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.]*

Building Pressurization Can Affect Possibility of Mold Growth

The following case studies demonstrate the various ways that forced-air systems can significantly affect building pressures. In each case, the authors were contacted to determine the cause of mold growth on interior drywall. Also, in each case, mold growth was determined to be caused by moisture accumulation in the drywall, primarily from the uncontrolled flow of outside air into the building envelope.

Case Study 1: Central Exhaust System

A multistory hotel in Florida experienced moisture damage during the final stages of construction. As shown in Figure 1, the toilet area of each room is exhausted by a roof-mounted ventilator. The corridors on each floor are fed by a conditioned, continuous makeup air system. Cooling and heating is provided by a self-contained, fan-coil, air-handling unit (FCU) in each guest room. This is an air-handling unit with a cooling and heating coil. The design intent of the system was equal balance between the exhaust system and the makeup air system. Conventional testing and balancing of the HVAC forced-air systems showed that the conditioned makeup air system was supplying more air than was being exhausted by the toilet exhaust system. The exhaust air equaled 1,472 cubic feet per minute (cfm) and the makeup air equaled 1,560 cfm.

While the commissioning requirements were satisfied as the forced-air systems were tested and balanced and all airflow delivery requirements had been met, severe moisture problems developed shortly after construction was complete. As the moisture patterns were symptomatic of outside air leakage, pressure measurements were taken between the corridor, the room, the room wall cavities, and outside (see Figure 2). The measurement showed that the building was being depressurized, despite air balance measurements indicating that more makeup air was being supplied than was being exhausted.

The pressure relationship between the interior and the exterior of the building was reversed when the toilet exhaust systems were turned off. For example in Room 606, differential room pressures were reversed from -6 Pascals (Pa) to +5 Pa (see Figure 3).

Airflow Visualization

As shown in Figure 1, the airflow directions were consistent with the pressure measurements. Under normal operating conditions, airflow was from the exterior wall into the corridor and from the stairwell into the corridor. When the toilet exhaust system was turned off, airflow reversed, indicating that the makeup air system was pressurizing with respect to the outdoors and the stairwell.

CH2M Hill Offers Commissioning Guide

Both our Tools and Techniques article and this month's Case Study came from CH2M Hill, which has had extensive experience in dealing with IEQ problems in hot, humid climates. The firm has developed a manual on these problems in conjunction with Walt Disney Imagineering. Titled *Commissioning Buildings in Hot, Humid Climates,* the manual addresses needs of the entire construction team.

The manual, which costs $70, targets moisture and mildew problems that cost owners millions of dollars a year in lawsuits, worker compensation claims, and building renovation. It shows readers how to cost effectively prevent building failures in both new and existing construction.

For more information on either the articles or the manual, contact CH2M Hill, 225 East Robinson Street, Orlando, FL 32801. Tel: (407) 423-0030; Fax: (407) 839-5901.

