Smoke Control Association

Guidance on Smoke Control to Common Escape Routes in Apartment Buildings (Flats and Maisonettes)

Revision 2: October 2015

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1 Foreword

When this guide was first produced back in 2012, it quickly became the default reference document for many designers, installers and approving authorities throughout the UK and even beyond.

Due to its popularity and the ever increasing complexity of building design, it very quickly became necessary to update it and so I am very pleased to be able to introduce this latest revision from the Smoke Control Association.

The prevention of smoke spread through buildings is of critical importance, but little guidance is currently available in one publication. This document provides details and gives recommendations not previously covered in other standards or codes of practice and should make a significant contribution to improved understanding of smoke control systems.

Contained within the document are sections on the different types of system and their function, information on all the relevant legislation, standards and codes of practice. The SCA particularly recognises the importance of using certified products for smoke control applications, and is particularly pleased to see these topics addressed here.

Included in this revision are many new recommendations, updated product standards, a new section on Fire Service Intervention and a limitation on the extension of travel distances to which all member organisations have agreed.

I would like to thank the working group for their hard work and dedication in producing this guide, and appreciate the contribution made by the many practitioners, Building Control Officers, fire engineers and Fire Officers who gave up their valuable time.

The Smoke Control Association in conjunction with other experts from the fire industry promotes high standards of fire protection. The SCA is sure that this Guide will continue to be an essential reference work within the industry and shows a commitment from our members of using best practice in all that they do.

Conor Logan
Chairman of the Smoke Control Association

2 Introduction

This document covers information and requirements on the design, calculation methods, installation and testing of systems intended for smoke control within the common escape routes within apartment buildings.

The provision of such systems is recommended in order to improve the conditions for escape and fire fighting.

2.1 Primary Objectives

The primary objective of the smoke ventilation system is to protect the staircase and protect the common circulation areas. The performance criteria and the design of the system vary depending on the layout of the common corridor or lobby.

Where the travel distances are no more than 7.5m in distance from the door to the staircase (or sterile lobby) to the most remote apartment entrance door, the primary objective of smoke control in residential buildings is to protect the staircase enclosure by ensuring that the stairway(s) remain relatively free from smoke and heat in the event of a fire within a dwelling.

Note: where a sterile lobby is provided to the staircase, e.g. a lobby not approached by apartments or other areas of significant fire risk, there is no restriction on the travel distance in the lobby, whether the lobby is ventilated or not, and the travel distance can be measured from the apartment door to the door to the sterile lobby.

However, where corridors are extended, the primary objective of the smoke control system is to protect both the common corridor and the staircase enclosure. There are considered to be two forms of extended corridors:

I. Extended corridors – These typically have no more than 15m travel distance from the furthest apartment door to the staircase or sterile lobby. The primary objectives of the smoke control system are to protect the common corridor for means of escape and the staircase enclosure for means of escape and fire-fighting.

II. Significantly extended corridors – These typically have more than 15m travel distance from the furthest apartment door to the staircase door or sterile lobby. The primary objective of the smoke control system is to protect both the common corridor and the staircase enclosure for means of escape and Fire Service operations. The increased length of the corridors can adversely affect fire-fighting operations and require additional consideration of design factors such as tenability limits, time lines and fire sizes.

   Note: regardless of the corridor design, it is recommended that the maximum travel distance should be limited to 30m from the furthest apartment door to the staircase door. See section 5.4.

This guidance document also covers the provision of systems where no communal lobbies or corridors are provided, such as small single stair buildings as detailed in Approved

Document B or BS 9991. Here the primary objective is solely to protect the staircase enclosure, with an emphasis on Fire Service access rather than means of escape.

2.2 Smoke Control Methods

The effect of the air movement forces, including buoyancy experienced by hot gases on the fire storey, thermal expansion of hot gases in the fire zone and even stack effect, can cause smoke to spread through leakage paths in vertical barriers between rooms, e.g. doors, walls, partitions, from the apartment of fire origin and into the corridor.

The ventilation methods most commonly used to limit the degree of smoke spread, or to control its effects, in the common areas of residential apartment buildings are:

a) Natural smoke control systems.
b) Mechanical smoke ventilation systems.
c) Pressure differential systems.

The design implications for each of the three system types are considered within this design guide.

2.3 Responsibilities

Through this document, the Smoke Control Association provides guidance on the design of smoke control systems in apartment buildings. While there is limited guidance in both Approved Document B and BS 9991 for either designers or approving authorities, this document sets out the information and parameters that the designer should incorporate into the design when using calculations and/or CFD models.

Smoke control systems form one element of the overall fire engineering strategy for apartment buildings and should not be designed in isolation. It is the responsibility of the designer of the smoke control systems to ensure that any proposed systems complement the fire safety strategy and provide a suitable level of fire safety, just as it is also the responsibility of the architect and fire engineer to ensure that building layout provided to the smoke control system designer is adequate for the purpose. Early consultation by the design team with a smoke control system designer is therefore recommended.

For the design and approval process to be successful it is strongly recommended that, except perhaps in the simplest cases, the system objectives, the scenarios to be calculated or modelled, the modelling criteria, the expected reporting and the success criteria are all agreed and documented prior to commencement of design.

Guidance in this document is based around compliance with Building Regulations. Designers should note that they should also consider the requirements of the Construction (Design and Management) Regulations, the Workplace (Health, Safety and Welfare) Regulations, the Regulatory Reform (Fire Safety) Order and any other relevant legislation. Consultation with the regulatory authorities may assist in achieving an appropriate design.

While this document predominantly references the principles of Approved Document B and BS 9991 and BS 7346-8, the majority of the principles are relevant where other design guidance is utilised (such as the Technical Standards in Scotland) although reference should be made to the authority having jurisdiction.

3 Scope

The principles detailed within this document are specifically designed for apartment buildings containing flats or maisonettes. No specific limitations are set within this document on the age, disability, or familiarity of the occupants to each other or to the building provided that they are able to evacuate the building without considerable assistance. On this basis this document can be used for the design of smoke ventilation systems for the following examples of apartment buildings:

a) Owner occupied housing
b) Social housing, including assisted living and extra care accommodation.
c) Apartments provided for short term rental, including student apartments and apart-hotels, if designed and constructed to the same principles as apartment buildings.

This document is not considered suitable for use for prisons, hospitals, nursing homes or other building types where the occupants are not considered able to evacuate without substantial assistance. Notwithstanding this, system designers and approving authorities may wish to consider the principles detailed in this document where insufficient other design guidance exists.

While this design guide is intended for buildings operating a ‘stay put’ evacuation policy, it may also be appropriate for buildings operating staged, phased or simultaneous evacuation. Where such evacuation policies are considered the system designer and authority having jurisdiction (AHJ) should carefully consider the evacuation policy on the design objectives.

Where such evacuation policies are considered, the system designer and authority having jurisdiction (AHJ) should carefully consider the impact of the evacuation on the design objectives, and any supporting justification put forward (including how any computer modelling used will account for the proposed evacuation regime and the potential need to maintain tenable conditions within the corridors throughout the whole of the means of escape phase).

This document specifies smoke control systems designed to control the spread of smoke from the apartment of fire origin into the common escape routes. It covers methods for calculating the parameters of the smoke control systems as part of the design procedure.

It gives test procedures for the systems used, as well as describing relevant and critical features of the installation and commissioning procedures needed to implement the calculated design in a building. It covers systems intended to protect means of escape from common escape routes such as stairwells, corridors and lobbies, as well as systems intended to protect fire service access routes.

The systems incorporate smoke control components in accordance with the relevant British and European Standards. This document gives requirements and methods for the evaluation of conformity for smoke control systems as well as testing regimes.

4 Terms and Definitions

1.1. Authority having jurisdiction (AHJ)
Organisation, office or individual responsible for enforcing the requirements of legislation or standards, or for approving equipment, materials, an installation, or a procedure.

1.2. Common escape route
Designated route from the front door of an apartment to a place of safety or relative safety

1.3. Compartment
Enclosed space, comprising one or more separate spaces, bounded by elements of construction having a specified fire resistance and intended to prevent the spread of fire (in either direction) for a given period of time

1.4. Computational Fluid Dynamics (CFD)
The use of computers to solve mathematical equations that simulate the flow of fluids, heat transfer and other associated phenomena. (Note: For the purposes of this paper, CFD modelling can be used to predict fire, smoke movement, heat, radiation, ventilation flow etc based on the input parameters provided)

1.5. Depressurisation
Smoke control using pressure differentials where the air pressure in the fire zone or adjacent spaces is reduced below that in the protected zone

1.6. Design fire
Hypothetical fire having characteristics that are sufficiently severe for it to serve as the basis of the design of a smoke control system

1.7. Fire engineering strategy
A strategy developed using application of scientific and engineering principles to the protection of people, property and/or the environment from fire

1.8. Fire resisting (resistance)
The ability of a component or construction of a building to satisfy for a stated period of time, some or all of the appropriate criteria specified in the relevant standard test.

1.9. Fire Separation
A compartment wall, compartment floor, cavity barrier or construction enclosing a protected escape route and/or a place of special fire hazard.

1.10. Manual control point

The term “manual control point” encompasses generic phrases such as fire fighter’s switch, call point, break glass etc. (refer to 8.2.5.2)

1.11. Mechanical (or powered) ventilation
Ventilation caused by the application of external energy to displace gases through a ventilator Note: fans are usually used

1.12. Natural ventilation
Ventilation caused by buoyancy forces resulting from differences in density between smoky and ambient air gases due to temperature difference

1.13. Pressurisation
Smoke control using pressure differentials, where the air pressure in the spaces being protected is raised above that in the fire zone

1.14. Primary power supply
Power supply that is used whenever it is available (Note: usually the normal mains supply to the building)

1.15. Secondary power supply
Power supply that automatically replaces the primary power supply in the event of its failure (Note: usually provided by batteries, generators or a separate mains supply)

1.16. Steady state design
Design based on the largest fire with which a smoke control system is expected to cope
Note: there is no expectation that this fire size will be maintained for any significant period in practice)

1.17. Stay put strategy (*as per BS 9991*)
Strategy normally adopted in blocks of flats and maisonettes whereby, when a fire occurs in a flat or maisonette, the occupants of that dwelling evacuate, but occupants of all other dwellings can safely remain in their dwellings unless directed to leave by the fire and rescue service

1.18. Tenable
Measure of the level of exposure to hazards from a fire that can be tolerated without violating safety goals

1.19. Time dependent design
Design based on a fire for which the heat release rate and/or other parameters change with time

1.20. Time line
A sequence of events and times representing actions that is sufficiently severe for it to serve as the basis of the design of a smoke control system

1.21. Vent
An operable ventilation opening, either direct to outside or into a ventilation shaft, from a stair, lobby or corridor Note: The term has the same meaning in ADB

1.22. Zone model
A computer program using simplified calculations treating the space or spaces modelled as a series of homogenous zones and taking average characteristics for those zones

NOTE: These definitions are taken from or based on definitions in relevant British or European Standards or other HEVAC guides wherever possible.

5 Objectives and Performance Criteria

5.1 General

All residential ventilation systems are intended to help protect means of escape (MOE) and assist fire-fighting operations (FF) in case of fire in a dwelling.

Generally, for most smoke control systems applied in apartment buildings, the common spaces requiring smoke ventilation are the stairs and the lobbies and/or corridors opening onto the stairs. The level of protection will vary with the design of the stair core and corridors and the type of ventilation system provided.

Where the building design and the ventilation system are in direct conformity to ADB to the Building Regulations or equivalent (outside England and Wales), there is no requirement to consider objectives or performance criteria as the ventilation system is deemed to be suitable by virtue of its prescription to the relevant document. This section then does not apply.

In other cases it is necessary to consider the objectives and performance criteria for the system. Depending on the design of the common escape routes, this can either take the form of an assessment to ensure that the proposed design provides 'equivalence' to the prescriptive systems or a detailed engineering analysis.

Where travel distances are compliant with the relevant code of practice, a smoke control system can be designed to show equivalence to the code compliant solution, based on the same building layout and geometry.

Where travel distances are extended and/or corridor sub-divisions are removed in buildings with a 'stay-put' policy, proving 'equivalency' to code compliance is not appropriate. A detailed engineering analysis is required although in every design strategy the relevant prescriptive benchmarks and functional requirements should be used for comparison

As with any alternative solution there are a number of methods which allow the investigation and demonstration of its performance. These range from hand calculations through to more sophisticated computer models such as zone models and CFD. Each method offers different benefits with associated limitations, ranging from fast calculations with limited spatial and temporal resolution to extensive spatial and temporal resolution with extended calculation time.

It is the responsibility of the assessing engineer to determine which method of investigation should be used. It is recommended, however, that the technique to be used be agreed with the relevant approving authorities prior to an assessment being performed.

It is further recommended that, where an authority having jurisdiction (AHJ) is unfamiliar with the technique used or does not have the necessary technical knowledge to assess the technique, a peer review should be considered.

There is often confusion regarding fire fighting stairs in residential buildings. While specific reference should be made to the relevant design guide to which the building is constructed, in the case of buildings designed using BS 9991 or ADB, fire fighting stairs are recommended when the top storey is more than 18m above fire service access level. However, as long as the building layout conforms to ADB and the normal corridor/lobby ventilation is provided, there is no requirement for a dedicated fire fighting lobby and the more onerous ventilation recommendations for a fire fighting lobby do not apply. See clause 17.14 of ADB: 2006 (as amended).

5.2 Objectives

5.2.1 Commentary

Fire statistics show that the majority of fire deaths in residential buildings are caused by smoke inhalation and not through direct exposure to the fire. In high rise buildings, the flow of heat and smoke from a fire creates even greater risks for the occupants and fire-fighters alike.

Most design guides identify the primary means of controlling the flow of smoke in residential buildings as the fire rated separation (i.e. the provision of protected escape routes and protected stairwells), with smoke control designed to supplement these provisions.

As stairs will be used by the majority of the occupants of the building, potentially for a longer duration than the common escape routes on the floor of fire origin, as well as being an access and egress route for the fire service, it is considered of primary importance to protect the stair(s) irrespective of the design of the smoke ventilation system.

The ability of the system to prevent smoke from entering the staircase is affected by the proximity of the apartment door to the staircase. Although there is no control on this proximity in many design guides, including ADB and BS 9991, where possible, apartment doors should not be located in close proximity to doors to the staircase. Some smoke leakage into the staircase due to thermal expansion of hot gases in the fire zone (apartment of fire origin) may occur irrespective of the door location. This is because fire induced expansion of gases can result in a build-up of pressure, leading to a rapid flow of hot gases out of the compartment when the apartment door is opened, especially if the staircase door is already open. However, in most cases, the initial expansion forces dissipate quickly and the leakage of smoke into the stair due to this action is limited and may be acceptable to the designer and the approving authorities where it does not adversely affect the tenability conditions within the stair.

Work by the BRE and others, as confirmed in ADB, has made it clear that it is not possible to keep common corridors and lobbies completely free of smoke (except possibly by pressurisation systems with protection extended past the entrance door to each dwelling). Any system should, however, be designed to promote tenable conditions for travel through the ventilated corridors/lobbies during the escape period. It should be noted that this may only be possible during periods when the apartment door is closed and the flow of smoke from the apartment into the corridor is substantially reduced by the passive fire protection provided by the door.

5.2.2 Recommendations

The guidance provided describes single corridors with single direction travel but the recommendations also generally apply to building designs with multiple corridors or corridors with multiple direction of travel.

The design objective of any system should be to maintain relatively smoke free conditions within the staircase such that it can be used for evacuation and fire service access/egress at all times. Where the travel distance from the furthest apartment to the door to the staircase or the door to a sterile lobby does not exceed 7.5m, this is considered to be the only design objective. Therefore, where a mechanical ventilation system is provided to the common escape routes, it is not considered necessary to assess conditions within the corridor or the sterile lobby against specific performance objectives. The system provided should have at least equivalent performance to a compliant natural ventilation system and conditions should not be made worse. Where a compliant natural ventilation or pressurisation system is provided then generally no further consideration is required.

Where the building design follows BS9991 or, where the AHJ is willing to accept the proposal, and travel distances from the furthest apartment entrance door to the staircase door does not exceed 15m, and the building is provided with residential sprinklers meeting the design guidance given in BS 9251, then irrespective of building height it is considered appropriate for the smoke ventilation system to meet the same performance criteria as a system provided for a building where the travel distance from the apartment of fire origin to the door to the staircase does not exceed 7.5m.

Where sprinklers are not provided and where the travel distances from the apartment to staircase or sterile lobby are over 7.5m but do not exceed 15m, the performance objectives of the system are to maintain the staircase relatively free of smoke and to ensure the designer’s specified tenable limits for means of escape are met within the corridor. Additional performance objectives for protection of fire fighters are required where the building is of significant height and, therefore, under the relevant design guide (e.g. ADB) additional provisions for fire-fighting access, such as fire-fighting shafts, may be required. Note: generally natural ventilation is not appropriate for corridors of this length, so the system provided should be mechanical.

