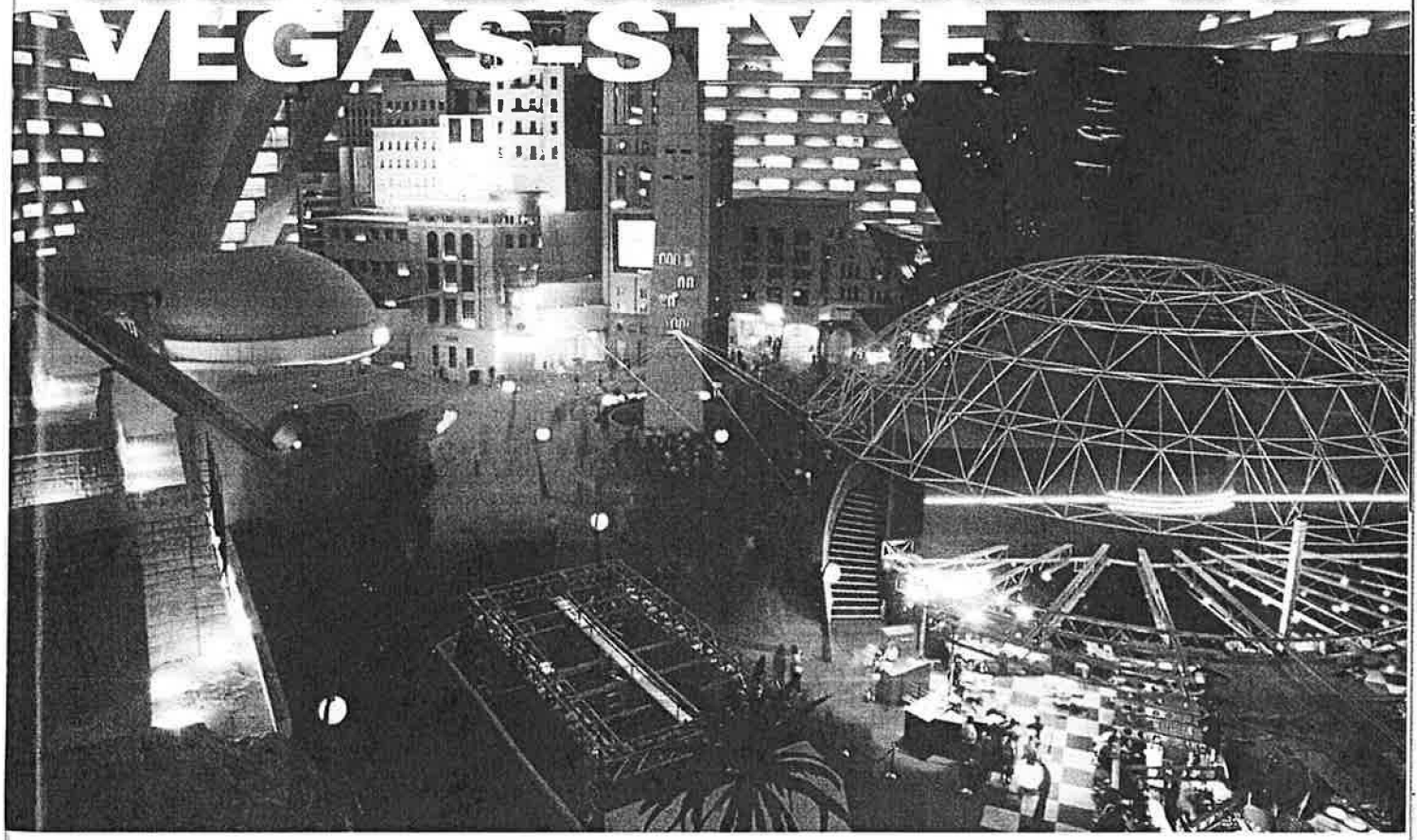
SMOKE MANAGEMENT VEGAS-STYLE



The attractions level of the Luxor Hotel and Casino.

