BRITISH STANDARD

BS 5588-4:1998

Incorporating Amendments Nos. 1 and 2, and Corrigendum No. 1

Fire precautions in the design, construction and use of buildings —

Part 4: Code of practice for smoke control using pressure differentials

ICS 13.220.20; 91.040.01

British Standards

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee FSH/14, Fire precautions in buildings, upon which the following bodies were represented:

British Gas plc
British Retail Consortium
British Standards Society
British Telecommunications plc
Chartered Institution of Building Services Engineers
Chief and Assistant Chief Fire Officers' Association
Consumer Policy Committee of BSI
Department for Education
Department of Health
Department of the Environment (Building Research Establishment)
Department of the Environment (Property and Buildings Directorate)
Department of the Environment for Northern Ireland
District Surveyors' Association
Electricity Association
Fire Brigades Union
Health and Safety Executive
Home Office
Institute of Building Control
Institution of Gas Engineers
Institution of Structural Engineers
London Fire and Civil Defence Authority
Loss Prevention Council
National Association of Fire Officers
National Council of Building Material Producers
Royal Institute of British Architects
Scottish Office (Building Directorate)
Timber Research and Development Association

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Access Committee for England
Association of Building Engineers
Association of Consulting Engineers
British Automatic Sprinkler Association
British Council of Shopping Centres
British Fire Protection Systems Association Ltd.
British Fire Services' Association
British Property Federation
Building Services Research and Information Association
Flat Glass Manufacturers' Association
Hevac Association
Institute of Fire Safety
Institution of Fire Engineers
Intumescent Fire Seals Association
Nationwide Fire Services
Steel Window Association
Warrington Fire Research Centre

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10019 Corrigendum. No. 1	April 1998	Unit corrected
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Contents

Foreword

This code of practice was prepared under the direction of Technical Committee FSH/14. It supersedes BS 5588-4:1978, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags A1⟩ ⟨A1. Tags indicating changes to text carry the number of the amendment. For example, text altered by Amendment No. 1 is indicated by A1⟩ ⟨A1.

The other parts which comprise BS 5588 are as follows:

— *Part 0: Guide to fire safety codes of practice for particular premises/applications;*

— *Part 1: Code of practice for residential buildings;*

— *Part 5: Code of practice for firefighting stairs and lifts;*

— *Part 6: Code of practice for places of assembly;*

— *Part 7: Code of practice for the incorporation of atria in buildings;*

— *Part 8: Code of practice for means of escape for disabled people;*

— *Part 9: Code of practice for ventilation and air conditioning ductwork;*

— *Part 10: Code of practice for shopping complexes;*

— *Part 11: Code of practice for shops, offices, industrial, storage and other similar buildings;*

— *Part 12: Managing fire safety.*

It has been assumed in the drafting of this code that the execution of its provisions will be entrusted to appropriately qualified and experienced people.

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 73 and a back cover.

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Introduction

The pressure differential systems referred to in this standard are primarily intended for life safety and firefighting purposes with the objective of maintaining tenable conditions in protected escape routes, refuges, firefighting shafts, lobbies, etc. The general principles presented in this standard may also be applied in situations where the primary aim is to prevent contamination by smoke, of goods or equipment in rooms adjacent to a fire-affected space.

Guidance is given on the design of systems intended either to maintain a positive pressure within protected spaces (pressurization) or to remove hot gases from the fire zone so as to maintain it at a lower pressure than the adjacent protected space (depressurization).

Pressure differential systems provide one means of improving the level of fire safety within a building. A decision as to whether such a system is appropriate to a particular project should be taken in context with the overall design strategy for means of escape, firefighting and property protection within the building.

This standard presents the general principles to be adopted in the design of various types of pressure differential system. However, circumstances vary from building to building and it is not possible to cover every situation here, although it may be possible to design an effective system for other applications using the principles of this standard.

1 Scope

This part of BS 5588 gives guidance on the design, installation, testing and maintenance in new and existing buildings of systems intended to limit the spread of smoke by means of pressure differentials.

However, this standard does not cover smoke ventilation systems used in theatres and other places of assembly which protect the auditorium from a fire in the stage area by creating a pressure differential between the stage and the auditorium.

2 References

2.1 Normative references

This part of BS 5588 incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on page 72. For dated references, only the edition cited applies; any subsequent amendments to, or revisions of the cited publication apply to this part of BS 5588 only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

2.2 Informative references

This part of BS 5588 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on page 73, but reference should be made to the latest editions.

3 Definitions

For the purposes of this British Standard the following definitions apply.

3.1
accommodation area
area of a building where the main work function of the building is carried out

3.2
air release
means by which pressurizing air is able to escape from the accommodation area or other unpressurized space to external air

3.3
atrium
space within a building, not necessarily vertically aligned, passing through one or more structural floors

NOTE Enclosed lift wells, escalator wells, building services ducts and stairways are not classified as atria.

3.4
basement
storey with a floor that is at some point more than 1.2 m below the highest level of ground adjacent to the outside walls

3.5
controlled fire load
fire load that is limited by means of management controls on the quantities of combustible material that are present on the atrium base or where the fire load is limited by an effective automatic suppression system

3.6
dedicated system
pressure differential system that does not share components with any other system

3.7
depressurization
smoke control using pressure differentials where the air pressure in adjacent spaces is reduced to below that in the protected space

3.8
depressurized space
part of a building from which air and smoke are extracted for the purposes of depressurization

3.9
depth (of a building)
distance to the surface of the lowest point of the floor of the lowest storey, measured at the centre of that face of the building where the measurement is greatest from the level of the footway or paving in front of that face, or if there is no such footway or paving, from the level of the ground

3.10
escape route
route forming part of the means of escape from any point in the building to a final exit

3.11
evacuation lift
lift that may be used for the evacuation of disabled people in an emergency

3.12
final exit
termination of an escape route from a building giving direct access to a street, passageway, walkway or other open space sited to ensure the rapid dispersal of persons from the vicinity of a building so that they are no longer in danger from fire and/or smoke

3.13
fire compartment
building or part of a building, comprising one or more rooms, spaces or storeys, constructed to prevent the spread of fire to or from another part of the same building, or to an adjoining building

3.14
fire detection zone
sub-division of the building such that the detection of a fire within it will be indicated by the fire alarm system separately from an indication of fire in any other sub-division

3.15
fire resistance
ability of a component or construction of a building to satisfy for a period of time some or all of the appropriate criteria specified in the relevant part of BS 476

3.16
fire zone
room or compartment in which the fire is assumed to occur for the purposes of design of pressure differential systems

3.17
firefighting lift
lift designated to have additional protection for firefighting use, directly controllable by the fire service when fighting a fire

3.18
firefighting lobby
protected lobby providing access from a firefighting stair to the accommodation area and to any associated firefighting lift

3.19
firefighting shaft
protected enclosure containing a firefighting stair, firefighting lobbies and, if provided, a firefighting lift together with its machine room

3.20
firefighting stair
protected stairway communicating with the accommodation area only through a firefighting lobby

3.21
height
for buildings, the distance to the surface from the highest point of the floor of the highest storey (excluding any such storey consisting exclusively of plant rooms), measured at the centre of that face of the building where the measurement is greatest to the level of the footway or paving in front of that face, or if there is no such footway or paving, to the level of the ground

3.22
HVAC
heating, ventilation and/or air conditioning

3.23
inherent leakage paths
gaps or cracks in the construction or around doors and windows etc. which provide a path for air to flow between the pressurized/depressurized space and the external air

3.24
lift well
space in which the lift and the counterweight (if any) move. This space is materially enclosed by the bottom of the pit, the vertical walls and the ceiling

3.25
means of escape
structural means whereby a safe route is provided for persons to travel from any point in a building to a place of safety

3.26
neutral pressure plane
point in a building where the internal air pressure due to wind and stack effects is equal to the external ambient pressure

3.27
non-dedicated system
pressure differential system that shares components with another system, such as an HVAC system

3.28
over-pressure relief
provision for releasing excess pressurizing air from the pressurized space

3.29
phased evacuation
system of evacuation in which different parts of premises are evacuated in a controlled sequence. Those parts of the building expected to be at greatest risk are evacuated first

3.30
place of safety
place in which persons are in no danger from the consequences of a fire within the building

3.31
pressurization
smoke control using pressure differentials, where the air pressure in the spaces being protected is raised above that in the fire zone

3.32
pressure containment lobby
lobby provided at fire access level to reduce the loss of pressure from a stair due to a final exit door being constantly open

3.33
pressure differential system
system of fans, ducts and vents provided for the purpose of creating a pressure differential between the fire zone and the protected space

3.34
pressurized space
shaft, lobby, corridor or other compartment in which the air pressure is maintained at a higher value than that of the fire zone

3.35
protected corridor
circulation area consisting of a corridor enclosed with fire-resisting construction (other than any part that is an external wall of a building)

3.36
protected escape route
escape route having an adequate degree of fire protection

3.37
protected lobby
circulation area consisting of a lobby enclosed with fire-resisting construction (other than any part that is an external wall of a building)

3.38
protected space
fire-resisting shaft or compartment within a building which is protected against the ingress of smoke by a pressure differential system

3.39
protected stairway
stair discharging through a final exit to a place of safety (including any exit passageway between the foot of the stair and the final exit) that is adequately enclosed with fire-resisting construction

3.40
refuge
area that is both separated from a fire by fire-resisting construction and provided with a safe route to a storey exit, thus constituting a temporarily safe space for disabled persons to await assistance for their evacuation

3.41
simple lobby
lobby that does not give direct access to lifts, shafts or ducts that could constitute a significant leakage path for smoke to spread to other storeys within the building. A simple lobby may be either unventilated or naturally ventilated

NOTE A lobby connected to a lift well or other shaft is still a simple lobby if all such shafts are pressurized.

3.42
single-pressure system
pressure differential system in which the air supply to a pressurized space or extraction from a depressurized space is designed to operate only in an emergency

3.43
single-stage system
pressure differential system designed to work only in an emergency

3.44
smoke control
technique for influencing the production, movement or removal of smoke from a building in order to protect the means of escape, contents or structure, and/or to assist firefighting operations

3.45
smoke control zone
sub-division of a building for smoke control purposes

3.46
smoke damper
mechanical device that when closed prevents smoke passing through an aperture within a duct or structure. The device may be open or closed in its normal position and may be automatically or manually actuated

3.47
smoke shaft
enclosed space in a building provided for venting smoke from a firefighting stair or one or more firefighting lobbies or other protected areas

3.48
stack effect
pressure differential resulting from the differences in density of two interconnected columns of air at different temperatures, one inside the building at the internal ambient temperature, and the other outside the building at the external ambient temperature

3.49
storey exit
final exit (see **3.12**), or a doorway giving direct access to a protected stairway, protected lobby or external escape route

3.50
two-pressure system
pressure differential system in which a continuous low level of operation is provided as part of the normal ventilation system, with provision for increasing the pressure differential in an emergency

3.51
two-stage system
pressure differential system designed to provide a low level of ventilation normally and is brought into full operation in an emergency

3.52
vent
window, roof-light, door, louvre, grille or other ventilating device either open or capable of being opened to permit the passage of air between a part of the building and the external air

3.53
zoned smoke control
system that combines depressurization of the fire zone and pressurization for all contiguous spaces requiring protection

4 Analysis of the problem

4.1 General

The purpose of a pressure differential system, whether used for the protection of means of escape, property or for firefighting operations, can have a significant influence on the system design and specification. It is therefore essential that the fire safety objectives are clearly established and agreed with the appropriate approval bodies at an early stage in the design process.

The need for smoke control and the type of system chosen should not be considered in isolation but as an integral part of the total package of fire safety measures for the building, e.g. means of escape, firefighting facilities, degree of compartmentation.

The acceptability of any system depends ultimately on whether the necessary pressure differential levels and airflow rates are achieved (see Clause **12** [A2⟩ and BS 5588-12 ⟨A2]).

NOTE 1 Guidance on the means of calculating the air supply rate for these levels and rates is given in Clause **14**. However, provided that the appropriate functional objectives [see items a), b) and c) below] are met, the designer may choose to use other calculation procedures if these are appropriate to the specific case.

The main objectives addressed in this standard are as follows.

a) *Occupant safety*. It is essential that tenable conditions are maintained in protected escape routes and refuges for as long as they are likely to be in use by the building occupants.

b) *Firefighting*. To enable firefighting operations to proceed efficiently, firefighting shafts should be maintained essentially free of smoke so that access to the fire-affected storey can be achieved without the use of breathing apparatus. The pressure differential system should be designed so as to limit the spread of smoke from the lobby into the protected shaft under normal firefighting conditions.

c) *Property protection*. The spread of smoke into sensitive areas such as those containing valuable equipment, data processing facilities and other items that are particularly sensitive to smoke damage should be limited.

NOTE 2 A pressure differential system may be used for property protection. The procedures for occupant safety detailed in this standard are generally appropriate to the protection of such sensitive items. However, it may be desirable first to investigate the sensitivity to smoke damage of the individual items of concern and to ensure that the system design provides an adequate pressure differential and sufficient dispersal of any stray smoke in order to maintain smoke concentrations within acceptable limits.

4.2 Smoke movement in the building

In the event of fire, the smoke produced follows a pattern of movement arising from the following main driving forces.

a) *Buoyancy experienced by hot gases on the fire storey*. Within the fire zone smoke produced by the fire experiences a buoyancy force owing to its reduced density. In a building this can result in an upwards smoke movement between storeys if leakage paths exist to the storey above. In addition, this buoyancy can cause smoke to spread through leakage paths in vertical barriers between rooms, e.g. doors, walls, partitions. The pressure differential typically causes smoke and hot gases to leak out of gaps at the top of a door and cool air to be drawn in through gaps at the bottom.

b) *Thermal expansion of hot gases in the fire zone*. Fire-induced expansion of gases can result in a build-up of pressure, accompanied by a flow of hot gases out of the compartment. However, in most cases the initial expansion forces may be ignored.

c) *Stack effect throughout the building*. In winter the air in a building is generally warmer and less dense than the external air. The buoyancy of the warm air causes it to rise within vertical shafts in the building, and a pressure gradient is set up in the column such that cold air is drawn into the bottom of the shaft and warm air is forced out at the top. In summer, when the air inside the building can be cooler than that outside, the reverse condition may exist, i.e. air is forced out at the bottom of the stack and drawn in at the top. In either case, at some intermediate point a neutral plane is formed where the pressures of the external and the internal air are equal.

d) *Wind pressure forces*. When wind blows against the side of a building, it is slowed down, resulting in a build-up of pressure on the windward face. At the same time the wind is deflected and accelerated around the side walls and over the roof, creating an eddy on the leeward side of the building and a consequent reduction in pressure, i.e. suction in these areas. The greater the speed of the wind, the greater the suction. The main effect of these pressures is to produce a horizontal movement of air through the building from the windward to the leeward side. If the building is tightly constructed this effect will be slight. However, if the building is loosely constructed, i.e. with openable doors and windows, then the effect will be more pronounced. For example, in a fire, if a broken window exists on the windward side of the building, the wind can force the smoke through the building horizontally or in some circumstances vertically. It is difficult to predict accurately the wind pressures that will be exerted on buildings or the resultant internal airflows, and computer (see **9.1.5**) or wind tunnel analysis may be necessary for a full understanding.

NOTE Guidance on wind loadings is given in CP 3:Chapter V:Part 2 or BS 6399-2.

e) *HVAC systems*. HVAC systems can supply air to the fire zone and aid combustion or transport smoke rapidly to areas not within the fire zone and should generally be shut down in the event of fire. However, such systems can often be modified to assist in restricting smoke spread or be used in conjunction with pressure differential system air supply and/or release systems.

4.3 Methods of smoke control

4.3.1 *General*

The effect of the air movement forces described in **4.2** is to create pressure differentials across the partitions, walls, floors and doors that can cause smoke to spread to areas removed from the fire source.

The techniques most commonly used to limit the degree of spread are listed below.

a) Smoke containment using a system of physical barriers, e.g. walls and doors, etc., to inhibit the spread of smoky gases from the fire-affected space to other parts of the building.

b) Smoke clearance, using any method of assisting the fire service in removing smoky gases from a building when smoke is no longer being produced, i.e. after extinction.

c) Smoke dilution; deliberately mixing the smoky gases with sufficient clean air to reduce the hazard potential.

d) Smoke (and heat) exhaust ventilation, using any method to achieve a stable vertical separation between the warm smoky gases forming a layer under the ceiling and those lower parts of the same space requiring protection from the effects of smoke for evacuation of occupants and firefighting operations. For example, the continuous exhaust of smoke using either natural or powered ventilators, and the introduction of clean replacement air into the fire-affected space.

e) Pressurization. (See **3.31**.)

f) Depressurization. (See **3.7**.)

g) Zoned smoke control. (See **3.53**.)

NOTE This standard provides guidance and information on smoke control using pressure differentials, i.e. only the techniques given in items e), f) and g).

4.3.2 *Pressure differentials versus other forms of smoke control*

A combination of containment and extraction/venting is usually used as smoke control in large undivided spaces, e.g. shopping malls, atria, warehouses etc. Smoke produced by the fire is allowed to flow under its own buoyancy toward smoke reservoirs above the occupied space. Powered extraction systems or natural vents assist in the containment process by removing smoke from the reservoir and thus maintain the base of the smoke layer at a safe height. However, the entrainment of air into the smoke plume can produce a large volume of hot smoky gases, even from a modest fire, and high extraction rates are generally required.

Smoke clearance systems are generally intended for clearing smoke in the aftermath of a fire and are therefore generally unsuitable for meeting the functional objectives listed in **4.1**.

Smoke dilution systems work on the principle of supplying and exhausting large quantities of air from the fire zone. They do not control the movement of smoke, but instead rely on diluting the smoke to such a level that the vision and breathing of occupants in that space are not critically affected.

Smoke control using pressure differentials generally requires lower ventilation rates but is limited to the protection of enclosed spaces adjacent to the fire.

5 System classification

5.1 General

Smoke control using pressure differentials can be implemented in several different types of buildings, with differing requirements and design conditions.

For the purposes of this standard, the design conditions have been placed into five separate systems (classes A, B, C, D and E) and are detailed in Table 1.

Systems for atrium buildings are not covered within this standard, but the recommendations given in Annex A should be followed.

Table 1 — Classification of buildings for smoke control using pressure differentials

System class	[A1) Examples (A1]
A	Residential, sheltered housing and buildings designed for three door protection (see **5.2**)
B	Protection of firefighting shafts (see **5.3**)
C	Commercial premises (using simultaneous evacuation) (see **5.4**)
D	Hotels, hostels and institutional-type buildings, excluding buildings designed to meet class A (see **5.5**)
E	Phased evacuation (see **5.6**)

NOTE 1 The system classes listed above are not exhaustive.

NOTE 2 Attention is drawn to the Building Regulations 1991 [1] regarding means of escape and firefighting, and to the recommendations in the relevant parts of BS 5588.

5.2 Class A system

The design conditions for blocks of flats and maisonettes are based on the assumption that dwellings (other than the dwelling of fire origin) are not evacuated unless directly threatened by fire.

NOTE 1 The class A system is not to be used if the flats form part of mixed use development.

[A1) The level of fire compartmentation in blocks of flats and maisonettes at design stage is such that is usually safe for the occupants to remain in their own dwellings during a fire. The prime objective of the class A system is to maintain the staircase(s) free from smoke when there is a fire in a dwelling. The system would offer equivalent or better arrangement for the protection of the staircase compared with natural smoke ventilation systems. Therefore a class A system does not provide a form of smoke control to the front entrance door of the flat/dwelling.

NOTE 2 Smoke seals should be provided to the flat front entrance doors.

NOTE 3 On projects where smoke control is required to the front entrance doors of the flats/dwellings, this situation is outside the scope of a class A system, and therefore should be referred to a fire engineering solution.

NOTE 4 It is imperative that the designer of the system consults with the appropriate authority to establish the correct design objective. (A1]

It is unlikely that more than one door onto the protected space (either between the stair and the lobby/corridor or the final exit door) will be open simultaneously.

NOTE 5 Where there is three door protection between the protected stairway enclosure and the compartmented accommodation area, the recommendation for open door airflow velocity as applicable to items a), b), c), d) and e) below does not apply.

The airflow through the doorway between the pressurized stair and the lobby or corridor should be not less than 0.75 m/s when:

a) the door between the lobby/corridor and the pressurized stair is open on any one storey;

b) the air release from the lobby/corridor on that storey is open;

c) all doors between the pressurized stair and the lobbies/corridors are closed on all other storeys;

d) all doors between the pressurized stair and the final exit are closed; or

e) the final exit door is closed.

The pressure difference across a closed door between the pressurized stair and the lobby/corridor should be not less than 50 Pa ± 10 % when:

1) the air release from the lobby/corridor on that storey is open;

2) on all other storeys the doors between the pressurized stair and the lobby/corridor are closed;

3) all doors between the pressurized stair and the final exit are closed;

4) the final exit door is closed.

The above design conditions for class A systems are shown in Figure 1.

NOTE 6 Figure 1 can include lobbies.

A1

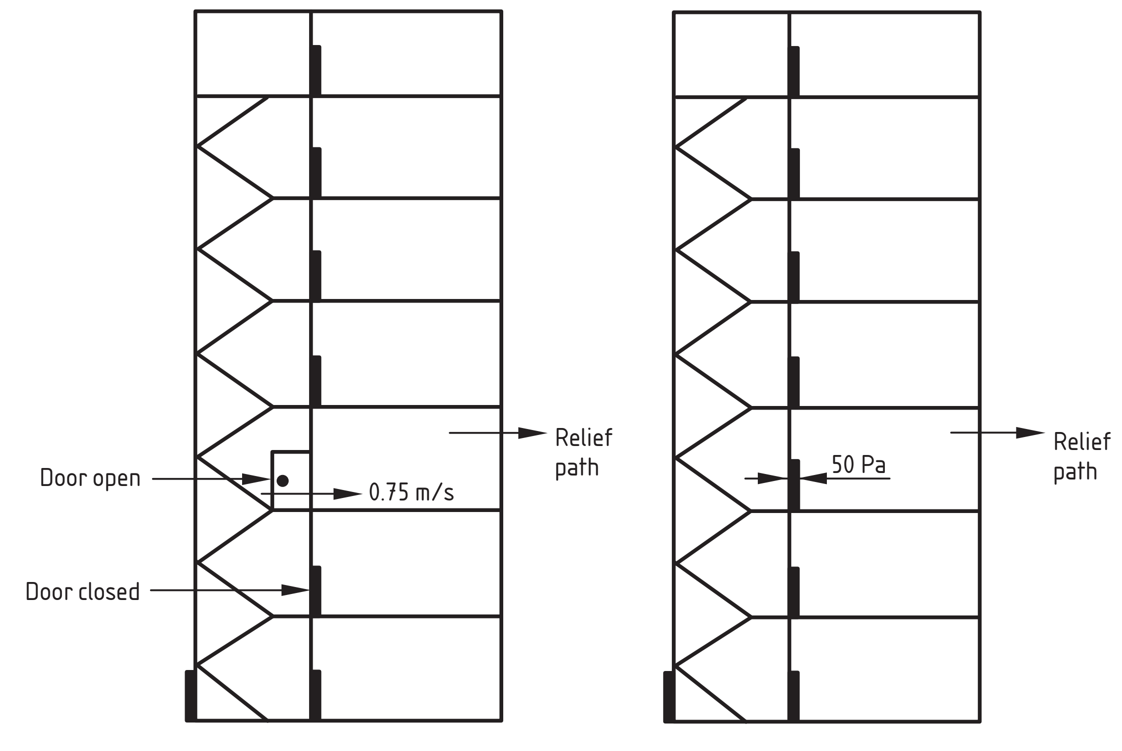


Figure 1 — Design conditions for class A systems

A1

5.3 Class B system

A pressure differential system can be used to minimize the potential for serious contamination of firefighting stairs by smoke during fire service operations.

BS 5588-5 provides guidance on the general design and construction of firefighting stairs and lifts.

NOTE 1 During firefighting operations it is necessary to open the door between the firefighting lobby and the accommodation area to deal with a fully developed fire.

It is common firefighting practice that the first crews arriving at an incident in a building with a firefighting shaft obtain information about the floor involved and set up a bridgehead/forward control.

Crews committed from forward control to attack the fire usually attempt to take hoselines uncharged to the protected lobby on the fire-affected storey and connect to the riser outlet. However, if the lobby area on the fire-affected storey is untenable, hoselines are connected to the riser on the floor below or, in the case of basements, the floor above the fire-affected storey.

Where hoselines are connected to the riser on a floor other than the fire-affected storey, the hoselines can prevent the closing of the doors between the lobby and stairs whilst firefighting operations are in progress. This can cause smoke to enter the protected area.

The velocity of hot smoke and gases from a fully developed fire can reach 5 m/s. Although firefighting operations, such as the use of a jet, can contribute significantly to the holding back of hot smoke and gases, it is impractical to provide sufficient through-flow of air in order to prevent ingress of smoke into the firefighting lobby.

It is, however, essential that the stair shaft is kept clear of serious smoke contamination. To limit the spread of smoke from the fire zone to the lobby and thence into the stair an air velocity of at least 2 $m \cdot s^{-1}$ through the open door between the firefighting lobby and the accommodation area should be provided.