Where the travel distances from the apartment to staircase or sterile lobby exceed 15m, the performance objectives of the system are to maintain the staircase relatively free of smoke and to ensure the designer’s specified tenable limits for means of escape and Fire Service operations are provided within the corridor. This may necessitate discussions with the Fire Service and authority having jurisdiction (AHJ), prior to design or installation of the smoke control system, to ensure the system performance allows the operational requirements for fire fighters to be met, irrespective of building height.

Any ventilation design will form part of an overall fire safety strategy and should not be designed in isolation. The designer of a smoke ventilation system should define how it fits into the fire safety strategy.

5.3 Performance Criteria

5.3.1 Introduction

Before setting any performance criteria it is necessary to set the design conditions under which these criteria should be met.

In its study of smoke ventilation where travel distances are code compliant, BRE focused its research on 'steady-state' conditions, examining a number of design fires and fixed door openings. This approach allows a straightforward comparison of different geometries and ventilation methods. It does not, however, capture the transient nature of an actual fire scenario, where the fire develops with time and doors open and close at various stages during the event. Nevertheless, an analysis of steady-state conditions can provide a convenient way to assess a smoke ventilation system, in particular with regard to the protection afforded to the stair enclosure and to after the arrival of the fire service, where fixed door opening conditions may be relevant.

The alternative approach, employing a timeline of events and actions, is more realistic but generally requires additional analysis and consideration of time dependent performance criteria, e.g. the time to return a corridor to conditions suitable for means of escape.

Performance criteria are generally based on tenability. The main criteria of interest could include visibility, gas temperature, thermal radiation and toxicity within the common corridors, lobbies and stair enclosures. Selection of appropriate performance (acceptance) criteria for assessing a fire engineered system design should be established at the start of the design process, typically at the qualitative design review.

Pressure differences between the corridor/lobby and adjacent stairs and accommodation should not cause door opening forces to exceed 100N. It is important also to consider the potential impact of the pressure difference between the dwelling and the corridor to ensure that smoke is not unduly pulled into the corridor when the dwelling door is in a closed position. The maximum acceptable level of depressurisation in the corridor relative to the apartment will depend on factors such as the doorset construction, including the performance of the smoke seals and size of gap under the door.

Air flows from the stair enclosure into the corridor, in the situation where the door is open, might be adopted as a performance criterion, with a minimum design air speed set to prevent the flow of smoke into the stair.

It is recommended that performance criteria and accompanying fire scenarios be agreed with the authority having jurisdiction (AHJ) as part of the approval process, preferably in advance of detailed calculations or modelling. This will be relevant particularly where the performance is being assessed against specific tenability criteria rather than against a code-compliant solution.

Typical performance criteria and accompanying fire scenarios are discussed below for both code-compliant and extended travel distances, and encompass both steady-state and time-dependent design analyses. While these are offered as a suitable 'point of reference' for use in apartment buildings, they are not exhaustive and should not restrict the use of alternative criteria and scenarios that are considered more suitable for a specific project. It is the responsibility of the designer to determine which fire scenarios and performance criteria should be used.

5.3.2 Tenability criteria for means of escape

Where system performance is being assessed deterministically (and not compared to an ADB compliant one) it will generally be necessary to set acceptance limits for one or more performance criteria based on tenability. It is not appropriate to give definitive values here as they need to be established on a case by case basis as part of the overall fire strategy. However, published information is available (see, for example, BS 7974:2001 and associated PD 7974 series *Application of fire safety engineering principles to the design of buildings*, BS 7899-2:1999 *Guidance on methods for the quantification of hazards to life and health and estimation of time to incapacitation and death in fires*, the SFPE *Handbook of Fire Protection Engineering* and the ASHRAE *Handbook of Smoke Control Engineering* and CIBSE Guide E *Fire Engineering)*. Some recommendations that might be considered are provided below. The appropriate choice for an individual system should take into account the specific design details such as travel distances, occupancy characteristics etc.

Exposure gas temperature and thermal radiation flux (irradiance) limits of 60°C and 2.5kW/m^2 represent typical acceptance limits in respect to tenability for means of escape.

Visibility distance and toxicity levels may also be important performance criteria in respect to means of escape. Both are functions of the smoke concentration, with visibility being approximately inversely proportional to the density of soot particulate. Care and engineering judgement is required as the calculated values will be strongly dependent on the choice of soot and toxic yields (generally an input parameter in a zone or CFD model) and also the ventilation conditions. Visibility distance is a widely used performance criterion for smoke control design, and in addition to allowing an estimate of how far a person could see provides a measure of the toxicity associated with the smoke. It is generally accepted that if visibility is acceptable then the toxicity condition is likely also to be acceptable, at least for the exposure times during the escape. It should be noted, however, that visibility distance is a working engineering parameter rather than a precise measure of how people will respond in a real emergency.

A commonly adopted conservative visibility distance limit is 10m (approx. 0.1m^{-1} optical density) as measured to a light reflective surface, representing an approximate value through which persons unfamiliar with a building would be prepared to travel (see, for example, ref: *T. Jin, "Studies on Human Behavior and Tenability in Fire Smoke," Proceedings, 5th International Symposium on Fire Safety Science, pp. 3–22, 1997*). A lower value of 5m might be acceptable where the persons escaping are familiar with the building and the travel distance is relatively short. At a visibility distance of 5m (approx. 0.2m^{-1} optical density) conditions will remain tenable with respect to asphyxiant gases for at least 30 minutes (see PD 7974-6) for the majority of fires.

An alternative, and potentially more rigorous, approach is to determine whether or not the stair door is visible from the apartment entrances. This involves calculating the spatially averaged visibility distance along the line of sight from the apartment to the stair door, which could be seen on the proviso that the average visibility distance exceeds the travel distance. This approach is explored further, for example, in the ASHRAE *Handbook of Smoke Control Engineering*.

It is often difficult to maintain a minimum visibility distance when the apartment door to the corridor remains open; this is because the corridor fills with smoke generated by the apartment fire. BRE Report 213179 found that it was difficult under most fire scenarios to keep the corridor clear of smoke when the apartment door remained open (even partially). This highlights the importance of the reliability and the maintenance of the door closing device.

While the protection to the stair is of primary importance, where there are extended travel distances the rate of smoke clearance from the corridor is also likely to be an important requirement of the smoke control system. A time dependent analysis will be required to determine how long it takes to return the corridor to a specified visibility or other tenability criteria once the apartment door has closed or the smoke ventilation system activates (these will not generally be the same). A time of two to three minutes is typically acceptable to the approving authorities. The event that marks the start of the smoke clearance period should be clearly identified in the presented results.

5.3.3 Tenability criteria for fire fighting

While it is acknowledged that it is extremely challenging to design smoke ventilation systems to maintain tenable conditions for occupant means of escape in common corridor and lobby areas once the door to the flat of fire origin has been opened for fire service intervention, consideration should be given to what additional protection these smoke ventilation systems can offer fire fighters during fire fighting operations. This is of particular importance when dealing with common escape routes that do not accord with prescriptive guidance contained in the relevant approved codes of practice (for example, Approved Document B Volume 2, or BS9991 guidance).

Although fire fighters will be wearing suitable Personal Protective Equipment (PPE) when conducting search, rescue, and fire fighting activities within a building, this equipment does have limitations. Fire fighters themselves also have different, individual physiological capabilities which can further limit their ability to perform tasks, depending upon the fire scenario and conditions in which they are working.

Therefore, for common escape routes where smoke ventilation systems are being proposed to justify extended single direction travel distances of more than 7.5m in length (or more than 15m where appropriate suppression is provided in accordance with BS9991 guidance), specific assessment of the conditions within these spaces should be completed by the system designer to demonstrate that effective fire service intervention can actually be achieved. This should also be considered where extended travel distances are proposed in corridors with two or more directions of escape/ fire fighter access.

Publicly available and recent research relating to fire fighter tenability is somewhat limited at present, however it is suggested that the criteria in Table 5.1 (as adopted by the Australasian Fire Authorities Council (AFAC)) could be applied by system designers when assessing this issue:

Table 5.1 Illustrative fire fighter tenability conditions

Exposure Condition	Maximum exposure time (minutes)	Maximum air temperature (0C)**	Maximum radiated heat flux (kW/m2)	Remarks	Recommended distance from apartment door*
Routine	25	100	1	General fire-fighting	15-30m
Hazardous	10	120	3	Short exposure with thermal radiation	4-15m
Extreme	1	160	4 – 4.5	For example, snatch rescue scenario	2-4m
Critical	<1	>235	>10	Considered life threatening	0-2m

* This column and remarks are not part of the original research document and are the opinion of the SCA
** Measured at a height of 1500mm from FFL

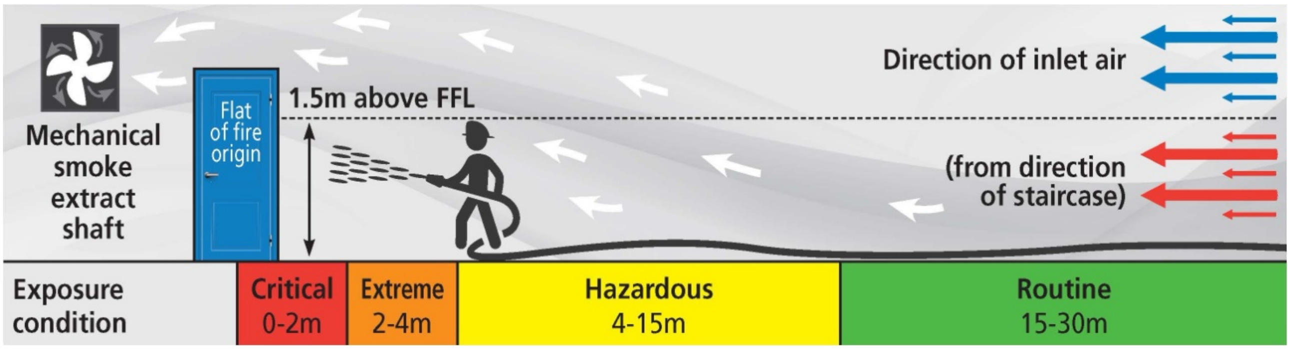


Figure 5.1 Fire fighter tenability conditions

5.3.4 Code-compliant travel distance systems

Where the travel distance in the corridor or lobby is code-compliant the primary issue is the protection afforded to the stair enclosure. As acknowledged in ADB, for example, performance criteria in the corridor are not explicitly demanded; adequate levels of safety are provided by the fire separation and limited travel distance.

Adopting a steady-state analysis allows a direct and potentially less time consuming design process. With the fire size, compartment ventilation provisions and door opening distances fixed, conditions (e.g. visibility, temperature) in the corridor and stair can be compared for different smoke ventilation schemes. In particular, conditions can be compared for the proposed smoke ventilation system against those generated by a code-compliant system, e.g. an alternative mechanical system against a code-compliant one as described in ADB.

It is important when adopting this approach to use the same fire scenario boundary conditions for the proposed and code-compliant designs.

Table 5.2 shows one set of boundary conditions, based on those used in BRE project report 213179. These are for an un-sprinklered fire in a simplified representation of a dwelling, comprising a single room with floor dimensions 5m by 5m and height 2.2m, vented to the outside by a size of opening sufficiently large that replacement air is available to enable combustion within the room, but also small enough that most of the smoke is exhausted into the corridor (and not to the outside via the vent).Three stages of a fire scenario are indicated. Note that it is the flow of smoke passing through the dwelling entrance door and its associated temperature that determine the severity of the fire scenario in respect of the common areas rather than the fire size per se. Note also that heat losses to the compartment (room) boundaries account for a significant (majority) proportion of the heat generated by the fire.

Table 5.2 Illustrative steady-state design boundary conditions (buildings without sprinkler protection, code compliant travel distances) – taken from BRE report 213179

Fire size in dwelling (kW)	Dwelling and stair door opening widths (m)	Size of low level vent to outside	Average temperature of smoke at door (°C)	Flow of smoke from dwelling			Fire stage
				Mass (kg/s)	Heat (kW)	Soot (kg/s) *	
250	0.1	$0.65m^2$ (1.3m W by 0.5m H)	210	0.2	40	1.25×10^{-3}	Early stages of fire, relevant to period following initial MOE
1000	0.5	$1m^2$ (1.4m W by 0.7m H)	360	0.9	350	5×10^{-3}	Developed fire, relevant for later MOE and arrival of fire service
2500	0.78	$1.9m^2$ (2.1m W by 0.9m H)	690	1.4	1100	12.5×10^{-3}	Immediately prior to flashover in fire compartment, relevant for fire service intervention

***** This value corresponds to an effective heat of combustion of 20 000 kJ kg^{-1} and a soot yield of 10%, and then represents an upper bound on the premise that all the soot enters the corridor (and is not vented to the outside or deposited on the internal surfaces). Alternative heats of combustion or soot yields would have a direct impact on the amount of soot entering the corridor.

If employing the steady-state design conditions in Table 5.2 it is recommended to either model a fire in a room with similar dimensions and ventilation conditions as used in the BRE study or alternatively to impose the smoke flow as an explicit boundary condition at the location of the apartment door. Where the geometry or ventilation conditions are significantly different to those used in the BRE study, the designer may need to consider alternative steady-state design boundary conditions. Note that while the data in Table 5.2 describe more closely conditions corresponding to an open plan apartment, they are considered nonetheless to provide a useful 'design fire scenario' to allow a comparative analysis of more general apartment layouts. The data may not be appropriate where the size of fire is controlled by the operation of sprinklers or water mist.

5.3.5 Extended travel distance systems

Where the common area travel distance in the corridor or lobby exceeds that of a code compliant layout, then a time-dependent analysis is likely to be necessary. This might include a set of separate steady-state analyses, each representing a stage in the fire scenario where conditions are quasi-steady, e.g. during fire fighting operations and where the door opening positions are fixed and the fire is burning at a (potentially full-developed) steady-state. However, the designer will need to undertake time-dependent calculations or simulations of part, or all, of the fire scenario timeline, e.g. to determine the time required to return the corridor to tenable conditions following a period of smoke exposure.

When a time-dependent approach is used, it is recommended that the fire scenario time line is first established and agreed with the authority having jurisdiction (AHJ). Table 5.3 presents a typical time line, and covers most of the events that might be considered in the design of the smoke control system. Other events, such as occupants escaping from other apartments, can be added as required.

The actual timings will depend on various factors such as the internal geometry of the apartment and the fire service attendance time and will generally need to be agreed on a project by project basis.

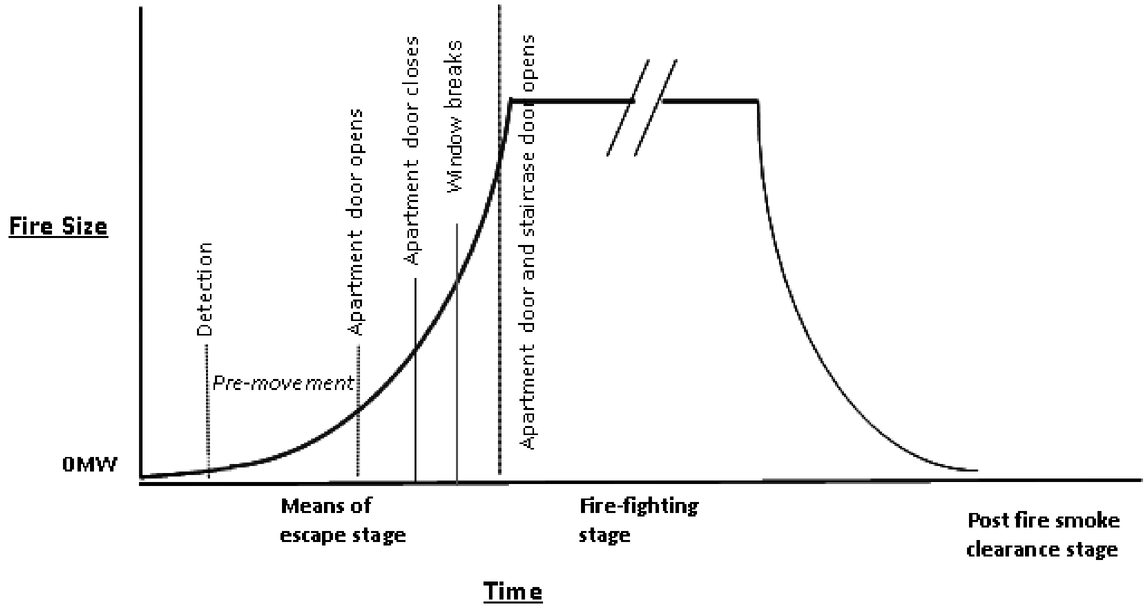
Table 5.3 Typical time line for time-dependent design

Event	**Note**
Start of fire	Ignoring any smoldering period
Fire continues to burn at an increasing rate	A medium growth, t-squared fire (e.g. see PD 7974-1) is widely adopted
Fire detected in apartment	
Door to apartment opens (for occupant escape)	
Door to apartment closes	Generally this will be between 10s and 20s after the door opens
Door to stair opens (for occupant escape)	
Door to stair closes	Generally this will be between 10s and 20s after the door opens
Ventilation system reaches operational state	Smoke detection in the corridor will initiate the ventilation system. Full operation not likely to occur until after the first occupants have evacuated the corridor.
Ventilation system continues operating	Ventilation assists in protecting the stair, and depending on the performance criteria, to clear smoke from the corridor.
Fire continues to burn at an increasing rate to reach max heat release rate for design	Assuming sufficient ventilation is available in the apartment and there is no fire suppression (e.g. sprinklers). Additional ventilation by glazing failure is likely to be required.
Fire service access door(s) opens	

Door to stair opens (fire service arrival) and remains open	The degree of door opening is case dependant
Door to fire apartment fully opens (fire fighting operations)	Ventilation protects the stair and reduces severity of conditions in the corridor.