Two Las Vegas hotel and casinos demonstrate new ways of thinking about smoke control

By **DOUGLAS H. EVANS, PE**
Clark County Building Dept.
Las Vegas, Nev.

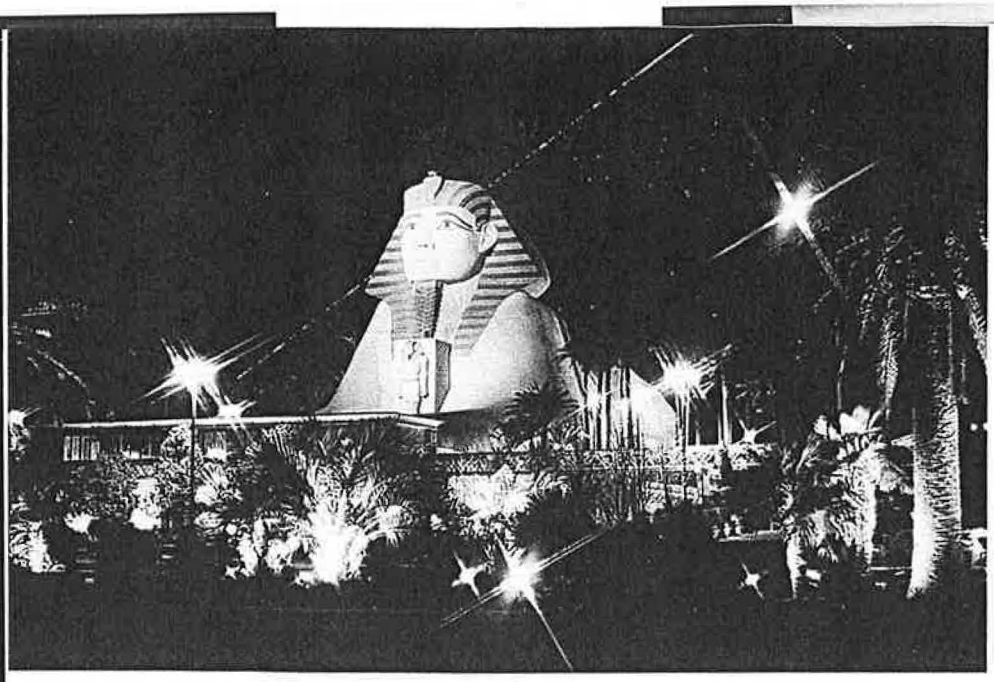
Several of the most unique buildings in the world are located in Las Vegas. Because the architectural designs of these structures are so unique, the mechanical smoke-management systems must be just as unique. This article provides an overview of two unconventional smoke-management designs and demonstrates that buildings need not be unique to warrant different ways of thinking about limiting the movement of smoke.

LUXOR HOTEL AND CASINO

The 30-story Luxor Hotel and Casino certainly is one of the most unique structures in the world. Its principal feature is its pyramidal shape. The interior contains an atrium exceeding 21 million cu ft in volume. Interior dimensions are approximately 500 ft by 500 ft at the base and 120 ft by 120 ft at the uppermost level, which is 200 ft up.

The casino level, which is the ground floor, is located directly below the lowest level of the atrium (the attractions level). The attractions level contains several interior structures, including restaurants and theaters, that are occupiable. Several structures are facades and essentially are unoccupiable.

A member of HPAC Engineering's *Editorial Advisory Board, Douglas H. Evans, PE, is a fire-protection engineer with the Clark County Building Dept. in Las Vegas, where he is responsible for the coordination and review of fire-protection approaches for major structures, including malls, atria, arenas, mega-resorts, and high-rises.*



A southeast view of the Luxor Hotel and Casino.

Balconies, which are open to the atrium on 27 floors, provide access to more than 2,500 guestrooms. A room at the apex of the pyramid contains mechanical equipment.

