LENNOX™

APPLICATION AND DESIGN GUIDELINES

ALL PRODUCTS

INDOOR AIR QUALITY

INDOOR AIR QUALITY IN COMMERCIAL APPLICATIONS

Form No. 485098
November 2006

INTRODUCTION TO IAQ IN COMMERCIAL APPLICATIONS

Indoor Air Quality (IAQ) is a primary area of concern within all types of commercial buildings. Because we spend much of our time at the office, and in stores, restaurants, and other commercial settings, good IAQ is essential. Poor IAQ can lead to serious health, productivity, and financial consequences.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has attempted to address the IAQ issue with Standard 62-2004. This standard specifies minimum ventilation rates and indoor air quality that will be acceptable to human occupants. More and more state building codes now reference ASHRAE 62-2004. Because the Standard is continually evolving, it is in your best interest to stay current with changes that are being made.

The indoor air quality issue is widely recognized as a major health threat and environmental concern. Your company's HVAC expertise makes you uniquely qualified to assist your customers in this area.

This guide is designed to show you how you can help your customers improve the quality of the air within their commercial buildings. Throughout the guide you will see the term "HVAC comfort consultant" used, rather than "dealer", "contractor" or "technician." By taking on the role of the consultant or problem-solver, you offer your customers a higher level of service while improving your company's position in the marketplace.

THE IAQ PROBLEM

The indoor air quality issue has become recognized as a major health concern. Schools, restaurants, office buildings, shopping malls... none are immune to indoor air pollution. Pollutants found in the indoor air have been shown to heighten many of the health conditions from which people suffer. Areas affected by poor IAQ include occupant productivity and morale, union grievances, and medical and legal expenses. In addition, litigation has greatly raised the visibility of IAQ and has shown that all parties involved can be held responsible. Allegations of liability can involve - but are not limited to - the building's owner, designer, engineer, contractor, equipment manufacturer, and service company.

For these reasons, it is wise to develop and implement a proactive IAQ plan, as the investment is typically less than that required when operating in a reactive mode.

A Closed Environment

As a result of efforts to save energy and lower utility costs, commercial buildings are being built tighter than ever. With thicker walls, more insulation, and better designed windows and doors, commercial buildings have become closed environments. The movement to reduce energy consumption, which gained momentum in the 1970's, has also led to the tightening-up of existing structures.

Making structures more energy efficient does have a negative side. Indoor air quality suffers as the exchange of indoor and outdoor air is limited. Clean outdoor air stays out and indoor air pollutants such as smoke particles, dust, bacteria, fungus, mold spores and chemical vapors remain trapped inside. This leaves the potential for pollutants to build up to harmful levels.

As buildings have become more energy efficient, new health issues have emerged. Conditions known as "Sick Building Syndrome" and "Building Related Illness" have been linked to structures that were constructed, maintained, and operated in such a manner that those who occupied these buildings were contracting various illnesses. Conditions such as these brought to light the severity of the indoor air quality issue.

The Health Threat

Research undertaken by universities, the Environmental Protection Agency (EPA); the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE); public health officials; and professional engineers revealed a serious health hazard involving the indoor air people are breathing. According to the American Lung Association, poor indoor air quality is the most serious health threat facing us.

EPA studies indicate that an individual's exposure to air pollutants can be up to 100 times higher indoors than outdoors. The EPA ranks indoor air pollution in workplace as one of the top environmental issues in the United States. Based on ongoing research and mounting evidence from the medical profession, this health hazard must be addressed.

Poor indoor air is a nondiscriminatory problem. It can exist in a new store or an older store, in a large supermarket or in a convenience store, or in a modern office or an industrial manufacturing facility. No one is immune to the hazards of indoor air pollutants, and unfortunately there is no single cure. However, there are ways to reduce exposure to pollutants and greatly improve indoor air quality.

ASHRAE 62-2004 Overview

The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) has established Standard 62-2004, Ventilation for Acceptable Indoor Air Quality which addresses the complex IAQ issue. It is the best reference on ventilation in commercial buildings and, for this reason, many states have elected to adopt it as code. Though the title implies that it strictly deals with ventilation, the Standard also includes guidelines for controlling sources of contamination, humidity, and filtration. Like most ASHRAE standards, 62-2004 was developed through input from advisory groups of engineers, manufacturers, chemists, physicists, and hygienists.

According to ASHRAE 62-2004, acceptable indoor air quality is defined as "Air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction."

The Standard includes suggestions and requirements ("should" and "shall"). The HVAC industry in general advocates compliance with both.

ASHRAE 62-2004 provides minimum ventilation rates which are expected to result in IAQ that is acceptable to building occupants. This most-recent version of the Standard increased minimum ventilation rates from 5 cfm/ person (ASHRAE 62-1981) to 15-30 cfm/person in most instances. This manual is current with this version of ASHRAE 62-2004.

Revisions to the Standard are being made on a continuous basis. Proposed changes are available for review and comment on the ASHRAE website (**www.ashrae.org**).

SOURCES OF INDOOR AIR POLLUTION

There are a variety of air pollutants that affect indoor air quality and can potentially affect an individual's health. They are generally categorized as:

- **Particulate matter**
- **Biological contaminants**
- **Volatile organic compounds (VOCs)**
- **Airborne chemicals**
- **Radon**

Individual reactions to indoor air pollutants depend on several factors, including age, pre-existing medical conditions and the individual's sensitivity. Some people may be affected immediately while others may not experience symptoms until years later. Specific symptoms and their severity often depend on the concentration and frequency of exposure to indoor air pollutants. One fact is certain: **physical symptoms or not, everyone is exposed to indoor air pollution**.

The following table shows pollutants in each category and the physical symptoms they may cause occupants.

Pollutants and Related Symptoms

	Biological Contaminants				Airborne Chemicals			Volatile Organic Compounds (VOC's)		Carcin-ogens	Particulate Matter				
	Mold, Mildew, Fungus	Bacteria, Virus	Pet Dander	Dust Mites	Nitrogen Dioxide	Carbon Monoxide	Ozone	Formaldehyde	Others VOC's	Radon	Dust, Soil, Ash...	Tobacco Smoke	Pollen	Asbestos	Temperature
Headaches					X	X		X	X			X	X		X
Dizziness	X	X	X	X		X			X						X
Drowsiness						X									
Fatigue						X		X					X		X
Nausea						X			X						
Skin Irritation (Dry/Scaly)									X						
Skin Rash		X						X	X						X
Eye Irritation	X	X	X		X	X	X	X	X		X	X	X		
Nose Irritation	X	X	X	X	X			X	X		X	X	X		
Throat Irritation					X		X	X			X	X			
Respiratory Irritation	X	X		X	X	X	X	X	X			X			
Cough	X	X	X	X		X	X	X			X	X	X		
Chest Tightness	X	X	X	X			X								
Respiratory Infections	X	X						X			X	X			
Asthma (Exacerbation of)	X	X	X	X	X		X	X	X		X	X	X		X
Allergic Reactions	X	X	X	X							X		X		
Lung Cancer										X		X		X	
Asbestosis														X	

Particulate Matter

Particulates are dust and dirt particles which can also be comprised of ash, tobacco smoke, pollen and asbestos. These particles can settle on surfaces (walls, window coverings, floors, carpeting and furnishings) or become airborne from air movement and activities within the structure. Particulates can also be the vehicles for biological contaminants such as bacteria and viruses to move about in the environment.

Dust tends to be sticky and very irregular in shape. It clings to walls, drapes, furnishings and floors, staining these surfaces. The fact that it is sticky allows it to attract other pollutants suspended in the air.

Pollens are a vital component in the reproductive cycle of plants. Pollen is everywhere at certain times of the year. Its presence indoors causes allergy sufferers all sorts of misery like watery eyes, sinus irritation, sore runny noses, breathing difficulties and asthma attacks.