Recommendations for suitable design fires can be found, for example, in PD 7974-1:2003 and the BRE Trust publication FB 29 (2011) *Design Fires for use in Fire Safety Engineering*. The growth of the fire is likely to take a form similar to that shown in Figure 5.2.

Figure 5.2 Typical time-dependent design fire (buildings without sprinkler protection)



It is likely that a medium growing t-squared fire (see PD 7974-1:2003) will be a suitable choice for a typical residential fire scenario. The size to which the fire grows will be strongly influenced by the availability of ventilation (air) to the apartment from the outside and whether suppression (sprinklers or water mist) is available.

If a medium growing t-squared fire is assumed, then after 5 minutes the heat release rate will be approximately 1MW. This size of fire might be considered as appropriate at the time the occupants of the fire apartment make their escape.

Unless the fire is controlled by a suppression system, subject to sufficient availability of fuel and air it will continue to grow. Typically, fully-developed, or post flashover, conditions will occur as the fire grows and once the upper smoke layer temperature has reached about 600°C.

In order to provide reasonably worse case (onerous) fire conditions up to the point of flashover, it is generally necessary to allow for just sufficient ventilation (from the outside at low level) to maintain most combustion within the apartment, i.e. to allow the fire to continue to burn and not become under-ventilated. This will generate the most onerous conditions with the maximum smoke and heat entering the corridor when the apartment door is opened and is representative of the methodology adopted in BRE project report 213179 which supported the current guidance on smoke ventilation in ADB. While a small opening (to the outside) will suffice in the early stages of the fire, a larger one will be required if the fire is allowed to grow. Timing and size of this opening needs to be justified.

If post-flashover, fully-developed fire conditions involving all or most of the combustible items in the room are to be included in the fire load, then it is likely that a significant amount of glazing will have failed and the fire has reached its ultimate ventilation controlled state.

For the purpose of justifying a smoke control system at fire service access time it is generally reasonable to consider a fixed area fire size with sufficient ventilation to support complete combustion inside the room of fire origin and to generate conditions akin to those at flashover. Typically, in the absence of a suppression system, this will involve a fire generating of the order 2 to 6 MW depending on compartment size, and a ventilation (e.g. window) opening area in the range 1 to 3 m^2 (depending on the fire size and vent aspect ratio). The choice of the fire size and ventilation opening conditions needs to be considered carefully by the fire engineer and agreed with the authorities having jurisdiction. The need to complete a sensitivity analysis in relation to the fire size and extent of the glazing failure may, in some cases, be required.

It would generally be expected that the fire and the apartment is included within a CFD model for the later stages of the fire scenario (after the fire service arrives and the stair and apartment doors are opened). This allows the full dynamic interaction between the apartment and the common areas to be included. However, at the initial stages of the fire scenario, where the rate of smoke clearance from the corridor is being examined, it might be more practical to impose the smoke, heat and soot source terms directly as a boundary condition at the apartment door. For example, if the fire is assumed to grow to 1MW as discussed above, then Table 5.4 presents boundary conditions that are considered appropriate to apply directly at the (open) apartment door, where it has been assumed (conservatively) that all the smoke generated by the fire (gaseous components and soot particulate) enters the corridor. Typically, the corridor might be exposed to this level of smoke for a period of 10 to 20s as the occupants make their escape: the actual time period would be agreed as part of the fire strategy time line.

Table 5.4 Illustrative boundary conditions at the opened apartment door at the initial MOE stage (time-dependent design; assuming all smoke vents into corridor after 5 minutes of a medium t^2 fire)

Fire size in dwelling (kW)	Temperature of smoke (°C)	Flow of smoke from dwelling		Condition
		Mass (gas) (kg/s)	Soot (kg/s) *	
1000	120 **	1.0 ***	5.0×10^{-3}	Early stages of fire, relevant to period following initial MOE

* This value corresponds to an effective heat of combustion of 20 000 kJ kg^{-1} (e.g. PU foam) and a soot yield of 10%.

** 120°C is a representative smoke temperature for persons to still be able to evacuate at the apartment door, A sensitivity analysis using ambient and 220°C (maximum tenable limit for very short exposure) might be considered.

*** 1kg/s is a representative of conditions where most of the smoke is transported through the door (e.g. see relevant entry in Table 5.2), A sensitivity analysis using 0.3kg/s and 1.5kg/s might be considered, representing lower and upper bounds derived from a compartment fire engineering analysis for a 1MW fire.

Where water suppression is to be considered, it might be appropriate to assume that the fire grows until the suppression activates and then remains fixed at this size. Fully-developed or flashover conditions would not subsequently be reached.

5.4 Fire Service Intervention

The national guidance for the design and construction of apartment buildings, flats and maisonettes has historically encouraged the principles of compartmentation and ventilation to protect occupants and assist the fire-fighting operation, particularly where a 'stay put' policy is in place. Such design principles are based on a reliance that occupants not affected by fire or smoke will remain within their flats during the fire-fighting intervention phase. However, occupants not at immediate risk are free to evacuate at any stage and enter common escape routes despite the principle in design and advice to 'stay put'. Consideration should be given to the likelihood of uncontrolled occupant movements within common areas and both designers and the Fire and Rescue Service (FRS) should establish and align their strategies and areas of responsibility, taking such scenarios into account.

There are, however, some key aspects that should be considered when designing smoke control systems as compensation for extended travel distances:

- In the design and construction of extended length corridors beyond 7.5 metres served by a single stair, BS 9991 recommends that, in single stair buildings above 11m in height with accommodation on two (or more) sides of the common stair, the various wings of the building should be isolated by fire doors in order to prevent corridors from becoming contaminated by smoke. Where corridors are provided with smoke control systems as compensation for extended travel distances these cross corridor doors may be omitted, providing the designer is able to demonstrate that the ventilation provisions can provide acceptable tenability for occupants using escape routes to exit the building.

- Despite the absence of suitable research in this area, designers should be aware that single direction travel distances over 30m in length (measured from the staircase door to the furthest flat entrance door) in common escape routes are considered to present onerous conditions for fire fighters. It is therefore recommended that they are not proposed.

- It is acknowledged that it is unlikely a mechanical smoke ventilation system can be designed to maintain tenable conditions in corridors for escaping occupants once fire fighting has begun or if the door to the flat of fire origin remains open for any other reason.

- It should be noted that where 'stay put' policies are incorporated into the building's fire strategy, particularly where single direction travel exists, the approving authorities may place a much greater emphasis on the need for sprinklers or fire suppression systems in flats and/or the provision of cross corridor suitably fire resisting doors to separate extended corridors into manageable sections.

- As outlined in section 6.4.1 of this document, it is recommended that smoke ventilation systems extract smoke away from the stairs where single direction travel distances exceed 7.5m. This will help to ensure that the staircase is adequately protected from the products of combustion, as well as assist with fire fighter access (ideally fire fighters will be approaching the flat of fire origin with the flow of inlet air).

- The FRS have expressed their concerns in relation to the lengths of undivided corridor that fire fighters may have to navigate to carry out rescues or reach safety in situations where fire conditions deteriorate during intervention. Therefore the designer should consider that corridor sub-divisions may increase fire fighter safety.

- Where cross corridor doors are provided the ventilation strategy should take these into account when demonstrating performance capability.

- There needs to be an understanding and acceptance of responsibility between approving authorities, smoke control system designers and the Fire and Rescue Service that the risk to occupants should not be increased beyond that provided by a fully code compliant layout.

  Where extended common escape route smoke ventilation solutions are proposed, it is recommended that designers discuss all relevant fire service intervention aspects with the local fire and rescue service.

5.5 Documentation

Results should be presented in an appropriate form for each agreed criterion. Sufficient information should be provided to allow relevant parties to assess the analysis undertaken in relation to checking and meeting the required performance criteria.

The results of the analysis should be documented and may be provided in the form of a report, together with any necessary supporting animations from advanced modelling.

The documentation should include at least the following information:

- A description of the residential area and the proposed ventilation system
- The design criteria and performance objectives of the analysis
- The scenarios investigated
- Details of the techniques used and related information
- The results of the analysis
- A statement as to whether the design criteria and objectives have been met
- Summary input/output data for the modelling used

For time dependent analyses, graphical results should be presented wherever possible to quantitatively show conditions plotted against a time line.

A sensitivity analysis should be carried out and presented such that it allows important outputs between different scenarios to be easily compared.

6 System types

6.1 Commentary

Smoke control can be achieved by natural, mechanical or a combination of mechanical and natural ventilation methods. Mechanical systems may be designed to allow extended travel distances subject to agreement from the approving authorities.

Four different system types are considered:

- Natural ventilation
- Pressure differential
- Mechanical (powered) smoke ventilation
- Small single stair building

Small single stair buildings have been provided with their own system type since the functional requirements for the systems, whether natural, pressurisation or powered are slightly different to other residential building types.

6.2 Natural Ventilation

6.2.1 Introduction

ADB, while allowing both natural and mechanical ventilation to common corridors/lobbies, makes the presumption that natural ventilation is the norm and mechanical ventilation is an alternative.

Natural ventilation has many benefits including simplicity, reliability, low noise and low energy use. However its performance can be sensitive to wind effects and, for natural shaft systems, there is a relatively large loss of floor space.

ADB provides recommendations for natural wall vents, natural vent shafts and vents at the head of the stair. The guidance in this section is intended to support the guidance in ADB.

6.2.2 General principles

Natural ventilation works by harnessing the natural forces of wind and thermal buoyancy to drive flow through the ventilator. For this application, the intended driving force is the buoyancy of hot smoke from the fire. Since buoyancy forces can be small compared to wind forces the performance in use can be significantly affected by wind.

For natural ventilation to operate effectively there needs to be both a source of inlet air and an exhaust opening. For a wall mounted vent, the vent generally provides both inlet at the bottom of the vent and exhaust at the top. Otherwise inlet air can be provided through the stair door when it is opened. To assist this, and to vent any smoke which enters the stair, a vent is needed at the head of the stair.

ADB recommends that the stair and the corridor/lobby adjoining the stair (i.e. the one the stair door opens onto) be ventilated.

6.2.3 Corridor/lobby vents

ADB recommends:

- A vent with a minimum free area of 1.5m^2 should be located on an external wall of each corridor/lobby to be ventilated.
- The vents should be located as high as practicable and such that the top edge is at least as high as the top of the door to the stair.
- In single stair buildings the vents should be actuated by smoke detectors in the corridors/lobbies served. In multi-stair buildings the vents may be manually actuated. In either case the vent at the head of the stair needs to automatically open with the vents.

NOTE: In reality it is unlikely that escaping occupants will manually activate the corridor/lobby vents during the means of escape phase. It is beneficial to automate the activation of corridor/lobby vents as per the guidance for a single stair building. Additional considerations regarding manual corridor/lobby vents are described in 6.2.6.2

6.2.4 Natural smoke shafts

The requirements for a natural smoke shaft are given in 2.26 of ADB: 2006 and reproduced below.

Vents, designed in accordance with the relevant guidance given in 6.2.3 above, should*:*

discharge into a vertical smoke shaft (closed at the base) meeting the following criteria:

i. *Minimum cross-sectional area 1.5m^2 (minimum dimension 0.85m in any direction), opening at roof level at least 0.5m above any surrounding structures within a horizontal distance of 2.0m. The shaft should extend at least 2.5m above the ceiling of the highest storey served by the shaft;*
ii. *The minimum free area of the vent from the corridor/lobby into the shaft and at the opening at the head of the shaft and at all internal locations within the shaft (e.g. safety grilles) should be at least 1.0m^2 (see Appendix C of ADB:2006);*
iii. *The smoke shaft should be constructed from non-combustible material and all vents should have a fire/smoke resistance performance at least that of an E30Sa fire door. The shaft should be vertical from base to head, with no more than 4m at an inclined angle (maximum 30º); and*
iv. *On detection of smoke in the common corridor/lobby, the vent(s) on the fire floor, the vent at the top of the smoke shaft and to the stairway should all open simultaneously. The vents from the corridors/lobbies on all other storeys should remain closed.*

Note: designers should be aware that the relationship between the vent and the shaft may restrict the free area and should take this into account, where possible, when selecting, locating and sizing the vent.

Shaft construction should comply with 8.2.4

6.2.5 Stair vents

ADB recommends that a vent with a free area of at least 1.0m^2 be provided between the top storey of the stair and the outside. This is to be operated automatically. See 6.2.6 and 8.2.1.2

The design of the stair vents should meet the guidance given in 6.2.3 above.

6.2.6 Free Area Calculation

Measurement of the free area of a vent is defined in Appendix C to ADB: 2006, reproduced below. Use of any other form of measurement should be justified as part of a fire engineering analysis.

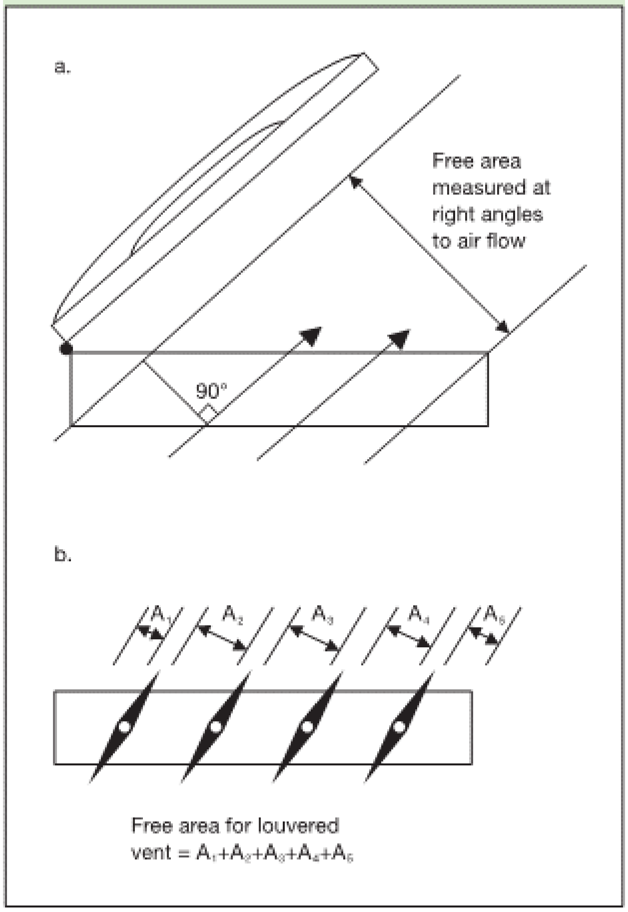
Free Area of Smoke Ventilators

5. The free area of a smoke ventilator, specified in this Approved Document, may be measured by either:

a. the declared aerodynamic free area in accordance with BS EN 12101-2:2003 *Smoke and heat control systems. Specification for natural smoke and heat exhaust ventilators; or,*

b. The total unobstructed cross sectional area, measured in the plane where the area is at a minimum and at right angles to the direction of air flow (see diagram C7).

Diagram C7 **Free area of smoke ventilators**



The Smoke Control Association offer the following guidance for interpreting Diagram C7.

The free areas defined in ADB are geometric in nature and in order to correlate these with a CE Marked ventilator they should be approximated to an aerodynamic free area. Consequently, where a ventilator CE Marked to EN12101-2 is used in accordance with 5a (above) then the declared aerodynamic free area of the vent must be no less than $1.0m^2$ for a $1.5m^2$ requirement and $0.7m^2$ for a $1m^2$ requirement.

Where 5b (above) is used then the following methodology should be followed:

1. Establish the maximum free area of the ventilator by multiplying the height by the width of the internal throat dimensions of the ventilator irrespective of obstructions such as actuators or blades (Av)
2. Measure the free areas that can be reasonably achieved when the vent is in the emergency open position (see illustrations below). Subtract obstructions such as damper or louvre blades, overhanging soffits, builders work reveals, frame sections etc. (AvCalc).
3. Sum the free areas measured in 2.
4. Compare Av to AvCalc.
5. The free area of the installed ventilator is MIN(Av,AvCalc).