To achieve the recommended flow of 2 m/s through the open stair door, sufficient leakage should be ensured from the accommodation area to the exterior of the building. In the later stages of fire development more than adequate leakage is generally provided by breakage of external glazing. However, it should not be assumed that windows will have failed before the arrival of the fire service, and it is therefore essential to ensure that sufficient leakage area is available, via the ventilation ductwork or specifically designed air release paths.

The system should be designed to keep the firefighting stair and firefighting lobby and, where provided, the firefighting lift well, clear of smoke. In the event of smoke entering the lobby, the pressure within the stair should not drive smoke into the lift well or vice-versa. This should be achieved by providing separate pressurization of the firefighting lift well, lobby and stair.

The fan/motor units for a firefighting lift well may be common with its associated stair, providing that:

a) the air is provided through separate ductwork;

b) the distribution of air to each duct is controlled so that sufficient air is provided to each space at all times.

The air supply should be sufficient to maintain the pressure differential given in Table 2 when all doors to the lift, stair and lobby, and the final exit doors are closed and the air release path from the accommodation area is open.

Table 2 — Minimum pressure differentials between specified areas for class B systems

[A1)

Specified area	Pressure differential to be maintained min
Across lift well and accommodation area with all doors closed[b]	50 Pa ± 10 %[a]
Across stairway and accommodation area with all doors closed[b]	50 Pa ± 10 %[a]
Across closed doors between each lobby and accommodation area with all doors closed[b c]	45 Pa ± 10 %[a]

[a] The ± is not to be used in designing the system, it is only there for flexibility when testing the system.
[b] Air release path from the accommodation on the storey (fire floor) where the pressure difference being measured is open.
[c] 45 Pa is required to overcome wind pressure, fire pressure and stack effect components incorporating a safety margin. Providing 45 Pa is the outcome, there are no restrictions on how it is achieved.

(A1]

The air supply should be sufficient to maintain an airflow of 2 m/s through the open door between the lobby and the accommodation area at the fire-affected storey with all of the following doors open between:

1) the stair and the lobby on the fire-affected storey;

2) the stair and the lobby on the adjacent storey;

3) the firefighting lift well and the lobby;

4) the stair and the external air at the fire service access level;

5) the air release path from the accommodation area, on the storey on which the airflow is being measured.

See Figure 2 for these design conditions.

NOTE 2 Where a class B system is used within a residential building, the air release path may be from the non-firefighting lobby corridor on the storey where the airflow is being measured.

NOTE 3 Where a door has two leaves, one leaf (or the leaf with the least openable area where unequal size doors are provided) may be assumed to be in the closed position for these calculations.

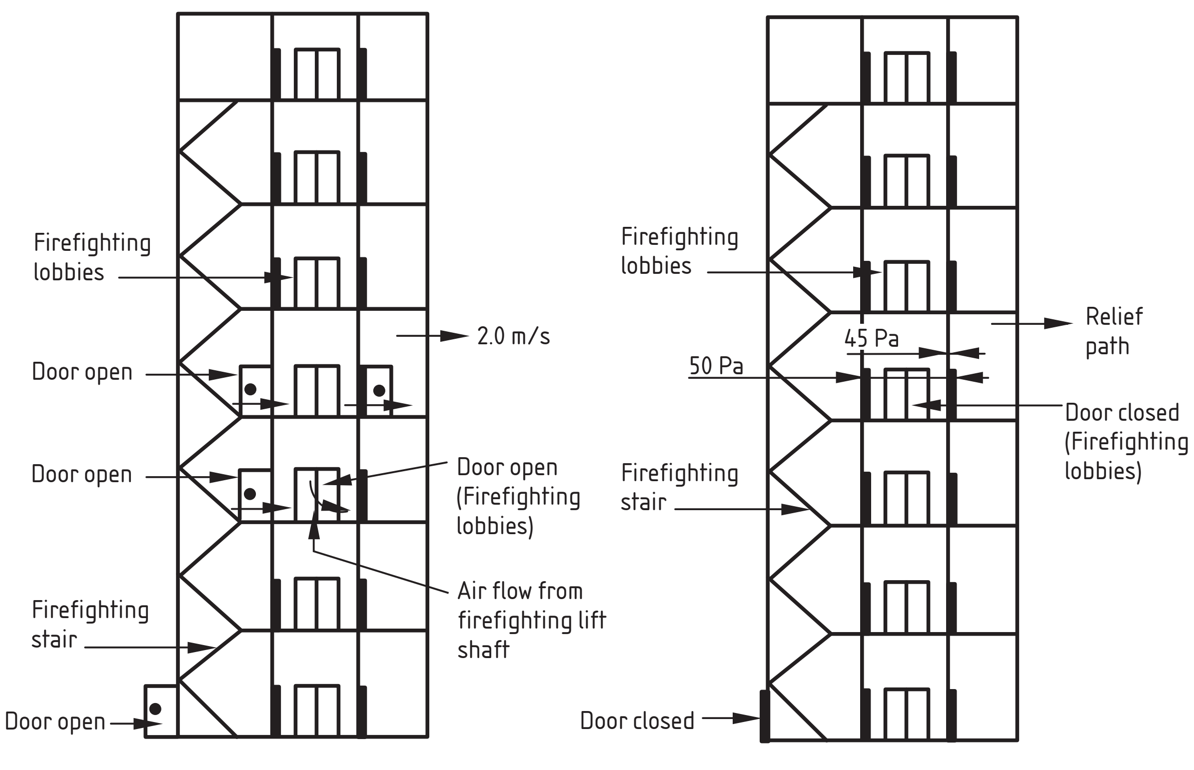
NOTE 4 If a pressure containment lobby is provided at fire service access level, for design purposes, the door indicated in item 4 above may be closed. [A1] The design of such pressure containment lobbies and their effect on pressure differential smoke control systems should be justified on a case by case basis. [A1]

Any air supply system serving a firefighting shaft should be separate from any other ventilation or pressure differential system.

The maximum force required to open any door within the escape route should in no circumstances exceed 100 N, applied at the door handle.

NOTE 5 The corresponding maximum pressure differential across the door can be determined using the procedures in Annex B, as a function of the door configuration.

[A1]



Airflow criterion

Pressure difference criterion (all doors closed)

Figure 2 — Design conditions for class B systems

[A1]

5.4 Class C system

This classification applies to systems other than classes A, B or D using simultaneous evacuation and with one of the following:

a) [A1⟩ with lobbies, no restrictions in height ⟨A1];

b) [A1⟩ without lobbies, a single stair up to 11 m and ⟨A1];

c) [A1⟩ without lobbies, more than one stair up to 18 m ⟨A1].

In the event of a simultaneous evacuation it is assumed that the stairways will be occupied for the nominal period of the evacuation, and thereafter will be clear of evacuees. Consequently, the evacuation will occur during the incipient stages of fire development, and some smoke leakage onto the stairway can be tolerated. The airflow due to the pressurization system should clear the stairway of this smoke.

The occupants being evacuated are assumed to be alert and aware, and familiar with their surroundings, thus minimizing the time they remain in the building.

The airflow through the doorway between the pressurized space and the accommodation area should be not less than 0.75 m/s when:

1) the doors between the accommodation area and the pressurized stairway and any lobby on the fire floor are open;

2) the air release path from the accommodation area on the storey where the airflow being measured is open;

3) all other doors other than the fire floor doors are assumed to be closed.

The pressure difference across a closed door between the pressurized space and the accommodation area should be as given in Table 3.

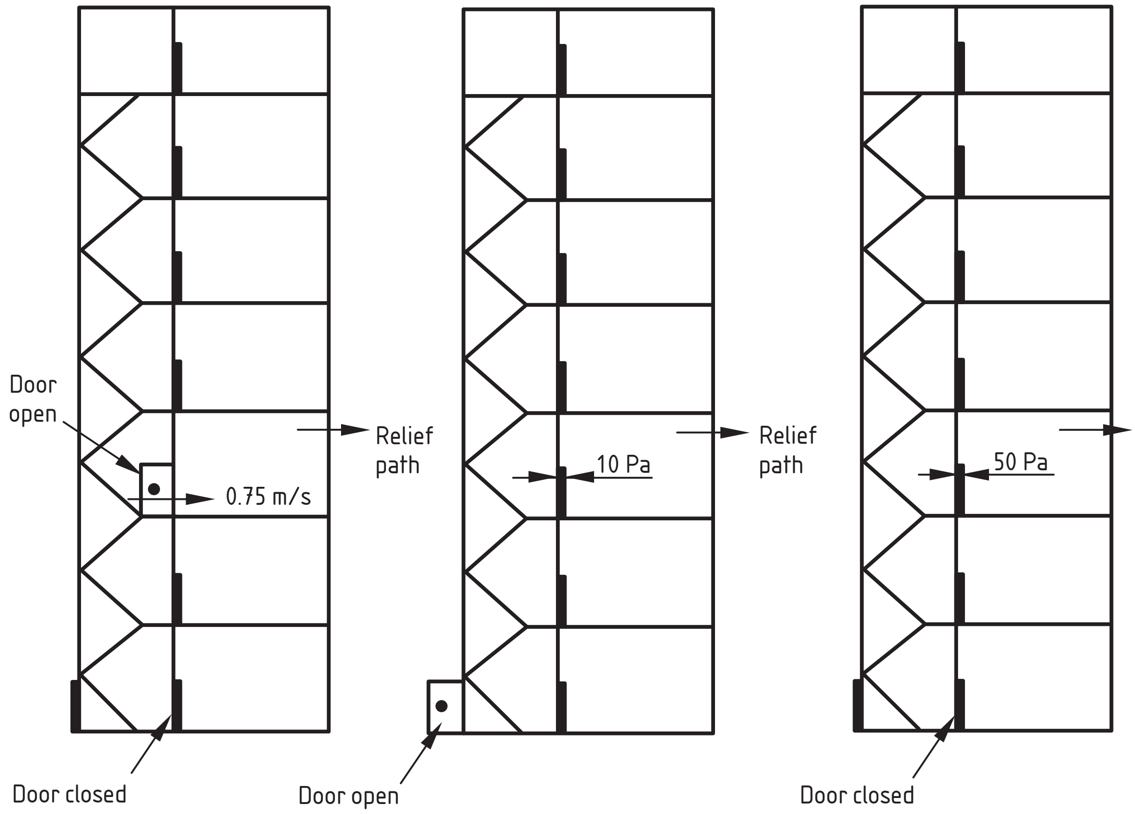
Table 3 — Minimum pressure differentials for class C systems

Position of other doors	Pressure differentials to be maintained min.
i) Doors between accommodation area and the pressurized space are closed on all storeys	50 Pa ± 10 %
ii) All doors between the pressurized stair and the final exit are closed	
iii) Air release path from the accommodation on the storey where the pressure difference being measured is open	
iv) Final exit door is closed	
v) Final exit door is open and other items i) to iii) above	10 Pa

The design conditions for class C systems are shown in Figure 3.

NOTE Figure 3 can include lobbies.

A1



NOTE Figure 3 can include lobbies.

Figure 3 — Design conditions for class C systems

A1

5.5 Class D system

This classification applies to systems used in the following:

a) hotels, hostels and institutional-type buildings, excluding buildings designed to meet class A system classification;

b) any building where a discounted stairway has not been provided because a pressure differential system is installed;

c) any buildings more than 18 m high where the pressure differential system has been adopted in lieu of the provision of lobbies (not including residential-type buildings or firefighting shafts).

Class D systems are appropriate in buildings where the occupants may be sleeping, e.g. hotels, hostels and institutional-type buildings. The time for the occupants to move into a protected area prior to reaching the final exit can be greater than that expected in an alert or able-bodied environment, and occupants may be unfamiliar with the building or need assistance to reach the final exit/protected space.

Class D systems are also appropriate when the presence of a pressure differential system has served to justify the absence of a discounted stairway and/or lobbies that would normally be required under the appropriate building regulations (England and Wales, Scotland, Northern Ireland) [1].

The airflow through the doorway between the pressurized space and the accommodation area on the fire floor should be not less than 0.75 m/s when:

1) the door between the accommodation area and the pressurized space on the fire storey is open;

2) all doors within the pressurized spaces on the fire floor to the final exit which cross the escape route from the accommodation area are open;

3) all doors between the pressurized stair and the final exit are open;

4) the final exit door is open;

5) the air release from the accommodation area on the fire floor is open;

6) the doors on the other floors are closed.

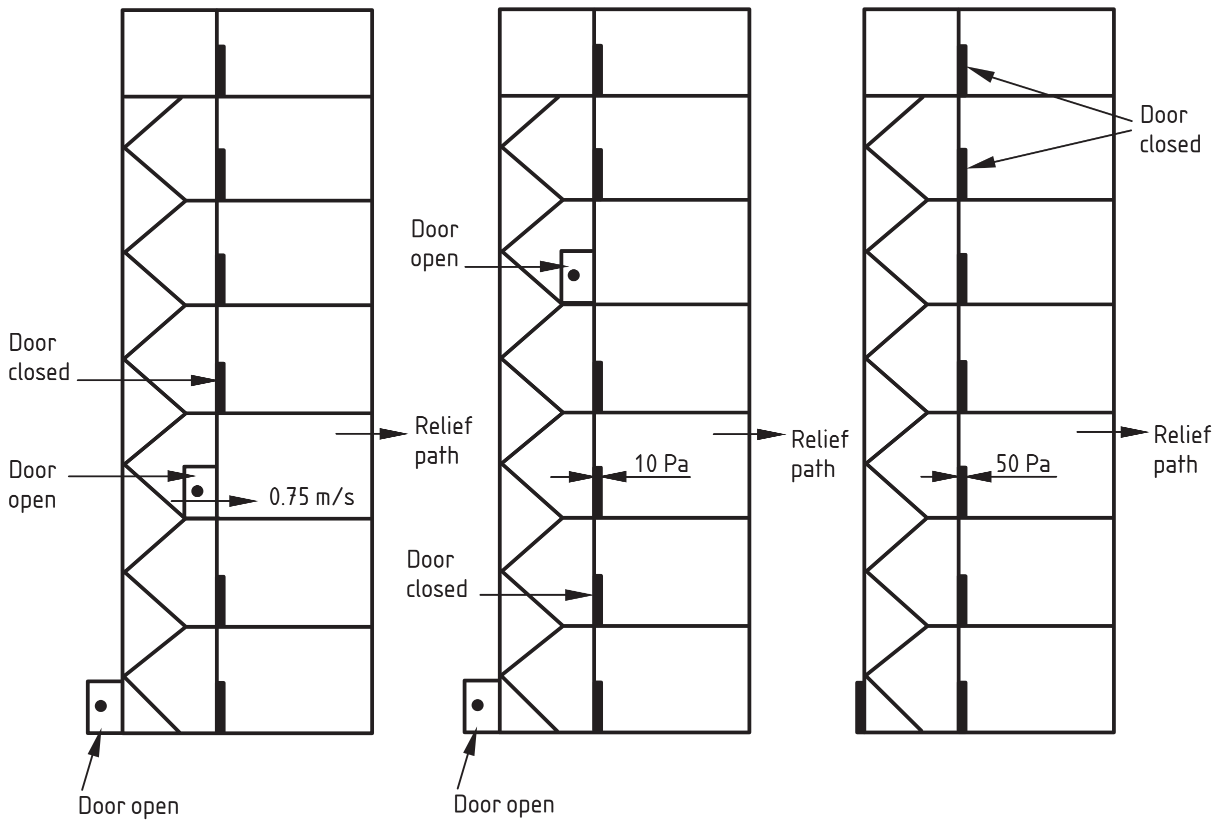
The pressure difference across the closed door between the pressurized space and the accommodation area on the fire storey should be as given in Table 4.

Table 4 — Minimum pressure differentials for class D systems

Position of other doors	Pressure differential to be maintained min.
Door between accommodation area and pressurized space on the fire storey is closed	10 Pa
All doors within pressurized space that cross the escape route from the accommodation area to the final exit door are open	
All doors between the pressurized stair and the final exit door are open	
The final exit door is open	
The air release path from the accommodation area on the storey where the pressure difference is being measured is open	
The doors between the accommodation area and the pressurized space are closed on all storeys	50 Pa ± 10 %
All doors between the pressurized stair and final exit door are closed	
The air release path from the accommodation area on the storey where the pressure difference being measured is open	
The final exit door is closed	

The design conditions for class D systems are shown in Figure 4.

NOTE Figure 4 can include lobbies.



Airflow criterion

Pressure difference criterion

Pressure difference criterion
(all doors closed)

NOTE Figure 4 can include lobbies.

Figure 4 — Design conditions for class D systems

5.6 Class E system

This classification covers systems used in buildings with phased evacuation, and where the expected total evacuation time exceeds 10 min. For design purposes, this represents the situation where the number of evacuation stages is greater than three, using two floors at a time.

It is assumed that the building would still be occupied for a considerable time during phased evacuation whilst the fire develops. The protected stairways should be maintained free of smoke to allow persons to escape in safety from floors other than the fire floor at a later stage in the fire development.

The airflow through the doorway between the pressurized space and the accommodation area on the fire floor should be not less than 0.75 m/s when:

a) the doors between the accommodation area and the pressurized space on the storey above the fire floor are open;

b) all doors within the pressurized spaces on those two storeys that cross the escape route from the accommodation area to the final exit are open;

c) all doors between the pressurized stair and the final exit are open;

d) the final exit door is open;

e) the air release from the accommodation area on the fire floor is open.

The pressure difference across the closed door between the pressurized space and the accommodation area on the fire floor should be not less than as given in Table 5.

Table 5 — Minimum pressure differentials for class E systems

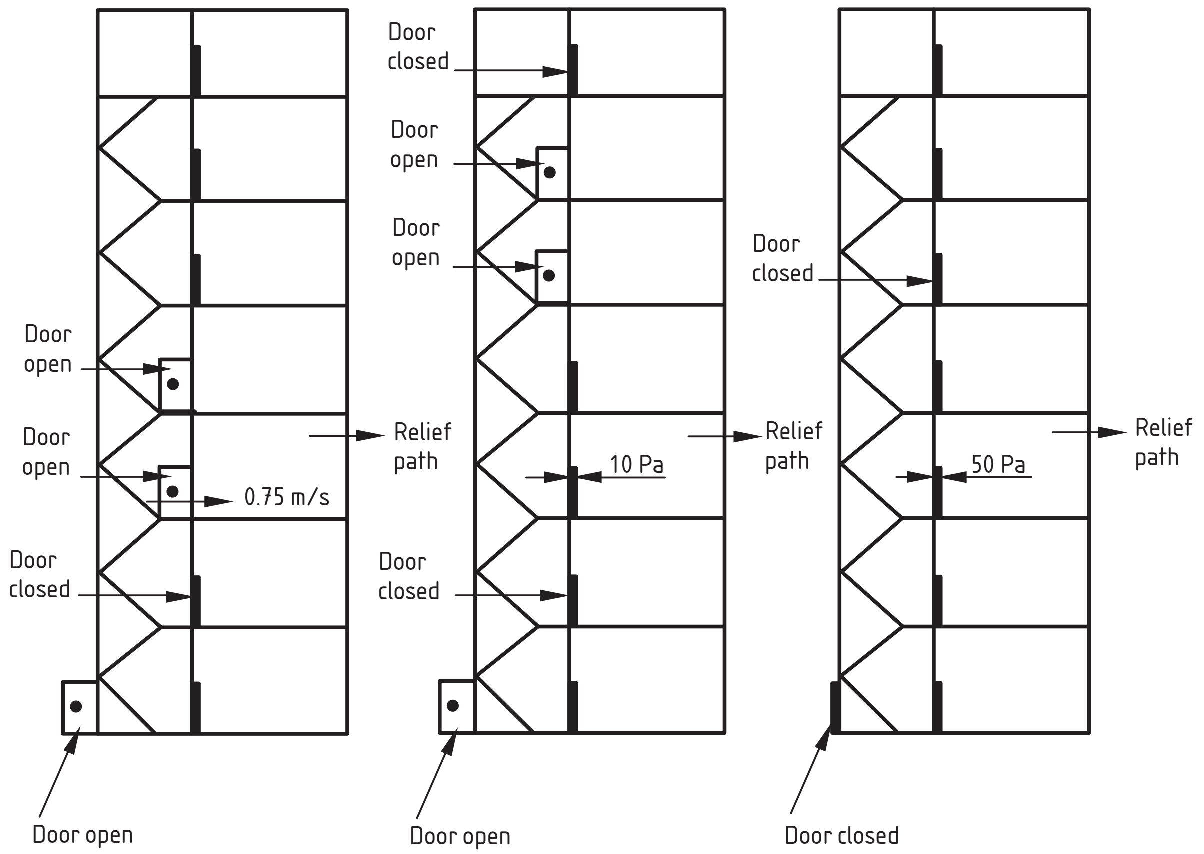
Position of other doors	Pressure differential to be maintained min.
The doors between the accommodation area and the pressurized space are open on two adjacent storeys	10 Pa
All doors within the pressurized space on those two storeys that cross the escape route from the accommodation area to the final exit are open	
All doors between the pressurized stair and the final exit are open	
The final exit door is open	
The air release path from the accommodation area on the storey where the pressure difference being measured is open	
The doors between the accommodation area and the pressurized stair on all storeys are closed	50 Pa ± 10 %
All doors between the pressurized stair and the final exit are closed	
The air release path from the accommodation area on the storey where the pressure difference being measured is open	
The final exit door is closed	

NOTE 1 See **9.2.2.2** regarding pressure gradient.

The design conditions for class E systems are shown in Figure 5.

NOTE 2 Figure 5 can include lobbies.

A1



Airflow criterion

Pressure difference criterion

Pressure difference criterion (all doors closed)

Figure 5 — Design conditions for class E systems

A1

6 Equipment

6.1 General

The equipment needed to create a pressure differential between the protected space and the accommodation area consists of:

a) fans and drive mechanisms;

b) air release provisions;

c) actuation systems;

d) over-pressure relief vents;

e) electrical power supplies (primary and secondary);

f) stand-by equipment;

g) distribution ductwork system.

Where a ventilation system (HVAC) is used to form part of the pressure differential system, the components should conform to the recommendations of this clause.

To ensure that the system operates satisfactorily at all times in the event of an emergency there should be provision for an alternative power supply and stand-by plant.

Installations should conform to BS 5720.

6.2 Fans and drive mechanism

The fan duty is calculated by summation of the leakage from all the identifiable leakage paths in the pressurized zones. It is essential that the architect and builder agree with the installing engineer what is expected from the escape route construction, e.g. gap size under doors, leakage through joints in the construction and through the boundary of the pressurized space, so that the actual leakage closely matches that of the design. The calculated leakage should then be increased by a factor (see below) to allow for uncertainties in identified leakage paths.

A factor of 1.5 should be used where solid construction encloses the protected space. Where materials and construction techniques that may produce significant leakage are used, e.g. plasterboard walls and false ceilings, this factor of 1.5 may need to be increased, following consultation with the architect and builder.

Where there is doubt as to the air tightness of an existing building construction (particularly in the case of a building refurbishment), and where refurbishment is taking place, it may be advisable to assess the leakage areas using a calibrated portable fan prior to specifying the fan performance.

The ductwork should be sized according to the expected flow rate. The pressure loss in the ductwork and through any dampers and registers should be used together with the required pressure in the protected space to specify the fan performance.

When selecting a fan for the required duty, account should be taken of the temperature and time for which the system is required to work. (See Table 6 for air release and depressurization systems.)

The fan duty should be assessed for the following.

a) *Volume flow rate*. The volume flow rate is the total air supply to or from all pressurizing or depressurizing spaces served by the particular fans plus an allowance for unidentified leakage paths and for probable ductwork leakage. The allowance for leakage to be added to the volume flow rate should be 15 % for sheet metal ductwork and 25 % for builders' ducts, unless an on-site test determines a lower level of leakage.

b) *Total fan pressure*. This is the total resistance of the distribution system plus the emergency pressurization level.

c) *Static fan pressure*. This is the fan total pressure minus the velocity head at the fan discharge.

d) [A1) *Text deleted* (A1]

To control the pressure differential, over-pressure release vents may need to be fitted in the pressurized spaces. It is recommended that the pressure release vents are located at the top of each stair and should open directly to the external air.

Where pressure differential fans serve more than one pressurized space concurrently, it may be necessary to interpose high-pressure drop volume control dampers to ensure that when high leakage occurs from an area, e.g. when doors are open or construction failure occurs, some protection continues in the remaining areas.

6.3 Air release

It is essential that a low-resistance path to external air is provided in a pressurization/depressurization system. By providing such a path from the accommodation area, the desired pressure differential between the accommodation area and the protected space can be maintained, thus excluding smoke from the protected space.

The methods of air release are:

a) external wall vents, which include automatically openable windows and trickle ventilators;

b) vertical shaft air release, where vents in accommodation area spaces connect to a common vertical shaft which releases smoke at the top of the building;

c) mechanical extraction, which consists of fans and ductwork, either dedicated to the removal of air/smoke from the spaces affected by fire or an HVAC system suitably equipped and controlled to fulfil this function. [A1) The fan should be suitable for continuous operation for the appropriate period of time and temperature specified in Table 6. (A1]

Where the actuation of the air release system is automatic it should be controlled in such a way that it only operates in the fire zones.

NOTE Arrangements for the control of a powered automatic air release system are given in Annex C.

