Doc Ref: SCR112/20-R5

Report on Smoke control in high rise buildings using pressurization

Advanced Smoke Group Limited April 2020

Introduction

The subject of smoke control in high rise residential apartment buildings has come under the spotlight during the past couple of years.

Several issues have been raised, from why allow single stair high rise buildings in the first place to whether building regulations are sufficiently robust in connection with life safety systems.

It is right that the type of smoke control system that is deemed acceptable for a particular building is thoroughly examined, including the performance criteria that is considered acceptable for high rise buildings.

The vast majority of mechanical smoke control systems are based on the depressurization principle, which creates a negative pressure within a protected space and any smoke that enters the space will be extracted. The downside of this system is that, by creating a negative pressure in the protected space smoke can be induced into the space that the system is designed to protect. This is not the best available option particularly where extended travel distances exist as smoke may be induced from the fire compartment into the escape corridor.

A pressurization system is the very opposite; the system creates a pressure within the protected space and thereby stops smoke entering the space in the first place. This type of system is extremely efficient in protecting escape routes, particularly stairwells and extended escape corridors, due to the continuous supply of freshair.

In the Advanced Smoke Group report SCR103/19 published last year, two key reasons for pressurization smoke control systems not being used were identified:

1. Smoke control specialists resist it because they perceive it to be more expensive and will make them less competitive, b) the system is more complex to design and c) because it will be more complex and difficult to commission
2. Architects and Consulting engineers resist it because they are advised by some smoke control specialists, as they reflect on systems of bygone years, that such systems will be complex to design and commission.

These assumptions may have had some degree of justification 10-15 years ago, but this is no longer the case due to the type of controls and equipment available today to construct a pressurization system and the fact that buildings are generally more airtight. **The subject of life safety must now take priority and pressurization should be considered the only acceptable solution to smoke control in tall buildings** and this must be reflected in building regulations.

But what has probably been most astonishing during research for this paper is the lack of understanding about how pressurization systems work, even senior and experienced members in our industry were shown to lack a full understanding of crucial design principles used in pressurization systems.

Guidance and standards

Guidance for compliance with current building regulations is provided in Approved Document B1 and the reader is referred to BSEN12101-*6 Smoke and heat control systems. Specification for pressure differential systems. Kits* for further guidance

Further guidance is given by the Smoke Control Association in their publication *Guidance on Smoke Control to Common Escape routes in Apartment Buildings (Flats And Maisonettes'* Revision 3. The superior performance of a pressurization system in controlling smoke is underlined in the Smoke Control Association's document where states that "….it is not possible to keep common corridors and lobbies completely free of smoke except possibly by [the use of] pressurization systems….".

Pressurization systems have been used and are still in regular use in the United States, especially in high rise and tall buildings. Their experience is reflected in their national guidance documents, the NFPA regulations. Whilst obviously not in use in the United Kingdom, maybe there are lessons to be learnt from their approach.

Application of Pressurisation

The primary objective of a pressurization system is to stop smoke entering a defined area by forcing clean, cool air into the protected spaces; the protected space could be the stairwell, lobbies and common corridors, areas used for escape in the event of fire.

The crucial difference between a pressurization system and other forms of smoke control systems is that those alternative systems allow smoke to enter protected spaces and then remove it.

The use of a pressurization system is the only type of system that would enable the system designer to consider the stairwell a potentially sterile space, all other options can result in the migration or induction of smoke into the stair.

System design

The first consideration is to determine which spaces are to be protected. For example, the most important space within a building that must be protected is the stairwell. The stairwell is **the one space that will be occupied by all occupants** escaping from a building in the event of fire.

Other spaces that should be considered are the firefighting lift shafts, lobbies and common corridors used as a route for escape. Pressure levels for "door closed" conditions are given in BSEN12101-6.

Air release path

The pressurization system is designed to maintain a pressure within a protected space or maintain a fixed velocity across an open door. In the event that a door linked to the protected space opens during either the escape phase or during fire-fighting activities, air will pass through the open doorway at a predetermined velocity, typically 2m/s in order to hold back any migration of smoke into the protected space. Cold smoke testing at commissioning stage can be used to demonstrate the efficiency of the system in stopping the migration of smoke into the protected space.

