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

Smoke Control Association

Acknowledgements

Contributions to this guide are gratefully acknowledged from the following people:

Hugh Mahoney	Novenco Ltd
Conor Logan	Colt International Ltd
Andy Bartlett	Belimo UK Ltd
Tony Breen	Nuaire Ltd
Richard Brooks	Advanced Smoke Group
Paul Compton	Colt International Ltd
Gary Daniels	Hoare Lea
Ian Doncaster	Airvent Systems Services Ltd
John Dorkins	Vent Axia Ltd
Keith Elves	City of Westminster
Will Perkins	SE Controls
Trevor Jackson	The Smoke Ventilation Company Ltd
Stewart Miles	International Fire Consultants Ltd
Jamie Stern-Gottfried	Arup
Paul White	BSB Dampers Ltd
Mike Duggan	HEVAC

Date of publication: November 2010

Contents

1 Foreword

I am pleased to have been asked to introduce this new publication from the Smoke Control Association.

This publication from the SCA should be welcomed by designers, installers, insurers and approving authorities. 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.

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 become an essential reference work within the industry and shows a commitment from our members of using best practice in all that they do.

H M Mahoney
Chairman of working group

2 Introduction

Smoke control in common escape routes within blocks of flats and maisonettes is recommended in order to improve the conditions for escape and fire fighting. This is achieved by limiting obscuration, toxicity and thermal exposure in the common escape route and also providing improved conditions for fire and rescue activities.

While there are some prescriptive methods of providing smoke control, these methods cannot always be implemented due to space restrictions and/or architectural layout.

It has become necessary to develop performance based solutions to achieve improved conditions within common escape routes.

These performance based solutions are becoming more common and are supported by calculations and/or Computational Fluid Dynamics (CFD) analysis.

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.

Since smoke control systems are usually dual purpose, providing ventilation for means of escape and for smoke clearance by the fire and rescue service, consideration should be given to which operational modes require analysis as the scenario and operating conditions will be different depending upon the choices made.

Smoke control systems form an 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.

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 appropriate regulatory authorities may assist in achieving an appropriate design.

3 Scope

Approved Document B (ADB), BS5588 Parts 1, & 5 and BS 9999 provide guidance on prescriptive methods of smoke control in common escape routes of apartment buildings, but they do not give guidance for performance based solutions.

Through this document The Smoke Control Association provides guidance on the design of smoke control systems in apartment buildings.

As there are no other suitable published guidance documents 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.

It also provides recommendations to designers on the information to be provided to the approving authority, within their package of supporting information, when submitting the calculations or CFD model for information and/or approval of design intent.

This document is intended to support the recommendations for smoke ventilation of common escape routes as detailed in the statutory guidance of ADB and supporting guidance of British Standards BS 5588 parts 1 & 5 and BS 9999.

This document refers in places to the recommendation given in ADB. Where other design guidance is utilised (such as the Technical Standards in Scotland) reference should be made to the appropriate guidance documents.

4 Terms and Definitions

4.1 Approving authority

Any one of a number of different bodies having jurisdiction including the Local Authority and Approved Inspectors (in England and Wales), Verifiers (in Scotland) and Fire and Rescue Services,

4.2 Common escape route

Designated route from the front door of an apartment to a place of safety or relative safety

4.3 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

4.4 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)

4.5 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

4.6 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

4.7 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

4.8 Mechanical (or powered) ventilation

Ventilation caused by the application of external energy to displace gases through a ventilator (Note: fans are usually used)

4.9 Natural ventilation

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

4.10 Pressurisation

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

4.11 Primary power supply

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

4.12 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)

4.13 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)

4.14 Tenable
Maximum exposure to hazards from a fire that can be tolerated without violating safety goals

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

4.16 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

4.17 Vent
A term used here and in ADB to indicate an operable ventilation opening, either direct to outside or into a ventilation shaft, from a stair, lobby or corridor

4.18 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.

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 in ADB. This section then does not apply.

In other cases it is necessary to consider the objectives and performance criteria for the system. Until recently there was no guidance on these issues other than a requirement to provide ‘equivalence’ to the prescriptive systems in ADB. Recent work by BRE to support the 2006 edition of ADB, while not specifically intended to provide such guidance, has now given some insight into both the objectives and performance of systems prescribed in ADB.

Under ADB, 2006 edition, the common spaces requiring smoke ventilation are the stairs and the lobbies and/or corridors opening onto the stairs.

As with any alternative solution there are a number of methods which allow the investigation 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 a great amount of 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 approving authority is unfamiliar with the technique used or does not have the necessary technical knowledge to assess the technique that a peer review be considered.

5.2 Objectives

5.2.1 Commentary

Recent work by BRE, confirmed in ADB, has made it clear that it is not possible to keep common corridors and lobbies free of smoke (except possibly by pressurisation systems with protection extended to the entrance door to each dwelling). Furthermore it is clear that it is considered more important to protect the stairs than the corridors as stairs will be used by greater numbers of people if a fire occurs.

5.2.2 Recommendations

Any system should be designed to keep the stairs relatively free of smoke under design conditions.

Any system should 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 when the apartment door is closed.

5.3 Performance criteria

5.3.1 Commentary

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

BRE used ‘steady-state’ conditions in their work, assuming a number of design fire outputs and fixed door openings. While this approach allowed easy comparison of multiple geometries, it may not provide a good representation of reality, where conditions are expected to be transient, with the fire developing and doors opening and closing as time progresses. Nevertheless, since these steady-state conditions are readily available and simple to use, they can provide useful design conditions. The alternative is to use time dependent conditions with a set timeline of actions. This is more realistic but requires more complex analysis and time dependent performance criteria.

Performance criteria should be based on tenability. The main criteria of interest are therefore likely to be visibility, temperature, thermal radiation and toxicity within the ventilated corridors/lobbies. For stairs these criteria should be adjusted to reflect ‘relatively smoke free’ conditions, although protection of the stairs can also be indicated as a function of maintaining a suitable positive ventilation flow from the stair to the corridor or lobby.

An alternative method of assessment is to compare the performance of the proposed system with that of an ADB compliant system under the same design conditions. In this case the performance criterion is that tenability should be no worse than that provided by the ADB compliant system.

Design conditions and performance criteria should be agreed with the approving authority as part of the approval process, preferably in advance of detailed calculation or modelling.

