UK DESIGN REQUIREMENTS

England, Wales, Scotland and Northern Ireland all have different guidance, so for the purposes of brevity this paper concentrates on the guidance on the design of residential apartment buildings in England. These design principles can be found in both Approved Document B (AD-B) (1) or in BS 9991 (2). Notwithstanding many of the principles are the same throughout the different countries forming the UK, but any principles given in this paper should be reviewed against the requirements of the respective code of practice.

In England, the provision for means of escape from apartments is based on the assumption that:

a. the fire is generally in a flat;
b. there is no reliance on external rescue (e.g. by a portable ladder);
c. measures are taken to provide a high degree of compartmentation between each apartment and the adjoining apartments, ancillary accommodation and escape routes, and therefore there is a low probability of fire spread beyond the flat of origin. On this basis, the simultaneous evacuation of the building is unlikely to be necessary; and
d. although fires may occur in the common parts of the building, the materials and construction used there should prevent the fabric from being involved beyond the immediate vicinity (1).

e. Sprinkler provision is only required where the apartment building is in excess of 30m in height from Ground floor level to finished floor level of the highest floor.

Means of escape within residential buildings is generally considered in two parts, means of escape from within each flat or apartment, which is outside the scope of this paper, and escape from the entrance door of each apartment to the final exit from the building. In this case the final exit from the building is typically taken as the door at the base of the staircase to the outside.
Because of the stay-in-place evacuation policy and the provision of extensive compartmentation between apartments and the adjoining accommodation, residential buildings in the UK are permitted to be either single or multiple stair buildings irrespective of height. E.g. Single staircase tower blocks of 15-20+ storeys in height are not uncommon.

To provide an enhanced level of protection, the codes of practice recommend that every flat is separated from the common stair by a protected lobby or common corridor (unless permitted to be a ‘small single staircase building’, which is not considered further in this paper) and the travel distance limitation of 7.5m (unsprinklered) or 15m (sprinklered) are met where escape is possible in a single direction. This increases to 30m where escape is possible in two, or more, directions.

Note: * Only BS 9991 currently permits doubling of the travel distance to 15m where sprinklers are provided.

SMOKE VENTILATION METHODOLOGIES

There are two main methods of smoke ventilation:

a) Natural smoke ventilation systems. The general principle is that a vent is provided to the lobby or corridor adjoining the stair to facilitate the removal of smoke through the vent prior to it entering the staircase enclosure. The vents can be located either on an external wall or in a vertical shaft. A vent is also provided from the top storey of the stairway to outside air, to act as an outlet if smoke enters the staircase or as an inlet to make the system more efficient prior to the arrival of the fire and rescue service.

b) Mechanical smoke ventilation systems. This can take the form of either a pressure differential system, which is not commonly used in the UK, or a mechanical smoke ventilation system, which is the more common system type. Typically for both mechanical ventilation and pressurisation, a vent is also provided from the top storey of the stairway to outside air, to act as an inlet to make the system more efficient prior to the arrival of the fire and rescue service or to provide pressure relief from the staircase and prevent excessive forces being formed at the door, preventing the stair doors from being opened.

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

Figure 1 shows the typical ventilation arrangements for four common arrangements, including a two stair building with no dead-ends, a two stair building with dead-ends, a single stair building with a protected ‘sterile’ ** lobby and a single stair building with no sterile lobby.
Note: ** A sterile lobby is defined in the UK as a lobby which does not serve any other apartment. This is typically a loft lobby or draft / acoustical lobby provided at each floor level.

As can be seen from Figure 1, the key criteria of the smoke ventilation system is that the portion of the corridor adjacent to the staircase(s) is ventilated. It is possible, and permitted, to have unventilated sections of corridor for both multiple and single staircase buildings. This is because it is recognised in AD-B that it is probable that some smoke will get into a common corridor or lobby from a fire in a flat, if only because the entrance door will be opened when the occupants escape. There should therefore be some means of ventilating the common corridors/lobbies to control smoke and so protect the common stairs. This offers additional protection to that provided by the fire doors to the stair.