Of course, in order to allow the air to maintain that velocity there must be a constant flow and the airflow must be allowed to ultimately pass to atmosphere; therefore an air release path needs to be provided in the correct position. Failure to make provision for an air release path would of course result in failure of the system.

System response times

The pressurization systems of yesteryear employed relatively low-level technology, such as pressure relief dampers or pressure sensors, to maintain a constant pressure level within a stairwell for example. Such systems were relatively high maintenance as they need frequent examination to ensure they maintained the required level of pressure and did not jam or create a higher than designed resistance to airflow.

The reliable and accurate control of pressure within any system is fundamental to the control of smoke control systems, whether they employ pressurization or depressurization as a means of controlling the smoke. Pressure sensors and pressure relief dampers are not as reliable in maintaining a constant pressure due to either a slow reaction time or poor maintenance or both. The problem frequently experienced was that the fan speed would respond to "historical" data (the event had already happened) resulting in a significant fluctuation in pressure as the system attempted to reach a balanced state.

Reference to historical data relates to an event recorded by a control device which then activates the pressurization or depressurization fan to adjust speed and return to the conditions identified to the design criteria. What invariably happens is that, before the control system identifies that the system has returned to design conditions, the design pressure has been exceeded, resulting in peaks and troughs in the pressure conditions experienced.

BSEN12101-6 requires a maximum 3 second reaction time to bring pressure differential system from a changed condition back to a design condition. For example, if a door closes the pressure in a space may rise above the design pressure, the standard requires that pressure be brought back to the design pressure within 3 seconds.

The time taken to react to changing conditions is vital to a) maintain design conditions to provide reliable protection to the protected space and b) avoid the large spikes in excessive overpressure or underpressure which may cause doors within an escape route to be difficult to open or slam shut. ASG focus the system design on maintaining a constant fixed velocity across the open door gap until the door is fully closed; once the door is closed, the system maintains the correct design pressure within the protected space.

Current Control Technology

21st century research has brought modern day control technology into the sphere of smoke control; to say this research has revolutionised smoke control systems may be an overstatement, but it has brought a level of control and reliability to pressure differential systems that has not previously been available and made the design of such systems far simpler than used to be the case.

Door Proximity Sensor

The most important features within the modern-day controls are the door proximity sensor, the computer control system (the PLC) and the means of rapidly controlling the fan speed. This system of control has now enabled pressure differential systems to react within the specified 3 second time frame.

The door proximity sensor (DPS) is a device which is mounted on as many doors as required according to the system design in the way illustrated in figure 1.

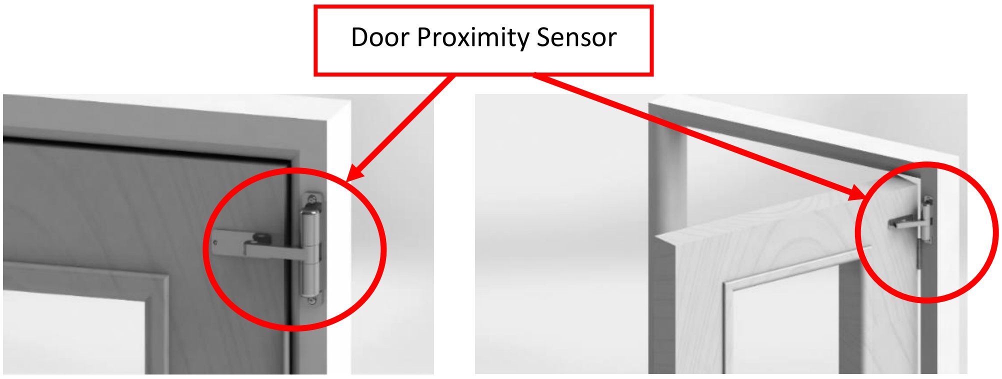

Figure 1 – The door proximity sensor in action

The sensor is linked directly to the smoke control system panel via fire rated data cable. The DPS device incorporates a potentiometer and will send a signal to the PLC within the control panel to indicate which doors are open and what their actual position is in order that the correct rate of airflow is provided in order to maintain the correct velocity across the door openings, see second image in figure 1. The control system will adjust the speed of the pressurization fan to meet the conditions required to maintain the integrity of the smoke control system, whether this be for maintaining air velocity across doors or pressure within the protected space.

