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Life Safety DIGEST

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Some ABCs of Smoke Control

What Architects Can Learn From Firefighters

One-Size-Fits-All Engineering Judgments Don't Work

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Maintenance and Management

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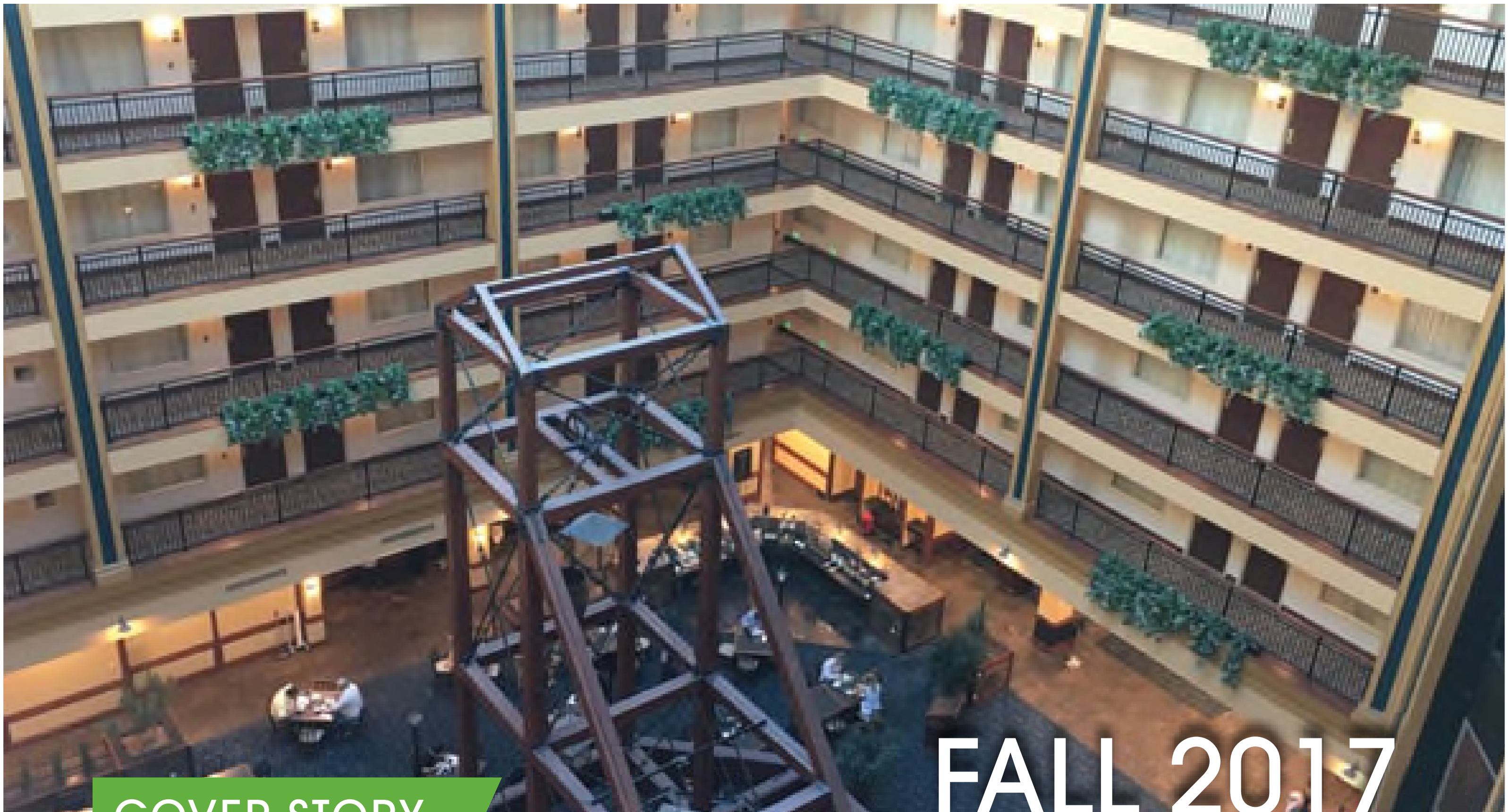

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SOME ABCS OF SMOKE CONTROL

When we think of the dangers of a fire inside a building, we instinctively imagine the spread of flames and heat. However, the bigger threat in a building fire is often the spread of smoke, which can incapacitate victims and prevent them from reaching otherwise accessible exits.[1]

Because of these dangers, the code often requires a smoke control system for large-volume and high-occupant load spaces such as shopping malls, theaters, atriums, airport terminals and sports arenas. Smoke control systems are also typically required in specialized spaces such as smokeproof stair enclosures, underground buildings, laboratories, high-rise buildings and tunnels. As buildings become taller and more complex, with open floor plans and interconnected levels now the norm, the challenge of designing and installing a successful smoke control system has increased. Smoke control is a comprehensive system such that its design and implementation requires a strong collaboration among the design team and contractors. Due to the complexity, it is often beneficial to involve a fire protection engineer with proper knowledge of code requirements, system types and available analysis methods at the beginning of the design process.

