Title:	**Pressurization Systems Don't Work & Present a Risk to Life Safety: Discuss!**
Author:	Simon Lay, Director of Fire Engineering, AECOM
Subject:	Fire & Safety
Keywords:	Fire Safety Performance Based Design
Publication Date:	2012
Original Publication:	CTBUH 2012 9th World Congress, Shanghai
Paper Type:	1. Book chapter/Part chapter 2. Journal paper 3. **Conference proceeding** 4. Unpublished conference paper 5. Magazine article 6. Unpublished

Pressurization Systems Don't Work & Present a Risk to Life Safety: Discuss!

关于正压送风系统性能之于生命安全风险的讨论

Simon Lay

Simon Lay

AECOM
1 New York Street
Manchester
United Kingdom M14HD

tel (电话): +44 (0) 161 601 1700
email (电子邮箱): simon.lay@aecom.com
www.aecom.com

Simon Lay is a former chair of the CTBUH Working Group on Fire Safety in High Rise Buildings and a member of the CTBUH Advisory Group. Simon has led the fire safety design on many tall building projects and is the author of many papers and articles on fire engineering and high-rise design. As a strong proponent of performance-based design as the best way of ensuring safety through design, Simon is well known and respected for introducing innovation and challenging apathy in building design.

Simon Lay是世界高楼协会（CTBUH）高层建筑消防安全事务委员会的前主席，并兼任该协会的顾问组成员。Simon领导过诸多高层建筑项目的消防安全设计，撰写了多篇消防工程与高层建筑设计论文。Simon认为性能化设计是确保设计安全性的最佳方法，并以建筑设计创新和挑战常规设计而闻名。

Abstract

This paper considers why some fire safety professionals have become critical of a reliance on pressurization as the dominant form of smoke control in high rise buildings. Design, installation and operational challenges are discussed and alternative solutions presented alongside guidance to building designers and approval authorities.

Keywords: Smoke Control, Pressurization, Tall Buildings, Fire Safety, Performance Based Design

摘要

本文讨论了为什么有些消防专业人员质疑作为高层建筑防烟主要形式的正压送风系统。本文讨论了其设计、安装以及操作难点，提出替代方案以及对设计人员和审核机构提供指导意见

关键词：烟气控制，正压送风，高层建筑，消防安全，性能化设计

The successful operation of pressurization systems is routinely called into doubt by fire fighters and numerous respected engineers have raised concerns about the practical use of pressurization systems. However, pressurization systems remain a standard feature of high rise building codes from the USA, UK, Australasia, China, India, the UAE and many other locations. In addition to stairs, some codes include the pressurization of elevator shafts and lobbies / vestibules.

There is considerable anecdotal evidence of problems with pressurization systems. The author has been called on a number of occasions to support Mechanical Engineers who are trying to commission a pressurization system which refuses to perform as intended. In conversations with fire fighters from the UK, the USA, India and across Europe, the author has repeatedly been told that they do not trust pressurization systems, having seen them underperform on many occasions. Discussions with fellow fire and life safety professionals have also suggested that many experts share the reservations of the author with regards to the application of pressurization systems.

消防人员和许多著名工程师通常会怀疑正压送风系统的性能及其在实际操作中的可行性。然而，正压送风系统仍是美国、英国、澳大利亚、中国、印度、阿联酋等国高层建筑设计规范所要求的内容。除了楼梯间增压，有些规范还要求对电梯井、大厅/前厅提供正压送风。

曾有大量事实表明正压送风存在问题。笔者曾有多次协助机电工程师排除正压送风系统故障的经历。笔者也从英国、美国、印度及欧洲各国消防人员那里了解到正压送风系统常常因性能欠佳而不具可行性，且很多专家在该系统的应用方面也均持保留意见。

除了大量实例，根据田村先生（1989年）等研究人员在模拟状态、实验室及实地测试中所做的研究也对正压送风系统的性能提出了质疑。烟控技术的知名工程师及正压送风系统早期支持者Budnick和Klote（1989年）等也发表文章重申正压送风系统的重大挑战以及需要考虑的设计问题。