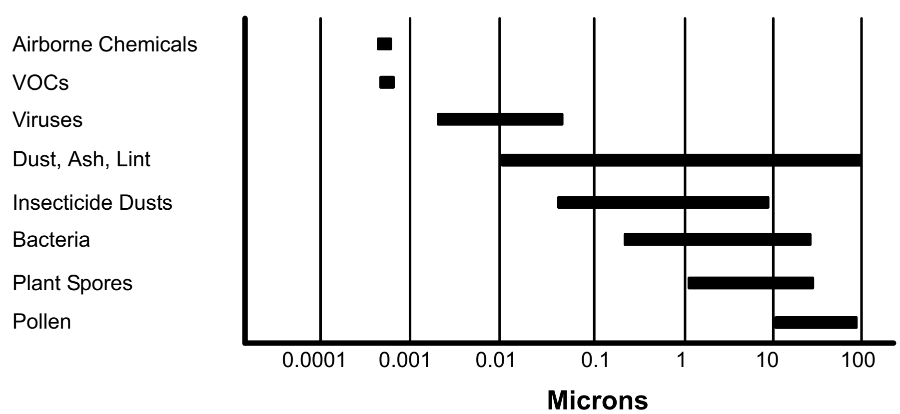
Tobacco smoke also contains particulates which can cause eye, nose, throat and respiratory irritation.

Asbestos is contained in several previously common building materials such as roofing, flooring and insulation. It can be released into the air as these materials abrade or disintegrate. Lung cancer can be the result of prolonged exposure to large amounts of asbestos.

99% of the components that constitute indoor air pollution are extremely small and cannot be seen with the unaided eye. The size of these particles is measured in microns.

A **micron** is equal to one-millionth of a meter. The smallest particle that can be seen with the naked eye is 10 microns. As a-point of reference, the diameter of a single human hair is typically about 100 microns.

TYPICAL SIZE RANGES FOR COMMON POLLUTION COMPONENTS



Large particulate matter will be trapped in the nose or upper lungs where it will eventually be removed from the body by small hairs and mucus. However, particulate matter that is less than 10 microns in size can be inhaled and slip past the body's natural defenses.

These small particles are very important because they comprise more than 99% of the particles in a normal air sample. Each breath you take contains about 10,000 particles. Knowing that adults breathe in an estimated 15,000 liters of air daily, it's easy to see why particulate matter is a concern. We inhale 100 to 200 million particles per day, most of which reach our lungs!

Biological Contaminants

Biological contaminants consist of airborne living organisms or parts of once living organisms. Common biological contaminants found in most indoor air include:

- Bacteria
- Viruses
- Mold and mildew
- Fungi
- Pet dander
- Dust mites

Two conditions are essential to support biological growth: nutrients and moisture.

Microscopic bacteria, viruses, and fungi are all lightweight enough to travel throughout the indoor environment on the air currents. They search for a suitable host where they can attach themselves and thrive.

Viruses usually occur in clusters or may attach themselves to other particles. Bacteria may attach themselves to larger particles such as skin flakes. They usually find their way into the moist nasal and breathing passages of the occupants inhabiting the structure. This often causes allergic reactions, respiratory infections, and in some cases exacerbation of asthma.

All mold growth can not be seen. Do not underestimate the size of the problem if a small patch of mold is observed on a wall surface. Mold can actively grow on drywall, most often on the side that cannot be seen. It can also thrive underneath carpeting and in attics. Even dead mold spores can be dangerous. Mold can be made inactive by drying out a surface, but it seldom disappears completely. It will grow again if it becomes damp or wet.

Mold growth can be more than a nuisance. Those who suffer from allergies are especially susceptible, as are those with compromised or not fully developed immune systems.

Mold needs five things to grow:

- Mold spores or parts of living mold
- Dead or living organic matter for food
- The right temperature range
- Either normal oxygen or none at all
- Enough moisture to make things damp

The first four elements are never in short supply. Moisture control is the key to keeping mold growth in check.

Dust mites live out their entire reproductive lives in our carpets and furnishings. They leave behind trails of droppings, carcasses and more dust mites. Our bodies are continually growing millions of new skin cells daily. As new cells are formed the millions of old, dry skin flakes fall off. These dead flakes provide a very rich source of nutrition for millions of dust mites in the indoor environment.

Odors may be associated with some forms of biological contaminants.

Volatile Organic Compounds (VOCs)

At room temperature, **volatile organic compounds** are emitted as gases from certain solids or liquids. These include items such as carpets, building materials, pesticides. Some VOCs are inherent in the water supply. They are released into the indoor environment as water is sprayed while showering, washing clothes or dish washing.

Volatile Organic Compounds often have a strong odor. The smell of a pine tree or the aroma of a skunk are poignant examples as well as the aroma associated with paint, paint thinner, gasoline and cleaners.

Formaldehyde is a VOC inherent in many building materials, carpet and furniture. Indoor exposure level guidelines are available from various organizations in the US and Canada.

At certain concentrations, exposure to VOCs may cause skin irritation, rashes and a variety of other symptoms.

Airborne Chemicals

Airborne chemicals such as nitrogen dioxide, carbon dioxide, carbon monoxide, sulfur dioxide and ozone can also exist in indoor air, particularly if fuel-burning equipment is not properly installed and maintained.

Nitrogen dioxide and sulfur dioxide act mainly as an irritant affecting the eyes, nose, throat and respiratory tract.

Carbon monoxide (CO) is an asphyxiant. This colorless, odorless gas can cause a variety of symptoms, including headaches, nausea, and drowsiness. High levels of carbon monoxide can be fatal.

Ozone is a desirable element in the upper atmosphere as a shield against the full strength of the sun's energy. Hence the reason for the concern about the "ozone layer" eroding and increasing global warming. However, excessive ozone at ground level is a concern to health and comfort. Ozone is one of the main constituents of smog created by combustion processes. The EPA has defined 40 major US cities as being out of containment limits during part of each year. It can cause difficulty in breathing for athletes, children, older people and those with lung disease.

Indoor exposure level guidelines are available from various organizations in the US and Canada for carbon monoxide, carbon dioxide, nitrogen dioxide, sulfur dioxide and ozone.

Radon

One of the most publicized indoor air pollutants is radon. **Radon** is an odorless, colorless, tasteless, naturally occurring radioactive gas. It is emitted by soil and rock beneath and around the foundation, ground water wells and some building materials.

Radon enters buildings through dirt floors, cracks in concrete walls and floors, floor drains and sumps. If radon builds up, it becomes a major concern. It is a carcinogen and is the second leading cause of lung cancer. Scientific evidence indicates that smoking combined with radon is an especially serious health risk.

Indoor exposure level guidelines are available from various organizations in the US and Canada.

THE FUNDAMENTALS OF A SUCCESSFUL IAQ STRATEGY

It would be convenient to point to a single culprit in the battle against indoor air quality, but it is not that simple. In reality there are so many potential sources that it is impossible to devise a single blanket solution.

In order to create and maintain good indoor air quality, four main strategies must be continually practiced. These are illustrated below:

FOUR BASIC IAQ STRATEGIES

1. **Eliminate**

   Elimination (source control) is the most effective way of correcting any indoor air quality problem. If a contaminant is not present, it will not create an issue. This should be the basic long-term IAQ strategy for any building.

2. **Ventilate**

   Many publications and agencies call this step ”dilution.” It simply involves bringing in outside air to dilute the concentration of indoor air contaminants and to force some contaminants to be exhausted.

3. **Clean**

   Cleaning (filtration) and purifying are effective methods of correcting indoor air quality problems. Particles can be removed from the air by various filtering devices or biological contaminants can be killed in a purification process.

4. **Monitor**

   Although monitoring won’t correct an indoor air quality problem, it can often identify the problem and lead to corrective measures. Monitors can adjust equipment operation, sound alarms beyond preset limits or be used to locate and diagnose the source of contaminants.

   To create and maintain good indoor air quality, careful attention to these four fundamentals during construction, installation, and operation of the building’s HVAC system can reduce the risk of IAQ problems.

   Each strategy will be explained more fully in the following sections of this manual.

ELIMINATE: BEGIN AT THE SOURCE

Eliminating pollutants before they become a problem is the key to source control. The elimination of these contaminants at their source can often be more cost-effective in the long term than cleaning or diluting them through ventilation once they have already inhabited the building space.

By becoming familiar with the pollutants and their sources, you can know what can be eliminated or controlled. A large portion of elimination simply involves good construction and maintenance practices, and common sense.

Indoor air pollution can originate from inside the building, outside the building, or both.

The following table shows pollutants and lists many of their sources.