Smoke-management approach. At the time the facility was being designed, the Uniform Building Code required a minimum mechanical exhaust capacity of four air changes per hour. In atria, the code also required half of the air being exhausted to be mechanically injected upward at the base of the atrium. This translated to an exhaust capacity of approximately 1.35 million cfm and 675,000 cfm of supply.

These prescriptive requirements created several problem areas. The mechanical room at the top of the pyramid would have to be designed to accommodate a large number of fans. Also, a significant wall of exterior grills would be necessary. Since the atrium would narrow as it approached the top, there was the possibility of the upper several levels of exit balconies having excessive air velocity upon activation of the smoke-management system. Stratification of smoke could have limited the system's ability to exhaust smoke and could have caused intermediate levels to become untenable.

One of the main concerns was smoke obscuring exit balconies while it was being drawn upward. Smoke is expected to rise until it contacts one of the exit balconies. That balcony and balconies above can be expected to become untenable.

It appeared that strict code compliance might fail to solve these concerns and actually increase the hazard to occupants on the upper levels. It was agreed that the desired goals more likely would be achieved with a performance-based approach than with prescriptive requirements. Those goals were:

- Maintain a tenable environment for occupants not intimate with a fire.
- Limit temperature and smoke generated by a fire to maintain exit balconies tenable for evacuation purposes.
- Reduce the impact of the stratification of smoke at an intermediate level.

The engineer working with the design team proposed a radical departure from the prescriptive code. He suggested a series of fans and ducts supplying air to the lowest level open to the atrium, oriented so that the entire volume of air would rotate. This rotation would work in conjunction with exhaust fans located in the mechanical room at the top of the pyramid. He theorized that this counterclockwise rotation would cause smoke to be drawn into the atrium void and away from exit balconies while it was exhausted from the apex of the atrium.

The Clark County review team, which consisted of the Clark County Building and Fire departments and third-party peer reviewers, was skeptical that this proposal would achieve the desired goals, but agreed that it would be considered if documentation substantiating the theory were submitted.

Fuel loading on the attractions level also needed to be considered. Because of the height of the space, the attractions level essentially is unprotected by automatic sprinklers. Agreements significantly restricting the combustible load in nonsprinklered portions of the attractions level to no more than 2,110 KW (2,000 Btu per sec) were reached.

To estimate smoke quantity, carbon-monoxide levels, the direction of air movement, and temperature, the design team used several sources.[1, 2, 3, 4, 5, 6]

The FloVENT computer model[1] indicated that this counterclockwise rotation in conjunction with the mechanical exhaust would draw the air mass toward the center of the atrium and up. Alternate calculations were performed to determine/estimate temperature and smoke concentration on exit balconies. These calculations indicated that temperature and carbon-monoxide levels would be within tenable limits 75 ft above the nozzle of the vortex supply fans.

The Clark County review team thoroughly analyzed the proposed design. Several meetings and iterations of the design were necessary to achieve concurrence, which allowed this unique smoke-control design to be conditionally approved. Final acceptance was based on the system's performance during commissioning.

Eight supply fans were installed outside of the building at the base of the pyramid (Figure 1). Their associated ductwork was routed to the interior perimeter portions at the base of the atrium. Each of these fans is capable of providing up to 30,000 cfm at 3,150 ft per min. The discharge was oriented approximately 22 degrees from the horizontal and 11 degrees from guestroom balconies. A total atrium exhaust rate of 400,000 cfm was provided at the apex of the atrium. This combination of exhaust and injection

