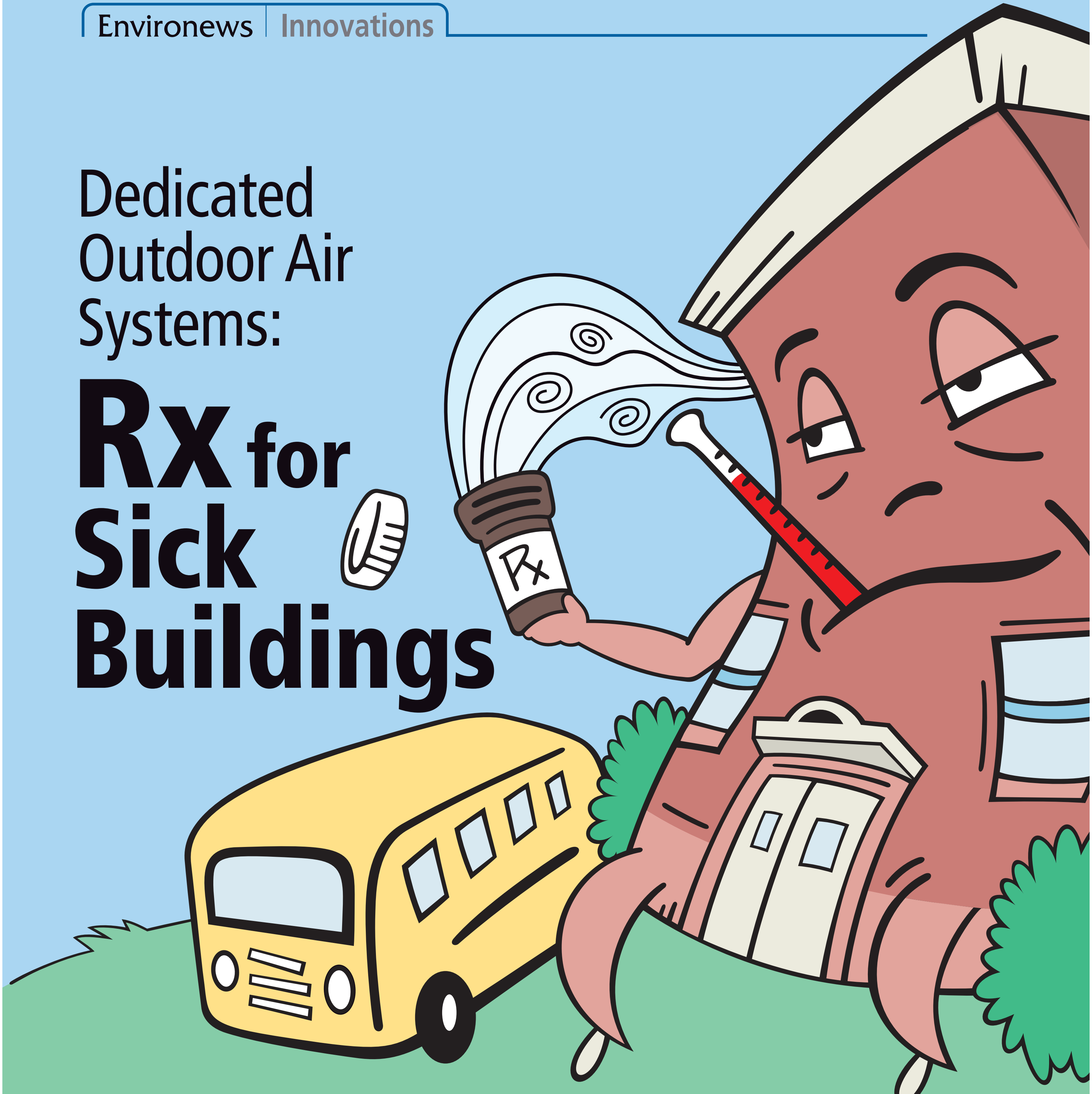
Dedicated Outdoor Air Systems:

