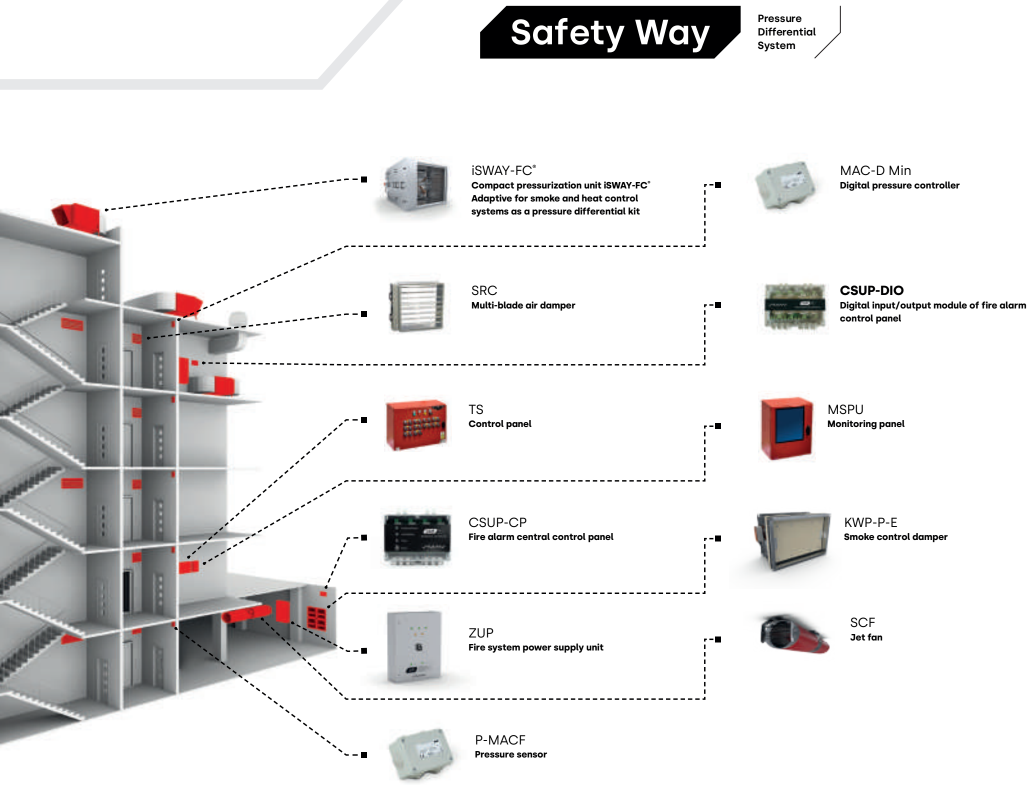
SMAY™

Safety Way

Pressure
Differential
System

The new focal point in creating Fire Safety Strategy for high-rise buildings

- Fire Experts (e.g. CIBSE, Smoke Fire Protection) suggest rethinking how standards protect high buildings in case of fire.
- The report following the Grenfell Tower tragedy showed that adding a second exit, as proposed by the government (december'22), may not be enough.
- Fire and smoke protection should be designed with an overview of how all elements work together.
- Considerations should be adopted early in the project life cycle.
- This material explains why it is worth considering the use of a pressure differential system.



Why use pressure differential systems instead of smoke exhaust systems in building higher than 18m?

Smoke Exhaust Systems:

- **Operation:** extract volatile products of combustion (smoke and gases) created during a fire out of a building
- **Application:** low and mid-rise buildings, some tall buildings
- **Escape and Rescue Routes:** evacuation impossible or significant difficulties in safe evacuation.
- **Rescue and Firefighting Action:** access for rescue teams protected below the source of fire, sometimes smoke extraction after the fire.

Pressure Differential Systems:

- **Operation:** prevent volatile products of combustion (smoke and gases) created during a fire from getting into designated safe evacuation zones
- **Application:** all types and categories of multi-storey buildings with designated safe evacuation zones
- **Escape and Rescue Routes:** protect escape routes, it is possible to leave a building safely
- **Rescue and Firefighting Action:** easy and safe access for fire-fighting crews to the source of the fire

Challenges for pressurisation systems

01. Natural

- dynamically changing wind load
- stack effect in tall buildings

02. Technical

- malfunction protection
- changing space tightness

03. Human factor

- rearrangements
- wrong design

Talk to us to learn how we handle them

Look inside practical cases and talk with
Radek Sikorski
experienced PDS expert.