The air release system should be such that in normal operation or in the fail-safe mode there is no movement of smoke between different fire compartments.

Where the air release is achieved by mechanical extraction the fans and ductwork should operate continuously at the appropriate temperature and period of time as given in Table 6.

Air release system components should be tested in accordance with BS 7346-1 and BS 7346-2.

If the discharge points of the air release system are at the same level as the air intakes, they should be installed in accordance with **11.1**.

Table 6 — Minimum temperature/time design criteria for fans and HVAC ductwork used for air/smoke release

Features of building design			Minimum temperature and time design criteria
Phased evacuation on or over 30 m high	Fire- fighting shaft	Life safety sprinklers	
Yes	No (see Note)	No	600 °C for 2 h
Yes	Yes	No	600 °C for 2 h
Yes	Yes	Yes	300 °C for 2 h
Yes	No	Yes	300 °C for 2 h
No	No	Yes	300 °C for 1 h
No	No	No	600 °C for 1 h
No	Yes	Yes	300 °C for 2 h
No	Yes	No	600 °C for 2 h
NOTE It is unlikely that a building over 30 m high will not have a firefighting shaft but the alternatives have been included for the purposes of clarity.			

Recommendations for life safety as given in BS 5306-2 should be followed when designing and installing the sprinkler system.

6.4 Stand-by fans and drive mechanisms

It is essential that stand-by pressure differential equipment is provided in all cases to ensure that the system can operate at all times in the event of an emergency. The equipment should consist of duplicate fans and/or motors depending on the type of system installed and the layout of building served.

The following recommendations are applicable to systems protecting escape routes and firefighting shafts.

Stand-by fans and motors should be of the same type and duty as the primary pressure differential system equipment.

The changeover from the primary pressure differential system equipment to the stand-by equipment should be automatic. The control should be such that in the event of a primary power failure the switch-over to stand-by equipment does not occur when the power is restored by the secondary supply.

The stand-by equipment should be housed in the same protected enclosure as the primary pressure differential system equipment, [see item a) of **11.2**].

Stand-by pressure differential system equipment should be provided in accordance with Table 7.

Table 7 — Provision of stand-by pressure differential system equipment

Function of pressure differential system equipment	Equipment to be provided
To provide air under pressure to the escape routes within a building	Duplicate fans complete with motors
To extract air/smoke from the accommodation area and is the sole means of creating the pressure differential within the escape routes from a building	Duplicate fans complete with motors
The powered air release system equipment extracts air/smoke from the accommodation area and is not the sole means of creating the pressure differential within the escape routes from a building	At least single fans with duplicate motors

6.5 System status indication

When firefighters arrive at a fire they need to be able to make an immediate assessment of the situation, including the integrity and operation of the pressure differential system protecting the firefighting access and the means of escape from the building. To assist this assessment, pressure differential system status indicators should be provided.

Indicator lights displaying the status of any pressure differential system protecting the firefighting access and the means of escape from the building should be located at each fire service access point.

Where there is more than one fire service access point to the building, the status of all pressure differential systems should be indicated at either the central control room or at a fire service rendezvous point, the location of which should be agreed by the fire authority.

The indicator lights should show the status of each smoke control zone, primary and emergency power supplies, and primary and stand-by fans.

7 Actuation of pressure differential system

Automatic smoke detectors should be used to actuate the pressure differential system equipment, since a considerable quantity of smoke may be produced in the early stages of a fire before a heat detection, sprinkler or other extinguishing system is initiated. [A1) *Text deleted* (A1]

Point type smoke detectors should be used, mounted in the accommodation area adjacent to the doors leading to the protected space at each storey served by the system. Location of the smoke detectors should be in accordance with Clause **12** of BS 5839-1:1988.

In blocks of flats and maisonettes it is essential that the smoke detectors are sited in the common lobbies/corridors or, when a lobby is required, within the common space.

The smoke detectors may be part of the fire detection system protecting the building or may be dedicated to the pressure differential system.

Where the operation of the air release system is automatic, its actuation should be by the same detector that actuates the rest of the system.

[A1) Where a pressure differential system is required to protect both:

a) the means of escape prior to the arrival of the fire brigade (Class A, C, D or E systems); and

b) the fire brigade during firefighting operations (Class B system).

Consultations should take place with the fire brigade and, where otherwise, the enforcing authority to gain agreement on the mode of initiation and operation of the resulting system.

The enforcing authority may agree that the pressure differential system should start automatically on detection of smoke within the space in the:

a) means of escape mode (Class A, C, D or E systems) and subsequently, on arrival of the fire brigade, the system boosted manually, by the operation of a switch by the fire brigade, into the firefighting operational mode (Class B system); or

b) firefighting mode (Class B system), with no subsequent change of operation of the system. (A1]

Manual system-override switches for the pressurization system should be situated at the following locations:

a) the building services plant room and the pressure differential system equipment plant room (where separate); and Where

b) near the building entrance at a location agreed with the fire authority.

Those switches given in item a) above should be capable of being locked in an “on” position.

8 Electrical installations

8.1 General

All electrical services should be installed, and periodically inspected and tested. Any necessary maintenance should be carried out by suitably qualified engineers in accordance with BS 7671.

8.2 Primary power supplies

All primary power supplies to the following should originate from the point at which the power supply enters the building and should be independent of the main switched fuse of the building:

a) pressure differential system supply fans and any associated relief air path equipment;

b) depressurization fans and any associated supply make-up air equipment;

c) fire alarm control systems and damper and plant control systems, etc.

This is to ensure that the failure of other equipment does not render the installations listed above inoperative.

Since it is not possible to determine where a fire may start, all power supplies and their associated control equipment back to the power supply intake position should be regarded as being within the hazard/risk area. Therefore great care should be taken in the design to ensure that power is available at all times.

Consideration should also be given not only to routeing of cables, but to the position of terminations, circuit protection facilities and control panels, to ensure that these are also provided with adequate protection from the effects of fire.

The electrical power supply to life safety and fire protection equipment should be separate from all other circuits in the building.

Each connection to the power supply should be via an isolating protective device reserved solely for the life safety and fire protection equipment and independent of any other main or sub-main circuit. Such isolating protective devices (with high-rupturing safety devices) should be clearly labelled and identified as to their purpose. They should be secured against unauthorized operation and should, except for maintenance, be kept locked in the “on” position.

The supply to these isolating protective devices should be independent of the main power switch for the building and should be appropriately labelled in accordance with **16.2** of BS 5839-1:1988.

Monitoring facilities should be provided at the central control room, if present, or adjacent to the fire alarm control panel, to show, as far as is reasonably practical, that power is available up to the final control point to all fire safety systems, e.g. to the motor contactor.

8.3 Wiring systems

Wiring systems required to operate in the event of fire should be of a type or installed in such a manner that, in the event of fire anywhere in the building, the circuits continue to operate and the cables maintain circuit integrity.

Wiring systems should either:

a) consist of one of the following:

1) mineral insulated, copper sheathed cables conforming to BS 6207;

2) cables with the classification CWZ in accordance with BS 6387;

or

b) be protected against exposure to the fire by separation from any significant fire risk by a wall, partition or floor having a fire resistance of:

i) at least 1 h for systems designed to protect means of escape;

ii) at least 2 h for systems designed to protect firefighting shafts.

NOTE 1 In each case the cable should be protected by a construction having the recommended integrity and insulation, in accordance with BS 476, when the fire is located on the side of the construction remote from the fire.

NOTE 2 The mechanical protection of cables by conduit, ducting or trunking is not considered to give adequate protection against fire.

The wiring systems should be separate from any other circuit.

The wiring systems should be such that they are not affected by fire at any position where cable connections are made.

The wiring systems should be adequately protected from any mechanical damage.

NOTE 3 To achieve greater integrity of the system, separate or independent sources of electrical power supply are necessary.

8.4 Secondary power supplies

It is essential that a secondary power supply is provided to reduce the risk of the loss of electrical power supply in a fire. This supply should be independent of the primary power supply and should be provided by an automatically-started generator or a separate substation of sufficient capacity to maintain operation of the following for at least 2 h for systems protecting firefighting shafts, and at least 1 h for systems protecting means of escape:

a) any pressurization or depressurization fans;

b) any powered equipment associated with the air release or supply air make-up systems;

c) any other fire control and damper systems.

The secondary power supply should be capable of providing the power supply for items a), b) and c) within 15 s of the failure of the primary power supply. Where the alternative power source is a generator, it should be capable of providing the power necessary for at least 3 h without replenishment of fuel.

The secondary power system should be designed to operate safely in fire conditions. Consideration of the means of provision of a secondary supply should include the overall electrical distribution system within the building, and also the power needs for other equipment requiring a secondary power supply.

Any electrical substation or enclosure containing a distribution board, generator, powered smoke control plant, pressure differential system plant or communication equipment associated with life safety and fire protection systems should be separated from the building by construction with a fire resistance of not less than:

— 1 h for systems designed to protect the means of escape; and

— 2 h for systems designed to protect a firefighting shaft.

A power supply from a second substation does not offer protection against the occurrence of a fault (unconnected with a fire in the building) on the high-voltage distribution network, e.g. the severing of a high-voltage cable during construction work. Therefore, either a generator should be provided, or the secondary power supply should be taken from a high-voltage distribution network other than that normally supplying the building.

Where the secondary electrical supply is to be taken from a substation separate to that supplying the primary electrical supply, the following criteria should be satisfied.

1) The electrical supplies to the two independent substations should be taken from two separate high-voltage supplies, and should not originate from the same substation.

2) The failure of one substation should not lead to the failure of the other.

3) The two independent substations should be adequately separated. Where the substations are located within the building they serve, the following criteria should be satisfied:

   i) each substation should be enclosed within a fire resisting structure having a minimum of 2 h fire resistance;

   ii) the two substations should be located in two separate parts of the building;

   iii) the entry/access to the substations should be direct from the outside and not via the building;

   iv) supply cables to the substations should enter directly from the outside and should not pass through the building unless suitably fire protected.

4) Supply cables from the high-voltage substations should enter directly the high-voltage/low-voltage switchrooms and should not pass through the building unless suitably fire protected.

5) Both sets of supply cables should be adequately separated to avoid a single fault affecting both supplies.

The primary and secondary power supply cables should be terminated in a changeover device located within the plant room(s) housing the life safety and fire protection equipment. The changeover device should automatically effect the transition from primary to secondary power supply if the primary supply to the particular plant fails, so that the life safety and fire protection installations continue to operate.

Both the primary and secondary supplies to the life safety and fire protection installations should be protected against fire and water damage, and also separated from each other, so that the failure of cables or equipment, either by mechanical breakdown or damage by fire, in any one system, does not affect the other supply. Protection against fire may be achieved by choice of cable, choice of route, (for example, through protected areas, or external to the building) or by the provision of additional fire protection.

Cables supplying current to the life safety and fire protection installations should be installed in accordance with BS 7671 and the manufacturer's instructions. The cables should have an inherently high resistance to fire and should be protected where necessary against mechanical damage. Cables, switchgear and other equipment transmitting the secondary power supply should be separate from those of the primary supply, and where necessary be physically segregated by barriers with a fire resistance not less than that recommended in item b) of **8.3** so that a breakdown, or any cause of breakdown, on one supply does not lead to a simultaneous failure of the other supply.

It is essential that the fire procedures of the building do not include the isolation of circuits supplying power to the life safety and fire protection installations.

9 Smoke control using pressure differentials

9.1 General

9.1.1 *Design*

When analysing a complex system of interconnected pressurized spaces, the calculation process can become excessively laborious and time consuming. In these circumstances it may be desirable to demonstrate compliance with the functional objectives of this standard by use of a computer-based flow model. (See **9.1.5**.)

The purpose of a smoke control system using pressure differentials should be to minimize the contamination by fire gases of the protected spaces by preventing the movement of smoky gases through leakage paths (e.g. door cracks) between the fire and the protected space. In order to achieve this the pressure difference generated in the protected space should be greater than and opposed to the pressure difference driving the smoke.

The design of a smoke control system using pressure differentials should take into account both maximum and minimum allowable pressure differentials across these paths.

Any alterations to the internal layout, or any subdivision to the open storeys, or the fitting out of speculative buildings, should ensure that air relief paths are maintained.

9.1.2 *Pressure forces*

The pressure forces which can drive the smoke are given below.

NOTE 1 The thermal expansion of the gases in the fire compartment may generally be ignored for design purposes since any pressure increase produced in this way is usually relieved via the inherent leakage or designed air release paths from the accommodation.

a) *Wind*

When wind blows against a building it causes a rise in pressure on the upwind face of the building and a fall in pressure on the downwind face. Most buildings allow some air infiltration through their facades (e.g. through window cracks) and the wind-induced pressure difference across the building produces an airflow through the building, which in turn causes pressure differences to appear across flow resistances (e.g. door cracks) within the building [see Figure 6a)]. The largest wind-induced pressure difference driving smoke into a protected space occurs when that space is downwind of the accommodation on that storey. Wind-induced pressure differences, both external and internal, tend to be greater for taller buildings.

b) *Stack effect*

Where a vertically-connected column of warm air (e.g. the air inside a heated building) is linked via one or more openings to a vertical column of cooler air (e.g. the atmosphere outside the building) the absolute pressure in the warmer column changes more slowly with height than in the cooler column since warm air is less dense than cooler air. Where there are many leakage paths at different heights between the columns of warm and cool air, this buoyancy effect produces a higher pressure at the top of the warm column than in the cool column, and a lower pressure at the bottom of the warm column than in the cool column. The pressures in the two columns are equal at one height, commonly referred to as the neutral pressure plane [see Figure 6b)]. Near the top of a building the effect is to drive air (and any smoke carried by it) away from the vertical column of warm air towards the cooler air, commonly known as the stack effect.

In a pressurization (or depressurization) system, the protected space (e.g. the stair) rapidly fills with air at the external air temperature (unless the pressurizing air supply has been specifically heated as is sometimes done in very cold climates). This results in the protected space being effectively at the same temperature as the cooler column referred to above (i.e. the air outside the building) while any accommodation spaces joined vertically to form a warm air column develop a stack-effect buoyant pressure relative to both the exterior and the protected space. Consequently, this stack effect tends to produce a flow across any intervening leakage paths (such as door-cracks) from such accommodation spaces into the protected space in the upper parts of the building.

NOTE 2 In air-conditioned buildings in hot climates where the air column inside the building is cooler than the external air, the stack effect will tend to drive air into the shaft in the lower part of the building.

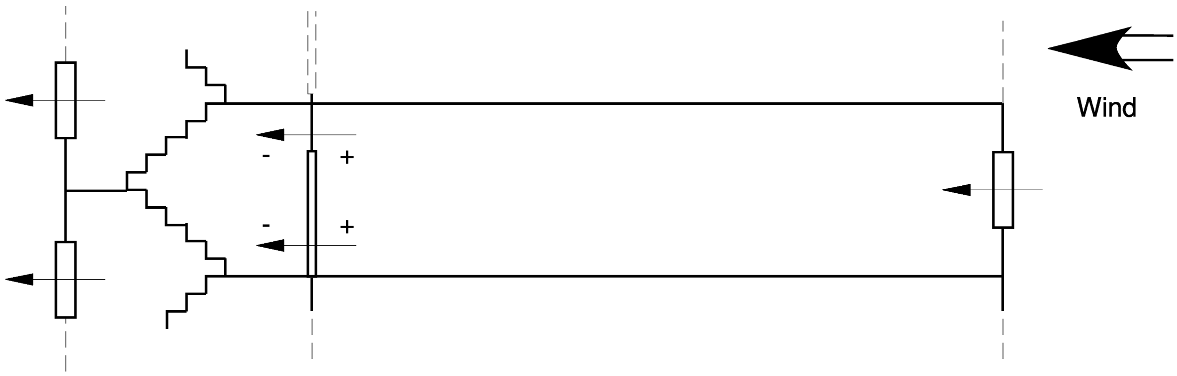
It also follows that the stack effect can only build up pressure differences over the height of the warm column. In a building with complete horizontal separation at each floor storey except in the protected shaft, pressures in the accommodation cannot communicate across the storey, and so the stack effect starts afresh at each storey.

c) *Fire*

The third major cause of pressure difference driving smoke into the protected space is the fire itself. The mechanism here is essentially the same buoyant behaviour as the stack effect, but with much higher temperatures and restricted to the height of the fire room, typically the height of the door, with a neutral pressure plane roughly half way up the door [see Figure 6c)]. The effect is to produce a pressure difference at the top of the door driving smoke into the protected space, with a flow into the fire room at the bottom of the door.

Figure 6 demonstrates that in the worst case the pressure differences at the door linking the accommodation to the protected space reinforce each other. Consequently, it is essential that the minimum design pressure difference for the system is equal to the sum of the three adverse pressure differences.

NOTE 3 Wind and stack pressure differences are present in the absence of any fire. Consequently, when testing an installed system it is important to realize that the measured pressure difference across the target door should be greater than the difference between the design value and the sum of wind and stack pressure differences at that door with the system switched off (see **4.2**).



a) Wind

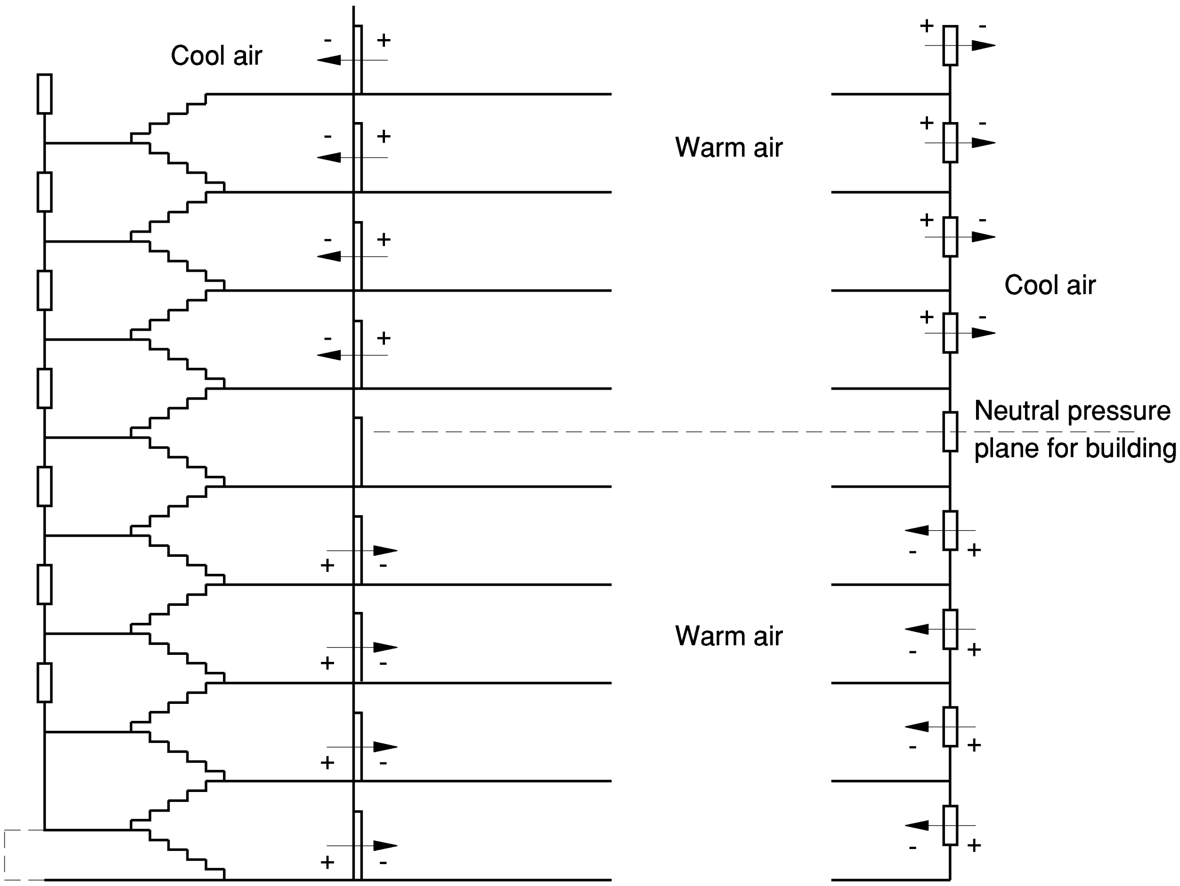
Key

Air leakage flows

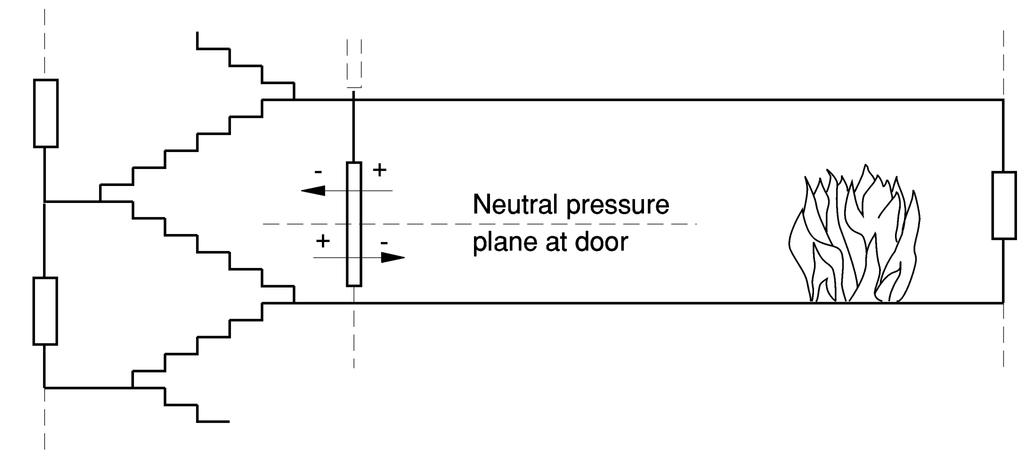
\+ A region of higher pressure

\- A region of lower pressure

Figure 6 — Pressure differences at an internal door



b) Stack effect in a heated building



c) Fire-induced pressure differences at an internal door

Figure 6 — Pressure differences at an internal door *(continued)*

9.1.3 ***Minimum pressure differentials***

To ensure that a system performs satisfactorily the minimum design pressurization or depressurization level should be capable of overcoming the combination of stack, wind and buoyancy pressures that may occur during a fire. The minimum pressure difference required can depend on the nature of the building and its usage (see Clause **5**). See also **5.2**, **5.3**, **5.4**, **5.5** and **5.6** for the values of minimum pressure differential appropriate to design and to acceptance testing.

9.1.4 ***Maximum pressure differentials***

The maximum pressure differential across the doors between the protected space and the accommodation should not be so high as to result in door opening forces which prevent occupants from opening doors onto the escape route. The maximum acceptable pressure differential therefore depends on the force of the door closer, the size of the door and the physical abilities of the occupants. For people escaping, the maximum door opening force should be limited to 100 N at the door handle.

NOTE 1 The corresponding maximum pressure differential across the door may be determined using the equation in **14.4**, as a function of the door configuration. The force required to overcome the door closer will often not be known at the preliminary design stage and a maximum pressure differential of 60 Pa can be utilized for design purposes.

NOTE 2 The force that can be exerted to open a door will be limited by the friction between the shoes and the floor and it may be necessary to avoid having slippery floor surfaces near door openings into pressurized spaces, particularly in buildings in which there are very young, elderly or infirm persons.

9.1.5 ***Building model or simulation***

In such a model the building is typically represented by a network of nodes or spaces, each at a specific pressure and temperature. Stairways and other shafts can be modelled as a vertical series of spaces connected to each floor level. Leakage paths between spaces and to the external air can be simulated together with the effects of wind and stack pressures. Such models enable the simulation of flow rates and pressures throughout the building.

When using a computer simulation of this type it is important to ensure that it has been adequately validated for the type of problem being analysed and that the design assumptions in relation to wind and stack pressures are appropriate.

NOTE 1 The use of a computer model is not a substitute for the physical testing of the installation (see Clause **12** [A2) and BS 5588-12 (A2]).

When utilizing computer simulation techniques to analyse air and smoke flow through buildings, the following measures are recommended.

a) The program should be capable of realistically simulating building airflows and pressure differentials at normal temperatures, but may not need to take account explicitly of the expansion of gases in the fire zone.

b) Use should be made of the following general design assumptions, which have been used in the development of the simplified procedures described in this standard and which will be appropriate for most design purposes:

1) a maximum floor-to-ceiling height of 4 m;

2) an external temperature of −10 °C;

3) an internal building temperature of 21 °C;

4) an external wind velocity at 10 m above ground level of 20 m^3/s;

5) a pressure differential to overcome a fire-induced smoke buoyancy pressure across a doorway of 10 Pa, as well as any wind or stack effect pressures at that doorway.

The calculation procedures detailed in this standard incorporate several safety factors and are appropriate in most circumstances where climatic conditions are similar to those onshore in the UK. However, where severe climatic conditions are anticipated or where the height of the fire compartment exceeds 4 m it may be necessary to vary some of the basic assumptions summarized above.

NOTE 2 Recommended assumptions regarding the number of open doors and their associated flow velocities are given in Clause **5**.

Clear documentation should be produced for submission to the appropriate approvals body of the simulation procedure, the basis of its validation and any assumptions made in the analysis, together with the input data and results.

