The risks associated with speed control of fans for mechanical smoke shafts

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DOCUMENT REFERENCE	SCS/RISKS_FAN_SPEED_CONTROL_MECHSS/REV_00x
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SUBJECT TAGS	MECHANICAL SMOKE SHAFT, MEANS OF ESCAPE MODE, FIREFIGHTING MODE, SMOKE CONTROL, MANUAL OVERRIDE, VSDs
DATE OF REVISION	JANUARY 08, 2018

Mechanical smoke shafts are the most common method of smoke control in high rise apartments and although they are in essence very simple systems comprising relatively few components, because they are not yet included in the Building Regulations they tend to be shrouded in mystery and thought of as a specialist package. In most simple buildings however, it is possible to use a one-size-fits-all approach and come up with a standardised solution that can be employed on multiple projects.

The primary purpose of a mechanical smoke shaft is to maintain a clear escape route for occupants of the building in the event of a fire in an apartment, known as Means of Escape Mode. For tall buildings there is also a requirement to maintain safe conditions for the fire brigade to enter the building to fight the fire, commonly known as *Firefighting Mode*.

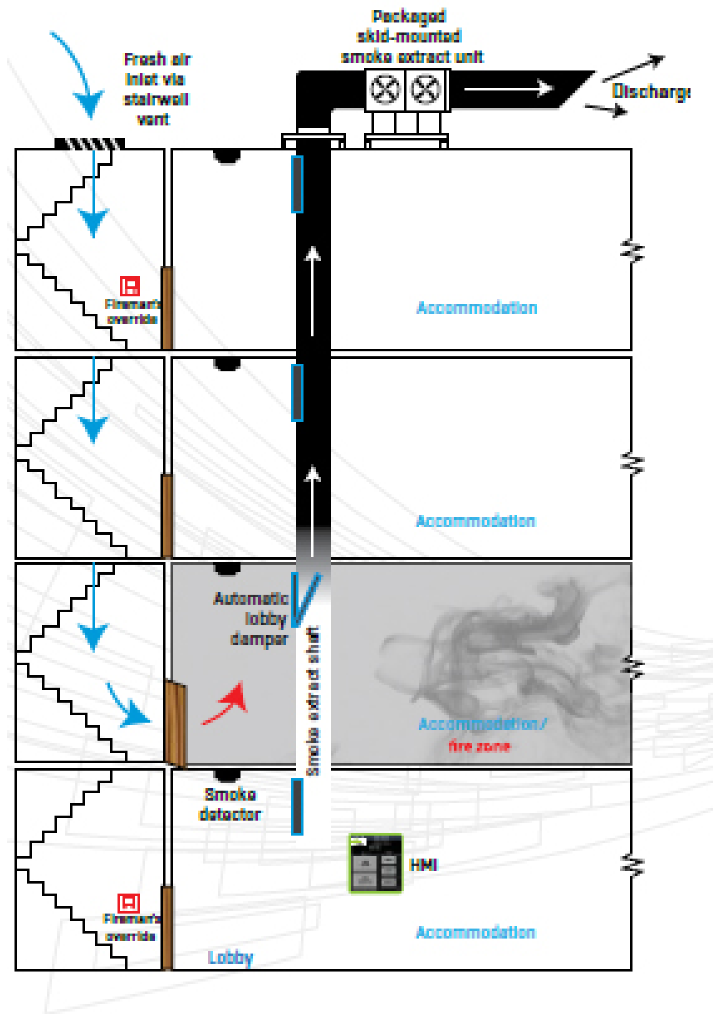

Figure 1Mechanical smoke shaft illustration

Means of Escape mode

Each apartment in a building is a separate fire compartment so in theory a fire in one apartment should not affect any other dwellings and occupants of flats would not necessarily be aware of the incident. Anyone leaving the apartment during the early stages of the fire would exit by the door onto the common lobby and this could allow some smoke to exit into the lobby in the time that the front door is open. In the Means of Escape mode, the smoke shaft would be used to extract any smoke that has leaked into the lobby to ensure the stairs and lobbies remain relatively smoke free to allow other occupants of the building to leave safely should the need arise.

Firefighting mode

In buildings with a floor higher than 18m above ground level, the fire brigade would have to enter the building to fight the fire as this is beyond the reach of the tallest ladder. Under these circumstances, the firefighters would open the door to the apartment containing the fire allowing a lot of smoke to enter the lobby. In this condition, the mechanical smoke shaft would be required to exhaust this smoke and prevent it from entering the stairwell.

