Escape route pressurisation systems

Escape route pressurisation systems aim to protect key areas of a building during a fire. These systems are sometimes included in building designs to help demonstrate compliance with fire safety regulations, but their effectiveness is not clear. BRANZ research into past building fires found evidence that fire and smoke spread may be more contained when these systems are installed. However, the research could not verify whether they significantly improved human safety. Several operational issues observed in pressurisation systems in six buildings are consistent with reporting elsewhere. Revising the standards and procedures for the design, installation, functioning, inspection and testing of these systems is highly recommended.

The intention of escape route pressurisation systems is to keep occupants safe while evacuating the building and/or improve conditions for fire and rescue operations. Common examples are stairwells or corridors.

Pressurisation systems create a pressure difference between a key part of a building's escape route (often staircases and lobbies) and adjacent areas of the building designed to limit fire spread (other fire compartments, such as apartments or offices). The system aims to prevent the escape route from filling up with smoke and noxious gases. Pressurisation occurs in one of two ways:

- Negative pressurisation - gases are extracted from a compartment to reduce the air pressure below that of adjacent compartments.
- Positive pressurisation - fresh air is forced into a protected compartment.

A more complex system is a 'zone' or a 'sandwich' pressurisation system, which aims to keep fire smoke and gases in the compartment where the fire started by pressurising compartments around the area containing the fire.

The pressure difference between areas is maintained by creating air movement across the parts of the building's structure that usually restrict airflow (such as walls and floors/ceilings). The system must be able to adjust and account for changes or disruptions in how the air is intended to flow between these areas, such as when doors open and close as the occupants leave the building.

In some cases, the system will share components with the building's usual heating, ventilation and air conditioning (HVAC) systems.

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Components of an escape route pressurisation system

Some systems may be as simple as a single fan connected to the alarm system, or some may involve hundreds of interdependent components with each fire location requiring the components to react in a differently coordinated manner.

Depending on complexity, an escape route pressurisation system may include:

- a mechanical fan for driving the pressurisation
- a means to trigger the system when there is a fire - usually a connection to the fire alarm system
- compartment boundaries (walls, ceilings and floors)
- adjustments to the doors to make them more difficult to open or force them to open
- a network of ducts, grilles, diffusers and dampers to move air
- a control panel to allow automatic control and manual overrides of the fans and dampers
- system redundancy and back-up measures
- an electric supply and a back-up generator and wiring with protection against fire to ensure the system can continue functioning
- protection against mechanical and water damage.

Implementation issues

Although pressurisation systems are a straightforward concept, there are several factors that make implementing them difficult:

- Mechanical systems do not operate instantaneously - forces are involved in their operation and the system response can lag behind changes in the situation.
- The way the air flows to and from a pressurised compartment can change - for example, due to doors opening and closing - so the system must adjust to maintain the required pressure difference.
- If a compartment leaks air faster than the design intended, the fans may not be able to keep up to provide the required pressure difference.
- The path of air must be designed so that pressure in the fire compartment does not equalise with the pressurised compartment over time.
- Temperature differences between the pressurised compartment and the outside can create a stack effect like a chimney, reducing the pressure at the bottom and increasing the pressure at the top when compared to cold air outside. This becomes more pronounced in taller vertical compartments such as stairwells and for larger temperature differences but can be minimised by using untreated outside air in the pressurised compartment.

A study for the New Zealand Fire Service Commission in 2008 estimated that stairwell pressurisation system effectiveness could range from 6% to 84% depending on system design, commissioning, testing and maintenance. The study identified the critical parts of these systems - fans, dampers, door closure, and electrical and electronic components, such as control panels, alarms and power supply - and how they might fail.

Compliance requirements in New Zealand

The installation of escape route pressurisation systems must satisfy the New Zealand Building Code clauses that ensure occupant and firefighter safety and facilitate firefighting operations: safety of people (C1(a) and(c)), functioning of the building (C3.1, C4.2, C5.1, C5.2) and performance of the building (C3.9, C4.3, C4.5, C5.6 and C5.8). Prior to 2012, systems installed as part of Acceptable Solution C/AS1 fire safety designs were also required to comply with AS/NZS 1668.1:1998 section 9 and to meet additional pre-occupancy and annual post-occupancy testing

The New Zealand Building Act 2004 also specifies how certain building systems should be inspected and maintained (in sections 100 and 108), including escape route pressurisation systems. Building owners must supply the local territorial authority with an annual building warrant of fitness (BWOF), and guidelines are given in the Compliance Schedule Handbook.