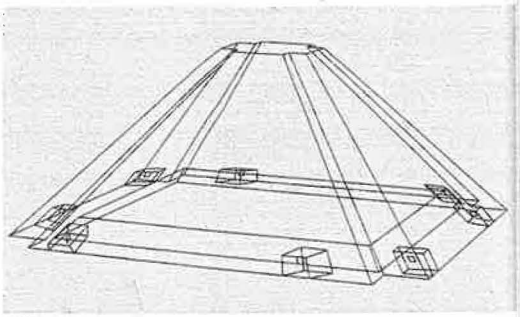
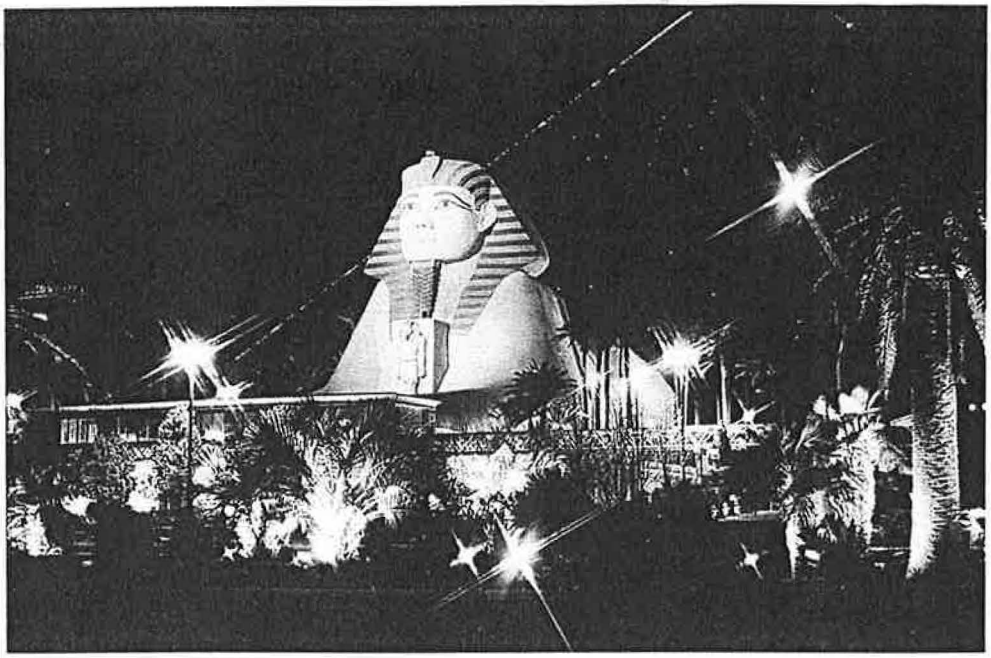


FIGURE 1. A three-dimensional view of the interior of the Luxor Hotel and Casino showing approximate locations of vortex injection fans.



A southeast view of the Luxor Hotel and Casino.

Balconies, which are open to the atrium on 27 floors, provide access to more than 2,500 guestrooms. A room at the apex of the pyramid contains mechanical equipment.

Smoke-management approach. At the time the facility was being designed, the Uniform Building Code required a minimum mechanical exhaust capacity of four air changes per hour. In atria, the code also required half of the air being exhausted to be mechanically injected upward at the base of the atrium. This translated to an exhaust capacity of approximately 1.35 million cfm and 675,000 cfm of supply.

These prescriptive requirements created several problem areas. The mechanical room at the top of the pyramid would have to be designed to accommodate a large number of fans. Also, a significant wall of exterior grills would be necessary. Since the atrium would narrow as it approached the top, there was the possibility of the upper several levels of exit balconies having excessive air velocity upon activation of the smoke-management system. Stratification of smoke could have limited the system's ability to exhaust smoke and could have caused intermediate levels to become untenable.

One of the main concerns was smoke obscuring exit balconies while it was being drawn upward. Smoke is expected to rise until it contacts one of the exit balconies. That balcony and balconies above can be expected to become untenable.

It appeared that strict code compliance might fail to solve these concerns and actually increase the hazard to occupants on the upper levels. It was agreed that the desired goals more likely would be achieved with a performance-based approach than with prescriptive requirements. Those goals were:

- Maintain a tenable environment for occupants not intimate with a fire.
- Limit temperature and smoke generated by a fire to maintain exit balconies tenable for evacuation purposes.
- Reduce the impact of the stratification of smoke at an intermediate level.

