Persily didn't see the consensus issue as a major roadblock, although he also seemed unclear on how to resolve major technical disagreements without going out for public review. "The idea is that you'd better make sure you resolve all controversy before you go out for public review. If you can't, you need to try harder. If you still can't, and it's a policy issue, you need to go to the board." Persily said he saw the directive as an effort to deal with big controversies sooner rather than later.

ASHRAE's own statement announcing the streamlined process invoked the idea of consensus building, but was unclear on the process that would lead to such a consensus before public review. Instead ASHRAE said it would require only a two-step approval process, as well as a shorter public comment time and a greater use of the Internet.

According to ASHRAE, the public review period will go from the current 60 days to 30 days. Also, the society will accept comments by e-mail and will use its Web site — www.ashrae.org — to keep members informed of standards activities.

### Appeal Denied

The appeal that was denied by the ASHRAE board dealt with the removal of the words "a moderate amount of smoking" from the ventilation rate tables in the standard. Several tobacco and business groups had objected to the removal. This means that the addenda involved can now go on to the American National Standards Institute (ANSI) to be incorporated into the standard.

Removal of the words was designed to make it clear that the standard couldn't be met in buildings where smoking was allowed (an exception being buildings where smoking is allowed in separately ventilated areas). However, it's not entirely clear what the final effect of removing the words would be. One possible reading of the standard now is that it is silent on the issue of smoking and, therefore, smoking would be allowed. Other addenda, now in the approval process, deal with the issue of separate smoking areas.

### For More Information

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# Tools and Techniques

## Why HVAC Commissioning Doesn't Work in Hot, Humid Climates

**by George DuBose and J. David Odom III, CH2M HILL, and Philip Fairey, Florida Solar Energy Center**

Moisture-related damage in commercial buildings is a pervasive, costly problem in hot, humid climates. Excess moisture in buildings can stem from failure to control moisture sources, including rain, groundwater, moisture diffusion, and airflows. A growing body of evidence indicates that the most problematic of these climatic moisture sources in hot, humid climates is the uncontrolled flow of outdoor air within the building envelopes. Solving this problem is difficult for the following two reasons:

- Current commissioning techniques cannot accurately predict airflows because they do not measure their driving force. As a result, owners cannot identify potential moisture-control problems prior to acceptance of new buildings.
- Air-transported moisture is invisible and can travel long distances through interstitial cavities in buildings before accumulating and manifesting in such problems as mold, mildew, or corrosion. Thus, moisture-control problems are not easily diagnosed.

Forced-air heating, ventilation, and air conditioning (HVAC) system imbalances can easily induce the negative pressure that results in unwanted airflows through interstitial cavities in buildings. In hot, humid climates, these airflows carry large quantities of moisture into the building envelope from outdoors. If it accumulates, this moisture inevitably results in moisture damage to building materials and components.

The case studies we cite in this article illustrate the complexity of this problem and identify common sources of uncontrolled airflows in commercial buildings. In all of the cases cited, the forced-air HVAC systems were the primary cause of building depressurization and the resulting flow of outdoor air into interstitial building cavities. Examination of the case studies also revealed the following common characteristics:

- Measured building and interstitial cavity pressures and observed airflows contradicted both the design intent and the test and balance reports for the facilities.
- Building depressurization resulted in expensive moisture-related damage, with associated additional, uncontrolled outside air infiltration.
- The diagnostic procedures employed in the studies disclosed sources of moisture accumulation and damage that could not be determined by conventional HVAC commissioning procedures.

Perhaps most important, the diagnostic procedures used in the case studies could be adapted to serve as additional elements of the commissioning process. Employing these procedures would greatly assist architects, engineers, and building owners in ensuring that the design intent of a facility is achieved prior to final acceptance of the building.

## Background

While the relationship between HVAC system design and moisture problems in the exterior building envelope is well known, it only recently has been recognized that a great potential for moisture damage exists at the beginning of a building's life. In 1990, more than a dozen hotels were identified with multimillion dollar moisture-related problems that occurred in the final stages of construction or within the first year of operation.

During the commissioning and the final stages of construction, conditions that promote severe moisture accumulation in the building envelope materials often exist. This damage can be greatly increased if the final stages of building construction occur during the humid summer months. Also, while many HVAC systems are intended to provide the proper pressure relationships between the building and outdoors, these systems often rely on distribution and air control techniques, which may fail to achieve the stated design intent.

A growing body of field evidence indicates that standard HVAC commissioning practices are insufficient to identify system imbalances that often result in the leakage of significant quantities of outside air into the exterior building envelope. In humid climates, this leakage almost invariably results in moisture accumulation and damage within the building envelope and adds a substantial energy load to the building.

In hot, humid climates, leakage of outside air into a building is the most pervasive cause of moisture damage. In a survey of more than 10,000 of its members, the American Hotel & Motel Association found that moisture-related problems are costing more than $68 million annually. The Design Professionals Insurance Company investigated 5,000 construction claims and determined that the most prevalent problems were moisture-related, such as corrosion, building material degradation, and mold and mildew.

## Moisture Control Strategies

Understanding the pattern of moisture accumulation in buildings provides the basis for preventing moisture-related problems when commissioning a building or when analyzing the relationship between HVAC systems and the building envelope. Although mold and mildew growth, staining, and corrosion are the most visible signs of moisture-related damage in buildings, they are only symptoms of the fundamental problem of moisture flows. Thus, controlling the flow of moisture is key to preventing premature degradation of building components.