Rx for Sick Buildings



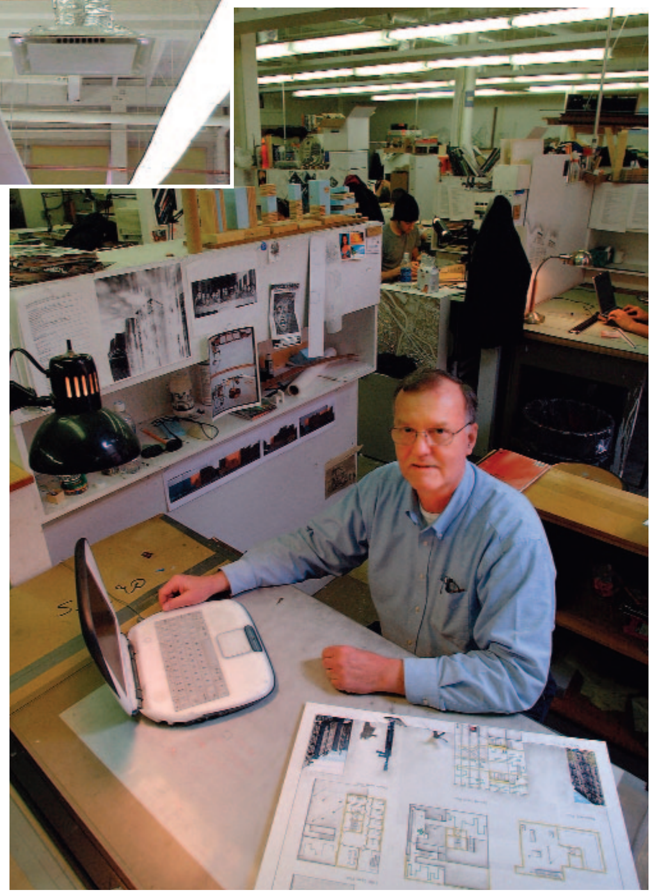
Matt Ray/EHP

It's been 27 years since bacteria spread by a hotel air-conditioning system sickened 221 people and killed 34 at an American Legion convention in Philadelphia, sounding a wake-up call to the American public about the link between indoor air quality and human health. Since then, there has not been another U.S. incident involving multiple deaths from bad indoor air, yet concerns persist that conventional heating, ventilation, and air-conditioning (HVAC) systems are making people sick. Fortunately, the growing acceptance of a new HVAC design known as a dedicated outdoor air system (DOAS) promises to improve indoor air

quality and comfort while lowering operating costs.

Most conventional HVAC systems circulate conditioned air through a duct system to different parts of the building. Conventional HVAC systems are designed to control both room temperature (the "sensible load") and humidity (the "latent load") while providing sufficient fresh air to dilute pollutants generated by building occupants and equipment. Different amounts of outside air must be added to the recirculating air and supplied to different parts of the building, depending upon the number of occupants in each space.

In contrast, a DOAS allows the building designer to decouple the latent and sensible loads, using separate systems to control temperature, ventilation, and dehumidification. A DOAS provides the exact amount of dehumidified ventilation air required in each part of a building. And it can be used in conjunction with cooling systems that discourage the growth of mold and microbes.



Breathing room. Stanley Mumma works in a demonstration space at The Pennsylvania State University that is conditioned using a DOAS and radiant cooling.

Pennsylvania State University

Diagnosis: Sick Buildings

"Sick building syndrome" (SBS) is a term that came into use in the mid-1980s to describe situations in which building occupants experience acute health effects and discomfort associated with time spent in the building. Symptoms may include headache, dry cough, itchy skin, dizziness, nausea, and eye, nose, or throat irritation.

Because these symptoms can be caused by factors outside the building environment, some may question whether the link between an individual's illness and the air quality in a specific building is real or imagined. However, more than 100 published studies have now established links between indoor air quality and human illness. And because of the potential for lost productivity, increased insurance costs, and lawsuits related to SBS, building owners and operators, as well as tenants, must take occupant complaints about health and comfort seriously.