On this basis, the primary objective of smoke control in residential buildings is to minimise the risk of smoke flow into the stair. Whilst the adjacent protected corridor or lobby might also benefit from the removal of smoke, the ventilation system is provided to protect the staircase and not the occupants, either fire service or occupants of adjoining apartments, provided the travel distances are limited to the 7.5m (15m) given in the code.

However, BS 9991 recognises the benefits of providing mechanical ventilation, and recommends that travel distances in the corridor can be extended past the typical ‘code’ limits provided the primary objective of the smoke control system is to protect both the common corridor and the staircase enclosure for means of escape.
SMOKE VENTILATION SYSTEM TYPES

As stated there are two main types of smoke ventilation system, with natural ventilation being the most popular, mainly due to the fact that it is relatively inexpensive, simple to design and install and environmentally friendly with low maintenance and ongoing costs. However, mechanical ventilation is rapidly gaining popularity amongst developers and designers due to the reduced space requirements and ability to increase travel distance. It is also gaining popularity amongst enforcement and fire fighters due to the higher reliability of ensuring tenable conditions during fire-fighting operations.

Natural Ventilation

Natural ventilation works by harnessing the buoyancy of hot smoke from the fire to drive flow through the ventilator located in the corridor. Ventilation systems tend to form one of type types, external vents or natural smoke shafts.

External vents should be located on an external wall with minimum free area of 1.5m².

Smoke shaft systems, which are closed at the base of the shaft, should be designed as follows:

1) The shaft and vent should have a minimum cross-sectional area 1.5m² (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;
2) The shaft should extend at least 2.5m above the ceiling of the highest storey served by the shaft;
3) 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 1.0m²;
4) The smoke shaft should be constructed from non-combustible material and all vents should have a fire/smoke resistance performance at least that of an E30Sa fire door. The shaft should be vertical from base to head, with no more than 4m at an inclined angle (maximum 30°);
5) The vent on the floor of fire origin should open automatically, but the vents from the corridors/lobbies on all other storeys should remain closed.

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, with inlet being formed at the bottom of the vent (typically 1/3rd) and exhaust occurring at the top of the wall mounted vent (typically 2/3rd's). For both window and smoke shaft systems, inlet air can be provided through the stair door when it is opened either to allow occupants to escape or facilitate fire service activities. On this basis, and to vent any smoke which enters the stair, a vent is needed at the head of the stair, which must open at the same time as the ventilator on the floor of fire origin.
The downside of a natural ventilation system is that buoyancy forces can be small compared to wind forces so the performance of a natural ventilation system can be significantly affected by wind. Smoke shaft systems are more reliable as they are less affected by adverse wind conditions, but can take up valuable space.

**Pressurisation**

While a pressure differential system can be in the form of either a pressurization system or a depressurization system, in the UK a pressurization system is usually used to protect staircases. It should be noted that a pressurisation system will not normally provide tenable conditions within the corridor and is not typically used to justify extended travel distances.

The general principle of a pressurisation system is that a non-fire rated duty / standby fan set injects air into the staircase to create a higher pressure than in the adjoining spaces (e.g. corridor and apartments). This prevents any combustion products from entering the staircase even when the door is open. Pressurization systems are typically designed and installed in accordance with BS EN 12101-6 (4).

As well as providing supply air, it is also necessary to ensure that the adjoining spaces do not pressurise by providing an air release path as well as ensuring that the pressurised space (staircase) itself does not over-pressurise.

Preventing the staircase from over-pressurising is typically achieved by either modulating the supply airflow by providing a pressure sensor within the staircase linked to an inverter controlling the fan or by a pressure sensor operated vent direct to the outside (typically a roof vent).

However, the reason pressurisation tends to be less common in the UK than elsewhere in the world, is due to the need to provide an air / smoke release path. If an insufficient air / smoke release path is provided to the adjoining space, adjacent to a pressurised one, then over time the adjoining space will reach the same pressure, and smoke and other combustion gases could flow from the adjoining space into the staircase as a result.