自上世纪六十年代以来，正压送风系统作为高层建筑防烟楼梯间的防烟方式被广泛接受，且其原理相对简单。正压送风系统通过向楼梯间送风防止烟气通过关闭的门渗入楼道，使楼道气压高于附近的消防分

In addition to anecdotal evidence, there have been studies by researchers such as those carried out by Tamura (1989) which raised doubts about the performance of pressurization systems in simulated conditions, test facilities and field trials. Well-respected experts in smoke control techniques and early proponents of pressurization, such as Budnick and Klote (1989) have published papers reiterating important challenges and design considerations that need to be considered for pressurization systems.

Since the 1960's pressurization has been a popular option for protecting stair enclosures in tall buildings and the principle is relatively simple. A pressurization system is intended to prevent smoke leaking passed closed doors into stairs by injecting clean air into the stair enclosure such that the pressure in the stair is greater than the adjacent fire compartment. Then, if the stair door is opened, the system is intended to maintain a flow of air through the open doorway to oppose smoke flow and prevent contamination of the stair enclosure.

So if pressurization systems operate on logical principles and are based on simple physics, why are fire fighters and engineers concerned about their effectiveness, and if pressurization systems don't work, what are the consequences and alternatives?

Consequences of Failure of Pressurization Systems

The intended function of pressurization systems is to provide protection to both building occupants and fire fighters.

In high-rise buildings, evacuation is normally phased such that occupants do not all move to the escape stairs at the same time. Instead, occupants who are most at risk (on the fire floor) evacuate first, followed by the rest of the occupants, phase by phase. The result of this is that evacuation routes need protection from smoke for an extended period of time, and pressurization aims to provide this protection.

Fire fighters may rely on pressurization to maintain a smoke free environment from which to commence fire fighting activities. Then, during fire fighting, pressurization should protect the escape route for fire fighters to use if required.

Lobbies and elevator cores may also be pressurized to limit smoke spread. In situations where elevators are used to support fire fighting activities or evacuation (something which is increasingly being considered in tall buildings), then pressurization of elevator cores may be proposed to ensure that the elevators are available and protected from contamination.

Under some building codes (for example NFPA Life Safety Code 101 and the International Building Code), pressurization can be proposed instead of providing a smoke proof vestibule. This makes the pressurization system the primary line of protection for building cores. Failure of the pressurization system could therefore place occupants and fire fighters at serious risk of incapacitation or death.

The Challenges for Pressurization

The principles of pressurization systems are simple, but the problems associated with them are many and complex. They can be broken down into problems associated with; design, commissioning, operation and legacy.

In the design process there are a number of key design parameters that have to be taken into account. The most fundamental parameter to have an impact on the design is estimation of leakage from the core.

区。如果楼梯间是开着的，该系统会通过开着的门送风，不让浓烟进入疏散通道。

如果正压送风系统按照正常原理并基于简单物理学工作，那么，消防人员及工程师为什么会质疑其有效性呢？如果该系统不可行，其影响及替换方案又如何呢？

正压送风系统故障的影响

正压送风系统的正常性能是为了保护建筑内的居民及消防人员。

在高层建筑中，消防疏散通常是分步骤进行的，以防居民同时涌向逃生通道。处于最危险的起火层的居民先疏散，然后逐层疏散。在这样的过程中，疏散通道需要提供一段时间内的控烟保护，正压送风就是提供这样的保护。

消防人员可能需要正压送风保持无烟环境，以进行灭火操作。在灭火过程中，该系统应确保消防人员的使用。

大厅及电梯核心筒也可通过正压送风进行控烟。如果通过电梯协助消防操作或疏散（越来越多的考虑使用在高层建筑中），可能建议电梯核心筒的正压送风以提供控烟保护及确保电梯的使用。

