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purports to do, and that remains to be generally accepted by the scientific community.

Ionization Not Scientifically Proven

David Veil of the Cooling Tower Institute (CTI) Water Treating Committee told ***IAQU*** that he groups the Electron Pure system in "the category of devices and gadgets. Electron Pure is not one of the many hocus-pocus groups out there trying to sell magic. However, it flies in the face of traditional water treatment. I'm not saying it doesn't work, but it simply has not been scientifically proven, as has chemical treatment." Veil also pointed out that the system requires "buying a lot of equipment up front. If I were approached by the company, I would ask them for the use of the product for a month. Depending on the cost, I would buy it if I found that it works. If it did not work, I would send it back to [the company] at my cost."

Art Brunn, also with CTI, told ***IAQU*** that the CTI's Water Treatment Committee does not currently plan to study the ionization devices.

In reference to ionization systems in general, Thomas Laronge of Thomas M. Laronge Inc., a technical consulting firm in Vancouver, Washington, USA, told ***IAQU*** that, "yes, there are problems; and no, they do not do everything." Laronge, who has been involved in water purification for more than two decades, said that he has seen many companies with similar products for swimming pools come and go: "The market for devices is a wave market, and usually accelerates during recessionary times." He added that there are numerous problems in trying to apply a swimming pool technology to cooling tower water treatments.

The use of Electron Pure brings up another issue: health impacts from copper and silver. Electron Pure corporate literature states that copper and silver do not present a significant health risk. However, federal regulation of copper and silver recently increased; according to Brunn, "silver and copper are becoming two of the most heavily regulated inorganics." How these standards would apply to cooling tower water, which is typically discharged to a sewer system, remains to be seen.

For More Information

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CASE STUDY

*In each issue **IAQU** presents a case study on an investigation of indoor air problems in a particular building. The editorial staff relies on information provided by the environmental consultants involved in the investigation. **IAQU** 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 **IAQU's** endorsement of the investigative procedures, analysis, or mitigation techniques employed in the case. **IAQU** invites readers to submit comments, suggestions, and questions concerning any case. At the discretion of the editors, correspondence may be presented in a future issue.*

Moisture and Mildew in a Florida Health Facility

Less than a month after the construction of a Florida health facility, the building developed severe moisture problems on the interior and interstitial surfaces of its exterior and interior walls. Managers of the building contracted a technical consulting firm to investigate the structure. Encountering extensive mold growth, investigators made several recommendations for improving IAQ conditions in the building.

Building Description

Workers finished construction of the health facility in August 1991. The building is a two-story structure consisting of two wings intersecting in a common area. The building encompasses approximately 100,000 square feet of floor area, composed of Wing A (approximately 40,000 sq. ft.), Wing B (approximately 60,000 sq. ft.), and Unit C, which is a separately ventilated section of Wing A.

Air supply and conditioning throughout most of the building are provided by individual room packaged terminal heat pump (PTHP) units. The PTHP units are located in the walls and run on electricity. The building design calls for several central exhaust systems to continually draw air from the bathrooms. Corridors utilize separate air handling and space conditioning systems.

In Unit C, central systems control both air supply and space conditioning. A central exhaust system continuously draws air out of the wing via the bathrooms.

Identifying the Problem: Moisture

Moisture problems first appeared in early July 1991, while construction workers were still working on the building. Initially, observers noted that wood trim had separated from exterior walls and that condensation was visible around window openings. Subsequently, observers noted that mold was growing through wall coverings and that interior gypsum wall board had become wet. Where vinyl wall coverings were in place, pink blotches showing through were characteristic of biological growth. Biological growth was also evident on painted surfaces of the wall. Complaints of "musty" odors within the conditioned spaces followed. Soon after, mold appeared on exterior surfaces of painted gypsum board and the insides of cabinets.

Biological contaminants, such as mold and mildew, can grow on moist surfaces. In conditions of high humidity (approximately 70%) adjacent to surfaces, spores can germinate. Should they become airborne, they can lead to health problems such as allergies and asthma.