The engineer working with the design team proposed a radical departure from the prescriptive code. He suggested a series of fans and ducts supplying air to the lowest level open to the atrium, oriented so that the entire volume of air would rotate. This rotation would work in conjunction with exhaust fans located in the mechanical room at the top of the pyramid. He theorized that this counterclockwise rotation would cause smoke to be drawn into the atrium void and away from exit balconies while it was exhausted from the apex of the atrium.

The Clark County review team, which consisted of the Clark County Building and Fire departments and third-party peer reviewers, was skeptical that this proposal would achieve the desired goals, but agreed that it would be considered if documentation substantiating the theory were submitted.

Fuel loading on the attractions level also needed to be considered. Because of the height of the space, the attractions level essentially is unprotected by automatic sprinklers. Agreements significantly restricting the combustible load in nonsprinklered portions of the attractions level to no more than 2,110 KW (2,000 Btu per sec) were reached.

To estimate smoke quantity, carbon-monoxide levels, the direction of air movement, and temperature, the design team used several sources.[1, 2, 3, 4, 5, 6]

The FloVENT computer model[1] indicated that this counterclockwise rotation in conjunction with the mechanical exhaust would draw the air mass toward the center of the atrium and up. Alternate calculations were performed to determine/estimate temperature and smoke concentration on exit balconies. These calculations indicated that temperature and carbon-monoxide levels would be within tenable limits 75 ft above the nozzle of the vortex supply fans.

The Clark County review team thoroughly analyzed the proposed design. Several meetings and iterations of the design were necessary to achieve concurrence, which allowed this unique smoke-control design to be conditionally approved. Final acceptance was based on the system's performance during commissioning.

Eight supply fans were installed outside of the building at the base of the pyramid (Figure 1). Their associated ductwork was routed to the interior perimeter portions at the base of the atrium. Each of these fans is capable of providing up to 30,000 cfm at 3,150 ft per min. The discharge was oriented approximately 22 degrees from the horizontal and 11 degrees from guestroom balconies. A total atrium exhaust rate of 400,000 cfm was provided at the apex of the atrium. This combination of exhaust and injection

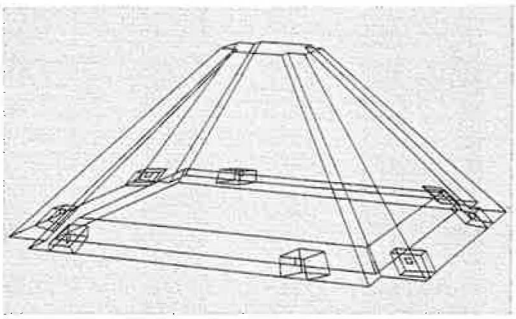
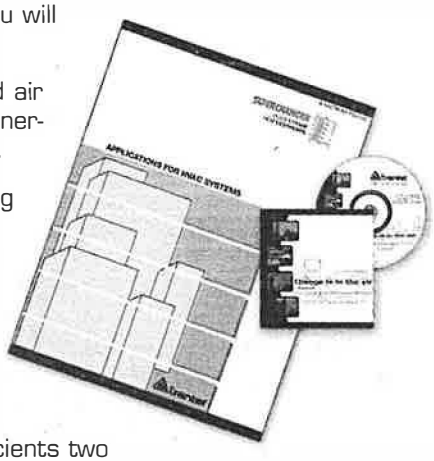


FIGURE 1. A three-dimensional view of the interior of the Luxor Hotel and Casino showing approximate locations of vortex injection fans.

Got Any Ideas for Better HVAC Efficiency?

WE DO!

If you haven't been asked this question lately, it's a certainty you will be, and soon.



The dawning of the 21st century in the heating, ventilating and air conditioning industry is threatened by an old nemesis...rising energy costs, particularly for commercial and institutional buildings.

Optimizing temperature control to improve productivity is driving a revolution in HVAC system design. A revolution led by Tranter—upgrading old traditional shell and tube technology to plate-type heat exchangers—offering greater efficiency and flexibility.