IAQ POLLUTANT SOURCE CHART

Pollutant	Source
Formaldehyde	Tobacco smoke, carpet, upholstery, drapery fabric, furniture
Biological Contaminants Mold, Mildew, Bacteria & Viruses	Areas where standing water is present
Airborne Chemicals Nitrogen Dioxide, Sulfur Dioxide & Carbon Monoxide	Fuel-burning equipment that is burning improperly or are not properly vented
Dust Mites	Dust
Volatile Organic Compounds (VOCs)	Caulking, adhesives, carpets, paints, solvents
Radon	Soil, rock, building materials
Asbestos	Roofing, flooring, insulation, cement
Ozone	Copy machines, other office equipment
Particulates	Dust, soil from outside
Pollen	Plants from outside

Proactive Measures

A proactive approach to controlling sources of contaminants by the Building Manager and the HVAC Comfort Consultant can prevent IAQ problems from occurring in the first place. As they say, ”an ounce of prevention is worth a pound of cure.”

Proactive Measures by the Building Manager

To control **particulate matter**:

- Ensure that vacuuming is done frequently and that high-efficiency vacuum bags are used.
- See that dusting and cleaning of both horizontal and vertical surfaces (i.e., walls, drapes, etc.) is performed.
- Review the smoking policy and actual practices.
- Make sure that air filters are changed or cleaned regularly.

To control **biological contaminants**:

- Eliminate standing water, water-damaged materials or wet surfaces.
- Avoid keeping sources of bacteria growth (e.g., trash containers) in the occupied area of the structure.
- Clean carpets and furniture regularly.

To control **VOCs**:

- Reduce quantities of office equipment which emit pollutants (photocopiers, fax machines, etc.) wherever possible, or use local exhaust to keep emissions out of space.
- Specify reduced-emission office products.
- Select building materials and products with low emissions of VOC's.
- Ensure the proper storage and disposal of all chemicals.
- Control pest intrusion through the use of light, sound, barriers, or other non-chemical approaches.
- Use pesticides during unoccupied periods with good ventilation.
- Limit the use of VOCs containing cleaners to low-occupancy periods whenever possible and ensure adequate ventilation.

To control **airborne chemicals**:

- Properly operate and maintain all fuel burning equipment.
- Make sure all fuel burning equipment is vented to the outside.
- Ensure air from shop areas does not flow into other occupied areas.

To control **Radon**:

- Seal any cracks or openings in the foundation and provide proper ventilation of the occupied space.
- Test the building for radon. There are kits available for this purpose.

Proactive Measures by the HVAC Comfort Consultant

To control **particulate matter**:

- Properly clean the HVAC system on a regular basis. This plays an important role in the elimination of potential sources of particulates.
- Change filters before they are totally loaded. If used too long, they become a source for particulates. Periodic duct cleaning and keeping HVAC equipment clean and sanitized will help.
- Seal duct systems in all areas external to the conditioned space. Duct system leakage can be a major contributor to indoor air pollution. Leakage in the return air ducting can draw in particulates such as dust, dirt, and pollen.

To control **biological contaminants**:

- Control the relative humidity. By doing so, the growth of some sources of biological contaminants can be minimized. ASHRAE recommends a relative humidity of 30% to 60%.
- Control the temperature. This can also help reduce moisture, as the amount of moisture the air can hold depends on the temperature of the air.
- Ensure that all air handling equipment is equipped with sloped, non-corrosive condensate drain pans. This assures positive drainage and eliminates standing water both when the system is operating or idle.
- Inspect and clean HVAC equipment and duct systems. Drain pans, insulation, and ductwork should be periodically inspected for any signs of microbiological growth. These areas must be readily accessible.
- Make sure that any outdoor air connection is not located over standing water or where there is potential for standing water.

To control **VOCs**:

- Seal duct systems in all unconditioned areas external to the structure. Leakage in the return air ducting which is outside the occupied space can draw in VOCs and other sources of pollution.

To control **airborne chemicals**:

- Inspect, clean, and adjust furnaces, boilers, or hearth products prior to each heating season. Also inspect the venting system and combustion air supply as well as the separation of the circulating air system from the combustion air supply.
- Ensure that fresh air intakes are separated from fuel burning equipment vents to prevent recirculation of combustion products into the conditioned space. Also ensure that vents from fuel burning equipment meets National Fuel Gas Code or local code requirements for spacing from doors, windows, and other building openings or fresh air intakes.

Dehumidification

Humidity is one of the most frequent causes of IAQ problems in buildings today. As noted earlier, controlling indoor humidity levels is the most effective way of addressing the spread of microbiologicals. Such contamination (commonly referred to as mold and mildew) can spread in carpets, ductwork, and walls, often leading to offensive odors, occupant complaints, and IAQ problems.

In the optimum health range of 30% to 60% relative humidity, both the growth rate of biological organisms and the speed at which chemical reactions occur are minimized. Dust mites, respiratory infections, allergic reactions, and asthma attacks are significantly reduced.

High internally-generated latent loads are found in many commercial settings, such as restaurants, schools, and cinemas. Additionally, moisture that enters buildings in the form of ventilation air poses a particularly challenging problem. Humidity control is particularly difficult in schools and in other buildings with high occupancy that require high ventilation rates. ASHRAE 62-2004 guidelines mandated an increase in outdoor air from 5 cfm/person in the earlier version to 15-20 cfm/person in most commercial applications, resulting in a substantial increase in cooling capacity requirements. Direct expansion HVAC systems typically have a cooling coil of adequate capacity to sensibly cool and remove moisture from the mixed return and ventilation air at maximum (design) outdoor air conditions (e.g., 92°F dry bulb and 78°F wet bulb).

The Part-Load Challenge

A consistent amount of air is provided to an occupied space by *constant-volume/variable-temperature systems*. The temperature of the air provided is varied, generally by compressor cycling in a direct expansion system, in order to satisfy the thermostat. However, there is often a need for additional latent (dehumidification) capacity at lower outdoor air dry bulb temperatures, i.e., 82°, due to a high dew point temperature. For instance, the coincidental dew point in New Orleans is 72° at 92° dry bulb, but can be as high as 77° at 84° dry bulb. The challenge with *constant-volume/variable-temperature systems* is that latent and sensible loads rarely peak at the same time. The following sections describe methods of providing enhanced dehumidification at the sensible heat part-load conditions associated with outdoor air dry bulb temperatures less than design conditions.

Heat Pipes

A heat pipe heat exchanger is a passive energy recovery device. It has the outward appearance of an ordinary plate-finned water or steam coil, except that the tubes are not interconnected and the pipe heat exchanger is divided into evaporator and condenser sections by a partition plate. Hot air passes through the evaporator side of the heat exchanger, and cold air passes through the condenser side. Heat pipe heat exchangers are sensible heat transfer devices, which precool return air, raising its relative humidity (RH) before it enters the cooling coil. The higher RH lowers the S/T ratio of the coil, resulting in more humidity removal. The condenser section of the heat pipe is located in the supply air stream and lowers the supply air RH by rejecting heat into the supply air.

Condenser Reheat

This dehumidification strategy involves the addition of a reheat coil circuit on the leaving-air side of the evaporator. Activation of this circuit may be controlled through the use of a humidistat and discharge-line solenoid valve. When the humidity level in the space is acceptable (based on the humidistat), the commercial HVAC equipment operates as normal. However, when the humidistat senses a humidity level that is out of range, it activates the compressor and reheat circuit. The hot vapor refrigerant leaving the compressor now flows through the reheat coil which partially condenses the refrigerant, warming the leaving air such that the sensible capacity is reduced. Since the reheat coil is located on the leaving-air side of the evaporator, it reheats the air prior to its entering the space, so that dry-bulb temperatures remain in check.

Energy Recovery

The Energy Recovery Ventilator (ERV) has become a popular choice in treating incoming humid air. It consists of a desiccant-coated medium that rotates through adjoining exhaust and incoming outdoor air streams. It recovers both sensible and latent energy from the exhaust air and uses it to temper outdoor ventilation air that is brought into a building. This method reduces the energy required to treat the outdoor air and may also reduce the HVAC equipment tonnage requirements. ERV's can usually provide dehumidification for larger percentages of outdoor air than can other methods.

Humidification

Studies have shown low humidity levels contribute to IAQ complaints. A dry environment can cause the occupant considerable discomfort: Dry skin, sore eyes, dry mouth and throat, and electrostatic shocks. Dried-out nasal and throat passages make people more susceptible to respiratory aliments like runny noses, colds, and flu. Even drowsiness, headaches, and general listlessness can occur.

