humidity, building pressure with respect to outdoors, heating and cooling system performance, occupant comfort, energy use, and IAQ. The relative importance of the leaks depends on two factors: the amount of air that is leaking and where that air is coming from.

In their report, the authors focus on return-side leaks, because the building cavities are almost always used as return air ducts. They explain that the amount of leakage depends on two main variables: the size of the holes in the distribution system and the pressure differentials that exist across the holes. Return systems are almost always very leaky and, consequently, if large pressure differentials exist, then the air leaks will be very large. The impact that these leaks have on indoor conditions also depends on two variables: the amount of air entering the system and where that air comes from. The second is crucial because it determines the thermal condition of the air. For example, if the air comes from within the conditioned space, it will have a negligible impact on the system. However, if the air comes from outside the conditioned space — such as a vented attic — it can have a very large impact on the indoor conditions.

Recommendations

Recognizing the pitfalls involved in using buildings cavities as return ducts, the authors make three recommendations for designers to consider:

- Use only cavities that are located inside the conditioned space. This is to prevent the ducts from drawing air from outside the air and thermal boundaries. There also shouldn't be substantial leaks from the ducts to rooms or other cavities that may, in turn, draw air from unconditioned spaces.
- Ensure that plenum depressurization can be maintained at 1 pascal or less with regard to unconditioned adjacent spaces. This will result in few negative consequences. Ceiling spaces would meet this criterion. Other spaces could be designed to comply.
- Ensure that construction and maintenance practices maintain air tightness in the ducts, although this is more difficult to achieve. Construction practices for building cavities aren't comparable to standards for ducts. However, even if these cavities are airtight when constructed, subsequent workers often cut holes for such things as plumbing and electrical access. Unless these holes are later sealed, they will compromise the air tightness of the system.

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Case Study

*(In each issue, **IEQS** presents a case study on an indoor air investigation in a particular building. The information in the cases comes from various sources, including published material, reports in the public record, and, in some cases, reports supplied by the consultants involved in the case. **IEQS** presents a variety of approaches to investigation and mitigation implemented by consultants with a broad range of experience, philosophies, and expertise. Inclusion of a particular case study in the newsletter does not imply **IEQS**'s endorsement of the investigative procedures, analysis, or mitigation techniques employed in the case. **IEQS** invites readers to submit comments, suggestions, and questions concerning the case. At the discretion of the editors, correspondence may be presented in a future issue.)*

Unplanned Airflows Can Cause Perplexing Problems in Buildings

Even the best plans can go astray. Experience has shown us that unplanned airflow in buildings can provide pollutant pathways and degrade IAQ, sometimes despite the best efforts of those managing the building. Terry Brennan of Camroden Associates (Westmoreland, New York) says the results of the unplanned airflow can occur under various conditions: continually, periodically, or when dynamic systems change from stable to unstable operations.

According to Brennan, a building is a distributed-resistance airflow network. For the most part, air movement through HVAC components and throughout the building is planned and a part of the system design. However, unexpected factors — leaks in the building envelope, pipe chases, electrical conduits, open doors, and leaky windows — can all result in air moving in ways that aren't intended, and carrying pollutants into occupied spaces.

Any of four conditions can result in this unintended airflow:

- An opening in a building component where there should be a barrier
- A barrier in a building component where there should be an opening
- The building zone being positive or negative when it should be the opposite
- An unanticipated force producing pressure differences in the building

Brennan and colleagues presented a paper on this phenomenon at *Healthy Buildings '97*, and gave four short case studies to illustrate their point. We have adapted this report from that paper.

Case #1

The first case involves a school building that consists of three stories plus a basement. When workers spread a styrene-based sealer on the first floor of an adjacent unoccupied space, school occupants began experiencing reactions, and officials had to evacuate the school. One reason for the problem was a cold ambient temperature — –2°C (28°F) — that created a negative pressure situation in the school building.

The contractor had assumed that the school would be under positive pressure because it received outdoor air from a rooftop air handler. The contractor had also made the extra effort to seal the work site with polyethylene film and to seal cracks and openings between the work site and the school. After occupant complaints began, workers set up a fan to introduce more outdoor air (O/A) into the work site in an effort to stop the migration of contaminants into the school building. While this offered some dilution in the work site, it did nothing to stop the flow of pollutants.

Consultants remediated the situation by turning the fans around to draw air out of the work site, thereby putting it under negative pressure relative to the school. This prevented the transport of contaminants from the unoccupied to the occupied space. The consultants also met with all parties involved to explain the basic principles of managing contaminant flow through pressure isolation. According to Brennan, this was a simple case of air, powered by an unintentional force, flowing through unintentional openings and transporting contaminants to an occupied space.

