Refrigeration Service
Engineers Society
1666 Rand Road
Des Plaines, Illinois 60016

FUNDAMENTALS OF INDOOR AIR QUALITY

Frank Prah, CMS

INTRODUCTION

HVAC technicians are not medical doctors or industrial hygienists. However, it is estimated that over 80% of IAQ-related problems could be remedied by improving the design or maintenance program of HVAC systems. The conclusion is obvious—in many cases, a trained HVAC technician can improve the IAQ of a building or facility.

An HVAC system serves as a distribution network for properly conditioned and filtered air in a building. The same system can serve as a path—and sometimes a source—for airborne pollutants. The contaminants can and do affect the health and productivity of the building's occupants.

In the past, most of the instruction that a HVAC technician received revolved around the mechanical, piping, and electrical aspects of installing and servicing equipment. Environmental concerns were rarely discussed. Today the environmental aspects of HVAC systems are becoming much more important, and cannot be ignored.

Outbreaks of Legionnaire's disease have been traced to air conditioning systems. There are news reports about buildings that make their tenants sick. Individual homes are linked to increases in allergies and asthma. Can this happen to your home, or to the building that you service? What can you do to prevent it or correct it?

Growing concerns about indoor air quality present HVAC technicians and contractors with increased opportunities. Knowledgeable HVAC professionals can assist building owners and managers in solving problems and avoiding the expensive repairs and high legal costs associated with poor indoor air quality. (Indoor air quality, or IAQ, is also referred to as indoor environmental quality, or IEQ.)

Indoor air quality in earlier times

Anthropologists and forensic scientists know that primitive humans who lived in caves often suffered from poor IAQ. Smoke inhalation, dampness, and generally unsanitary conditions, combined with a poor diet, led to respiratory problems and arthritis. Smoke was also a problem in the Native American tepee. The tepee actually had a ventilation system that worked reasonably well. However, the Indians who lived in tepees had the same problem that we have today, especially during the winter. When we increase ventilation, we pay an energy price. They also had to put up with cold drafts. Interestingly, some winter camping sites were recently studied and combustion air tunnels were found that led from outside the tepee to its center, where the fire was located. Today, of course, heat wheels or heat tubes serve as heat exchangers and help reduce the energy penalties associated with using outside air. Some claim 80% efficiency rates.

Indoor air quality in recent times

Before the energy crunch in the early 1970s, indoor air quality wasn't as much of a problem as it is now. At that time, buildings were not as "tight" as they are today, and the cost of bringing in outside air was not a significant factor. In many cases, the quality of the *outside* air was also better. In the mid-1970s, however, operating and maintenance costs for commercial buildings escalated rapidly, largely because of rising fuel prices and higher utility rates. Contractors began to construct "tighter" buildings and added more insulation. A house built prior to the 1970s may have had one or two "natural" air changes per hour. A new house today may have one-tenth of an air change per hour.

Most people are aware that *outdoor* air pollution can damage their health, but may not know that *indoor* air pollution can also have significant effects. EPA studies of human exposure to air pollutants indicate that indoor air levels of many pollutants may be 2 to 5 times—and in some cases more than 100 times—higher than outdoor levels. High levels of indoor air pollutants are of particular concern in our society today because most people spend more time inside than outside. In fact, it is estimated that many of us spend more than 90% of our time indoors (including time spent at home, at work, in the car, shopping, etc.). Despite the fact that most people spend more time in their homes than at work, the majority of IAQ complaints originate in the workplace.

Over the past several decades, our exposure to indoor air pollutants is believed to have increased due to a variety of factors, among them the construction of more tightly sealed buildings, reduced ventilation rates (widely practiced as a means of saving energy), the use of synthetic building materials and furnishings, and the prevalence of chemically formulated personal care products, pesticides, and household cleaners. In recent years, comparative risk studies performed by the EPA and its Science Advisory Board (SAB) have consistently ranked indoor air pollution among the top five environmental risks to public health.

IAQ problems in schools[1]

U.S. government studies have shown that one in five schools has IAQ problems, but they are problems that can be improved through the use of active humidity control and continuous ventilation. More than 8 million students are affected by IAQ problems, according to government research outlined in an article in *IAQ Applications*, published by ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers). Problems can include drowsiness, lack of concentration, and headaches, all of which affect the student's comprehension and motivation.