Note 1: Ideally where doors or side hinged flaps are used as ventilators into a smoke shaft the door or flap should open to 90º.

Note 2: Roof mounted ventilators can be susceptible to positive wind pressures. Single flap ventilators should be opened to a minimum of 140 degrees and double flap ventilators should be opened to a minimum of 90 degrees per leaf.

Note 3: Top hung ventilators should not be installed for natural smoke ventilation.

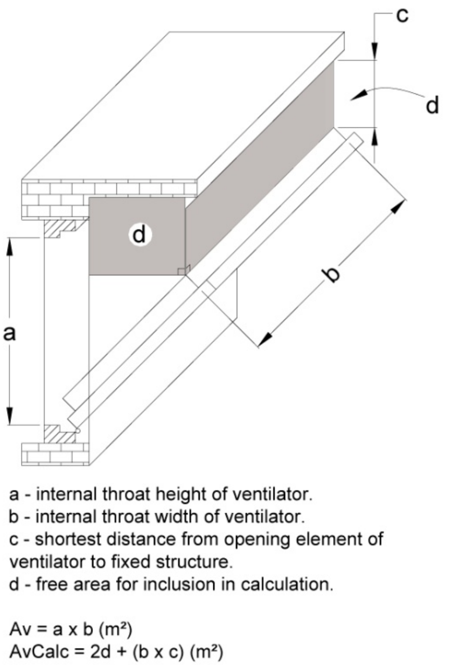


Fig a Typical bottom hung vent with overhang window reveal

(Note: If AvCalc from figure a. is greater than AvCalc from figure c. then use AvCalc from figure c. when comparing AvCalc to Av.)

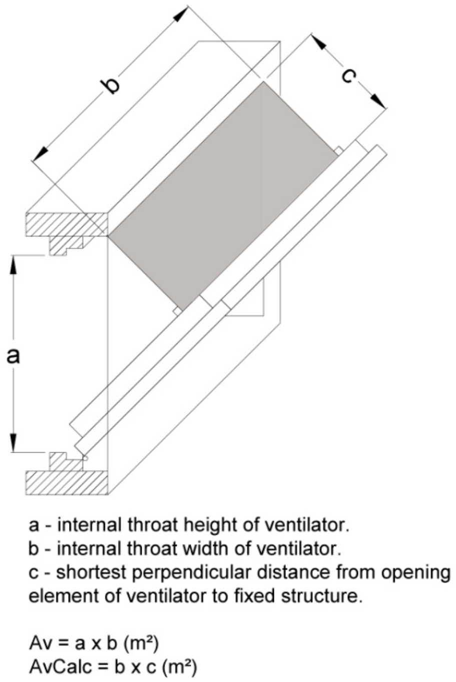


Fig b Typical bottom hung vent with

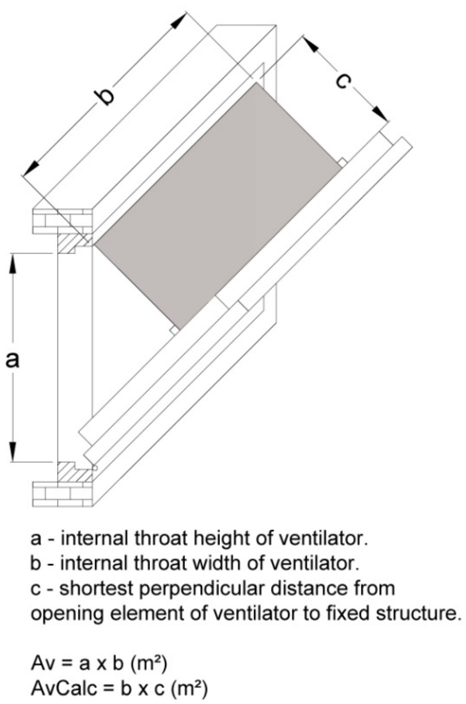


Fig c Typical bottom hung vent

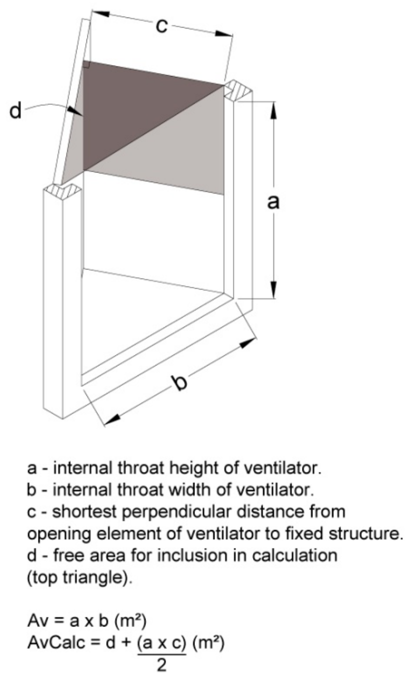


Fig d Typical side hung vent

6.2.7 Control

6.2.7.1 Minimum control requirements

The minimum control requirements for natural ventilation are set in ADB:

Design should be based on a single floor level being affected by the fire and therefore only the smoke vents on the floor of fire origin and any other design critical vents (such as the head of the smoke shafts and staircase) are required to open. System designers should avoid opening ventilators on multiple floor levels, especially where connected by a smoke shaft, to avoid smoke spread to otherwise unaffected parts of the building, and/or reduction of ventilation rate from the floor of fire origin.

For single stair buildings the controls should be fully automatic, operating from smoke detectors in the corridor/lobby at each storey. The vent on the fire affected floor only, the vent at the head of the smoke shaft and the vent at the head of the stair are required to open simultaneously. The vents on all other storeys should remain closed even if smoke is subsequently detected on floors other than the fire floor.

For multi-stair buildings smoke detectors are not required and the vents may be manually opened (where travel distances are code compliant). However, when any vent is opened the vent at the head of the stair is required to open simultaneously.
NOTE: In reality it is unlikely that escaping occupants will manually activate the corridor/lobby vents during the means of escape phase. It is beneficial to automate the activation of corridor/lobby vents as per the guidance for a single stair building. Additional considerations regarding manual corridor/lobby vents are described in 6.2.6.2

Consideration should be given, when positioning the manual activation switches, to ensure that these are not susceptible to vandalism or 'accidental' operation, leaving multiple vents open.

6.2.7.2 Additional considerations

It may be concluded from reading 6.2.6.1 that for multi-stair buildings simple manual windows can be used as vents to the corridors/lobbies. In this case, some additional issues need consideration:

- Since the vent at the head of the stair has to open automatically when any vent is opened, each window will need a limit switch or other device to initiate this automatic opening;
- Manual windows may be opened by occupants for general ventilation or other purposes. This would cause nuisance opening of the stair vent which, if not weathered, may allow significant water entry if left open in the rain;
- Windows on upper storeys often have restricted opening to prevent falls, making it difficult to achieve the desired free area;
- Windows opened manually can lead to smoke ingress on non-fire floors.

These problems can be overcome be installing automatic opening vents forming part of the overall smoke control system. Day to day ventilation can be achieved through local control such as a publicly accessible switch but on fire activation, any automatic opening vents on non-fire floors must close safely.

Consideration should be given to mitigating the risk of entrapment when vents close automatically, for example through the installation of movement sensors.

6.2.7.3 Additional Fire Service controls

While ADB does not require a central fire-fighters panel, in complicated buildings, a central fire-fighter's panel may be desirable. Care should be taken to avoid adding over-complexity and risk of inappropriate operation.

The fire service will usually require some manual control for fire service use. Simplicity is recommended as fire-fighters will rarely have the time or knowledge to make proper use of complex controls.

Control should also be designed to ensure that the system responds to the first point of detection only and that subsequent detectors operating do not further activate the system.

Any controls provided for fire service use should be clearly identified with permanent signage, indicating what function the controls have and that they are for 'Fire fighter use only'.

Designers should also refer to the equipment guidance notes given in 8.2.5 below.

6.3 Pressure differential systems

6.3.1 Introduction

It is generally recognised that pressure differential systems (usually pressurisation as opposed to depressurisation in this context) can provide a high level of protection to stairs and lobbies.

The aim of a pressure differential system is to establish a pressure gradient (and thus an airflow pattern) with the protected escape stair at the highest pressure and the pressure progressively decreasing through lobbies and corridors.

With the correct level of pressure differential it is possible to be certain that smoke from a typical apartment fire will not enter the stair under normal conditions.

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, fire-fighting and property protection within the building.

6.3.2 General principles

Air will naturally try to move from an area of higher pressure to an area of lower pressure. By increasing the pressure in the protected areas (i.e. the escape routes) above that in the areas where the fire is likely to occur (in this case the apartments), it is possible to prevent smoke spread into these escape routes. This is usually achieved by pressurising the parts of the escape route to be protected.

In a building, the movement of smoke and air is restricted by the building fabric. If the building fabric were leak free, a pressure differential could be maintained once developed with no further action. However, since buildings leak, air needs to be continually blown in to maintain a pressure differential.

The amount of air that is required will be dictated by how much leakage is present. This is usually a function of the number of doors which will permit leakage around the perimeter, the area and type of wall construction and any other openings which could let air out from the protected space.

A difficulty is that when doors to the protected space are opened as people escape and the fire service attend, the leakage area increases substantially, making it difficult to maintain a significant positive pressure. It is therefore necessary to design a system that is robust enough to provide sufficient protection even under conditions with some doors open while limiting the pressure differentials achieved with all doors closed. Too much pressure when all doors are closed will make doors opening into the pressurised space difficult to open and will impede escape into the protected area.

BS EN 12101-6 provides guidance on the performance to be achieved by a pressure differential system under both “doors closed” and “doors open” conditions and on which doors should be considered open. Under the 2005 edition of BS EN 12101-6, for a residential building, a system intended to protect means of escape is Class A and a system designed to assist fire-fighters is Class B.

Table 1: Classes of system

System class	Examples of use
A	For means of escape. Defend in place.
B	For means of escape and fire-fighting.
C	For means of escape by simultaneous evacuation.
D	For means of escape. Sleeping risk.
E	For means of escape by phased evacuation.
F	Fire-fighting system and means of escape*.

* included for use in Austria and not normally specified in the UK

BS EN 12101-6 also provides a suitable calculation method to assess the air flow rates required through the system.

A pressure differential system requires three main components:

- a means of maintaining the pressure differential (usually a supply air system)
- a means of avoiding excess pressure differentials (usually a pressure relief damper or variable speed drive to the fan)
- a means of releasing air flowing through the open door to avoid eventual pressure equalisation (usually ventilators, automated windows or a natural ventilation shaft).

6.3.3 Areas to be pressurised

To provide the best level of protection, all of the common escape route from each apartment door to the final exit door would be pressurised. Unfortunately this is usually impractical due to the difficulties of providing and maintaining air release facilities from each apartment. It is therefore normal to provide air release from the common corridors/lobbies.

To protect means of escape (Class A), if there are no lifts, the stair only is usually pressurised. If there are lifts, then both the stair and either the lifts or lift lobbies may be pressurised in order to prevent smoke spread through the lifts.

To protect fire-fighters (Class B), the stair, lobbies and fire-fighting lift should be pressurised.

6.3.4 Supply air system

BS EN 12101-6 allows a single fan set to be used for each system, but recommends separate risers for supply to the stair and lift and lobbies/corridors (if pressurised). A standby fan is recommended if the building has only one stair.

Fans and ducts are not expected to operate at high temperature, so ambient rated fans and standard ducting to DW144 are adequate unless the duct crosses fire compartment boundaries, in which case relevant portions of the duct should be fire resisting. A supply grille is recommended at least every 3 storeys in the stair although, to keep grille sizes down, more are commonly used.

Inlet air should be taken from a point unlikely to be affected by smoke. When inlet is taken at roof level BS EN 12101-6 recommends dual inlets taken from 2 facades. Where this is impracticable, inlets separated by at least 5m and facing opposite directions are commonly accepted as sufficient. In either case in-duct smoke detection should be provided to shut down an inlet affected by smoke.

6.3.5 Pressure control

As noted earlier, there will be a difference between the air flow required to maintain pressurisation when all doors are closed and the air flow required to maintain the design velocity through an open door. The open door air flow is usually the greater.

A gravity operated pressure relief damper is usually mounted in the roof of the stair, sized to relieve the excess air flow at the design pressure. A sizing method is given in BS EN 12101-6 and manufacturer’s data should always be consulted.

An alternative method is to use a variable speed drive to the fan, controlled from pressure sensing in the stair. Care needs to be taken in selection and commissioning to achieve the speed of response required by BS EN 12101-6 to avoid overpressures that can prevent doors from opening or slam violently, possibly resulting in injury, damage or preventing escape.

6.3.6 Accommodation air release (AAR)

Although often forgotten, this is an important part of the system. AAR is required on the accommodation side of every door leading from the pressurised areas into the unpressurised areas. In residential buildings this usually means the common lobbies or corridors.

Normal options are:

- automatic windows or vents
- natural shafts
- powered shafts
- HVAC system or other building leakage routes

Designers should carefully consider the positioning of AAR, if within an apartment, as this will be challenging for the responsible person to manage, monitor and maintain.

If AAR is to be provided by automatic windows or vents, these need to be located on two facades for each lobby/corridor. This is usually impractical so AAR is provided by shafts, with fire resisting dampers or vents at each level, with only the vent on the fire floor opening.

AAR shafts may be natural or powered. If a powered shaft is selected care should be taken to ensure that the combined effect of the pressurisation supply and the AAR does not cause excess pressure differentials to occur.

Extract fans used in powered AAR shafts should have an appropriate temperature rating for the application and standby fans should be provided.

Where an HVAC system or shaft passes through multiple compartments, it should have an appropriate level of fire resistance. Fire dampers may not be used in an AAR system.

6.3.7 Power supply and controls

A maintained power supply should be provided, with automatic changeover to the secondary power supply in case of interruption of the primary supply.

The main control panel should be located either within the pressurised space or in a separate one hour fire resisting compartment.

A fire service control should be provided at the entrance to the stairs. It should provide, as a minimum, status of the power supply and each fan (run, trip) and an off/auto switch, protected against unauthorised use. The switch may also have a test position for ease of testing in use.

6.4 Mechanical (Powered) smoke ventilation

6.4.1 General principles

Mechanical smoke ventilation may be used as an alternative to natural ventilation systems. The recommendations of this section are based on the assumption that a shaft system will be used, but there is no reason why any floor level may not have its own dedicated mechanical system.

Benefits of mechanical systems include specified extraction rates, low wind sensitivity, known capability to overcome system resistances and reduced shaft cross sections.

Requirements of mechanical systems include a maintained power supply, fire resisting wiring, temperature classified equipment and a standby fan.

Suitable air inlet and exhaust is needed to prevent damage to the system and to ensure that excessive pressurisation or depressurisation of the ventilated area does not occur.

This ensures that excess smoke is not drawn from the apartment of fire origin and that escape doors are neither rendered inoperable nor pulled open.

Design should be based on a single floor level being affected by the fire and therefore only the smoke vents on the floor of fire origin and any other design critical vents (such as the head of the smoke shafts and staircase) are required to open. System designers should avoid opening ventilators on multiple floor levels, especially where connected by a smoke shaft, to avoid smoke spread to otherwise unaffected parts of the building, and/or reduction of extract rate from the floor of fire origin. See section 8.2.1.4 and 8.2.1.5.

Smoke shafts should be constructed of non-combustible material, The fire resistance of the shaft should be equivalent to the requirements of the elements of the structure through which it passes.

All vents to the lobbies/corridors should have a fire/smoke resistance performance at least equivalent to that of an E30Sa fire door. The fire rating of the vent needs to be agreed with the AHJ.

Activation of the system is subject to discussion with the AHJ and other interested stakeholders, however the system is typically activated on detection of smoke in the common corridor / lobby. Upon activation of the system the smoke vent(s) on the fire floor, the vent(s) at the top of the smoke shaft(s) and the vent at the head of the stairway should open and any fans should run at the design speed. The vents on all other storeys should remain closed even if smoke is subsequently detected on floors other than the floors of fire origin.

Basic mechanical systems are commonly provided simply as an equivalent to the natural ventilation systems described in Approved Document B. It is possible to design systems providing a higher performance that may then be used to allow extended travel distances in corridors although care should be taken when considering removal of corridor subdivision doors. In this case the system objectives and performance should follow the guidance in section 5.

Note: As well as limiting the potential travel distance through smoke these doors may also limit the number of apartments needing evacuation by fire fighters and protect fire fighters. Removal of these doors may compromise fire fighter safety.

The location of extract and inlet points should be designed to protect the stair and to ensure that the layout minimises the potential for heat and smoke in the corridor/lobby to affect escaping occupants and fire fighters. It is important to ensure that the location of the inlet air source in relation to the point of smoke extract does not create dead spots in the protected zone.

It is recommended that extracting smoke away from the stairs should be the default position where travel distances are in excess of 7.5m. This will normally result in the extract shaft(s) being positioned remote from the stair. Where it is not possible to provide the extract(s) in a remote location from the staircase for extended corridor systems, the location of the extracts should be subject to early discussions with the AHJ.