Our SUPERCHANGER® plate and frame heat exchangers regularly operate at a 1-2°F temperature approach, compared with a shell and tube's 8-10°. Turbulent flow created by SUPERCHANGER corrugated plates offers heat transfer coefficients two to five times greater than in conventional systems. The result? Retainable heat often reaching 90%.

From cooling tower isolation to "free cooling," to waste heat recovery, solar collection and numerous other successful heating and cooling applications, SUPERCHANGER units are providing optimum efficiency in heat transfer.

Need better ideas for efficiency in your HVAC system? We've got 'em!

Contact us. We'll send you our latest HVAC Applications Bulletin chock full of heating and cooling details, along with our company CD. Next time someone asks if you have any ideas for greater efficiency, you'll be able to say, "I certainly do!"

Visit Us at AHR Expo 2001 Booth #4520

TRANTER®

A DOVER DIVERSIFIED COMPANY

Tranter PHE, Inc. ▲ P.O. Box 2289 ▲ Wichita Falls, TX 76307 ▲ (940) 723-7125 ▲ Fax: (940) 723-5131
http://www.tranter.com ▲ E-mail: sales@tranter.com

650435

Circle 347

ports creates a high-velocity air stream parallel to guestroom balconies, which results in a low-pressure area that draws smoke into the atrium for exhausting through the apex. This design provides fewer than one air change per hour.

The atrium smoke-management system activates whenever water from an automatic sprinkler flows in the atrium, including on an exit balcony; any two of the more than 2,000 area smoke detectors installed on the exit balconies operate; or any one of 24 beam smoke detectors located in a structure in the center of the attractions level is activated. Manual overrides are provided in a protected room (fire command center, or FCC) specifically designated for fire-department emergency response.

Acceptance testing/commissioning. After contractors and designers have confirmed that a fire-protection system functions as intended and prior to granting occupancy for a major facility, the Clark County Building and Fire departments witness "all-systems" tests. These series of tests are intended to simulate reasonable fire scenarios. A significant portion of the facility is methodically stepped through to confirm the proper functioning and coordination of all fire-protection systems.

During testing of the atrium smoke-control system, a 2,110-KW (2,000-Btu-per-sec), 10-ft-diameter propane burner was moved to the attractions level. Theatrical smoke was injected into the heat plume generated by the propane burner to visually verify air movement. Through visual verification, as well as a review of output from carbon-dioxide monitors and thermocouples placed at 12 locations on the exit balconies, it was determined that the atrium system functioned as indicated by the models. Proper configuring of all dampers, fans, and other operating equipment also was confirmed. Status and manual overrides were confirmed from the FCC.

To simulate a guestroom fire with the door blocked open, the engineer of record injected theatrical smoke onto an intermediate-level balcony. While the air mass was rotating, the "floor of origin" was relatively clear. The theatrical smoke did not adversely impact alternate floors. Smoke was drawn into the atrium and exhausted through the apex. Without the air mass rotating, the theatrical smoke impacted not only the floor of origin, but the balconies above and below.

During an alternate test, theatrical smoke was injected into one of the corners of an exit balcony where the exit stairs and elevator lobbies create a partial enclosure. Initially, the smoke was so thick that visibility was reduced to approximately 3 ft. Within a couple of minutes, the rotational air mass drew smoke from the enclosed portion of the balcony into the atrium and toward the exhaust fans to the extent that visibility was increased significantly.

MGM HOTEL AND CASINO

The MGM Hotel and Casino boasts more guestrooms than any other hotel in the world (more than 5,000). A few years after it opened, the owners decided to add a four-story atrium with a domed skylight above a garden-like central court. This portion of the facility was to contain 25 guest suites, each ranging in size from 8,000 to 12,000 sq ft. Each suite was to be a single level with windows and private balconies opening onto the central court.

To make these "villas" as comfortable as possible, the designers decided on operable windows and doors from the suites into the atrium on all four levels. These doors and windows were proposed to be neither fire-rated nor self- or automatic-closing. The prescriptive codes adopted at that time were the 1994 Uniform codes, which specifically required the separation between guestrooms and the atrium to act as a smoke barrier; therefore, the proposed arrangement was not allowed.