5.3.2 Recommendations

Typical design conditions and performance criteria are set out below for both steady state and time dependent design. While these are offered as suitable for use in apartment buildings they are not exhaustive and there is no bar to the use of alternatives considered more suitable for a specific project.

5.3.2.1 Steady-State Design

5.3.2.1.1 Design Conditions

Steady state design conditions should be selected to provide likely but challenging fire conditions for the situation under consideration. Table 5.1 shows one set of design conditions, based on those used in BRE project report number 213179. Design conditions with sprinklers may be taken from BRE project report number 204505. These cover three stages of a fire, allowing a choice of the most appropriate one(s) for calculation or modelling. Note that it is the amount and temperature of the smoke passing through the dwelling entrance door that determines the severity of the fire scenario in respect of the common areas rather than the size of fire itself. Heat losses to solid boundaries and through windows etc will account for a significant proportion of the heat generated by the fire.

Table 5.1 Illustrative steady-state design conditions (buildings without sprinkler protection) – taken from BRE report 213179

Fire size in dwelling (kW)	Dwelling door opening width (m)	Approx temperature of smoke at door (°C)	Flow of smoke from room		Stair door opening width (m)	Condition
			Mass (kg/s)	Heat (kW)		
250	0.1	210	0.2	40	closed	Early stages of fire, relevant for MOE from fire compartment
1000	0.5	360	0.9	350	closed	Later stage of fire, relevant for MOE from other compartments and arrival of fire service
2500	0.78	690	1.4	1100	0.78	Late stages of fire, relevant for fire service intervention

A conservative design fire could have a rate of heat release of 250 kW/m^2 and a soot yield of 10%, based on the involvement of polyurethane foam.

5.3.2.1.2 Performance Criteria

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. Where the performance of a fire engineered system is being compared against an ADB compliant one, the assessment is essentially one of judicially comparing the smoke (visibility and/or toxicity) and thermal (temperature and/or radiation flux) conditions generated by the two systems.

Where the system performance is being assessed deterministically (and not compared to an ADB compliant one) then it will generally be necessary to set acceptance limits for one or more of the performance criteria identified above. In a steady-state design the acceptance limits will be selected on the assumption that people escaping will be exposed to these limiting conditions for a limited period only. It is not appropriate to give definitive values in this guidance 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* and the SFPE Handbook of Fire Protection Engineering).

Temperature and radiation flux limits of 60°C and 2.5 kW/m^2 are representative of acceptance limits that have been adopted. However, the appropriate choice for an individual system design should take into account the specific design details such as travel distances, occupancy characteristics etc. Note that the radiation flux criteria is sometimes expressed alternatively as a temperature of a smoke layer above head height, with a smoke temperature of 200°C corresponding approximately to a flux of 2.5 kW/m^2.

Smoke visibility and toxicity may also be used for the purpose of setting performance acceptability criteria. However 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 CFD model) and also the ventilation conditions. A widely used smoke criterion is that of 10 metres visibility distance. This value represents a value towards the middle of values observed in various human experiments (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*), and should be treated as a working engineering parameter rather than a precise measure of how people will respond in a real emergency.

Visibility in the stairs should be greater than in the corridor. Note that it is generally accepted that if the visibility is acceptable then the toxicity conditions are likely also to be acceptable.

It is often difficult to maintain a minimum visibility distance when the apartment door is open to the corridor; this is because the corridor fills with smoke generated by the apartment fire. BRE Report 213179 found that it was difficult under most smoke control scenarios to keep the corridor clear of smoke. The designer, approving authorities and other interested parties should take this into account when determining design and performance criteria.

Pressure differences between the corridor/lobby and adjacent stairs and accommodation should not cause door opening forces to exceed 100N at the door handle. This is unlikely to be exceeded if pressure differences across the door are limited to 60Pa.

5.3.2.2 Time Dependent Design

5.3.2.2.1 Timeline of Events

Depending on the method used to analyse the proposed alternative solution, either a steady state analysis or a time dependent analysis may be more appropriate. Usually a steady state approach is used for hand calculations and a time dependent approach for computer model analysis.

It is the responsibility of the assessing engineer to determine which approach should be used. It should be noted that it is recommended that the approach be agreed with the relevant authorities prior to any assessment being undertaken.

Where it is decided that a steady state approach is to be undertaken the following time periods should be considered:

1. Fire development
2. Escape of the occupants
3. Fire Fighting activities.

During these periods the fire conditions and open door conditions appropriate to the circumstances as outlined in Section 5.3.2.1 of this document should be used.

When a time dependent approach is used, it is recommended that a time line as outlined in Figure 5.1 be utilised. This time line allows for a reasonable assessment of the proposed scenario including the state of doors (open or closed), fire size, window breakage, ventilation conditions, and any methods of fire suppression.

Time dependent design provides a more detailed analysis of conditions over the life of a fire. Time dependent design requires setting both a time line for physical events such as door opening and assessment of fire development and decay.

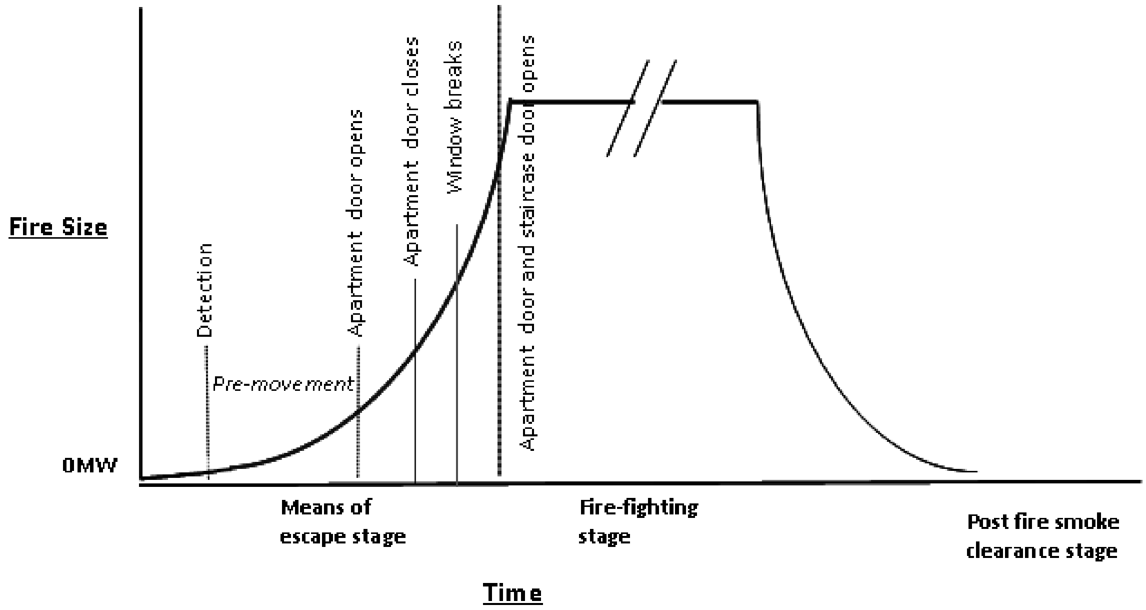
Table 5.3 below shows a typical basic generic time line. Other events, such as occupants escaping from other apartments, can be added as required. Project specific times need to be assessed for each event.