根据有些建筑规范（如《美国国家消防协会生命安全法规101》以及《国际建筑规范》等），可使用正压送风系统，来代替防烟前厅。这使得正压送风系统成为建筑核心筒的首要防线。一旦发生故障，将置大楼居民及消防人员于非常危险或死亡的境地。

正压送风系统面临的挑战

正压送风系统的原理不复杂，但与其相关的问题却是繁杂的。这些问题可分为相关问题；设计、验收、操作及维护问题。

在设计过程中，必须考虑诸多关键设计指标。 影响设计的最基本指标是评估核心筒的烟气渗漏。

漏气途径包括楼道门、窗、墙之间的缝隙、墙体材料的自然渗漏、电梯门、辅助竖井、外立面及地板架高系统等。正压送风设计导则中规定了标准计算。然而，只有这些计算是准确的，才能确保系统的正常性能，设计该系统的工程师还将有赖于其它设计过程、承包商设计、施工、验收、装修及建筑的后期维护等将这些设计变量转化为静态变量。

同时，设计过程中通常允许一定的公差，这些不能对漏气途径重大变动提供足够的设计灵活性。另外，要求高效的建筑整体维护设计，很难确保最初设计阶段之后再行变更管道、风机尺寸、供电、泄压风门等部件。

建筑主体基本完工之后才能进入验收阶段。不能通过微调已安装的设备解决调试阶段发现的问题有可能导致成本增加及工期延误。在调试阶段一般安装临时门或是留出仅供施工使用的未完全密封的开口。此外，很多建筑仅作为一个“外壳”进行设计及交付，最终装修由租户来提供。这会形成很多漏气及送风途径。

验收结果还可能取决于测试当天的风向与温度条件。这在正压送风系统的设计规范中得到普遍认可。例如，在英国控制系统标准BS EN 12101-6 (2005)中规定了针对测试当地天气状况的标准化测试规程。然而，在同一天可能处于不同天气条件的情况却未被考虑。该影响程度随着建筑高度及位置发生变化，而对于全年温度变化较大的城市以及不断受风影响的超高层，在单一天气条件下设定的系统性能可能造成在其它情况下出现问题。

对于不从事建设设计和施工的人来说，有关天气影响生命安全系统不给出充分解释显然是不恰当的。这可能是实际情况，但最终会影响系统的其实是实际使用。

在任何时候下，开门的数量是决定正压送风系统风扇峰值送风量的关键。设计中一般开在楼道下部的门在消防情况下是打开的（

Air leakage paths can include stairway doors, windows, gaps in walls, natural leakage through wall materials, elevator doors, service shafts, facades and raised floor systems. There are standard estimates which are recommended in pressurization design guides. However, if the calculations are to be correct, such that the system performs as intended, the engineer designing the system will be reliant on these variables being static from the point of design, through the rest of the design process, subcontractor design, construction, commissioning, fit-out, refurbishment and so on for the lifetime of the building.

Whilst it is common to include tolerances in the design process, these cannot guarantee sufficient design flex to accommodate significant changes in leakage paths. Also, the need for integrated building services design to be efficient means that it is very difficult to achieve changes to components such as ducts, fan sizes, power supplies and relief dampers after the initial design process.

The commissioning process cannot take place until the building is substantially complete. Any significant problems identified at commissioning that cannot be resolved by fine tuning the equipment already installed is likely to lead to substantial costs and delays to the building. It is common during commissioning for temporary doors to be in place or for construction openings to not be fully sealed. Also, many buildings are designed and handed over as "shell" only, with a final fit-out by a tenant. This final fit out by the tenant can have significant implications for the leakage paths and air supply paths.

Results from commissioning can also be highly sensitive to the wind and temperature conditions on the day of testing. This is well recognized within design codes for pressurization systems. For example, the BS EN 12101-6 (2005) includes protocols to normalize the system test against the climate conditions on the day of the test. However, no account is taken of what might happen on a different day under different wind or temperature conditions. The impact of this will vary with the height and location of the building, but in cities which see large variations in temperature throughout the year, and in the case of very tall buildings where wind effects are a continuous feature, the significance of setting a system to work under a single climate condition is likely to result in system performance problems under other conditions.