On this basis, the corridor is typically provided with the air / smoke release path, in the form of a smoke shaft. Where an air release path is provided by natural ventilation; the following equation should be used:

\[
\frac{Q}{A_{VA}} = 2.5
\]

Where:

- \(Q\) = airflow into a pressurized space (m\(^3\)/s)
- \(A_{VA}\) = Area of air / smoke relief vent (m\(^2\))

On the basis that the required airflow through a door is 2m/s, the open door is 1.8m\(^2\) in area (giving 3.6m\(^3\)/s) the area of the air /smoke release path is 1.44m\(^2\). This air / smoke release path
would be nearly the same area as a natural ventilation smoke shaft without the additional costs of providing the fans, duct system for the pressurisation system etc.

**Mechanical Ventilation**

Where used to extend travel distances, typically these systems are fire engineered solutions designed to achieve specific objectives. Where a fire engineered solution is proposed, the system is typically designed in accordance with industry guidance in the form of the Smoke Control Association Guide (3).

Such systems take into account the need to maintain tenable conditions for both occupants seeking to evacuate from adjoining apartments and the fire service.

![Figure 2](image)

**Figure 2 – Figure and Table showing the SCA Guide Recommended Tenable Limits for First Responders**

However, single injection systems, when used with code compliant travel distances, can now be purchased and installed as ‘off the shelf’ products such is the degree of familiarity with the systems amongst UK Authorities Having Jurisdiction.
Design of the system is dependent on the layout of the building and the recommended performance and design criteria. On this basis, systems types vary, but the most common ones are:

1) Mechanical Extract and Natural Inlet

The system comprises mechanical extract shaft(s) serving one or more common spaces on all, or some, floor levels supplemented by the provision of natural air inlet provided by automatically opening vents or permanent vent to the outside (either directly or by way of a shaft, stairway or duct).

Typically the mechanical extract is by a shaft although it can be via fans direct to the outside, although this is a less common design solution and typically only provided where single floor levels require smoke ventilation.

![Figure 3 – Mechanical Extract and Natural Inlet](image)

The mechanical extract should discharge directly to the outside. Where only a single mechanical extract is provided duty/standby fans should be provided as fan failure would result in failure of the system. Such systems can be provided with a variable rate of extraction (typically provided with a ‘fire service boost’ button) or can be steady state.
The area of natural air inlet openings should be sufficient to ensure not only that an excess pressure differential does not occur across a closed door but also that the pressure differential does not otherwise compromise means of escape by ‘pulling’ excessive amounts of smoke through door cracks or other leakage sources from the apartment of fire origin into the corridor.

2) Dual Reversible Mechanical Extract

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

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.

![Mechanical Extract and Mechanical Inlet](image)

*Figure 4 – Mechanical Extract and Mechanical Inlet*
3) Mechanical Extract Only

The system uses a single mechanical extract shaft, with replacement air typically provided by natural leakage. Air replacement forms a key component of a mechanical extract only system and careful consideration is required during the system design stage on how this is to be achieved and also how this is to be confirmed and tested onsite, including after handover and while the building ‘settles’.

The key design consideration is to ensure that excessive pressure does not occur across a closed door or otherwise compromise means of escape by pulling smoke into the common escape routes from the adjoining space.

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

SUMMARY

Post 2006, emphasis in the UK has been on using smoke ventilation systems to protect staircases and ensure the safe egress of occupants and fire service personnel vertically. However, in recent years we have moved back to include smoke ventilation systems in the design in order to ensure safe conditions during horizontal evacuation, as well as protecting the staircase.

The partnership of industrial, academic and research and authorities having jurisdiction looking at system types, tenable requirements and lessons learnt over the last decade are contributing in maintaining life safety but also increasing flexibility.

REFERENCES


2) BS 9991: Fire safety in the design, management and use of residential buildings – Code of practice, British Standards Institute, 2015.

3) Guidance on Smoke Control to Common Escape Routes in Apartment Buildings (Flats and Maisonettes) Revision 2, Smoke Control Association, 2015