Dr. Charlene Bayer, of Georgia Tech Research Institute, says that IAQ should be a top priority because children, who are still developing physically, are more likely to suffer due to indoor pollutants. In addition, the number of children with asthma has increased 49% since 1982. It is estimated that one child in five has asthma.

IAQ problems may stem from the fact that school administration and maintenance personnel do not understand how to operate ventilation systems, and from the introduction of contaminants, such as plug-in chemical deodorizers and art supplies, into classrooms.

SICK BUILDING SYNDROME[2]

The term "sick building syndrome" surfaced in the 1970s when, to conserve energy, many naturally ventilated homes, schools, and offices were replaced with tightly sealed, air conditioned buildings. Insulation, treated wood, volatile adhesives, and synthetic fabrics, furnishings, and carpets were often incorporated into these buildings. Especially when new, many of these products release low levels of potentially harmful chemicals, such as formaldehyde, into the recycled air. Carpets can add to the problem by absorbing various cleaners and solvents and then releasing them over a long period of time.

A book entitled *Chemical Exposures: Low Levels and High Stakes* states that "vapors from various solvents are the most prevalent of indoor air contaminants," and goes on to point out that "solvents are among the chemicals most frequently implicated by chemically sensitive patients." Many people like the smell known as "new car smell," produced by the volatile organic compounds (VOCs) found in new cars. But many of the same materials—upholstery, adhesives, carpeting, and other such outgassing components—are found in so-called "sick" buildings.

While most people seem to be able to cope with the environment inside such buildings, some develop symptoms ranging from headaches and lethargy to asthma and other respiratory tract problems. These symptoms generally disappear when the affected people leave the environment. But the British medical journal *The Lancet* notes that in some cases, "patients may develop multiple chemical sensitivities." Why do some individuals get sick from chemicals while others do not? This is an important question, not least because those who seem to be unaffected may find it difficult to be understanding of those who become ill.

As noted previously, many building owners and managers responded to the increased energy and utility costs of the 1970s by reducing outside air, and by making their buildings tighter with weatherstripping. To make matters worse, maintenance personnel sometimes were cut to help pay for the additional energy costs. Even today, some buildings are wrapped with plastic over the outside walls. Many buildings have no provision at all for outside air. In some strip malls, you can see rooftop units without economizers. A building of this type depends on opening and closing the front door for ventilation.

All of these conditions create an indoor environment in many buildings where fresh air is virtually nonexistent. The air is recirculated along with cigarette smoke and other pollutants. In some cases, bacteria, fungi, and germs grow in the duct system and spread throughout the entire building. There have been extreme instances of “sick” buildings that could not be cleaned up economically, and had to be torn down completely (at great cost, because of the biohazards involved). Both commercial and residential buildings have been demolished with severe infestations of black mold.

Symptoms of poor indoor air quality

So what is sick building syndrome? Sick building syndrome (SBS), sometimes also known in the U.S. as “tight building syndrome,” refers to those short-term reversible health symptoms that are associated with the occupancy of a specific building. SBS exists when a significant percentage (e.g., more than 20%) of the occupants complain during a two-week period of a set of health-related symptoms. Those symptoms may include headaches, skin or eye irritation, hay fever-like symptoms, dizziness, nausea, asthma, sinusitis, allergies, and various upper respiratory tract infections.

In addition to health problems (even life-threatening ones like Legionnaire’s disease and carbon monoxide poisoning), indoor air pollution can have other undesirable effects:

- reduced productivity due to physical discomfort or employee absenteeism
- deterioration of furnishings or equipment
- strained relations between people
- low occupancy of rental space
- lawsuits.

If you service a building with SBS, what should you do?

Attempting to correct IAQ problems without understanding the cause of the problems can be ineffective, expensive, and legally catastrophic. However, there are things that a capable HVAC technician can do when SBS is suspected:

- First, ensure that there is sufficient ventilation in occupied spaces. Measure and record air flow rates.
- Ensure that the HVAC system is clean and free from chemical or biological contaminants.
- Identify potential sources of contaminants, such as building exhausts, internal combustion exhaust, condensate pans, rodents, etc.
- If possible, eliminate all potential sources of the problem, and continue to monitor.
- Consider installing a UV (ultraviolet) light near the outlet of the evaporator coil (or, in some cases, on both sides of the evaporator).
- Obtain professional help if complaints persist.