The handbook states that preventive and responsive maintenance must be undertaken to ensure the system will operate effectively during a fire. It also recommends using Australian Standard AS 1851 or a bespoke solution to determine which components are inspected and tested and how often.

In 2012, the structure of AS 1851 changed substantially, including new requirements for routine servicing against baseline data from installation and commissioning along with inspection, testing and maintenance to ensure system performance meets or exceeds the benchmark set at installation.

At the same time, some requirements were removed. This included the need for AS 4655 fire safety audits, the requirement for the owner or occupier to keep extensive documentation of the system and skill level and experience of personnel conducting inspection, testing, maintenance and survey tests.

Approach

Effectiveness is difficult to measure in escape route pressurisation systems, and there is little direct evidence on how well these systems actually work under fire conditions.

BRANZ used two approaches to investigate. The first was a review to see what could be learned from previous building fires in Auckland, Wellington and Christchurch in buildings with and without a private fire-alarm connection. The second involved identifying individual systems documented in local council property files and following up with site visits and interviewing relevant experts.

Review of buildings with fire incidents

Buildings with pressurisation systems and private fire alarms (PFAs) in Auckland, Wellington and Christchurch were located using council records and Fire and Emergency New Zealand (FENZ) data (Figure 1).

In the 404 buildings with an escape route pressurisation system listed in their compliance schedule, council records did not show the type of pressurised escape route (corridors, stairwells or combinations of these) or any potential fire safety trade-offs in the building design as a result of installing the pressurisation systems.

BRANZ obtained records from FENZ of PFA-monitored incidents in Auckland, Wellington and Christchurch that involved structure fires between 1 January 2006 and 28 September 2018:

- 3,475 incidents were recorded as “structure fire with damage”.
- 310 of these incidents involved buildings with pressurisation systems.

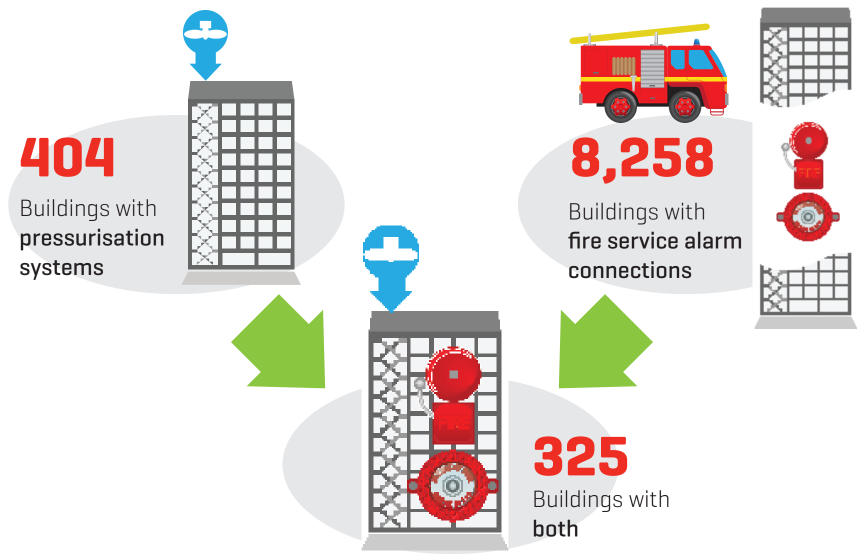

Figure 1. Buildings with pressurisation systems and private fire alarms in Auckland, Wellington and Christchurch.

The small number of incidents analysed meant that conclusions could not be drawn about the effectiveness of escape route pressurisation systems for saving lives, but the flame and smoke damage records did appear to show that pressurisation systems have some success at limiting fire and smoke spread in buildings, particularly in residential buildings (Table 2).

Visiting installed systems and interviews with professionals

Six buildings were chosen with escape route pressurisation systems in consultation with Auckland Council and FENZ. All were built before 2012 and before the introduction of the NZBC Verification Method C/VM2. Two were commercial buildings constructed before 1991 under NZS 1900 *Model building bylaw*, although one was under development and being converted for residential use at the time of the visit. The other four were residential and built in the mid-2000s.

