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Technical Information

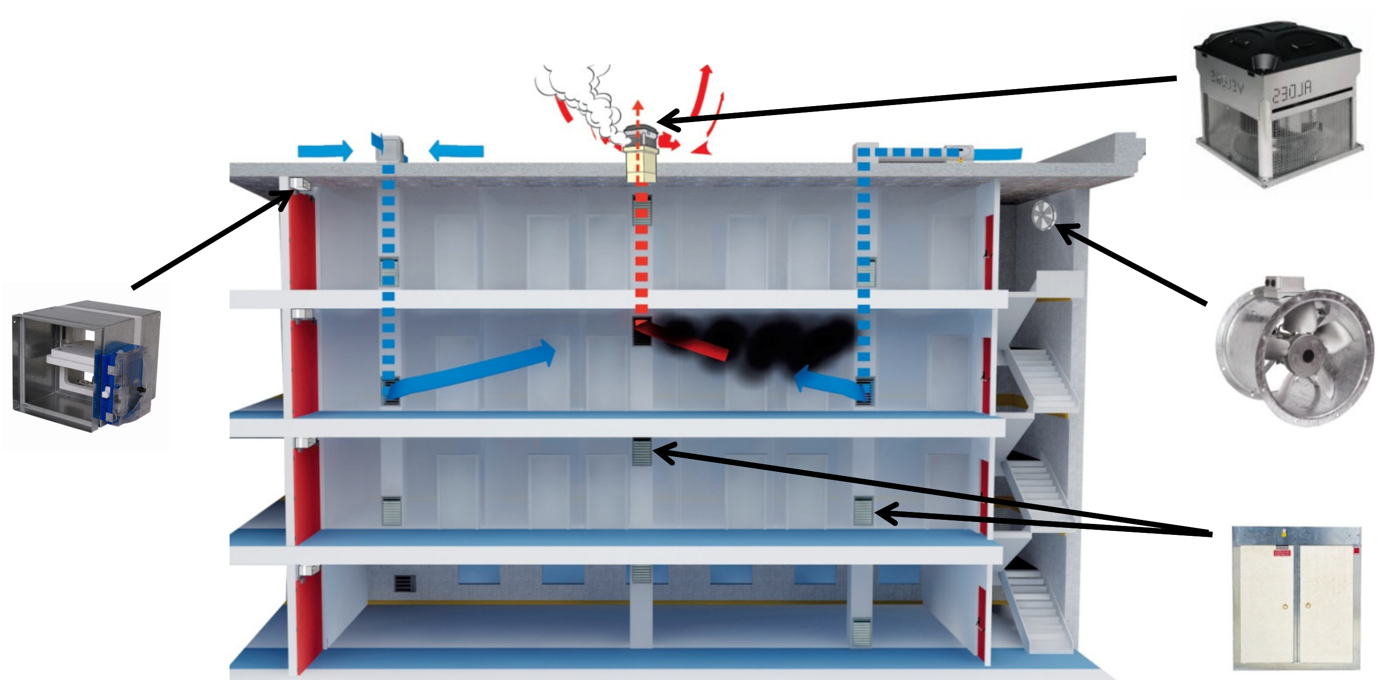
How to design easily a smoke management system?

Stairwell pressurisation for safe evacuation of people

Stairwell pressurisation: a complement to corridor smoke extraction

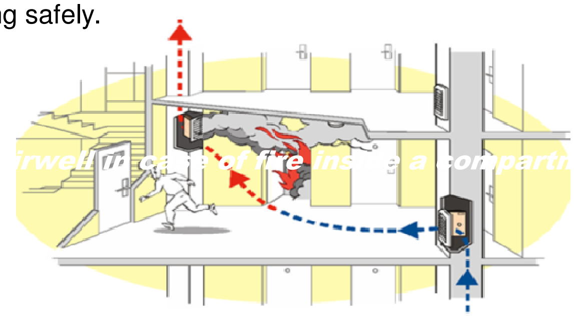
A **safe compartmentation** using reliable motorised fire, smoke & heat dampers (cf. *European ISONE Fire Dampers*) will prevent effectively the spread of fire, smoke and heat through the whole building and will thus manage to keep the smoke (the major killer in fire situations) inside the same compartment.