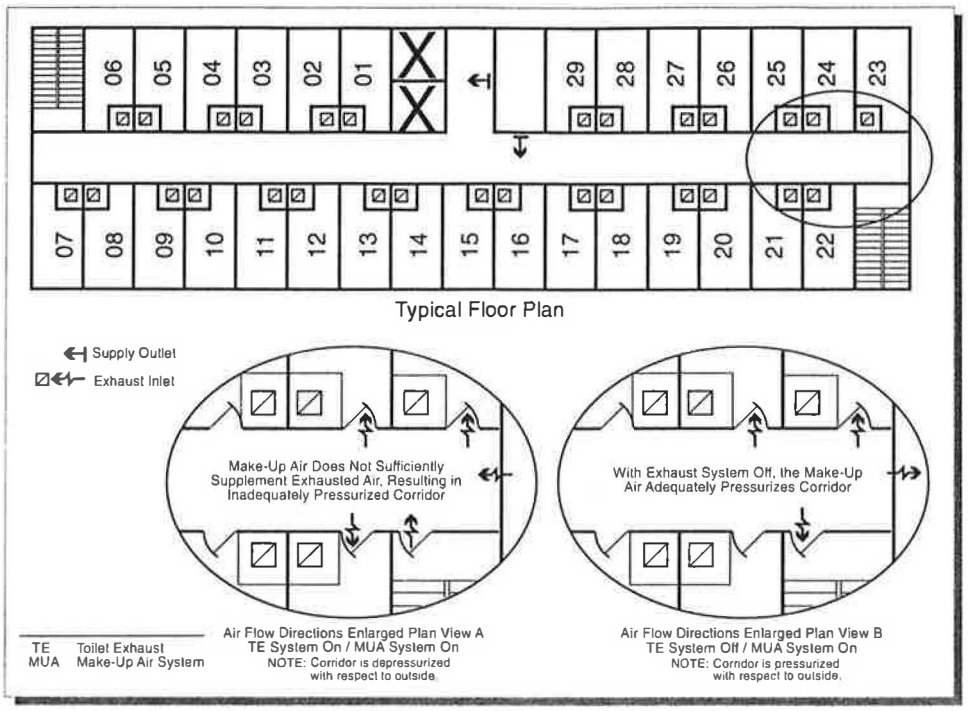


Figure 1 — Despite air balance measurements to the contrary, the HVAC system was not properly pressurizing a multistory hotel in Florida.

This building satisfied typical HVAC commissioning requirements. Airflow volume measurements indicated that the HVAC systems were performing according to their design intent. In fact, according to the commissioning procedure, the forced-air systems should have slightly pressurized the building as more air was being supplied than removed. However, pressure measurements indicated that the forced-air systems were directly affecting all the building cavities and depressurizing the entire building with respect to the outside.

Case Study 2: Building Air Chases Used as a Distribution System

In a central Florida hotel, a medium-rise, twin-tower building connected by a common atrium-style public area, air pressure differential measurements were taken between the rooms and outside, the corridors and outside, and the wall cavities and outside. These measurements were taken to determine if air leakage was causing moisture-related problems in the wall systems. HVAC air balance testing indicated that proper airflows were being delivered to the interior building spaces.

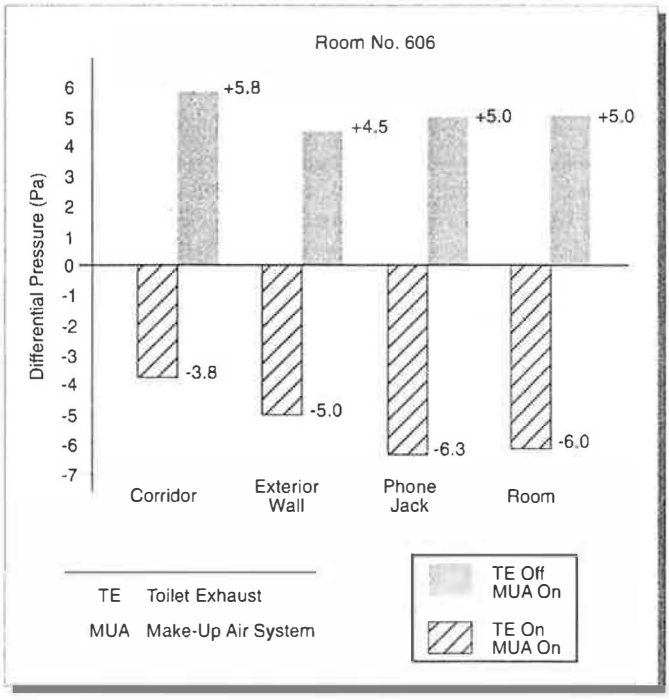


Figure 2 — In case study 1, the average room boundary component pressures were negative with respect to outside under normal operating conditions, causing air to be drawn into the wall system.

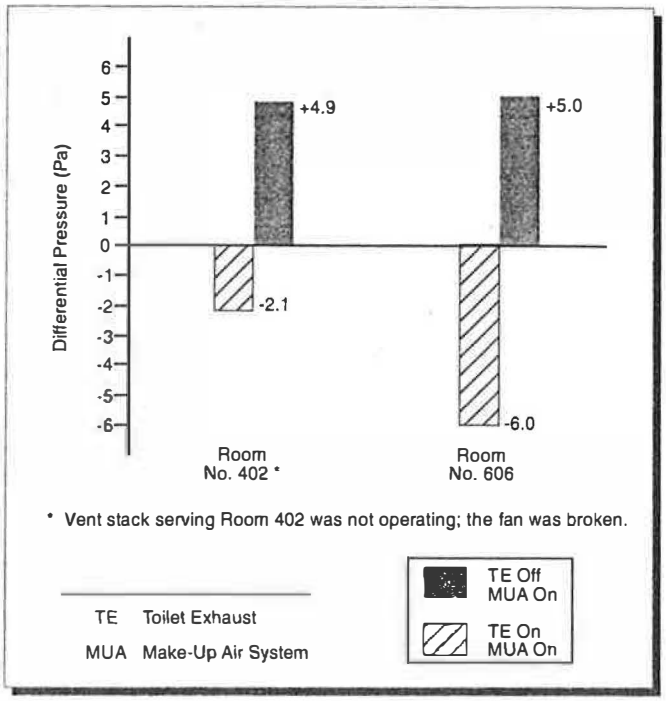


Figure 3 — Another cause of air leakage into the rooms in case study 1 was that room pressures were negative with respect to outside.