The presence of moisture in proper amounts makes a building feel warmer without actually turning up the heat. In fact, with proper humidity levels, the thermostat can be set back a couple of degrees without the occupants feeling the difference. The addition of a humidifier can make the occupants more comfortable, as high ventilation rates often increase the need for humidification in the winter.

When using humidifiers, it is important to control the moisture added such that the supply air can absorb it without becoming saturated. Otherwise, condensation can occur on cold building surfaces.

VENTILATE: THE DILUTION SOLUTION

Ventilation is a method for diluting the concentration level of indoor pollutants in the conditioned space by introducing fresh outdoor air and/or expelling contaminated air. As noted earlier, indoor air quality suffers as the exchange of indoor and outdoor air is limited. This is because the elimination of pollutants at their source is often difficult and cleaning (filtration) cannot capture all contaminants that reside in a space. Therefore, ventilation addresses the very important task of reducing contaminant concentrations to acceptable levels.

As noted earlier, ASHRAE 62-2004 increased minimum acceptable ventilation rates from 5 cfm/person to 15-30 cfm/person for most types of buildings. While this can create a better IAQ environment, it also presents the challenge of dealing with this additional ventilation air.

Definitions

Ventilation is defined as the process of supplying or removing air by natural or mechanical means from any space. Such air may or may not be conditioned.

The principal functions of ventilation in the structure are:

1. To ensure a continuous source of fresh air containing oxygen
2. To dilute any contaminants generated in the conditioned space
3. To force contaminated air to be exhausted

Ventilation can be thought of as two sub-topics: Supply ventilation and exhaust ventilation.

Supply ventilation involves forcing outdoor air into the structure using fans or blowers. The air moving devices may be a part of or separate from the HVAC system. Forcing outdoor air into the structure causes indoor air to leave the structure through planned or unplanned avenues.

Exhaust ventilation involves forcing indoor air and contaminants out of the structure either through exhaust fans, open doors and/or windows, or an **Energy Recovery Ventilator** (ERV), or through leaks in the structure. Exhausting indoor air causes outdoor air to enter the structure through planned or unplanned avenues, resulting in less contaminated air inside the building.

It is important to maintain a proper balance of supply and exhaust air so that the building does not over- or under-pressurize. Too much internal building pressure may cause doors to swing open, while a pressure that is too low may make them difficult to open.

Also, supplies and exhausts should be separated to prevent recirculation, and contamination. The location of the outdoor air ventilation supply should consider potential contaminant sources as gas vents, vehicle exhaust, and standing water.

Ventilation Requirements: ASHRAE 62-2004

The table below lists selected minimum outdoor air requirements from ASHRAE 62-2004 for various types of commercial facilities.

MINIMUM VENTILATION RATES

Application	cfm/person
Classroom	15
Pharmacy	15
Auditorium	15
Supermarket	15
Office	20
Fast food	20
Bar/lounge	30
Dry cleaner	30
Operating room	30
Smoking lounge	60

The VAV Challenge

Variable-volume, constant temperature (VAV) systems are another commonly used system. In these systems, the supply air temperature is held constant, while the amount of air delivered varies according to the thermal load in each space. Ventilation air is introduced by VAV systems and distributed to the various spaces (or ”zones”). Low temperature air is supplied to the space during the cooling mode, so humidity control is generally good. The challenge with such systems is to design for adequate ventilation at all loads, and to minimize energy usage.

Ventilation Rate Procedure

This procedure (described in Sections 4.1 and 6.1 of ASHRAE 62-2004) defines acceptable air quality achieved by providing a specified quality and quantity of ventilation air to a space. The first step is to determine if the *quality* of outdoor air is acceptable. The Standard references threshold levels contained in ”EPA National Ambient-Air Quality Standards for Outdoor Air.”

Next, if the outdoor air is determined to be unacceptable, then the Standard recommends to treat it prior to its entering the building.

Third, the *quantity* of outdoor air required should be determined. Many constant-volume and VAV systems condition multiple zones. Each of these zones usually requires different levels of outdoor air.

Introducing an outdoor air volume that equals the sum of the zone requirements often results in under-ventilation. To solve this problem, the ratio of outdoor air in the supply air must adjust as the supply air cfm to the zones adjusts. The Multiple Space Equation (Equation 6-1 in the Standard) allows the calculation of the required outdoor airflow such that each space receives adequate ventilation at all load conditions. Appendix B includes a sample calculation.

Building occupancy can also have a bearing on ventilation strategy. Sometimes contaminants can accumulate in a space when it is not occupied. In this case unoccupied ventilation may be required. Usually, this is scheduled based on the time of the day. Where peak building occupancies of less than 3 hours duration occur (*intermittent occupancy*), the outdoor airflow rate may be reduced on the basis of average occupancy for the building, as long as it isn’t less than half the maximum. When the contaminants are generated in the space independent of the occupants or their activities, supply of outdoor air should lead occupancy so that the acceptable conditions will exist at the start of occupancy. With this *pre-occupancy purge* it is important to keep indoor humidity levels under control.

Indoor Air Quality Procedure

The IAQ Procedure (described in Sections 4.2 and 6.2 of the Standard) defines acceptable air quality within a space by controlling known and specifiable contaminants. This procedure sets limits for contaminants, defines an odor level analysis, and -details the use of treated, recirculated air to reduce the minimum outdoor air rates.

Because of the more straightforward requirements of the Ventilation Rate Procedure, most building designers prefer it over the IAQ Procedure which is somewhat subjective.

Ventilation Methods

There are several methods of providing mechanical ventilation to a building via the HVAC system. These include manual outdoor air dampers, economizers, demand control ventilation, power exhausts, and energy recovery ventilators (ERVs).

Manual outdoor air dampers introduce a fixed amount of fresh air into a building through an air handler or rooftop unit. The damper position is fixed, resulting in a continuous percentage of outdoor air for ventilation.

Motorized outdoor air dampers provide automatic damper operation and typically satisfy 0-25% outdoor air requirements.

Economizers modulate to a minimum-ventilation setpoint. They are more sophisticated devices that control the introduction of additional amounts of outdoor air depending upon the conditions (i.e., dry bulb and wet bulb temperatures). Economizers take advantage of ”free cooling” by using outdoor air as the first-stage of cooling whenever conditions permit. They modulate to a fully-closed position when a building is either unoccupied, or when electrical power is lost.

Demand Control Ventilation is a dynamic ventilation method which automatically adjusts to the activity of occupants in a building, thus reducing energy costs and optimizing IAQ. This is accomplished through the use of an integrated system that includes a microprocessor-based controller, and a carbon dioxide (CO_2) sensor in the occupied space. Inside buildings, people are the major source of CO_2, a byproduct of human respiration. Therefore, CO_2 is an indicator of the number of people occupying a given space.