Table 5.3 typical time line for time dependent design

Event
Start of fire (ignoring any smouldering period)
Fire detected in dwelling
Door to dwelling opens (for occupant escape)
Door to dwelling closes
Ventilation system operates from corridor/lobby detection system
Door to stair opens (for occupant escape)
Door to stair closes
Apartment window breaks
Door to stair opens (fire service arrival) and remains open
Door to fire dwelling opens (fire service inspection)
Door to fire dwelling opens (fire service arrival)

Suitable design fires are recommended in CIBSE Guide E and BS 7974. The growth of the fire is likely to take a form similar to that shown in figure 5.1.

Figure 5.1 Typical time dependent fire



5.3.2.2.2 Performance Criteria

When using time dependent design, the performance criteria in 5.3.2.1.2 for steady state design are still applicable although transient excesses of short duration may be acceptable, for example upon opening of the apartment door.

In addition it may be beneficial to set specific time dependent criteria such as the time taken to return the corridor to a specified visibility or other tenability criterion once the apartment door has closed. A suitable time might be approximately 2 minutes for a long corridor as recommended in the LDSA Fire engineering performance criteria Paper “Mechanical Smoke Venting of Residential Lobbies and Fire Fighting Shafts” dated July 2006.

5.4 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

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

It is an accepted fact that the majority of fire deaths in residential buildings are caused by smoke inhalation and not through the flames and heat.

In high rise buildings, the flow of heat and smoke from a fire creates even greater risks for the occupants and fire-fighters alike.

ADB identifies the primary means of controlling the flow of smoke in residential buildings as the fire rated compartmentation, (e.g. the provision of protected escape routes and protected stairwells).

A recognised hazard is smoke entering the escape route as the occupants make their escape during a fire and again when the fire and rescue service enter the accommodation unit to fight the fire.

Any ventilation design will form part of an overall fire safety strategy and should not be designed in isolation.

If not following the prescriptive solution the designer of a smoke ventilation system should define how it fits into the fire safety strategy and the category of the system type, i.e.

- Means of escape
- Fire-fighting
- Means of escape and fire-fighting

Smoke control measures, in each of these categories, can be achieved by natural, mechanical or a combination of mechanical and natural ventilation methods.

Mechanical systems, as described in 6.4, may be designed to allow extended travel distances subject to agreement from the approving authorities.

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 compartmentation as the floor/wall through which it passes.

There is often confusion regarding fire fighting stairs in residential buildings. 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.

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 and can be designed to provide fail-safe operation. 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

- 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.

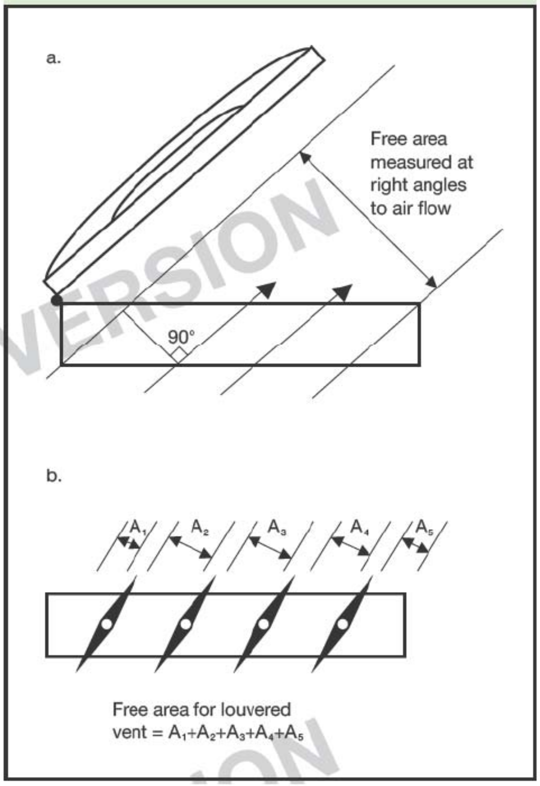
Free Area of Smoke Ventilators

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 – Part 2: 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**



ADB sets no further recommendations for the vents, although they should of course also comply with all other regulations regarding energy conservation, weathering, protection from falling, etc.

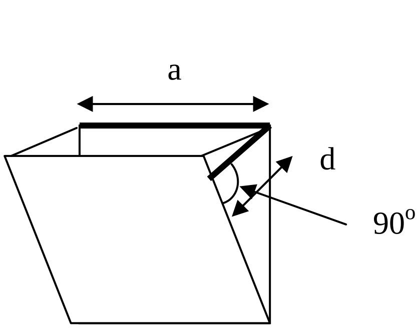
Providing that the free area is achieved, the designer is therefore free to use any form of vent. Normal choices would be a louvred vent or bottom or side pivoting window; flap ventilator; etc.

A result of this freedom is that vents may be selected and located such that they are very susceptible to adverse wind effects, potentially blowing smoke back into the corridor/lobby and into the stair. Designers should consider mitigation of wind effects when selecting and locating vents despite the lack of a regulatory requirement.

