# Control risks

**Paul Grimwood** raises concerns over the use of mechanical extract smoke control systems for common corridors in residential buildings

IN DESIGNING a building, the incorporation of a smoke control system may serve to enhance life safety or assist firefighting access, while also protecting structural components and building contents. However, where design principles fail to follow established technical guidance, there is potential for such systems to actually serve to create hazards for firefighters and escaping occupants.

There may be clear commercial benefits to be gained in utilising smoke control measures that are used as compensatory features in trading for extended travel distances and single stairways in residential buildings. However, Kent Fire and Rescue Service has recently established a policy that serves to rigorously challenge the introduction of such fire engineered solutions without clear proof of concept, where firefighters and possibly relevant persons may be at an increased level of risk.

Building control officers as well as approved inspectors may wish to become aware of the associated technical aspects involved. There is no doubt that this stance may be seen by some as controversial and some reasoned debate is likely to follow. Nevertheless, this should be encouraged and welcomed.

## Smoke control objectives

The primary objectives of smoke control systems are to:

- maintain smoke-free and tenable conditions within protected escape routes
- assist firefighting operations by maintaining tenable conditions for firefighters
- delay or prevent the onset of flashover and further fire development
- reduce thermal damage to structural components
- reduce smoke damage to the building and its contents

The various smoke control concepts rely upon natural or forced air movements, as follows:

- natural cross-flow ventilation
- natural buoyancy of hot smoke
- natural pressure differentials created by the difference in temperatures existing between the inside and outside of buildings
- mechanically created pressure differentials using powerful air movement fans to pressurise protected escape routes or depressurise fire-involved areas adjacent to escape routes
- mechanical smoke flushing systems that use fans to force air into protected routes, in order to dilute smoke before flushing it out via smoke shafts or exterior wall outlets

A report[1] from BRE in 2002 proposed a design of smoke shaft used to naturally ventilate stair lobbies with the primary objective of protecting escape stairs. The design concepts were limited to research that used real fire tests on small-scale models, validated by computational fluid dynamics (CFD) simulation based on a 2.5MW ventilated compartment fire. Later adaptations of this useful research (note BRE report, BD 2410: 2005) saw several fire ventilation designers and commercial fire engineers develop mechanical smoke extract systems using smaller-dimensioned smoke shafts to save on expensive floor space. However, this adaptation may cause many problems for firefighters and, at this time, there has been no research as to how such systems may function where under-ventilated fire conditions occur within a flat or compartment. Furthermore, the evacuation time for occupants may be compromised in several ways, depending on specific design features.

In order to ensure engineered smoke control systems are fit for purpose, the system designers must first demonstrate that they have followed approved technical guidance and then offer evidential proof of concept that the design will meet a broad range of realistic (including under-ventilated) fire conditions. At this time, system designers have struggled to meet these requirements where mechanical smoke extract shafts have been located in common area corridor escape routes.

## Ventilation of common corridors

The engineered solutions associated with these systems work on the principle that automatic detection by smoke detectors in common area corridors will initiate the removal of smoke penetrating these common areas, most notably on the fire floor itself. The original design concepts were commonly based around open-plan flat layouts without protected hall protection but with sprinkler coverage to BS 9251: *Sprinkler systems for residential and domestic occupancies. Code of practice.* However, later designs started to see sprinkler systems phased out, placing greater reliance on corridor smoke removal. At this point, the integrated fire/smoke management system became flawed in its design capability, where larger fires (even to 10MW in open-plan flats) became possible.

The systems commonly have two automatic modes of operation:

- evacuation mode (medium rate of extract)
- firefighting mode (high rate of extract)

System operation while in the evacuation mode will attempt to maintain tenable conditions in escape routes (corridors) affected by smoke. After a predetermined period in the evacuation mode, the fan extract speed will automatically increase its speed and begin to draw smoke out from the corridor(s) at a much greater rate. This is termed the firefighting mode. The increase in extract rate is intended to assist firefighters by removing larger quantities of smoke during the period they are accessing the fire compartment(s).

## Operational issues

However, there are clear operational considerations that must take account of the likely stages of fire development, in line with the pressure differentials these systems create. Here are some important points to be considered from an operational perspective:

1. An automatic transition from evacuation mode to firefighting mode may well occur before firefighters actually reach the fire involved floor.