A 1984 report titled *Indoor Air Pollutants: Exposure and Health Effects. Report on a WHO Meeting* suggests that up to 30% of new and remodeled buildings worldwide may be the subject of excessive complaints related to indoor air quality. More recent reports, including *America's Schools Report Differing Conditions*, a 1996 publication of the General Accounting Office, have found that at least 20% of all U.S. schools suffer from poor indoor air quality.

Studies have tied this problem to a variety of factors, including malfunctioning or improperly designed and maintained HVAC systems, the presence of volatile organic compounds, mold growth, dust, radon, and asbestos. According to the U.S. Environmental Protection Agency, one of the chief causes or contributing factors to poor indoor air quality is inadequate ventilation.

Inadequate humidity control in particular has been linked to discomfort (such as drowsiness and headache), mold growth, and the incidence of respiratory illness. Asthma, the most common cause of absenteeism in schools, has been tied to indoor air quality and mold, both impacted by space humidity.

Until the mid-1970s, building ventilation standards called for approximately 15 cubic feet per minute (cfm) outside air for each building occupant. Following the 1973 Arab oil embargo, however, national energy conservation measures called for a reduction of outside air to 5 cfm per occupant. Experts thought this would be sufficient to ensure adequate health and comfort, but they were quickly proven wrong.

Complaints from building occupants increased, becoming commonplace in the 1980s and 1990s and bringing "sick building syndrome" into the public lexicon. In response, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has since revised its ventilation standard 62-2001 to provide a minimum of 15 cfm outside air per person, or 20 cfm per person in office spaces. This standard has been adopted by all the major building codes, which in turn have been incorporated into enforceable local building codes.

Yet problems with indoor air quality persist, particularly as it relates to humidity. "The problem is that code recommendations are not always followed," says John Fischer, a technology consultant with SEMCO of Columbia, Missouri, one of the nation's largest manufacturers of energy recovery systems. "People tend to want to do things the way they have in the past, and many building designers and managers apparently don't believe it's necessary to increase ventilation rates to comply with ASHRAE standards."

Furthermore, Fischer says, conventional packaged HVAC equipment—which includes heating, ventilation, and air-conditioning all in one unit—often is simply not capable of providing sufficient outdoor air on a continuous basis without causing indoor humidity problems.

Updated Treatment

Although the DOAS idea is just now gaining acceptance in the building community, the concept has been around for more than a decade. Stanley Mumma, a professor of architectural engineering at The Pennsylvania State University, began promoting DOAS in the early 1990s as a way to improve energy efficiency while meeting tighter ventilation requirements.

Most office and institutional buildings are conditioned by "variable air volume," or VAV, systems, which supply air at a constant temperature but varying flow rate. Through his research, Mumma found it was very difficult to ensure both proper temperature and proper ventilation in all spaces with VAV systems. "For a given room, we might only need two hundred cfm to meet the temperature setting, but more to provide the needed ventilation for the occupants," Mumma says. "There's no good way to meet [both needs] with a VAV system, especially with all the infiltration, exfiltration, and short-circuiting of air flow in a building. With DOAS, if a room needs two hundred cfm of ventilation air, we supply exactly that."

Mumma also found that to even attempt to meet the new ASHRAE ventilation standards, a VAV system generally required 20–70% more outside air than a DOAS. That's because VAV systems must be set to provide the proper amount of outside air for the space with the highest ventilation requirements, overventilating the rest of the building in the process. Cooling and dehumidifying all of that additional air in the summer and humidifying it in the winter requires more energy and thus greater cost. A DOAS, on the other hand, provides only the amount of outside air needed for each space, thus reducing the operating costs.

Finally, Mumma found that VAV systems—which attempt to control both sensible and latent loads while supplying the proper amount of ventilation—invariably lead to high relative humidity. The only solution he could find was to use a DOAS.

Although outside air used for ventilation can also be used for cooling, there are times and places (such as summertime in the South) where a parallel cooling system must be used to make temperatures comfortable. A DOAS can be used in tandem with virtually any type of cooling system.

