Guidance on Shafts for Smoke Control

A useful guide to practical smoke shaft principals and specifications

Incorporating the Smoke Shaft Vent
Smoke shafts – an overview

Scope of this guide

‘Smoke shaft’ is the common term for ventilation systems in the lobbies of tall buildings, used to maintain tenable conditions in the common escape routes in the event of a fire in the building.

This document is a practical guide to the implementation of smoke shaft systems for multi-storey buildings.
Origins

Smoke shafts originated from research carried out by BRE and presented in a report in 2002 entitled *Smoke Shafts Protecting Fire Fighting Shafts, Their Performance and Design*.

This report specifically looked at fire-fighting shafts and proposed natural ventilation – with the output being commonly known as the ‘BRE Shaft’.

The desire to reduce the space occupied by the ventilation system led to the development and common acceptance of mechanically ventilated shafts to provide both firefighting and means of escape protection.

IN COMMON USAGE

The mechanical smoke shaft is now the most commonly employed smoke control measure for high-rise buildings, overtaking the other available approaches, namely automatic opening vents and pressurisation.
Standards


Unlike natural ventilation and pressurisation systems, mechanical smoke shafts do not yet appear in the Building Regulations and are treated as a fire safety engineered approach. This means that whilst they are now very common, their use is subject to approval by the Authority having jurisdiction (AHJ), usually the Local Authority Building Control department or an approved inspector.

As there is no single common standard applying to these products they are typically approached using the appropriate parts of several related documents.

This document applies current guidance from various sources to reach a quick and reliable route to a robust solution for most common situations.

- Approved Document B (ADB) of the Building Regulations is applied to the stairwell ventilators, lobby ventilators, system triggering method and ventilator free area measurement.
- European Standard 12101 Parts 3, 6, 7, 9, and 10 are referenced for fans, ducts, control equipment and power supplies.
- PD 7974-6: 2019 is used to identify acceptable conditions for the escape of occupants of buildings.
- In addition, the Smoke Control Association (SCA) document Guidance on Smoke Control to Common Escape Routes in Apartment Buildings (Flats and Maisonettes) Revision 2: October 2015 offers a comprehensive guide to smoke shaft applications for residential buildings.
Smoke shafts are essentially a simple ventilation system designed to extract any smoke leaking into a common lobby to protect the escape stairs. Typically a vertical builder’s work duct rising through the building would be used to extract smoke from the lobbies and each lobby would have a damper connected to the builder’s work duct.

For natural shafts, the head of the shaft is terminated with an automatic opening ventilator. Mechanical shafts use extract fans, mounted on the roof and connected to the builder’s work duct with sheet metal ducting. An automatic opening ventilator is mounted at the top of the stairwell and the complete system is controlled by an addressable control system that provides automatic operation of the ventilation by interface with the fire alarm system or smoke detectors.

**FIREFIGHTING**

For buildings with a storey over 18m high, firefighting access would also need to be taken into account. This would usually mean that the system is designed to cope with the door to the fire room being open to the lobby, representing firefighting conditions. In practice this simply means that a higher extract volume flow rate is needed for mechanical systems. Typically the required conditions within the lobby would be based on the tenability criteria in *PD 7974-6: 2019*.

The tenability criteria described in the guidance are:

- Visibility (5m for small enclosure and 10m for large enclosure - extended travel distance would require a 10m visibility)
- Temperature (smoke temperature is less than 120°C – some say 60°C in a moist environment)
- And a requirement by London Fire Brigade that the lobby/corridor returns to a smoke-free environment within 2 minutes of the last occupant’s escape through the stair before the onset of firefighting. *PD 7974-6: 2019* recommends design fire sizes for a range of applications.

For natural systems, a larger smoke shaft may be required for non-residential buildings with larger ventilators. See page 16 for details.
Replacement air

For mechanical extract systems to work effectively, fresh air must be introduced to replace the smoke being extracted. The most common method of achieving this is via a vent in the stairwell, with other methods including vents in the lobby or via inlet fans.