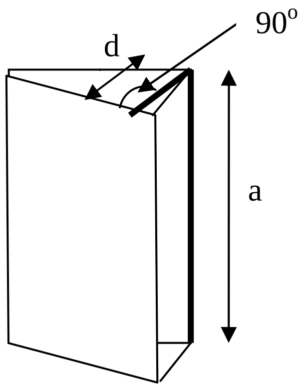
Where a rooflight is used as an outlet automatic opening vent (as illustrated in Diagram C7), in accordance with BS EN12101-2:2003 a minimum opening angle of 140º will mitigate any adverse wind effects (refer 8.2.2).

Where a corridor/lobby vent is bottom or side hung opening outwards, the following calculation method should be applied.

In accordance with Diagram C 7, the measured free area of the open ventilator should be measured in the plane where the area is at a minimum and at right angles to the direction of the airflow, as illustrated below.



Bottom hung



side hung

Free area = a x d ≥ 1.5m²
(where d is the distance ventilator opens measured at 90^o to the opened flap or window)

6.2.4 Smoke shafts

The requirements for a smoke shaft are given in ADB and reproduced below.

Smoke control of common escape routes by natural smoke ventilation

2.26 In buildings, other than small ones complying with Diagram 9, the corridor or lobby adjoining the stair should be provided with a vent. The vent from the corridor/lobby 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.

There should also be a vent, with a free area of at least $1.0m^2$, from the top storey of the stairway to the outside.

In single stair buildings the smoke vents on the fire floor and at the head of the stair should be actuated by means of smoke detectors in the common access space providing access to the flats. In buildings with more than one stair the smoke vents may be actuated manually (and accordingly smoke detection is not required for ventilation purposes). However, where manual actuation is used, the control system should be designed to ensure that the vent at the head of the stair will be opened either before, or at the same time, as the vent on the fire floor.

Vents should either:

a. be located on an external wall with minimum free area of $1.5m^2$ (see Appendix C); or

b. 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);

   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 $E30S_a$ fire door. The shaft should be vertical from base to head, with no more than 4m at an inclined angle (maximum 30^o); 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.

While the recommendations of ADB reproduced above suggest use of Appendix C for measurement of the free area of the vent from the corridor/lobby into the shaft, designers should be aware that the relationship between the vent and the shaft may restrict the free area and should take this into account when selecting, locating and sizing the vent.

Ideally where doors or side hinged flaps are used as AOVs into the shaft the door or flap should open to 90º. Otherwise the free area should be justified

Flaps that are hinged at the bottom and open in to the shaft have an increased risk of failing in a detrimental mode (by opening under gravity) and it is particularly important that the complete assembly is properly fire tested.

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.

6.2.6 Control

6.2.6.1 Minimum Control Requirements

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

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.

For multi-stair buildings smoke detectors are not required and the vents may be manually opened (this does not apply when a smoke shaft is used). 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 made, when positioning the manual activation switches, to ensure that these are not susceptible to vandalism or ‘accidental’ operation, leaving multiple vents open.

6.2.6.2 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.

These problems can be overcome by use of motorised vents manually operated from local break glass switches.

An additional consideration is trapping as vents are closed. If vents may be closed remotely after a test or a false alarm there is a risk of injury by trapping. If the location and type of vent make this a possibility, consideration should be given to requiring local reset.

6.2.6.3 Additional Fire Service Controls

Each vent at the head of a stair should be provided with a manual override switch at the fire service entrance point.

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.

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.

Unfortunately, pressure differential systems tend to be the most expensive as well as the highest performance solution. 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. Although it is possible to achieve the same effect by depressurising the apartments, this is not usually a practical option.

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 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 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.

Note: At the date of publication of this guide it is understood that the next edition of EN 12101-6 will be significantly altered.

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

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 EN 12101-6 recommends dual inlets taken from 2 facades. In practice this is difficult to achieve and commonly inlets separated at least 5m and facing opposite directions are accepted as sufficient. In either case 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. Although a sizing method is given in EN 12101-6, this is too generic for accuracy and manufacturer's data should be consulted.

An alternative method is to use a variable speed drive to the fan, controlled from pressure sensing in the stair. If this option is chosen, care needs to be taken in selection and commissioning as the speed of response required by EN 12101-6 is difficult to achieve and the resulting overpressure can cause doors to slam violently, possibly resulting in damage.

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

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, as recommended in ADB. 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 powered 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 powered systems include the need for maintained power, temperature classified equipment, fire resisting wiring, standby fan unit. Internal pressures within the building need to be considered and limited, so that doors remain operable.

It is necessary to provide air inlet to the communal area to prevent damage to the system, as well as to ensure that excessive pressurisation or depressurisation of the ventilated area does not occur. By avoiding excessive pressurisation or depressurisation, this ensures that large amounts of smoke are not drawn from the apartment of fire origin or such pressure differentials occur that escape doors are either rendered inoperable or are 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.

The smoke shafts should be constructed of non-combustible material and all vents to the lobbies/corridors should have a fire/smoke resistance performance at least equivalent to that of an $E30S_a$ fire door.

Activation of the system is subject to discussion with the approving authorities 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.

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 sub-division 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 following are examples of typical design principles for mechanical systems:

6.4.2 Mechanical Extract, Natural Inlet

The purpose of a mechanical extraction system is to assist in the ventilation of common access spaces. The system comprises mechanical extraction shaft(s) serving one or more common spaces on all, or some, of the floor levels. The mechanical extraction ventilation shaft(s) should discharge directly to the outside.

The shaft is provided with a duty and stand-by fan at the discharge end of the shaft, and these fans provide the ventilation of the smoke from the communal area.

Design of the system is dependent on the layout of the building and the recommended performance and design criteria (as detailed in Section 5). Air replacement forms part of the powered system and the designer should specify how this is to be achieved. The provision of replacement air is one way of ensuring that excess pressure does not occur across a closed door, and/or otherwise compromise means of escape.

The design of powered systems should take into consideration that the source of inlet air should not compromise normal passive compartmentation.

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 8.2.12). The decision regarding the ventilation rates, undertaken by the designers, should be undertaken according to the specific risks presented within the building.