9.1.6 ***Features of a pressure differential system***

A typical pressure differential system should comprise the following elements (see Figure 7a).

a) *Air intake*. Means should be provided for drawing in fresh air from outside the building in such a way that it is not contaminated by smoke from a fire in the building.

b) *Supply fan and ductwork*. Suitable consideration should be given to the siting and construction of the ductwork and fans supplying fresh air to the pressurized space, to ensure that they are not compromised by fire. Similarly, the outlets of the exhaust ductwork should be in such positions that smoke does not threaten the safety of occupants, firefighters etc.

c) *Pressurized space*. See **3.34**.

d) *Door closers*. All doors between pressurized and unpressurized spaces should be fitted with automatic closing mechanisms.

NOTE 1 The door closing forces may be increased if a pressurization system is installed.

e) *Overpressure relief*. Small gaps and cracks together with open doors provide leakage paths from pressurized to unpressurized spaces. Additional pressure relief such as barometric dampers may be required, for example to ensure that the pressure build-up does not make it difficult to open doors into the pressurized space.

f) *Air release*. Means should be provided for ensuring that the air flowing from a pressurized to an unpressurized space can leak or be extracted to external air by a powered air/smoke release fan so as to maintain the required pressure differential or open door velocity between the two spaces. The extraction of air/smoke from the unpressurized space, while the door to the pressurized space is closed, should not cause the door opening force to be excessive (see **9.1.4**).

In calculating the air supply needed for a pressure differential system, assumptions have to be made about the leakage characteristics of the building, in particular between:

— pressurized and unpressurized spaces;

— adjoining pressurized spaces;

— pressurized spaces and the external air;

— unpressurized spaces and the external air.

NOTE 2 In existing buildings it is advantageous to measure the leakage characteristics before the detailed design is carried out.

It is essential that agreement is reached between the specifiers and the designers as to what products, components and construction techniques will be used in the building. Particular attention should be paid to the construction of the shafts to be pressurized and the building envelope. Unrealistic assumptions about the air-tightness of these constructions are a common cause for pressure differential systems failing to meet acceptance criteria.

It is essential that the architect and the builder are made aware of the importance of controlling leakage areas from the pressurized spaces so that, when fitted out, there is not an excessive loss of pressurizing air.

In a single-stage pressure differential system the pressurization is applied only when a fire occurs, and in a two-stage pressure differential system a low level of air supply is maintained at all times, for example for ventilation, and is increased to the emergency level when a fire occurs. Either system is acceptable.

The emergency level of pressurization should be the same whether a single or two-stage pressure differential system is used.

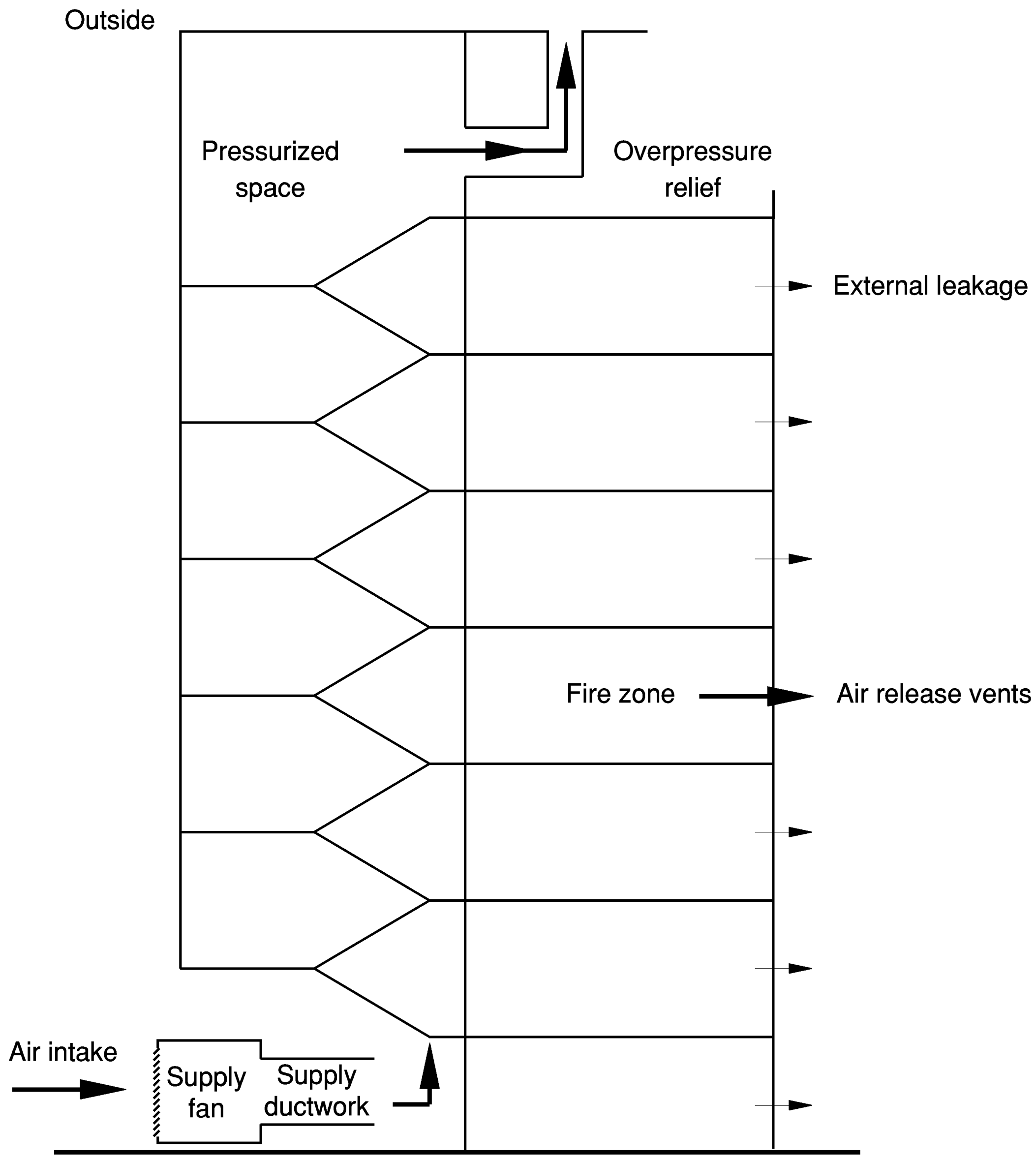


Figure 7a — A1 Principles of a typical stair pressure differential system for means of escape A1

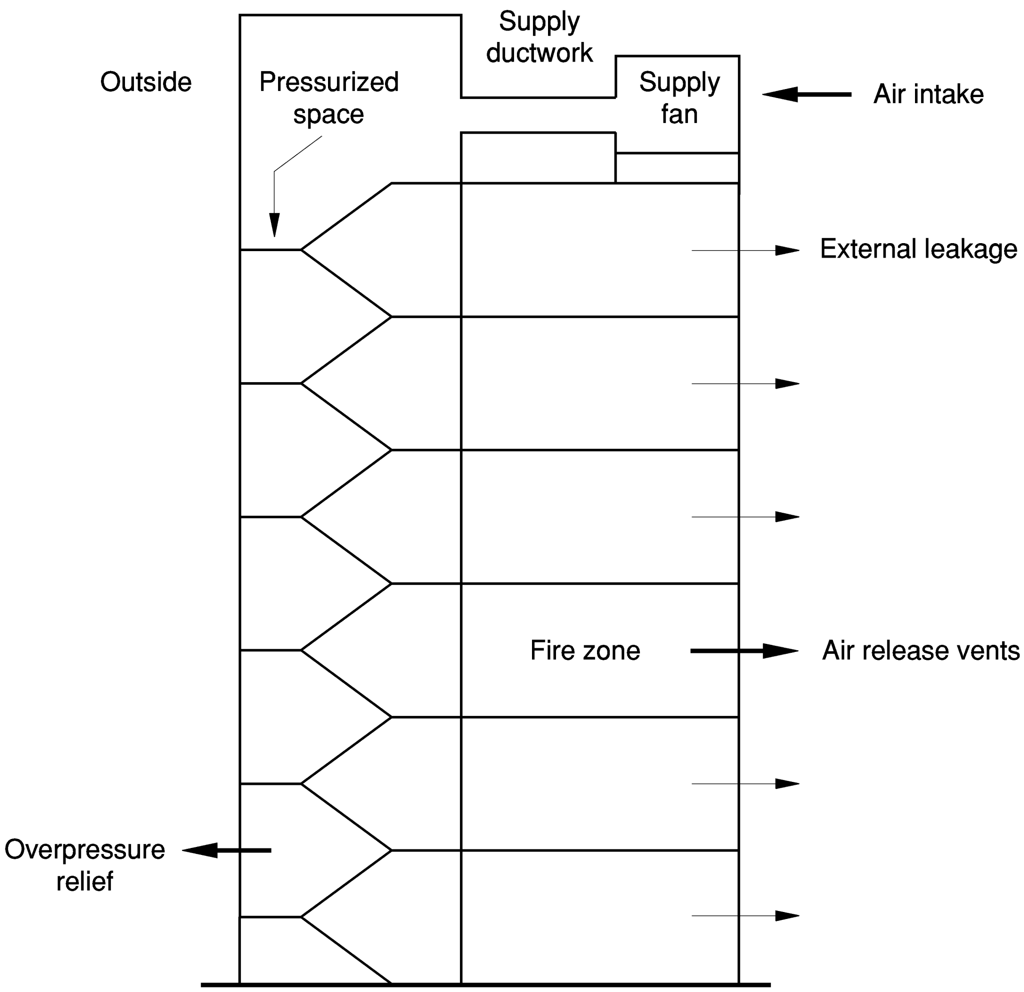


Figure 7a — [A1⟩ Principles of a typical stair pressure differential system for means of escape *(continued)* ⟨A1]

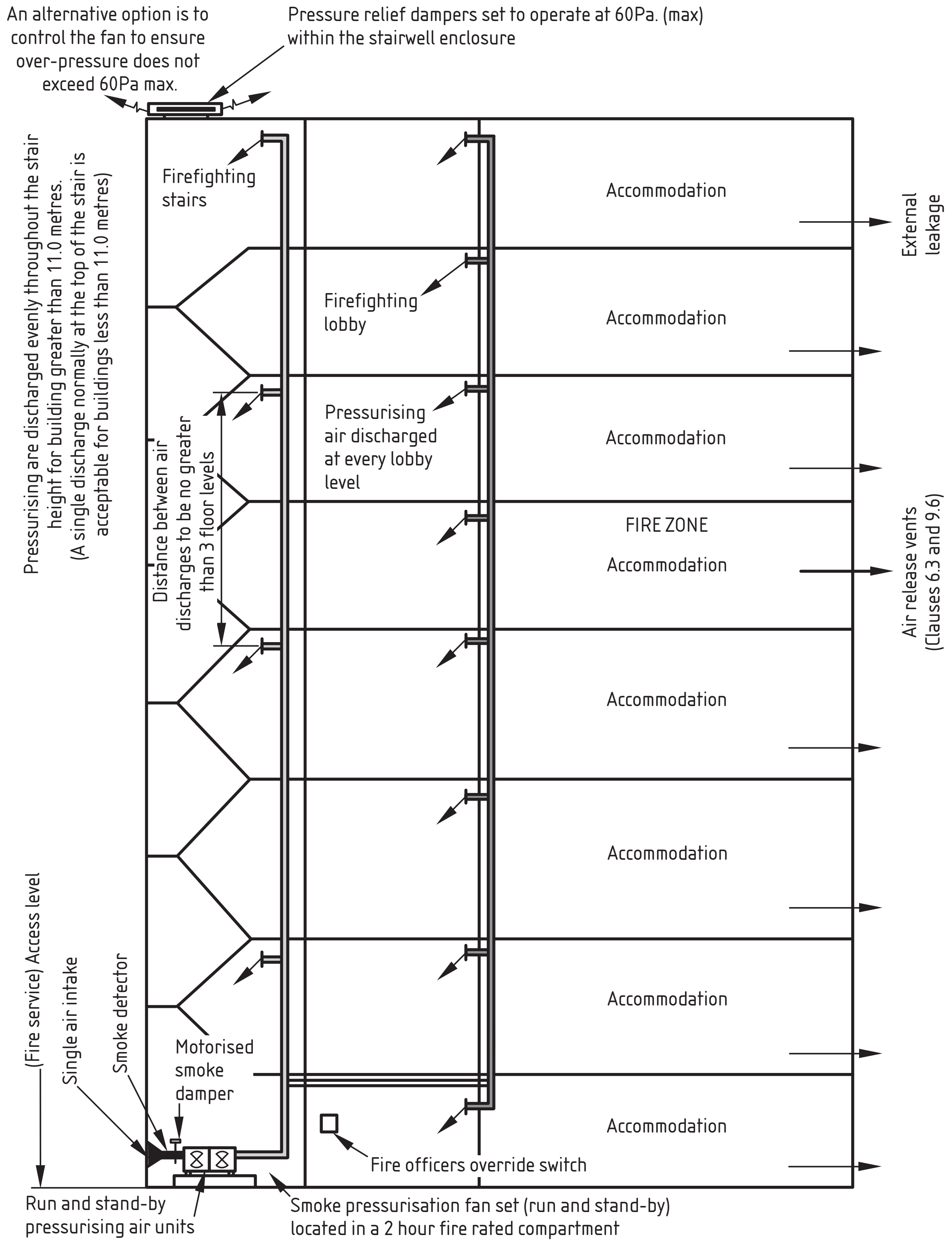


Figure 7b — [A1⟩ Principles of a typical stair pressure differential system for a firefighting shaft ⟨A1]

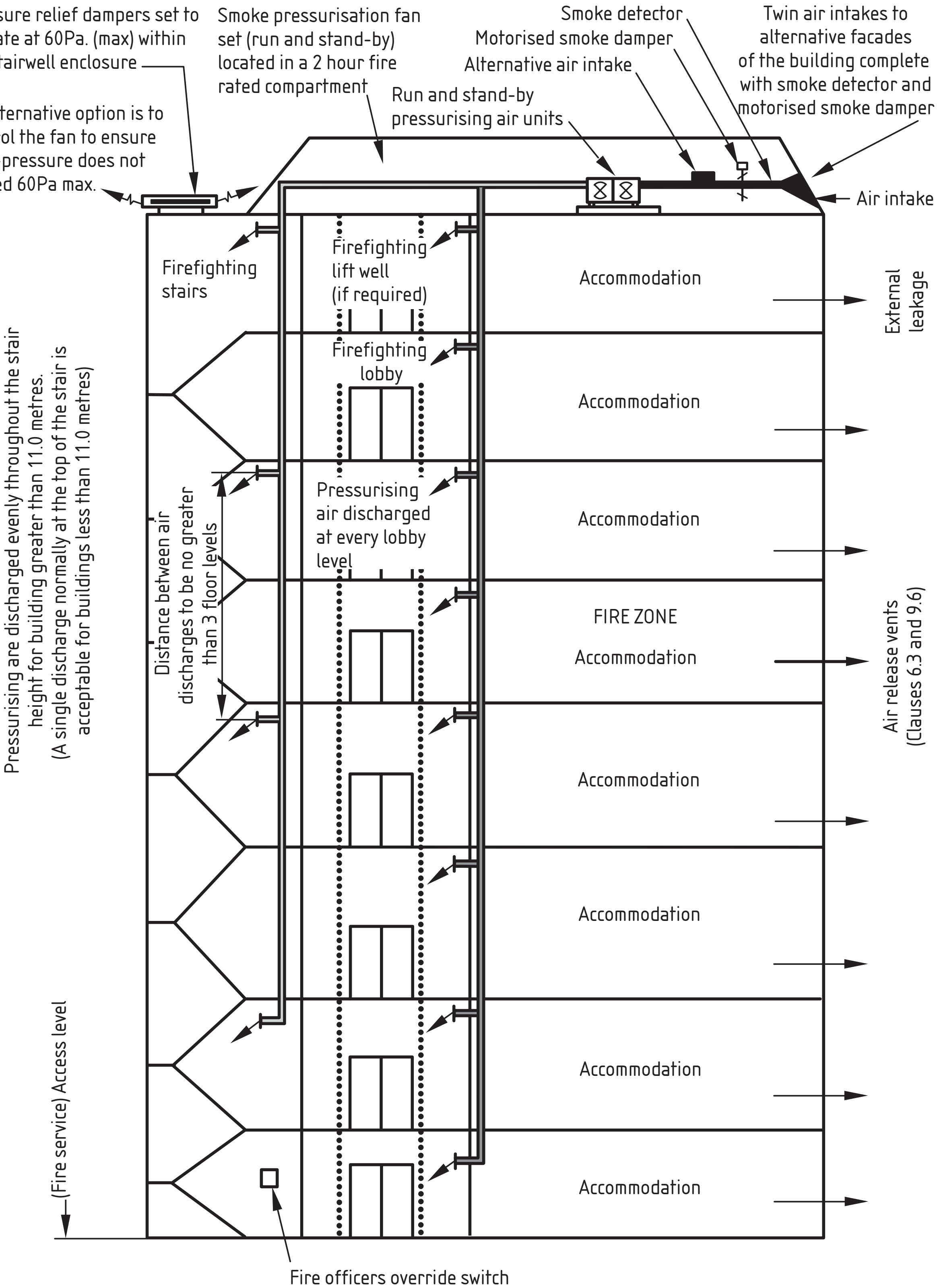


Figure 7b — [A1) Principles of a typical stair pressure differential system for a firefighting shaft *(continued)* (A1]

9.2 Pressurization systems

9.2.1 *General*

The space to be protected should be supplied with fresh air to maintain the pressure at a level higher than that in the fire zone (see Figure 8). In this way air moves towards the fire from the protected space, thus preventing smoke flow in the opposite direction. The provision of a leakage path from the accommodation to the external air is essential, in order to maintain a continuous flow out of the protected space.

NOTE If there is no leakage path, the pressure differential between the accommodation and the protected space cannot be maintained and smoke spread between the two areas will occur.

The two basic requirements for a pressure differential system are:

— a mechanically driven supply of fresh air into each protected space, to maintain the pressure at a level higher than that in the fire zone;

— a leakage path from the accommodation to the external air, to maintain a continuous flow out of the protected space, preventing pressure equalization.

Depending upon the design it may also be necessary to provide for overpressure relief from the protected space (see **9.7**).

Evacuation of the fire-affected storey should occur within the early stages of fire development and should be completed before conditions within the accommodation become untenable, making access to protected escape routes impossible. The storey exit doors should then be closed. During this initial period the potential for contamination of the protected routes is small. Consequently, there is no need for the pressure differential system to hold back smoke from a fully developed fire at an open door, as long as the airflow is sufficient to hold back such cool smoke from the fire floor whilst persons are escaping.

Following evacuation of the fire-affected storey, the fire can continue to develop with the potential to induce smoke flow into the stair via gaps around stair and lobby doors. It is therefore important to ensure that a positive pressure is maintained within the stair for the full duration of the evacuation process. However, during this stage the final exit from the stair is likely to be continuously in use, producing a loss of pressurizing air and hence tending to reduce the pressure in the stair, and it is necessary to take account of this when calculating the air supply.

Protected escape routes should be constructed in accordance with the appropriate part of BS 5588.

All doors onto the pressurized space, excluding the final exit door, should be fitted with a self-closing device.

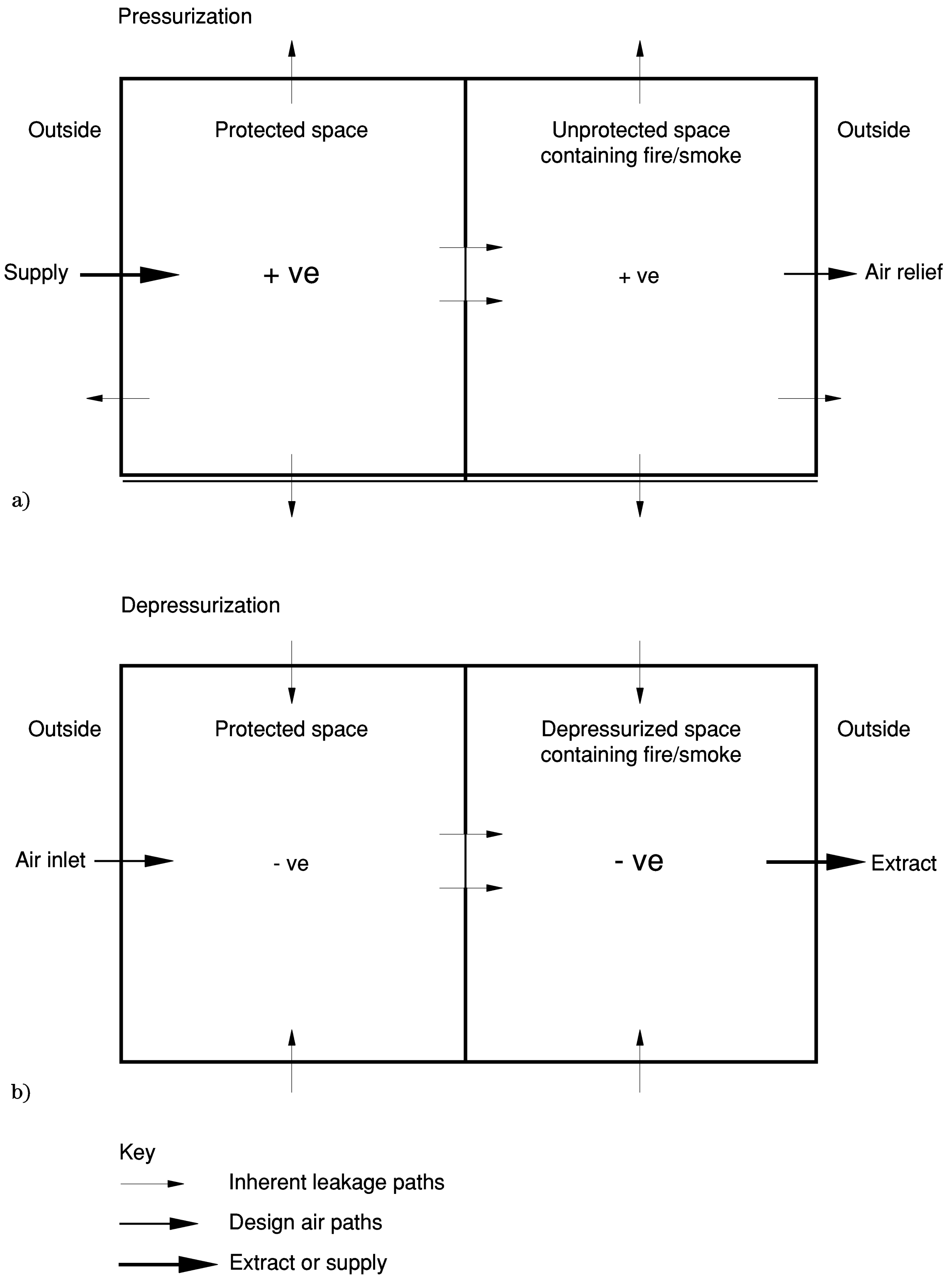


Figure 8 — Airflow patterns for pressure differential systems

9.2.2 ***Choice of spaces to be pressurized***

9.2.2.1 *General*

The design considerations detailed in **9.1.6** should be taken into account when deciding which spaces to pressurize. The various configurations of pressurized and adjacent non-pressurized spaces are considered in **9.2.2.2** to **9.2.2.8**.

9.2.2.2 *Pressurization of protected escape routes*

9.2.2.2.1 A pressure gradient (and thus an airflow pattern) should be established when stairs, lobbies and corridors etc. are pressurized, with the protected space at the highest pressure and the pressure progressively decreasing in areas remote from the protected space.

One or more of these spaces (stairs, lobbies and corridors) may be pressurized but full protection should be assumed to be afforded only to those spaces that are directly pressurized; secondary protection may be afforded to adjacent areas. The spaces most commonly pressurized are:

a) stair only;

b) stair and lobby only;

c) stair, lobby and corridor.

9.2.2.2.2 *Pressurizing the stair only*

The protection afforded by this method is confined to the vertical part of the escape route; no significant protection is afforded to the horizontal part of the escape route on each storey.

Where a pressurized stair is separated from the fire zone by a naturally-ventilated lobby, the protection afforded by pressurization is completely confined to the stair. If the lobby is ventilated for reasons other than smoke control, the pressure differential system will do little to keep the lobby clear of smoke as it will only provide a steady supply of fresh air to dilute any smoke entering the lobby [see Figure 9a)].

For this method, the stair should be designed to be approached directly from the accommodation or through a simple lobby.

All systems pressurizing the stairs on all storeys should be activated simultaneously whenever there is an alarm of fire.

9.2.2.2.3 *Pressurizing the stair and lobby*

Where, on any storey, the lobby separating the stair from the accommodation is other than a simple lobby, this lobby should be pressurized independently of the stair, in order to carry the protection against smoke ingress right up to the door leading towards the accommodation area in which a fire might occur [see Figure 9b)].

The lobby should have pressurizing air supplied through ductwork that is independent of that supplying the stair.

With all doors closed, the pressure differences across the door between the lobby and the accommodation should be as shown in Figure 9b).

All pressurized stairs and pressurized lobbies on all storeys should be pressurized simultaneously whenever there is an alarm of fire.