1. INLET FROM STAIRWELL

An Automatic Opening Ventilator (AOV) above the stairwell can be used to provide replacement air for the smoke shaft. There are three commonly used methods of getting the air into the lobby: actuated stair door; pressure control system; and reverse-hung stair door.

A. Actuated stair door

This is the safest and most reliable of the stairwell air inlet methods. The door between the stair and the lobby, is automatically opened a set amount on smoke being detected in the lobby. This allows fresh air to be drawn into the lobby from the open stairwell ventilator. For buildings requiring firefighting protection, the system can be initiated at high speed removing the need for manual intervention by firefighters which can be problematic.

B. Pressure Control System

With this method, the speed of the extract fan is varied according to the pressure difference between the lobby and the stairwell such that the force required to open the lobby/stair door does not exceed 100N. There are a number of points
to bear in mind with such systems:

a. *BS EN12101 Part 3: 2015* suggests precautions to be undertaken when using inverter drives to control fans in fire mode. The fan and inverter must be tested and certified together as a unit. Alternatively, it is possible to include the addition of output filters and to derate fan motors by 20%. These precautions substantially increase the cost of the control system.

b. Pressure sensors can be sensitive and should be sited where they are protected from damage.

2. **INLET FROM LOBBY**

   Fresh air may be introduced directly into the lobby, either from outside through an Automatic Opening Ventilator (AOV) or via a natural ventilation shaft. Examples of these are given later in this guide.

3. **MECHANICAL INLET**

   It is also possible to use fans to introduce fresh air. This can be via a dedicated air inlet system or may use reversible fans so that depending on the fire location, each shaft may be an inlet or an extract point.

C. **Reverse hung stair door**

   This method employs a stair/lobby door hung to open into the lobby. The door closing device is adjusted such that the door is pulled open when the pressure in the lobby exceeds a set point. This relieves the pressure and allows the escape route to remain accessible. It is considered good practice for doors to open in the direction of escape travel which may render this method unacceptable.

**Location of inlet relative to extract**

To ensure effective smoke clearance, the extract shaft should be located as far away as practicable from the stairwell, which is the source of replacement air.

This is particularly important in buildings with extended travel distance where the exhaust position would ideally be at least 5m away from the stairwell vent to prevent smoke being drawn into the building.

There is no risk of depressurisation with natural smoke shafts, however the exhaust rate is more critically affected by the heat and buoyancy of the smoke, the resistance of the riser through the building and the effect of wind on the outside of the building and discharge louvre.
Computational Fluid Dynamics (CFD) are often used to ascertain the volume flow rate required to maintain the design conditions within the lobby; this was essential in the early days of adoption of such systems as each situation was in effect a new scenario.

However, after more than ten years of common usage, there is a bank of data available to inform such selection for most buildings, particularly residential where one lobby is very similar to another.

At SCS Group we have available data from multiple models and have aggregated this into a matrix to develop suggested extract rates for buildings within the parameters of this guide.
Environmental ventilation

Heat build-up in corridors, particularly in residential buildings with energy centres providing heating, can be problematic and it is possible to use the smoke control system to dissipate some of this heat.

There are various approaches in use, from running the smoke fans at low speed and opening the smoke lobby dampers proportionately, to adding smaller environmental fans and dedicated dampers above the ceiling. Such approaches are obviously limited by the outside air temperature and are not guaranteed to reduce corridor temperature in all conditions. If this is likely to be a significant issue then a thermal model of the building should be undertaken and appropriate cooling measures implemented which would be outside the scope of this document.

A typical pragmatic approach to ventilation using the smoke control equipment would be to add a temperature control function to the control strategy such that ventilators are opened on excess temperature in a predetermined sequence to evacuate heat. For mechanical ventilation, the smoke fans would be inverter controlled and run at low speed to deliver a notional air change rate within the lobby, typically 4 air changes. Automatic rain-sensing control would also be required to prevent the stairwell ventilator opening in poor conditions.

All day-to-day ventilation functions must be overridden in an emergency condition.
Installation & commissioning

Installation should be undertaken by a specialist contractor who understands the working relationship of each installed element of the shaft system.