In September 1991, investigators removed interior vinyl wall covering and gypsum board from some of the interior and exterior walls. Excessive mold growth had occurred between the vinyl wall covering and the gypsum board, as well as within the interstitial spaces at numerous locations.

Quantifying the Problem: Testing

The consultants utilized a wide range of investigatory techniques, including:

- Visual observations;
- Air pressure measurements;
- Determinations of the flow rate characteristics of the air-handling systems;
- Air pressurization testing;
- Tracer gas testing;
- Infrared scanning; and
- Rain penetration and rain absorption testing.

Visual Observations

During the investigation, consultants noted mold on the surface of gypsum board and window sill cupping. Mold was noted in approximately half of the rooms in each wing, except for Unit C, where approximately a quarter of the rooms contained mold contamination. During the course of the investigation, it rained. Within an hour, water spots appeared at the ceilings of several first-floor rooms. The water spots were specifically located where the ceiling intersected the exterior wall.

After the rain, investigators removed the vinyl siding and rigid insulation exterior to one of the rooms with ceiling water spots. The structural concrete block wall surfaces showed rain adsorption.

In several rooms, consultants removed baseboard trim, gypsum board, the PTHP units, and their sleeves (a sleeve holds the PTHP in place) to allow for visual observation of the wall cavity. Moisture infestation was visible throughout the wall, and the back side of the trim in both rooms was visibly water-stained and wet to the touch. Gypsum board from the exterior wall was soft and waterlogged.

In two meeting rooms in Unit C, mold growth was evident on the back of the wall covering and on the interior surface of the gypsum board. In one of the rooms, the gypsum board was saturated with water and soft to the touch. Investigators noted that the entire room emitted an overpowering odor.

Investigators found the mold spots in the first-floor rooms at the intersection of the ceiling and exterior wall. Investigators also noted numerous mold spots throughout the rest of the building in similar locations. In addition, mold growth had occurred in bathroom dropped ceilings.

After removing numerous PTHP units, investigators found standing water and microbial slime in the bottom of the pan area of each PTHP sleeve. Many of the sleeves did not allow for proper drainage of the condensate. Though some of the sleeves allowed for proper drainage, considerable amounts of slime and condensate still accumulated in all of the units.

In addition to the exterior walls, investigators observed mold contamination on the interior partition walls and around the ceiling diffusers.

Air Pressure Measurements

Using smoke pencils and digital micromanometers, investigators determined air pressure differentials between the building's exterior, interior (conditioned), and interstitial (wall and other building assembly cavity) spaces. From these measurements, investigators created detailed maps of air pressure fields for the entire facility.

Investigators found that under typical conditions, the entire facility operated under a negative air pressure relative to the exterior. Negative pressures averaged about five Pascals, depending on specific operating conditions, door openings and closures, location, and ambient climatic conditions (wind). Smoke pencil testing indicated that the majority of the interior partition interstitial spaces were leaking air into the conditioned spaces.

Excluding Unit C, smoke pencil and air pressure measurements revealed four more air flow paths than were supposed to occur according to design. These four paths resulted from air leaks into the porous exterior wall and passage to the interior through outlets, under baseboards, through the bathroom dropped-ceiling cavities, and through service openings of the mechanical wall. The unintended air flow in Unit C was similar to the rest of the facility.

Investigators mapped flow paths and air pressure fields with bathroom doors and room doors open and closed. In general, differences in the air pressure relationships between closed and open bathroom doors were minor. When investigators shut down the central exhaust fans, the entire facility went to a slight positive air pressure relative to the exterior.

Measuring Exhaust, Supply and Return Flows

Investigators determined bathroom exhaust air, PTHP supply air, and air handling unit (AHU) flows to assess the nature of air flow in the building. They determined air flows using flow hoods (Shortridge Airdata Flowmeter) and a hot wire anemometer (Solmat).