Figure 6.4.2a – Indicative layout showing a typical mechanical extraction and natural inlet ventilation solution for a common access corridor using a smoke shaft

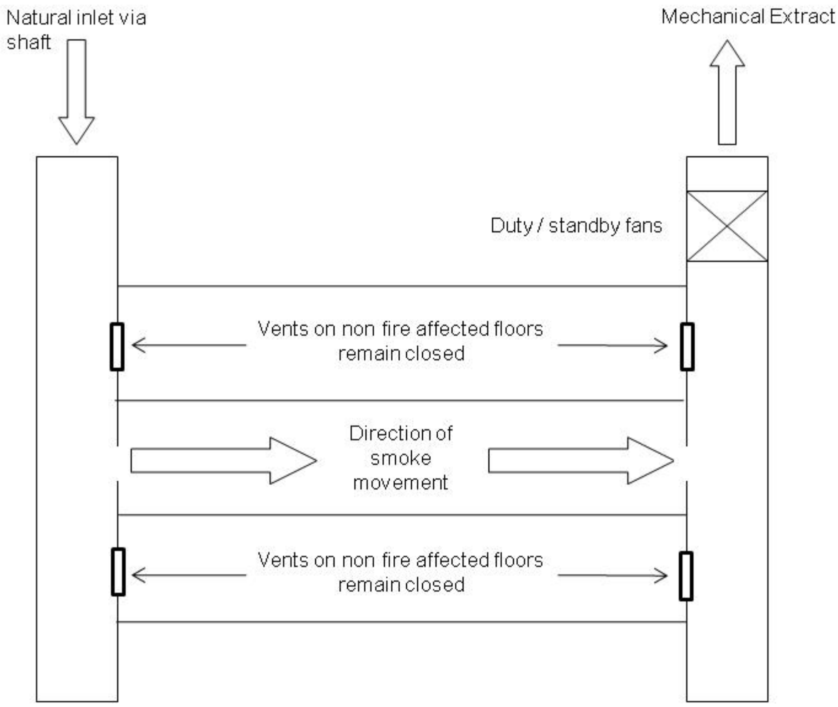
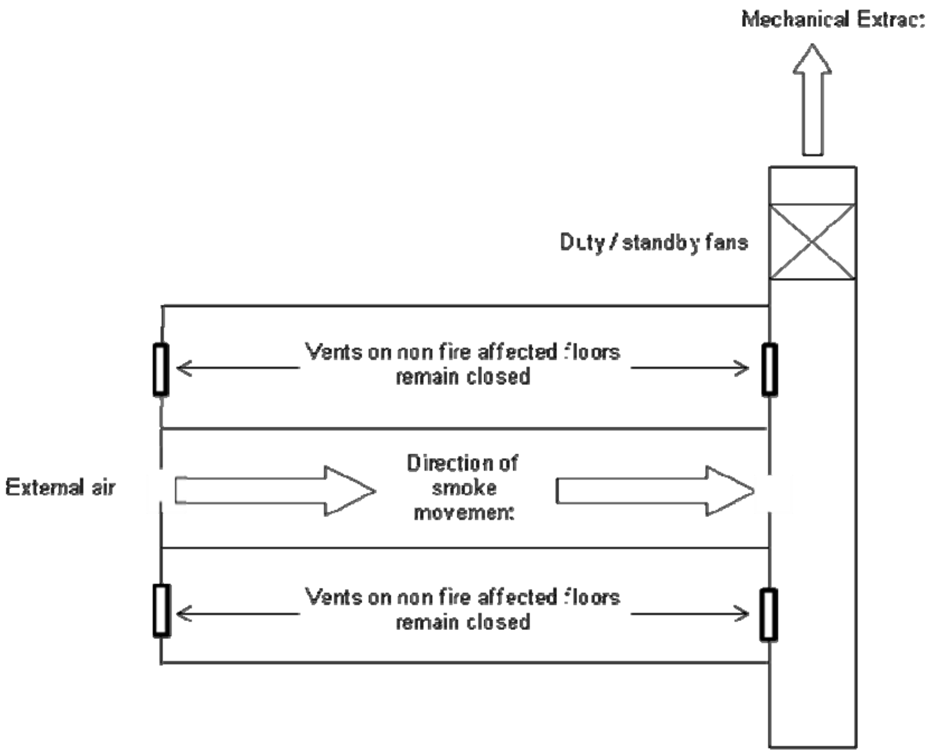


Figure 6.4.2b – Indicative layout showing a typical mechanical extraction and natural inlet ventilation solution for a common access corridor using a vent directly to the outside



6.4.3 Mechanical Extract, Mechanical Inlet

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. Such systems can be provided with a fire fighters switch to enable some or all of the fans to be reversed.

One typical example is a corridor designed with a reversible fan which provides mechanical extraction and a reversible fan providing mechanical air inlet. With this design, the system can be controlled by the fire detection system such that the fan closest to the initial point of detection can be selected as the smoke extract fan in means of escape mode.

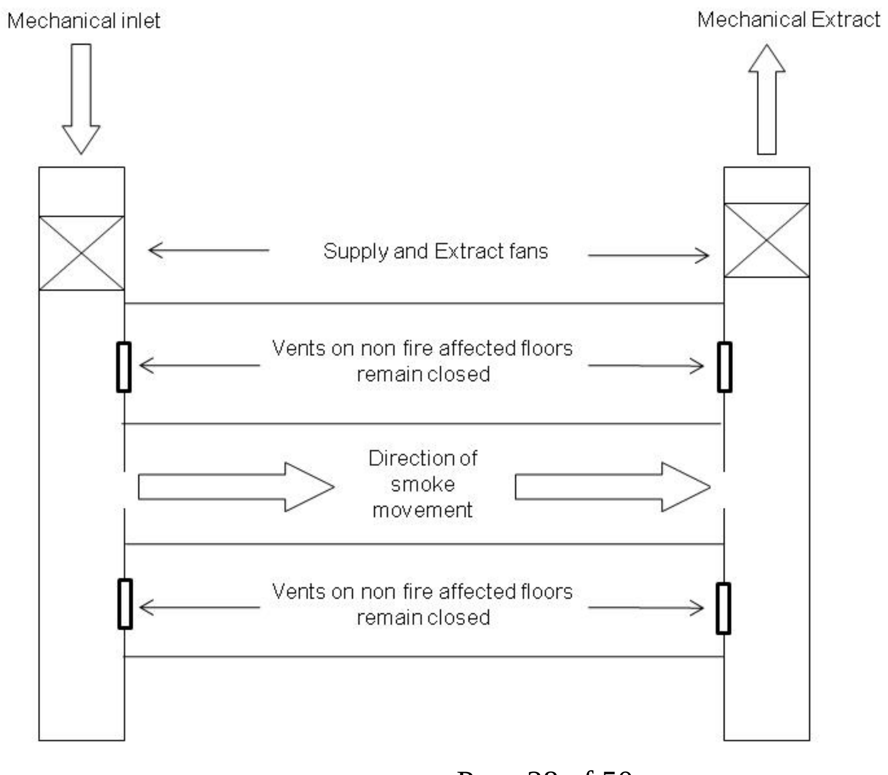
The system can also be provided with an override switch allowing the Fire Service to switch both the fans to extraction mode, providing another source of inlet air (such as the vent at the head of the staircase) is available.