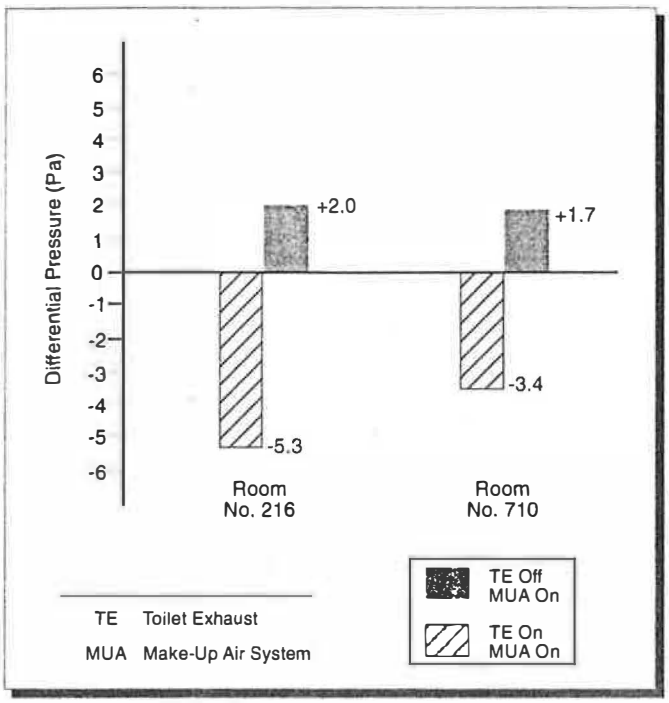


Figure 4 — In case study 2, the average room pressure was negative with respect to outside under normal operating conditions, drawing air into the room.

Normal operating conditions consisted of continuous operation of the toilet exhaust fans; thermostatically controlled guest room air conditioners; a continuously operated, corridor-fed makeup air system; and a continuously operated atrium exhaust fan. The design intent of the guest room HVAC system had the following features:

- Removal of air in the toilet area through the central, continuous, toilet exhaust system
- A corridor-fed makeup air system to replace the removed air (makeup air was intended to enter the guest room through a guest room door undercut)
- An air conditioner designed for thermostatic control to cool or heat the room

Commissioning Techniques

Pressure measurements revealed the following conditions under normal operating procedures:

- The guest room interiors were negatively pressurized compared to the building exterior (see Figure 4)
- The guest room wall cavities were negatively pressurized compared to the building exterior (see Figure 5)
- The corridors were negatively pressurized compared to the building exterior (see Figure 5)

Airflow visualization of the tested rooms supported the pressure measurements (see Figure 6). Furthermore, airflow direction indicated that the toilet exhaust system was directly affecting the demising wall cavity pressures and that the airflow direction was from the rooms to the plumbing chase. Even in the toilet area where the exhaust inlet is located, airflow direction was predominantly from the toilet area to the wall cavity. The pressures also indicate that air entering the exterior building envelope is likely to travel down the demising wall toward the plumbing chase where pressures are lowest.

The use of building chases as exhaust ducts can produce negative pressures within the building envelope. As a result, design airflows can be satisfied in all the building spaces, yet the system can create negative pressures within other connected cavities and chases.