An **efficient corridor smoke extraction** using motorised smoke & heat exhaust dampers (cf. *European VANTONE/VRFI Smoke Exhaust Dampers)* and 400°C – 2hrs smoke exhaust fans (*VELONE / CYCLONE / HELIONE Smoke Exhaust Fans*) will manage the extraction of smoke, fumes and hot gases inside the compartment under fire to let the people escape safely the corridor during the early stage of the fire.



A **stairwell pressurisation system** is an essential part of smoke management system directly complementing the corridor smoke extraction system. The main goal of the stairwell pressurisation system is to prevent any smoke leakage from the corridor into the stairwell for safe evacuation of people from the building under fire, and also to let the fire fighters access the building safely.

Escape route from corridor



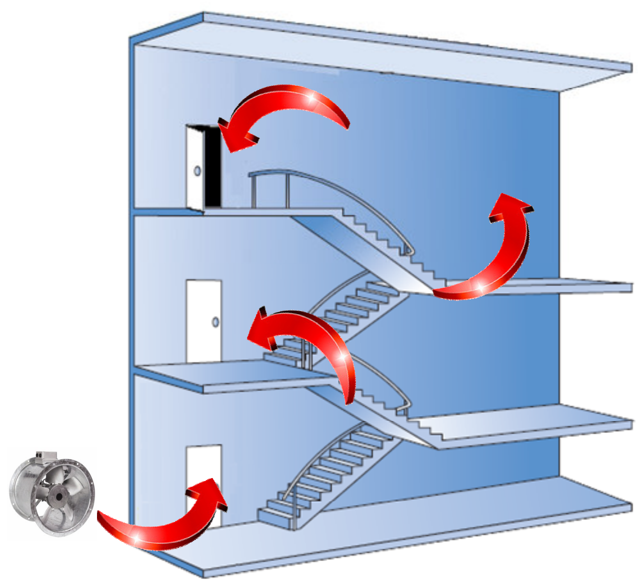
Basic principles of a stairwell pressurisation system & design guidelines

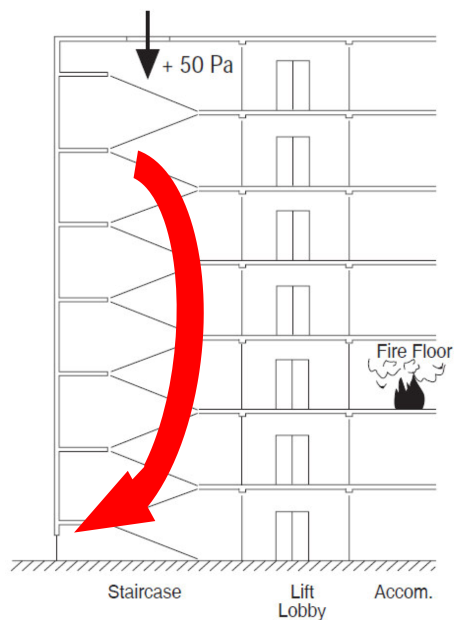
Two key basic principles

As described in ASHRAE 2007 HVAC Applications – Fire and Smoke Management, a stairwell pressurisation system is designed "*to provide a **smoke-free escape route** in the event of a building fire as well as a smoke-free staging area for fire fighters*".

"*On the fire floor, a pressurised stairwell must maintain a **positive pressure difference** across a closed stairwell door to prevent smoke infiltration.*

*During building fires, some stairwell doors are opened intermittently during evacuation and fire fighting, and some doors may even be blocked open. Ideally, when the stairwell door is opened on the fire floor, **airflow through the door** should be sufficient to prevent smoke backflow*".





The two key basic principles controlling the movement of smoke, and described here above, are **PRESSURE** & **VELOCITY**. These two basic principles are the basis of any standard and code of practice related to stairwell pressurisation design. When PRESSURE is considered for *small gaps and closed doors*, VELOCITY is used for *large gaps and open doors*. Obviously, the number of effective open doors and the air velocity through these open doors will have the greatest impact on the size of the stairwell pressurization fan.

Location of stairwell pressurisation fan and injection points

The stairwell pressurisation fan can be located anywhere, but as the exit door is located at the bottom of the stairwell, the **stairwell pressurisation fan is usually located at the top of the building** to prevent any failure and short-circuit due to open exit door near the single air supply injection point.