To anyone not engaged in the building design and construction process, it may appear inappropriate that the effects of the weather on life safety systems are not fully accounted for. That may be the case, but ultimately it is a matter of practicality.

The number of doors open at any one time is critical to determining the peak flow rate of the fans serving the pressurization system. Normally in the design process, a door at the foot of the stair is assumed to be open during fire fighting (for fire fighters entering the building) and also a single door on the fire floor. However, this may not represent the practicalities of evacuation or fire fighting in a tall building. Any doors being opened beyond the small number assumed in the design case will cause a loss of air, preventing the pressurization system from performing as intended, potentially allowing smoke into the core.

One of the primary concerns for pressurization systems in operation is the effect that they may have on door opening forces. As doors typically open into stairways, the increased air pressure in the core arising from a pressurization system can prevent occupants from being able to open doors.

It can be very difficult to balance the different air flow requirements for creating positive pressure in a core with closed doors and the

供消防员进入大楼），同时在火灾层有一扇单独的门。然而，这可能并不代表高层建筑疏散或消防的可操作性。如果开门数量超过设计假设的少量开门数量的情况下，将会造成空气流失，妨碍正压送风系统正常工作，从而可能造成烟气进入核心筒。

运行中的正压送风系统主要问题在于形成开门压力。门一般开向楼道，正压送风系统引起核心筒内空气压力升高，可能使门无法打开。

核心筒产生正压所需的空气量与门打开状态所需的大量空气量可能是很难平衡的。这个问题在超高层建筑中尤为突出。

有些设计试图解决平衡空气量与开门压力的问题。包括采用轻质气流调节器、复变量驱动风机或与竖井内压力传感器相连的调节装置等。而即使采用这些装置，实际上还是会受增压竖井高度的限制。

《美国采暖、制冷与空调工程师协会（ASHRAE）烟控设计手册》等正压送风系统设计导则承认了这一实际高度限制。由此提出将超高层建筑的楼梯间分为多个堆叠且独立竖井的设计建议。但是，这并不为所有的建筑规范所认可，设计师可能会忽略楼梯间尺寸的影响。例如，在英国控制系统标准BS EN 12101-6（2005）中，不包括任何给定核心筒剖面最大高度的预留规定。

正压送风系统作为广泛采用的设计解决方案最早出现在美国，那里有强大的基地系统制造业和维修服务以及完善的立法确保业主，保证建筑的生命安全。因此，该系统在美国等地应是可靠性最高的。尽管如此，Lay（1996年）基于消防专业人员、产品制造商、业主以及研究人员所做的广泛研究发现35%的正压送风系统存在性能故障。Tamura（1992年）所做的调查显示，所有的实际测试的系统并未按照预想发挥实际作用。

高层建筑和都市住宅委员会2010年数据明确，在过去十年中，新兴经济体高层建筑开发已超过西方发达经济体的高层建筑项目数量。然而，有些新兴经济体的检查、维修及整体建筑管理体制却较发达经济体有所欠缺。在这些国家和地区，消防安全法规定执行往往是事后的，而非前摄性或预防性的。在有些地区，这些问题有些地区的法规中得到承认，例如印度国家建筑法规（2005版）规定了对正压送风系统谨慎接受；而一般而言，技术已实现国际流动，却未考虑到确保持续安全操作需解决的维护问题。

承认正压送风系统设计挑战

当然，《美国国家防火协会92》和《英国控制系统标准BS EN 12101-6 》等导则也为设计师提供了应对正压送风系统设计挑战的建议。该导则提出考虑使用负压抽风的附加控烟装置、设置前厅或增压楼道。但是这些附加考虑并未在所有地区的设计规范中得到广泛采用。而且，即使在提出这些设计建议的地方，它们也有时会由于增加设计复杂性或影响建筑节能而被建筑设计师忽略。