When calculating the rate of extract and making fan selections, adequate allowance should be made for system leakage, including for example, leakage through ductwork, smoke shaft and all other closed dampers in the system. Calculation of the leakage rate should take account of the pressure to which the system is subjected. Some guidance on smoke shaft leakage rates is given in section 8 of this guide, but it is important that any published data is adjusted according to the system pressure.

The following are examples of typical design principles for mechanical systems:

6.4.2 Mechanical Extract, Natural Inlet

The system comprises mechanical extract shaft(s) serving one or more common spaces on all, or some, floor levels supplemented by the provision of natural air inlet provided by automatically opening vents or permanent vent to the outside (either directly or by way of a shaft, stairway or duct). Typically the mechanical extract is by a shaft although it can be via fans direct to the outside. Design of the system is dependent on the layout of the building and the recommended performance and design criteria as detailed in Section 5.

The mechanical extract should discharge directly to the outside. Where only a single mechanical extract is provided duty/standby fans should be provided as fan failure would result in failure of the system.

The area of natural air inlet openings should be sufficient to ensure not only that an excess pressure differential does not occur across a closed door but also that the pressure differential does not otherwise compromise means of escape by ‘pulling’ excessive amounts of smoke through door cracks or other leakage sources from the apartment of fire origin into the corridor.

Mechanical extract can be designed such that the system provides a steady extraction rate throughout all the stages of the fire (e.g. means of escape and fire-fighting).

Alternatively the system can be provided with a variable rate of extraction, varied to reflect the different stages that occur during the fire. For example the system may incorporate an increased extraction rate (boost facility) that provides a higher level of ventilation (e.g. on commencement of fire-fighting activities). The transition between normal mode and boost mode should be manual (see 8.2.5.3. The decision regarding the ventilation rates, undertaken by the designer, should reflect the specific risks presented within the building.

Figure 6.4.2a – Indicative layout showing a typical mechanical extract and natural inlet ventilation solution for a common access corridor using two shafts

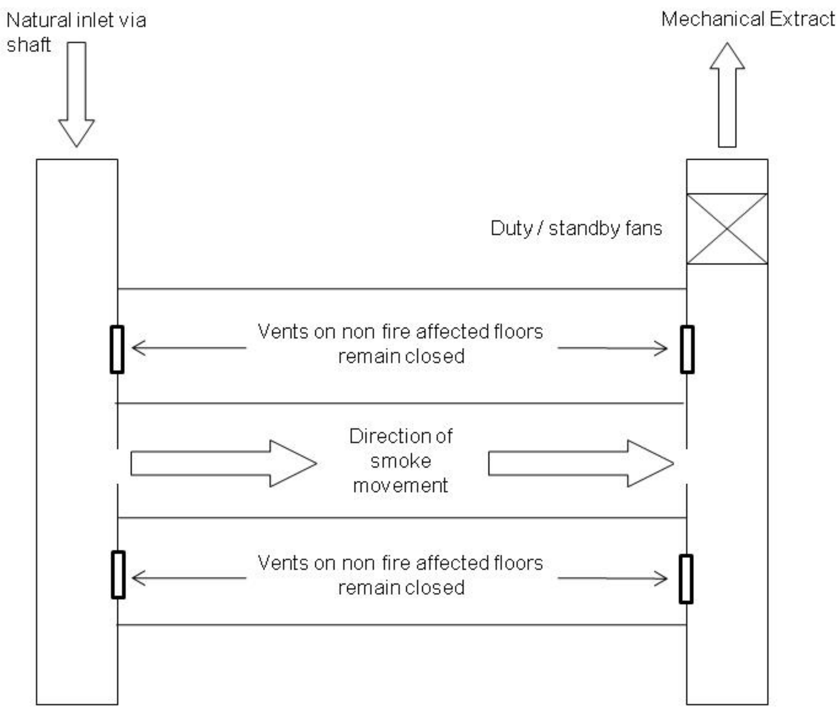
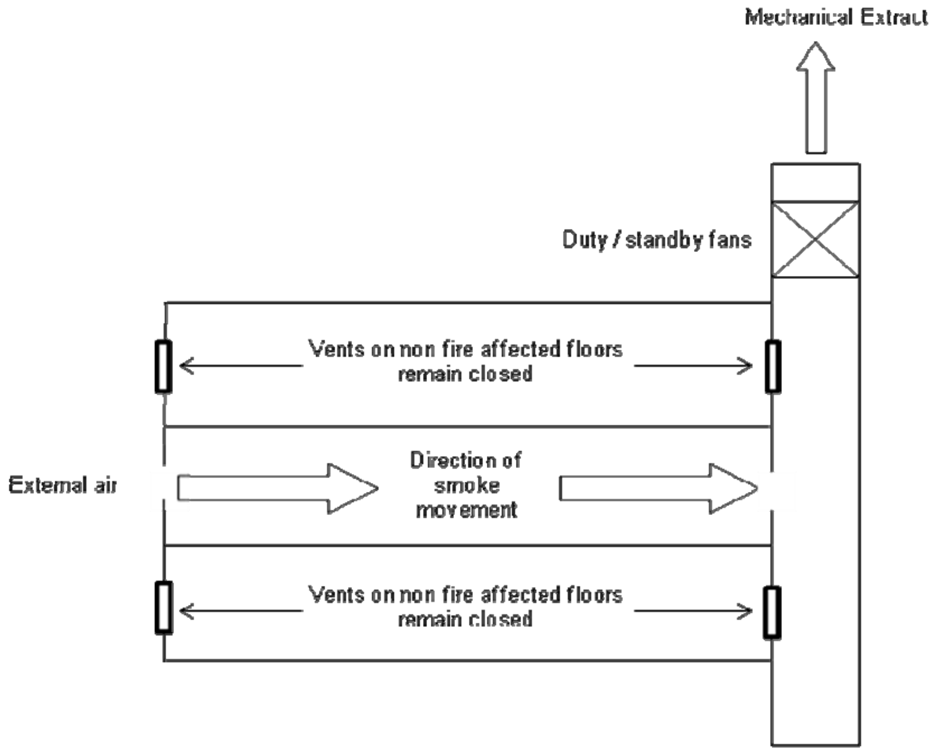


Figure 6.4.2b – Indicative layout showing a typical mechanical extract and natural inlet ventilation solution for a common access corridor using an inlet vent directly from the outside and an extract shaft



6.4.3 Mechanical Extract, Mechanical Inlet

Typical examples are:

a) Reversible fans which provide mechanical extract and mechanical air inlet. With this design, the system can be controlled by the fire detection system so that the fan closest to the initial point of detection can be selected as the smoke extract fan in means of escape mode with selected fans providing air inlet.

b) Systems with dedicated extract and inlet fans.

The system design is dependent on the exact requirements to match the building layout and other arrangements are possible.

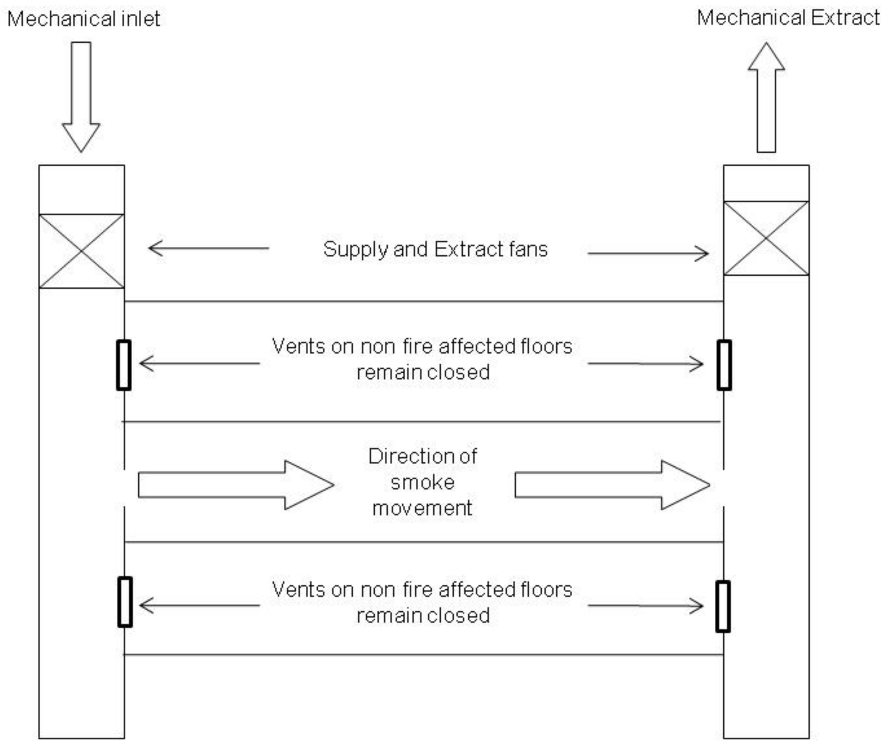
A mechanical extraction system provided with mechanical inlet requires careful balancing to ensure that the common access spaces are not overly pressurised or depressurised for all fire scenarios.

While the extract fan should be specified to operate at the appropriate temperature range, the inlet fans need not be temperature rated unless a reversible system is used.

This system can be designed to provide a steady extraction rate throughout all the stages of the fire. Alternatively the system can be provided with a variable rate of extraction, to reflect the different stages that occur during the fire and the requirements of the building. The transition between normal mode and fire fighting mode (e.g. the operation of any reversible fans) should be manual (see 8.2.5.3). The decision regarding the ventilation rates, undertaken by the designer, should reflect the specific risks presented within the building.

Where an inverter forms a component of the fan extract system, the impact of failure of the inverter should be considered. Typically this will result in the system running at the highest extract rate unless a standby inverter is provided.

Figure 6.4.3 – Indicative layout showing mechanical inlet and mechanical extract ventilation for a common access corridor.



6.4.4 Mechanical Extract only

The system comprises mechanical extract shaft(s) serving one or more common spaces on all, or some, of the floor levels. The system uses a single mechanical extract shaft, with replacement air typically provided by natural leakage. Air replacement forms a key component of a mechanical extract only system and the designer should specify how this is to be achieved and how this is to be confirmed and tested onsite to ensure excessive pressure does not occur across a closed door or otherwise compromise means of escape by pulling smoke into the common escape routes from the adjoining space.

The design of the system is dependent on the layout of the building and the recommended performance and design criteria (as detailed in Section 5).

The design of the system should take into consideration that the source of inlet air should not compromise normal passive fire separation. Any such inlets should be automatic in operation and should not be temperature controlled (see section 7.5).

Where only a single mechanical extract is provided the fans should be duty/standby fans as fan failure would result in failure of the system.

Mechanical extract can be designed so that the system provides a steady extraction rate or alternatively the system can be provided with a variable rate of extraction, varied to reflect the different stages that occur during the fire. The decision regarding the ventilation rates, undertaken by the designer, should reflect the specific risks presented within the building.

Mechanical extract only systems using natural leakage for replacement air are not suitable where extended travel distances occur, unless specific consideration of the risks is undertaken by the designer and approval obtained from the authority having jurisdiction.

6.5 Small Single Stair Buildings

6.5.1 General principles

In England and Wales a small single staircase building is considered to be one which meets the following criteria:

a. the top floor of the building is no more than 11m above ground level;
b. there are no more than 3 storeys above the ground level storey;
c. the stair does not connect to a covered car park;
d. the stair does not serve ancillary accommodation unless the ancillary accommodation is separated from the stair by a protected lobby, or protected corridor, which has not less than $0.4m^2$ permanent ventilation or is protected from the ingress of smoke by a mechanical smoke control system; and
e. a high level openable vent, for fire and rescue service use, is provided at each floor level, with a minimum free area of $1m^2$. Alternatively, a single openable vent may be provided at the head of the stair which can be remotely operated from the fire and rescue service access level.

Buildings which do not comply with the criteria, unless otherwise approved by the AHJ, should be designed in accordance with Sections 6.2 to 6.4 above (as appropriate). Designers of buildings using other codes of practice should discuss the applicability of the guidance given below with the AHJ.

Those buildings which do comply with the small single staircase building criteria can be provided with natural or powered extract or pressurisation.

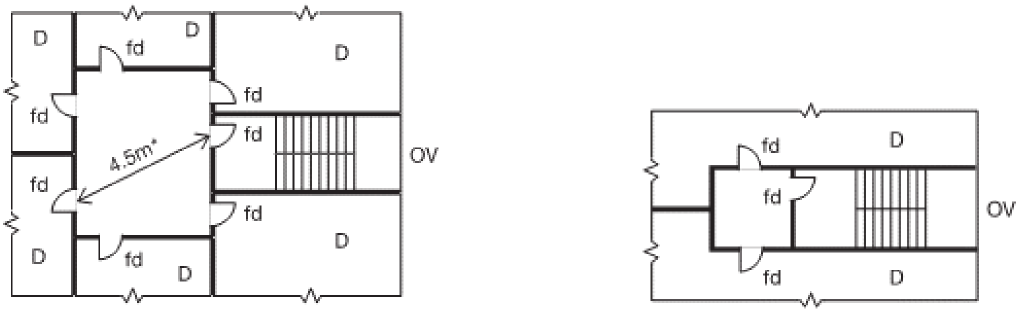
6.5.2 Natural ventilation

Smoke ventilation from the common areas should be designed in accordance with the guidance given in Diagram 9 of ADB: 2006.

The smoke ventilation should otherwise comply with the guidance given in Section 6.2 above (e.g. with regards to calculation of ventilation area, provisions of control points etc.)

Diagram 9 **Common escape route in small single stair building**

See para 2.21



a. SMALL SINGLE STAIR BUILDING
*If smoke control is provided in the lobby, the travel distance can be increased to 7.5m maximum (see Diagram 7, example b).

b. SMALL SINGLE STAIR BUILDING WITH NO MORE THAN 2 DWELLINGS PER STOREY
The door between stair and lobby should be free from security fastenings.

If the dwellings have protected entrance halls, the lobby between the common stair and dwelling entrance is not essential.

Notes:

1. The arrangements shown also apply to the top storey.
2. If the travel distance across the lobby in Diagram 9a exceeds 4.5m, Diagram 7 applies.
3. Where, in Diagram 9b, the lobby between the common stair and the dwelling is omitted in small single-stair buildings, an automatic opening vent with a geometric free area of at least $1.0m^2$ is required at the top of the stair, to be operated on detection of smoke at any storey in the stair.

Key

— Fire-resisting construction
OV Openable vent at high level for fire service use ($1.0m^2$ minimum free area) see paragraph 2.21e
D Dwelling
fd Fire door

6.5.3 Pressurisation

Pressurisation may be used as an alternative to natural ventilation as a means of protecting the staircase. The design of the system should be as per Section 6.3, for a means of escape (Class A) system if BS EN 12101 Part 6 is used as the basis of design.

It may not be acceptable to provide a pressurisation system where access is required into a resident's apartment in order to maintain any part of the equipment. External access is recommended; for example, if an air release path is required via a vent from an apartment, the actuator of the vent should be accessible from a location outside of the apartment.

The system designer should provide an access and maintenance statement in the O&M manual on how the equipment can be readily maintained and replaced in the event of failure.

6.5.4 Mechanical (powered) ventilation

Mechanical ventilation may be used as an alternative to natural ventilation as a means of protecting the staircase. The design will vary depending on the building layout.

6.5.4.1 With an unventilated common lobby

Where the apartments access the staircase by an unventilated common lobby, ventilation of the stair is required for fire-fighting (only). It is not needed for means of escape. It can therefore be actuated by a fire fighter's switch and is not required to operate automatically. A fire fighter's manual control point should be provided at the designated fire service access point in accordance with 8.2.5.2.

The system is likely to pull smoke into the staircase if it is operated while the apartment/lobby door is open. It is therefore recommended that the system is only used to clear the staircase of smoke post fire fighter attendance and/or to ensure that the smoke layer does not descend below the floor of fire origin if excessive quantities of smoke are already flowing into the staircase, or are likely to flow into the staircase.

It is important that a replacement air source is provided, usually via a manually opening door to the outside of the building. The air inlet route is not usually permitted to be via an enclosed corridor which is accessed by apartments or other accommodation (residential or otherwise), unless this has been specifically addressed by the system designer, as a fire occurring in one of these apartments may affect the ability of the system to operate effectively (e.g. smoke may be pulled into the staircase rather than clean air).

The systems extract rate is considered to satisfy the functional requirements if it meets the higher of the following:

a) A minimum of 10 air changes is provided to the staircase, or
b) The minimum extract rate is not less than $2m^3/s$.

Note: These values have not been scientifically proven but are based on good practice. The minimum flow rate ensures sufficient air flow into the staircase and is solely based on the committee's opinion. It is acceptable for a designer to alter these values subject to approval from the authority having jurisdiction.

Duty and standby fans should be provided.