For tall buildings (H > 15m or 8 stories), there are usually **several injection points** for the supply of pressurising air into the stairwell to ensure an **even pressure distribution.** These injection points should be at a **distance not greater than 3 floor levels** to ensure an even pressure distribution.

Protection of the air intakes from smoke hazards

As there is a potential hazard for smoke to enter the stairwell through a pressurisation fan air intake, there should be **two air intakes** facing different directions in order not to be affected by the same source of smoke. Each air intake shall be protected by a **smoke control damper** operated independently via a **smoke detector** in such a way that if one damper closes due to smoke contamination, the other air intake will supply the air requirements of the system without interruption. The air intake shall also **not be less than 5m horizontally from any exhaust discharge opening** and be independent from wind speed and direction.

Air leakage paths (except open doors, windows, and air transfer grilles)

Air leakage paths must be identified and evaluated to **keep a positive differential pressure** between the stairwell and the accommodation when all doors are closed. Some leakage paths are obvious such as **cracks around closed doors**, elevator doors; **construction cracks** in building walls are less obvious but they are equally important. The area of these leakage paths depends on such features as workmanship, door fit and weather-stripping.

Example: A 0.9 by 2.1 m door with an average crack width of 3 mm has a leakage area of 0.018 m2. However, if this door is installed with a 20 mm undercut, the leakage area is 0.033 m2, a significant difference. The leakage area of elevator doors is in the range of 0.051 to 0.065 m2 per door.

Table 1 Typical Leakage Areas for Walls and Floors of Commercial Buildings

Construction Element	Wall Tightness	Area Ratio
		A/A_w
Exterior building walls[a] (includes construction cracks and cracks around windows and doors)	Tight	0.50×10^{-4}
	Average	0.17×10^{-3}
	Loose	0.35×10^{-3}
	Very Loose	0.12×10^{-2}
Stairwell walls[a] (includes construction cracks but not cracks around windows or doors)	Tight	0.14×10^{-4}
	Average	0.11×10^{-3}
	Loose	0.35×10^{-3}
Elevator shaft walls[a] (includes construction cracks but not cracks around doors)	Tight	0.18×10^{-3}
	Average	0.84×10^{-3}
	Loose	0.18×10^{-2}
		A/A_f
Floors[b] (includes construction cracks and gaps around penetrations)	Tight	0.66×10^{-5}
	Average	0.52×10^{-4}
	Loose	0.17×10^{-3}

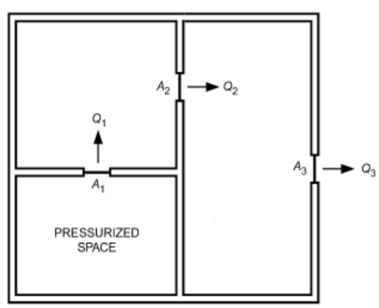
A = leakage area; A_w = wall area; A_f = floor area
Leakage areas evaluated at [a]75 Pa; [b]25 Pa.

flow as the system when it is subjected to the same pressure difference over the total system of flow paths. This is similar to the effective resistance of a system of electrical resistances. The effective flow area A_e for **parallel** leakage areas is the sum of the individual leakage paths:

$$A_e = \sum_{i=1}^{n} A_i \qquad (12)$$

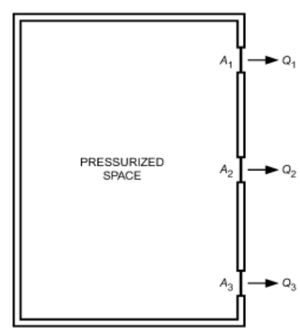
Leakage areas in series:

$$A_e = \left[\sum_{i=1}^{n} \frac{1}{A_i^2}\right]^{-0.5}$$



Leakage areas in parallel:

$$A_e = \sum_{i=1}^{n} A_i$$



Typical leakage areas - Leakage areas in series or parallel
ASHRAE 2007 HVAC Applications

Door-opening force requirement

The door-opening forces resulting from the **differential pressure** between the stairwell and the accommodation must be considered. Unreasonably high door-opening forces can make it difficult or impossible for occupants to open doors to refuge areas or escape routes. The force required to open a door is the sum of the forces to overcome **the pressure difference across the door** and to overcome **the door closer.**