Main risks of this method

The methods of smoke control for lobbies contained within the Building Regulations are natural ventilation - which uses the buoyancy of the hot smoke as the driving force to evacuate it from the escape route - and pressurisation - where fans are used to blow air into the escape route thus pressurising it and preventing smoke from entering it. Mechanical extract, where high temperature fans extract smoke from lobbies, is a fire-engineered approach that sits outside of the regulations and carries some inherent risks that must be mitigated. The primary concern is that extracting a high quantity of air from a relatively small lobby without sufficient replacement air would cause the lobby to become depressurised

Common methods of control

Replacement air must be brought into the lobby to replace the smoke being extracted and this is usually provided by opening the stairwell smoke ventilator and allowing the air to reach the lobby by one of three methods. It is recommended that whichever method is used that the mechanical smoke shaft is located as far as practical from the stair/lobby door and ideally a minimum of 2/3 of the total length of the lobby.

Automating the stair/lobby door

It is possible to automatically open the door between the stair and the lobby with an automatic door opener such as the Folding Arm a sufficient amount to allow fresh air to be drawn into the lobby while maintaining sufficient velocity to prevent smoke entering the stairwell. An opening dimension of 500mm at the door jamb has proved successful in most cases for firefighting extract duty.

Reversing the stair/lobby door

Another method is to reverse the opening direction of the door such that it opens into the lobby against the escape travel direction. The theory behind this is that the negative pressure within the lobby would be sufficient to pull the door open to relieve the pressure in the lobby. It is difficult to predict precisely how far the door would open and therefore the effectiveness of any modelling done to support this until commissioning tests are carried out.

Monitoring the lobby pressure and fluctuating fan speed

It is possible to monitor the pressure difference between the lobby and stairwell and to adjust the fan speed to prevent excessive build-up of pressure in the lobby. Although commonly specified, this relies on the use of inverters to control the fan's speed in an emergency condition which is not recommended by BS EN 12101-3 (2015) (see below).

Why manual control by firefighters is a bad idea

In active fire systems – such as fire alarms and smoke control systems – there is often a requirement for manual override controls for firefighters to use to control such systems in an emergency.

Stairwell ventilators, for example, are usually provided with manual controls at the top and bottom of the staircase to allow firefighters to open or close them. In smoke pressurisation systems, it is also common to have a manual switch to increase the speed of the fans from an initial Means of Escape duty to the higher firefighting speed.

The design, positioning and precise function of these switches can vary greatly from one supplier to another and also from building to building. There are key switches (often without keys), touchscreens and break glass call points of various colours and types. Often they are positioned near fire alarm call points, which may be likely to confuse building occupants during an incident which could lead to erroneous triggering of the system.

Figure 2The design, positioning and precise function of switches can vary greatly from one supplier to another and also from building to building

The proliferation of high rise buildings in inner cities has coincided with an increase in the use of fire-engineered solutions for smoke control in such buildings, particularly mechanical smoke shafts which fall outside the scope of current Building Regulations and British and European standards. As a result of these two factors, many new tall buildings are equipped with unique fire-engineered smoke control systems, placing unrealistic demands on firefighters that may compromise their safety and that of building occupants.

It is unrealistic for the fire brigade to gain a thorough understanding of the particular fire safety systems of individual buildings, particularly when these are bespoke to the building and not conforming to a common standard or type.

A fireman's override switch for a smoke control system will often look the same, regardless of the type of system it controls, and the attending fire crew will be unlikely to know the detailed functionality of the smoke control system at a particular building. Operating the fireman's switch may, for example:

- Open an automatic vent into a natural shaft and a vent at the head of the shaft;
- Switch a pressurisation fan into high speed;
- Switch an extract fan into high speed.

If this is done out of sequence, for example the extract fans are put into high speed before the stair/lobby door is opened, the system could be rendered ineffective. In the worst case the lobby could become depressurised, making it impossible to open the door to the staircase**.** If the switch was operated by a member of the public during the evacuation phase this could have serious consequences, with occupants being unable to exit the building.

Issues with inverter control in emergency mode

Inverter drives (also known as variable speed drives or VSDs) are commonly used in smoke control applications to limit and modulate fan speed to suit a particular system design.