2. The high extract rates in the firefighting mode may cause additional smoke to be drawn out of the fire-involved flat, into the corridor, from under and around the door to the flat itself. This may also have the undesirable effect of increasing the rate of fire development in the flat, as well as causing a 30-minute fire door to fail earlier than expected. This point was not disputed by several system designers during consultation.

3. The smoke extract system will create a noticeable negative pressure in the corridor, and this will increase dramatically while the system is operating in the firefighting mode.

4. There are clear concerns where under-ventilated fire conditions exist, or in situations where exterior windows have been heated to near failure point. The negative pressure created in the corridor may ‘pull’ windows inwards and draw hot smoke, heat and fire directly into the corridor as firefighters open the main entry door to the flat or fire-involved compartment.

5. The systems are designed to extract smoke, most commonly via a smoke shaft fitted with a powerful extract fan at roof level. The design concept requires an adequate amount of air (make-up air) be provided to replace the smoke (air) being extracted via the smoke shaft. This may typically be drawn down from the head of the firefighting shaft stairs via an automatic opening ventilator at roof level (or alternatively another smoke shaft). In order for this make-up air to transport into the smoke charged corridor(s), the doors leading from the firefighting shaft stairs into the corridors are automatically drawn into a partially open state (around 0.2m). Where the door to the fire-involved flat remains open, or where the fire surpasses design limits (commonly, one room well-ventilated post-flashover fire to 4MW), the smoke in the corridor may eventually overspill into the stairs, potentially cutting off the sole escape route for occupants on upper floors.

6. Fire authorities may wish to consider issuing operational directives for firefighters to deactivate such systems prior to accessing fire compartments, and to further consider the effects of allowing the system to continue in firefighting mode during the setting up of attack and support hose-lines during the establishing of a firefighting bridgehead.

## Proof of design concept

At this time, there has been little, if any, convincing research into the design concepts associated with smoke control systems that propose to remove smoke directly from common corridors via mechanical extract fans located at the head of smoke shafts. In reviewing a large number of design consultations based on such pressure differentials, it is noted that the proof of concept generally relies on CFD analysis, with occasional reference to some live fire tests. These fire tests were never intended to represent realistic under-ventilated fire conditions and, if one reviews the test process, the wood crib fires used were only ever able to develop under ideally ventilated situations.


Some mechanical smoke extract systems, it is argued, can fail to maintain tenable conditions in protected routes and may potentially cause rapid fire development

Where computer field models are used to demonstrate proof of design concepts, for most applications a 'mixture fraction' combustion model forms part of the analysis. This model assumes that combustion is mixing controlled and that there is rapid reaction between fuel and oxygen. While CFD mixture fraction models may allow unburned fuel and combustion products from under-ventilated fires to be tracked, the remote ignitions associated with detached flaming in the gas layers appear extremely complex and are not well understood or represented in the model.

There are also many variables and onerous parameters that control the way the transporting fuel load is burned, and CFD models will require a much greater amount of sensitivity in such variables before a reasonable level of accuracy is established. Therefore, at this point in time, any computer modelling may only offer a very limited analysis in support of smoke control systems where under-ventilated fires are concerned, despite recent efforts. Simple zone models may present unequally convincing but alternative results when analysing the likely outcomes where negative pressure differentials exist behind firefighters on gaining access to fire compartments demonstrating under-ventilated fire conditions.

## Under-ventilated fire

A compartment fire may develop in a ventilation-controlled state through various stages of growth to the flashover period and beyond. Alternatively, where air supply is limited, a fire may develop in an under-ventilated state and during this process may discharge vast amounts of unburned pyrolyzates and other combustibles into the smoke layer.

It has been demonstrated that one in every four compartment fires[2] will spread to involve a greater area following fire service arrival, while one in every 187 building fires[3] in the UK will result in some form of abnormal rapid fire phenomena as the smoke-laden fuel load ignites. Attention to such hazards has just recently been reiterated through the publication of a fire service technical bulletin[4] following recent tragic events.

> "System designers must follow approved technical guidance and offer proof of concept"

While statistics suggest that this type of event may not be a frequent occurrence, the dangers are so severe that in some instances, both firefighters and occupants have lost their lives as a result. Such statistics seem to suggest there is a tactical need to take control of the fire environment very early on, as fire compartments are being opened up and buildings are being entered by firefighters.