In an effort to shed some light on these potentially confusing topics, this article discusses the various design methods available for smoke control systems, as well as some guidance on properly commissioning the systems once installed.

DESIGN

The 2015 edition of NFPA 92, Standard for Smoke Control Systems, includes two basic approaches to smoke control: smoke containment and smoke management.[2] Smoke containment refers to containing smoke to certain compartments through the use of building pressurization and passive compartmentation, while smoke management refers to the control of smoke within communicating large-volume spaces such as atriums. Knowledge of which design method is appropriate for what building conditions is fundamental toward creating a functional and efficient system. The following sections outline each method in more detail.

A Hotel Atrium, SGH photo

SMOKE CONTAINMENT SYSTEMS

This approach is used for zoned smoke control by pressurizing certain zones (stairwells, elevator shafts, vestibules, compartments adjacent to the fire compartment), while potentially depressurizing the compartment of origin. It works by creating pressure differences across smoke barrier walls to control the movement of smoke. The goal of this method is not to maintain a tenable environment in the compartment of origin, but rather to limit the spread, such that tenable conditions are maintained on the non-fire side of the barriers.[3]

The challenge is to develop minimum pressure differences that can limit smoke migration (0.05-in. water gauge is specified in the 2015 IBC for fully sprinklered buildings), while avoiding pressure differences so large that they interfere with the operation of egress doors (which are limited to a maximum door opening force). This is especially challenging in tall buildings due to stack effect. To this end, the computer modeling software CONTAM can be very useful. CONTAM is a multi-zone ventilation analysis program developed by NIST, which is used by fire protection engineers for the analysis of pressurization smoke control systems. The pressure differences across smoke control zone boundaries are predicted in the model by accounting for supply and exhaust fan sizes, leakage areas, temperature, wind and stack effect.

Even with the help of comprehensive computer modeling, sometimes the real-life pressure differences measured during testing are outside the specified design range because of differences between design assumptions and the realities of construction. One way to address such issues is to specify variable drive fans and to adjust them to match the as-built conditions during commissioning. Balancing can also be achieved by adjusting the fan sheaves, undercutting doors and installing door-open devices, with a proper eye on maintaining fire and smoke-rated walls.

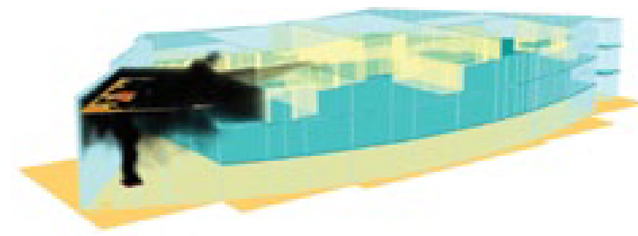
It should be noted that the pressurization method depends heavily on the proper functioning of the smoke barrier walls, floors and shafts, i.e. that these barriers do not have unprotected penetrations or openings that would affect the calculated pressure differences. Proper firestopping is always a critical life safety feature in buildings, but is especially so in buildings utilizing pressure differences for smoke control.

SMOKE MANAGEMENT SYSTEMS

The smoke management approach (also referred to as the exhaust method) has a wide application in large open spaces, such as arenas, atriums and malls. Smoke from fires in such spaces accumulates at the ceiling level and starts to descend as the fire burns. The basic strategy of the exhaust method is to maintain a tenable environment by keeping the smoke layer above a certain level (e.g. 6 feet above a walking surface as per 2015 IBC). This can be accomplished by strategically specifying smoke exhaust at the high points of the space, by creating a reservoir large enough for smoke to accumulate without reaching walking surfaces, by utilizing opposing airflow in communicating spaces or a combination of all the above.

NFPA 92 provides two basic ways to design the exhaust system: algebraic equations and computer modeling. Algebraic equations can be used to calculate the exhaust volumes needed to maintain a certain layer height, and can be very helpful at the early stage of the design process. However, these equations are most appropriate for simple rectilinear geometry (i.e. square boxes) with centrally located (axisymmetric) fires. The equations for balcony spill plumes can over predict the exhaust quantities. This conservatism can negatively impact the space arrangement and limit the architectural design.