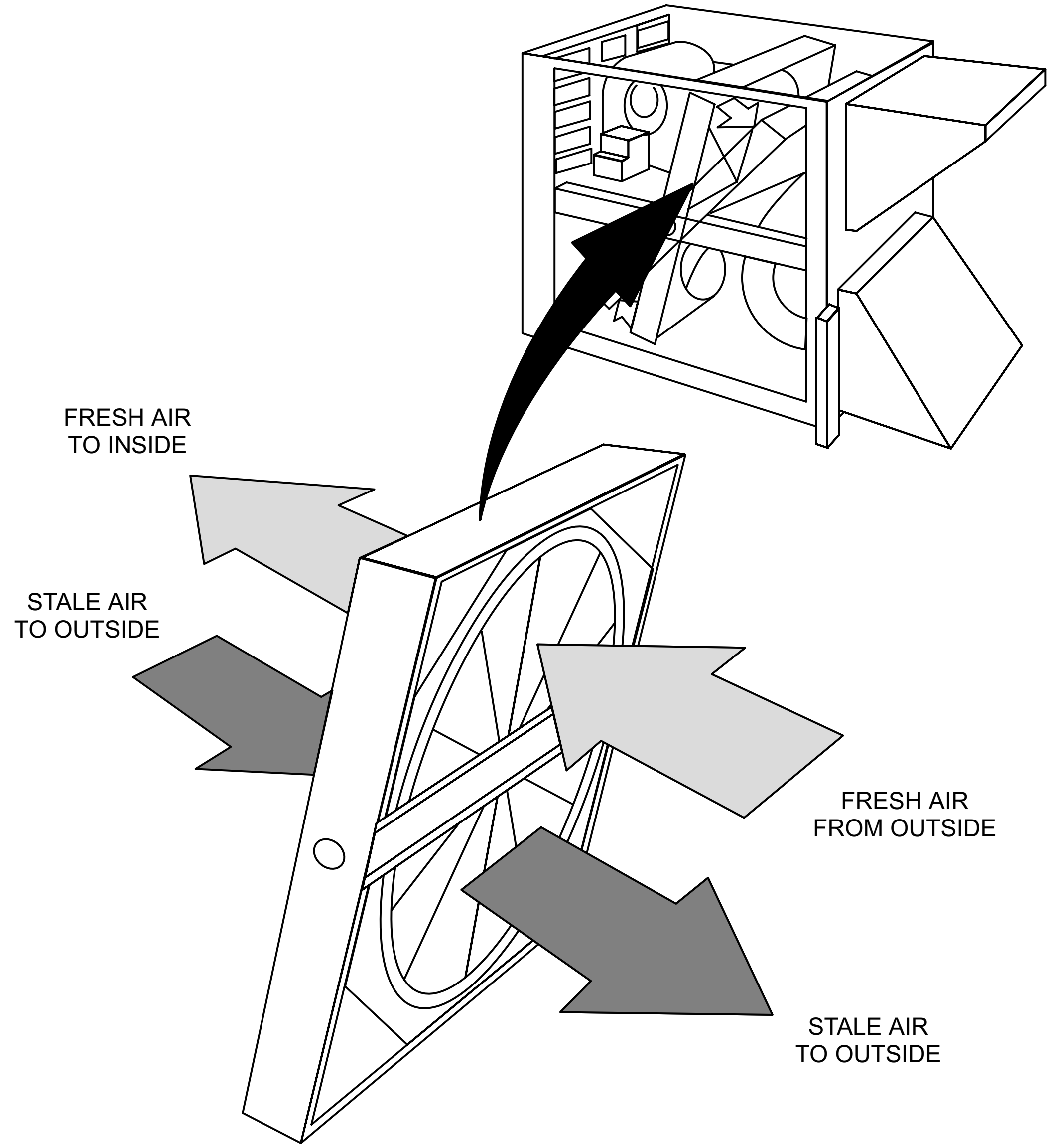
By monitoring CO_2 levels, these systems automatically adjust outdoor air intake and allow building owners to meet ASHRAE ventilation standards without costly over-ventilation during intermittent or variable occupancy.

The ***power exhaust*** generally incorporates an economizer, as well as a powered fan exhaust system which provides mechanical building pressurization relief. The introduction of large quantities of outdoor air can cause building over-pressurization which often cannot be handled through a gravity (non-mechanical) barometric relief damper.

Currently, the best way to ventilate and conserve energy is by using an ***Energy Recovery Ventilator*** (ERV). ERVs are air exchangers that ”exchange” inside air for fresh outside air without sacrificing all of the energy used to condition the inside air. These devices provide for mechanical exhausting as well as supply for the structure. ERVs are currently the most energy-efficient way to ventilate a building.

The ERV works with sensible and latent heat. The ERV is a heat exchanger that has the capability of transferring the heat and humidity properties of the exhaust air to the incoming fresh air. This is achieved by passing the incoming air and the exhaust through a counterflow heat exchanger. This saves energy by recovering heat and humidity from air that is exhausted from the building. It reuses this energy to pre-condition incoming ventilation air rather than additional energy. Cross-contamination of the two air streams is controlled and typically less than 5%. These devices typically recover up to 85% of the energy being exhausted out of the building. Routing the incoming air through an ”energy wheel-type” heat exchanger allows the incoming air to closely resemble the exhaust air in terms of heat and humidity by the time it reaches conditioned space. (See Energy Recovery Ventilator Diagram.)

DIAGRAM OF ENERGY RECOVERY VENTILATOR



Air Distribution

In order for ventilation to be effective, the outdoor air delivered to a space must reach its occupants. Therefore, air distribution systems should be designed and selected to minimize bypass. Bypass occurs when air travels directly to the return duct without being properly mixed with the room air. Diffusers with good throw characteristics at all air velocities should be specified. Inadequate throw due to low air velocity may cause air to be ”dumped” into a space. In contrast, a VAV damper located too close to a diffuser can lead to high air velocities resulting in noise.

Interior air distribution should be controlled such that return air is not pulled from smoking lounges, labs, shops, etc. Air should be distributed into, not out of, these types of areas.

CLEAN: FILTRATION AND PURIFICATION

The majority of particles in the air are extremely small and cannot be captured by standard (often referred to as ”throwaway”) air filters. These minute particles, if not trapped, can slip by your body’s defenses and get lodged in the lungs.

Filters do not remove bacterial contaminants. However, filters treated with antimicrobial coating or ultraviolet lights can inhibit the growth of bacterial contaminants.

Ratings

ASHRAE Standard 52.1 is currently used to rate air filters. It establishes three ratings that are useful in selecting a filter for use in an HVAC system.

The first rating is a **Synthetic Dust Arrestance** value. This measurement relates to the filter’s ability to remove large, coarse particles in the circulating air. The test is conducted by placing the test filter into a clean test duct where a measured quantity of synthetic dust is fed to the filter. The weight of dust the filter traps is divided by the total weight of dust fed into the filter to obtain the arrestance value.

The next measure is **Atmospheric Dust Spot Efficiency**. It is a rating of the filter’s ability to remove small particles from the circulating air. This test is based on the undesirable quality of finer dust particles to stain or discolor surfaces they settle on. Dust spot efficiency is determined by observing the amount of discoloration (staining) caused by known quantities of small particles in a white filter downstream of the test filter.

The third rating, **Pressure Drop**, is a major consideration when selecting air filtering devices. For satisfactory use in an HVAC system, the filter pressure drop must be included with the other system losses to determine that the system will have sufficient air moving capability to serve the building loads. Excessive device pressure drop can reduce airflow to critical levels resulting in coil freeze-up, nuisance limit trips, or even heat exchanger and compressor failures.

Pressure drop is specified as both initial pressure drop and final pressure drop. Initial pressure drop is for new or clean filters and final pressure drop is for filters that are fully loaded. Since media type filters rely on particle straining to remove particulates from the air stream, their efficiency increases as they load with dirt. However, the pressure drop also increases, resulting in less pressure available for pushing the ah” through the system, causing reduction in system airflow.

ASHRAE Standard 52.1 measures the ability of filters to protect the HVAC equipment and reduce soiling. Concerns about indoor air quality and respirable particles led to the development of a new standard, ASHRAE 52.2. This new standard establishes a test procedure for evaluating the performance of air cleaning devices as a function of particle size. Particles ranging from .3 microns to 10 microns are used. The new standard establishes a **Minimum Efficiency Reporting Value** (MERV) number for the test filter based on its particle size removal efficiency as measured by a particle counter.

All filters must be certified as at least Class II per Underwriter’s Laboratories (UL) standard 900.

Filter manufacturers are in the process of testing their products and ratings are expected to be available when the new standard is published.

Disposable Filters

Also known as ”throwaway” filters, disposable filters are generally made from coarse fiberglass mats in a frame or mounted in a filter rack. Very large particles are collected by straining, as they are too large to escape through the openings in the media. Particles are also deposited on strands of the filter media when they come in direct contact. The filter efficiency increases as it loads up with particles until it reaches the point of saturation and begins to lose as many particles as it gains. The disposable filter’s capability is limited to large particles greater than 10 microns. It is generally rated to operate at 300 fpm velocity.

Pleated Filters

Pleated filters are constructed of fiberglass or synthetic fibers woven into a more dense material. The media is arranged in V-shaped forms to increase the surface area without increasing the face area of the filter. This increases the particle-holding capability and allows the filter to have a lower pressure drop due to the increased flow area in the V shape. Depending on the design, the filters are rated at 300 or 500 fpm. They have the capability to provide enhanced IAQ because they remove some of the smaller particles from the air. The following table shows the MERV rating and typical performance of common filters.