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Safety Way

Pressure
Differential
System

tested and certified game-changer for emergency exits

- Fast and reliable automation with a patented predictive algorithm based on machine learning.
- Wide working range allowing units to operate down to 200 m^3/h and maximum capacity of 75,000 m^3/h.
- Ideal for high-rise buildings with a flow system that mitigates the stack effect and has been tested in dozens of buildings over 100m.
- Reliable in all weather conditions with dynamically adjustable airflow to maintain set parameters in response to changing wind loads and pressure changes.
- Auto-testing every 24 hours with device data stored in memory and test reports available to replace daily checks in 12101-13.
- Anti-freeze protection with infrared heater to prevent the shut-off damper from freezing in sub-zero temperatures.
- Ring topology offers significant savings on cabling and maintaining communication between devices in case of line interruption.
- Solutions for all types of buildings, years of experience, hundreds of references, and various options for air transfer and overpressure units.
- Full project support with the preparation of installation concepts, calculations based on 12101-6 or 12101-13, equipment selection, electrical guidelines, stack effect elimination reports for high-rise buildings, and possible CFD simulations and Revit libraries.

TM

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Ventilation
Systems

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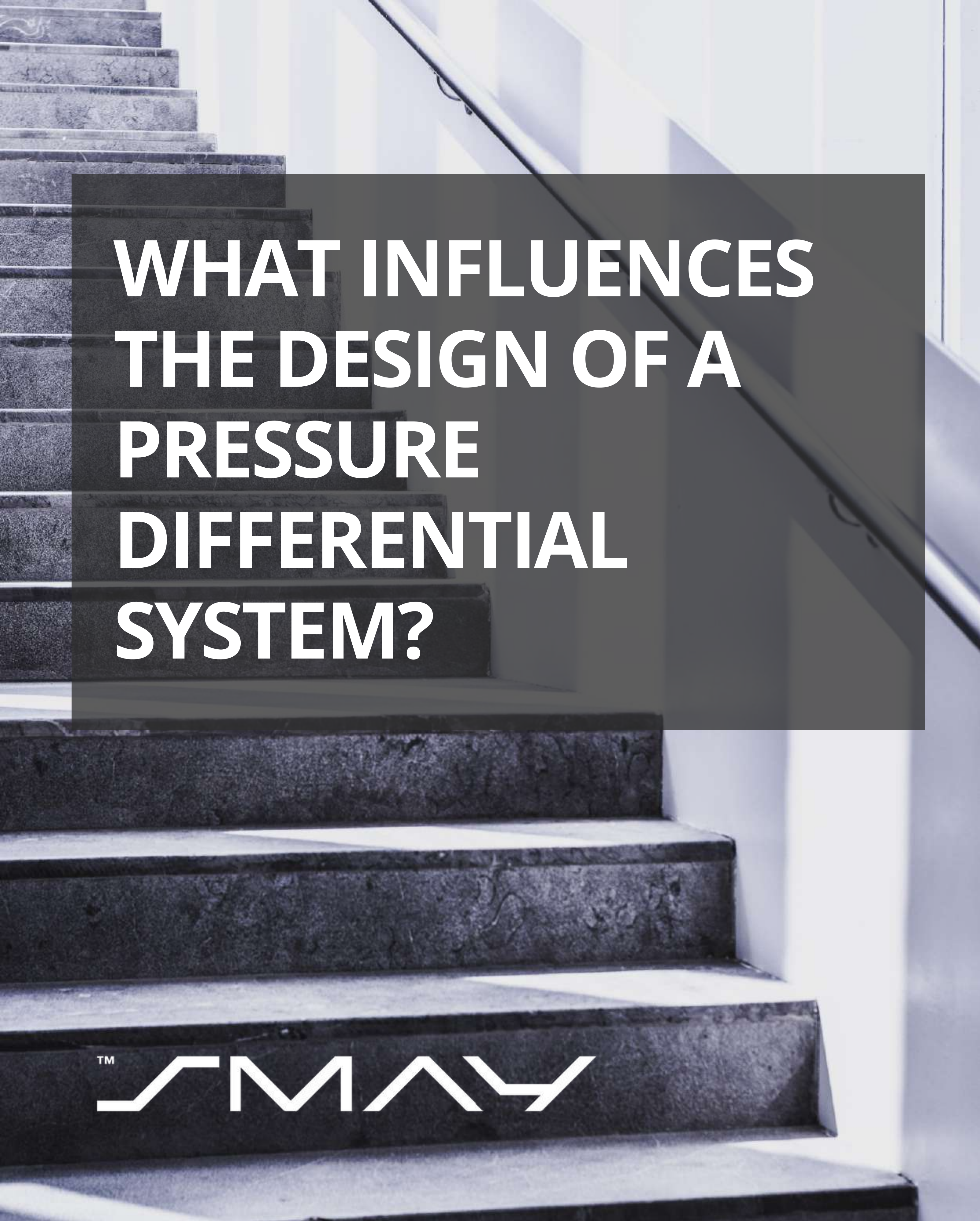
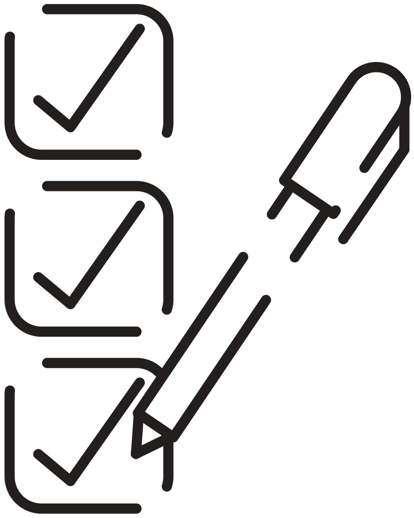