Mumma prefers using a radiant cooling system (one that circulates cool water through ceiling panels) over those that employ forced air. "Radiant cooling wins hands down over forced air systems in terms of safety, comfort, and energy savings," he says. "Forced air systems that employ fan coil units with condensate pans are breeding grounds for microbial growth. And any time you blow air around, you increase occupant discomfort, as well as the chances of spreading germs and other contaminants."

Mumma has installed a demonstration DOAS at The Pennsylvania State University and reports it has operated through the summer with no problems. The results of this demonstration will be published in an upcoming issue of the ASHRAE publication *IAQ Applications*.

Fischer agrees that radiant cooling offers the best option for large commercial and institutional buildings in the future. However, in the near term, he believes it is likely that most buildings will combine a DOAS with conventional packaged cooling equipment. Radiant cooling requires chilled water, which many facilities, especially schools, avoid because of the perceived complexity of these systems' design and maintenance, Fischer says. "[Facility managers] prefer packaged cooling equipment that can be easily serviced by most HVAC contractors or replaced if failure occurs."

The Cost of the Cure

Under contract with the U.S. Department of Energy, Fischer and Charlene Bayer, a principal research scientist at Georgia Tech Research Institute, studied the impact of humidity control and ventilation in 10 school facilities in Georgia. Five of the schools were equipped with conventional HVAC systems and five with a DOAS. Fischer and Bayer found that the 15 cfm per student ventilation rate prescribed by ASHRAE was the minimum necessary to keep concentrations of potentially dangerous airborne contaminants (such as formaldehyde and total volatile organic compounds) below recognized guidelines set by the Environmental Protection Agency, the National Institute for Occupational Safety and Health, and other regulatory bodies.

None of the schools served by conventional HVAC systems were in compliance with the 15 cfm ventilation standard, instead averaging only 5.4 cfm per student. Fischer and Bayer say this was because the conventional systems were simply unable to maintain comfort levels with respect to humidity at higher ventilation rates. Conversely, schools using a DOAS provided ventilation at the rate of 15 cfm per student while maintaining the space humidity as desired. Average absenteeism for schools using a DOAS was 9% lower than for the conventional schools, a factor tied to improved comfort and health. DOAS setups proved to be both energy-efficient and cost-effective, reducing annual operating costs by $15,000–20,000 for a typical school building. Fischer and Bayer's findings were reported in the May 2003 *ASHRAE Journal*.

Although it might seem more costly to design a building with separate temperature control and ventilation systems, Mumma insists that a properly designed DOAS is actually less expensive than a conventional VAV system. That is because smaller heating and cooling units can be used if they don't have to perform the double duty of removing the latent load. Smaller units cost less to buy and are cheaper to operate.

As an example, Mumma provides comparative cost estimates for heating, cooling, and ventilating a theoretical 186,000 square foot office building located in Philadelphia with a conventional VAV system versus a DOAS using radiant cooling. Mumma estimates the installed cost for the conventional system at approximately $1.4 million versus $1 million for the DOAS. He estimates annual operating costs at $77,350 for the conventional system and $59,730 for the DOAS.

Chris Downing, associate director of the Advanced Technology Development Center, which is part of Georgia Institute of Technology in Atlanta, agrees that a DOAS can be economical. "If you start with a blank sheet, you can design a DOAS for no more than a conventional [system]," he says. "Retrofitting a DOAS on an existing building will add to the cost, but you should be able to pay that off in energy savings in less than four years."

As building owners and operators strive to meet the new ASHRAE standard, they are increasingly turning to DOAS technology. Hundreds of schools have now been designed using DOAS setups, and they are performing well, according to Fischer, with fewer complaints about indoor air quality and better student performance. "This is the way building design is going," he says.

John S. Manuel

Suggested Reading

Dedicated Outdoor Air Systems website. Available: http://doas-radiant.psu.edu/ [accessed 26 August 2003].

Fischer JC, Bayer CW. 2003. Report card on humidity control. ASHRAE Journal 45(5):30–37.

Indoor Air Facts No. 4 (Revised): Sick Building Syndrome (SBS). 1991. Washington, DC:U.S. Environmental Protection Agency. Available: http://www.epa.gov/iaq/pubs/sbs.html [accessed 26 August 2003].