Information was collated from the property files about the pressurisation system design, operation, inspections, testing and maintenance - a total of 8,854 documents were consulted.

In general, design information for the pressurisation systems was limited. It did not appear that any of the buildings had been modelled using a tool like NIST's CONTAM network model, which is used to design and balance pressurisation systems.

In some cases, relief air paths and leakage were discussed, but not in all. Leakage considerations and different door opening scenarios were generally not modelled to investigate how the pressure differences and velocities could be maintained during a fire event, considering occupant evacuation and fire service intervention.

BRANZ found little data on initial system commissioning. In some cases, the door velocities had been reported but not door-opening forces or noise levels. It is unclear how much design and/or commissioning information may exist but was not in the property file system. A lack of information in the property file does not necessarily prove that the necessary work was never completed or documented, but it does raise questions about the adequacy of the system when little documentation is available.

In some cases, the BWOF was reported as overdue. There were also multiple instances where a report was issued instead of the BWOF. Reasons included insufficient evidence of required inspection and maintenance in the preceding period, relief vents not working properly and problems with the back-up power supply.

Two independent contractors who are qualified to inspect buildings with pressurisation systems were interviewed. In the systems they inspect, they had encountered:

- a non-operational fan
- cases where the fan speed or pressure switches needed adjustment
- instances where doors were too hard to open with the system operating

Table 2. Comparison of reported flame and smoke damage in residential and non-residential buildings with and without escape route pressurisation systems.

FLAME DAMAGE – FLOOR AND BEYOND	RESIDENTIAL	NON-RESIDENTIAL
No pressurisation system	5%	10%
Pressurisation system	0%	3%
Improvement	100.0%	64.8%
FLAME DAMAGE – STRUCTURE AND BEYOND	**RESIDENTIAL**	**NON-RESIDENTIAL**
No pressurisation system	2%	7%
Pressurisation system	0%	3%
Improvement	100.0%	52.1%
SMOKE DAMAGE – FLOOR AND BEYOND	**RESIDENTIAL**	**NON-RESIDENTIAL**
No pressurisation system	22%	29%
Pressurisation system	7%	19%
Improvement	68.8%	36.1%
SMOKE DAMAGE – STRUCTURE AND BEYOND	**RESIDENTIAL**	**NON-RESIDENTIAL**
No pressurisation system	11%	18%
Pressurisation system	3%	11%
Improvement	68.8%	37.7%

- fans moving air in the wrong direction
- a lack of evidence of needed maintenance and testing work.

One out of the three buildings regularly visited by one of these contractors has a system which, in their opinion, is likely to work correctly in the event of a fire, whereas the other two buildings were more uncertain.

The observations during these site visits, from the documentation and during the interviews are in line with the evidence of widespread problems already reported in the literature.

Conclusions

- Escape route pressurisation systems may limit smoke and flame damage beyond the fire-affected areas of a building. However, confidence amongst fire professionals in these systems and their performance in New Zealand buildings currently remains low.
- Confidence in these systems could be improved if New Zealand building regulations are updated to include requirements for professional qualifications (such as a certifier role and third-party requirements and qualifications for designers, installers, inspectors and maintenance personnel).
- Confidence could be further improved by referencing international standards and implementing New Zealand-specific standards for the robust design, installation, commissioning, inspection and testing of these systems (for example, at the same level as found in NZS 4541:2013 for sprinklers or in NZS 4512:2010 for alarm systems).
- It is likely that a change to the building regulations could take longer to implement than issuing guidance, and regulation may initially be affected by a shortage of people with adequate skills and experience to meet professional certification requirements.
- It is important that the performance and state of escape route pressurisation systems continues to be monitored following property fires. An official building numbering scheme and a compliance schedule with associated database should be introduced to facilitate this.
- Future research could focus on using emerging digital methods, such as machine learning and artificial intelligence, to automate the time-consuming task of collating information about fire safety system performance. Further modelling and experimental work could improve understanding of crucial parts of these systems, such as door velocity and performance of systems under air pressure differentials. Beneficial comparisons to alternative design approaches could be made, such as corridor air-flushing systems.

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More information

BRANZ Study Report SR440 *Escape route pressurisation systems: A pilot study of New Zealand data*

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