有些设计师一厢情愿地认为希望按照设计标准中的简单计算过程就可得到可接受的设计，而无需处理更复杂的设计挑战。规范要求设计师向承包人或业主告知正压送风系统设计造成的局限也未受重视。该做法没有从根本上承认建筑设计与施工过程的可行性，仅仅弥补了设计者将面对的不可避免的建筑设计改动。

替代方案

为了解决正压送风系统问题，设计师可通过重新考虑该系统的使用目标以及烟控预定方案，满足具体项目的需要及风险控制。

正压送风在有些方案中可以发挥作用，但不适用于较低建筑（高度低于30米）方案，其应用应相当谨慎。该系统从来也不是逃生通道防烟的万能方法。

large volume required when doors are open. This problem becomes exaggerated in very tall buildings.

There are design solutions intended to overcome the problems of balancing air flows and door opening forces. These range from simple weighted dampers to complex variable drive fans or damper arrangements linked to pressure sensors within the shaft. However, even with these arrangements there are still practical limits to the height of shaft that can be pressurized.

Some guidance documents for pressurization design recognize this practical height limit, such as the ASHRAE Design Manual for Smoke Control. This leads to recommendations that in very tall buildings, the stair enclosure may need to be split into a series of stacked, but separated shafts. However such guidance is not recognized in all building codes, and the implications on stair enclosure size may be overlooked by designers. For example the BS EN 12101-6 includes none of the reservations on maximum height of any given section of core.

Pressurization systems emerged as a popular design solution initially in the US, a country where there is a strong manufacturing and servicing base for mechanical systems coupled with legislation to ensure that building owners maintain life safety buildings. As a result of this, the reliability of pressurization systems should be highest in the US or similar territories. Despite this, a study by Lay (1996) drawing on the experience across a range of fire safety professionals, product manufacturers, building occupiers and researchers, estimated that 35% of pressurization system might fail to function as intended. Tamura (1992) found that none of the field tested systems that were studied actually performed as originally intended.

Data from the CTBUH (2010) confirms that high-rise development in emerging economies over the last decade has overtaken tall building projects in the established 'western' economies. However, some emerging economies have less robust inspection, maintenance and general building management regimes than those in established economies. Often fire safety enforcement in emerging regions is reactive, seeking prosecution after an event, rather than proactive or preventative. In some regions, these challenges are recognized such as the cautious acceptance of pressurization within the Indian NBC (2005), but in the main, technologies have been transferred internationally without proper regards for the legacy resources that are required to ensure continued safe operation.

Recognizing the Challenges for Pressurization Systems

It is fair to note that guidance documents such as NFPA 92 and the BS EN 12101-6 include recommendations for many of the challenges encountered by pressurization systems to be taken into account by designers. These guides note that considerations should be given to additional smoke control elements such as floor plate extract in tandem with pressurization, or the use of vestibules as well as pressurized stairs. However, these additional considerations are not universally repeated in the guidance provided in all jurisdictions. It is also evident that even where such considerations are noted, they are sometimes ignored by building designers because they add complexity to the design or impact on building efficiency.

There is an inherent expectation by some designers that following the simple calculation processes in design standards will lead to an acceptable design, without tackling some of the trickier design challenges. There is also little value in statements in codes which require the designer to make the contractor or building owner aware

防烟设计要求在建筑设计初期可说明，形成安装必须遵守的规范，在建筑使用期间发挥正常功能，且在操作地区获得健全的法规支持。适当解决方案不是修改该系统设计的简单计算得来的。相反，要求提出满足保护居住者和消防人员目标的性能化设计方法。

近年来，在英国采取的设计方案已在很多案例中取消正压送风设计，而采用基于风交换率或“冲洗”式控烟系统的性能化设计。荣获世界高楼协会（CTBUH）奖项的英国曼彻斯特的比瑟姆塔安装的正是这样的系统（见图1）。