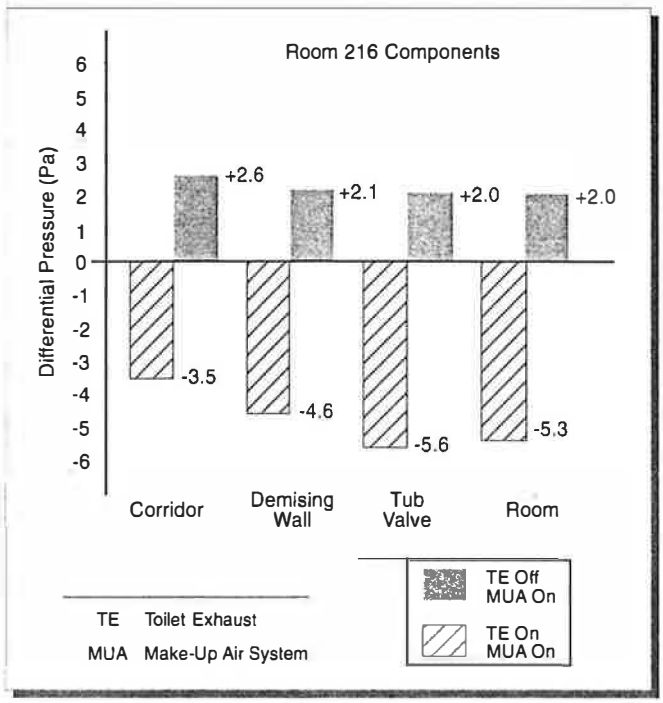


Figure 5 — Negatively pressurized wall cavities also caused air to be drawn into the rooms in case study 2.

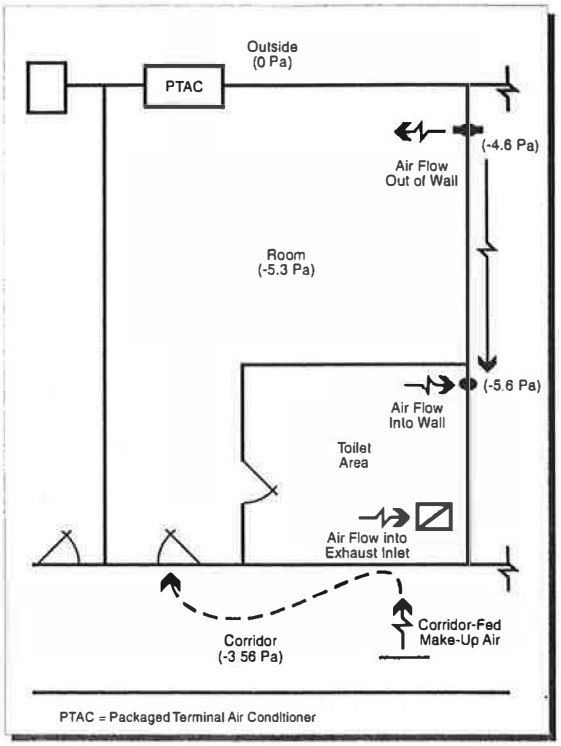


Figure 6 — In case study 2, airflow visualization showed that air was entering the exterior building envelope and traveling down the demising wall.

Under these conditions, the toilet exhaust systems not only depressurize the rooms, but also directly depressurize the plumbing chase and adjacent wall cavities because of ductwork leakage (see Figure 7).

Pressure measurements were also taken with all the guest room toilet exhaust fans off. Under this condition, all areas were pressurized with respect to the outside.

Case Study 3: Leakage at Guest Room Fan Coil Units

Individual space FCUs can also directly affect the pressures of the building interior and building envelope cavities. If the FCU has return-side air leaks, depressurization of the adjacent wall cavities can occur. Pressure differential measurements in this case study identified the potential for individual-space FCU fans to induce outside air in the exterior and demising walls.

Cooling and heating of the building is provided by individual FCUs. The FCU is installed vertically in a small mechanical closet near the entry of each room. The FCU discharge is ducted to a supply outlet. The inlet of the FCU is open to the mechanical closet enclosure with a return grill mounted at the guest room wall to allow return air to enter the closet from the room. Visual inspection of the enclosure showed that it was open to the drop ceiling and adjacent wall. The corridors are fed by a 100% outside air makeup air system. Makeup air is intended to enter the room through the entrance door undercut. The building toilet areas are exhausted through individual, occupant-controlled fans, which operated intermittently.