9.2.2.2.4 *Pressurizing the stair, lobby and corridor*

Where the lobby opens into a corridor that forms part of the escape route, the pressure differential system may be extended to include the corridor and so take the smoke control right up to the door of the fire zone. However, if the corridor has many doors (or other leakage paths) the air supply needed may be large. The design aim should be to ensure airflow from the stair, through the lobby, through the corridor and into the accommodation spaces [see Figure 9d)].

For this method, the corridor should be a protected corridor, and should have pressurizing air supplied from a duct (or source) that is separate from the lobby and the stair supply.

NOTE An unventilated lobby may be pressurized by air leakage from the stair.

With all doors closed, the pressure differences across doors between the corridor and the accommodation should be as shown in Figure 9d).

Arrangements should be made to ensure that the corridor has adequate leakage to the external air, either directly or via the accommodation.

Only the corridor on the fire-affected storey need be pressurized.

All systems pressurizing stairs and lobbies on all storeys should be activated simultaneously whenever there is an alarm of fire.

9.2.2.3 *Pressurizing stair and lift*

Where smoke enters an unpressurized lobby, a lift well forms a potential route for the spread of smoke from the fire storey to other storeys. By pressurizing the lift well it is possible to restrict the spread of smoke via the lift well to other storeys. The pressurization of the lift well may also be required for firefighting purposes [see Figure 9c)].

Where a lift is accessed via an unpressurized lobby, the lift well should be pressurized to the same level as the associated stair.

All systems pressurizing the stair and lift well on all storeys should be activated simultaneously whenever there is an alarm of fire.

9.2.2.4 *Pressurizing lobbies and/or corridors only*

Lobbies and/or corridors connected to an unpressurized stair should not be pressurized as any smoke that does enter the lobby may be forced into the unpressurized stair.

9.2.2.5 *Pressurization of lift wells*

Some lift wells may require pressurization for firefighting purposes. It may also be desirable to pressurize other lifts in special buildings, e.g. hospitals, where there could be delays in the evacuation of infirm, disabled or elderly people. Pressurized lift wells should not be considered as an alternative to normal requirements for means of escape but as an additional measure that could improve the level of life safety. For pressure differential system design purposes non-firefighting lifts should be considered on the same basis as firefighting lifts.

9.2.2.6 *Pressurization of firefighting shafts*

A pressure differential system may be used to minimize the potential for the serious contamination of firefighting stairs by smoke during fire service operations. BS 5588-5 provides guidance regarding the general design and construction of firefighting stairs and lifts.

During firefighting operations it is necessary to open the door between the firefighting lobby and the accommodation to deal with a fully developed fire. Where a firefighting shaft includes lobbies, stairway and a firefighting lift each of these elements should be pressurized separately to ensure that the likelihood of contamination of each part of the shaft is kept to a minimum. A single plant may be used for this purpose, providing that arrangements are made within the plant room to direct the pressurizing air to each part of the firefighting shaft separately. If any part of the firefighting shaft enclosure fails, the pressurizing air supply should continue to be supplied to the remaining parts of the firefighting shaft.

9.2.2.7 *Pressurization of evacuation lift wells*

A tenable environment should be maintained within the evacuation lift well. The provision of a lift pressure differential system may be used to increase the level of protection to an evacuation lift. See BS 5588-8 for the design of evacuation lifts for disabled people.

NOTE A firefighting lift may be used for the evacuation of disabled persons prior to the arrival of the fire service, who will then assume responsibility for the evacuation of any remaining persons.

Evacuation lifts should conform to the relevant clauses of BS 8300, BS 5655-1 and BS 5588-8, and should be located within a protected enclosure consisting of the lift well itself and a protected lobby at each storey.

An evacuation lift well should not be pressurized if it connects to the same lobby as an unpressurized stair.

Where an evacuation lift is pressurized then, for design purposes, all lift landing doors may be assumed to be closed, and either:

— the lift well should be pressurized to the same level as the associated pressurized stair;

or

— the pressure difference between the lift well and the accommodation should be not less than 50 Pa (±10 %) where a lift is approached through a lobby that does not provide access to any other shaft.

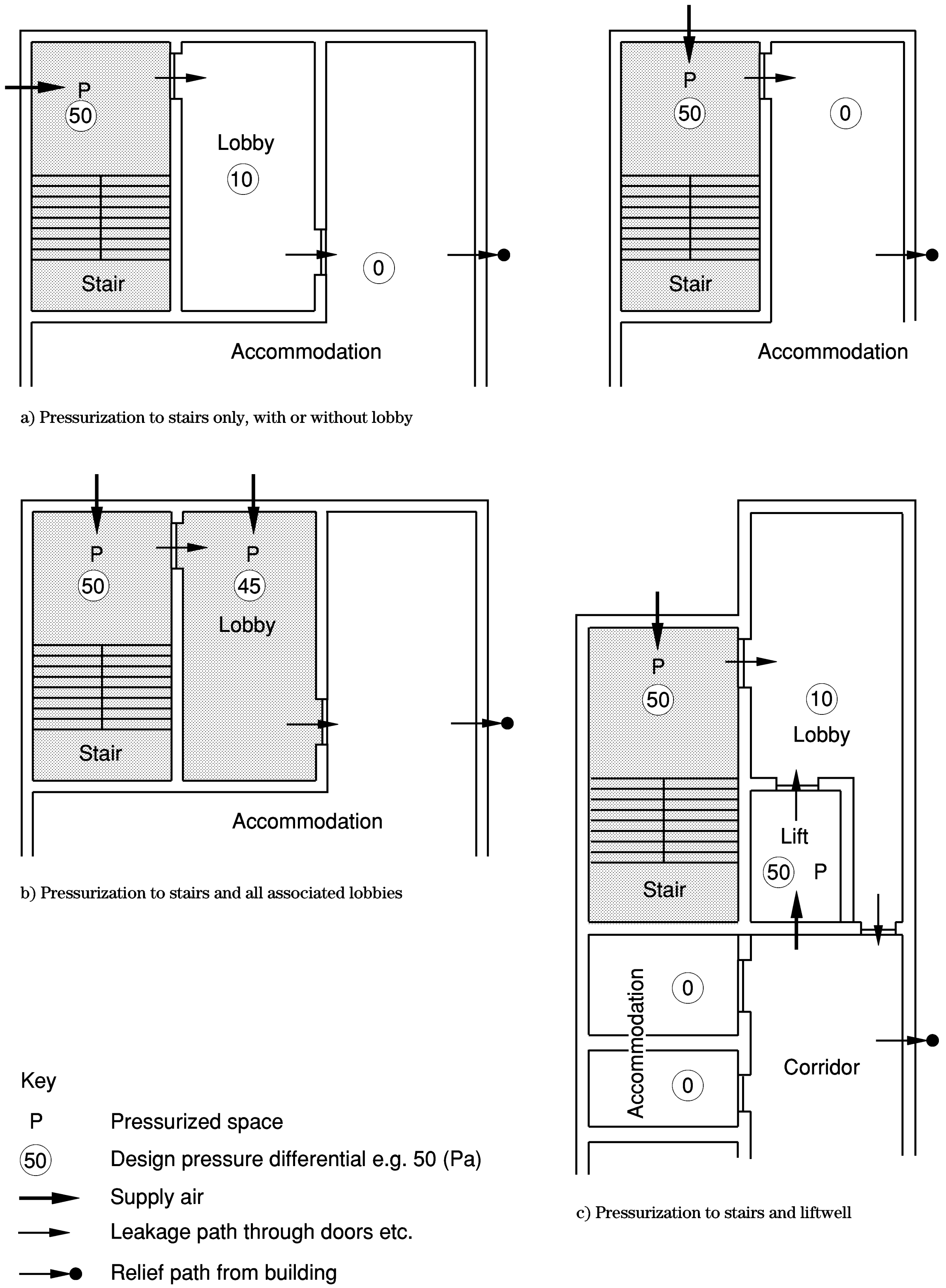
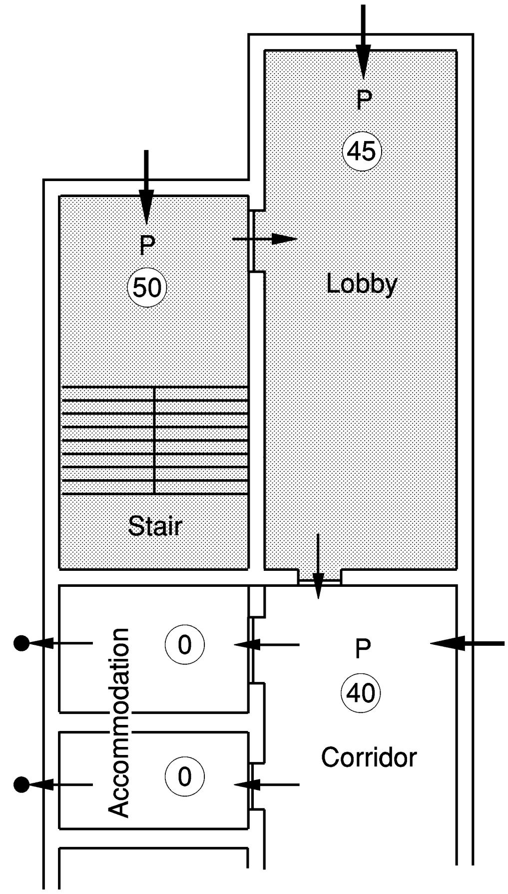
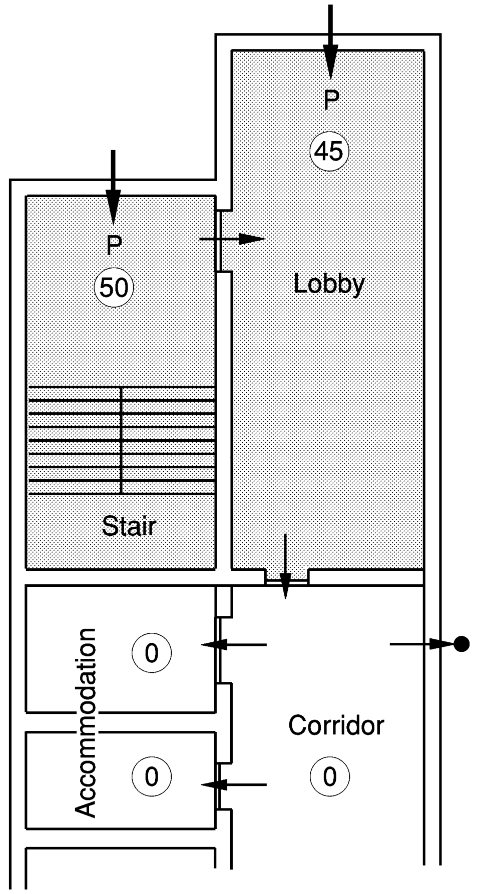


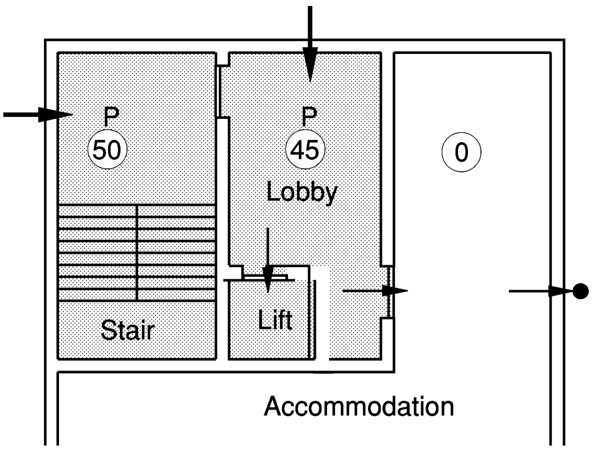
Figure 9 — Stair pressure differential system configurations



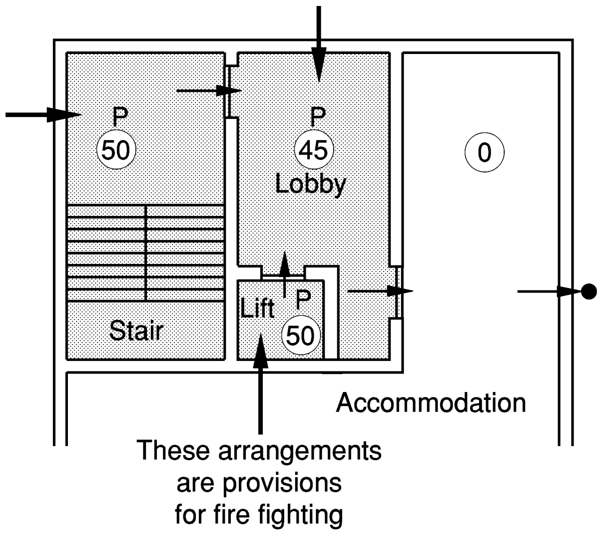
d) Pressurization to stairs (associated lobbies and corridors)



e) Pressurization to stairs and associated lobbies, relief from corridors



f) Pressurization to stairs and lobbies (not liftwells)



g) Pressurization to stairs, lobby snd liftwell

Figure 9 — Stair pressure differential system configurations *(continued)*

9.2.2.8 *Pressurization of refuges and central control rooms*

It may be necessary to provide refuges and central control rooms in buildings where occupants need to await evacuation for some time after the inception of a fire. The refuge or central control room should be separated from the fire zone by fire-resisting construction and should be provided with a protected route to a storey exit. Guidance on refuges for disabled people is given in BS 5588-8.

In many buildings the refuge room may form part of the protected escape route, for instance, when stairway and lobby are pressurized and the lobby is used as the refuge. In such cases the design should ensure that the lobbies are large enough for their purpose.

Where a central control room needs to be staffed during the course of a fire, it is essential that a fire-resisting construction is used and a protected route to a storey exit provided.

A net pressure differential of 25 Pa between the refuge or central control room and fire zone should be sufficient to overcome the effects of wind and buoyancy on the fire storey (see Figure 10). Stack effect need not be considered since the refuge or central control room does not connect directly to other storeys within the building [see Figure 10a) and Figure 10b)].

The pressurized space should also be a fire compartment.

Where more than one system serves any storey, account should be taken of the total leakage paths via the unpressurized spaces with all the systems operating simultaneously.

In many cases the normal HVAC system may be used as a means of supplying air to the pressurized space; in other cases a dedicated air supply system may be necessary.

NOTE The "open-door" airflow recommendation (see Clause **5**) applying to stairwells and lobbies does not apply to refuges or central control rooms which are not integral with a pressurized stairwell or a pressurized lobby.

A pressurized refuge or central control room should not be connected to an unpressurized stair and the pressure within the refuge or central control room should not be greater than that within the pressurized stair.

9.2.3 ***Implications of pressurization system for building design***

9.2.3.1 *Pressurized and unpressurized stairs in the same building*

Where pressurized and unpressurized stairs are present in the same building, the potential exists for the unpressurized stair to become smoke logged as a direct result of the airflow created by the pressure differential system.

All stairs in a building should be pressurized unless it can be clearly demonstrated that smoke will not be forced into the unpressurized stairs as a result.

The use of pressurized and unpressurized stairs serving the same storeys should only be considered if either of the following conditions is met.

a) The unpressurized stair is separated from the pressurized stair by a large undivided space, and air can escape by an opening twice as large as the door through which it enters.

b) A detailed design flow analysis has shown that operation of the pressure differential system would not increase the airflows on the fire storey into the unpressurized stair.

NOTE In the case of item b), detailed evidence should be supplied by the designer to justify this approach in the circumstances of the design.

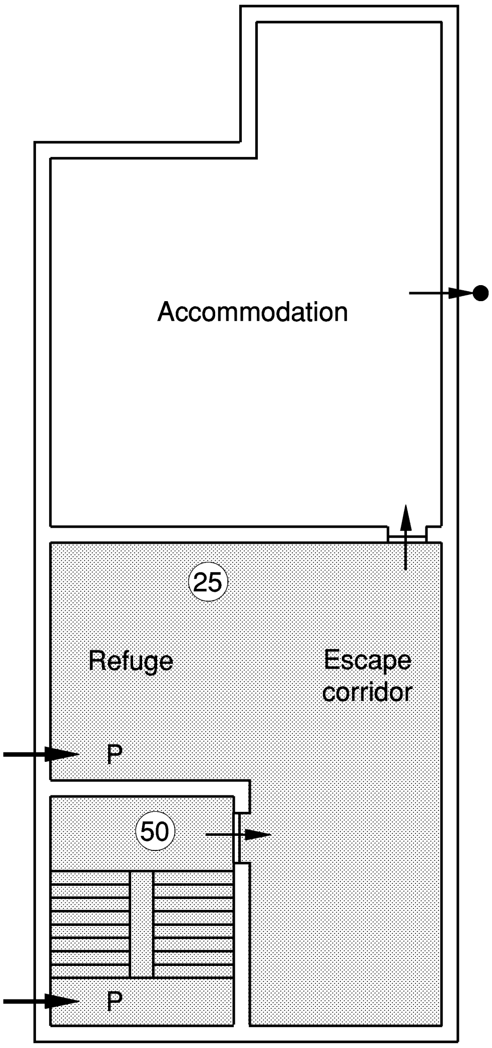
9.2.3.2 *Pressurized escape routes and other pressurized spaces in the same building*

A building may contain several spaces, such as computer suites or medical facilities, that are pressurized for reasons other than fire, and therefore consideration should be given to protecting pressurized escape routes from the effects of fire in such pressurized spaces.

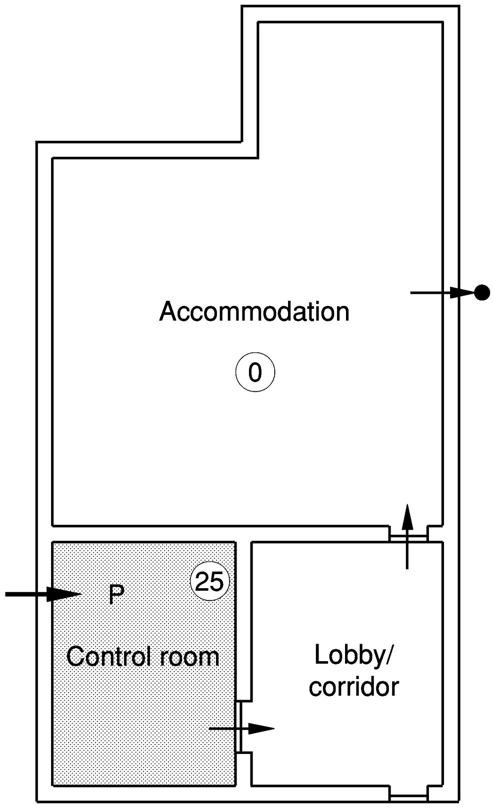
Each pressurized escape route should have its own independent air supply.

Where a pressurized escape route is directly connected to a pressurized space, the pressure in the escape route should be at least 10 Pa greater than that of the pressurized space.

Suitable leakage arrangements should be provided in unpressurized spaces to allow the pressurizing air from all the pressurized spaces to escape to external air.



a) Unenclosed refuge, integrated with escape route



b) Enclosed control room, with escape route

Key

P Pressurized space

(50) Design pressure differential e.g. 50 (Pa)

→ Supply air

→ Leakage path through doors etc.

→● Relief path from building

NOTE Control rooms have to be enclosed as in Figure 10b).

Figure 10 — Pressurization of refuges and central control rooms

9.2.3.3 *Interaction with normal ventilation equipment*

The purpose of a pressurization system is to establish a differential pattern in the building that limits the spread of smoke towards or past the doors onto the protected escape route. It is therefore preferable that the airflow patterns established in the building by the normal HVAC systems should also be away from escape routes. This can be achieved by integrating the ventilation and pressure differential systems in such a way that graded pressurization levels are established from the escape route down to the occupied spaces in which a fire might occur.

The design of HVAC systems providing zoned smoke control in addition to pressurization should only be considered as part of a full fire-engineered solution for the entire building (see **9.4**).

The design of HVAC systems providing the removal or relief of vitiated air from the fire zone in conjunction with the pressure differential system should be in accordance with Annex C.

9.3 Depressurization systems

9.3.1 ***General***

In some buildings pressurization may not be a practical option and it may be preferable to use depressurization, e.g. basement occupation enclosures or occupation enclosures of fire-resistant sealed-envelope design and construction. A depressurization system reduces the pressure in the fire-affected zone to below that in the protected space (see Figure 11). The pressure differential created draws air into the fire zone via leakage paths from the adjacent accommodation, and also from external air. This limits the smoke flow in the opposite direction, from the fire zone to the accommodation and the protected space.

In order to prevent the pressures in the fire zone and the protected space from equalizing, sufficient air from outside the building should be provided to the protected space to maintain the airflow into the fire zone.

A depressurization system should achieve the same protection at the doorway between the depressurized space (e.g. a basement) and the protected space (e.g. a stairwell) as would be achieved by pressurizing the protected space. It is important to note that this gives no protection to any part of an escape route within the depressurized space itself, which may be entirely filled with smoke, or may even be fully affected by fire. This constitutes a fundamental difference between depressurization and smoke exhaust ventilation, with which it is sometimes confused.

NOTE 1 Smoke exhaust ventilation is a technique for protecting means of escape (or property) within the same space as the fire itself by using the buoyancy of the gases to achieve a vertical separation between the smoky gases and the protected space.

[A1) NOTE 2 Air release path from the accommodation on the storey (fire floor) where the pressure difference being measured is open (50 PA ± 10 %). (A1]

9.3.2 ***Depressurization of fire zone***

Each depressurized space should be bounded on all sides by fire-resisting construction, since any loss of integrity would result in equalization of pressure between the depressurization zone and the external air (see Figure 11), rendering the depressurization system ineffective. Extract ductwork should also be capable of handling the high temperature smoke and gases that are produced in the fire zone.

Since depressurization zone boundaries need to be fire-resisting, a depressurization system is likely to be unsuitable in open plan buildings with glazed exteriors. However, in compartmented buildings it may be possible to depressurize individual spaces. Where, for example, a building contains areas of high fire risk, depressurization may be used to limit the spread of smoke from such high-risk areas to other parts of the building.

The most appropriate use of depressurization systems is likely to be in basement spaces.

Depressurized zones should be bounded on all sides (including the floor slab above and below) by construction having fire resistance at least equal to that required for the protected space.

All doors to the depressurization zone should be self-closing.

The extract ductwork from the depressurization zone should be in accordance with BS 476-24.

The extract fan from the depressurization zone should be capable of handling smoke at a temperature of 600 °C for unsprinklered buildings, or 300 °C for sprinklered buildings, for a period at least equal to that required for fire resistance of the protected space.

With all doors closed, the extraction rate of smoke and hot gases from the depressurization zone should be capable of maintaining a pressure differential not less than that given in Clause **5** for the appropriate classes of system and, where relevant, the open door airflow criterion.

Inlets from external air to the protected space should be provided to ensure replacement airflow from the protected space to the depressurized space.

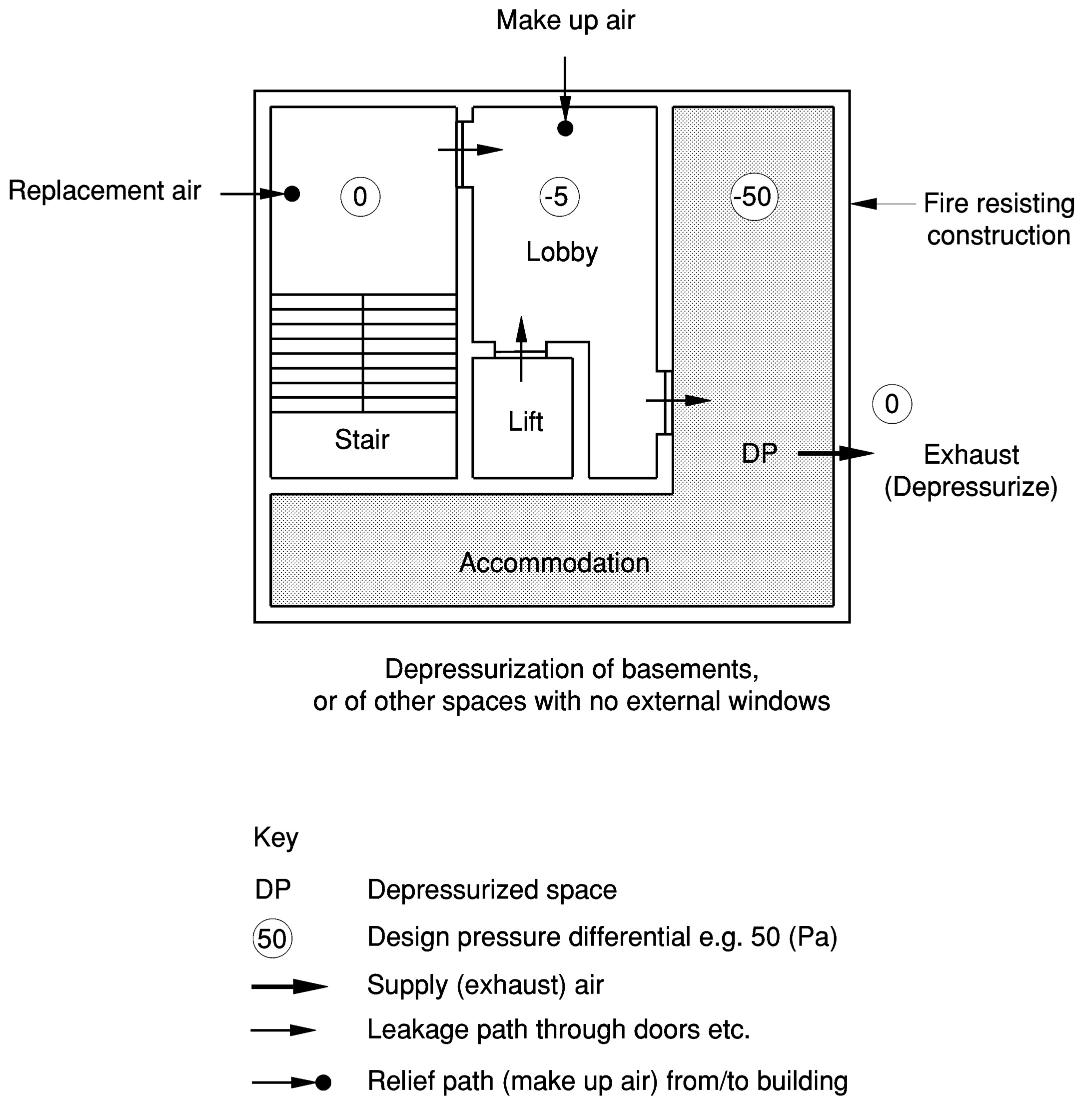


Figure 11 — Features of a depressurization system

9.4 Zoned smoke control systems

9.4.1 *General*

During a fire, smoke and toxic gases can spread through construction gaps and service shafts to areas removed from the initial fire source. Whilst compartmentation should prevent fire spread between storeys it may also be desirable to provide smoke control to restrict the spread of smoke and hence to protect the following:

— rooms that cannot be evacuated immediately in the event of a fire either because of other safety implications (e.g. air traffic control towers or process plant control rooms) or for practical reasons (e.g. hospital wards with bed-ridden patients or tall buildings where phased evacuation is being used);

— rooms that house expensive or safety-related equipment that could be damaged or rendered inoperative by smoke contamination, e.g. computer suites.