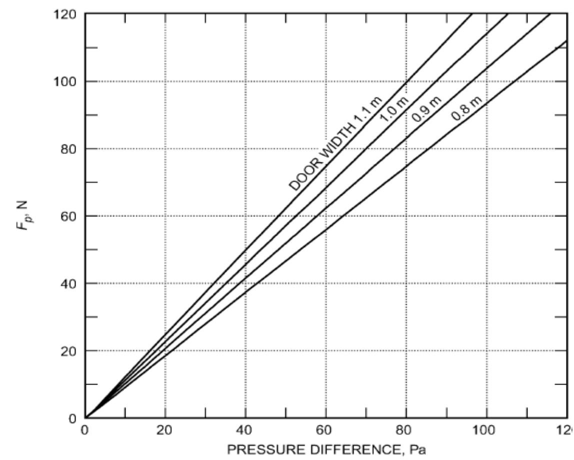
$$F = F_{dc} + \frac{WA\Delta p}{2(W-d)}$$

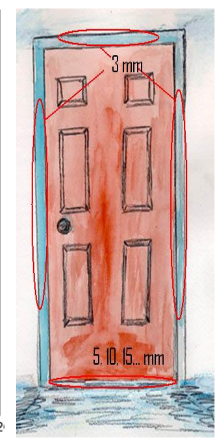
WHERE

F = total door-opening force, N
Fdc = force to overcome door closer, N
W = door width, m
A = door area, m2
Δp = pressure difference across door, Pa
d = distance from doorknob to edge of knob side of door,m

This relation assumes that the door-opening force is applied at the knob. Door-opening force Fp caused by pressure difference can be determined from the below figure for different door widths and for d = 75 mm. The force to overcome the door closer is usually greater than 13 N and, in some cases, can be as great as 90 N.

Door opening-force due to pressure difference
Air leakage through a door
<u>ASHRAE 2007</u>
HVAC Applications – Fire and Smoke Management

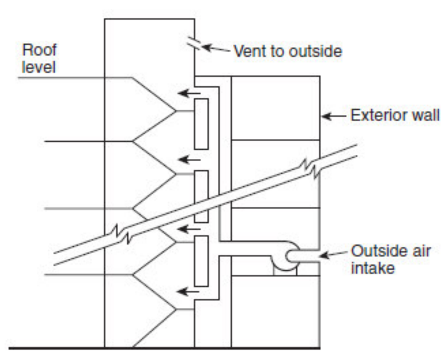


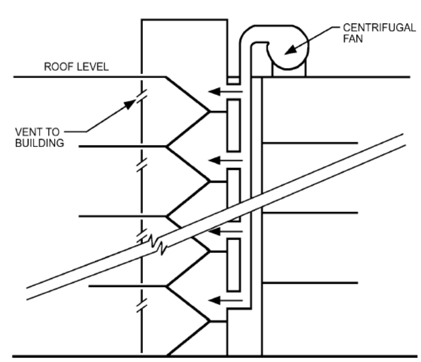


Overpressure relief

An overpressure relief is mandatory as the design of pressurised stairwells is evaluated **under two really different conditions**, ie *<u>all doors closed</u>* and with *<u>selected doors open</u>*. As a system designed under "all doors closed" conditions cannot provide sufficient airflow through selected open doors to prevent smoke backflow, and the pressure difference across the remaining closed doors can drop to low levels, the system has to be finally designed for the worst case (ie with selected doors open). But to prevent the build-up of excessive pressures when all doors are closed, an overpressure relief has to be implemented in the stairwell.

Different configurations with PRD to the outside or to the building
<u>ASHRAE 2007</u>
HVAC Applications & NFPA 92.A





In case the PRD is connected **to the building on each floor**, a *<u>fire damper</u>* should be connected in series. In case the PRD is connected **to the outside**, a *<u>windshield</u>* is recommended to prevent wind pressures.

Corridor smoke extraction & air relieve

The **corridor smoke extraction system** is the best solution to offer a low resistance path for the supply air penetrating inside the corridor from the stairwell to leave the building through **vertical ducts** and **400°C – 2hrs smoke exhaust fans**. The corridor smoke extraction is perfectly complementary with the stairwell pressurisation system. Indeed, by creating a low pressure point in the fire area, the corridor smoke extraction ensures that all airflow will be directed towards this fire area, and consequently that the smoke will be prevented to enter unaffected parts of the building via unidentified leakage paths.