Typical Filter Performance

MERV Rating	ASHRAE 52.2			ASHRAE 52.1		Particle Size range (Microns)	Typical Applications
	Particle Size Efficiency (PSE)			Test			
	E1 0.3 to 1.0 Microns	E2 1.0 to 3.0 Microns	E3 3.0 to 10.0 Microns	Arrestance	Dust Spot		
1	- - -	- - -	less than 20%	less than 65%	less than 20%	more than 10	Residential/Min. Light/Commercial Min./ Equipment Protection
2	- - -	- - -	less than 20%	65-70%	less than 20%	more than 10	
3	- - -	- - -	less than 20%	70-75%	less than 20%	more than 10	
4	- - -	- - -	less than 20%	more than 75%	less than 20%	more than 10	
5	- - -	- - -	20-35%	80-85%	less than 20%	3.0-10.0	Industrial Workplaces Commercial Better/ Residential Paint Booth/Finishing
6	- - -	- - -	35-50%	more than 90%	less than 20%	3.0-10.0	
7	- - -	- - -	50-70%	more than 90%	20-25%	3.0-10.0	
8	- - -	- - -	more than 70%	more than 95%	25-30%	3.0-10.0	
9	- - -	less than 50%	more than 85%	more than 95%	40-45%	1.0-3.0	Superior/Residential Better/Industrial Workplaces Better/ Commercial Buildings
10	- - -	50-65%	more than 85%	more than 95%	50-55%	1.0-3.0	
11	- - -	65-80%	more than 85%	more than 98%	60-65%	1.0-3.0	
12	- - -	more than 80%	more than 90%	more than 98%	70-75%	1.0-3.0	
13	less than 75%	more than 90%	more than 90%	more than 98%	80-90%	0.3-1.0	Smoke Removal General Surgery Hospitals & Health Care Superior/ Commercial Buildings
14	75-85%	more than 90%	more than 90%	more than 98%	90-95%	0.3-1.0	
15	85-95%	more than 90%	more than 90%	more than 98%	95%	0.3-1.0	
16	more than 95%	more than 95%	more than 95%	more than 98%	more than 95%	0.3-1.0	

Particle vs. Gas-Phase Filters

Filters can reduce indoor pollutant levels of both particles and gases. Particle filters include filter media and electronic air cleaners. Gas-phase filters include carbon-based or catalytic types. Carbon-based filters are effective in reducing ozone in indoor air.

Air Purification

Filters are available that are treated with antimicrobial materials. These filters can inhibit the growth of bacteriological contaminants such as mold, mildew, fungi and bacteria.

For odor removal pleated filters can be impregnated with carbon or activated carbon canisters and can be used. The pleated filters must be changed periodically to maintain their odor removal capability. In some cases, the carbon canisters can be regenerated and reused rather than being replaced.

Ultraviolet light at a specific band of wavelengths and above a minimum intensity level will kill some of the biological contaminants passing through the effective field of view. Since some odors are associated with these biologicals, odors may be reduced in some instances. The units consist of lamps, similar in appearance to fluorescent tubes, requiring a power supply. The lamps are inserted in the return air ducts of the HVAC system. Controls are available on some models to limit the on-time of the lamps for increased life.

Filter Operation and Maintenance

The need to replace or clean filters is a function of many variables such as run time, efficiency, size and type, etc. Typically, low efficiency disposable and permanent filters need to be replaced or cleaned more often than deeper extended surface filters. Integrated microprocessor-based controls often have a built-in dirty filter switch input which signals the need for filter change.

The use of continuous blower during non peak load conditions significantly increases the quantity of particles removed from the conditioned space. Note that in warm weather, this may cause condensate to re-evaporate and raise the relative humidity level if the system is not equipped with active dehumidification control.

MONITOR: BEYOND TEMPERATURE CONTROL

Monitoring is the key to defining and maintaining a good IAQ environment. Because this environment is made up of a number of components, their operation in response to air quality measures must be coordinated.

Instruments for testing and monitoring temperature, relative humidity, carbon monoxide and carbon dioxide are readily available for monitoring space or equipment operating conditions. Many are available with data logging capability, either internally or via portable computer. These instruments can be used to quantitatively determine equipment performance or indoor air conditions. This allows the comfort consultant to verify proper operation or begin to pinpoint any abnormal or undesirable conditions.

Integrated Controls

Direct digital control systems can be installed in premium line HVAC equipment at the factory (example: The Integrated Modular Controller in Lennox' L Series® and S-Class™ rooftop units). These controllers take individual system controls and bring them together, and allow interfacing with energy management systems.

Air quality control is one integrated control feature that can prove to be valuable. Built-in IAQ-related functions often include **Dirty Filter Indication and Demand-Control Ventilation**.

Dirty Filter Indication

An optional Dirty Filter Switch senses a static pressure increase, indicating a dirty filter condition. This information is relayed to the integrated control, which alerts the service person to install a new filter.

Dirty Filter Switch

Demand-Control Ventilation

CO_2 Sensor

Inside buildings, people are the major source of carbon dioxide (CO_2). All living beings inhale oxygen and exhale CO_2. Carbon dioxide should not be confused with carbon monoxide, CO, which is a deadly byproduct of combustion. People involved in the same level of activity, such as those in schools or offices, exhale CO_2 at a known and predictable rate.

Demand-Control Ventilation is a method of ventilation control which uses CO_2 as an indication of occupancy. By ventilating "on demand" and following actual occupancy patterns versus fixed ventilation rates, outside air requirements can be met at all times while minimizing energy costs.

An integrated modular controller controls the outside air dampers to maintain ideal fresh air ventilation. Simply adding a carbon dioxide sensor in the occupied zone or return air ductwork will allow the system to modulate ventilation based on actual vs. design occupancy. The role of CO_2 control in indoor air quality and ventilation has been clarified in an interpretation (1C 62-2004-27) to ASHRAE 62-2004. This interpretation, which is provided as an addendum to the Standard, details the criteria that a control strategy must meet to allow application under the variable and intermittent occupant provisions.

In colder climates, there may be a need to add a control, limiting the amount of outside air that can be brought into a space. This is to prevent low supply air temperatures from making the space uncomfortable during the heating season. The cold air can also cause condensation in the heat exchanger, eventually leading to rust. Stainless steel heat exchangers can tolerate this condition as they will not rust due to condensation.

A Fresh Air Tempering option provides heating and cooling as needed to maintain the supply air temperature within a comfort range, regardless of the thermostat demand.

Measuring Pollutants

Measuring paniculate matter is possible but requires very expensive instrumentation. As sensor technology for instrumentation advances, this may become more viable as an instrument for the technician.

Biological contaminants (bioaerosols), by the nature of their microscopic size and complex composition, are very difficult to collect and evaluate in indoor air. Very specialized collection and evaluation methods are required.

The **AirAdvice IAQ Monitor**™ helps easily uncover IAQ problems in customer buildings. This compact, multi-sensor monitor continually measures temperature, humidity, carbon dioxide, VOCs, and airborne particles in one-minute cycles. Once a day, it transmits IAQ data from it's location over the phone lines late at night via a toll free number. Once the test is complete, the customer can log on to the AirAdvice Website and print out a personalized IAQ report, generated from the data the monitor collected. AirAdvice generates personalized reports about IAQ levels in the customer's buildings. Reports can be requested via the Internet. Reports contain a cover page with a summary, analysis, and recommendations section based on the test results, and a detailed analysis section with charts and graphs. Recommendations to improve Indoor Air Quality can then be submitted to the customer. For additional information, visit the AirAdvice website (**www.airadvice.com**).

The **Viable Impactor Air Sampler** is a common device used to collect biological contaminants from the indoor air. The air sample is drawn into the viable impactor sampler with a vacuum pump. The biological contaminants are separated from the air and deposited in a Petri dish. The dish is then sent to a laboratory for evaluation. This process is able to identify the different biological contaminants in the sample as well as quantify the levels present.

Another method utilized in the field to measure biological contaminants is to simply place an open Petri dish in the indoor environment for several days and evaluate the number of colonies that develop in the dish. This test will indicate the presence of these contaminants, but it will not specifically identify them. This method is useful for doing a before-and-after evaluation to determine if additional measures are required to correct the problem.

The practical measurement of Volatile Organic Compounds (VOCs) is advancing rapidly. Some sensors and devices are available now that claim to measure the presence of these chemicals. Sensor technology is rapidly advancing and we can expect to see advances in this measurement to assist the technician in analyzing environments and diagnosing issues.