比瑟姆塔系统通过进风井向任何选定楼层的一般住宅走道直接送风。自然送风道同时开启。该系统设计提供楼层底部设备层进风口，顶层设置出风口。这样，气流向上流动，通过防烟走廊，最后由屋顶出风口排出。建筑自然竖向布局配合该系统，风的影响加强系统性能，且该设计不会形成开门压力。

测试发现，比瑟姆塔系统在未使用任何机械风扇协助的情况下性能发挥约70%。该设计在维护不当的情况下仍可提供适当性能。同样，发现该系统对于送风设备的需求为正压送风系统所需的三分之一。该系统的关键优势在于楼道开门不会对性能造成重大影响，且该系统可同时用于多楼层，使消防操作更具灵活性。

比瑟姆塔的设计概念曾被应用于伦敦的一个项目，该项目最初使用正压送风系统，却发现只发挥所需功能的10%。将相同的机械装置改装成“冲洗”式控烟系统提升了性能。类似方案近年来已应用于大量高层办公、住宅、酒店以及综合开发的设计方案中 。

尽管比瑟姆塔的设计方法与加拿大国家研究委员会（NRC）Tibor Harmathy提出的“排火系统”概念有类似之处，但还是存在很大区别，比瑟姆塔的设计未使用排火系统中下架系统，比瑟姆塔方案中使用了机械送风装置提升性能，特别是当烟气由防火分区渗入通道时，降低灭火或火灾初期产生的烟的温度。而Harmathy探索当地很多分析原理在比瑟姆塔的设计中得到验证。

比瑟姆塔（及其它方案）安装的系统关键优势是大大减少对于漏气途径数量的依赖。这样，即使建筑材料发生变化，建筑设计后期发生重大调整，防烟策略仍然保持不变，减小设计风险。

在孟买的一个项目中，设计师正在考虑采用电梯井正压送风的替代方案，以提升长期性能，并解决200米高电梯井压力过高造成火灾疏散中电梯门操作障碍的问题。

上述案例等性能化系统的优势在于，性能要求可具体体现一些系统故障、未来防护及非标准疏散或消防策略。使很多基于规范设计的正压送风方案无法回答的“发生了该怎么办”的问题得以解决，确保设计方案获得切实的安全性而不是基于假设的安全性。

除了提供更为安全的设计，重要的是，上述方案可提供增加建筑价值的更为节能的建筑设计，减少长期维护成本以及减少初期施工成本。

给设计师及审核机构的指导意见

本文基于实际案例及研究数据，阐述了对用于高层防烟的正压送风系统的可靠性问题。该系统有关的主要问题在于：

- 设计师对于与高层建筑压力系统设计的有关问题不够了解
- 在特定操作条件下对于系统性能的限制
- 长期维护及适应性

建议建筑师、承包商及开发商向具有高层建筑核心筒防护系统设计及调试经验的消防及生命安全专业人员进行咨询。要求设计团队如果提出正压送风系统设计，应提供非常明确的设计限制与假设，同时坚持要求考虑性能化设计的替代方案。目的在于形成综合建筑设计并反映建筑功能与风险的设计方案。

of the restrictions arising from the design of the pressurization systems. This approach fundamentally fails to recognize the practicalities of the building design and construction process, and does little but attempt to indemnify designers against inevitable changes in buildings.

Alternative Solutions

Designers can address the challenges for pressurization systems by reconsidering what the objectives of the systems are and considering bespoke smoke management solutions that match the needs and risks of individual projects.

Pressurization has a role in some schemes, but beyond application to relatively short (less than 30m tall) schemes, its use needs to be very carefully considered. It is not a panacea to smoke protection of escape routes and was never conceived as such.

The challenge is to develop smoke protection solutions which can be specified in the early stages of building design, developed to a specification with confidence that they can be installed without compromise, perform as intended through the lifetime of a building, and achieve an adequate level of robustness for the jurisdiction where they are to operate. Appropriate solutions will not be developed by amending simple design calculations from pressurization codes. Instead a performance-based design approach to meet the functional objectives of protecting occupants and fire fighters is required.