Zoned smoke control systems are intended to limit the spread of smoke from storey to storey (or zone to zone) within a building. The general approach is to divide the building up into a number of smoke control zones, the size and number of which vary according to the particular building circumstances. Typically each storey may be considered as a smoke control zone. The boundaries of the zones that limit the movement of smoke are the walls, floors, doors etc., within the building. Pressure differentials are produced by exhausting from the fire zone and supplying fresh air to the surrounding areas.

9.4.2 *Features of a zoned smoke control system*

In many buildings the most convenient means of supplying air to and exhausting from the relevant smoke control zones is by adapting the HVAC system.

Most HVAC systems are capable of providing in excess of three air changes per hour. This can be used to assist in restricting to some degree the spread of smoke from one zone to another.

Ventilation systems intended for use in zoned smoke control applications should satisfy the following minimum recommendations.

a) For systems serving multiple smoke control zones:

1) the common air supply should be capable of being selectively shut off from any zone by a remotely controlled smoke damper or, where the supply ductwork passes through the accommodation, by a combination fire/smoke damper;

2) the common exhaust should be capable of being selectively shut off from any of the covered zones by a remotely controlled smoke damper or a combination fire/smoke damper;

3) the HVAC system should be capable of fully closing off any return air by means of a remotely controlled damper, to prevent recirculation of smoke into the supply air.

b) For systems serving only one smoke control zone:

1) the system should be capable of operating in a supply-only as well as an exhaust-only mode;

2) the HVAC system should be capable of fully closing off the return air by means of a remotely controlled damper, to prevent recirculation of smoke into the supply air.

c) Duct materials should be selected and the ducts designed to handle smoke, withstand additional pressure (both positive and negative) by the supply and exhaust fans when operating in a smoke control mode, and to maintain their structural integrity during the period for which the system is designed to operate.

9.4.3 *Choice of smoke control zones*

The choice of smoke control zones is likely to be dictated by the air conditioning zones. In some buildings it is likely that the zoning of the building for ventilation purposes will be different from that designated or desirable for smoke control purposes and this may preclude the use of a zoned smoke control system.

There are no predefined limits for the size of smoke control zones. However, since the concentration of smoke in the smoke zone will go unchecked it is important that the occupants should be able to evacuate the zone quickly in the event of fire. It is also advisable that zones are kept as small as practicable so that the quantity of air required to pressurize the surrounding spaces is kept to a manageable level. Conversely, the smoke control zones should be large enough to ensure that the hot smoke and gases produced by the fire are sufficiently diluted with surrounding air to be cooled to a temperature that will not cause failure of the components of the smoke control system.

Smoke control zones may be separate storeys, parts of storeys, or even a number of storeys together. The choice of zones depends on the building configuration and it is left to the discretion of the designer to identify the most appropriate layout, e.g. in high rise buildings with individual air handling units at each storey it is sensible to zone on a storey-by-storey basis, but in a hospital facility where horizontal evacuation is planned, it is advisable to divide each storey into a number of smoke control zones to give a greater degree of protection.

All of a building, other than the fire floor, may be pressurized, or alternatively only those spaces adjacent to the fire zone. However, the protection afforded by the latter approach is limited in that it is possible to have smoke flow through shafts past the pressurized zone and into the unpressurized spaces, particularly if the building is zoned on a storey- by-storey basis. Figure 12 indicates the common arrangements of smoke control zones.

Individual smoke control zones should be separated from each other by fire-resisting boundaries.

The choice of smoke control zones should be consistent with the location and zoning of smoke detectors to avoid actuation of the wrong zones.

Automatic actuation of a zoned smoke control system which is designed to exhaust air from the fire area and supply air to the other areas should be carefully considered before being undertaken because of the possibility of actuation of a detector outside the zone of the fire origin.

Zoned systems should not be activated from manual call points, because the call point may not be located in the fire zone.

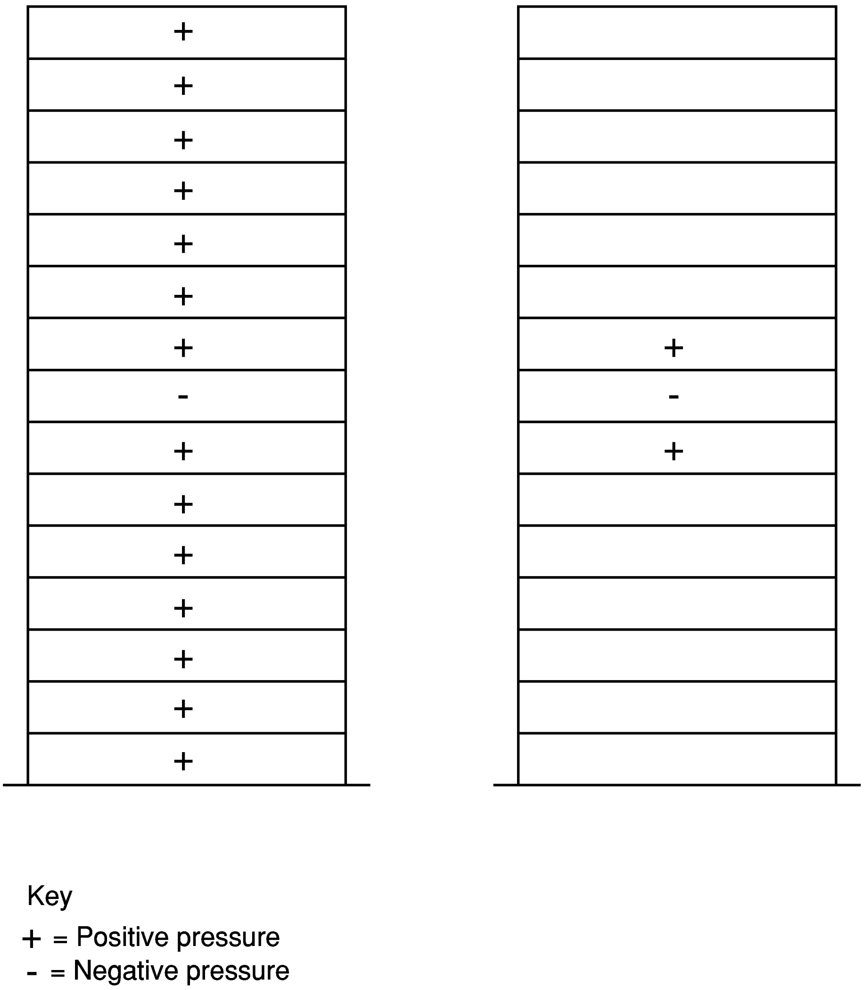


Figure 12 — Configuration of zoned smoke control system

9.5 Air supply — stair pressurization systems

When designing pressure differential systems for stairways it should be ensured that there is an even distribution of pressurizing air throughout the stair and that there is no likelihood of the air supply being short-circuited.

Where doors are open near to the injection point, supply air can be lost through them and adequate pressurization may not be achieved at doors further from the injection point. This may be particularly true in the case of ground level injection systems where the exit door is likely to be open for substantial periods of time.

When a stair pressure differential system is designed on the basis of an open door at final exit level, the vertical airflow in the shaft is likely to be high and consequently the pressure losses due to friction may be substantial. The distance between injection points should be kept relatively small to reduce the pressure drop.

Where the supply point is located near the final exit door an analysis such as described in **9.1.5** is desirable to ensure that the recommended pressures are achieved at each storey.

A separate pressure differential system should be provided for each pressurized stair.

For buildings not exceeding 11 m in height, a single air supply point for each pressurized stair is acceptable. Where a single air supply point is being provided it should not be located at or near the level of the final exit door. In most cases the most suitable position will be at the top of the stair.

For buildings exceeding 11 m in height, air supply points should be evenly distributed throughout the height of the stair, and the maximum distance between air supply points should not exceed three storeys unless it can be demonstrated by appropriate analysis (see **9.1.5**) or by testing of the completed [A2) system so that the design objectives can be met with a greater spacing. (A2]

9.6 Air release

During operation of the system, pressurizing air flows from the pressurized space into the accommodation. It is important that provision is made on the fire storey for the air that has leaked into the unpressurized spaces to escape from the building, in order to maintain the pressure differential between pressurized spaces and the accommodation. Relief vents should be located at as high a level as possible and well away from storey exits.

[A1) The required pressure differential should be maintained across the accommodation door with the air release open only on the fire floor. (A1]

As it is not possible to exercise continuing control over air relief paths through dwellings in blocks of flats and maisonettes, there should be an air relief path from each common corridor.

The required leakage rate depends on the particular layout of the building and the application of the pressure differential system.

In many cases the leakage paths via normal ventilation ductwork will be sufficient, particularly if the extract continues to operate as described in Annex C. The effective air release capacity will be restricted if fire dampers operate and isolate the ductwork in the fire zone (see Annex C).

On each storey in blocks of flats and maisonettes the air relief paths should be from the common corridors directly to the open air.

If it can be shown by an appropriate fire engineering study that sufficient leakage paths via the ventilation system will be available prior to window breakage, it is not necessary to provide additional provision for air release from the building. In the absence of such a study, air release should be provided by one of the following methods.

a) *Special vents at the building periphery*. Where the building is sealed, special vents should be provided on at least two sides of the building.

NOTE 1 In existing buildings situations may arise where periphery venting can only be achieved on one face of the building. This may be acceptable under exceptional circumstances, with the prior approval of the controlling authority, if compensatory features are made available, e.g. three door protection to the escape route or the periphery vent is designed to compensate for the possible adverse actions of the wind.

NOTE 2 If the unpressurized space is partitioned or compartmented into offices or similar units, then the relief vent should be provided between the door into the pressurized space and the start of the partitioning.

b) *Vertical shafts*. If venting the pressurizing air by building leakage or peripheral vents is not possible or desirable, vertical shafts may be used for this purpose (see **14.3.4**).

c) *Mechanical extraction*. The release of the pressurizing air by mechanical extraction is a satisfactory method.

[A1] System designs should be checked to ensure all requirements of the standard are met when using mechanical air release. In particular the specified pressure differences across closed doors and the opening forces (see **9.1.4**) should not be exceeded. [A1]

In assessing the effective area of air release venting required per storey, one side of the building should be discounted. Where the venting is not evenly distributed around the external wall, the side with the largest area of venting should be discounted for the calculation.

Where special vents are provided:

— the vent closure should normally be held (or should rest) in the closed position;

— the vent closure should be released when the emergency pressure differential system operates so that the pressurizing air is free to escape without having to develop any appreciable pressure to do so.

NOTE 3 Where automatically controlled venting is proposed, it is preferable that the venting should take place on the fire storey only and the air release vents on all other storeys should remain closed.

Where powered extraction is provided:

— the extraction rate per storey should be not less than the calculated maximum flow rate into the accommodation;

— the extract system (ducts and fan) should be in accordance with **6.3**, having either a separate extract system for each storey, or by arranging for the ducts on all storeys to be normally closed by fire-resisting dampers. When the emergency pressure differential system operates, the dampers closing the extract system should open only on the fire storeys.

Vents should be located at or immediately below ceiling level, in such a way that the air relief paths do not coincide with escape paths.

Where air release is actuated by powered air/smoke release fans, the air/smoke release fan system should be capable of working at the temperature and for the period of time stated in **6.3**.

9.7 Overpressure relief

The design of pressurized stairs involves evaluating the required airflow under two different conditions (i.e. all doors closed and with selected doors open). In most circumstances the airflow requirement with doors open will be greater than with all doors closed.

If excessive pressures are allowed to develop in the protected space it may become difficult or impossible to open doors into the space (see **9.1.4**). To prevent the build-up of excessive pressures, the following solutions may be used to provide for the release of excess pressurizing air from the protected space.

a) *Overpressure relief vents*. The pressure relief vent area may be closed by a counter-balanced flap valve so designed that it will only open when the pressure exceeds the design pressure. Overpressure relief vents should not discharge into the accommodation, as any penetration of a fire-resisting barrier (even if protected by a suitable damper) represents a potential weakness between the protected space and the fire zone. The overpressure relief from the pressurized space should discharge either directly to external air or via appropriate ductwork.

The overpressure relief vent should be sized so that it is capable of discharging the total excess airflow. This is determined by subtracting the total air leakage from the shaft with all doors closed from the total required airflow rate under the most onerous air supply conditions. An initial estimate of the required area of the pressure relief vent may be calculated in accordance with equation (27) (see **14.3.5**).

b) *System controlled by pressure sensors*, so that the air supply or exhaust can be continuously varied to produce the pressure or flow required. However, a variable supply fan will maintain a large continuous flow of flushing air through the protected space but a variable supply system may be more prone to component failure than a simple relief vent.

Variable supply fans or dampers controlled by pressure sensors should not be used unless the system can achieve between 90 % and 110 % of the new volumetric requirements within 5 s of a door being opened or closed.

10 Design procedures

10.1 Pressurization systems

10.1.1 *General*

NOTE The following paragraphs are intended to illustrate the general design principles involved and may be adapted to suit other applications.

Where a stair is intended for firefighting purposes it is more appropriate to carry out the firefighting design procedure before that for means of escape.

Information regarding air leakage areas for typical forms of construction is given in Annex D. Guidance regarding the calculation of effective leakage areas for flow paths in series and in parallel is given in **14.1**.

10.1.2 *Design for means of escape*

Evaluate effective leakage areas for the following flow paths at each storey (see **14.1**):

— from stair to simple lobby to accommodation;

— from stair direct to the external air;

— from accommodation to the external air;

— from lift well to the lobby;

— from lift well direct to the external air;

— from lobby to accommodation.

NOTE 1 In existing buildings the leakage areas will be highly dependent upon the quality of the workmanship and the nature of the structure, hence the actual leakage values may vary considerably from assumed design values. Effective leakage areas should, if possible, be evaluated by an on-site airflow measurement. Only where this is impractical should assumed values be used.

Estimate the air leakage rate via each flow path from the pressurized shaft at the design pressurization level with all stair, lift and lobby doors closed (see **14.1**).

NOTE 2 For simplicity, the leakage area from the accommodation may be assumed to be large relative to the leakage area of the lobby and stair doors.

Sum all air leakage rates to give the theoretical air supply rate. To give the total required air supply rate, multiply this value by a factor of at least 1.5 to take account of uncertainties in identified leakage paths (see Note 4).

Determine air release requirements in accordance with **9.6** and **14.3**.

NOTE 3 Calculating the air release requirements may be ignored if the firefighting design procedure has previously been carried out.

Determine the required air supply rate in accordance with the respective class of system (see **5.2**, **5.3**, **5.4**, **5.5** and **5.6**). The calculation should also take account of leakage via closed doors, lobbies and accommodation, and to other identified leakage paths from the shaft.

NOTE 4 The anticipated leakage via all paths other than the open door should be multiplied by the factor of at least 1.5.

Where:

a) the air required to satisfy the airflow criteria is in excess of the factored air supply required to satisfy the pressurization criteria, i.e. air for the airflow criteria > 1.5 × the air required for pressurizing the shaft; and

b) the fan performance characteristic would ensure that the needed pressure is available in the shaft with the unidentified leakage paths having been considered; then this 1.5 factor need not be applied.

Compare the required airflow rates for the closed and the open door conditions, and select the higher as the total required air supply rate.

Determine the excess air supply rate with all doors closed, i.e. the total air supply rate minus air lost through leakage with all doors closed.

Calculate the nominal area of overpressure relief vents required to relieve excess air supply from the shaft (see **9.7** and **14.3.5**).

NOTE 5 The lift well should not require overpressure relief vents if the supply system is initially set up so as to achieve the required pressurization level with all doors closed.

10.1.3 ***Design for firefighting shaft***

A stair in a firefighting shaft may require a greater air supply rate and greater air relief provisions from the accommodation than a stair used only for means of escape.

In order to simplify the calculation procedure, it may be assumed that there is no interaction between the stair and the lift pressure differential systems. (This will tend to give an overestimate of the total required air supply rate to the stair because it does not take account of the additional airflow between the lift and the stair.) The use of computer-based analysis, as described in **9.1.5**, is likely to provide a better estimate of the required air supply rate.

The following procedures are intended to establish the required air supply with the final exit door and the stair and lobby doors on an adjacent storey open.

Calculate the required airflow rate through the open lobby-to-accommodation door to provide an air velocity of 2 m/s, assuming the lobby-to-accommodation door is fully open.

NOTE 1 For double-leaf doorsets the effective area of the open door may be assumed to be a single leaf of the open doorway.

Calculate the air release capacity required on the fire storey. Suitable air release arrangements (see **9.6** and **14.3**) should be provided on all storeys.

Determine the pressure differential necessary to develop the required flow velocity of 2 m/s via the flow path from stair to lobby to accommodation to external air (see **14.1**).

Using the stair pressure calculated above, estimate the airflow required to maintain this pressure with the final exit door open, taking into account all of the leakage paths from the shaft at this design pressure (see **14.1**). The anticipated leakage via all paths other than the open doors should be multiplied by a factor of at least 1.5 to take account of uncertainties in identified leakage paths.

NOTE 2 Where:

a) the air required to satisfy the airflow criteria is in excess of the factored air supply required to satisfy the pressurization criteria, i.e. air for the airflow criteria > 1.5 × the air required for pressurizing the shaft; and

b) the fan performance characteristic would ensure that the needed pressure is available in the shaft with the unidentified leakage paths having been considered; then this 1.5 factor need not be applied.

Compare the supply airflow rate required for firefighting purposes with that required for the means of escape (see **10.1.2**) and select the higher value as representing the total required air supply rate for design purposes.

If the total air supply rate required for firefighting purposes is greater than that for the means of escape then the size of the stair shaft pressure relief vent should be recalculated.

10.2 Depressurization systems

Evaluate the leakage paths from the exterior of the building into the depressurized space, other than through the doors being protected by the design.

Calculate the required exhaust volume flow rate to obtain the desired airspeed of 0.75 m/s for means of escape, and 2 m/s for firefighting shafts, through the open doors between the protected spaces and the depressurized space. Calculate the pressure difference across those same doors to maintain this airspeed. Ensure that the effect of the leakage paths from the exterior of the building to the protected spaces is included in the calculation.

NOTE 1 If the final exit door is open, the flow resistances of these leakage paths will be sufficiently low to be ignored.

Calculate the additional volume flow rate drawn in through the leakage paths, identified by the pressure difference across the open doors between the protected spaces and the depressurized space.

Calculate the exhaust fan duty required to maintain this airspeed, i.e. the sum of the volume flow rates given above.

Calculate the exhaust fan duty required to provide a minimum pressure difference of not less than 50 Pa ± 10 % across the closed doors between the protected spaces and the depressurized space, based on the leakage paths identified.

NOTE 2 Usually this fan duty will be less than that calculated to maintain the required airspeed. If it is greater, then this fan duty should be specified for the exhaust fan.

Using the known characteristics of the fans proposed for use, together with the effects of any ductwork associated with those fans, the leakage areas previously identified, and the size of fan identified, whichever is the larger, calculate the pressure drop which will be exerted across the closed doors into the depressurized space. If this pressure difference would cause the door-opening force at the door handle to exceed 100 N, install pressure relief dampers set to open before this door-opening force is reached.

10.3 Design for maintainability

It is essential that the pressure differential equipment can be relied upon at all times in the event of an emergency, and it therefore follows that it should be adequately maintained. The system designer can have a considerable impact on the ease of maintenance, e.g. by providing easy access to components, and therefore on the actual level of maintenance that occurs in practice. The system should be designed with consideration to installation, measurement/testing, adjustment, maintenance, repair and replacement.

Consideration should be given to access routes, lifting beams, trap doors, etc. to enable satisfactory installation, repair and replacement to be carried out.

Access should be provided for measuring the rotational speed of the fans. Test points and access should be provided for the fan static pressure and Pitot tube traverses in ductwork branches.

Access should be provided for adjustment of the inlet guide vanes of the fans and the distribution system balancing dampers.

Access doors should be provided in ductwork and adjacent to balancing dampers, with approximately 400 mm clearance. Clearance around generators should be approximately 1 000 mm. Access panels should be placed so as to give safe access to damper manual release mechanisms.

11 Installation and commissioning

11.1 Distribution ductwork for pressure differential systems

For multi-storey buildings the preferred pressure differential system distribution system is a vertical duct running adjacent to the pressurized spaces.

When a common duct system serves several separate pressurized spaces it should be ensured that when the pressure in one or more spaces is disturbed because of open doors the effect on the air supply to the others will be minimal.

It is essential that the air supply used for pressurization is never in danger of contamination by smoke. Any increase or decrease in inlet or outlet pressure due to wind effect will be communicated through the building, possibly modifying the differential pressure balances through it. Therefore, the air pressure conditions for the pressure differential system air intake and exhaust should be substantially independent of wind speed and direction.

When a pressure differential system is used in conjunction with a HVAC system in the building it is also essential that any effects of wind speed and direction are the same in both systems.

The distribution ductwork should be in accordance with BS 5588-9, BS 5720 and BS 8313.

The ductwork sizing and layout should be designed in accordance with appropriate guidance such as the CIBSE Guide B [2].

The ductwork construction should be in accordance with appropriate guidance such as HVCA publication DW/142 [3]. Adhesive tape should not be used to seal joints.

The air intake should always be located away from any potential fire hazards. Air intakes should be located on or near ground level (but well away from basement smoke vents) to avoid contamination by rising smoke. If this is not possible, air intakes should be positioned at roof level.

Where air intakes are positioned at roof level there should be two air intakes, spaced apart and facing different directions in such a manner that they could not be directly downwind of the same source of smoke. Each inlet should be independently capable of providing the full air requirements of the system. [A1⟩ Each inlet should be protected by an independently operated smoke control damper system in such a way that if one damper closes due to smoke contamination, the other inlet will supply the air requirements of the system without interruption ⟨A1]. The discharge point of a smoke ventilation duct should be a minimum of 1 m above the air intake and 5 m horizontally from it. An override switch to reopen the closed damper and to close the open damper should be provided for fire brigade use in the positions stated in Clause **7**.

When an air intake is distant from the fan, air should be ducted from the intake to the fan.

Where air intake is not at roof level a smoke detector should be provided in the intake duct or within the immediate vicinity of the supply ductwork in order to cause the automatic shut down of the pressure differential system if substantial quantities of smoke are present in the supply. An override switch to reopen the closed damper should be provided for fire brigade use in the positions stated in Clause **7**.

Sheet metal ductwork should be run either within the protected space, or in protected shafts.

NOTE 1 Builders' ducts may be used provided that such ducts are used solely for air distribution and the internal surface is rendered to limit air leakage, a sheet metal lining is used, or it is shown that the leakage is satisfactory.

NOTE 2 Ductwork mounted on the external face of an external wall enclosing the protected space is deemed to be within the protected space.

The fitting of fire dampers in branch ducts is considered detrimental to the reliable operation of a pressure differential system, since the closing of a damper would seriously disrupt the pressure differentials.

Fire dampers should not be used in pressure differential system supply ductwork. If such ductwork penetrates a fire-resisting compartment, the ductwork should be protected using the methods given in BS 5588-9:1989.

Air supply grilles should not be located near any major leakage path from a pressurized zone.