Finally, hand-held CO_2 monitors can be used to quickly measure the ventilation rate. While CO_2 is not a direct measure of IAQ, it is an excellent measure of effective ventilation. The higher the $C0_2$ concentration, the lower the ventilation. When indoor CO_2 levels are very high (above 1800 ppm) ventilation is low (below 7 cfm/person) and other contaminants can build up causing irritation and discomfort.

RECOMMENDED IAQ SYSTEM SPECIFICATIONS

In the previous chapters, we have walked through the reasons why good IAQ is desirable, the contaminants that can be present, the basic strategies for controlling them and the equipment available to carry out those strategies.

We've discussed the actions the owner or occupants need to contribute for acceptable IAQ. But, what does the contractor need to provide to create and maintain good IAQ?

Here are the minimum IAQ products and services to provide good IAQ in most commercial buildings.

- Properly sized heating and air conditioning units with a quality thermostat to provide temperature control and associated dehumidification in the cooling season.
- Equipment which incorporates sloped, non-corrosive condensate drain pans.
- Cleanable interior surfaces.
- Accessibility for Cleaning and Inspection.
- A duct system capable of providing an adequate supply of ventilation and conditioned air to all spaces.
- Return air ductwork located outside the conditioned space that is sealed to prevent importing contaminants to the conditioned space.
- Adequate combustion air for all fuel burning equipment to prevent spillage and/or incomplete combustion.
- A pleated air filter with the capability to remove particles smaller than 10 microns and the dust holding capability to be effective throughout the maintenance period.
- An outdoor air damper or ERV to provide adequate ventilation to the space in accordance with ASHRAE 62.
- Continuous air circulation capability to provide continuous filtration, purification and ventilation.
- Face-split evaporator coils on multiple-compressor units for best dehumidification with continuous fan operation.
- A humidifier with humidistat to maintain heating season humidity levels.
- Carbon Monoxide (CO) detectors in appropriate areas to provide warning of any substantive concentrations.
- A Planned Service™ agreement for semiannual inspection and maintenance of the equipment to maintain its effectiveness.

For applications where more precise ventilation control is desired:

The addition of a CO_2 sensor in the occupied zone or return air ductwork will allow the system to modulate ventilation based on actual versus design occupancy. This "demand control ventilation" saves energy by avoiding costly over-ventilation during intermittent or variable occupancy.

As you have seen, creating and maintaining good indoor air quality is complex, but not impossible. The occupants must be interested in having a good indoor environment and be willing to provide for certain activities. They also need an HVAC comfort consultant who understands what is needed for good indoor air quality and the contributions of the HVAC system and regular preventative maintenance.

The following checklist can be used by the building manager and comfort consultant to quickly evaluate the basic IAQ needs of commercial buildings. The comfort consultant should be familiar with the basic system requirements and use the comment section of the checklist to explain the existing deficiencies and remedies to the building manager.

COMMERCIAL BUILDING AIR QUALITY CHECKLIST

□. Have there been any changes in space use, contaminants, or operation? Any of these may require a re-evaluation of the design and implementation of needed changes. (Reference: ASHRAE 62-2004, Section 4.2)

□. If natural ventilation and infiltration is relied upon, can sufficient ventilation be demonstrated? (Reference: ASHRAE 62-2004, Section 5.1)

□. If mechanical ventilation is required, is a provision for air flow measurement included? (Reference: ASHRAE 62-2004, Section 5.1)

□. Has the use of energy recovery ventilation systems been considered for energy conservation purposes in meeting ventilation requirements? (Reference: ASHRAE 62-2004, Section 5.1)

□. Is the ventilating system designed and installed so that the ventilation air is supplied throughout the occupied zone? (Reference: ASHRAE 62-2004, Section 5.2)

□. When the supply of air is reduced during times the space is occupied (e.g., in variable-air-volume systems) have provisions been made to maintain acceptable indoor air quality throughout the occupied zone? (Reference: ASHRAE 62-2004, Section 5.4)

□. Is the ventilating system designed to prevent re-entrainment of exhaust contaminants, condensation or freeze-ups (or both), and growth of microorganisms? (Reference: ASHRAE 62-2004, Section 5.5)

□. Are ventilating ducts and plenums constructed and maintained to minimize the opportunity for growth and dissemination of microorganisms through the ventilation system? (Reference: ASHRAE 62-2004, Section 5.6)

□. Are contaminants from stationary local sources within the space controlled by collection and removal as close to the source as practicable? (Reference: ASHRAE 62-2004, Section 5.7)

□. Is fuel-burning equipment, including fireplaces, provided with sufficient air for combustion and adequate removal of combustion products? (Reference: ASHRAE 62-2004, Section 5.8)

□. Is the relative humidity in the space maintained between 30% and 60% relative humidity to minimize the growth of allergenic or pathogenic organisms? (Reference: ASHRAE 62-2004, Section 5.11)

□. Are air-handling unit condensate pans designed for self-drainage to preclude the buildup of microbial slime? (Reference: ASHRAE 62-2004, Section 5.12)

□. Are provisions made for the periodic cleaning of cooling coils and condensate pans? (Reference: ASHRAE 62-2004, Section 5.11)

□. Are air-handling and fan coil units easily accessible for inspection and preventive maintenance? (Reference: ASHRAE 62-2004, Section 5.11)

□. Has special care been taken to avoid entrainment of moisture drift from cooling towers into the makeup air and building vents? (Reference: ASHRAE 62-2004, Section 5.12)

IAQ DEFINITIONS

Air Distribution	The delivery of air to a space and its occupants.
CO	Carbon monoxide - a colorless, odorless toxic gas.
CO_2	Carbon dioxide - a gas which all living beings exhale; can be used as an indicator of occupancy.
Condenser Reheat	A dehumidification strategy involving the addition of a reheat coil circuit utilizing reclaimed condenser heat to provide reheat on the leaving-air side of the evaporator.
Dehumidification	The removal of moisture (water vapor) from the air.
Demand-Control Ventilation	A method of ventilation control which uses CO_2 as an indication of occupancy.
Desiccant	A media that dries air in one stream and rejects the moisture to another air stream.
Dilution	A method of reducing the concentration level of indoor pollutants in the conditioned space by introducing fresh outdoor air.
ERV	A heat exchanger that has the capability of transferring the heat and humidity properties of the exhaust air to the incoming fresh air.
Heat Pipe	A heat exchanger that is a passive energy recovery device.
Integrated Controls	Direct digital modules that take individual controls and bring them together, allowing interface with energy management systems.
Part-Load	Operating conditions at less than design load.
Purification	The process of inhibiting the growth of bacteriological contaminants.
VAV	Variable-volume, constant temperature systems where the supply air temperature is held constant, while the amount of air delivered varies according to the thermal load in each space.
Ventilation	The process of supplying and removing air by natural or mechanical means to and from any space.

LENNOX IAQ SOLUTIONS

The **Lennox L Series®** commercial packaged heating and cooling systems feature a number of IAQ solutions. Among them:

Humiditrol® option, available with L-Series 3, 4, and 5 ton high-efficiency models. With this option, the unit will operate to remove moisture without over cooling the space. This is especially beneficial when high-humidity fresh air is being brought into the space to meet ASHRAE 62-89 fresh air guidelines.

Demand-Control Ventilation uses CO_2 levels within the space to determine the amount of ventilation required (using EVIC board and CO_2 sensor).

Energy Recovery Ventilators, designed specifically for use with L-Series products, allow fresh air to be brought into a building while recovering a large percentage of the energy being exhausted. Pivoting wheel models allow the use of economizers.

Economizers with optional enthalpy controls minimize the amount of outdoor air humidity introduced into a building.

Sloped condensate drain pans are standard on all units. These drain pans are non-corrosive, and are sloped to assure positive drainage and eliminate standing water. Such standing water is a potential source of microbial contamination.

Cleanable surfaces in the sections of the units that are expected to become wet are cleanable, minimizing the opportunity for the growth of microorganisms.

Accessibility is outstanding, with hinged access panels for easier and quicker access to unit components. A cleanable surface is of questionable value if it cannot be readily accessed.

2” Pleated Media Filters offer enhanced particle removal vs. commonly-supplied non-pleated filtration.

Dirty Filter Indication results from the sensing of a static pressure increase, indicating a dirty filter condition.

APPENDIX A: CASE STUDY #1

Humiditrol® System Solves Humidity Problem In Restaurants.