WHAT INFLUENCES THE DESIGN OF A PRESSURE DIFFERENTIAL SYSTEM?



- ☐ Building height and architecture
- ☐ Fire strategy and evacuation scenario
- ☐ Planned fire protection solutions
- ☐ Standards and legislation
- ☐ Exposure to weather conditions such as wind and temperature
- ☐ Detailed design assumptions
- ☐ Cooperation with other systems
- ☐ Budget


With all this in mind, designers begin to make the following choices

9 considerations steps

1. Defining protected spaces,
2. Choice of system class,
3. Determination of scenarios and number of open doors,
4. Determining the method of air release path,
5. Airflow calculations,
6. Consideration of the stack effect,
7. Selection of pressurisation units including accessories,

...two more on the next slide >>

9 considerations steps

8. Location of equipment, supply and extract points, pressure sensors, sizing of sizers and damper,
9. Selection of other system components, control systems, and system wiring guidelines.

A lot, but that's not all.
What's more? >>


Especially for tall buildings, mathematical analyses or CFD simulations should be carried out to assess whether the system works under all conditions.

It can be challenging with pressurisation systems at the outset of the journey.

If you require any **design or technical training or support** for fire ventilation projects, don't hesitate to contact us at **hello@smay.eu.**

Make more informed decisions based on experience from hundreds of completed PDS projects of the SMAY team.

Smoke, stacks, and second stairs

LAST MONTH marked six years since the Grenfell tragedy. It was a deeply painful blow for British society and the trauma of it continues to resonate. It was also a shock to the fire safety and construction industry - a wake-up call. It was obvious that action had to be taken and it had to be done quickly.

Therefore, in 2021, a draft update to BS 9991 (Fire safety in the design, management and use of residential buildings. Code of practice) was released. It regulates fire safety in residential building design, management, and use, and provides specifications and practices for appropriate fire safety measures. The previous update took place in 2015, while the current version is out for consultation.

One of the new requirements in the draft document is for buildings higher than 18m (10.1) to have at least two escape staircases or to meet additional conditions, one of which is overpressure protection of the escape route. This is a change to the previous provision 14.1.3 in the 2015 document, which allowed for a single staircase, giving a very wide range of measures for buildings higher than 11 m (natural ventilation or mechanical extraction or pressurisation).

Following this, the DLUHC proposed an amendment to the Approved Document B to prohibit single staircases in new blocks of flats over 30 m in height, and the Mayor of London has ordered that residential buildings over this height must have a second staircase in order to get planning permission. However, at this time it is not part of any new legislation and there are many experts who believe this is not the way forward.