11.2 [A1⟩ Plant location ⟨A1]

The pressure differential equipment, i.e. fan, motor and control gear, should be [A1⟩ positioned ⟨A1]:

a) in an enclosure with a fire resistance of not less than 1 h, preferably in a plant room separate from other plant on or near the ground level and close to the air supply intakes; or

b) at the roof level if the fire resistance separation between the plant [A1⟩ *Text deleted* ⟨A1] and the building below is not less than 1 h within 5 m measured horizontally of any part of the pressure differential system equipment/enclosure.

Access doors to the enclosure should have a fire resistance of not less than 1 h and be self-closing.

NOTE Where the pressure differential system protects a firefighting shaft the level of fire resistance should be increased to 2 h.

11.3 Regulations and standards

Attention is drawn to the following regulations and standards which are applicable to equipment specification and installation:

a) ductwork: BS 8313 and BS 5588-9;

b) fans: the Electrical Equipment (Safety) Regulations [4];

c) ventilation system: the Electrical Equipment (Safety) Regulations [4], BS 7346;

d) fire alarms and detectors: BS 5839.

e) electrical installations and supply: Building Standards (Scotland) Regulations [5], Electricity at Work Regulations 1989, 635/1989 [6];

f) general: BS 5720 and the Building Regulations 1991 Approved Document B [7].

11.4 Commissioning of systems

The procedures for commissioning a pressure differential system are similar to those for other air handling units, with the addition of the actuation and control system.

The air handling side of the pressure differential system should be commissioned by reference to appropriate guidance such as the CIBSE Commissioning Code A [8], BSRIA Application Guide AG3/89.1 [9].

The actuation system should be commissioned in accordance with BS 5839-1.

12 Testing and maintenance

12.1 Acceptance testing

Acceptance testing should only be carried out once the installation is complete and the pressure differential system and air conditioning, where applicable, have been commissioned and correctly balanced. All building work should have been completed.

The design recommendations made in this standard presume pressure differential systems to include components to overcome both stack-effect pressures caused by unpressurized shafts elsewhere in the building and wind-induced pressure differences. These are only measurable in an actual test if there is no wind, and if the entire building interior is at the external ambient temperature. Achieving such conditions on any test day is, at best, unlikely. Consequently, acceptance testing should be carried out in two stages: first, to establish pressure differences due to wind and stack effect with the pressure differential system fans switched off, and second, to record the changes in measured pressures when the system fans are then switched on. This change in measured pressures should be taken as the measure of performance of the system.

The entire pressure differential system should be tested. Two conditions should be examined to ensure that smoke is excluded from the protected space. Firstly, that the pressure differential can be maintained at an adequate level with the doors closed for the specified system class (see **5.2**, **5.3**, **5.4**, **5.5** and **5.6**), and secondly, that the air movement from a pressurized to an unpressurized space is sufficient to restrict smoke contamination when a door is opened between the spaces.

The acceptance test should conform to the following recommendations:

a) when tested in accordance with Annex E, the net pressure differential across each door separating a pressurized and an unpressurized space should be not lower than that specified in **5.2**, **5.3**, **5.4**, **5.5** and **5.6**;

b) when tested in accordance with Annex B, the door opening force should not exceed 100 N (applied at the door handle);

c) when tested in accordance with Annex F, the air velocity through an open door separating a pressurized and an unpressurized space should be not less than that specified in **5.2**, **5.3**, **5.4**, **5.5** and **5.6**.

All test equipment should be accurate to ±5 %. The calibration of all test equipment should be traceable to national or international standards of measurement which, in the UK, are the responsibility of the National Physical Laboratory.

NOTE Guidance on measuring ductwork leakage is given in HVCA Publication DW/142 [3].

Possible solutions where the design pressure differential has not been obtained are given in Annex G.

12.2 Maintenance and functional testing

12.2.1 *General*

The pressure differential system, including the smoke detection system or any other type of fire alarm system used, the switching mechanism, the fans, the emergency power supply arrangements and the automatically operated ventilation equipment, should be subject to a regular maintenance and functional testing procedure. Where a two-stage system is provided, the equipment in continuous operation should be subjected to a regular maintenance programme. Similarly, for single-stage systems it should be ensured that the equipment operates when required and is maintained correctly, and therefore these systems should be subjected to a regular functional testing programme plus a less onerous maintenance schedule.

The equipment should be included in the building services maintenance schedule, with written confirmation of maintenance carried out. The building management should be notified of any unsatisfactory findings. The annual inspection and testing should be carried out by suitably qualified personnel. The consultant or installer responsible for the design of the system should provide the occupier with a maintenance checklist. A record should be kept of all maintenance and functional testing by the building management.

Maintenance and functional testing of the pressure differential system equipment should be carried out at the frequencies given in Table 8.

The entire pressure differential system should be re-tested in accordance with **12.1** following any modification to the building that could affect the pressure differential system, e.g. alterations to internal partitions, extensions, etc. [A2) (See also BS 5588-12.) (A2]

12.2.2 *Maintenance*

A2⟩ BS 5588-12 provides guidance in preparing a maintenance schedule. ⟨A2

Table 8 — Frequency of maintenance and functional testing of pressure differential system plant

Equipment	Frequency	
	Maintenance	Functional testing
Fans and drive mechanism		
General	6 monthly	weekly
Belt drive	3 monthly	weekly
Motor	3 monthly	weekly
Ventilation system	12 monthly	weekly
Actuation and control system	6 monthly	weekly
Emergency power system	6 monthly	monthly
Stand-by equipment		
Fan	6 monthly	monthly
Belt drive	3 monthly	monthly
Motor	3 monthly	monthly
Distribution ductwork		
Ductwork	12 monthly	12 monthly
Dampers	6 monthly	12 monthly
Grilles	6 monthly	12 monthly
A1⟩ **Whole system**	Not applicable	12 monthly ⟨A1

A2⟩ *Text deleted* ⟨A2

13 Documentation

A2⟩ BS 5588-12 provides guidance on documentation and who should have copies. ⟨A2

14 Design calculations

14.1 Airflow and leakage paths

14.1.1 *General*

The design of a smoke control system using pressure differentials involves balancing the airflows into and out of the building and analysing the pressure differentials across smoke barriers. It is important that all the relevant airflow paths should be identified and their effective flow areas evaluated.

Typical leakage paths that can exist in a building are open doors, gaps around closed doors, lift doors, windows, etc. Attention should also be given to the inherent leakage due to construction cracks etc. that exist in walls, floors and partitions. Both the type of construction material and the quality of workmanship can significantly affect the leakage area.

The air supply required for a pressure differential system should be determined by the air leakage areas. The air supply requirements should be considered for two situations: all doors closed and doors open, appropriate to the class of system.

Worked examples using the equations below are given in Annex H, and common leakage data is given in Annex D.

When air flows through an opening, the flow can be expressed in terms of the area of the restriction and the pressure differential across the opening by the following equation:

$$Q = 0.83 \times A_E \times P^{\frac{1}{N}} \qquad (1)$$

where

Q is the airflow (in m^3/s);

A_E is the total effective area of the leakage paths out of the space (in m^2);

P is the pressurization level in the pressurized space (in Pa);

N is an index that can vary between 1 and 2, depending on the type of leakage path being considered.

NOTE 1 For wide cracks such as those around doors and large openings, the value of N may be taken to be 2 but for narrow leakage paths formed by cracks around windows a more appropriate value of N is 1.6.

The flow velocities and pressure differentials given in Table 9 have been derived from equation (1) assuming $N = 2$ and A_E is 1 m^2, and may be used as a means of quickly determining leakage rates and pressure differentials around door gaps and through large openings.

Table 9 — Airflow velocities through gaps and large openings

Pressure differential Pa	**Airflow velocity** $m \cdot s^{-1}$
50.0	5.9
25.0	4.2
8.5	2.4
6.0	2.0
4.0	1.7

In order to calculate the airflow it is first necessary to evaluate the effective leakage areas between each adjacent space. This is most readily achieved by combining each type of crack or gap into one effective flow area. The effective flow area of a given system of flow paths is the area of the equivalent single opening that results in the same flow as the given system when subjected to the same pressure differential.

Flow paths may be in series, as indicated in Figure 13 or in parallel as indicated in Figure 14. An example of a parallel path occurs when all the doors opening out of a stair lead directly to an unpressurized space. Leakage paths in series occur when there is an intermediate space into which the air from a pressurized space first flows before finally leaking out to the unpressurized space through another leakage path. An example of this is the simple lobby interposed between the stair and the accommodation.

NOTE 2 The calculations in **14.1.2** and **14.1.3** apply only to leakage paths having the same value of N in equation (1). Furthermore, in the case of equation 4 the value of N should be 2. However, since the predominant leakage paths will almost invariably be through doors, the contribution from window leakage is likely to be small, and this calculation may be used as an approximate estimate when windows form part of the leakage path.

14.1.2 *Parallel leakage paths*

The effective leakage area of the four parallel paths in Figure 14 is the sum of the leakage areas concerned.

$$A_e = A_1 + A_2 + A_3 + A_4 \qquad (2)$$

where

A_e is the total effective leakage area (in m^2);

A_1, A_2, A_3 and A_4 are the leakage areas of the four parallel paths (in m^2).

14.1.3 ***Series leakage paths***

The effective leakage area of the four series paths in Figure 13 is:

$$A_e = \left(\frac{1}{A_1^2} + \frac{1}{A_2^2} + \frac{1}{A_3^2} + \frac{1}{A_4^2}\right)^{-1/2} \quad (3)$$

where

A_e	is the total effective leakage area (in m^2);
A_1, A_2, A_3 and A_4	are the leakage areas of the four parallel paths (in m^2).

In the context of pressurization analysis there are frequently only two paths in series, in which case:

$$A_e = \frac{A_1 \times A_2}{(A_1^2 + A_2^2)^{1/2}} \quad (4)$$

where

A_e	is the total effective leakage area (in m^2);
A_1 and A_2	are the leakage areas of the two series paths (in m^2).

14.1.4 ***Combinations of series and parallel leakage paths***

The total effective leakage of combinations of series and parallel paths can usually be obtained by successively combining simple groups of individual leakages into their equivalent single path (see Figure 15, for example). Such calculations apply strictly only to leakage paths for which the value of N in equation (1) is 2 (i.e. for doors). However, they may be used for an approximate calculation when windows form part of a series leakage path.

$$A_{4/5} = A_4 + A_5 \quad (5)$$

$$A_{9/10} = A_9 + A_{10} \quad (6)$$

Thus, in Figure 15b),

$$A_{1/2} = \frac{A_1 \times A_2}{(A_1^2 + A_2^2)^{1/2}} \quad (7)$$

And in Figure 15c),

$$A_{3/5} = \frac{A_3 \times A_{4/5}}{(A_3^2 + A_{4/5}^2)^{1/2}} \quad (8)$$

and similarly for $A_{6/7}$ and $A_{8/10}$.

In Figure 15d),

$$A_{3/10} = A_{3/5} + A_{6/7} + A_{8/10} \quad (9)$$

The total equivalent leakage from the pressurized space is given by:

$$A_{1/10} = \frac{A_{1/2} \times A_{3/10}}{(A_{1/2}^2 + A_{3/10}^2)^{1/2}} \quad (10)$$

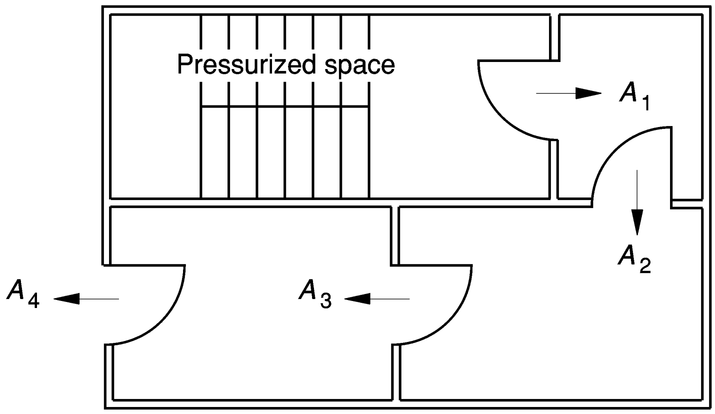


Figure 13 — Leakage paths in series

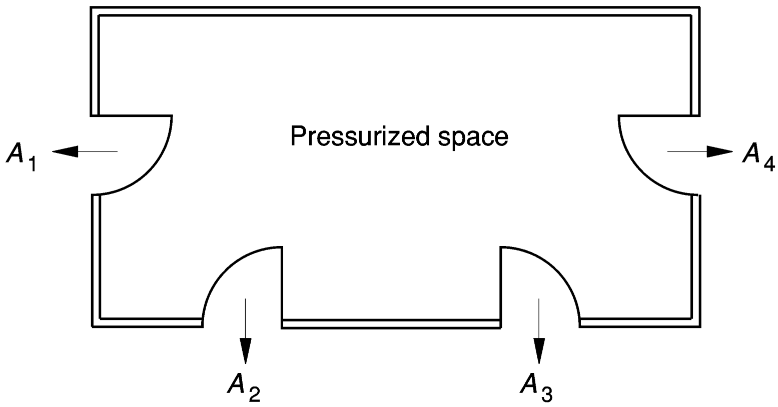


Figure 14 — Leakage paths in parallel

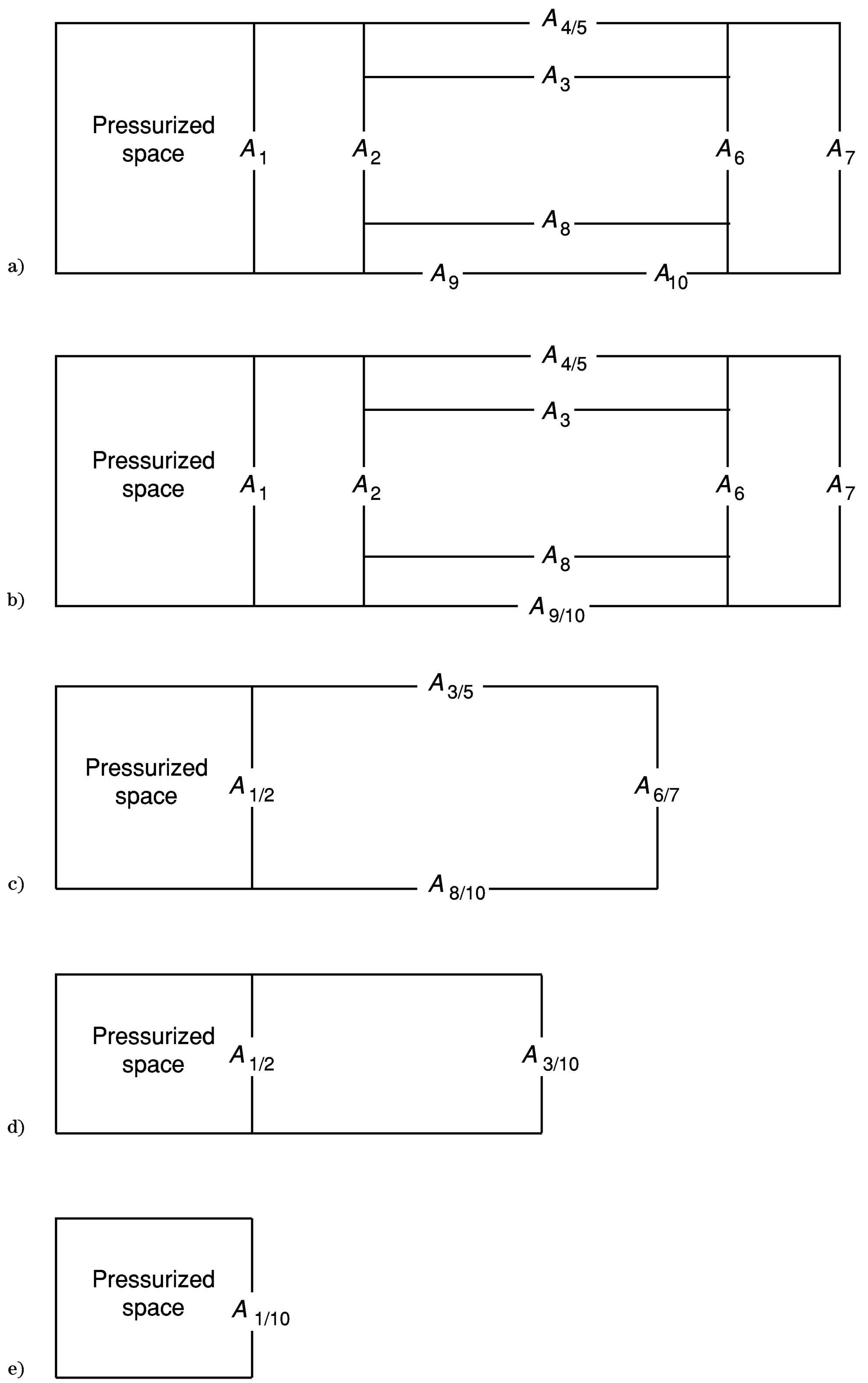


Figure 15 — Combination of series and parallel leakage paths

14.2 Air supply requirements with all doors closed

14.2.1 *General*

Leakage from the pressurized space can occur via a number of identifiable paths:

a) gaps around closed doors;

b) cracks around windows;

c) gaps in lift landing doors;

d) mechanical extraction from adjoining spaces;

e) other leakage paths.

The rate of air leakage is primarily a function of the effective area of the leakage path and the pressure differential required across it.

In calculating the air supply two major assumptions have to be made. These are:

1) that the leakage paths identified and the areas used in the calculations will apply to the building when it is completed;

2) that there are no unidentified leakage paths out of the pressurized space.

The air supply required is determined by summing the individual leakage rates via the routes listed in items a) to e) above and making an allowance for uncertainties in the values of the leakage areas that have been assumed. Based upon experience it is recommended that the total air supply rate should be determined by adding at least 50 % to the calculated leakage rate, i.e.

$$Q_S = 1.5 \times Q_L \quad (11)$$

where

Q_S is the total air supply rate required (in m^3/s);

Q_L is the total identified leakage rate from the pressurized space (in m^3/s).

Q_L is estimated using the following:

$$Q_L = Q_D + Q_W + Q_{LD} + Q_T + Q_O \quad (12)$$

where

Q_D is the air leakage rate via gaps around closed doors (in m^3/s);

Q_W is the air leakage rate via cracks around windows (in m^3/s);

Q_{LD} is the air leakage rate via lift landing doors (in m^3/s);

Q_T is the air leakage rate via mechanical extraction from toilet or other areas (in m^3/s);

Q_O is the air leakage rate via other paths that may exist (in m^3/s).

The methods for calculating individual leakage rates from the pressurized space are given in **14.2.2**, **14.2.3**, **14.2.4**, **14.2.5** and to **14.2.6**.

14.2.2 ***Estimation of leakage via doors and large openings***

The total air leakage rate via doors and large openings should be calculated using the following equation:

$$Q_D = 0.83 \times A_D \times P^{1/2} \qquad (13)$$

where

Q_D is air leakage rate via gaps around closed doors or large openings (in m^3/s);

A_D is the total effective leakage area of all doors out of the space (in m^2);

P is the pressurization level in the pressurized space (in Pa).

The total effective leakage area for all the doors should be estimated using the method outlined in **14.1**.

Typical leakage areas for the types of door likely to be found as the closure to a pressurized space are given in Annex D.

14.2.3 ***Estimation of leakage via windows***

The total air leakage via cracks around windows should be estimated using the following equation:

$$Q_W = 0.83 \times A_W \times P^{\frac{1}{1.6}} \qquad (14)$$

where

Q_W is the air leakage rate via cracks around windows (in m^3/s);

A_W is the total effective leakage area of all windows out of the space (in m^2);

P is the pressurization level in the pressurized space (in Pa).

The total effective leakage area for all the windows should be estimated using the method outlined in **14.1**.

Typical leakage areas for the types of windows likely to be found in the pressurized space are given in Annex D.

14.2.4 ***Estimation of leakage via lift landing doors***

Where the lift well is independently pressurized in accordance with the recommendations of this standard, then it may be assumed that leakage via this route is negligible.

Where the lift well is not pressurized but is connected to a pressurized lobby or other space then the overall flow depends upon the following leakage paths:

a) between the lobbies and the lift well on all floors; and

b) between the lift well and the outside air.

The following equation may be used to estimate the total air leakage in these circumstances.

$$Q_{LD} = 0.83 \times \left(\frac{1}{A_t^{\,2}} + \frac{1}{A_F^{\,2}}\right)^{-1/2} \times P_L^{\,1/2} \qquad (19)$$

where

Q_{LD} is the air leakage rate via lift landing doors (in m^3/s);

A_t is the total leakage area between all lobbies and the lift well (in m^2);

A_F is the total leakage area between the lift well and the outside (in m^2);

P_L is the pressure differential between the lift lobby or other space and outside (in Pa).

Generally,

$$A_t = n \times A_d \quad (20)$$

where

n is the number of pressurized lobbies opening into the lift well;

A_d is the leakage area of one lift door (in m^2).

The above calculation relates to one lift and it is assumed that the lift well is protected. A separate calculation should be made for each lift. Where there are two or more lifts in a common well it is sufficient for the purposes of calculation to treat each lift as being in its own single well, in which case the value of A_F used should be that relating to each separate lift (usually A_F for the large common well divided by the number of lifts in that well).

14.2.5 ***Estimation of leakage via other areas containing mechanical extraction systems***

When toilets or other areas that are directly connected to the pressurized space have mechanical extract systems, the leakage rate into them may be estimated as follows:

a) the extract rate when the extract fan is running, (in m^3/s);

b) when the extract fan is off, the following value:

$$Q_T = Q_B \times K \quad (21)$$

where

Q_T is the leakage into the toilet (or other) space (in m^3/s);

Q_B is the door leakage rate at the design pressurization as calculated from equation (13) (in m^3/s);

K is a factor derived from Table 10.

Table 10 — Values of *K*

A_X/A_G	K
4 or more	1
2	0.9
1	0.7
0.5	0.45
0.25 or less	0.25
NOTE A_X is the minimum cross-sectional area of extract branch ductwork (this may be a ductwork cross section or the balancing device at the orifice or damper) (in m^2); A_G is the door leakage area including the area of any airflow grilles or large gaps for air transfer (in m^2).	

NOTE The value of A_G including airflow grilles and/or large gaps for air transfer should also be used to calculate the value of Q_B when the leakage area is greater than the normal total area of cracks.

14.2.6 ***Estimation of leakage via other paths***

Other combinations of series and parallel leakage paths may occur in other situations and the above methods (suitably adapted to take account of the particular circumstances) may be used.

14.3 Air release requirements from unpressurized spaces with open doors

14.3.1 ***General***

The sizing of air release equipment is based on the net volume of pressurizing air flowing into the fire storey, (excluding the air leakage to atmosphere via lift shafts and toilets). The appropriate airflow value for the open-door condition, as in **5.2**, **5.3**, **5.4**, **5.5** and **5.6**, should be taken for this purpose. In the following calculations this value is referred to as Q_N.

14.3.2 ***Estimation of vent area requirements***

The total effective area per storey may be estimated as follows:

$$A_V = \frac{Q_N}{2.5} \qquad (22)$$

where

A_V is the vent area per storey (in m^2);

Q_N is the air needed to be released (in m^3/s).

14.3.3 ***Estimation of size of vertical air release shafts***

Unless detailed pressure loss calculations are carried out, the minimum sizes of shaft and vents that are acceptable for this purpose are:

$$A_V = \frac{Q_N}{2} \qquad (23)$$

where

A_V is the net vent area per storey and should be at least maintained throughout the route to the outside of the building, i.e. from the accommodation into the shaft, the shaft cross-sectional area and the top vent area (shaft to atmosphere) (m^2).

14.3.4 ***Estimation of mechanical extract requirements***

The extract rate per floor when a free path exists through open doors to the pressurized space should be not less than Q_N m^3/s.

The air release specifications given in **14.3.2** and **14.3.3** are based upon an assumed pressure differential between the accommodation and the outside air of 10 Pa. It is possible, however, to increase the airflow rate or reduce the required vent area if the pressure differential between the accommodation and outside is increased. In such circumstances it is necessary to evaluate the air leakage rate in accordance with equation (1) (see **14.1.1**).

Where two or more pressurized stairs or lobbies open into the same unpressurized space then the area of the relief vent per storey should be multiplied by the number of pressurized stairs or lobbies concerned.

Where the unpressurized space is partitioned into offices or similar units then the relief vent should be provided between the door into the pressurized space and the start of the partitioning.

14.3.5 ***Estimation of area of relief vent required in the pressurized space***

Where the air supply needed to provide the required airflow through the open door into the fire room is greater than the air supply to the stair or lobby needed to satisfy the pressure differential requirement, then an excess pressure will be developed in the stair (or lobby) when the fire door is closed.

In this case a pressure operated relief vent, area A_X, should be provided out of the pressurized space since a maximum pressure of 60 Pa is recommended to ensure that the specified door opening force of 100 N is not exceeded.

Then:

$$A_x = \frac{Q_F - Q_P}{0.83 \times 60^{1/2}} \tag{24}$$

where

A_x is the area of the pressure operated relief vent (in m^2);

Q_F is the air supply needed to provide the required airflow through the open door into the fire room (in m^3/s);

Q_P is the air supply to the stair or lobby needed to satisfy the pressure differential requirement (in m^3/s).