A solution adopted in recent years in the UK has been to move away from pressurization in many cases to a performance-based solution based on air-exchange rates or "flushing" of smoke. The system installed at the CTBUH award-winning Beetham Tower in Manchester is one such system (see Figure 1).

The Beetham Tower system uses an air inlet shaft which can direct air into the common residential corridors on any chosen floor. A natural smoke relief shaft simultaneously opens. The system is configured to provide inlet from a plant floor below the floors served, with the vent to roof. In this way, the air flow route is upwards then, through the corridor being protected and finally out the relief shaft, towards the roof. The natural stack in the building works with the system, wind effects enhance the system performance and the design does not have an adverse impact on door opening forces.

In tests, the system at the Beetham Tower was found to deliver approximately 70% of its performance without any mechanical fan assistance at all. This provides a very robust design as potential maintenance failures are mitigated by a reduced, but still adequate, performance. Similarly, the system was found to need approximately 1/3 of the air supply plant that a pressurization system would require. A key benefit of the system was that opening doors to the stair did not significantly impact performance and the system could be applied on multiple floors simultaneously, giving fire fighters much greater flexibility of operations.

The concept applied at the Beetham Tower was previously applied on a project in London which had originally been constructed with a pressurization system that had subsequently been found to deliver less than 10% of the required performance. The same mechanical plant was adapted into a "flushing" based system to great success. Similar solutions have been adopted on a large number of high rise office, residential, hotel ad mixed use schemes in recent years.

There are similarities in the approach used at the Beetham Tower to a concept known as the "Fire Drainage System" proposed by by Tibor Harmathy at the NRC Canada in 1987 although there are significant differences as the system of downstands proposed in the Fire Drainage System was not employed in the Beetham Tower and a mechanical input was used in the Beetham scheme to enhance performance, particularly for the cooler smoke that could occur from a suppressed fire or during the early stages of a fire when smoke is leaking into a corridor from the fire apartment. However, many of the analytical principles explored by Harmathy were validated in the Beetham Tower system.

A key driver in the system installed at the Beetham Tower (and other schemes) is that they are much less reliant on quantifying the air leakage paths. So even though construction materials changed and the building design underwent significant changes following the initial design stage, the smoke protection strategy remained unchanged, reducing design risk.

On a project in Mumbai, alternatives to pressurization of elevator shafts are being considered to improve long term robustness and address concerns that high pressures in a 200m tall elevator shaft could impede the operation of elevator doors, preventing them from being available to support evacuation in a fire.

An advantage of a performance-based system such as the cases described above is that the performance requirements can embody elements of system failure, future proofing and non-standard evacuation or fire fighting tactics. Many of the "what if this happened" type questions which remain unanswered by code-based pressurization solutions can be addressed ensuring that the design solution proves that safety is achieved, rather than assuming that safety can be achieved.

As well as delivering a safer design, it is important to note that the above solutions deliver a more efficient building design which improves building value, reduces long term maintenance costs and reduces initial construction costs.

Guidance to Designers and Approvers

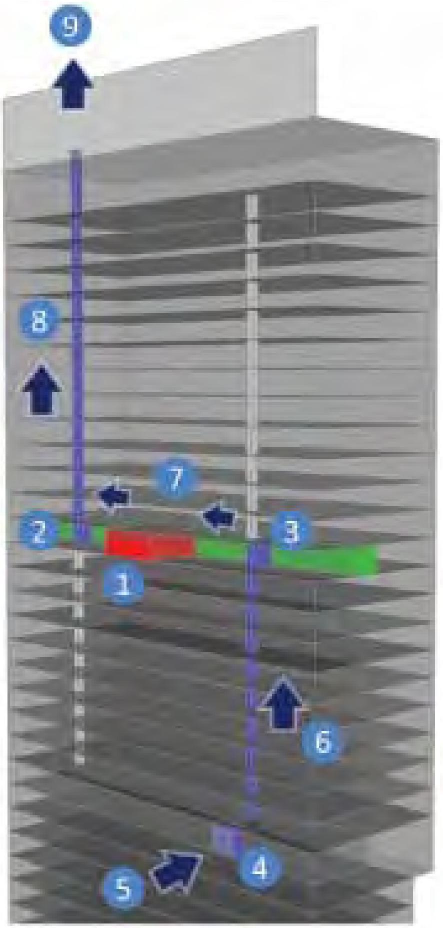
This paper has drawn together anecdotal and research data which raise concerns on the reliability and performance of pressurization systems used for smoke control in tall buildings. The primary concerns relating to such systems are:

- Inadequate appreciation by designers of the challenges associated with designing a pressure sensitive system in a high rise building.
- Limitations on system performance under typical operational circumstances.
- Life time maintenance and adaptability.

To architects, contractors and building developers, it is recommended that advice be sought from a fire and life safety professional with specific experience in the design and commissioning of core protection systems in high-rise buildings. Challenge your design team to set out very clearly what restrictions and assumptions are inherent in the design if pressurization is being recommended and insist that alternative, performance-based options be considered as well. The goal should be to seek out solutions which are integrated into the building design and reflect the building function and risks.

To approval authorities, the advice would be to challenge from an early stage precisely how the building designers and construction teams intend to deliver a pressurization system that performs as intended. It should not be acceptable for a designer to pass the responsibility

In the event of a fire in an apartment (1), smoke will enter the common corridor, activating the system.
With system activation, a damper opens into the outlet shaft (2) and a damper opens from the inlet shaft (3) so that the fire door only is connected to the system.
Fans in the plant room (4) start up and draw fresh air from outside (5) into the inlet shaft.
On the fire floor, the air is forced into the common corridor (3) and then flows along this corridor (7) to the outlet shaft (2) and flow upwards (8) to the outlet vent (9).
The natural stack effect in the building is such that with the fans (4) shut down, there is still a flow through the system, even with cool smoke from a suppressed fire.
Under fire service control, subsequent floors can be connected to the system by manually activating the inlet and outlet dampers on other floors.



一旦公寓（1）内发生火灾，烟气将进入公共楼道激活系统。
随着系统的激活，闸阀向出风井（2）打开，同时闸阀从进风井（3）打开，这样，起火层将只与系统相连。
机房（4）风扇开启，从室外（5）吸风至进风井。

在起火层，向公共楼道（3）送风，然后，沿该楼道（7）流至出风井（2），同时收集沿线着火产生的烟。
被稀释的烟气经过出风井（2）向上流动（8），由出风口（9）排出。
由于建筑内的自然烟囱效应，随着风机（4）的关闭，即使灭火降低烟气温度，仍会有气流通过系统。
在消防控制下，其它楼层可通过相互激活其它楼层的进风和出风阻尼器而与系统相连。

Figure 1. Schematic of the smoke management system at the Beetham Tower (Lay)
图1. 比瑟姆塔的防烟系统图（Lay）

for material specifications and installation on to the contractor unless the contactor has made it absolutely clear that they understand the restrictions and challenges. By insisting on such evidence, designers will be forced to address some of the inherent challenges that pressurization systems face.

Ultimately, tall buildings require a bespoke fire and life safety solution which matches the needs and risks of each building. This performance-based approach will deliver a safer, more efficient design and will address the specific challenges of each individual project creating more sustainable, lower cost, safer buildings.

建议审核机构应在初期提出设计及施工单位如何提供达到性能要求的正压送风系统。设计师将材料规格与安装的责任推给承包商的做法是不允许的，除非承包商明确了解限制与问题所在。通过这样的方式，设计师将必须解决正压送风系统面临的固有问题。

从根本上说，高层建设设计要求提供与各建筑要求及风险相协调的消防与生命安全预定方案。这一性能化设计方法将提供更安全、更高效的设计，并将解决各项目在可持续、低成本、更安全建筑方面的具体问题。

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