It should be noted that this system design is dependent on the exact requirements proposed by the building layout and that other arrangement are possible (e.g. dedicated extract and inlet fans).

While the extract fan should be specified to operate at the appropriate temperature range, in this system 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.

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



7 Interaction with other Fire Protection Systems and other Building Systems

7.1 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.

7.2 Residential sprinklers

Provision of sprinkler systems in individual apartments or common areas does not remove or reduce the need for smoke control.

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

7.3 Compartmentation

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

8 Installation and Equipment

8.1 Introduction

All equipment should be chosen to meet the specific performance requirement of the system. Without proper installation of all of its components, the system may not operate correctly nor meet the performance targets for which it has been designed.

A detailed engineering plan should be prepared which should include:

Size, location and identification of all equipment

Rating of power supplies

Sizing and routing of cables

Cause and effect summary

8.1.1 System general requirements

The system should have a primary and secondary power supply.

A failure of a component should only affect the operation of that component and other components controlled by it.

All smoke extract fan systems should be installed in a 100% duty/standby configuration, with auto-changeover facility on duty fan failure.

Any use of the smoke and heat ventilation system for a purpose other than the ventilation of heat and smoke under fire conditions should not prevent the smoke and heat exhaust ventilation system from performing its design function when required. The ventilation of heat and smoke under fire conditions should have priority over any other use of the system.

It should only be possible to reset a component from the fire position to the standby position by a manual operation.

8.1.2 Installation general requirements

All components should be installed in accordance with:

— the manufacturer's instructions;

— building regulations;

— project specific drawings and instructions..

When selecting and installing components, environmental conditions, user safety, ease of access and protection should be taken in to account.

All installed components should be capable of being safely maintained and cleaned. Access should be planned for routine maintenance tasks such as lubrication and cleaning. Doors or access panels should be provided as required. To aid the removal and repair of components, lifting eyes or beams should be installed where required.

Clearance should be provided for all moving parts of the components to move through their designed operating range without obstruction from any other fixed or moving part of the building.

Components should be installed so that smoke and heat does not discharge on any adjacent or nearby structure. The exhaust discharges should not point at walls or windows and any combustible parts of the roof structure near the exhaust opening should be protected.

For equipment and relevant test standards refer to TABLE 8.1.1

Table 8.1.1 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	*prEN12101-8*, 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	
				Rooflight	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				*prEN12101-7*, EN13501-4, BS 476-24, EN1366-8, EN1366-1	AD-B	
8.2.7		Builders Work Shaft				BS 476	AD-B	

Control Systems

8.2.11		Control Panels Centralised						
		Control Panels Distributed				*prEN12101-9*, EN12101-10, LVD 2006/95/EC, EMC 89/336/EEC		
		Control Panels - Motors						
8.2.12		Manual Control Point				*prEN12101-9*, EN12101-10, LVD 2006/95/EC, EMC 89/336/EEC , EN60335-2-103		
8.2.13		Automatic Smoke Detection				*prEN12101-9*, 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		
8.2.16	**Actuators**		Casement Window	Chain Actuator				
			E30Sa Fire Door	Door Actuator		EN12101-2 Annex G, EN 60335-2-103, LVD 2006/95/EC, EMC 89/336/EEC		
			Rooflight	Linear Actuator				

8.2 Equipment (including components)

8.2.1 Automatic Opening Louvre, Automatic Opening Casement Window – Used for External Wall Ventilation

This type of product will generally be installed to an ADB compliant system. The most relevant product standard associated with these products is BS EN12101-2. ADB refers to this standard. However it is not always practical to install a product compliant with BS EN 12101-2. In this case a best practice approach should be adopted to ensure the product is fit for the purpose it will be used for, including (but not limited to) calculated free area (refer Appendix C7 of Approved Document B), weathering performance, compliance with Part L of the Building Regulations and safe opening and closing. As it is likely that the louvre or casement will be driven by some kind of actuator, it is worth considering the suitability of this actuator – typically by ensuring the product has undergone some independent testing as a component part to BS 7346-1 or BS EN12101-2.

8.2.2 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 possible it will always be beneficial to install a product tested to BS EN12101-2 but where this is not practical a best practice approach should be taken. 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.

8.2.3 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. These products should comply with BS EN12101-2. 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 effect 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.

8.2.4 Automatic Opening Vent (Actuated E30Sa Fire Door) – Used for Ventilation from Corridor or Lobby into Smoke Shaft

No formal product standards exist for the use of these products in this application. Where an actuated fire door is used care should be taken to ensure that the necessary performance is achieved. It is recommended the AOV should be supplied and installed as a tested assembly comprising of the door, frame, hinges and electric actuator(s) that have been subjected to, and passed the tests for an $E30S_a$ fire door detailed in the Equipment List table within this section.

The door element should have as a minimum the fire resistance equivalent to that of an $E30S_a$ door that has been fire tested on both sides to meet compartmentation rules.

The actuator should be tested to BS EN 12101-2 classes Re 1000, B300 (annexes C and G in the 2003 edition).

The door element, when subjected to elevated temperatures, should not fall open should the actuator fail mechanically, this can be achieved by the use of thermal locking pins.

The use of a fire-tested (BS476 part 22/24 or equivalent) $E30S_a$ fire door with ironmongery removed or modified will void any fire test the door may have been subjected to. Therefore where a non-tested assembly is proposed to be installed to meet the requirements for a code compliant system (under ADB), an independent third-party assessment as to the combined suitability of the separate components is recommended.

There is no expectation for the actuator to operate the door after prolonged exposure to heat as a consequence of a fire occurrence.

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

A bottom hung flap used in a smoke shaft can be treated as a fire door for testing purposes.