HVAC system

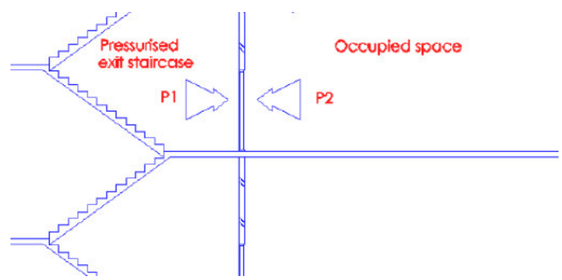
In order not to affect the pressure differential, the **HVAC system shall be shut down** to prevent the smoke movement penetrating other interconnected spaces (same requirement for compartmentation and smoke extraction system).

How to implement efficiently a stairwell pressurisation system in the UAE?

In the UAE, the design criteria are quite stringent due to the number of high-rise buildings, the building occupancy and the difficulty to reach the ground level, resulting in a really important need for a safe evacuation. As per the new **UAE Fire Code,** the stairwell pressurisation system should thus be implemented in **any building with habitable height exceeding 23 m** when internal exit staircases are without adequate provision for natural ventilation**,** and should deal with the following **design criteria**:

❶ DETECTION PHASE → Pressure Criterion:

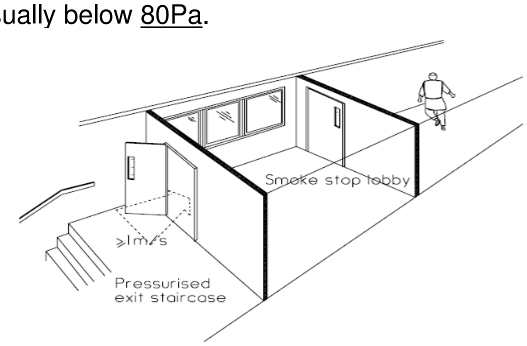
Minimum pressure differential between stairwell & adjacent accommodation space is **12.5Pa** in *sprinklered buildings* **or 25Pa** in *non-sprinklered buildings* when all doors are closed. A value of 50Pa can also be considered without any problem (cf. drawings in this document).

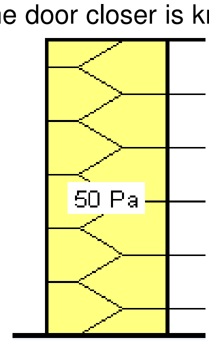


❷ ESCAPE PHASE → Velocity & Force Criteria:

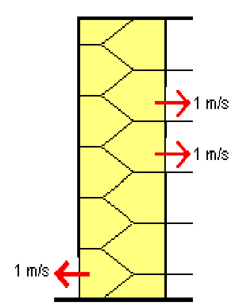
Minimum velocity shall be higher or equal to **1m/s** through **3 open doors** (1 main exit door + 2 doors on consecutive floors)

Maximum force required to open any door at the door handle shall not exceed **133N.** This maximum force means finally a maximum differential pressure as long as the force of the door closer is known. This maximum differential pressure is usually below 80Pa.





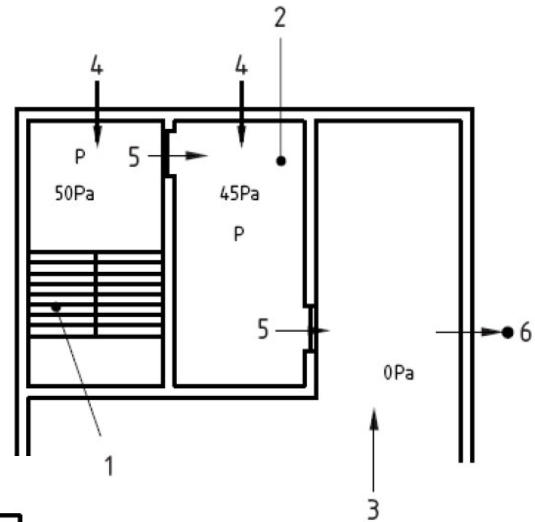
Pressure Criterion (all doors close)



Velocity Criterion (3 doors open)

❸ DIFFERENT POTENTIAL CONFIGURATIONS

Note:
1 = Staircase
2 = Lobby
3 = Accommodation
4 = Supply Air
5 = Leakage path through doors
6 = Air release path through building
P = Pressurized space