This article will look at both of the solutions proposed in those revisions, consider what consequences the choice of each alternative may have, and also attempt to answer the question: are the solutions in fact alternatives to each other?

Second staircase - is this a solution?

Banning single-staircase high-rise residential buildings was not one of Dame Judith Hackitt's report recommendations, but it was a consequence of a lack of trust in the stay-put strategy after Grenfell. This is hardly surprising as the incorrect compartmentation, the rapid fire's development along the façade, and the resulting smoke in the stairwell meant that evacuating as quickly as possible was the only solution that allowed people to survive.

Following the opinion of the National Fire Chiefs Council *"a correctly designed second staircase removes the risk of a single point of failure, buying critical time for firefighting activities, and providing residents with multiple escape routes."* This is true. The second staircase gives an alternative. It doubles the capacity of people flow, so makes it easier for firefighters to reach the fire floor uninterrupted.

Still, it is unclear what height of building makes the use of two staircases necessary - 30m, 18m, or 11m? The economic cost of this solution (on an investment and economic scale) is also being estimated. It has been estimated that adding a second staircase causes a loss of £215,000 per storey (assuming £1,000 per ft^2) through reduced saleable space, and will cost £1.6bn over a decade for the industry (£2.5bn for 18m-plus buildings), not only through reduced viability but also changes to existing plans and delays. This is not a problem exclusive to developers - this cost will be passed onto residents, will be reflected in savings on other elements (smoke control systems for instance), or will result in buildings being built as tall as possible to compensate for the loss.

Moreover, it is also still unclear whether such a prescriptive solution is the most efficient way to ensure the safety of evacuees. There is considerable concern about whether this order will be interpreted as a panacea that will exempt investors from seeking performance-based solutions. Or to be clearer – whether this passive solution shouldn't be complemented by active measures, such as a pressurisation system.

After all, what is the point of having two staircases if both of them are filled with smoke?

Pressurisation systems - is this a solution?

There is a solution that can keep smoke out of escape routes, whether in one or two stairwells. It is widely used in continental Europe, the US, the UAE, and many other places. However, pressure differential systems are not highly trusted in the UK and for good reason. It is true that popular, simple systems have been failing to cope with the stack effect in tall buildings (and the BS EN 12101-6:2005 standard helped to cover this up) and that the passivity of constant-rate systems meant that they were unable >>>

***Radek Sikorski** examines two different, and not mutually exclusive, methods of enabling safe exit routes from high-rise buildings*

Radek Sikorski, International Business Development Manager at Smay Ventilation Systems

An MEP designer with many years of experience in ventilation and smoke control system projects, Radek is responsible for supporting consultants in the design of pressurisation systems. He has been involved in the design of such systems in many European countries, including the UK. He is also a member of the Council on Tall Buildings and Urban Habitat.

to respond to dynamically changing conditions, such as the impact of temperature, the influence of wind, or the changing airtightness of the space over time.

Other concerns were raised as well, such as compatibility with the chosen evacuation strategies or the reliability of systems – concerns that were all justified for the systems used at the time. However, this does not mean that pressurisation is a poor choice per se. It just means that it must be done right.

Innovation for safety – the Polish experience

As pressurisation systems are mandatory in Poland for most buildings over 25m, and over the last 30 years the country has experienced unprecedented economic development followed by a boom in high-rise buildings, the Polish market has a very wide range of applications for these systems. At the same time, being aware of the disadvantages of this solution mentioned earlier there has been a drive for improvements to create a fully functional pressure differential system for high-rise buildings.

The SMAY research group spent two years (2008-2010) carrying out field research on a 92m high testing rig in Krakow. They aimed to find a solution to mitigate the stack effect - a directed air movement in vertical spaces caused by temperature differences, resulting in uneven pressure distribution. This can make it difficult to maintain the correct pressure in a pressurised stairwell.

The outcome was the development of the Flow System, consisting of two reversible units located at the extreme ends of the staircase. When the system is activated, the temperature difference is measured and the units are set on supply or extract. Then, they operate variably on the basis of a continuous pressure difference measurement. The airflow through the stairwell compensates for the pressure difference and thus allows an even pressure distribution to be achieved throughout the height of the protected space, regardless of the time of day or season, as soon as the system is activated. The effective performance of this approach was later proven on dozens of tall buildings, including more than a dozen >120m and several >200m.