6.5.4.2 With no common lobby

Where no common lobby is provided and the apartments directly access the stair, the system is required to be automatic and activated by smoke detection in line with the guidance given in ADB. The system is intended for use for both means of escape and fire service access. A fire fighter's override should be provided in accordance with 8.2.5.3 with an on/auto/off function.

It is likely that smoke will enter the staircase when the door to the apartment of fire origin is opened and this smoke may reduce the visibility distances in the staircase to below the recommended tenability limit. This is unavoidable and also occurs when natural ventilation is used.

To mitigate against excess smoke entering the stair the following criterion is applied: When the doors from the apartment to the stair are closed the maximum pressure difference in the staircase should be no more than -15Pa to -20Pa. For pressure differences greater than this there is considered to be a risk that excessive smoke may enter the staircase via door leakage paths.

Note: the recommended limit is based on the experience of the working group and limited research and is subject to further scientific assessment. It should be noted that at -25Pa, CIBSE Guide E identifies that doors opening into staircase may be pulled open.

To ensure the system operates correctly a suitably sized, automatic opening, replacement air inlet source should be provided at the base of the stair. Replacement air should ideally be provided naturally. If this is not possible a mechanical alternative is acceptable provided the stair is kept at a negative pressure. The air inlet route is not usually permitted to be via an enclosed corridor which is accessed by apartments or other accommodation (residential or otherwise), unless this has been specifically addressed by the system designer, as a fire occurring in one of these apartments may affect the ability of the system to operate effectively (e.g. smoke may be pulled into the staircase rather than replacement air).

The systems extract rate is considered to satisfy the functional requirements if it meets the higher of the following:

a) A minimum of 10 air changes is provided to the staircase, or
b) The minimum extract rate is not less than $2m^3/s$.

Note: These values have not been scientifically proven but are based on good practice. The minimum flow rate ensures sufficient air flow into the staircase and is solely based on the committee's opinion. It is acceptable for a designer to alter these values subject to approval with the authority having jurisdiction.

All testing during commissioning should be undertaken with the doors closed.

Duty and standby fans should be provided.

7 Interaction with other Fire Protection Systems and other Building Systems

7.1 Introduction

The designer should consider all interactions between the smoke control system and other systems to ensure that the smoke control system meets its intended design performance when required to do so in an emergency.

Where smoke control systems interact with other systems:

a) Any interaction in a fire situation should not compromise the operation and effectiveness of the smoke control system and visa versa;

b) The smoke control system should work with other fire protection systems as defined by the fire strategy.

The designer may need to consider the specific performance of individual manufacturers' systems and equipment, and take this into account in the design of the smoke control system.

7.2 Heating, Ventilation and Air Conditioning (HVAC) systems

Unless specifically designed to aid the smoke control system, HVAC systems in common areas should be switched off upon detection of fire or manual operation of the smoke control system.

Where HVAC ducts may cause unacceptable spread of smoke or fire, they should be shut off by an appropriate smoke or fire damper upon detection of fire or manual operation of the smoke control system.

7.3 Automatic fire suppression

Provision of automatic fire suppression systems in individual apartments or common/ancillary areas does not remove or reduce the need for smoke control.

The effect of automatic fire suppression systems should only be taken into account when all areas that could affect the system are fitted with an appropriate automatic fire suppression installation. In this case a reduction in the design fire size may be justified.

7.4 Fire Separating Elements

The design of the smoke control system components should be such that there is no reduction in the level of fire separating elements provided.

Where fire dampers are to be used to enforce lines of fire separating elements in conjunction with a mechanical smoke ventilation system, intumescent type dampers should not be used as the cooling effect of the ventilation system is likely to prevent the temperature build up necessary for the dampers to function correctly. Motorised fire and smoke dampers, of a suitable rating, operated by a smoke detector in the smoke zone should be used.

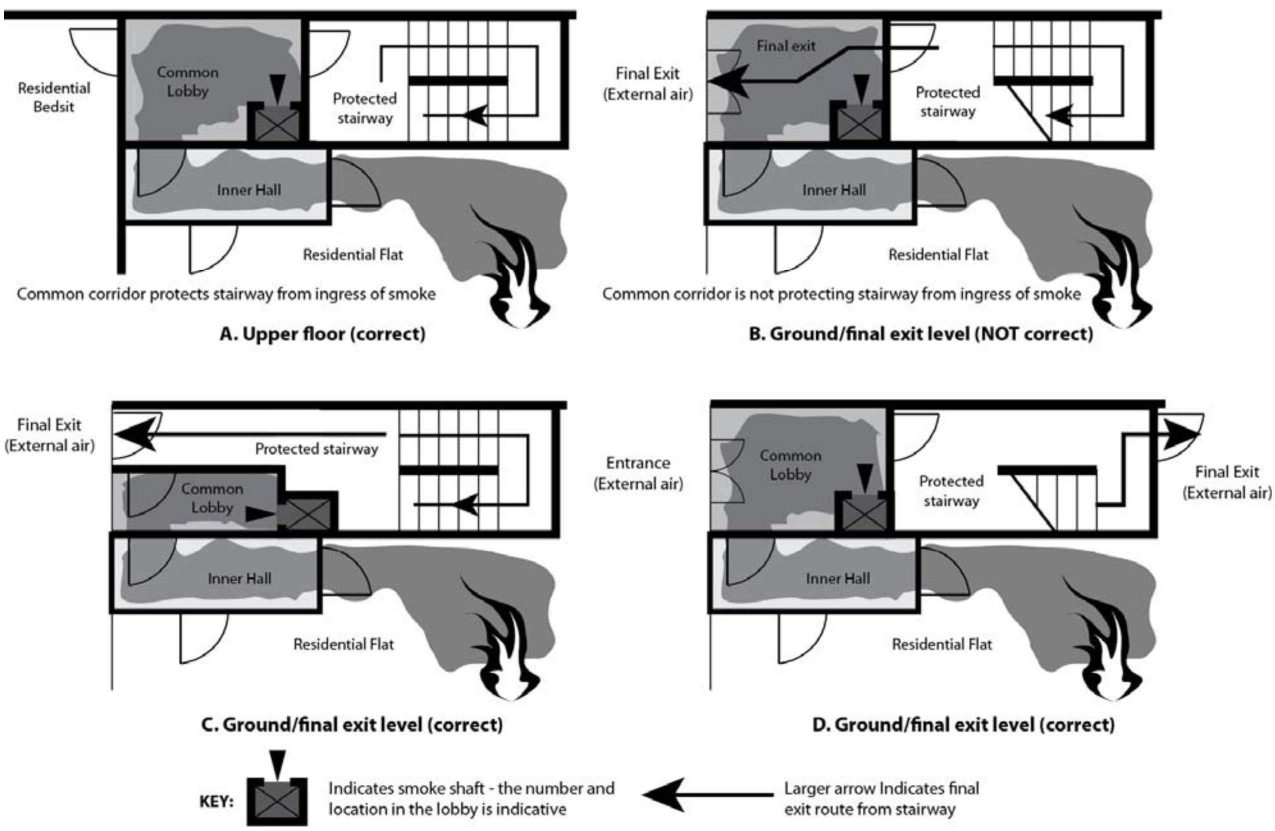
7.5 Ground floor / exit level final exit

A ventilated common lobby serving the stair and accommodation at the final exit level should not be regarded as suitable as part of the final exit route from the stair. It is important to ensure the protection to the stairway is maintained throughout the stairway and its final exit.

Diagram A in Figure 7.5 below shows a typical layout and lobby ventilation system on an upper floor. If this layout is repeated at the final exit level with the ventilated common lobby forming part of the final exit route from the stair, as indicated in Diagram B, escaping occupants may be forced to escape through a smoky lobby to the final exit door.

Diagrams C and D show alternative layouts which avoid escaping occupants being exposed to smoke and therefore provide the correct level of protection.

Figure 7.5 Location of lobby ventilators at Ground / exit level



7.6 Ventilation of lobbies to ancillary accommodation

The prescriptive codes recommend for means of escape that ancillary accommodation (e.g. car park or places of special fire hazard) is separated from the staircase by means of a natural ventilated lobby (e.g. where ADB recommends for a small single staircase building a 0.4 m^2 vent). This is normally achieved by a fire rated plenum linking the lobby to the outside of the building allowing any smoke in the lobby to be ventilated.

This natural ventilation provision cannot always be easily achieved. An alternative approach may be to use one of the following mechanical ventilation systems:

1. Mechanical extraction from the lobby at a rate equivalent to the natural vent and a pressure not exceeding 20 Pa across the lobby doors. The fan discharge should be ducted to the outside.
2. Positive pressurisation of the lobby above the surrounding space.

In developing the above system, the replacement air should be taken from the sterile area ensuring smoke is not actively drawn into the lobby. This could be from the staircase or riser and where dedicated active openings are provided, they should be controlled by a local smoke detector.

Duty and standby fans should be provided to ensure the system operates in the event of component failure.

All testing during commissioning should be carried out with the doors closed.

8. Equipment and Installation

8.1 Introduction

A smoke control system must operate in the intended manner when called upon to do so in an emergency situation. To ensure the system operates correctly, it is essential that the processes of planning, design, installation, commissioning and maintenance are undertaken by competent parties and that clear responsibilities are established.

Typically a smoke control system is made up of a number of components, interconnected and controlled in a way which meets the performance requirements set out in the system design. The products will generally meet European or International product standards.

The Construction Products Regulation (CPR) came into force in July 2013 and introduced a mandatory requirement on manufacturers to only place products onto the European Union market which comply with relevant harmonised standard. EN12101 is the umbrella regulation which covers smoke and heat control systems. Several parts of EN12101 are harmonised under the CPR is therefore essential for any stakeholder to incorporate products which comply with this standard into the construction.

Compliance with the CPR is demonstrated by the manufacturer issuing a Declaration of Performance (DoP) for the product. As these products are designed to protect life, under the CPR's System of Attestation of Conformity, they must be tested to an Assessment & Verification of Constancy of Performance (AVCP) Level 1. This means that the manufacturer MUST appoint a Notified Body accredited to the relevant part of EN12101 to issue the manufacturer with a certificate of constancy of performance for the product which is necessary to allow the manufacturer to issue the DoP.

The certificate of constancy of performance will be based on:-

- Type Testing of the Product
- Initial Inspection of the Factory Production Control
- Continuous surveillance, assessment and evaluation of the Factory Production Control

The DoP will contain information about the essential characteristics of the product. These characteristics will indicate the suitability of the product for the required function.

The installation of these products should be undertaken in accordance with the manufacturer's instructions and the SCA encourages the use of third party accreditation schemes (for example, the SCA supports the FIRAS scheme for Installation and Maintenance of Smoke Control Systems).

Guidance on these processes can be found in BS 8519, BS9999 and BS9991 as well as the recently published BS 7346 Components for smoke control systems: Part 8 Code of practice for planning, design, installation, commissioning and maintenance. These documents serve to illustrate best practice, including minimum performance criteria and sample certification. Furthermore these documents set out the statutory responsibilities for smoke control systems.

A smoke control system should be installed and commissioned in accordance with a detailed engineering plan which should have considered as a minimum:

- Sub division of system into zones
- Component selection and compatibility

- System activation
- Location of components and equipment
- Electrical power supplies and cables
- Cause and effect summary
- System performance

The following sections provide useful notes on equipment selection. This information is intended to supplement the guidance given in BS 7346 Part 8, BS 9991 and BS 9999.

8.2 Equipment Guidance Notes

A summary of equipment and relevant test standards is included in Annex A

8.2.1 Automatic opening vents

8.2.1.1 Automatic opening louvre, automatic opening casement window– used for external wall ventilation smoke ventilation

All casement windows or louvre windows placed on the market for smoke ventilation purposes should be CE marked to BS EN 12101 Part 2. It is essential that stakeholders satisfy themselves that products carrying CE marks are supported by DoPs relevant to their proposed use.

8.2.1.2 Automatic opening casement window, automatic opening sloping roof window, automatic opening rooflight, automatic opening louvre – used for stairwell ventilation

These products may be used for both inlet and outlet according to the design of the system. Where the product is used for smoke outlet then, under the rules of the CPR, it must be CE marked to BS EN12101 Part 2.

It is important that care is taken when selecting a suitable product and factors such as prevailing wind direction, proximity to other buildings, the angle of opening and the type of ventilator should all be taken into account as incorrect product selection can adversely affect the operation of the system leading to negative discharge. Where roof mounted hinged single flap ventilators are used for smoke extract a minimum opening angle of 140 degrees is recommended. Where an automatic opening vent is used solely for air inlet to the smoke control system, then it should also comply with BS EN12101-2.

8.2.1.3 Automatic opening rooflight, automatic opening louvre – used for ventilation to top of smoke shaft

These products may be used for both inlet and outlet according to the design of the system. Where the product is used for natural smoke outlet then, under the rules of the CPR, it must be CE marked to BS EN12101 Part 2.

It is important that care is taken when selecting a suitable product and factors such as prevailing wind direction, proximity to other buildings, the angle of opening and the type of ventilator should all be taken into account as incorrect product selection can adversely affect the operation of the system leading to negative discharge. Where roof mounted hinged single flap ventilators are used for natural smoke extract a minimum opening angle of 140 degrees is recommended.

Where an automatic opening rooflight or louvre is used above a smoke extract fan (or inlet fan on a push pull system) the activation of the unit must fail safe to the open position.

8.2.1.4 Automatic opening shaft ventilator (actuated fire door) – used for ventilation from corridor or lobby into smoke shaft

ADB requires the following: “all vents should have a fire/smoke resistance performance at least that of an E30Sa fire door”. In some applications a greater fire resistance may be required See section 6.4.1.

In principle, the requirement is a combination of a fire door controlled by an actuator retrofitted on site. The product must perform two functions according to its required activation in an emergency condition.

When the door is deployed on non-fire floors of a smoke shaft, it must close or remain closed (under the dictates of the smoke control system) and the door assembly, frame, seals and hinges should have as a minimum the fire resistance and leakage rate equivalent to that of a fire door that has been fire tested on both sides complete with smoke seals for the duration required by the application

The door shall be tested in the orientation in which it is to be installed (e.g. horizontal and/or vertical). This can typically be evidenced by testing of the door to EN1634-1 and EN1634-3.

When the door is deployed on the fire floor, it must open and remain open during the means of escape and firefighting mode.

It is the performance of the actuating mechanism that is the principle key element and the door should open to its fire open position in less than 60 seconds and remain open (time as required by EN12101-2).

Actuators shall have evidence of testing following the method as described in Appendix G of EN12101-2, noting their ability to open a door at 300°C after ramping up from ambient conditions for 5 minutes and stay open for a further 25 minutes.

Evidence should be available that the actuator used can perform 1000 operations (as required by EN12101-2). If day to day ventilation is facilitated by opening and closing the vent the number of operations should be extended to 10,000.

Recent experience of fires in residential buildings has reinforced the need to maintain smoke and fire separation. Smoke control systems must not contribute to the cross compartment proliferation of smoke and fire.

Magnetic locks with spring openers should not be used, as the magnets on floors above the fire floor can fail leading to the opening of the VENTILATOR, smoke contamination at the upper levels and breach of compartmentation.

In the same way, other failsafe actuators, spring openers and fusible links should not be used as the characteristics of these opening mechanisms can lead to a reduction in the compartmentation of the smoke shaft.

8.2.1.5 Automatic opening shaft ventilator (alternatives to an actuated fire door) – used for ventilation from corridor or lobby into smoke shaft

There are various acceptable alternatives to the fire door solution described in 8.2.1.4

1) An actuated hinged flap of whatever material that has been separately tested in the same manner as a fire door to EN1634-1 and EN1634-3 (bottom or side hinged is advised).
2) A smoke control damper that has been certificated for use partitions to EN12101-8.
3) A fire damper tested to EN1366-2, but fitted with an ON/OFF actuator and no fusible link. Ambient closed blade leakage should not exceed 360 $m^3/hr/m^2$ at 300 Pascals and this should be recorded in the test report.

In each case of the above:

1) The product shall be tested from the shaft side for fire resistance (as a minimum).
2) The product shall be tested for maintenance of opening from the non-shaft side (as a minimum).
3) The product shall be tested in the orientation in which it is to be installed (e.g. horizontal and/or vertical).
4) When the product is deployed on the fire floor, it must open and remain open during the means of escape and firefighting mode.
5) It is the performance of the actuating mechanism that is the principle key element and the product should open to its fire open position in less than 60 seconds and remain open (time as required by EN12101-2).
6) The above tests prescribe the requirements for actuators, but if changes are proposed, actuators shall have evidence of testing following the method as described in Appendix G of EN12101-2, noting their ability to open a door at 300°C after ramping up from ambient conditions for 5 minutes and stay open for a further 25 minutes.
7) Evidence should be available that the actuator used can perform 1000 operations (as required by EN12101-2). If day to day ventilation is facilitated by opening and closing the vent the number of operations should be extended to 10,000.
8) Magnetic locks with spring openers should not be used, as the magnets on floors above the fire floor can fail leading to the opening of the VENTILATOR, smoke contamination at the upper levels and breach of compartmentation.