For example, when using smoke extract to protect escape lobbies it is common to vary the speed of the fan according to the pressure in the lobby to prevent the lobby becoming depressurised which could make it difficult to open exit doors. VSDs also provide useful soft-start functionality to reduce large fan start-up currents reducing stress on essential power supply networks and generators.

The use of inverters in emergency conditions has long been a topic of conversation within the industry. Many manufacturers provide a fire mode option that disables the control functions and motor protection in an emergency and allows the motors to run to destruction if necessary; however, as there have been very few tests carried out under fire conditions there is a lack of certainty about their performance. The latest version of BS EN12101-3 (2015) 'Specification for Powered Smoke and Heat Control' looks to enforce a number of control conditions on the use of VSDs for smoke vent systems. BS EN12101-3 (2015) does not prohibit VSDs and they may still be used in conjunction with the list of conditions below. However, it's clear that the new rules will greatly impact system design in relation to the size of fans (and control panels), which in turn will affect system cost.

BS EN12101-3 (2015) states that use of a VSD is acceptable if any one of the following conditions are met:

1. The system has a bypass facility to switch from inverter control to DOL during smoke control mode. This is not possible if a pressure control system is used in a mechanical smoke shaft system as the inverter is required to control the fan speed in emergency mode.
2. Each fan/motor is tested together with the VSD it will be used with in that specific application. This combination is certified under BS EN12101-3. At the time of writing there are no such certifications available.
3. The fan/motor is tested alone and certified to BS EN12101-3 and both of the following sub-conditions are met:

    - The fan is derated (i.e. oversized) by 20%
    - All VSDs are supplied with output filters [dU/dt or Sine Wave]. Output filters provide additional protection to motor insulation.

The effect of these changes on some common smoke ventilation systems are summarised in the following table:

SYSTEM TYPE	USE OF VSD	POSSIBLE COURSE OF ACTION	COMMENTS
Stairwell Pressurisation System with mechanical air release	Use of pressure sensors to modulate fan speed and control rate of air release	VSD bypass not possible Oversize fans by 20% Supply VSD output filters	System is certifiable under BS EN12101-3 noting the following: • Increased system cost • Increased fan size • Increased control panel size
Stairwell Mechanical Extract System with no pressure control	Fan soft-start ramp up	Provide VSD bypass to run fan DOL post ramp up	This is a commercially viable solution and would be certifiable under BS EN12101-3
Stairwell Mechanical Extract System with dual smoke control modes and no pressure control	Provides dual speeds for Means Of Escape and Firefighting modes	VSD bypass not possible for Means Of Escape Oversize fans by 20% Supply VSD output filters	System is certifiable under BS EN12101-3 noting the following: • Increased system cost • Increased fan size • Increased control panel size
Stairwell Mechanical Extract System with pressure control	Use of pressure sensors to modulate fan speed and mitigate over-depressurisation	VSD bypass not possible Oversize fans by 20% Supply VSD output filters	System is certifiable under BS EN12101-3 noting the following: • Increased system cost • Increased fan size • Increased control panel size
Carpark 10ach/hr Extract System	Extract fan/Jet fan soft-start ramp up	Provide VSD bypass to run fan DOL post ramp up	This is a commercially viable solution and would be certifiable under BS EN12101-3

Figure 3Table showing use of VSDs and various systems

Summary

Smoke shafts are an important element of a building's fire safety regime and they must be of a suitably robust nature to function as required, when required, in all likely circumstances. The introduction of unnecessary complication should be avoided wherever possible. The use of pressure control by fan modulation is quite complex to commission on site and one of the most likely causes of system malfunction through sensor failure (pressure sensors are not an emergency rated component), damage to pressure pipes, obscuration of sensor heads e.g. painting over them, or incorrect calibration. Use of multiple fan speeds with manual switching to firefighting mode is another area of risk that can be avoided. The likelihood of the fire brigade using such a facility is low and there is the added risk of erroneous triggering of a fireman's override rendering the system inoperable.

Recommendations

Based on the level of risk associated with multiple speed fan systems it is recommended that a single speed approach (direct to firefighting duty if applicable) is adopted with a guaranteed make-up air supply in place before fan initiation, either through automation of the stair/lobby door or another air supply shaft or other means. It is further recommended that the system should operate automatically on detection of smoke within the escape route without the need for manual intervention by firefighters.