Variable air supply is also a perfect tool for reacting to dynamically changing conditions (wind influence, new leakages), as well as increasing the flexibility of the system (no need for a pressure relief damper, can be used in the vestibule without unsealing). However, for safety reasons, it is very important that the control system is able to achieve the required airflow in less than 3 seconds, yet is stable so oscillations do not occur when the setting is changed frequently.

Replacing the tracking algorithms with a predictive algorithm based on machine learning has been implemented as one of the solutions. By memorising all the settings and corresponding operating points, the system knows exactly what parameters need to be achieved in a given situation. This significantly increases the speed and safety of operation, but also the range of operation.

The need for a holistic approach

The ability to overcome some of the most basic physical challenges with advanced solutions is a big step forward toward a fully operational pressurisation system. However, this is a necessary, but not sufficient prerequisite. Equally important is the approach to the system as a whole – product- and design-wise.

Pressurisation systems not only require fans and pressure relief dampers, but also control panels, smoke detectors, pressure and temperature sensors, motorised dampers of dual intake system, and more. The standards for these products vary widely, and most are not tested for fire safety. If a device is tested for a feature such as electromagnetic compatibility or tightness, this will tell us nothing about its durability after 10,000 operating cycles.

This is why it is important to test all parts of devices and systems as a whole to meet the requirements given in the BS EN 12101-6:2022. Systems that haven't been verified in medium-scale tests at independent laboratories are like a car handmade by your neighbourhood mechanic in their garage - the car can run well if they are skilled and competent, but the lack of safety testing, repeatable production, or quality control makes cars from the factory a much better choice, even if the mechanic is skilled and competent.

The Warsaw skyline showing some of the buildings protected by the SMAY pressurisation system

"Systems that haven't been verified in medium-scale tests at independent laboratories are like a car handmade by your neighbourhood mechanic in their garage."

A system, no matter how smart it is, will never be smarter than its designer. Therefore, the know-how of the designers, supported by the experience of specialists working with the systems on a daily basis, is absolutely vital. All passive and active fire protection systems - detection, dampers, smoke extraction and its compensation, as well as aspects such as the location of pressure measurement points, potential rearrangements, and specific evacuation strategies - can all have an impact on the performance of the systems and must be taken into account at the design concept stage. It is also very good practice to validate concepts using computational fluid dynamics (CFD) or other mathematical methods of analysis. Such validation is also a requirement for buildings higher than 60m, due to the stack effect.

One of the criticisms of pressurisation is the challenge of a simultaneous evacuation scenario. If a system protects only a stairwell, the airflow through all the doors will result in the required pressure not being reached and in a risk of smoke entering the stairwell.

It is therefore much more advantageous to use individual systems for the vestibules, controlled by measuring the pressure in this space. In this arrangement, the staircase system is designed to achieve 1 Pa higher pressure so that all air from the vestibule is directed to the corridor at 2m/s. If the required pressure is not achieved, then the air volume splits into the stairwell and into the corridor, while the flow to the latter would still reach circa 1m/s. This is sufficient for a fire not yet fully developed. This, combined with mechanical extraction as the air release path (to ensure the staircase does not have less resistance), keeps the staircase smoke-free.

Summary

Second staircases may increase the safety of users to some extent, as the increased capacity will facilitate the operations of the fire brigade, but they are associated with a very high cost and still do not completely protect escape routes against smoke. A more effective method of ensuring the absence of smoke is the use of pressurisation systems that actively prevent its inflow to protected spaces.

These systems, due to numerous physical, design, and reliability challenges, have not been widely used in the UK to date, but during this time they have been under development in Poland. Thanks to this, it has been possible to create systems that deal with the stack effect and wind impact, are self-adapting, self-testing, that offer a lot of flexibility in design, and are reliable in terms of all the components working together. This makes it a very robust solution for securing a single staircase.

However, these systems should not be seen as an alternative to a second staircase. Active systems, such as pressurisation, complement well with fixed measures, such as compartmentation or the additional escape route. Both solutions are not mutually exclusive and can combine well to increase safety. But if the economic criterion excludes the use of both at the same time, then those responsible for the construction process should have the ability to make a fact-based analysis of all the solutions, together with their impact on safety. The prescriptive forcing of one may exclude the more effective solution.

