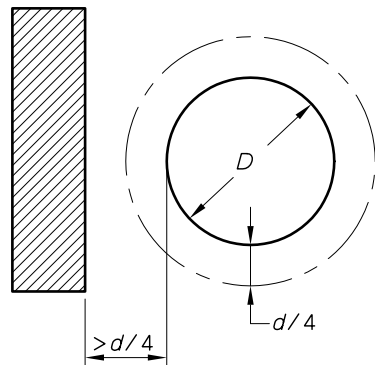


(b) Smoke reservoirs in pitched roof—possible alternative

FIGURE 5.1 SMOKE RESERVOIR BOTTOM EDGES

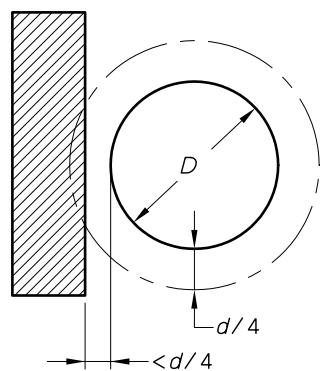


(a) Effective perimeter = $\pi(D + d/2)$

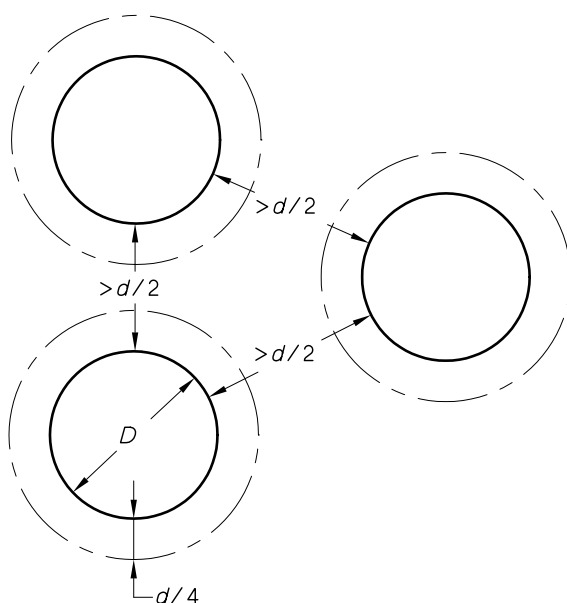


(b) A circular exhaust opening greater than one quarter the design smoke layer depth from a wall.
Therefore the effective perimeter is the full effective perimeter of the circular opening.

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



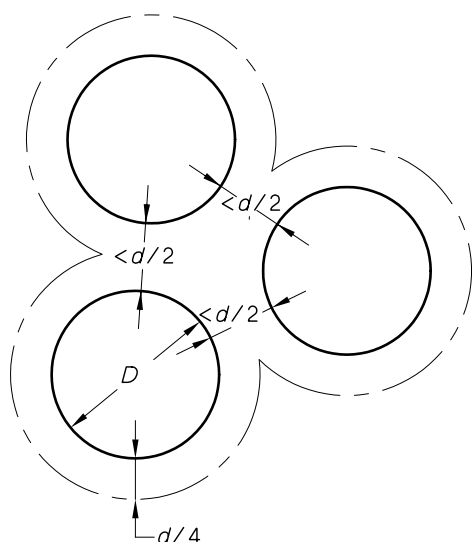
(c) A circular exhaust opening less than one quarter the design smoke layer depth from a wall will achieve a reduced effective perimeter.
No effective exhaust at point of overlap.



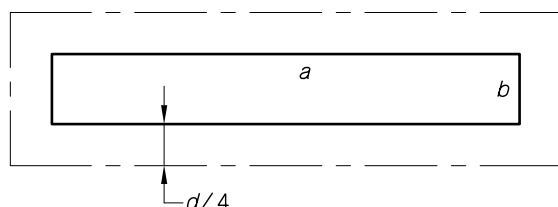
(d) Circular exhaust openings greater than half the design smoke layer depth apart. Therefore the effective perimeter is the full effective perimeter of the three circular openings.

Effective perimeter = $3\pi(D + d/2)$

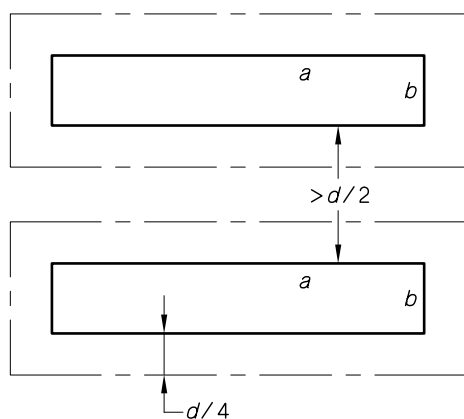
FIGURE 5.2 (in part) EFFECTIVE PERIMETER OF OPENINGS



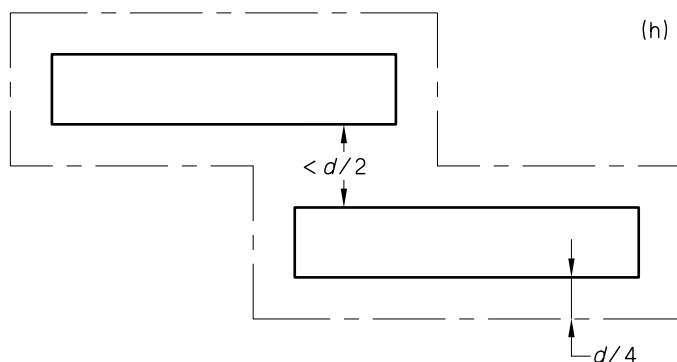
- (e) Circular exhaust openings less than half the design smoke layer depth apart achieve a reduced effective perimeter (no effective exhaust at points of overlap).



- (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