HUMIDIFICATION

There are probably more humidifiers in homes than in commercial office spaces. The benefits to the homeowner are well known—a reduction in heating costs, infections, and illnesses. Humidifiers also protect wooden furniture from drying out and help reduce static electricity.

ASHRAE has published statistics that support the idea that humidity levels affect health. When humidity drops below the optimum level of 50%, people are more susceptible to respiratory infections, viruses, and bacteria. When the relative humidity drops below the 40% level, more employees become sick and miss work. When humidification is installed in winter, complaints are reduced by 95%.

ASHRAE researchers believe that humidification is "a health and safety issue, and a main component of indoor air quality…An overwhelming amount of medical research indicates that humidification is beneficial for health as well as comfort reasons."[3] A prominent U.S. scientist, Dr. Charles S. Sale, concluded that humidity control was found to reduce respiratory illnesses, especially in winter, and assist allergy sufferers. As the result of three studies, Sale concluded: "The survival of airborne bacteria and viruses increases as the relative humidity falls below about 50%."

AIR FILTERS

Air filters are important IAQ tools, but they are frequently overlooked and misunderstood. They are the primary defense for building occupants and HVAC equipment against particular pollutants. Yet more time is typically spent selecting and specifying wall finishes than HVAC system air filters.

As a result, the people who specify which filters are to be used in a building often tend to use the same filter designs and specifications that they have used in the past, giving little or no consideration to their impact on building IAQ. Similarly, many building managers select replacement filters based primarily on their initial cost, not on the needs of the facility.

This problem has been compounded by the lack of a uniform standard for rating filter efficiency. A recently developed standard, ASHRAE 52.2-1999, *Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size*, is designed to help eliminate confusion and make it easier to match filters to facility needs.

Regularly replacing the air filters in a building is an important part in maintaining indoor air quality. The significance of proper air filtration is easy to overlook, since it is estimated that 99% of all airborne contaminants are invisible to the human eye (below 10 microns). But air filtration can be one of the simplest aspects of a regular preventive maintenance program. After all, an entry-level custodian is capable of removing a dirty filter and replacing it with a new one every three or four months. Today, with an ever-increasing emphasis on improving health by reducing exposure to second-hand smoke and other airborne contaminants, air filtration has taken on a new level of importance in the overall HVAC maintenance of commercial buildings.

Know how your filters are rated. The arrestance method, for example, is more concerned with larger particles, while the dust spot method is used for smaller particles. (A 70% filtration rate using the arrestance method could be equivalent to just 3% using the dust spot method.) Exercise caution as you retrofit, because as you increase filter media efficiency you also increase restriction to air flow. In addition, be aware that filters do not filter outgases, although you can install charcoal and other types of filters that will absorb certain gases.

Terminal air filtration

Terminal air filtration is not a new idea. It is a method of controlling the environment in specific areas of a building. In addition to the means of filtration used at the air-handling unit, extra filters are installed at the terminal units throughout the building. Even when being extremely careful, a technician may jar loose some dirt or debris, and pollutants can find their way down the ducts and into the occupied space. The chances of this happening are reduced by terminal air filtration.

DILUTION VENTILATION

It has been said that "dilution is the solution to pollution." In most cases, bringing in outside air ("fresh air") will reduce the concentration of contaminants. One problem, however, is that the greater the concentration of contaminants in the outside air, the more ventilation is required. And when more outside air is used for ventilation, energy consumption increases.

Ventilation is critical in meeting code requirements for air changes. But how does ventilation affect IAQ? It's true that adequate ventilation dilutes polluted air by pressurizing the building and forcing the contaminants outside. However, if the outside air is contaminated, pollutants also can *enter* a building through the ventilation system.

A case in point: The occupants of a building complained that every afternoon around 3:00 p.m., the quality of the air in the building became very bad. However, the symptoms went away in the summer. The source of the problem wasn't difficult to find. The building was near a school, and every day during the school year the diesel buses lined up outside to take the students home around 3:00 p.m. The prevailing winds pushed the exhaust from the buses toward the "fresh air" intakes of the building. The fresh air intakes had to be moved to a more favorable location.

When commissioning a new building, some contractors say that "cooking" the building for a few days before occupancy will reduce the VOCs. "Cooking" means to elevate the temperature to around 90°F, and ventilate with maximum outside air.