Prior to handover, the commissioning process needs to be able to prove the effectiveness of the system in a variety of test operation scenarios, in accordance with the agreed ‘cause and effect’. Guidance exists to govern the quality of installation and the extent and scope of commissioning, for example:

**BS 7346-8:2013 Part 8 - Installation:**

“The nature and quality of the installation work needs to be such as to ensure the integrity of the smoke control system and minimise the duration and extent of any disablement of the system during maintenance or modifications. Penetration of construction (e.g. for the passage of cables, conduit, trunking or tray) ought to be made good to prevent the free passage of fire or smoke, regardless of whether the construction has a recognised degree of fire resistance.”

**BS 7346-8:2013 Part 8 - Commissioning:**

“The process of commissioning involves thorough testing of the installed smoke control equipment, including interactions with other systems.

The responsibility of the commissioning engineer is to verify that the system operates in the manner designed and that the installation workmanship is of an adequate standard. It is therefore necessary for the commissioning engineer to be provided with the agreed specification for the system.”
The Regulatory Reform (Fire Safety) Order 2005 (RRO) dictates that a building’s “responsible person” (generally a building owner, manager or FM) has to ensure proper operational service and maintenance of smoke control systems.

Smoke shafts are life-critical aspects of a building’s operation so their proper maintenance is vital. Many components come under the scheduled service recommendations of BS 9999: 2017, and the latest standard on smoke control (BS 7346-8:2013 Part 8) states that: “Smoke control equipment should only be maintained by a competent person with specialist knowledge of smoke control systems, adequate access to spares and sufficient information regarding the system.”

It is important to bear in mind the fact the smoke control systems are more than just a parts list. While one aspect may be apparently operational, it must also be suitably operational in relation to the rest of the system. Software maintenance, too, is important, and the latest updates should always be installed to ensure maximum performance.
System components

Builder’s work shaft

The extract shaft or duct shall meet the requirements for fire resistance for a period at least equal to the highest period of fire resistance through which the ductwork passes, when tested and classified in accordance with BS EN 13501-3:2005+A1:2009. In practice this will usually mean a minimum of 1-hour fire resistance.

The internal surface should be smooth and the maximum air leakage should be 3.85m$^3$/hr/m$^2$ at 50Pa pressure difference, as specified in the pressurisation standard EN12101 Part 6. A pressure test should be undertaken to prove the leakage prior to installation of the system.

For mechanical shafts, the minimum free area is typically 0.6m$^2$ with an aspect ratio of 2:1 with the shaft rising vertically with minimal changes in direction or shape throughout its travel. The recommended size for ease of connection to roof extract equipment is 800mm x 800mm.

For natural shafts ADB specifies a minimum internal free area of 1.5m$^2$, with a minimum dimension in any direction of 0.85m. The recommended internal shaft dimensions for ease of roof vent sizing are 1.2m x 1.3m. Where there is a risk of falling into the shaft then floor grids may be required at intermediate levels and these should maintain a minimum free area of 1.0m$^2$. Shafts should be 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. In non-residential buildings requiring firefighting protection (those with a storey above 18m) the shaft free area required is 3.0m$^2$ (recommended dimensions 1.5m x 2.0m) and the construction should be 2hr fire resistant.
System components

**Control system**

The control system should comply with *BS EN 12101-10:2005* and *BS ISO 21927-9:2012* where applicable, and sensitive equipment such as inverters and PLCs should be located out of the fire zone.

The control system may be designed specifically for the building, or be a modular standardised product that can be configured to the building. Most residential applications will suit the modular approach, with local zone control panels located throughout the building communicating with a central processor usually located at the fan position, and a HMI panel at a convenient location that is used for commissioning and testing.

Triggering of the system may be from dedicated smoke detectors purely for the operation of the smoke control system, or through interface with a building smoke detection system compliant with *BS 5839-1:2017* L5 classification. Manual call points should be orange and, where located adjacent to a ventilator on a fire floor, should simulate an alarm on that floor.