Smoke-management approach. To justify this arrangement, the fire-protection engineer of record proposed mitigating measures to provide the level of protection intended by the prescriptive requirements. Since all exits above the atrium floor were independent of the atrium, using the atrium void as a smoke reservoir was proposed. Approximately half of the mechanically supplied air would be injected into the guest suites, with the remainder injected at a low velocity near the atrium floor. All exhaust fans were located at the top of the atrium.

This design concept was dependent on the area of fire origin. In other words, the smoke-management scenario would be different depending on where the fire started. To compensate for this, the automatic sprinklers protecting the suites were zoned independently of those protecting the atrium space. Beam-type smoke detectors were installed at two levels within the atrium to help compensate for strati-

The front entrance of the MGM Hotel and Casino.

fication. In addition, area-type smoke detectors were installed in the suites at openings into the atrium, as well as within each sleeping room. Using these initiating devices, the supply air could be deactivated within the suites on the floor of origin if it were determined that the fire originated within one of those suites.

Automatic sprinklers were installed just below the atrium skylight, approximately 110 ft above the floor. At this height, the automatic sprinklers were not expected to adequately control a fire on the floor. Therefore, a thorough analysis of reasonable fire scenarios on the atrium floor was conducted. Because of the limited combustible load, it was determined that fire size would not exceed the minimum fire size of 5,275 kW (5,000 Btu per sec) required by the Uniform Building Code. Doubling this fire size for a factor of safety, the smoke-plume dynamics were estimated, and the exhaust fans were sized to provide at least 300,000 cfm. This design is expected to contain smoke from the maximum design fire at a reasonable level above the atrium floor; however, it is not sufficient to maintain smoke below the upper guestroom levels.

The quantity of supply air into the suites was proposed to be limited to a maximum, based on all of the doors and windows being open. To restrict smoke migration from the atrium into the suites, the minimum velocity of supply air needed from the suites through these openings was estimated to be 130 ft per min, which was less than the 200-ft-per-min limit believed to impact plume dynamics. If all of the doors and windows were closed, the pressure in the atrium would be negative relative to the guest suites, which also would restrict smoke migration into an uninvolved suite.

This arrangement is expected to protect occupants whether they are on the atrium floor or in an uninvolved suite by maintaining smoke above the atrium floor and restricting smoke migration into an uninvolved suite. This approach allows occupants to remain in uninvolved suites or safely evacuate the building.

Acceptance testing/commissioning. Airflow and pressure differences were measured at various locations throughout the addition. Initial testing showed that the system was not performing as expected. After the problem areas were identified, corrective measures were implemented. It then became apparent that the system was not capable of living up to the originally approved design concept. After it was determined that reasonable modifications to the system were not an option, the design concept was reconsidered.

The system described above was the final design accepted. This example not only illustrates a unique approach to managing smoke, it serves as a reminder that we must not lose sight of our initial goal. In this case, the principal objective was to reduce the potential for smoke migration into an uninvolved suite and maintain the atrium floor for safe evacuation. If it appears that our first attempt to meet our goal has failed, maybe we only need to change the way we think about achieving that goal to realize the simplicity of the solution.

REFERENCES

1) FloVENT. Building Services Research and Information Association and Flomerics. UK.

2) ASHRAE. 1989. *Handbook of fundamentals*. American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc., Atlanta, GA.

3) Purser, D.A. 1988. "Toxicity assessment of combustion products." *SFPE handbook of fire protection engineering*. Society of Fire Protection Engineers, Bethesda, MD.

4) Klote, J.H. 1988. "Smoke control." *SFPE handbook of fire protection engineering*. Society of Fire Protection Engineers, Bethesda, MD.

5) NFPA. 1988. *Recommended practice for smoke control systems*. NFPA 92A. National Fire Protection Association, Quincy, MA.

6) NFPA. 1991. *Guide for smoke management systems in malls, atria, and large areas*. NFPA 92A and 92B. National Fire Protection Association, Quincy, MA.