CARBON DIOXIDE

One way to determine if meaningful ventilation is taking place is to sample carbon dioxide (CO_2) levels. Today's CO_2 meters are becoming more accurate and less expensive. New hand-held equipment can quickly and reliably measure the amount of CO_2 in any space in a building. High levels of CO_2, which indicate low levels of fresh air, can cause nausea, headaches, and dizziness. Outside air has a normal CO_2 level of 350 ppm (parts per million). Adults usually can tolerate CO_2 concentrations of 1,000 ppm (parts per million), and children usually can tolerate 500 ppm. Outside air dampers should open to allow enough air to enter a building to keep the CO_2 level below 1,000 ppm.

The DCV (Demand Control Ventilation) system uses CO_2 sensors tied to the outside air damper. This means that the amount of fresh air is controlled by the amount of CO_2 in the building. The result can save significant energy dollars. Table 1 below shows estimated DCV energy savings.

Proven energy savings with DCV retrofits have been the principal driver behind installing CO_2-based ventilation systems. But a critical criterion for the success of any new technology is how easily it can be integrated into existing systems.[4] Today virtually all major building control and HVAC equipment manufacturers offer CO_2 sensors to complement their product offerings. "Plug-and-play" simplicity is offered for control of all types of equipment, including economizers, rooftop systems, and DDC (direct digital control) systems.

As this technology has developed, so have codes and standards. For the last four years, the International Mechanical Code (IMC), the mechanical code of reference for most local building code bodies, has included provisions for CO_2-based DCV. In the past three years, ASHRAE Standard 62 has clarified the use of CO_2 as a parameter that can be used for controlling ventilation based on actual real-time occupancy while still maintaining target cfm-per-person ventilation rates.

CO_2 regulations in Canada

In the Canadian province of British Columbia, a unique partnership between government and commercial building owners has established not-to-exceed levels of CO_2 as part of a comprehensive health and safety standard for office workers (Province of British Columbia, 1998, *Regulations for Occupational Health and Safety*, Section 4.73–4.81).

FUNGI

Mushrooms are grown underground, and all that's required are water, soil, moderate temperatures, air, and seed. All of the same components are present in an air handler. There is a wet coil and a drain pan. There is dirt from dust on the coils, there are spores arriving in the outside airstream, and there are moderate temperatures. No, you won't find mushrooms in an air handler, but bacteria and fungi can and do grow in such an environment. It takes only a few days for a colony of spores to grow. The more humid the climate, the worse the condition that you might encounter.

In the warm, humid environment of southern Texas, for example, mold and mildew have proved to be a

	Air conditioning	Heating
Home	10%	28%
Store	17%	93%
Restaurant	16%	92%
School	10%	76%

HONEYWELL INC.

Table 1. DCV energy savings

persistent problem in school buildings.[5] Outbreaks of fungus have been reported in many schools in the region, and have even resulted in closures. In one school, a very aggressive maintenance program was managing to keep mold in check. But remedial measures showed no sign of eradicating mold and mildew problems until the air handlers were outfitted with high-output HVAC-style UVC (ultraviolet light in the "C" band) lights. These devices helped solve a costly maintenance problem and delivered unanticipated energy and operational savings. Cooling costs were reduced by 9%.

Evaporator coil cleaning

Although a UV light can reduce fungi growth and help keep the evaporator coil clean, contractors occasionally have had to replace the evaporator coil completely once a fungi infestation gets started. Attempts to kill the growth with chemicals have failed in some cases, and even steam cleaning the coils hasn't worked. Experienced technicians sometimes say that the most dangerous part of any duct system is the first 10 ft, beginning at the evaporator coil. Why is evaporator coil cleaning so important?

Simply put, keeping coils clean is a major way of preventing IAQ problems.[6] Restricted air flow prevents proper operation and shortens equipment life. Bacteria and fungi growing in coils are blown into the airstream and carried to the conditioned space, triggering occupants' allergies and causing other problems. All air conditioning equipment, refrigerators, dehumidifiers, and cooling towers have the potential to develop bacteria growth, mold, fungi, and mildew. A comprehensive maintenance program is a must in modern buildings. The dark, wet, cool recesses of an air conditioner and its condensate drain pan are ideal sites for microorganisms to colonize and breed. Any dust that gets through the filter is likely to impinge on the wet evaporator coil. The coil acts as an air filter if it is collecting dirt. The water and dust not only plug the coil, but support biological life.