Exhaust air rates for the building *as a whole* accurately reflected exhaust rates specified in the design. Investigators noted, however, that individual air flows in the facility were extremely varied, from 50%-200% of the original design (code requirements).

By design, around 60 PTHPs were to supply approximately 4,000 cubic feet per minute (cfm) to Wing A. In Wing B, 90 PTHPs were to supply 7,000 cfm. Field measurements indicated that when the PTHPs were not operating, no measurable air flow through the units occurred. Though design called for some variation between individual PTHP air flow rates, the PTHPs were expected to supply approximately 80 cfm. When the PTHPs were operating, they only delivered about 30 cfm of outside air to the rooms.

In a survey of the PTHPs, investigators discovered that the vent dampers had been removed. Investigators then tested the PTHP units with vent dampers, finding a supply air flow of approximately 60 cfm — still lower than the 80 cfm expected. When set in the open position, investigators found that the vent dampers functioned as scoops directing outside air through the openings in the PTHP with the assistance of the PTHP fan/blower. Without the vent dampers, the scoop function did not occur and only minimal outside air was supplied through the PTHP units, even with the fan/blower operating.

According to investigators, some individual AHU supply and return air flows varied up to 25% from design specifications. They noted that a variation of 10% between actual and design flows has traditionally been considered acceptable during HVAC system balancing and system commissioning.

Air Pressurization Testing

Investigators determined the total air flows required to pressurize the facility's interior with portable fan pressurization/depressurization equipment (several Minneapolis Blower Doors). The portable fan pressurization system was typically installed in a corridor/stairwell door with the exterior doors to the stairwell open during the test. Exterior air came into the stairwell and through the test equipment into the corridor. Researchers then monitored the amount of air flowing through the test equipment along with air pressure differences of corridor to outdoor and room to outdoor.

Investigators tested Wings A and B individually. Results of the tests indicated that approximately 4,500 cfm of outside air would be required to pressurize Wing A by one Pascal. Approximately 9,000 cfm of outside air would be necessary to pressurize Wing B by one Pascal.

Tracer Gas Testing

Investigators utilized tracer gas analysis in several sections of the facility. Creating a tent-like structure by covering a portion of the exterior wall with sheet polyethylene, investigators injected a tracer gas, sulfur hexafluoride (SF_6), into the space between the polyethylene and exterior wall. A gas chromatograph inside the room registered the gas within approximately 30 seconds of injection. According to investigators, the quick detection time was characteristic of a porous wall assembly and an inward-acting air pressure. In addition, investigators injected tracer gas into the vented attic. The gas chromatograph in the conditioned space registered the presence of the gas in less than one minute.

Infrared Scanning

Infrared photographs of several sections revealed "hot spots," indicative of infiltrating air flows at numerous construction assembly joints. Infrared photographs also indicated hot spots where the interior partition walls intersected the exterior walls. The hot spots corresponded to mold spot locations.

Rain Penetration and Rain Absorption Testing

Investigators hung a portable water spray rack from scaffolding outside the facility. The water spray rack deposited a film of water over a surface to simulate rain. Investigators also applied an air pressure differential across the wall utilizing portable fan pressurization/depressurization equipment to simulate wind.

At the conclusion of the wetting cycle, investigators removed the exterior cladding and rigid insulation. Water had wetted the exterior surface of the concrete block wall at numerous locations. Investigators did not find evidence of moisture in the rooms at this time. During a subsequent test at another location, investigators found that water had infiltrated into the room.

Findings

Investigators concluded that the migration of exterior moisture into the facility was due to liquid flow, air movement, and vapor diffusion. They made several other key observations:

- The rain-wetted cladding and exterior concrete block walls served to humidify infiltrating exterior air drawn inward by the negative air pressure differences. Continuous operation of the central bathroom exhaust systems induced these pressure differences.
- Even in the absence of rain, exterior hot humid air infiltrated through the porous building envelope due to the inward-acting air pressure difference induced by the continuous operation of the central bathroom exhaust systems.
- When the infiltrating hot humid air contacted cooled surfaces (due to air conditioning), high local relative humidities occurred adjacent to these surfaces, which led to mold and other biological growth.
- Temperature differentials induced by solar radiation and air conditioning resulted in substantial vapor pressure gradients (several times greater than outward-acting vapor pressure differentials in heating climates during winter). This meant that when moisture driven inward by the high vapor pressure differential met with impermeable interior wall coverings or painted surfaces, mold and saturated interior gypsum board resulted.