The most important operational feature of this type of control is that it operates in "real time", making it possible to respond to any change in condition very rapidly and in accordance with BSEN12101-6.

Programmable Logic Control (PLC)
Not only has there been a reduction in cost in PLC's over recent years, but there has also been a vast improvement in the programming power, bringing cost effective smart products to the area of life safety systems, including that of smoke ventilation. **There should be no part of the smoke control installation that should fail without a clear indication given back to the building operator**.

Fan Control
Inverters are now able to give extensive control over their full working range, giving an extremely fast response time for acceleration and braking operation. This rapid response time is made possible by the real time operation of the system and the use of a braking system within the fan inverter control which enables the acceleration or deceleration of the pressurization fan very quickly.

System installations

Whilst a depressurization is the more likely culprit, both pressurization and depressurization systems can cause the reintroduction some smoke into a building. A depressurization system can cause a negative pressure around the air intake point, usually the AOV at the head of the stair, and within the stairwell itself. In the case of a pressurization system, smoke can be drawn into the intake duct of the pressurization fan.

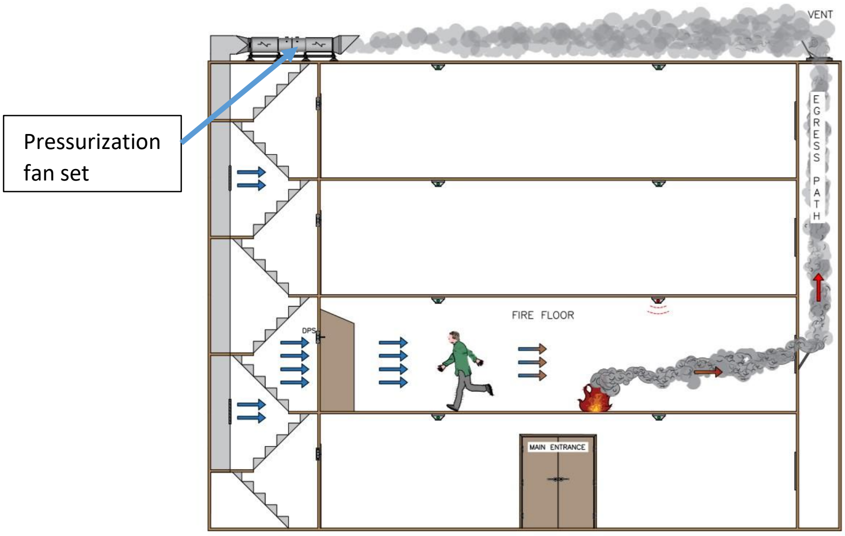

Figure 2 – Simplified diagram illustrating a traditional pressurization fan location with risk of inducing smoke back into the building

However, in the case of the pressurization system, a ductwork "T" section at the intake can provide added protection against inducing smoke into the pressurization system (figure 2), smoke detectors are used to sense if smoke is being induced into the intake duct. If this occurs a damper will close to the contaminated leg and air will be drawn through the opposite leg of the intake duct. Alternatively, and probably more reliably, the pressurization fan can be located at ground or basement level (figure 3).

Architects should make it their highest priority to design the pressurization system with its intake at the lowest possible level, ideally at ground or basement low level input.