Robert Tinsley, PE, states: "Dirty coils are prime breeding grounds for just about everything biological that can cause IAQ problems. Once many biologicals become established, they produce a biofilm, a coating that helps the growing colonies cling to the surfaces and protects them from chemical attack. If the colonies grow big enough, they can release into the airstream viable organisms that can establish other colonies throughout the duct system and in the conditioned space."[7]

Do air filters help?

Yes, but not as much as you might think. Filters are used to remove particulate matter within the airstream. A fiberglass filter may have a 10 to 15% efficiency rating, but that means that 85 to 90% of particles *aren't* being trapped. Remember, air filters were invented and designed to protect equipment from dirt and other particulates, not to filter gases, spores, or bacteria.

Filters are also rated according to their ability to remove specific sizes of airborne particles. A filter with an "arrestance" rating of 80% may indeed stop 80% of the bees, flies, and large particles of dirt that enter the airstream. But the same filter may have an efficiency of only 3 or 4% when evaluated using the dust spot method of testing.

The location of the air filter also must be taken into consideration. Usually it is placed *before* the evaporator coil to intercept the dirt coming in. Anything growing on the coil or in the first 10 ft after the coil can easily enter the airstream.

How do hygienists determine what the problems are?

An industrial hygienist typically places petri dishes around the area that is to be tested for bacteria, mold, and fungi. Testing is not limited to the building's occupied space—tests also can be performed for bacteria and mold spore counts *within* the air handlers. Test results indicate the types of growth that might be present, and the hygienist is often able to recommend possible solutions.

What can be done to eliminate or prevent such problems?

If mold spores and fungi are allowed to grow in condensate pans and ducts, the growth eventually will die. Then it will start to decay, causing foul odors and releasing micro-sized particles that can seriously affect occupants with allergies.

Antiseptic soaps specially formulated for the purpose of reducing bacteria are available for duct cleaning. Chemicals also are available for killing bacteria, spores, and fungi. You can place chemical blocks or strips in the condensate pan *before* biological growth becomes a problem.

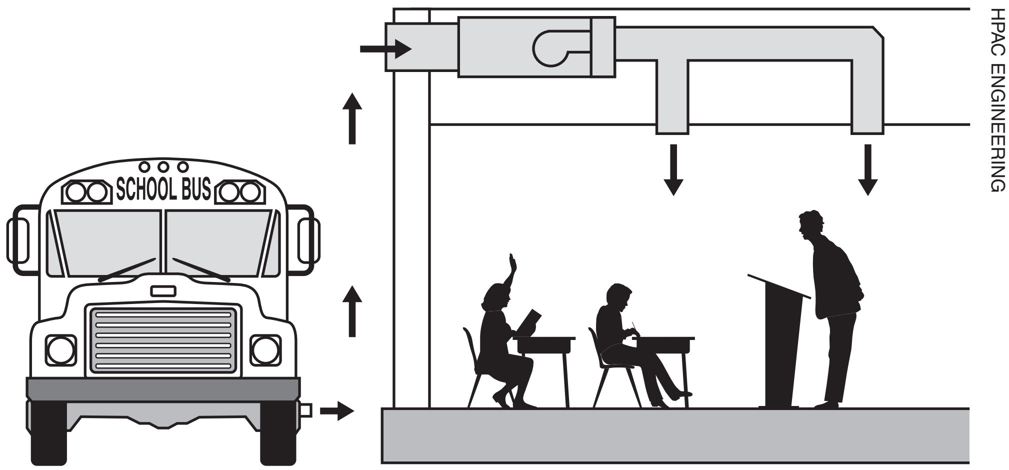

Figure 1. Engine exhaust can cause IAQ problems when vehicles idle near outdoor air intakes

When you are cleaning an HVAC system, don't forget the floors. Shampooing the carpets is especially important. Use only the approved concentration of cleaning solution. If you do not clean the carpets—and most HVAC service companies don't—then instruct the carpet cleaning company to do so.

GENERAL SERVICE GUIDELINES

Contractors are hired to prevent problems, if possible, and to solve problems when they do occur. In performing these tasks, they can provide a useful service while improving their financial bottom line. Here are some general guidelines for HVAC contractors and technicians who deal with IAQ issues.

Keep the building in a positive pressure. The typical residential building is usually in a negative pressure. If you maintain a building in a slight positive pressure, you can control where the building gets its outside air. You also enable exhaust fans, clothes dryers, and most heating equipment (combustion air) to work better.