Preliminary pressure differentials between the room and the corridor were measured. Pressure differentials were measured across each room entrance door threshold with respect to the corridor. For each measurement, the FCU fan was on, which positively pressurized the rooms in relation to the corridor. Since the FCUs are intended only to recirculate room air, the corridor would be expected to always remain at positive pressure with respect to the rooms. Initial results indicated that the rooms had a return-side FCU leak and were drawing air from outside the room, resulting in overpressurization of the room with respect to the corridor. Thus,

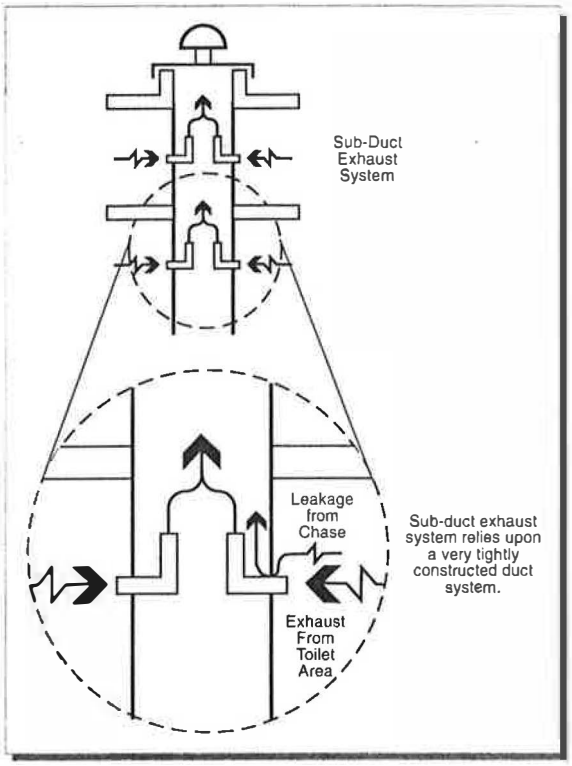
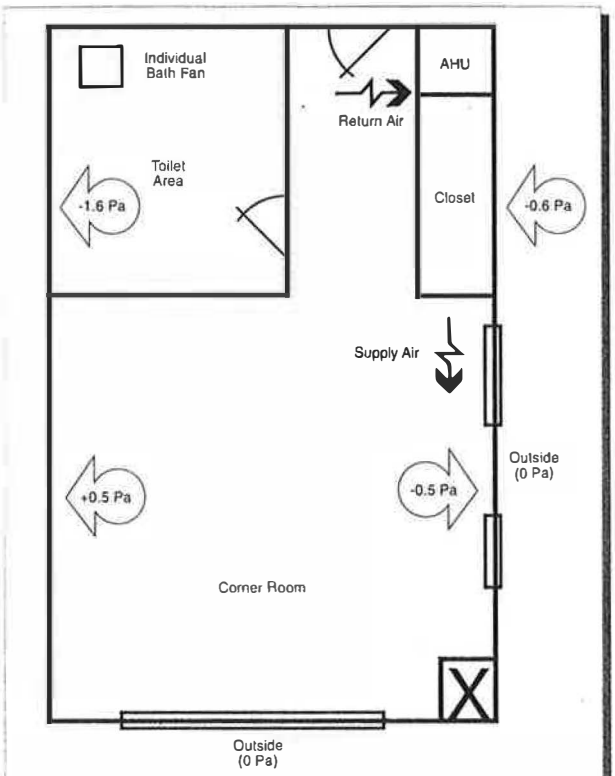


Figure 7 — In case study 2, air leakage from the plumbing chase to the central exhaust duct caused the entire chase to depressurize and draw air through the demising walls from outside.

airflow at the room door threshold was from the room to the corridor, rather than the design intent of from the corridor to the room. As a result, odors from the guest room were often detected in the corridor.

Detailed pressure measurements were taken in several rooms (see Figure 8). For each set of measurements, the outdoor air pressure was used as the reference and was taken with the FCU both on and off. The measurements indicated the room is always positively pressurized with respect to the outdoors; however, the wall cavities are positive only when the FCU is off, and with the exception of one interior wall, all are negative when the FCU fan is on.

Pressure measurements showed that the FCU was drawing air from outside the room because of the suction pressure at the return side of the FCU (see Figure 9). Pressure measurements also showed that many of the wall cavities and ceiling areas of the rooms were negatively pressurized with respect to the outside while the FCU was on. This was true despite the fact that the room was positively pressurized with



Measurement Location	FCU	Room Pressure	Wall Pressure
Outlet at Exterior Wall	On	+3.5	-0.5
	Off	+0.5	-0.5
Outlet at Demising Wall	On	+2.5	-0.5
	Off	+1.7	+1.7
Penetration in Closet Wall	On	+4.0	-0.6
	Off	+2.5	+2.5
Vanity Outlet	On	+3.2	-1.6
	Off	+1.8	+1.6

AHU Air-Handling Unit
FCU Fan-Coil Unit
Pa Pascals

Figure 8 — Case study 3 demonstrates that it is possible to have pressurized rooms and a depressurized wall system.

respect to the outside. Traditional HVAC commissioning techniques would not have measured the pressures that indicate a depressurized envelope wall cavity, which induces infiltration of outside air.