Moisture-related building damage can result from any of the following events:

- Intrusion of bulk moisture — rainwater and groundwater
- Moisture generated internally by human or operational activity
- Moisture diffusion through building envelope materials
- Leakage of moisture-laden air into a building
- Moisture in ventilation airstream
- Capillary flows

The architectural and mechanical engineering disciplines are responsible for controlling moisture in buildings. Architects are primarily responsible for controlling the intrusion of rainwater and groundwater through the design of the water shedding qualities of the building envelope. While the mechanism of vapor diffusion is based on the engineering principles related to temperature and vapor pressure differences between conditioned and unconditioned spaces, specification and placement of the moisture vapor retarder for the exterior building envelope is normally the architect's responsibility.

Mechanical engineers are responsible for controlling internally generated moisture and moisture in the airstream through designing, sizing, and specifying air conditioning equipment. Airflows induced by the mechanical systems must be controlled so that the potential for airflow across the building envelope is from the cool-dry environment toward the warm-hot environment. Unfortunately, the level of coordination required between the architectural and engineering disciplines to prevent moisture-control problems rarely exists.

## Air Leakage

In hot, humid climates, outside air contains a large quantity of moisture. If outside air is drawn into a building by negative pressures, it travels through the wall system and into the interior space. As the air flows through the wall system and moves past cool, interior surfaces, the moisture in the air condenses and accumulates in the wall cavity. While it is unrealistic to hermetically seal a building envelope, the magnitude and direction of airflows across the envelope can be controlled by construction "tightness" of and pressure gradients across the building envelope. The interrelationship between the forced-air systems and the building construction dictates the pressure characteristics of a building. Any feature that decreases the air barrier characteristics of the building envelope will increase likelihood that the HVAC system will be unable to adequately pressurize the building.

Because airflow follows the path of least resistance, air can be carried down demising walls of an interior space if they are connected to the building envelope. Also, because leaking air can travel long distances through wall cavities, it must be determined whether the HVAC forced-air systems are pressurizing not only the interior of building spaces, but also the interstitial spaces connected to them. Case studies have shown that building spaces can be adequately pressurized, while adjacent envelope cavities are depressurized with respect to the outside.

## Commissioning

The common practice for commissioning HVAC systems in new commercial buildings consists of verifying the following aspects of the system:

- The thermodynamic performance characteristics of individual heating and cooling components
- Airflows in the conditioned air distribution system and in the ventilation air system
- The operating characteristics of the system management and control components

Inherent in this process is the assumption that commissioning procedures will detect differences between the design intent and operating characteristics of the building HVAC system.

A primary cause of air leakage is depressurization of the building by the HVAC system, although most HVAC designs for hot, humid climates have the opposite intent — to pressurize the building. Unfortunately, current HVAC commissioning procedures are unable to accurately determine if the HVAC design intent has been accomplished. This is because these techniques are based on measurements of airflows at delivery and extraction points, such as supply registers and exhaust grilles. Airflow measurements at these points alone cannot properly assess the performance of the HVAC system or its impact on the pressure characteristics of a building because they fail to fully consider air distribution.

For example, the delivery of makeup air for a hotel corridor does not necessarily compensate for the extraction of air from guest rooms by bathroom vent fans. Furthermore, relatively large quantities of air often either leak from or are drawn into the air distribution ducting. Since this portion of the HVAC system is usually hidden from view and difficult to access, its contribution to the airflows within a building is not accounted for by the standard commissioning process.

In most cases, pressure gradients develop in building interiors, chases, wall systems, and other cavities within the building. If uncontrolled, these pressures will induce infiltration of outside air. Present commissioning protocols do not provide for measurement of these pressures. More important, they also do not provide for direct measurement of building pressures that are induced by operation of the building HVAC components.

The startup and shutdown sequence of a complex HVAC system is closely related to the management and control components of the HVAC system. Improper startup sequencing of HVAC systems can result in severe moisture problems. Generally, startup of forced-air HVAC systems in humid climates should consist of the following sequence of activities:

- Operation of conditioned makeup air systems, if applicable
- Operation of all main conditioning units
- Operation of exhaust air systems

Experience has shown that this startup sequence often is reversed and exhaust systems become operational first. This occurs because the exhaust system is the easiest to make functional and because of the belief that drawing air through the building will help "dry out" the structure. This assumption is untrue in humid climates because outside moisture levels typically exceed inside moisture levels. In humid climates, this scenario often results in severe moisture accumulation problems from depressurization of the building. This is especially destructive if the main conditioning units become operational before the makeup air units.

Two techniques — pressure differential measurement and flow visualization — are valuable additions to the commissioning process. These methods are helpful because the measurement of airflows at termination points of forced-air systems is insufficient for determining the overall pressure relationship between a building's interior and exterior. The pressure differential measurement is a direct measure of the driving force for airflows, while flow visualization confirms and verifies the pressure differential measurement.

## Pressure Differential Measurements

Maintaining proper building pressurization is critical in preventing the leakage of outside air into the building envelope. Pressure differential measurements are used to identify the potential for airflows between spaces. Even a very large opening will have no airflow across it unless a pressure gradient (driving force) exists. Conversely, a number of small holes and cracks with large pressure gradients across them can exhibit surprisingly large airflows.

The static pressure difference between a room and its surroundings is determined by comparing time-averaged pressure differential measurements between the room and outside, the room and other interior building spaces (e.g., the hall corridor or adjacent rooms) and the room and envelope cavities that bound the room (e.g., wall cavities, ceiling or floor plenums, and plumbing chases). These measurements are necessary to determine the driving forces for airflow between the room and its surroundings and the direction of airflows in building cavities.

## Airflow Visualization

Airflow visualization (i.e., smoke testing) qualitatively verifies airflow direction with devices that inject a visible gas across an orifice, making airflow visible. Airflow visualization can also be used to determine flow direction when pressure measurements are difficult or impossible to take, such as at junctions between wall and ceiling and floor planes.