8.2.5 Automatic Opening Vent (Smoke Control Damper) – Used for Ventilation from Corridor or Lobby into Smoke Shaft or Smoke Control Duct

No formal product standard exists for the use of these products in this application. To ensure the necessary product performance is achieved it is recommended that the AOV should be regarded as a smoke control damper and the relevant product standards should be considered.

The damper at the fire/smoke source must open to allow the smoke/heat to be extracted and therefore have proven ability to maintain its opening. ADB recommends that dampers on a non fire floor should be closed and capable of performing to the equivalent of an E30Sa Fire Door. Dampers tested to the standards below should satisfy this requirement. Dampers should be actuated using drive open drive close actuators. Spring return actuators and fusible links must not be used.

There is no expectation for the actuator to operate the damper after prolonged exposure to heat as a consequence of a fire occurrence.

Single compartment and multi compartment smoke control dampers are available and care should be taken to select the appropriate products. Further care should be taken to size dampers according to the system design allowing for items such as decorative grilles. There are several applicable smoke control damper standards and these are listed below:

prEN 12101-8: Smoke and heat exhaust ventilation: Smoke control dampers
prEN 1366-10: Fire resistance tests for service installations: Smoke control dampers
BS EN 13501-4: Fire classification of construction products and building elements - part 4: classification using data from fire resistance tests on components of smoke control systems
NOTE: The above standards state that smoke control dampers under automatic control of a smoke control system working directly from fire or smoke sensor inputs must be proven by test to shut (and open) within 60 seconds, having been actuated 30 seconds after the start of the test.

Any damper tested as fire resisting (tests are made using the standard time/temperature curve), supported by an ad hoc operation test at elevated temperature (e.g. 300° and/or 600°C for 1 hour etc) using a drive open/drive close actuator could also be acceptable. These test standards are listed below:

BS EN 1366-2: Fire resistance tests for service installations: Fire dampers - plus ad hoc test report 300° and/or 600°C for 1 hour etc
BS EN 1366-2: Fire resistance tests for service installations: Fire dampers - plus modified HOT400/30 test from prEN1366-10 using 300° and/or 600°C for 1 hour etc

Dampers tested in the closed position to BS 476-20 could also be suitable.

8.2.6 Smoke Control Ducts

Ductwork needs to maintain cross-sectional area at elevated temperature matching the fan specification, typically 300°C for 60 minutes, so that an unacceptable increased pressure drop does not occur, reducing the rate of extraction.

Smoke control ducts and any associated ancillaries have to be designed to extract smoke and hot air from the source of a fire. As the damper at the fire/smoke source will be open, the duct now forming the extract path has become part of the fire compartment from which smoke is being extracted. It may be seen that to extract smoke from a specific area, there is a great likelihood that the duct will cross many compartments and so in most cases will need to be fire resisting.

Smoke control duct sections can be tested to the standard/time temperature curve, confirming their fire resistance. The following are the CEN product standard (certification and CE marking), test standard and classification standards respectively.

prEN 12101-7: Smoke and heat exhaust ventilation: Smoke control duct sections
BS EN 1366-8: Fire resistance tests for service installations: Smoke extraction ducts (multi compartment)
BS EN 13501-4: Fire classification of construction products and building elements - part 4: classification using data from fire resistance tests on components of smoke control systems

As an alternative, any duct tested as fire resisting could meet this requirement, if these tests are made using the standard time time/temperature curve – these test standards are as follows:

- BS 476-24: Fire tests on building materials and structures – part 24: Method for the determination of the fire resistance of ventilation ducts
- BS EN 1366-1: Fire resistance tests for service installations: Ducts
- Note: Although in these instances no specific limits are made with respect to loss of cross-sectional area, BS476-24 includes this as an additional observation, so careful examination of test reports should be made.

Any proposed designs should be presented to the approving authority supported with the necessary tests and reasoning.

8.2.7 Builders Work Shaft

The shaft should be constructed from non-combustible materials, be smooth internally and air leakage should be minimised. The size of the shaft should be in accordance with the design specification. The shaft and its ancillary components should maintain fire compartmentation 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).

8.2.8 Smoke Ventilation Fan

All fans used for smoke extract should be tested and certified to BS EN 12101-3: 2002.

At present, there is no testing regime within EN 12101-3 to cover the use of temperature rated fans with inverters.

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.

8.2.9 Pressurisation Fan

Fans used for pressurisation systems are not expected to operate at high temperature, so ambient rated fans may be used (to ISO 5801 AMCA210-85). EN 12101-6 allows a single fan set to be used for each system in a multi-stair building however a standby fan is recommended if the building has only one stair. Care should be taken to ensure continuity of power supplies to the fans (see 8.2.17 Power Supplies).

8.2.10 Controls

A control system may be centralised, distributed or a mixture of both. 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.

8.2.11 Control Panel

Consideration should be given to the location of control panels and control equipment. Most control panels complying with prEN12101-9 are only designed to operate at ambient temperatures. Therefore they should be located such that the risk of exposure to high temperatures is minimised. For control panels which do not have primary system indication, it is acceptable to locate these 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.

Consideration should be given to access for maintenance purposes.

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.

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.

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

8.2.12 Manual Control Point

prEN12101-9 sets out the operational and aesthetic requirements for a manual control point. The term “manual control point” is designed to encompass generic phrases such as fireman’s switch, call point, breakglass etc. Under prEN12101-9 the manual control point should be deep orange to RAL 2011 and have a frangible element to discourage tampering.

For mechanical systems a manual switch providing off/auto or off/auto/boost (if boost is provided) facility should be installed close to the designated fire service access point.

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.

8.2.13 Automatic Smoke Detection

Any smoke detection system used to operate the smoke control system should comply with either BS5839 part 1 and be classified as an L5 system or prEN12101-9. The detectors should comply with EN54. If the system is only compliant with prEN12101-9 then the detection system should be used solely for the activation of the smoke control system and cannot be used for any other purpose.

8.2.14 Indication Panel

There are no requirements for centralised control and indication. However in complicated buildings, a central fire fighter's panel with indication showing the location (block and floor) of the fire and the status (open / closed) of all systems may be beneficial. Furthermore there is frequently no requirement for a fire alarm panel and the smoke control panel may be the only form of indication available to the fire fighter.

Simplicity is recommended as fire fighters will rarely have the time or knowledge to make proper use of complex controls.