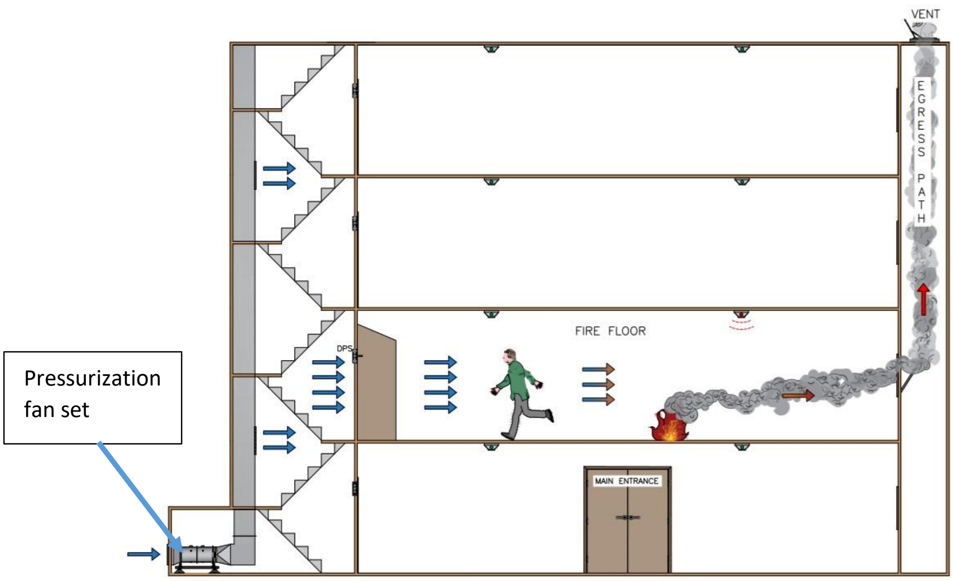

Figure 3 – Simplified diagram with pressurization fan located at ground or basement level

How Modern-Day Pressurization Systems Operate

The performance criteria for a pressurization system currently remain relatively unchanged to those systems installed many years ago, but the method of achieving these criteria has changed significantly.

Each door linked to the protected space is fitted with a proximity sensor and each sensor is given an address, so that the control system can, at any time, identify which door is in what position. The proximity sensor will issue a signal to the control system and the system will automatically adjust the rate of airflow to suit the prevailing conditions.

The allocation of an address to each sensor is also useful for system fault management during the life cycle of the building. In the event that a fault begins to develop in a sensor the control system can identify this and raise an alarm, identifying which sensor has recorded a fault.

Where a pressurization system is to be installed in a particularly tall building, the latest breed of controls are also capable of automatically taking into account the impact of stack and wind effect created within or around the building, and automatically adjusting the airflow in order to maintain design conditions to the fire floor. The installation of wind vanes on the building can aid the performance of the smoke control system (see figure 4).

Figure 4 - The installation of a wind vanes will help control of the smoke control system

System Commissioning

The door monitoring system makes commissioning much easier than previously experienced using old methods of control. Pressure levels are checked at each level of the building and the fan speed set. The “address” of each DPS device recorded on a laptop prior to these results being downloaded to the control system PLC.

The generation of cold smoke at commissioning stage can be a useful tool to test the efficiency of the system in stopping the migration of smoke into the protected spaces.

Verification of System design

As part of the system approval, commissioning and demonstration process, it is particularly helpful to have available formal endorsements of the type of system being proposed or demonstrated such as the Local Authority Building Control Approval Scheme.

Consideration at Building Design Stage

It is alarming that despite events in the last few years, life safety systems, particularly in the area of smoke control, are considered a secondary concern when designing buildings. Smoke ventilation shafts are considered a nuisance when they interfere with the building or apartment layouts.

It is time that life safety systems be brought to the front of the queue when considering a building layout and the most appropriate smoke control system for high rise buildings is at the head of it.

The phrase "it is the smoke that kills" has been heard time and again, but it is only recent events that makes it begin to hit home. Whether it is escape that is hampered or made impossible by the smoke, that results in the death of the building's occupants, or if it is the asphyxiation that kills them, it is the smoke that must be controlled to aid escape.

Whatever form of system selected, **it is essential that smoke control should form part of the architectural concept design at a very early stage** in order that its performance can be optimised by the necessary allowance being made within the structure of the building.

With the present-day technology making the design, installation and commissioning of a pressurization system so relatively simple and should therefore be the first option considered for smoke control in all high-rise buildings.

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