Photo 1: A length of angle iron and a section of lumber were found in the scroll of the supply air fan. Apparently, both had been there since the time of original construction.

Photo 2: The high velocity, turbulent airstream severely damaged interior fibrous glass insulation just downstream of the supply fan's blast zone.

Look Below Surface For IAQ Problems

Members of faculty in this large middle school continued to report illness attributed to time spent in the building. Although the ventilating system revisions were designed by professionals with the appropriate credentials, a critical provision in the ASHRAE ventilation standard was overlooked.

By Wane A. Baker, P.E., CIH, Member ASHRAE

In response to a history of occupant complaints of thermal discomfort, stuffiness and adverse health effects, the school district invested $1.6 million in upgrades to the HVAC systems serving this facility. Primary among the challenges remaining in this case were the residual effects of unresolved occupant concerns which, in some cases, resulted in expressions of outrage and a defensive, sometimes militant, attitude toward further investigation and remedial efforts.

Despite the sincere best efforts of administration, members of faculty in this large middle school continued to report illness attributed to time spent in the building.

Although the ventilating system revisions were designed by professionals with the appropriate credentials, a critical provision in the ASHRAE ventilation standard was overlooked.

Facility and HVAC System Description

This 148,000 ft^2 (13 800 m^2) single-story middle school building is located in a rural Midwestern community, and was constructed in 1985. Generally, each of the nine distinct functional areas is served by a separate air handling unit (AHU), located in several penthouses. The initial design was based on state building codes in effect at the time, which required only 5 cfm (2.4 L/s) of outdoor air per occupant. Ventilating systems were originally configured with variable air volume (VAV) boxes for interior zones, and fan-powered constant volume terminal units for perimeter zones. Auxiliary heat for the exterior zones is provided by hydronic radiant panels located in the ceiling.

At the zone level, distribution of supply air is provided by linear slot diffusers, while the original plenum return system relied on openings in the light troffers and a circuitous series of transfer ducts through fire separations.

The athletic area systems incorporate a total energy recovery wheel that is used to preheat outdoor air while also recovering a portion of the latent heat from the exhaust airstream.

Staff and Faculty Concerns

From the time the building was originally occupied, faculty and staff reported temperature control problems and a perception of stuffiness (i.e., lack of adequate air movement). Later reports included cases of Multiple Chemical Sensitivity/Environmental Illness (MCS/EI). The initial district response focused on "working the bugs out," and on additional training for maintenance personnel in the operation of the computerized energy management system (EMS), which was the first of its kind in this district.

An additional two years were devoted to rebalancing airflows, relocating sensors, revising segments of pneumatic controls, replacing faulty dampers/actuators, and upgrading the control algorithms. Occupant complaints continued, however, and were most prevalent during hot, humid weather.

History of IAQ Investigations

The district first hired Consultant A, who conducted tracer gas analyses to assess ventilation effectiveness, and used flow visualization techniques to determine that significant short-circuiting was occurring—the corridors were serving as the primary return air path. Their investigation determined that the original engineering design was deficient and that significant modifications to the air conveyance systems were required.

A second consultant conducted sampling for fungi and volatile organic compounds, finding limited evidence of bioamplification or unusual concentrations of solvent vapors within the building.

At the urging of certain members of the instructional staff, an ad hoc indoor air quality committee was formed. Among other activities, this group instituted a fragrance-free policy applying to all students, staff and visitors.

Fast-Tracked HVAC Revisions

The board of education hired Consultant A to design and specify numerous HVAC revisions that were implemented on a fast-track basis. For the classroom wing, these included:

1. Ducting the return air system; axial return fans were added;
2. Increasing delivery of outdoor air to 15 cfm/person (7 L/s per person)—a three-fold increase over the original design;
3. Upgrading and increasing the capacity of the chiller; installing larger primary cooling coils;
4. Converting VAV terminal units to constant volume;
5. Upgrades in filtration to 30% atmospheric dust spot efficiency (ADSE);
6. Adding pre-cooling coils to the outdoor air intake ducts; and
7. To mitigate the expected increase in operating costs, use of demand-controlled ventilation relying on a single carbon dioxide (CO_2) sensor in the return air main.

To lessen the impact of the three-fold increase in outdoor airflow rates, energy recovery equipment was also considered at that time. However, the district decided to cap their short-term expenditures, despite the certainty of considerable reductions in future operating costs. The science areas, located in the core of the classroom wing, remained under the same AHU as general instructional space. Science teachers were encouraged to use local exhaust ventilation as needed, based on classroom activities.

Photo 3: Large sections of the interior fibrous glass insulation had released from the metal ductwork, becoming lodged in balancing dampers.

Activities of the Author

Our work was commissioned as part of aiding the district in the implementation of an IAQ management plan, which included performance testing of the HVAC systems. We reviewed the history of investigative efforts and HVAC modifications. In the course of this review, we noted that the use of a single-point CO_2 sensor in the return air main did not address the concept of a "critical space" as described under Section 6.1.3.1, Multiple Spaces, of ANSI/ASHRAE Standard 62-1989, which had been adopted by reference into the state building code.

We proceeded to identify 11 potential critical spaces in the classroom wing, and recommended revisions to the demand controlled ventilation (DCV) strategy to incorporate high accuracy CO_2 sensors. Based on programmatic considerations as determined by the district, these sensors were located within four representative classrooms. We also recommended the implementation of a morning pre-purge cycle to reduce contaminant loading generated by interior furnishings and finishes (nonoccupant derived contaminant sources).

Additionally, we conducted a visual and robotic inspection of ductwork, terminal units, coils and the interiors of the air-handling units (AHUs). In the process of this inspection, we found foreign objects in the scroll of the classroom supply air fan (see *Photo 1*), and severely damaged fibrous glass interior insulation in the ductwork and AHUs, resulting in obstructed coils, balancing dampers and turning vanes (see *Photos 2* and *3*).

To assess potential occupant exposure to the release of glass fibers, we conducted air sampling and an analysis of multiple settled dust samples. In response to these findings, we developed a specification and solicited public bids for HVAC system cleaning and airside balancing. Rebalancing of the air supply was necessary in part to address normal degradation of the distribution system, as well as unauthorized occupant “modifications” to the linear diffusers in many classrooms.

Corrective Actions, Final Outcomes

The district faced an additional expenditure of more than $150,000 to remove the damaged fibrous glass insulation, clean-up the distributed glass fibers, reinsulate affected sections, and rebalance the air conveyance system.

Based on our follow-up with district buildings and grounds personnel, additional CO_2 sensors were installed in the defined critical spaces, and the operating controls modified to ensure an adequate flow of outdoor air during all occupied periods. Unfortunately, as is often the case in this type of consulting work, we were not retained to quantify the improvements in thermal comfort metrics and ventilation effectiveness, nor the reduction in occupant-generated contaminant levels. However, we were informed that the number of occupant complaints has been drastically reduced, and that faculty confidence in the district’s efforts to provide a safe and healthy indoor environment is much improved.

Lessons Learned

In this case, we learned that even qualified professionals sometimes overlook key aspects of industry best practices, such as ANSI/ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*. We also learned to look below the surface of air handling and conveyance systems, and gained a further appreciation for the potential benefits of the commissioning process.

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