14.4 Calculation of the permissible pressure to limit the door opening forces to 100 N

The maximum pressure differential across a door opening into a pressurized space should be determined as a function of the door configuration, using the following equation:

$$P = \frac{2(100 - F_{dc}) \times (W - d)}{A \times W} \tag{25}$$

where

P is the pressure difference across the door (in Pa);

F_{dc} is the force needed to be applied at the door handle to overcome the inherent resistance of the door to opening without a pressure differential applied to the door, e.g. the door closer mechanism, etc. (in N);

W is the door width (in m);

A is the door area (in m^2);

d is the distance from the door knob to the knob side of the door (in m).

If, at the design stage, the force required to overcome the door closer is unknown, a maximum pressure differential of 60 Pa may be utilized for design purposes.

Annex A (normative) Smoke control using pressure differentials in atrium buildings

A.1 General

An unenclosed atrium uniting several storeys within a building provides a route by which smoke and fire can readily spread from one storey to another. As an atrium essentially forms a vertical shaft passing through a number of storeys, any significant quantities of hot fire gases entering the atrium will tend to create a stack effect that will draw fresh air in at low level and drive smoke into the upper storeys of accommodation. It is not generally feasible to use a pressure differential system to control the spread of smoke from one open storey to another in an atrium building.

The building should be protected throughout with a sprinkler system designed and installed in accordance with the life safety provisions of BS 5306-2. This will limit the amount of heat entering the atrium, and as gas temperatures in the atrium are not likely to be much greater than the sprinkler operating temperature, 100 °C can be assumed as a generally pessimistic value.

Where there is a controlled fire load in the atrium and the adjacent spaces are separated from the atrium by fire-resisting construction, smoke ingress into the atrium may be prevented by pressurizing the atrium on the same basis as if it were a pressurized stairwell (see the relevant clauses of this standard).

Where the atrium could contain smoke and adjacent accommodation storeys and/or stairwells and/or shafts are to be pressurized, the height of the neutral pressure plane in the atrium should be assessed by calculation, allowing for normal building leakage. This is the height above which buoyancy causes the pressure in the atrium to rise above ambient. Heights below this experience a reduction in pressure due to buoyancy. Suitable calculation procedures can, for example, be found in *Design approaches for smoke control in atrium buildings*, Building Research Establishment Report BR258 1994 [12].

Where smoke exhaust is used to reduce the pressure in an atrium containing thermally-buoyant smoky gases, the design objective should be to raise the neutral pressure plane above the highest vulnerable leakage path, allowing explicitly for external wind pressures in the design calculation. Suitable calculation procedures can, for example, be found in *Design approaches for smoke control in atrium buildings*, Building Research Establishment Report BR 258, 1994 [12].

The minimum design pressure difference across a closed door (or other leakage path) between an atrium and an adjoining pressurized space should be 50 Pa for heights up to 10 m above the neutral pressure plane and 75 Pa for heights between 10 m and 25 m above the neutral pressure plane.

Any part of a storey served by any pressurized space at heights greater than 25 m above the neutral pressure plane should be separated from the atrium by means of an imperforate construction with a fire resistance of not less than 30 min unless it is itself protected by a temperature control system as described in BS 5588-7.

All designs based on calculation to the extent required in this standard can be considered to be a form of fire safety engineering, and should be supported by documentation fully detailing the calculations, any assumptions made and the values of any input parameters.

A.2 Characteristics of different atria designs

A.2.1 Where there is no appreciable fire load in the atrium and all storeys are separated from the atrium by fire-resisting construction, the atrium can be regarded as being fully analogous to a protected stairwell and should be pressurized in a similar way relative to the accommodation to prevent ingress of smoke into the atrium from any storey.

A.2.2 Where there is a sprinklered or controlled fire load in the atrium base, smoky gases can fill all or part of the atrium. Where higher storeys are separated from the atrium by smoke-retarding construction and are also sprinklered, and where there is no smoke exhaust ventilation from the atrium, the adjacent accommodation spaces (and/or any stairwells or shafts communicating via doors into the atrium) may be pressurized relative to the atrium. It should be noted that there is a significant difference between this circumstance and the pressurization of a stairwell described elsewhere in this standard.

The minimum design pressure difference for doors between a pressurized stairwell and accommodation storeys for a non-atrium building should include a component for overcoming the buoyancy of air (at the building's usual internal temperature) within unpressurized vertical shafts elsewhere in the building. The smoky gases filling the atrium will typically be at a higher temperature, resulting in a more rapid rise in buoyant pressure within the atrium with increasing height. Therefore the minimum design pressure difference across the atrium boundary's leakage paths on the higher affected storeys (expressed as a pressure relative to external ambient in the usual way) needed to prevent ingress of smoke from the atrium will be greater in a tall atrium than for a stairwell which does not connect with a smoke-filled atrium.

Whilst in principle it is possible to increase pressurization levels to compensate for the atrium stack pressure, this could lead to unacceptable door opening forces at the lower levels of a pressurized protected stairwell.

A.2.3 It may be feasible to reduce the pressures in the atrium sufficiently to prevent smoke entering adjacent spaces through leakage paths where:

— there is a sprinklered or controlled fire load in the atrium base;

— some or all higher storeys are separated from the atrium by smoke-resisting construction; and

— there is smoke exhaust ventilation from the atrium.

Where a large exhaust capacity is provided at high level in the atrium and the available inlet area for replacement air is restricted, there will be a general lowering of pressure within the atrium. This is equivalent to stating that the neutral pressure plane (relative to external air) will move upwards, hence reducing the stack pressures to be overcome by pressurization systems in stairwells or adjacent accommodation connecting with the atrium via doors or other leakage paths.

Depressurizing the atrium in this way has the effect of lowering the pressure at the base of the atrium, which could make it difficult to open doors away from the atrium. It is therefore advisable that where atrium depressurization is used, great care is taken to ensure that excessive door opening forces are not created.

It is essential in all such atrium depressurization designs to establish, by calculation, the height of the neutral pressure plane. This is especially important when ensuring that there is sufficient smoke exhaust from the atrium to raise the neutral pressure plane to be higher than the highest leakage path which might allow smoke to affect accommodation or stairwells requiring protection. It is also essential to include in these calculations the effects of wind pressure on the building's exterior.

It is possible to combine an atrium depressurization design with smoke exhaust ventilation, allowing some lower storeys to be open to the atrium beneath a buoyant smoke layer in the atrium. Such design requires careful calculation, incorporating all the performance parameters required for both aspects of the design, i.e. the performance parameters of the smoke exhaust ventilation system should conform to BS 5588-7 (see also **A.1**).

Annex B (normative)
Test method for measuring the opening force at a door

Actuate the pressure differential system, and measure the opening force at a door as follows.

a) Fasten the end of the force measuring device (e.g. a spring balance) to the door handle, on the side of the door in the direction of opening.

b) Release any latching mechanism, if necessary, holding it open.

c) Pull on the free end of the force measuring device, noting the highest value of force measured as the door opens.

Annex C (normative) Interaction of pressure differential systems with normal HVAC installations

C.1 General

The primary purpose of a pressure differential system is to establish an airflow and pressure differential pattern in the building that will limit the spread of smoke towards or past the doors onto the escape route being protected (see **9.1**).

It is therefore essential that the airflow patterns established in the building by the normal HVAC systems should also be away from escape routes. This will ensure that in the early stages of a fire, prior to the establishment of the designed pressure differentials by the system, the escape routes and other sections of the smoke control strategy are not adversely affected.

This can be achieved by integrating the HVAC and pressure differential systems in such a way that graded pressurization levels are established from the escape route down to the occupied spaces in which a fire might occur.

However, an HVAC system that uses the corridors (or the false ceilings of corridors) forming part of the escape route as the exhaust plenum for the vitiated air should not be used in conjunction with a pressure differential system unless special arrangements are made for closing off the whole exhaust system in the event of fire.

HVAC systems that could encourage smoke to enter the corridors should not be used.

The operation of the HVAC systems in an emergency should be designed so that it does not adversely affect the smoke control strategy.

If there is any possibility of the HVAC systems adversely affecting the pressure differential systems then the ventilation systems should be shut down in an emergency.

C.2 Integration of normal HVAC systems with pressurized escape routes

The HVAC system should shut down in an emergency unless it has been designed to one of the following:

a) a fully fire-engineered solution is applied to the entire building (see **9.4**);

b) the design of the HVAC system is to provide the exhaust of vitiated air from the fire zone;

c) the system operates as follows in an emergency:

1) the signal to activate the emergency mode of the HVAC system comes from the same source as that which operates the pressure differential system. The use of a smoke detector in the HVAC ductwork should not be relied upon for this purpose because dilution of the smoke within the system could cause a delay in making the necessary operational changes;

2) any re-circulation of air is stopped and all vitiated air exhausted to atmosphere, e.g. by means of suitable dampers to prevent siphoning of smoke to other parts of the building;

3) the return/exhaust air systems from the accommodation on the fire storey is switched to the total exhaust rate, whatever the status of any ventilation system throughout the building, which is suitable for the operation of the integrated system and does not make it necessary to apply forces to open escape route doors in excess of those recommended in this standard;

NOTE 1 HVAC ductwork exhausting air from the fire zone should be fire resisting (see **C.3**).

4) any air supply to the fire storey as well as to the non-fire storeys is turned off;

NOTE 2 It is often necessary to maintain local equipment cooling whilst plant is shut down safely, for example for mainframe computers. Cooling systems that recirculate air only within the fire zone may remain running during the plant shut down cycle if, on detection of smoke within the cooling unit, the cooling unit is automatically shut down.

5) the positions of the extraction points are compatible with the need to establish a general airflow that is away from storey exits.

C.3 Ductwork used for pressure differential system air supply and release systems

Ductwork used for pressure differential air supply and release systems presents a risk of spreading smoke and fire within the building. Careful consideration therefore should be given to the fire protection, integrity, construction and routeing of the HVAC ductwork used in conjunction with pressure differential air supply and release systems.

Normally, where a system is designed to provide fresh air to an escape route and the ductwork is not located within a risk area anywhere within the building, the ductwork will not be subjected to additional thermally induced stresses.

However, when ductwork is used for the release or extraction of smoke/gases, it quickly absorbs heat and expands in proportion to the temperature within the duct. The ductwork should be adequately braced to maintain the integrity of the system at the high temperatures and pressures that may exist, and should be designed to accommodate thermal expansion without distortion or damage.

NOTE 1 If no means are provided to absorb the expansion of the ductwork, it can exert forces which can cause distortion or total failure of the ductwork supports, and possibly other components of the system such as fire/smoke dampers.

The material from which the support is manufactured may have a reduced carrying capacity when subjected to hot smoke/gases or heat emitted from the ductwork. The design of the ductwork supports should reflect the need to eliminate, where possible, unnecessary forces being applied to the ductwork etc.

It is impossible to test systems using gases at a temperature expected to occur within the building at the time of a fire. Considerable thought should be given at the design stage to ensure that premature failure of the ductwork and other associated components will not occur when a fire, with smoke/gas temperatures in accordance with the recommendations of this standard, exists within the building.

Additionally, the designer should give further consideration to the mode of operation of any proposed smoke detector actuated fire/smoke dampers and the requirements for compartmentation within the building.

HVAC ductwork used for pressure differential air supply and release systems should be adequately protected against fire penetration where it is routed beyond the protected zone. If the ductwork fire protection is to be installed external to the ductwork, the fire protection should be adequately supported so that it will remain in place and retain its integrity when subjected to fire from either side of the ductwork (i.e. both inside and outside). Any additional fire protection should be supported from the building structure itself unless the ductwork supports are designed to bear the additional load.

The ductwork installation should not fail when exposed to the internal smoke temperatures stated in **6.3**.

NOTE 2 Fusible link operated fire dampers may be necessary in those sections of the HVAC system not used by the pressure differential system.

All of the system components associated with the HVAC ductwork used for pressure differential air supply and release systems should be designed to ensure that the system will continue to operate when any part of the system is exposed to fire outside of the fire zone being protected by the installation.

If the HVAC ductwork used for pressure differential air supply and release systems is fitted with smoke detector actuated fire/smoke dampers, and there are no requirements for compartmentation within the building, these dampers should fail-safe to the correct position for the system(s) to work satisfactorily in the air supply and release modes.

Fire/smoke dampers fitted in HVAC ductwork where the building is divided into fire compartments and where the HVAC ductwork is used for pressure differential air supply and for releasing surplus air/gases, should have the appropriate fire rating and should fail-safe to the closed position on actuation by a smoke detector. After all dampers are closed, the appropriate fire storey dampers should be driven open.

Fire/smoke dampers should be approved for reliability by the relevant authority and should be located and controlled as follows.

a) The damper drive motor should be located outside the risk area or otherwise protected in accordance with the manufacturer's instructions so that it will continue to operate throughout the period of time and temperatures specified in **6.3**.

b) The integrity of the associated electrical installation and equipment should be maintained at all times and any cables used for control or electrical supply purposes and located within a risk area should conform to **8.3**.

c) The dampers should be actuated by an automatic fire detection and alarm system designed in accordance with BS 5389-1.

Annex D (informative) Air leakage data

The leakage areas given in Table D.1, Table D.2 and Table D.3 are provided for guidance only. Leakage areas are highly dependent on the quality of workmanship and actual values may vary considerably from the range given.

Table D.1 — Air leakage data for doors

Type of door	Leakage area m^2	Pressure differential Pa	Air leakage m^3/s
Single-leaf opening into a pressurized space	0.01	8	0.02
		15	0.03
		20	0.04
		25	0.04
		50	0.06
Single-leaf opening outwards from a pressurized space	0.02	8	0.05
		15	0.06
		20	0.07
		25	0.08
		50	0.12
Double-leaf	0.03	8	0.07
		15	0.10
		20	0.11
		25	0.12
		50	0.18
Lift landing door	0.06	8	0.14
		15	0.19
		20	0.22
		25	0.25
		50	0.35

Table D.2 — Air leakage data for windows

Type of window	Crack area m^2 per m length	Pressure differential Pa	Air leakage m^3/s
Pivoted, no weather stripping	2.5×10^{-4}	8	0.77×10^{-3}
		15	1.1×10^{-3}
		20	1.4×10^{-3}
		25	1.6×10^{-3}
		50	2.4×10^{-3}
Pivoted and weather stripped	3.6×10^{-5}	8	0.11×10^{-3}
		15	0.16×10^{-3}
		20	0.19×10^{-3}
		25	0.22×10^{-3}
		50	0.34×10^{-3}
Sliding	1.00×10^{-4}	8	0.30×10^{-3}
		15	0.45×10^{-3}
		20	0.54×10^{-3}
		25	0.62×10^{-3}
		50	0.95×10^{-3}

Table D.3 — Air leakage data for walls and floors

Construction element	Wall tightness	Leakage area ratio A/A_w
Exterior building walls (including construction cracks, cracks around windows and doors)	Tight	0.70×10^{-4}
	Average	0.21×10^{-3}
	Loose	0.42×10^{-3}
	Very loose	0.13×10^{-2}
Internal and stair walls (includes construction cracks but not cracks around windows and doors)	Tight	0.14×10^{-4}
	Average	0.11×10^{-3}
	Loose	0.35×10^{-3}
Lift well walls (includes construction cracks but not cracks around windows and doors)	Tight	0.18×10^{-3}
	Average	0.84×10^{-3}
	Loose	0.18×10^{-2}
		Leakage area ratio A/A_f
Floors (includes construction cracks and cracks around penetrations	Average	0.52×10^{-4}

NOTE A = Leakage area
A_w = Wall area
A_f = Floor area

Annex E (normative) Test method for measuring the pressure differentials under closed door conditions

E.1 Initiate the pressure differential system operation. Allow fans to operate for at least 10 min to establish steady air temperatures.

E.2 Switch off the pressure differential system fans, leaving all other components in their operational mode.

E.3 Fully open the doors and allow them to close before any pressure difference measurements are taken. Measure the pressure differential across each door linking pressurized and unpressurized spaces using one of the following methods.

a) Pass a probe under the closed door and connect it to a calibrated manometer. Two tubes should be used so that the pressure at equal points on each side of a door can be measured. Each measuring point should be at least 50 mm above the floor.

b) Fit permanent tubes between the pressurized and unpressurized zones. The tubes should terminate flush with the face of the wall or door of the test zone and should be at least 50 mm above the floor.

NOTE The tubes should be provided with end caps to ensure that the fire resistance of the wall or door is not reduced and to keep the tubes clear of debris etc.

E.4 Within 15 min of completing **E.3**, switch the pressure differential system fans back on and repeat the pressure measurements detailed in **E.3**. The change in measurement between the first and second pressure readings should be compared with the performance requirements specified for the design pressure differences.

Annex F (normative) Test method for measuring air velocities

Ensure that the doorway is clear of obstructions when measurements are taken.

[A1⟩ Using a calibrated anemometer, measure the flow velocity through the open storey door, when all other doors are either open or closed, in accordance with the “airflow through the doorway between the pressurized space and the accommodation area” statement for the relevant system classification described in Clause **5**. ⟨A1]

NOTE A rotating vane anemometer or a hot wire anemometer is adequate for air velocity measurement purposes.

Take at least 10 measurements, uniformly distributed over the doorway, to establish an accurate air velocity. Calculate the average of these measurements.

Annex G (informative)
Possible solutions for inability to obtain design pressure differential

NOTE 1 The following guidance relates specifically to pressurization systems. However, similar principles, suitably adapted, may also be applied to depressurization systems.

The pressure differentials recommended in this standard are intended to take account of fire buoyancy and external wind conditions. If tests are carried out where external conditions give rise to high wind and gusts, it may not be possible to achieve the design pressure differential.

Where stack effect is likely to be a significant factor this may be minimized by operating the pressure differential system for a period of 1 h before testing so that the external air and shaft temperatures can equalize.

Apart from external conditions, there are three main reasons for failing to achieve the desired pressure differentials, as follows.

a) *Insufficient air supply to the pressurized space.* The required pressure differential will not be established if there is insufficient air supply to the pressurized space. There are two methods of assessing the airflow to the pressurized zones.

NOTE 2 For each method the procedures detailed in BSRIA Application Guide AG3/89.1 give appropriate guidance.

The first method is to measure the total air supply at the fan, subtract the ductwork leakage (see **12.1**) and then proportion the remaining airflow to each terminal according to measurements taken during commissioning (see **11.4**). The second method is to measure the airflow out of each terminal.

If the measured airflow is below the design value, open selected doors separating the pressurized and unpressurized spaces and measure the airflow again. If the airflow increases with the doors open, a ductwork leakage test (see **12.1**) should be performed and remedial action taken.

NOTE 3 Tape should not be used to seal ducts.

b) *Excess leakage from the pressurized space.* As stated in **6.2**, it is important that the architect and builder are aware of the need for the construction to be as airtight as possible.

Where the measured pressure differential is lower than the design value it is often because the structure exceeds the level of leakage allowed for in the design. The sealing of all penetrations through the pressurized space should be checked, e.g. trunking, pipework, ductwork and light fittings, and improved where necessary. A check should also be made of the fit of doors and the gap sizes under them, and of the installation of false ceilings etc.

If the leakage does not exceed the anticipated level, then it will be necessary to increase the air supply rate and possibly also to increase the leakage from the unpressurized spaces.

c) *Insufficient leakage from unpressurized spaces.* If, during the procedures outlined in item a), the air supply to the pressurized spaces increases when doors are opened between the pressurized and unpressurized spaces, the likely cause is a lower than expected rate of leakage from the unpressurized space.

Ensure that the ventilation system has operated as required on all storeys. If this is functioning normally, then it may be necessary to add further vents to increase the escape of air.

Annex H (informative)
[A1] Design calculations requirements

H.1 General

The calculation procedure listed in **H.2** and **H.3** below will, by selecting the appropriate parts of Clause **14** provide a method of estimating the pressure and airflow in the protected and unprotected spaces within a building. The pressure and airflow to be provided should be appropriate to the building type and selected from Clause **5** System classification and **9.3** for depressurization systems.

NOTE These calculations apply only to leakage paths having the same value of N in equation (1). Furthermore in the case of equation (4) (see **14.1.3**) the value of N should be 2. However, since the predominant leakage paths will almost invariably be through doors, the contribution from window leakage is likely to be small.

H.2 Pressurization calculation procedure

The following steps provide a method of evaluating the air needed.

NOTE Calculation methods that can be used are contained in Clause **14**. The corresponding calculation method is shown in brackets after the requirement.

H.2.1 Identify all the airflow paths with doors closed (see **14.2.1**).

H.2.2 Evaluate the effective leakage paths between each adjacent space (see **14.1.2**, **14.1.3** and **14.1.4** together with Figure 13, Figure 14 and Figure 15).

H.2.3 Calculate the total equivalent leakage rate via gaps around doors Q_D (see **14.2.2**).

H.2.4 Calculate the leakage rate via cracks around all the windows Q_w (see **14.2.3**).

H.2.5 Calculate the leakage rate via lift landing doors Q_{ld} (see **14.2.4**).

H.2.6 Calculate the leakage via other areas containing mechanical extraction systems Q_t (see **14.2.5**).

H.2.7 Calculate the leakage via other air paths (see **14.2.6**).

H.2.8 Calculate the total air supply required with all the doors closed Q_s (see **14.2.1**).

H.2.9 Identify which doors are open for the design condition referring to the appropriate class of system (see **5.1** to **5.6** inclusive, and Figure 1, Figure 2, Figure 3, Figure 4 and Figure 5).

H.2.10 Identify all the airflow paths with the doors identified in **H.2.9** open and evaluate leakage areas (see **14.1.2**, **14.1.3** and **14.1.4** together with Figure 1, Figure 2, Figure 3, Figure 4, Figure 5, Figure 13, Figure 14 and Figure 15).

H.2.11 Calculate the total air supply required with all the doors fully open (Q_{sdo}) in **H.2.10**. The total air supply required will include not only the open doors but also any air passing through the cracks around the doors and windows, etc. that remain closed. Calculation of the air supply required will, if the building contains a pressurized lift shaft, make it necessary to evaluate the leakage from the lift shaft into the lobby or stair. As a generally conservative estimate it can be assumed that approximately 50 % of the air supplied to the lift shaft will enter the stair or lobby.

H.2.12 From **H.2.8** the total supply air required, with all doors closed, should be increased by a factor of 50 % for unknown leakage paths not discussed in the previous normative statements (this value is Q_s).

H.2.13 Use the larger value of the calculated Q_s or Q_{sdo} for the fan duty.

H.2.14 For pressurization systems use the larger value of the calculated Q_s or Q_{sdo} to calculate the air release requirements from pressurized spaces with open doors (see **14.3**).

H.2.15 Calculate the door opening forces (see **14.3.5** and **14.4**). Should the force required to open the door exceed 100 N calculate the appropriate air release vent area from the pressurized space (over pressure relief). [A1]

A1 H.3 Depressurization calculation procedure

The following steps provide a method of evaluating the air needed. The fan duty now applies to the exhaust fan removing air and/or hot gasses from the fire room.

H.3.1 Identify all the airflow paths regarding doors closed (see **14.2.1**).

H.3.2 Evaluated the effective leakage paths between each adjacent space (see **14.1.2**, **14.1.3** and **14.1.4** together with Figure 11, Figure 13, Figure 14 and Figure 15).

H.3.3 Calculate the total equivalent leakage rate via gaps around doors Q_D (see **14.2.2**).

H.3.4 Calculate the leakage rate via cracks around all the windows Q_w if present (see **14.2.3** and **9.3.2**).

H.3.5 Calculate the leakage rate via lift landing doors Q_{Id} (see **14.2.4**).

H.3.6 Calculate the leakage via other areas containing mechanical extraction systems Q_t (see **14.2.5**).

H.3.7 Calculate the leakage via other air paths (see **14.2.6**).

H.3.8 Calculate the total air exhaust required with all the doors closed Q_s (see **14.2.1**).

H.3.9 Identify which doors are open referring to the classes of system (see **5.1** to **5.6** inclusive, and Figure 1, Figure 2, Figure 3, Figure 4 and Figure 5.

H.3.10 Identify all the airflow paths regarding doors open and evaluate (see **14.1.2**, **14.1.3** and **14.1.4** together with Figure 1, Figure 2, Figure 3, Figure 4, Figure 5, Figure 13, Figure 14 and Figure 15).

H.3.11 Calculate the total air exhaust required with all the doors fully open (Q_{sdo}) in **H.3.10**.

The total air exhaust required will include not only the open doors but also any air passing through the cracks around doors and windows, etc. that remain closed.

H.3.12 Calculate the total exhaust air required plus a factor of 50 % for exhaust air leaving the depressurized fire room.

H.3.13 From **H.2.8** the total exhaust air required, with all doors closed, should be increased by a factor of 50 % for exhaust air leaving the depressurized fire room.

H.3.14 Use the larger value of the calculated Q_s or Q_{sdo} for the fan duty.

H.3.15 For depressurization systems use the larger value of the calculated Q_s or Q_{sdo} to calculate the minimum leakage area from the interior and possibly exterior of the building into the unprotected space (see **14.3**).

H.3.17 Calculate the door opening forces (see **14.3.5** and **14.4**). Should the force required to open the door exceed 100 N calculate the appropriate air release vent area from the depressurized space (the over pressure relief must operate into the depressurized fire room). A1

List of references (see Clause 2)

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[A2) *Text deleted* (A2]

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