8.2.2 Smoke control damper (specifically for use in ductwork)

Smoke control dampers should as a minimum be classified to BS EN 12101-8. Further guidance on the application of the products is given in BS 7346 Part 8.

8.2.3 Smoke control ducts

Any smoke control ducts should as a minimum be classified to BS EN 12101-7. Further guidance on the application of the products is given in BS 7346 Part 8.

8.2.4 Builder’s work shaft used for smoke control

Builder’s work smoke shafts used for smoke control should follow the guidance given in Approved Document B, BS 9991 and BS 7346 Part 8.

The shaft should be constructed from non-combustible materials and be smooth internally. The size of the shaft should be in accordance with the design specification. The shaft and its ancillary components should maintain fire separation between corridors, lobbies and floors at all times. Suitable guarding should be provided where necessary to prevent injury when any ventilator is open to a shaft (e.g. floor grilles).

A builder’s work shaft should have a maximum leakage rate of 3.8 m^3 per hour per m^2 at 50 Pascals. This figure is derived from leakage data for walls in BS EN 12101-6 and is used to set a benchmark to limit air leakage from the shaft.

Whenever shaft systems are used, it is likely that the shaft will pass through a number of compartments, in which case it should be constructed to the same level of fire separation as the floors/walls through which it passes.

The smoke shaft should only contain equipment directly associated with the smoke ventilation system. No other building services should be contained within the smoke shaft.

All vents to the lobbies/corridors should have a fire/smoke resistance performance at least equivalent to that of an E30Sa fire door. The fire rating of the vent needs to be agreed with the AHJ.

8.2.5 Control equipment

All control equipment used for smoke control systems should comply with ISO 21927-9. A control system may be centralised, distributed or a mixture of both.

Where both are used, care should be taken such that an activation of a distributed override device does not compromise the capability of the central control panel or vice versa.

The nature of the system should be that under quiescent conditions the control equipment should be in automatic mode. In this mode the control equipment should be protected against improper use.

8.2.5.1 Control panel

Consideration should be given to the location of control panels and control equipment. Most control panels complying with ISO 21927-9 are only designed to operate at ambient temperatures. Therefore they should be located such that the risk of exposure to high temperatures is minimised. It is acceptable to locate control panels which do not provide the primary system indication below the bottom of the lowest vent in the smoke shaft, if adequately protected.

In all instances the fan control panel should be located in a separate fire compartment to that which it is designed to serve. Where fans are used for smoke extract, it is recommended that the control panel(s) ensure automatic changeover from duty to standby fan (and starting circuit) in the case of a duty fan failure. The controls should be located remote from the potential fire location.

Any fan starter circuit/panel, with or without inverters, needs to be as robust as possible to ensure that the fan will run for as long as practically possible in emergency mode.

Consideration should be given to access for maintenance purposes.

8.2.5.2 Manual control point

The term “manual control point” encompasses generic phrases such as firefighter’s switch, call point, break glass etc. and refers to a distributed activation device, located in or adjacent to the zone that it serves and designated to activate (or deactivate) the zone that it is located in.

There are several functions possible, for example:
- Simple activation (‘breakglass’) or frangible panel which is only capable of activating the zone/device
- Auto/on – switch that is capable of overriding the automatic function of the system and activating the zone/device, or returning it back to its automatic state
- Auto/on/off – switch that is capable of overriding the automatic function of the system and activating/deactivating the zone/device, or returning it back to its automatic state

Manual control points should be clearly visible and located and/or labelled so their purpose and function is clear. This should include clear indication of what the manual control point is associated with (for example, head of stair vent or corridor vent). Manual control points should comply with ISO 21927-9 and be coloured deep orange to RAL 2011.

Where these are for FRS use only, they should be mounted at a height of 1.8-2.0m from floor level to discourage tampering.

Note: EN 60335-2-103:2003 sets out safety requirements for automatic gates, windows and doors. Where a potential hazard is evident (such as an automatically closing window or door) the close function of the manual control point should operate on a biased off principle and should be located in sight of the window or door.

8.2.5.3 Manual control points (MCP) for mechanical systems

For mechanical systems a fire fighters override switch providing off/auto facility should be installed close to the designated fire service access point. For systems that are switchable between a ‘normal’ and ‘boost’ mode, (i.e. two-speed systems with different means of escape and fire-fighting extract rates), the MCP should be provided in a place of relative safety (usually the stair enclosure) at each floor level so that fire fighters can operate it locally, prior to entering the risk area on the relevant floor. Variations to these recommendations might be considered as part of the consultation process with the AHJ.

8.2.5.4 Manual control points (MCP) for mechanical systems (speed control)

For systems that are switchable between a ‘normal’ and ‘boost’ mode, (i.e. two-speed systems with different means of escape and fire-fighting extract rates), the MCP should be provided in a place of relative safety (usually the stair enclosure) at each floor level so that fire fighters can operate it locally, prior to entering the risk area on the relevant floor. Variations to these recommendations might be considered as part of the consultation process with the AHJ.

Note: Due to the potential for keys to be misplaced or lost, it is generally advisable to avoid using key operated manual control points as fire fighting operations may be significantly impacted if the relevant keys are not available.

If the use of key operated manual control points cannot be avoided, then their use should be carefully considered and discussed with the local fire and rescue service. How relevant keys will be stored on site and made available to the fire service, whether the keys have been provided with robust fobs to prevent loss if dropped, and whether fobs will indicate where a key can be used and its function will all need to be clearly discussed and defined as part of this process.

8.2.5.5 Centralised control and indication equipment

There are no specific requirements for centralised control and indication facilities set out in any of the relevant design guides. However, in complex buildings, a centralised firefighter's panel with indication showing the location (e.g. block and floor) of fire detection and the status (e.g. dampers open / closed, duty fan running) of all systems may be beneficial and should be considered. Furthermore, it is common that there is no requirement for a fire alarm panel to be provided in residential buildings with a 'stay-put' evacuation strategy and the smoke control panel may be the only form of indication available to the Fire Service.

The provision of centralised control and indication facilities may be particularly important where non-code-compliant designs, such as common corridors with extended travel distances, are proposed and the protection of the means of escape for occupants as well as access routes for the Fire Service may rely upon the successful operation of performance-based smoke control systems.

In such cases, it is strongly recommended that the indication of system faults (e.g. failed dampers or fans) and the indication of the status of key system components when the system is operating are provided. Such indication is likely to assist with regular maintenance and fire safety management by providing indication of any system faults that may occur and this will also assist the Fire Service in the event of an incident.

It is recommended that the monitoring of key system components be derived from direct feedback from the components (e.g. damper actuator end-switches or equivalent) and not simply from command status. This is particularly critical where a smoke control system is provided as a compensatory measure for non-code-compliant designs as safe occupation of the building may be contingent upon the availability of the smoke control system. Indication of the status of key system components may be via the fire alarm panel if no smoke control system control and indication panel is provided.

All power and control cabling should comply with the relevant recommendations of BS 8519:2010.Control and indication panels should comply with ISO 21927-9 and be provided with a secondary power supply.

Where Graphic User Interface (GUI) panels (e.g. touch screen panels) are used, these panels should not be the only means for Fire Service manual override of the system or for the control of critical functions. In particular, provision of a centralised control and indication panel should not replace manual control points for Fire Service use as the Fire Service may need to control critical changes in fan speed locally (for example, in the case of two-speed systems with means of escape and fire-fighting extract rates).

Control/override panels should incorporate the following:

- A simple, user friendly interface, considering the needs of the Fire Service
- The ability for the panel (whether GUI type or positive switched) to be used by firefighters wearing gloves
- Access level/security protection of the maintenance functions

- Protection from tampering when the panel is located in a public area, while continuing to allow override functionality for the Fire Service when the system is operational
- Suitable reliability, resilience and robustness for the application.

Simplicity of control and indication equipment is recommended, as firefighters will rarely have the time during an incident or the specialised knowledge to make appropriate use of complex controls.

In addition to the above, it is important that clear and concise operational instructions for firefighters on the system operation and its controls are provided, especially where it is expected that firefighters may need to manually interact with the system. Such information should be appropriately sited in a suitably identified premises information box or folder, marked “For Fire Service use only”.

The location of the centralised control equipment should be clearly indicated at all fire service access points.

The AHJs should always be consulted regarding additional requirements for control and indication equipment where non-code-compliant designs are proposed.

If the central fire-fighting control panel allows control of ventilators remotely, then care should be taken to ensure that occupants are not endangered by remotely closing vents. Refer to section 8.2.5.2.

8.2.5.6 Automatic smoke detection

Any smoke detection system used to operate the smoke control system should comply with either BS5839 part 1 at a minimum standard of L5 or ISO 21927-9. The detectors should comply with EN54. If the system is only compliant with ISO 21927-9 then the detection system should be used solely for the activation of the smoke control system and cannot be used as a fire alarm system

8.2.6 Power supply equipment

EN12101 Smoke and heat control systems: *Part 10 power supplies* is harmonised under the Construction Products Regulation and requires manufacturers to only place power supplies for smoke control systems onto the UK market which comply with this standard. It is therefore essential for any stakeholder to incorporate products which comply with this standard into the construction.

Compliance with this standard is demonstrated by the manufacturer issuing a Declaration of Performance (DoP) for the power supply. As these products are designed to protect life, under the CPR’s System of Attestation of Conformity, they must be tested to an Assessment & Verification of Constancy of Performance (AVCP) Level 1. This means that the manufacturer MUST appoint a Notified Body accredited to EN12101Part 10 to issue it with a certificate of constancy of performance of the product. This is an essential requirement to allow the manufacturer to issue the DoP.

The certificate of constancy of performance will be based on:-

- Type Testing of the Product

- Initial Inspection of the Factory Production Control

- Continuous surveillance, assessment and evaluation of the Factory Production Control
- The output of the power supply equipment (primary and secondary) should be independently sufficient to satisfy the maximum demands of the system.

The power supply equipment should either have inherent resistance to or be protected from mechanical damage. Each connection to the power supply should be via an isolating protective device reserved solely for the smoke control system and independent of any other main or sub-main circuit. The power supply, isolating devices and related equipment should be clearly labelled as to their purpose and be secured against unauthorised operation

8.2.7 Inverters

Power supplies for life safety systems derived from frequency inverters in order to vary the speed of the fan motor should be equipped with a fail-safe fire mode. The fire mode should effectively disable the motor protection function to enable, if necessary, the inverter/motor to run to destruction.

If the life safety ventilation system is required to have multiple speeds in fire mode, in order to perform the required duty, each speed should be separately hard-wired and initiated from the individual fire alarm interface modules.

When necessary to maintain the operation of the critical life safety equipment, the inverter should be equipped with a ‘Direct on Line’ (DOL) or ‘Star Delta’ bypass.

Designers of smoke control systems who wish to have variable speed operation in emergency mode due to the nature of the design of the smoke control system should satisfy themselves that the combination of fan and inverter are compatible and will operate satisfactorily under the design conditions.

Inverters, like other computer operated devices, are particularly sensitive devices and should be located in suitably designed panels, protected from significant variations in, and excesses of, temperature, humidity and dust. There is considerable variation in the reliability and robustness of inverters on the market and the system designer should ensure that the product used is of a suitable quality.

8.2.8 Fans

8.2.8.1 Smoke extract fans

All fans used for smoke extract should be tested and certified to BS EN 12101-3 *Smoke and heat control systems. Specification for powered smoke and heat exhaust ventilators*

Designers of smoke control systems who wish to have variable speed operation in emergency mode due to the nature of the design of the smoke control system should satisfy themselves that the combination of fan and inverter are compatible and will operate satisfactorily under the design conditions. Care should be taken to ensure continuity of power supplies to all fans (see 8.3).

Designers should also clearly define what temperature rating of fan they are using, and provide a statement as to why this rating is appropriate for the project in question.

8.2.8.2 Supply fans

Supply fans used for air inlet to smoke ventilation and pressurisation systems are not expected to operate at high temperature, so ambient rated fans may be used (to ISO 5801, AMCA 210-85). BS EN 12101-6 allows a single fan set to be used for each pressurisation system in a multi-stair building but a standby fan is recommended if the building has only one stair. Care should be taken to ensure continuity of power supplies to all fans (see 8.3).

Where a reversible system is proposed both sets of fans should be CE marked to BS EN 12101-3

8.2.9 Pressure sensing devices

Pressure sensing devices are typically utilised in a system to protect against excessive pressure differentials across escape doors. The pressure sensing devices give outputs to the control system which will vary the speed drive to the pressurisation fan to prevent over pressure occurring. Care needs to be taken in selection and commissioning as the speed of response required by EN12101-6 is difficult to achieve.

The operational reliability of pressure sensing devices needs to be maintained to ensure the correct operation of the system therefore location of sensors and ongoing maintenance regimes need to be considered.

Failure modes of pressure sensors should ensure that, on sensor failure, high pressure differentials do not create excessive door forces.

8.3 Cabling and Electric Power Supply Installation

8.3.1 Cabling

To ensure correct operation of the smoke ventilation system power and control cables must maintain their integrity during a fire incident. Cables should comply with the following categories for fire survival in accordance with BS 8519 as appropriate for different applications:-

- Category 1 (PH30/30 minute survival time) – Means of Escape systems
- Category 2 (PH60/60 minute survival time) – Means of Escape systems
- Category 3 (PH120/120 minute survival time) – Fire Fighting systems

Only single-operation, automatic natural smoke control systems which offer no firefighting facility to change the system status after initial operation are considered to be suitable for use with Category 1 cable (e.g. a smoke ventilation system in direct conformity to ADB).

Where a smoke control system has a fire fighting interaction, whereby a fire fighter can change the status of the smoke control system, then the system is regarded as a category 3 system in accordance with BS 8519, and both power and control cables should have a 120 min fire survival time.

BS 8519 specifies separate test standards for power and control cables. Generally it is considered that any cables providing power to the main control panel and fans should be considered a power cable, whilst cables to dampers and other devices should be considered control cables. BS 8519 specifies the test standard BS 8491 for power cables and BS EN 50200 for control cables.

There are circumstances where elements of cabling may not need to satisfy the categories identified in BS8519. In these instances an engineering view should be applied. For example where the fan control panel and smoke ventilation fans are located on the open roof, the roof is fire resisting and the cables between the fan control panel and the fans do not run through a fire compartment, it may be acceptable to relax the cable specification set out in BS 8519 providing sufficient justification is evidenced.

8.3.2 Power Supplies

If a smoke control system fails to the operational position on loss of power, then only one power source is required, in all other cases a dual supply is required

If the primary power source fails, then the power supply should be automatically switched over to a secondary power source. Failure of or damage to one of the power sources should not cause the failure of the other power source or the failure of the supply of power to the system.

Each power supply should provide the power requirements of the worst case scenario at design duty under ambient conditions.

For electrical systems it is generally recommended that the primary power source is taken from the public utility supply. Secondary power can be supplied from an alternative utility supply from another substation, a generator, a UPS or batteries.

Guidance on the provision of power supplies for life safety systems within residential buildings is further provided within BS 9991.

8.3.3 Power Distribution

For mechanical systems the primary and secondary power cables should only come together in the fire resisting enclosure or fire resisting roof area housing the fan control panel by means of an automatic transfer switch (ATS) conforming to BS EN 60947-6. The enclosures surrounding the ATS and the fan control panel should be provided with a minimum of 60 minutes fire resisting construction.

The electrical distribution system should conform to BS 7671 and the relevant parts of BS EN 60947, BS 7346 Part 8 and BS 8519.

9 Commissioning and Acceptance Testing

9.1 Introduction

Testing any form of ventilation system is a fundamental part of the process of setting to work and the proving of its performance against the design criteria.

As smoke control systems are primarily life safety systems and/or for assistance to the fire and rescue service it is imperative that the smoke control system is tested by the installer and then offered for witness testing to the authority having jurisdiction (AHJ) to prove its compliance with the project specification and the approved design criteria.

BS7346 Part 8 sets out the recognised code of practice for commissioning and acceptance testing of a smoke control system including examples of certification. The following sections provide useful guidance intended to supplement that given in BS 7346 Part 8.

In addition extract rates for mechanical systems should be proven. Guidance to testing airflows can be found in the BSRIA Guide – Commissioning Air Systems.

Where smoke tests/ system demonstrations are being completed for AHJ to witness, it would be expected that the specialist contractor confirms the method statement for the test/ demonstration in advance, which would include agreed acceptance criteria.

9.2 Documentation

All smoke control systems should be handed over to the end user with a complete set of documentation. This should include at least:

- Design information detailing the performance criteria for the system and a description of the system
- A control philosophy or cause and effect diagram
- As installed drawings
- Relevant CE marking or type test certificates
- Installation and commissioning certificates
- Witness testing certificates or other evidence that the system was tested in front of the authority having jurisdiction (AHJ)
- Operation, maintenance and testing instructions
- Instructions for fire service use

This information should meet the requirement of regulation 38 of the Building Regulations (England and Wales), requiring the person carrying out the work to provide sufficient information for persons to operate and maintain the building in reasonable safety. It will also assist the eventual owner/occupier/employer to meet their duties under the Regulatory Reform (Fire Safety) Order.