Today's weathertight homes trap airborne particles inside, where everyday household contaminants can become increasingly concentrated. The result: the air indoors can be up to 5 times more polluted than the air outdoors.

A whole-house heat recovery ventilator flushes stale air to the outdoors and replaces it with an incoming stream of fresh air. Plus, it efficiently recovers up to 80% of the energy used to heat the outgoing air.

Installing an air-to-air heat exchanger to allow for the use of more outside air without paying the usual energy penalty may be a good solution for some customers. More and more of these devices are being installed. There are a number of units that are manufactured for use in single-family residences.

To install a heat exchanger, the technician must locate a place where the outside air is of good quality before making the connection for the return air. The heat exchanger not only takes in outside air, but also provides a relief or exhaust outlet that tempers the air entering the building.

Take a look around the commercial buildings that you service. Do you know where the outside air intakes are located? All too often, they are near dumpsters, chimneys, exhaust hoods, or loading docks. A number of banks experienced problems when they modernized and offered drive-through teller service. Why? Because the air intake was right beside the drive-through lane and the exhaust fumes of the cars waiting in line were drawn directly into the building. Similar problems, as noted in a previous example, have been found in schools (see Figure 1). More often than not, the solution is to move the outside air intake to a better location.

Proper maintenance procedures and record-keeping

IAQ in the workplace has become a major concern for many businesses, building owners, and facility managers. More and more employees who believe that their work environment is not a healthy one are contacting OSHA or hiring lawyers. Some of the complaints are real, and some are hysteria. Most employees spend 23% or less of their time in the building in which they work. Most of their time is spent at home. Nevertheless, many complain that their shops or offices are making them sick. The building may or may not be the problem, but IAQ is becoming a top priority in many management meetings.

This is where proper maintenance procedures, regular preventive maintenance inspections, and good record-keeping pay off for the building owner/manager. Competent service contractors will provide service work orders detailing what work was done and when. A building owner can take positive steps by asking what can be done to the building to make it a healthier place to work or live. Mechanical contractors can offer suggestions on how to upgrade the building.

ASHRAE RECOMMENDATIONS

ASHRAE has developed a written standard (ASHRAE 62, *Ventilation for Acceptable Indoor Air Quality*) that has been adopted by many code-writing organizations into model-building codes. It gives direction to designers, engineers, and building operators, although there are no mandates by law that *require* a building owner to bring an existing building's HVAC system up to current ASHRAE standards. ASHRAE has changed and updated the standard at least three times in the last ten years. ASHRAE 62-2000 states that public buildings need 15 to 20 cfm of outside air per person.

PREVENTIVE MAINTENANCE

There are several things that a building owner or manager can do to help maintain acceptable air quality levels without retrofitting the entire HVAC system. Add the following to your maintenance contract:

- Regularly sample the CO_2 content of the space of each air handler.
- Clean the indoor heat transfer coils to remove dust, mold, and other contaminants.
- Clean the air handler and duct system of dirt, algae, and other contaminants.
- Consider using a UV light to control bacterial and microbial growth in the duct system.
- Use time-release chemicals to prevent the growth of algae and bacteria in the condensate drain pans.
- Verify that the outside air ventilation system is working correctly.
- Upgrade air filtration if the system can handle the extra static pressure drop.
- Verify that the path for the return air is free from dampness, mold, or other contamination.

As you can see, many of the items listed above can be done while the technician is performing the preventive maintenance part of the contract, so they can be added to your contract at a reasonable cost. Of course, following the steps listed above will not *guarantee* that you will never be party to a lawsuit, but providing these extra services with documentation will help you make a good case for your defense should the need arise.

In addition, there is a public relations benefit—the perceived value by the tenants or employees in knowing that their landlord or employer is going the extra mile to provide a clean work environment for them. Consider keeping the occupants informed about the steps you are taking to ensure the quality of their indoor environment.

BASIC MANAGEMENT PLAN FOR GOOD IAQ

Building owners and managers should observe the following minimum guidelines, and document each step to show that they have made "good faith" attempts to provide a healthy space for their tenants or employees:

- Become familiar with your building. What are its uses?

- Discuss the building's HVAC system with a responsible contractor.
- Review the local building codes.
- Ensure that the building has a program in place for regularly changing air filters.
- Ensure that the building is in a positive pressure.
- Ensure that the building is taking in adequate fresh air.
- Ensure that the duct system is free of mold and other micro-contaminants.
- Review and have available all MSDSs (Material Safety Data Sheets) of products and furnishings.
- Seek professional help if symptoms persist.