You can learn more about SMAY's research into pressure differential systems through their webinar available at **smay.pl/pds**

Under pressurisation

In the event of a fire outbreak in any high-rise residential building, the communal stairwell/staircase can serve as a vital evacuation route for residents and an operational avenue for those firefighters in attendance. For this reason, such spaces need to be maintained as smoke-free environments. Izabela Tekielak-Skałka evaluates the protection of stairwells from smoke ingress

LAST DECEMBER, the Department for Levelling Up, Housing and Communities put forward proposals to mandate second staircases for all new tower block developments over 30 metres in height. At the time, it was the latest move in the Government's updating procedure for statutory guidance underpinning Building Regulations to ensure the safety of occupants. A 12-week consultation process duly ensued and closed in mid-March this year.

Late last month, Michael Gove (Minister of State for Levelling Up, Housing and Communities) announced that any new regulations focused on second staircases would not be enforced ahead of 2026. As reported by Pinsent Masons LLP, developers will be afforded a circa 30-month 'transition' period (beginning when the revisions to Approved Document B are published), during which time Building Regulations applications would still be allowed to follow those fire safety requirements already in place.

Planning expert Nicholle Kingsley (Partner at Pinsent Masons LLP) explained: "Michael Gove's latest statement is an attempt to resolve some of the difficulties and uncertainties caused as a result of Government's changes in position since December 2022."

In the Government's initial consultation, the proposal was to mandate two staircases in all new residential buildings in England above 30 metres in height. However, in July, Gove confirmed the Government would impose the 'second staircase' ruling at the lower minimum height for buildings rising 18 metres or above.

According to Kingsley, uncertainty around the new rules has led to developments being put on hold, subsequently contributing to the fall in residential-centric schemes being put forward for construction.

The Secretary of State has made it clear that existing and upcoming single-staircase buildings would not later need to have a second staircase added if they're constructed in accordance with the relevant standards, well-maintained and properly managed. However, early compliance with the new requirements – even during the transitional period – may be preferred by some and, in any event, should at the very least be considered.

Pressure differential systems

Pressure differential systems are not common in the UK. Widely adopted across mainland Europe, as well as in the United States and the United Arab Emirates, they're deemed mandatory in Poland for the majority of structures of 25 metres and above in height.

At SMAY Ventilation Systems, we've conducted a great deal of research in order to mitigate those issues noted for such systems – ie system reliability, compatibility with evacuation strategies and, in particular, any failure to cope with the 'stack effect' in high-rise structures – and realise a fully-functional pressure differential system for adoption in high-rise structures.

To be clear, the 'stack effect' is best described as the directed movement of air in vertical spaces realised due to differences in temperature. This results in uneven pressure distribution, in turn engendering difficulties around maintaining the right pressure in a pressurised stairwell.

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For pressure differential system design and application in a low-rise or medium-rise building, the key task is to maintain an overpressure of 50 Pa in the protected space of the stairwell when doors are closed and to create airflow from the stairs to the fire floor when the door is open. Not so easy in high-rise buildings, though. where the main challenges are height, flow resistance and the aforementioned 'stack effect'.

As stated, the 'stack effect' influences the pressure inside vertical spaces within the building, such as stairwells and elevator shafts. The pressure difference is particularly evident in winter when outdoor temperatures can fall below the 0°C mark. As a result, the pressure increases in the upper part of the stairwell. At the same time, the pressure drops in the lower portion.

Research project

Back in 2012, we researched a pressure differential system in a 62 metre-tall building in Warsaw incorporating 23 storeys and two stairwells. Both were protected by a pressure differential system consisting of a multipoint air supply and a relief damper in their upper parts. Firefighting lobbies were equipped with air inlet points from a separate fan and transfer dampers employed in the wall between the lobbies and corridors to compensate for smoke and air extract from the corridors.

The core aim of this SMAY Ventilation Systems study was to discern the real pressure distribution during pressure differential system operation. In the event of fire, the pressure differential system in the stairwell would be activated. At the same time, the pressurisation system protecting the firefighting lobby and the corridor air extraction on the fire floor were activated. Fire ventilation on other floors remained inactive.