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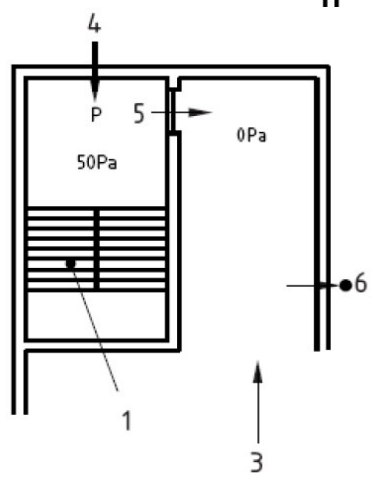

➡ Calculation Methodology:

1- Identify all the airflow paths with doors closed and calculate the leakage rate via these airflow paths (cracks around doors…).

2- Calculate the air supply required with all the doors closed with a 50% increase for unknown.

3- Identify all the different doors and calculate the air supply required through these doors with v=1m/s and an allowance of 15% for ductwork losses.

4- Calculate the total airflow (all doors closed + 3 doors open) and determine the fan duty point

5- Check that the door opening forces are below 133N

6- Calculate the size of the PRD

Selection of the stairwell pressurisation fan

In case of fire, a stairwell pressurisation fan is used to **supply fresh air** into the exit route stairwell to create a **sufficient pressure differential** with the corridor space.

Any type of fans could be used theoretically for stairwell pressurisation application. A major advantage of using axial fans for stairwell pressurisation is that they have a relatively flat pressure response curve with respect to varying flow. Therefore, as doors are opened and closed, propeller fans **quickly respond to airflow changes in the stairwell without major pressure fluctuations**.

A second advantage of using axial fans is that they are usually **less costly** than other types of fans and can provide adequate smoke control with lower installed costs.

But as they are operating at low pressures and are readily affected by wind pressure on the building, they often require **windshields at the air intake, especially when they are wall-mounted**. This is less critical when axial fans are mounted on roofs because they are often protected by parapets and the direction of the wind is at right angles to the axis of the fan.

A study from Hobson and Stewart, *"Pressurisation of Escape Routes in Buildings"* (1977), revealed also that **axial flow fans were more reliable** than centrifugal fans with a failure rate 10 times less than centrifugal fans and a high reliability of 94.9%. Nowadays, we can obviously consider that new centrifugal fans have achieved better performances with higher reliability and are now as reliable as axial fans. Despite this reliability, standards, codes of practice, and regulations are still enforcing **stand-by fans** requirements with **primary and back-up pressurising units**, mounted in parallel or series, especially in the case where the pressure differential system equipment provides air under pressure to the **only escape route within a building**.

Note: If there are two independent escape routes for each accommodation within a building (ex: 2 staircases) or if there is just one escape route within a building but there is possibility for the people to enter another compartment with other means of escape, there is no need for stand-by fans.

Stairwell Pressurisation Fan		
Type		Axial Fan
Model		HELIONE
Standards		EN 12101-3 (CE)
Key Features	Fire Resistance	200°C or 400°C - 2h
	Speeds	1 or 2 (1 speed is enough...)
	Direct/Belt driven	direct driven
	Max Airflow	72000 m3/h

HELIONE stairwell pressurisation axial fan is designed, **CE marked** and tested as per **EN 12101-3** for operation at **400°C for 2 hours** and hold Civil Defence approval.

Note: For the selection of the stairwell pressurisation fan, the fan performance shall be at least 1.5 times larger than that calculated for the predicted leakages in order to allow for the unidentified leakages plus an allowance of 15% for probable ductwork leakage as per EN 12101-6.

Selection of the pressure relief damper

The pressure relief damper shall be sized to discharge the total excess airflow determined by subtracting the total air leakage from the stairwells, lobbies and corridors with all doors closed from the total required airflow in the worst case conditions (selected doors open).

The pressure relief damper shall be able to maintain at or above the design pressurisation level but below the maximum pressure determined by the door opening force requirements.

Pressure Relief Damper – Model SG 662

Aldes ME has developed its own "stairwell pressurisation fan selector" to meet all these requirements.

For any information or enquiry or case study, please contact us!
www.aldes.ae