In order to more accurately design the quantities and location of exhaust, as well as incorporate complex architectural features, computational fluid dynamics (CFD) computer models such as the NIST-developed Fire Dynamics Simulator (FDS) can be used. Such models represent a more realistic simulation of the smoke movement in the often times complex geometry of interconnected compartments and floor levels. The models can also incorporate specific exhaust and supply locations, as well as time-based functions, such as the opening or closing of doors, windows and vents. These models are used to evaluate the tenability criteria (typically visibility distance, temperature and smoke toxicity) and establish whether occupants can reach safety prior to the onset of untenable conditions.



CFD Modeling of an Atrium

Besides specifying the supply and exhaust and geometric boundaries of the space, the other most important input is the design fire. The design fire quantifies the "load" for the smoke control system, and as such needs to be justified and documented. Fire test data is available and should be used for justification. Because the design fire is a key assumption and will limit the applicability of the smoke control system, the design team should work with the building owner to ensure that a wide enough range of design fires are evaluated in order to provide the owner with the desired flexibility for combustible items (displays, furniture, decorations) that may be present in the space – even on a seasonal basis!

DOCUMENTING THE DESIGN

Regardless of the type of system utilized, a rational analysis is required by code to support the smoke control system method to be used, the sequence of operations and the system equipment. The analysis must also cover the following topics per the 2015 IBC:

- Stack effect;
- Temperature effect on fire;
- Wind effect;
- HVAC systems;
- Climate;
- Duration of operation; and
- Commissioning/testing.

A well-organized rational analysis creates fluidity and continuity during design, construction and commissioning among the architect, contractors, fire protection engineers, mechanical engineers and building/fire officials.

COMMISSIONING

In addition to the typical inspection and test requirements that buildings are required to undergo, smoke control systems also require special inspection. Beyond the code-required special inspection, a comprehensive commissioning process has been shown to be beneficial to verify the proper functionality of the smoke control system in its final installed condition. Such a commissioning process is led by a commissioning agent (CxA) and should follow NFPA 3, Recommended Practice for Commissioning of Fire Protection and Life Safety Systems.

The commissioning process should actually start during design. A commissioning team should be created as early in the project as possible, made up of:[4]

- Owner/owner's representative
- Registered design professional (RDP) for the smoke control system (typically the mechanical engineer)
- Architect
- Fire protection engineer
- Electrical engineer
- Commissioning agent (CxA)
- Contractor and relevant subs
- Building/fire official

Documentation needs to be produced including the rational analysis discussed earlier, a written commissioning plan including commissioning schedule and the associated drawings and specifications for the system. The overall commissioning process goes more smoothly when the commissioning team is active in developing the commissioning plan.

Commissioning happens in phases, not all at once, with some of it happening early, during construction. For example, the special inspections' provisions of the building code require duct pressure testing to be performed. Typically this needs to be performed before the ducts are closed-in so the contractor can fix any deficient conditions noted during the test. Large smoke control systems should have inspections throughout the construction phase to look at the installation of dampers and fans so issues like reversed dampers are identified before the walls are completed.

One item that is often overlooked is that raceway enclosures are required for all control wiring, including fire detection wiring for devices that initiate the smoke control system and BMS wiring if that system manages the smoke control. Architectural features requiring inspection include shaft integrity, firestopping, doors and closers, glazing and smoke partitions.

Example of a Fire/Smoke Damper
SGH photo

Several rounds of operational testing are typically necessary to ensure all devices function and the sequence of operations perform properly, prior to acceptance testing with the AHJ. The whole commissioning team needs to work coherently for this to happen. If done correctly, the approval testing should merely be a demonstration to the AHJ that the system functions as the design and rational analysis specify. Always check with the local AHJ to determine local requirements for acceptance testing.

CONCLUSION

Successful design and implementation of smoke control systems on a project requires collaboration among the project team, including the architect, fire protection engineer, mechanical engineer, electrical engineer, building ownership, contractors and commissioning agent. These discussions should start early in the project. The proper approach to the smoke control design should be selected for the building conditions at hand. Some computer modeling may be helpful to provide a level of refinement to the system design. During construction, the special inspections and commissioning process should be coordinated by a dedicated commissioning agent. With all these components in place, the team is more suited to meet the challenges that come with implementing a successful smoke control system.

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REFERENCES

1. **National Fire Protection Association (NFPA), 'A Reporter's Guide to Fire and the NFPA,' www.nfpa.org, 2016.**
2. **NFPA 92, Standard for Smoke Control Systems, NFPA, Quincy, MA 2015.**
3. **Klote, J.H. "Basics of Passive and Pressurization Systems," Handbook of Smoke Control Engineering, ASHRAE, 2012.4.**
4. **NFPA 3, Recommended Practice for Commissioning of Fire Protection and Life Safety Systems, NFPA, Quincy, MA 2015**