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 6.2.6.2.

8.2.15 Pressure Sensing Device

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.

8.2.16 Actuator

It is important to ensure that any actuators used to operate the ventilators are fit for purpose. The best way of achieving this is to install an EN12101-2 compliant ventilator which will include a fully tested actuator. Where this is not possible, it is strongly advised that evidence is sought of independent testing undertaken on the actuator and illustrating suitability for use in a smoke control system. Test data should include performance at temperature (typically 300 degrees C), operational reliability (minimum 1000 cycles under load), opening speed (<60 seconds). Furthermore it is recommended that the actuator be demonstrated once installed to show suitability and that designed free areas are achieved.

8.2.17 Power Supply

All power supplies should comply with BS EN 12101-10.

There should be at least two power sources: the primary power source and the secondary power source. The primary power source should be designed to operate from the public electricity supply or an equivalent system. The secondary power source, for example batteries or a generator, should be permanently available, tested and maintained.
Each power source, on its own, should be capable of operating those parts of the system for which it is intended.

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.

The power supply equipment should either have inherent resistance to or be protected from mechanical damage. The power supply and related equipment should be clearly labelled as to their purpose and be secured against unauthorised operation.

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

The power supplies to each component(s) should be protected against the effects of fire for the required period of time of activation or operation of the component(s).

Electrical power for smoke ventilation fans can be provided by either:

2 independent electrical public utility supplies, or

1 electrical public utility supply and backup power supply (generating plant).

Power supplies should be installed such that they remain operational when other supplies to the building are isolated in an emergency.

8.2.18 Electrical Requirements

All electrical wiring, actuators and control equipment should be protected against fire for the appropriate period of time when the effects of fire will result in the failure or incorrect operation of the vents/damper/doors.

The cables for the power supplies should comply with the applicable classification from one of the following British Standards, in line with the system design parameters:-

- BS 8491
- BS 8434: Part 2 for fire fighting systems
- BS 5839: Part 1 for Means of Escape systems
- BS 8519 for cables and power supplies to fans

The electrical cables and associated equipment should be sized and fitted in accordance with manufacturer’s instructions.

All electrical wiring should be clearly labelled and identified.

9 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 witness tested by the approving authority to prove its compliance with the project specification and the approved design criteria.

Where windows are used as smoke and heat exhaust ventilators it may be prudent for the approving authority to request that a sample unit be type tested as a smoke ventilator to BS EN12101-2 test standard before being adopted on a particular project.

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 approving authority
- Maintenance and testing instructions
- Instructions for fire service use

This information should meet the requirement of regulation 16B 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 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.
- Check the operation of the manual control point to ensure the ventilator closes.
- 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.

9.3.2 Wall AOV

- Operate each wall AOV 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 and check the area for compliance with the specified area.
- Check the operation of the manual control point to ensure the AOV closes.
- 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 to the design intent.

9.3.3 Natural AOV 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 operate in accordance with the design cause and effect and inspect for correct operation and extension. Only one ventilator should open at any time.
- Measure the size of the opening provided by each of the ventilator 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 to ensure the ventilator closes.
- 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 to the design intent.

9.3.4 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.
- Inspect the motor drives for correct operation and extension.
- Check the ventilators and fans operate in accordance with the design cause and effect and inspect for correct operation and extension. Measure the flow rate into the shaft system at the AOV furthest from the fan position. Only one shaft ventilator should be open at any time.
- Check the operation of the manual control point to ensure the ventilator closes.
- 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.

9.3.5 Pressure Differential System (pressurisation and de-pressurisation)

- BSEN12101-6 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 the following inspections are also recommended:

  - Each motorised damper should be operated via the 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.
  - The motor drive should be inspected for correct operation and extension.
  - The ventilators and fans should operate in accordance with the design cause and effect and should be inspected for correct operation and extension.

- Check the operation of the manual control point to ensure the relevant damper(s) close and the fan(s) shut down.
- 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 smoke control systems provided to protect life safety are properly maintained in effective working order. A series of Guidance Documents are available to the RR(FS)O describing a suitable maintenance and testing regime.

Maintenance should be carried out to manufacturer's recommendations and should be done in compliance with BS 9999: 2008 Code of Practice for Fire Safety in the design, construction and use of buildings.

11 References

11.1 EU Directives

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 2000 No. 2531 as amended, The Stationery Office, London, 2000

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 dwellinghouses (2006 Edition), The Stationery Office, London, 2006

Approved Document L2A: Conservation of fuel and power (New Buildings other than dwellings) 2006 edition, The Stationery Office, London, 2006 (to be superseded by 2010 edition in October 2010)

2009 Technical Handbook, Non – Domestic, The Scottish Government, Building Standards Division, 2009 (to be superseded by the 2010 edition in October 2010)

DFP Technical Booklet E: 2005 – Fire Safety, Department of Finance and Personnel, Belfast, 2005

DFP Technical Booklet F2: 2006 – Conservation of fuel and power in buildings other than dwellings, Department of Finance and Personnel, Belfast, 2006

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-loadbearing 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 EN 1634-1:2008 *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 5588-1:1990 *Fire precautions in the design, construction and use of buildings. Code of practice for residential buildings*

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

BS 5839-1:2002+A2:2008 *Fire detection and fire alarm systems for buildings. Code of practice for system design, installation, commissioning and maintenance*

BS 7346-1:1990 *Components for smoke and heat control systems. Specification for natural smoke and heat exhaust ventilators* (withdrawn)

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 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 1363-1:1999 *Fire resistance tests. General requirements*

BS EN 1364-2:1999 *Fire resistance tests for non-loadbearing 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*

prEN1366-10 *Fire resistance tests for service installations. Smoke control dampers*

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*

prEN 12101-7 *Smoke and heat control systems. Smoke control ducts*

prEN 12101-8 *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 *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*

AMCA 210-85 *American National Standard Laboratory Methods of Testing Fans for 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 fo Common Access Areas of Flats and Maisonettes (BD2410) – Final Factual Report*, Building Research Establishment Ltd, Garston, 2005

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

DW/144, *Specification for sheet metal ductwork*, HVCA, London, 1998 with 2005 Appendix

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 Behavior and Tenability in Fire Smoke,* Proceedings, 5th International Symposium on Fire Safety Science, pp. 3–22, 1997