9.3 Test Procedures

9.3.1 Airflow measurement

There is no specific guidance for recording smoke extraction rates in mechanical smoke extraction systems.

Where it is difficult to undertake reliable pitot tube readings for mechanical smoke extraction systems due to the orientation of dampers, shafts and the fan location, the following guidance should be used.

BSRIA BG49/2013 clarifies that damper/grille flow rates can be considered as the average velocity multiplied by the grille face area with no correction for the free area of the grille. The readings should be taken as per the grid system recommended in Table 6 of the BSRIA document and the most favourable reading should be taken in each position making an allowance for the deflection of the grilles. In some circumstances depending on the grille finish, it may be necessary to record the readings 500mm away from the grille by means of a clear 4 sided box extension and the velocity multiplied by the box area.

It is recommended that the flow rates are recorded at the closest and most remote damper from the fan to ensure the required extraction rate through the damper/grille is achieved.

9.3.2 Stairwell ventilator

- Operate each stairwell ventilator via the activation of the designated manual or automatic device.
- Inspect the motor drive for correct operation and extension.
- Measure the size of the opening provided by the ventilator in accordance with Appendix C, paragraph 5, of ADB and check the area for compliance with the specified area or confirm the product meets the declared aerodynamic free area.
- Check the operation of the manual control point(s) to ensure the system operates as requested.
- Check that a secondary power supply is available on loss of the primary power supply.
- Reset the system on completion of test.
- Provide a certificate of test
- Provide a certificate of compliance.

9.3.3 Wall mounted ventilator

- Operate each wall ventilator via the activation of the designated initiating manual or automatic device.
- Inspect the motor drive for correct operation and extension.
- Check the ventilators operate in accordance with the design cause and effect and inspect for correct operation and extension.
- Measure the size of the opening provided by the ventilator in accordance with Appendix C, paragraph 5, of ADB:2006 and check the area for compliance with the specified area or confirm the product meets the declared aerodynamic free area.
- Check the operation of the manual control point(s) to ensure the system operates as requested.
- If present, check that a secondary power supply is available on loss of the primary power supply.
- Reset the system on completion of test.
- Provide a certificate of test
- Provide a certificate of compliance.

9.3.4 Natural ventilator shaft system

- Operate each shaft ventilator via the activation of the designated manual or automatic device.

- Inspect the motor drive for correct operation and extension.
- Check the ventilators into the smoke shaft operate in accordance with the design cause and effect and inspect for correct operation and extension. Only one shaft ventilator should open at any time, all ventilators on other floors should remain closed. The test should confirm that this continues to be the case even if an automatic signal is received on floors other than the original floor.
- Measure the size of the opening provided by each of the ventilators in accordance with Appendix C, paragraph 5, of ADB and check the area for compliance with the specified ventilator areas.
- Check the operation of the manual control point(s) to ensure the system operates as requested.
- Check the cross sectional area of the smoke shaft and that it complies with the specified design area.
- Where appropriate:

  - Check that the minimum dimension of 850mm (in any direction) for the shaft has been complied with.
  - Check the shaft opening at roof level is at least 0.5m above any surrounding structure within a horizontal distance of 2.0m
  - Check that the smoke shaft extends at a minimum of 2.5m above the ceiling of the highest storey served by the shaft.
  - Check that a secondary power supply is available on loss of the primary power supply.
  - Reset the system on completion of test.
  - Provide a certificate of test
  - Provide a certificate of compliance.

9.3.5 Mechanical shaft system

- Operate each shaft ventilator via the activation of the designated manual or automatic device.
- Check the automatic change over is operational for the standby fan.
- Check the automatic change over is operational for the secondary power supply.
- Check the ventilators in the smoke shaft and the fans operate in accordance with the design cause and effect and inspect for correct operation.
- Measure the flow rate into the shaft system at the ventilator furthest from the fan position.
- Only one shaft ventilator into one shaft should open at any time, all ventilators on other floors should remain closed. The test should confirm that this continues to be the case even if an automatic signal is received on floors other than the original floor.
- Check the maximum forces required to open escape doors whilst the system is operating in means of escape mode and record results. The recorded force must not exceed 100N.
- Check the operation of the manual control point(s) to ensure the system operates as requested. Where a manual control point for firefighting use is provided at each floor level to switch between fan speeds then the operation of this switch should also be checked that it results in the correct action.
- Carry out a cold smoke test if appropriate (generally only for systems used to allow extended travel distances).
- Reset the system on completion of test.
- Provide a certificate of test
- Provide a certificate of compliance with the design intent.

9.3.6 Pressure differential system (pressurisation and de-pressurisation)

BS EN 12101-6 provides a detailed set of test procedures which should be carried out, and recorded for this type of system and in addition to the test readings taken in accordance with the standard, the following inspections are also recommended:

- Operate each motorised damper by activation of the designated manual or automatic device.
- Check that the fan(s) operate at the same times as the opening of the dampers, measure its performance and check against the design value.
- Check the automatic change over is operational for the standby fan.
- Check the automatic change over is operational for the secondary power supply.
- Inspect the motor drive for correct operation and extension.
- Operate the ventilators and fans in accordance with the design cause and effect and inspect for correct operation and extension.
- Check the maximum forces required to open escape doors while the system is operating in means of escape mode and record results. The recorded force must not exceed 100N.
- Check the operation of the manual control point(s) to ensure the system operates as requested.
- Where applicable, the operation and function of the pressure sensors should also be checked.
- Reset the system on completion of test.
- Provide a certificate of test
- Provide a certificate of compliance.

10 Maintenance

It is the responsible person's duty under the Regulatory Reform (Fire Safety) Order to ensure that any smoke control system provided in their building for life safety and/ or fire fighting purposes is adequately maintained in effective working order at all times. The premises fire risk assessment should fully account for the type of smoke control system installed, its operation, and what monitoring checks and maintenance regime it is subjected to.

Routine inspection and maintenance of the smoke control system should be carried out in accordance with BS 9999:2008, Annex V.

Smoke control equipment should only be maintained by a competent person with specialist knowledge of smoke control systems, adequate access to spares and sufficient information regarding the system (such as the manufacturers' operation and maintenance instructions as a minimum). The SCA encourages the use of third party accreditation schemes (for example, the SCA supports the FIRAS scheme for Installation and Maintenance of Smoke Control Systems).

Further guidance on the maintenance of smoke control systems is available in BS 7346-8.

11 References

11.1 EU Directives

Council Directive CPR 89/106/EEC on Construction Products Regulation

Council Directive EMC 89/336/EEC on Electromagnetic Compatibility (as amended)

Council Directive LVD 2006/95/EC on Low Voltage Electrical Equipment (as amended)

11.2 Legislation

The Building Regulations 2010 No. 2214 as amended, The Stationery Office, London, 2010

The Construction (Design and Management) Regulations 2007 No. 320, The Stationery Office, London, 2007

The Workplace (Health, Safety and Welfare) Regulations 1992 No. 3004, The Stationery Office, London, 1992

The Regulatory Reform (Fire Safety) Order 2005 No.1541, The Stationery Office, London, 2005

Approved Document B (Fire Safety) – Volume 2 – Buildings other than dwelling houses (2006 Edition), The Stationery Office, London, 2006 including the 2010 and 2013 amendments

Approved Document L2A: Conservation of fuel and power (New Buildings other than dwellings) 2013 edition, The Stationery Office, London, 2013

2013 Technical Handbook, Domestic, The Scottish Government, Building Standards Division, 2013

DFP Technical Booklet E: 2012 – Fire Safety, Department of Finance and Personnel, Belfast, 2012

DFP Technical Booklet F2: 2012 – Conservation of fuel and power in buildings other than dwellings, Department of Finance and Personnel, Belfast, 2012

11.3 Standards

BS 476-20:1987 *Fire tests on building materials and structures. Method for determination of the fire resistance of elements of construction (general principles)*

BS 476-22:1987 *Fire tests on building materials and structures. Methods for determination of the fire resistance of non-load bearing elements of construction*

BS 476-24:1987, ISO 6944:1985 *Fire tests on building materials and structures. Method for determination of the fire resistance of ventilation ducts*

BS 5588-1:1990 *Fire precautions in the design, construction and use of buildings. Code of practice for residential buildings* (withdrawn)

BS 5588-5:2004 *Fire precautions in the design, construction and use of buildings. Access and facilities for fire-fighting* (withdrawn)

BS 5839-1:2013 *Fire detection and fire alarm systems for buildings. Code of practice for design, installation, commissioning and maintenance of systems in non-domestic premises*

BS 7899-2:1999 *Code of practice for assessment of hazard to life and health from fire. Guidance on methods for the quantification of hazards to life and health and estimation of time to incapacitation and death in fires*

BS 7974:2001 *Application of fire safety engineering principles to the design of buildings. Code of practice*

BS 8434-2:2003+A2:2009 *Methods of test for assessment of the fire integrity of electric cables. Test for unprotected small cables for use in emergency circuits. BS EN 50200 with a 930° flame and with water spray*

BS 8491:2008 *Method for assessment of fire integrity of large diameter power cables for use as components for smoke and heat control systems and certain other active fire safety systems*

BS 8519:2010 *Selection and installation of fire-resistant power and control cable systems for life safety and fire-fighting applications. Code of practice*

BS 9991:2011 *Fire safety in the design, management and use of buildings – Code of practice*

BS 9999:2008 *Code of practice for fire safety in the design, management and use of buildings*

BS EN 54 (all parts) *Fire detection and fire alarm systems.*

BS EN 1363-1:2012 *Fire resistance tests. General requirements*

BS EN 1364-2:1999 *Fire resistance tests for non-load bearing elements. Ceilings*

BS EN 1366-1:1999 *Fire resistance tests for service installations. Fire resistance tests for service installations. Ducts*

BS EN 1366-2:1999 *Fire resistance tests for service installations. Fire dampers*

BS EN 1366-8:2004 *Fire resistance tests for service installations. Smoke extraction ducts*

EN1366-10:2011 *Fire resistance tests for service installations. Smoke control dampers*

BS EN 1634-1:2014 *Fire resistance and smoke control tests for door, shutter and, openable window assemblies and elements of building hardware. Fire resistance tests for doors, shutters and openable windows*

BS EN 12101-2:2003 *Smoke and heat control systems. Specification for natural smoke and heat exhaust ventilators*

BS EN 12101-3:2002 *Smoke and heat control systems. Specification for powered smoke and heat exhaust ventilators*

BS EN 12101-6:2005 *Smoke and heat control systems. Specification for pressure differential systems. Kits*

BS EN 12101-7:2011 *Smoke and heat control systems. Smoke duct sections*

BS EN 12101-8:2011 *Smoke and heat control systems. Smoke control dampers*

prEN 12101-9 *Smoke and heat control systems. Control equipment*

BS EN 12101-10:2005 *Smoke and heat control systems. Power supplies*

BS EN 12589:2001 *Ventilation for buildings. Air terminal units. Aerodynamic testing and rating of constant and variable rate terminal units*

BS EN 13501-4:2007+A1:2009 *Fire classification of construction products and building elements. Classification using data from fire resistance tests on components of smoke control systems*

BS EN 60335-2-103:2003 *Household and similar electrical appliances. Safety. Particular requirements for drives for gates, doors and windows*

BS EN 60730-2-6:2008 *Automatic electrical controls for household and similar use. Particular requirements for automatic electrical pressure sensing controls including mechanical requirements*

BS EN 61000-6-3:2007+A1:2011 *Electromagnetic compatibility (EMC). Generic standards. Emission standard for residential, commercial and light-industrial environments*

BS EN ISO 5801:2008, BS 848-1:2007 *Industrial fans. Performance testing using standardized airways*

BS ISO 21927-9:2012 *Smoke and heat control systems. Specification for control equipment*

ANSI/AMCA Standard 210-07 | ANSI/ASHRAE 51-07: *Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating*

11.4 Guidance and papers

BRE project report 204505, *Smoke Shafts protecting Fire-Fighting Shafts: their performance and design*, Building Research Establishment Ltd, Garston, 2002

BRE project report 213179, *Smoke Ventilation for Common Access Areas of Flats and Maisonettes (BD2410) – Final Factual Report*, Building Research Establishment Ltd, Garston, 2005

BSRIA Guide BG 49/2013, *Commissioning Air Systems*, BSRIA, Bracknell, 2013

CIBSE Guide E, *Fire Engineering*, 3rd edition, CIBSE, London, 2010

DW/144, *Specification for sheet metal ductwork*, HVCA, London, 2014

LDSA paper, *Mechanical Smoke Venting of Residential Lobbies and Fire Fighting Shafts. LDSA Fire engineering performance criteria Paper,* London District Surveyor's Association, London, 2006

SFPE *Handbook of Fire Protection Engineering*. 4th edition, Society of Fire Protection Engineers, Bethesda, 2010

T. Jin, *Studies on Human Behaviour and Tenability in Fire Smoke,* Proceedings, 5th International Symposium on Fire Safety Science, pp. 3–22, 1997

Annex A: Equipment List

Ref	Product Group	Product	Location	Product Type	Application	Associated Standards	Regulatory Guidance	
Ventilators								
8.2.1		Automatic Opening Vent	External Wall	Automatic Opening Louvre	Outlet	EN12101-2, EN 60335-2-103	AD-B	AD-L
				Automatic Opening Casement Window	Outlet	EN12101-2, EN 60335-2-103	AD-B	AD-L
8.2.2			Stairwell Vent	Automatic Opening Casement Window	Inlet/ Outlet	EN12101-2, EN 60335-2-103	AD-B	
				Automatic Opening Sloping Window	Inlet/ Outlet	EN12101-2, EN 60335-2-103	AD-B	
				Automatic Opening Rooflight	Inlet/ Outlet	EN12101-2, EN 60335-2-103	AD-B	
				Automatic Opening Louvre	Inlet/ Outlet	EN12101-2, EN 60335-2-103	AD-B	
8.2.3			Smoke Shaft Vent	Automatic Opening Rooflight	Inlet/ Outlet	EN12101-2	AD-B	
				Automatic Opening Louvre	Inlet/ Outlet	EN12101-2	AD-B	

8.2.4				Automatic Opening Vent (Actuated E30Sa Fire Door)	Inlet/Outlet	EN12101-2 Annex G, BS 476-22, BS1634-1, EN1364-2, EN1363-1, EN 60335-2-103	AD-B	
8.2.5				Automatic Opening Vent (Smoke Control Damper)	Inlet/Outlet	EN12101-8, EN1366-2, prEN1366-10, EN13501-4, EN 60335-2-103	AD-B	
		Manual Opening Vent	External Wall	Louvre	Outlet		AD-B	AD-L
				Casement Window	Outlet		AD-B	AD-L
			Stairwell Vent	Casement Window	Outlet		AD-B	
				Roof light	Outlet		AD-B	
				Louvre	Outlet		AD-B	
Fans								
8.2.8		Powered Extract Fan	Smoke Shaft	Smoke Ventilation Fan	Outlet	EN12101-3		
		Powered Inlet Fan	Smoke Shaft	Fan	Inlet	ISO 5801 AMCA210-85		
Ductwork								
		Barometric (Pressure Relief / Non Return) Dampers				Special test to EN12589		

		Pressure Volume Flow Rate (PDS)				EN60730-2-6, Special test on basics of EN12589		
8.2.6		Smoke Control Ductwork				EN12101-7, EN13501-4, BS 476-24, EN1366-8, EN1366-1	AD-B	
8.2.7		Builders Work Shaft				BS 476 *BS 7346-8*	AD-B	
Control Systems								
8.2.11		Control Panels Centralised				*prEN12101-9,ISO 21927-9*, EN12101-10, LVD 2006/95/EC, EMC 89/336/EEC		
		Control Panels Distributed						
		Control Panels - Motors						
8.2.12		Manual Control Point				*prEN12101-9, ISO 21927-9*, EN12101-10, LVD 2006/95/EC, EMC 89/336/EEC , EN60335-2-103		
8.2.13		Automatic Smoke Detection				*prEN12101-9, ISO 21927-9*, EN54, BS5839		
8.2.14		Indication Panel				LVD 2006/95/EC, EMC 89/336/EEC		
8.2.17		Power Supplies		Primary		EN12101-10, LVD 2006/95/EC, EMC 89/336/EEC		
				Secondary				
8.2.18		Cables				BS 8491, BS 5839 enhanced, BS8519		
8.2.15		Pressure Sensing Devices				EN61000-6-3		
Actuators								

8.2.16			Casement Window	Chain Actuator		EN12101-2 Annex G, EN 60335-2-103, LVD 2006/95/EC, EMC 89/336/EEC			
			E30Sa Fire Door	Door Actuator					
			Rooflight	Linear Actuator					