The test rig was equipped with two pressure differential measurement devices. The devices allowed for measuring overpressure in the stairwell. The first measuring set was placed on the ground floor and the second on the uppermost floor. The temperatures of the outdoor air and the air inside the stairwell were recorded. The research included a full-scale test in the 62 metre-high building and computational fluid dynamics (CFD) analysis.

Examining the results

System testing was performed in winter conditions when the outside air temperature was between -18°C and -16°C. The temperature in the stairwell was +20°C. This temperature difference influenced the pressure distribution inside the building. A negative pressure of -45 Pa was measured in the lower part of the stairwell, and a positive pressure of +38 Pa in the upper part when the pressure differential system was inactive.

When the pressure differential system was activated, an airflow of 5,500 m^3/h was directed into the stairwell. The airflow changed the pressure distribution inside the stairwell. The pressure in the upper part of the stairwell increased to +70 Pa and -10 Pa in the lower part of the stairwell after activating the pressure differential system.

Clearly, the pressure was not increased to the expected level of 50 Pa in all parts of the stairwell. It's also worth noting that a negative pressure was created in the lower part of the stairwell, which means the stairs were not correctly protected.

Such operation of the pressure differential system in its simplest, but also most commonly used arrangement – ie multipoint supply and pressure relief damper – means there's a risk of smoke suction on the lower floors and excessive overpressure in the upper portion of the

building, which may result in residents being unable to open the door.

Numerical analysis was used to further investigate the pressure distribution inside the building. The analysis aimed to answer the question of how to improve the pressure distribution inside a stairwell in a high-rise building.

These analyses were performed in the Ansys Fluent simulation software. The model affords users the ability to consider many important issues, such as the geometry of the stairwell and any leaks, airflows and temperature changes. The stairwell model, all lobbies and the selected corridor were developed in the first stage of the process.

Numerical analyses

Numerical analyses were performed for numerous variants of the pressure differential system:

- the multipoint air supply with a total airflow of 5,500 m^3/h (ie the same as the volume used in the research) and the relief damper
- the Flow System, controlled by pressure sensors, with supply in the lower and middle parts of the stairwell and outlet points in the upper part (the idea of this solution is to create airflow inside the stairwell, with the flow intensity depending on the pressure measurement value near the air inlet)

The CFD simulations were performed for winter conditions and based on temperatures similar to those obtained from tests in the building. A much-improved pressure distribution was achieved using the Flow System rather than a system with a multipoint air supply. It allowed the overpressure to be maintained at the desired level inside the entire stairwell. Additional air inlets, such as the one used in the middle height of the stairs, were employed only to supplement the air flowing through leaks.

> The ventilation system in a high-rise building should operate slightly differently in each period. As such, ventilation systems based on a constant volume flow of air may only work correctly in specific periods

The results highlight that it's worth conducting CFD analysis when designing pressure differential systems. Such analyses can be performed for various temperature conditions and fire ventilation systems. They allow for an easy prediction of the pressure differential system's operation.

Using this tool, designers can avoid errors such as too low or too high overpressure and realise the configuration of an effective pressurisation system.

Design essentials

What are the 'essentials' when designing a pressure differential system for a high-rise building? Here, we've presented the operation of the pressure differential system in winter, but this system should also function well in summer and during isothermal conditions.

The ventilation system in a high-rise building should operate slightly differently in each period. As such, ventilation systems based on a constant volume flow of air may only work correctly in specific periods.

A much better solution is an active pressurisation system that generates controlled airflow inside the stairwell. The airflow creates resistance, which may positively affect the pressure distribution inside the stairwell. Sensors and flow-regulating devices are needed to control this airflow. This is precisely why the active system is equipped with pressure sensors and fans 'co-operating' with a frequency converter.

The largest volume of airflow is required in winter conditions when the 'stack effect' is at its greatest. In isothermal conditions, the airflows supplied to the stairwell are far smaller.

Measurements and analyses show that the effectiveness of the pressure differential system strongly depends on the outside temperature. This is particularly evident in relation to high-rise buildings. Systems composed of a multipoint air supply and a pressure relief damper will not guarantee the correct pressure distribution.

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Watch the webinar entitled 'The Key to Safe Evacuation: Pressure Differential Systems' at *www.smay.pl/pds/*