Manual control switches for firefighter use should be located adjacent to the fire service access point and be clearly labelled ‘Smoke Extract’. Where the system incorporates a higher extract duty for firefighting access, manual boost switches should be positioned on each floor for fire brigade use.
System components

Smoke exhaust plant

For mechanical shafts, extract fans should comply with BS EN 12101-3:2015 and a standby fan is required in case of fan failure. The selection of the appropriate temperature rating should be dictated by the results of any design calculations or CFD modelling, however, based on previous project data, a rating of 300 deg C for 1 hour will be suitable for most residential situations. Ventilators at the head of natural shafts should be to the same standard as stairwell ventilators, complying with BS EN 12101-2:2003. For residential buildings a free area of 1.0m² is required, while for firefighting shafts the free area should be 2.0m².

Stairwell ventilator

The ventilator above the stairwell will primarily be used as an air inlet for the smoke shaft and should have a minimum free area of 1.0m² when measured in accordance with diagram C7 of ADB.

The ventilator should comply with EN12101-02.
System components

Power supply and wiring
The system should have a secondary power supply in case of mains failure in accordance with BS EN 12101-10:2005. This may be from either an independent electricity utility supply or a generator back-up supply.

Electrical wiring should be of a suitable temperature rating for the application. For most residential systems FP200 Enhanced (PH120) or equivalent is suitable for sensors and devices, while FP600S is commonly used for power supplies to extract plant.

Lobby ventilator
The ventilator connecting the lobby to the builder’s work shaft may be a door type or a damper. The basic requirements are for it to open on the fire floor to exhaust smoke and for the remaining floors to remain closed, preventing smoke spread and maintaining fire compartmentalisation. There is no specific standard for these products so the two common approaches are to use an E30Sa fire door (with an electrical actuator) or a smoke damper, neither of which will be fully certified for the application but which offer pragmatic solutions. The actuators should be drive open, drive closed rather than a spring-return type.

For firefighting smoke shafts, the ventilator free area is increased to 1.5m².

In mechanical systems, the free area is calculated according to the required extract volume, and is typically around 0.6m².

The ventilator should be positioned as close to the ceiling as possible within the lobby, and at least as high as the top of the door from the lobby to the stairwell.

For natural shafts in all residential buildings the free area of the lobby ventilator is 1.0m².
Natural shaft systems rely on the buoyancy of hot smoke and the inlet of fresh air to extract smoke in the case of a fire. With mechanical intervention, the shaft will generally require a larger footprint than the equivalent mechanical system.

A simple system will typically comprise:

- Builder’s work shaft of 1.5m² free area
- Lobby vent
- Roof vent
- Control system
Examples – stairwell vent

The stairwell ventilator is a low-profile automatic opening hatch with an opening angle of 120°, to minimise wind effects.

It should be manufactured from corrosion-resistant aluminium and be fully insulated, with a geometric free area of 1.0m².

The control kit should comprise a local control panel with a battery-backed 24v DC supply and two remote control switches for positioning at the top and bottom of the staircase.

The control panel accepts a signal from lobby ventilators to automatically open with lobby ventilation.
Examples – mechanical shaft

Mechanical shaft systems are particularly suitable for buildings where space constraints prevent the use of simpler solutions.

A provisional design can be achieved in minutes by selecting modular components:

- Builder’s work shaft
- Lobby vent
- Roof extract unit
- Control system
References

- Smoke Shafts Protecting Fire Fighting Shafts, Their Performance and Design (BRE, 2002)
- Approved Document B – Volume 2 of the Building Regulations 2010
- Guidance on Smoke Control to Common Escape Routes in Apartment Buildings (Flats and Maisonettes) Revision 2: October 2015
- BS EN 12101-10:2005. Smoke and heat control systems. Power supplies
- BS 5839-1:2017. Fire detection and fire alarm systems for buildings. Code of practice for design, installation, commissioning and maintenance of systems in non-domestic premises
- BS 7346-8:2013. Components for smoke control systems. Code of practice for planning, design, installation, commissioning and maintenance
- The Regulatory Reform (Fire Safety) Order 2005 (RRO)