## Firefighting tactics

Where firefighting tactics are concerned, a series of risk control measures have been indoctrinated into tactical firefighting approaches where access to fire-involved compartments becomes necessary. These entail coordinated door entry procedures and fire stream applications that attempt to ensure some control over the potential for rapid fire development occurring. The primary objectives are to try and cool hot smoke existing near the ceiling and reduce the inflow of air as the entry door is opened, which may increase the burning rate within. However, the existence of large pressure differentials at the point of entry may greatly hinder such an approach and increase the potential for hazardous conditions:

- excessive positive pressures at the point of entry (without a predetermined vent outlet in existence) may cause an uncontrolled inwards air-flow into the fire compartment, resulting in an increase in the burning rate; increased temperatures as the fire develops; and ignitions (possibly explosive) of the heated smoke gases and combustion products near the ceiling
- excessive negative pressures at the point of entry may cause an uncontrolled outwards flow of smoke and hot combustion products. In turn, this air movement may cause heat-weakened windows to fail inwards and allow exterior air to further feed the fire. The common areas are instantly filled with heavy smoke and firefighters are unable to find their way back to the stairs as temperatures soar

If this unburned fire load in rich-mix smoke were to ignite, then a 4MW one-room fire can become a 15MW fire in less than 60 seconds. Fire development on this scale cannot be immediately managed effectively or safely by the fire service and, inevitably, further fire development may spread into the common areas. In this respect, it is almost certain that mechanical smoke extract systems will fail to maintain tenable conditions in the protected routes, and they may potentially have been the cause of rapid fire development in the first place.

## Technical guidance

The limited research that has gone into the development of modern powered smoke extract systems for the protection of common areas in flats includes CFD modelling and small-scale/full-scale well-ventilated fire tests. However, it is clear that there are limitations on such systems, since the research to date has failed to account for:

- fires in excess of 4MW (larger than small one-room fires)
- fires developing in an under-ventilated state
- remote auto-ignitions of combustion products transporting into areas adjacent to the fire compartment
- the hazards associated with firefighters advancing into a fire compartment with an excessive negative pressure differential existing/occurring behind them

The engineering proof of concept for such an approach is provided mainly through a series of mathematical hand calculations, coupled with both zone and field computer models, comparing traditional code-compliant methods of fire protection with the added benefits of powered smoke control systems. In some cases, previous research involving live fire tests is cited in support of these alternative approaches.

There are serious flaws with this engineering approach and, in some situations, the fire engineered solution may actually provide a decreased level of protection than that provided by the code-compliant situation. There is also great pressure on regulators to approve such complex systems, where they may not have the expertise to fully understand the technical design concepts that are based on impressive computer models.

We can now see hundreds of buildings being constructed across the UK that have increased travel distances, with critical code-compliant features of corridor fire resistance and alternative exit routes removed. Therefore, such engineering strategies should be viewed by regulatory authorities with a critical eye, to ensure that levels of protection to both occupant egress and firefighting access routes are not put at risk by unproven solutions.



Much more research is needed where mechanical smoke extract shafts are located in common area corridors. There is a situation that firefighters must avoid when accessing a fire compartment, and this is never to site firefighters between the fire and an area of negative pressure, such as that caused by a venting action to their rear. The large air movements caused by these systems may place firefighters in a most hazardous uncontrolled environment that may: 'pull' fire towards their position; prompt remote ignitions of heated fire gases as they mix with air in the corridor; and cause heated window glass to fail inwards on opening the door, allowing exterior winds to cause sudden 'blow-torch' effects.

In addition, fire authorities may wish to review their firefighting tactics in existing buildings where it might be prudent to consider deactivation of corridor smoke extract systems prior to firefighters gaining access to the fire-involved flat or compartments.

Technical guidance and relevant standards[5] clearly dictate the overriding objectives of pressure differential systems are:

- 'to create a lower pressure in the fire zone than in adjacent protected spaces'
- 'a method of protecting escape routes where air from unaffected spaces is induced to flow into the fire zone'
- 'the objective of a depressurisation system is to achieve the same protection... as would be achieved by pressurising the protected space'
- 'smoke control systems are required both for protection of the enclosure of fire origin, as well as preventing smoke spread to adjoining spaces'
- 'depressurisation is smoke control using pressure differentials in which air pressure in the space containing the fire is reduced below that in adjacent spaces requiring protection'
- 'the transition between means of escape mode and firefighting mode shall be manual'

The above design objectives, based on current technical guidance, represent a solid foundation for applying principles of pressure differentials into fire engineered solutions. Take a close look at the wording and apply these base principles the next time you need to review fire engineering proposals for mechanical corridor smoke extract systems ■

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### References


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