CONCLUSION

The effects of poor indoor air quality on humans can be dramatic. Consequently, IAQ is an important health concern, and will continue to be one for the foreseeable future. In a building with poor IAQ, major sources of contaminants include:

- the occupants themselves (bioeffluents)
- building materials and furnishings (especially VOCs such as formaldehyde)
- cigarette smoke
- paper processing from copy rooms
- pesticides
- cleaning products.

But not all of the contaminants originate inside the building. Some originate outside, and can be drawn into the building through its intake vents. Outdoor sources of poor IAQ include:

- industrial pollution
- internal combustion engines
- pesticides
- radon.

Service technicians and contractors can minimize the health risks to a building's occupants—and the legal risks to the building's owner or manager. How? By maintaining the HVAC system with a well-planned, regularly scheduled approach.

If the tenants or employees are experiencing any problems, complaints should be documented and addressed immediately. An evaluation of the building should be initiated, with an IAQ audit to identify the source of the problem and implement corrective action. Urge owners and managers to take a pro-active approach to your buildings by starting a comprehensive maintenance program to reduce IAQ risks and liabilities.

Note: Communication with occupants can take a variety of forms, including the placement of articles in a building's newsletter or the distribution of pamphlets on IAQ (an example is the EPA's *An Office Building Occupant's Guide to Indoor Air Quality*).

SUPPLEMENTAL INFORMATION

[1]*RSES Journal*, September 2000.

[2]*Awake Magazine*, August 8, 2000, "Everyday Chemicals: Are They Making You Sick?"

[3]*Air Conditioning/Heating/Refrigeration NEWS*, January 8, 2001.

[4]*HPAC Engineering*, February 2001.

[5]*HPAC Engineering*, May 2001.

[6] *Air Conditioning/Heating/Refrigeration NEWS*, February 23, 1998.

[7]*HPAC Engineering*, December 2000.

Links to the Web

For up-to-the-minute information, use your search engine. Type in the words "Indoor Air Quality" and press search. Some useful links include:

- ASHRAE:
  http://www.ashrae.org

- EPA:
  http://www.epa.gov/iaq

- Maintenance Solutions:
  http://www.facilitiesnet.com/ms

- RSES:
  http://www.rses.org

- Canada:
  http://www.healthyindoors.com
  http://www.ceeformt.org/resid/resid-main.php3

APPENDIX: MATHEMATICAL CALCULATIONS

Determining the percentage of outside air

By knowing the temperature of the outside air and the temperature of the return air, you can determine the temperature of the mixed air that enters the inlet side of the supply blower. Use the following equation:

$$TMA = (TOA \times \%OA) + (TRA \times \%RA)$$

where

TMA = mixed air temperature
TOA = outside air temperature
%OA = % of outside air volume
TRA = return air temperature
%RA = % of return air volume.

Let's say that the temperature of the return air is 70°F, and that the temperature of the outside air is 40°F. Assume that you're working on a building that requires a mixture of 10% outside air and 90% return air. Then:

$$\begin{aligned} TMA &= (40°F \times 0.1) + (70°F \times 0.9) \\ &= 4°F + 63°F \\ &= 67°F \end{aligned}$$

Now you know that the temperature of the mixed air should be 67°F. If you're servicing a 10-ton unit that moves 4,000 cfm of air, you also know that you want about 400 cfm of outside air (10% of 4,000). Measure the temperature of the air at the blower inlet. If the mixed air temperature is *above* 67°F, then the amount of outside air is *less* than 10%, or 400 cfm. If the mixed air temperature is *below* 67°F, then the amount of outside air is *more* than 10%, or 400 cfm. In either case, you can adjust the dampers accordingly. Within a short period of time, you can take another temperature reading to determine whether the dampers have been adjusted properly.

Air changes

To calculate the number of air changes per hour in a building, use the following equation:

$$N_O = \frac{cfm_O \times 60}{V}$$

where

N_O = number of outdoor air changes
cfm_O = cubic feet per minute of outside air (this figure must be multiplied by 60 because you are solving for number of air changes per *hour*, and there are 60 minutes in an hour)
V = total volume of the structure in cubic feet.

Refrigeration Service Engineers Society
1666 Rand Road Des Plaines, IL 60016 847-297-6464