trigger asthma symptoms in asthmatics (see ***IEQS***, February 2000).

In "Healthy Buildings, Healthy People," EPA estimated that there were 17 million Americans last year with asthma. Asthma is the leading chronic disease among US children and one of the leading chronic illnesses among adults. In 1998, it claimed an estimated 5,000 lives and $7 billion to $9 billion in medical and other costs. Cockroach allergens, dust mites, environmental tobacco smoke, pets, mold — all IEQ hazards — are either known or linked to the development of asthma and asthma attacks.

"The upcoming asthma campaign will help bring IEQ issues into the public consciousness and will probably get some people thinking about other indoor issues," Smith says. Regardless, gaining strong national support for healthy indoor environments will take many years. "I'm proud of what we've done in 'Healthy Buildings, Healthy People,' and I'm committed to moving it forward," she says. "People normally outline projects that span a year, or several years, and then move on. But indoor environmental issues will still be around in five years, and I will be, too. I have a commitment to see this through."

PRACTICAL RESEARCH BRIEF

Study of Natural Versus HVAC Ventilation at Intelligent Workplace Reveals Which Air-Supply Strategies Are Most Effective

A carefully controlled study at an intelligent workplace research laboratory showed that desk-mounted conditioning systems supplied the "breathing zones" of workstations with fresh air at an effective ventilation rate greater than the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) benchmark of 1.0. ASHRAE's 1.0 benchmark indicates perfectly mixed air. Air with an effectiveness rate that exceeds 1.0 suggests some displacement flow is present. The study's desk-mounted systems provided an effective ventilation rate greater than 1.0 even when only one of six workstations in the test bay had a worker, which caused the empty stations to receive minimum heating, ventilation, and air-conditioning (HVAC) ventilation.

The study also showed that directing desktop air diffusers away from an occupant's breathing zone diminished ventilation effectiveness. The findings are important because the dramatic increase of relatively airtight buildings in recent decades has caused a corresponding decrease in natural ventilation. Ventilation systems that remove indoor air pollutants and provide fresh air, therefore, are more important than ever to occupants' well-being.

The researchers set out to measure air-change rates in a test space as a function of how opened the windows and rooftop ventilators were. Ardeshir Mahdavi, Robert Ries, and Dongwoo Cho measured the building's infiltration and natural ventilation, including both windows and stack ventilation, and how well HVAC systems performed, especially user-based systems that deliver air directly to an occupant's breathing zone. Mahdavi is professor and director of the Built Environment Research Laboratory, Carnegie Mellon University School of Architecture at Pittsburgh, Pennsylvania. Ries is a research scientist and faculty member there, and Cho is a senior researcher for the Architectural Division at the Korean Institute of Construction Technology. The Advanced Building Systems Integration Consortium and the Center for Building Performance and Diagnostics at the Carnegie Mellon School of Architecture funded the study.

The study took place in an intelligent workplace with about 553 square meters (m^2) of floor area (1,814 square feet) and 2,214 m^2 (7,264 square feet) of interior volume. The facility provides office as well as research space. Each of its nine bays has a hip roof with a continuously opened ridge vent that has a longitudinal ventilator with open ends. The building also has windows that open. Its rooftop weather station provided data about outdoor conditions for the study.

Methodology

Using six sampling points, the researchers measured an average infiltration rate of 0.86 h^{-1} in late March 1998 and an average rate of 0.95 h^{-1} a few days later. The researchers suggest those rates were higher than expected for the tight building probably because ventilator caps remained unsealed and due to more leakage where the walls and roof met. They noted that an air-change rate of 0.9 h^{-1} in the facility roughly translates to a flow of 600 liters per second (L/s) of fresh air, which would meet the basic ventilation needs of 60 people.

The researchers isolated the test bay with clear polyethylene sheeting and evenly dispersed Sulfur hexafluoride (SF_6) tracer gas to measure infiltration and ventilation. The test bay measured 4.8 meters wide by 9.8 meters deep by 4.8 meters high, and had four windows, with two each on opposite sides. The space contained six workstations.

Mahdavi, Ries, and Cho tested the effect of the windows in four positions: once with all of them closed, and once each with all opened 10 centimeters (cm), 20 cm, and 85 cm. Rooftop ventilators were either fully opened or closed.

Each workstation had a desk-mounted air supply with a variable-speed fan and two diffusers. The person at the workstation could set each diffuser to provide 6.6 L/s, 18.2 L/s, or 29.3 L/s of air. The occupant could also turn the diffusers to change where the air flows. Each desktop unit had a sensor that automatically reduced airflow to the lowest setting when nobody was present for 15 minutes.