Investigators found that the building's problems were related to the original architectural design and mechanical engineering (HVAC) design. In addition, the PTHPs did not perform as implied by the manufacturer. Architectural design problems were primarily due to a lack of specifications for an exterior air barrier system and for an exterior vapor diffusion retarder (vapor barrier).

In addition, the specification of vapor impermeable wall coverings in the absence of control of air leakage and vapor diffusion exacerbated the observed moisture problems.

Investigators found a wide range of problems with the HVAC design and operation:

- An inadequate amount of supply air for the building from the PTHP units resulted in a negative air pressure design;

- Central bathroom exhaust systems were specified to operate continuously, while PTHP units were specified to operate intermittently;
- The building design did not take into account leakage of ductwork located outside of the conditioned spaces and its effect on the depressurization of the building envelope; and
- HVAC design did not provide for continuous dehumidification of ventilation and supply air.

The performance of the PTHP units did not meet the manufacturer's published specifications. Problems with the PTHP units included:

- The PTHP units did not deliver the rated supply air flows;
- No warning was provided with the PTHPs stating that supply air only enters through the unit when the blowers are operating;
- Supply air was humidified by passing over a condensate pan with poor drainage features; and
- Dehumidification of supply air did not occur prior to entering the building.

Recommendations

Investigators noted that the moisture problems in the building not only caused indoor air problems, but also significantly increased the operating costs of the building. In addition, the moisture is likely to affect the long-term durability of the building envelope. Investigators found several problems with the building, including rain penetration, vapor diffusion, air-transported moisture, and the faulty operation of the PTHP units. Specific recommendations for remediation included:

- Installing a continuous air barrier system and vapor diffusion retarder;
- Reinstalling PTHP vent dampers in a closed position to facilitate building pressurization;
- Installing of a central supply air system to provide conditioned air to each portion of the building;
- Balancing the continuous central bathroom exhaust ventilation systems;
- Increasing the dehumidification characteristics of the PTHP units by downsizing and increasing duty cycle; and
- Sealing all ductwork located in unconditioned spaces.

For more information on testing protocols and building science investigation techniques, contact Joseph Lstiburek, Building Sciences Corporation, 273 Russett Road, Chestnut Hill, MA 02167, USA; (617) 323-6552.

FROM THE FIELD

An IAQ History of the Cambridge School System

The city of Cambridge, Massachusetts, USA, built the Tobin School 20 years ago during the energy crisis. The school's design reflected the general attitude at the time toward indoor air space: seal it up to conserve energy. While energy savings may have been substantial, for the last several years teachers and students have reported numerous health problems resulting from poor IAQ. Health problems reported include pneumonia and sinus infections.

During the spring of 1991, the school system contracted with a Massachusetts engineering firm to investigate the building's IAQ. According to James Conry, executive director of management services for the Cambridge school system, the engineering firm did not find any significant threats to human health in the building: "The levels of contaminants found were consistent with the research data on urban areas, including extensive research by the [Environmental Protection Agency]." However, the firm did report that the school's ventilation system was inadequate. The engineering firm also detected methane in a number of unoccupied areas of the building.

After the school released the results of the study, the Tobin Parent Teacher Association (PTA) formed a subcommittee to study the problem further. Subcommittee member David Landrigan, a professor at the University of Massachusetts at Lowell, revealed several errors in the firm's study. According to Albert Giroux, director of public information for the Cambridge school system, the errors occurred during the consultant's initial analyses. "The calculations for the square-foot areas of the rooms were low," he said, "and thus calculations for the amount of airflow through the building were off."