Case #2

In a storefront restaurant located in an urban area, occupants were complaining of IAQ problems. The restaurant and adjoining commercial kitchen prepare and serve meals for people with various illnesses, including chemical sensitivity and environmental illnesses. Some of the participants in the program were complaining of symptoms they believed were related to being in the building.

An initial survey revealed that a kitchen exhaust fan had been installed improperly. The consultants found that installers had connected the exhaust duct to the fan fitting with 32-millimeter (1.25-inch) sheetrock screws, preventing the backdraft damper from opening. This meant that the air entered the center of the grille and exited from the edges. Brennan says this resulted in a barrier where there should have been an opening.

Because proper exhaust was lacking, cooking-related and other contaminants built up in the restaurant. Environmental monitoring showed that carbon dioxide concentrations were 2,400 parts per million 20 minutes after cooking had stopped.

On further investigation, consultants found that O/A entered the mechanical room through the fascia on the street side — an unintentional airflow — when the mechanical room door was closed. They also determined that the airflow from the supply diffusers in the occupied space was 30% O/A when the mechanical room door was closed and zero when it was open more then 8 centimeters (3.2 inches).

The mechanical room contained a warm air furnace that supplied air to the dining area through ductwork and a return air grille through an adjoining wall with no ductwork. According to the consultants, when the air handler was running and the door was closed, the mechanical room was under 20 pascals negative pressure. Because areas of the ceiling had been removed to run the ductwork, air entered the ceiling cavity from outdoors and from the upper portion of the building. This possibly resulted in contaminants moving from other parts of the building into the dining area. In this case, the occupants remedied the problem by moving to another facility.

Case #3

The third case involves a library and office building, which is connected by tunnels to two other buildings. In this case, the complaints in the library building resulted from the accidental consequences of intended airflows in all three buildings, as well as an opening where there should have been a barrier.

The investigation came about after several years of occupants complaining of diesel odors in the areas adjacent to a loading dock. Building managers had already attempted to eliminate the problem. They had installed ducted exhaust fans to collect the diesel fumes from the loading dock and had made efforts to isolate the building from the loading dock area. They also attempted to keep the main entrance foyer under positive pressure by blowing in air from the building. Other efforts included disconnecting air handlers that drew air from some of the rooms adjoining the loading dock. When the consultants conducted pressure tests, they discovered that the rooms adjoining the loading dock were under 4-14 pascals negative pressure relative to the dock. This was surprising, because based on O/A and exhaust air rates they had expected the building to be under positive pressure. The air handlers were operating as intended and there was no stack effect. On further inspection of the tunnel that connected the complaint building to the other buildings, the consultants found that about 4,000 liters per second (500 ft^3 per minute) of air was moving down the tunnel away from the building. The two other buildings were running under negative pressure because they had exhaust-dominated ventilation systems.

The tunnels carried significant traffic, as well as a book conveyance system. This meant that a physical barrier would be impractical. Consequently, the consultants recommended three steps to alleviate the problem:

- Pressurize the room adjacent to the loading dock, using corridor air and small transfer fans.
- Relocate the loading dock exhaust fan inlets to locations where the loading dock ceiling was stained by soot.
- Use the disconnected air handlers to wash loading dock walls with O/A to provide better conditions for workers there.

Case #4

A town hall in the northeastern US was experiencing high energy bills, moisture damage in the attic, and severe ice dam problems. The building is located in a village near a lake.

The consultants found that during construction the contractor had suggested mechanical system changes that he believed would save money on the installation. Original design had called for the mechanical equipment to be located within the conditioned space. The change relocated the equipment to the well-ventilated attic and changed the attic and ceiling detailing. The investigation revealed that this move caused significant equipment inefficiencies due to heat transfer between the attic and the ducts and air handlers. The changes also made it virtually impossible to effectively seal the conditioned space from the vented attic.

Pressure testing revealed that the building shell had a leakage of 6.1 ach at 25 pascals and an effective leakage area of 11,926 cm^2 (1,900 in^2). According to Brennan, this was a case of a building having holes where there should have been barriers, as well as having mechanical equipment in an inappropriate place.

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News and Analysis

Standard 62 Committee Considers Operations and Startup

The committee revising ASHRAE's Standard 62, *Ventilation for Acceptable Indoor Air Quality*, has approved a second package of addenda to the standard, now under "continuous maintenance," and those will go out for public review shortly (see ***IEQS***, August 1998). Now, the committee is considering another package, which will include requirements for cleaning of outdoor air, and new sections on operations and maintenance, and construction and startup. The new addenda package was still under discussion at our deadline for this issue,