Measurement Protocols and Conditions

How effectively a ventilation system delivers fresh air to an occupant's breathing zone depends on the rate that it takes in fresh air and how it distributes that air. The researchers installed tracer gas samplers at six points to measure the ventilation performance of the desktop systems and introduced 100% outside air to the desktop diffusers. They tested four scenarios. First, with diffuser fans working as if people were at all six workstations, the researchers performed experiments to test the impact of the maximum, medium, and minimum airflow rates on the local age of air. This "age" shows how long certain air has been in a given area. In this scenario, the local age of air ranged from 14.4 minutes at a seated workstation occupant's level to 24 minutes in a stagnant hall (see Table 1). In every case, the age of air at the workstation at seated level was the least, thanks to the significant outside air supplied to it.

Under the second scenario, the researchers set the system as though only one person was working. This reduced the airflow to the empty workstations to minimum (6.6 L/s) airflow. As a result, the researchers found that the average age was 3-4 minutes more than in the first scenario, because

Table 1 — Measurement Results for Scenario 1

Location	Maximum Mode		Medium Mode		Minimum Mode	
	A/min.	VE	A/min.	VE	A/min.	VE
Workstation, seated	14.4	1.20	16.8	1.16	20.8	1.14
Return duct, bottom	17.3	1.00	19.5	1.00	23.7	1.00
Supply diffuser	7.3	—	7.7	—	6.0	—
Workstation, standing	16.2	1.07	17.8	1.10	23.1	1.02
Return duct, top	17.1	1.01	19.5	1.00	24.4	0.97
Center of test bay	17.4	1.00	19.6	0.99	24.0	0.99
(A/min.= Age of Air in Minutes; VE = Ventilation Effectiveness)						

Table 2 — Measurement Results for Scenario 2

Location	Maximum Mode		Medium Mode		Minimum Mode	
	A/min.	VE	A/min.	VE	A/min.	VE
Workstation, seated	18.0	1.18	18.2	1.18	18.8	1.18
Return duct, bottom	21.2	1.00	21.5	1.00	22.2	1.00
Supply diffuser	9.2	—	6.1	—	7.0	—
Workstation, standing	20.0	1.06	20.9	1.03	21.3	1.04
Return duct, top	22.1	0.96	23.0	0.94	23.8	0.93
Center of test bay	23.3	0.91	22.9	0.94	23.9	0.93
(A/min.= Age of Air in Minutes; VE = Ventilation Effectiveness)						

seated and standing zones in almost all cases. Finally, their tests indicated a slightly better effectiveness of ventilation for a floor-level diffuser than one at the ceiling.

Mahdavi, Ries, and Cho plan to continue studying natural ventilation and HVAC systems to develop a well-documented model for formulating the requirements for and characteristics of standard building performance signatures.

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CASE STUDY

Followup: Mold Forces Cleanup Team's Hand at School in Austin, Texas

[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.]*

(Editor's note: Last month, **IEQS** *began a case study in progress on mold contamination and remediation at the Hill Elementary School in Austin, Texas. This installment reveals new challenges the work team must overcome to clear contamination from the 60,000-square-foot school before the teachers' scheduled return on August 14.)*

In April, the leader of a project team working to abate the mold and restore the Hill Elementary School estimated that about 75% of the 30-year-old building needed remediation. Within weeks, however, the project team and school officials agreed that their only recourse was to remove every ceiling and wall inside the 60,000-square-foot structure.

David Cooper, project administrator for the Beck Group, the prime contractor leading the remediation project, tells ***IEQS*** there are two reasons for that decision. First, abatement specialists discovered more mold colonies in ceilings they hadn't examined before. Second, as the specialists removed those ceilings to check for additional contamination or to remediate mold they'd already found, they extensively damaged walls. Cooper says they couldn't avoid that damage because the original contractor had installed the ceilings first, then attached the wallboard to them — an atypical construction method.

Hill Elementary School, which is built over a spring, had a long history of indoor air problems before the Austin Independent School District closed a fourth-grade classroom in the building in late February due to strong mold odors. Four days later, school officials evacuated the school's 777 students and 77 staff for the balance of the school year after preliminary environmental tests revealed extensive *Penicillium* and other mold contamination behind every exterior classroom wall. Some *Penicillium* mycotoxins are identical to mycotoxins produced by the widely feared *Stachybotrys chartarum* fungus, which Hill School remediators also found but in small amounts. *Penicillium* causes allergic symptoms and breathing difficulties, can trigger asthma attacks, and may cause other harmful effects. One area of *Penicillium* contamination inside the school covered more than 150 square feet.

"It's hard for people to realize how much mold there was," Cooper told ***IEQS*** in May. "I've never seen anything like it in more than 18 years in construction. You couldn't see mold when you walked in, but you'd pull off a piece of wall paneling and what you saw scared you to death."

Team Tackled Worst First

Cooper said the remediation team concentrated first on demolishing the heavily contaminated