Conclusions

Moisture-related damage in commercial buildings can result in millions of dollars in damage annually and can come from five possible sources of moisture:

- Bulk moisture intrusion
- Internally generated moisture
- Vapor moisture diffusion

- Capillarity
- Air leakage

A primary cause of air leakage is depressurization of the building by the HVAC system, although many HVAC designs 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 current commissioning techniques are based on measurement of airflows at delivery and extraction points, such as at 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 characteristics of a building because they fail to fully consider air distribution.

The startup sequence of HVAC forced-air systems is also a critical aspect of commissioning a building. The proper sequence consists of operating all makeup air systems first, then all air conditioning units, and then all exhaust systems. An improper startup sequence will prevent a forced-air system from performing according to the design intent. If this condition occurs during hot, humid weather, moisture accumulation and mildew can occur within several weeks.

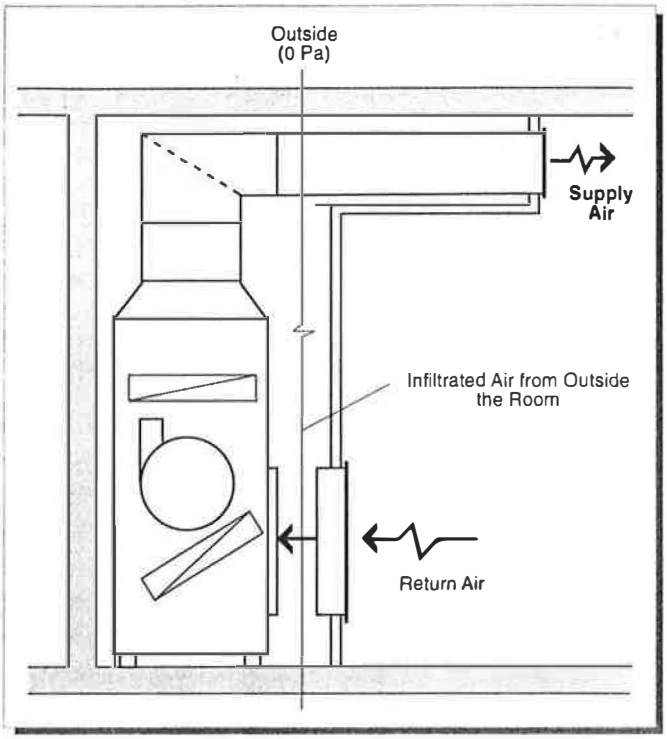


Figure 9 — As demonstrated in case study 3, the return-side leak in the FCU pressurized the room but depressurized the wall systems.

News and Analysis

Veterans Affairs Researcher Finds Gulf War Illness Clusters

Those who advocate for people with multiple chemical sensitivities (MCS) are taking some small comfort in a research report from epidemiologists at the US Department of Veterans Affairs, indicating a cluster of related symptoms among military personnel who were deployed to the Persian Gulf during the 1991 war with Iraq. Gulf War Illness is important to MCS researchers because many of the symptoms are similar, and some believe they were caused by chemical exposures during the war.

The research report came at a conference on Gulf War Illness in late June and was published by Dr. Han Kang, the department's chief epidemiologist. The result of the study of 11,442 veterans found a cluster of symptoms unique to the deployed veterans, which the researchers said could be classified as Gulf War Syndrome. However, one MCS resource group, MCS Referral and Resources (Baltimore, Maryland) has already attacked the veterans department for not following up on the discovery. Albert Donnay, president, said that the department has said it has no plans for further study or other actions to deal with the syndrome.

Kang and his colleagues looked at 11,442 Gulf War veterans and 9,476 other veterans, including mail and telephone questionnaires on various symptoms, exposures, and medical conditions. After looking at various symptom combinations, the researchers discovered a unique cluster that manifested itself among personnel deployed in the Gulf War. This unique cluster included blurred vision, dizziness and loss of balance, shaking and tremors, and speech difficulty. This appeared