A PERFECT CLIMATE FOR THE PERFECT DOUGHNUT

Krispy Kreme learns the importance of maintaining store temperature and humidity

The Krispy Kreme brand name has a special meaning to anyone who has ever raced into the doughnut shop when the “Hot Doughnuts Now” sign is on and consumed one (or several) of the delectable, sugar-glazed confections.

Central to producing the perfect doughnut is consistently delivering the right texture, taste, and appearance. This can only be accomplished by maintaining strict temperature and humidity standards in each store. Such careful attention to detail helps Krispy Kreme ensure their brand name retains the special and unique meaning it has held for consumers since 1937.

Great doughnuts? No sweat.

“Our glazed doughnut is our signature product, and it’s important the glaze on that doughnut be consistent in every store,” said Richard Sides, vice president of construction for Krispy Kreme. ***“If the humidity gets too high in the kitchen or dining area, the glaze starts to break down, and the doughnut begins to sweat.”***

Controlling humidity levels in a Krispy Kreme store is an around-the-clock job for the HVAC system. The kitchen is open 24 hours a day, making doughnuts for the store and off-site retailers—so even though the dining room climate does not need to be controlled all day, the kitchen does.

Another climate control issue is the hot steam resulting from pressure washing the kitchen for clean up. This process significantly increases humidity levels within a very short time frame. ***The store’s HVAC system must quickly and efficiently reduce humidity***

levels or risk damaging the product.

Previously, many franchisees used an HVAC system that did not adequately control humidity, because the equipment only removed moisture when there was a need to cool the store. If the store’s temperature level stayed within the desired range, the HVAC equipment would not operate, and the humidity would not be reduced. This problem resulted in higher than desired humidity levels, affecting Krispy Kreme’s high product standards.

“Selecting an inadequate dehumidification system affects product quality and can be very expensive to fix,” said Sides. “Retrofitting HVAC systems with a dehumidification device is much more expensive than just installing the device from the beginning.”

Finding a suitable dehumidification product

The challenge was assisting Krispy Kreme and their franchisees in finding an alternative dehumidification product that satisfied price, performance, and reliability needs. Ray Thornton, principal of Lehmann, Mehler, Hirst, Thornton Associates, an architectural and engineering firm, recommended using Lennox’ L Series® unit, featuring the Humiditrol® dehumidification system.

due to code changes,” said Thornton. “Higher ventilation rates yield higher cooling and heating loads, especially higher latent cooling loads in certain regions of the country. ***Lennox has effectively addressed these demands with the Humiditrol dehumidification system.”***

In addition to properly controlling humidity levels, the L Series units with the Humiditrol dehumidification system also help

Lennox national account manager Todd Buck contacted Krispy Kreme and their Oklahoma franchisee, the Hal Smith Restaurant Group.

After installing Lennox’ L Series units, featuring the Humiditrol system on the first Krispy Kreme store in Tulsa, Buck used data loggers to measure the relative humidity levels. In addition to the Tulsa location, Buck logged control operating costs by delivering dehumidification efficiently. ***By taking hot gas from the compressor and supplying it to the staged reheat coil, Lennox’ Humiditrol system offers an efficient, cost-effective alternative for controlling humidity, compared to other HVAC options or methods.***

“There were a lot of other choices we could have made for the HVAC system in these new stores,” said David Zimmer of The Hal Smith

data at Krispy Kreme stores in Atlanta and Greensboro. He learned the stores generate a significant amount of humidity during doughnut production.

The data revealed relative humidity inside the Atlanta and Greensboro stores averages 71%, while the outside relative humidity averaged only 57%. The data also showed stores which use Lennox’ Humiditrol dehumidification system average just 53% relative humidity inside.

Humidity inside a building is not the only concern. “Engineers have been facing higher ventilation standards around the country,

Restaurant Group. ***“The Humiditrol system helped us achieve our goals for less money, compared to other methods.”***

The L Series units featuring the Humiditrol dehumidification option, have been so successful in the three Krispy Kreme restaurants that the Hal Smith Restaurant Group plans to install these units in five more stores.

“I’ve had no complaints about the temperature, humidity, or any other maintenance issues,” said Zimmer. “In this case, no feedback is definitely good feedback.”

“The Humiditrol system helped us achieve our goals for less money, compared to other methods.”

David Zimmer
The Hal Smith Restaurant Group

APPENDIX A: CASE STUDY #2

Protecting Indoor Air Quality With Demand Control Ventilation

KEEPING STUDENTS HAPPY AND HEALTHY

Lennox demand control ventilation keeps classrooms comfortable

The job of indoor school maintenance is never ending. It is vital to keep your students comfortable and healthy in order to give them the best learning environment possible. But a school's ventilation needs change constantly, depending on classroom size and events going on throughout the day.

The more students and faculty in one area, the greater the challenge of providing acceptable indoor air quality (IAQ). People—and the carbon dioxide they breathe out—have a real impact on IAQ requirements and the bigger the class, the more fresh air needed to .x the problem. Too much fresh air driving the cost of heating and cooling can cause energy bills to skyrocket.

That was the case for Grandview High School and Meadowmere Elementary in the Grandview School District, Grandview, Missouri. Areas of the two schools were experiencing high CO_2 levels and some classrooms had mold problems. More fresh air and elimination of the mold was needed to maintain the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) standards.

“We needed to decrease the extreme temperatures inside the building to maintain an even climate control and bring more fresh air in for the students and faculty,” said Herb Wilson, Grandview School District Director of Maintenance. “The oxygen levels had to increase, while the mold had to be eliminated.”

The solution?

Wilson turned to demand control ventilation (DCV), the process of controlling the amount of fresh air introduced according to the level of carbon dioxide, in order to increase air quality in an energy efficient manner. ***Lennox has developed a unique and advanced DCV system in their premium line of packaged rooftop units. Lennox' L Series® and S-Class ™ rooftop units contain an intelligent microprocessor-based unit controller, the Integrated Modular Controller (IMC), that when coupled with a carbon dioxide sensor and an economizer or motorized outdoor air damper, provide a complete DCV system straight from the factory.***

Wilson purchased Lennox' L Series with DCV for Grandview and Meadowmere in 2001, and has the units scattered throughout the other eight schools in his district as well.

How it works

Demand control ventilation uses a carbon dioxide sensor to estimate the number of students in the classroom based on the current carbon dioxide levels and signals the rooftop's unit controller to open the outdoor air dampers. The outdoor air damper modulates open, allowing fresh air to enter the space. Once carbon dioxide levels have been reduced, the outdoor air dampers modulate back to their minimum position. This system allows fresh air ventilation rates in variable occupancy spaces to modulate according to the occupancy levels, controlling IAQ while minimizing its impact on energy use

Why the Lennox system is unique

Lennox' DCV system comes directly from the factory with any L Series® or S-Class™ unit that has an economizer or motorized outdoor air damper installed. The only additional component needed is a carbon dioxide sensor in the space.

Integrated controls make the system efficient and simple to use. The carbon dioxide measurement is read by Lennox' factory-mounted Integrated Modular Controller (IMC). The IMC sends a signal based on carbon dioxide measurement, overriding the economizer damper position to minimize energy use and ensure a comfortable, healthy environment. Its user-friendly design allows schools to monitor carbon dioxide levels on-site or from a remote location.

All economizers on Lennox units are gear-driven without linkages to eliminate binding and the need for adjustment. This helps ensure the correct amount of fresh outside air is always available to maintain comfort and minimize energy usage.

Schools feel the benefits of improved IAQ

Indoor air quality can have a tangible effect on schools. Poor IAQ can make students and faculty uncomfortable, detracting from the learning environment and making it difficult to concentrate.

Poor IAQ can lead to a range of problems, from undesirable odors to sick building syndrome. It can not only make students uncomfortable, it can make them sick. Students and faculty affected by poor IAQ have increasingly sought reparations through lawsuits. Liability is a major consideration when it comes to indoor air quality.

According to ASHRAE studies, about 15 CFM of ventilation air per person is adequate to dilute body odor to an acceptable degree. Per ASHRAE's standard, carbon dioxide is not considered a "specifiable contaminant," but is only an indicator of occupancy level. Carbon dioxide can be measured easily and cheaply. Many other contaminants cannot.

The goal of demand control ventilation is not to eliminate all contaminants based on carbon dioxide. It is to measure occupancy based on carbon dioxide and provide adequate outside air to promote a comfortable environment for all of the occupants. Carbon dioxide generation will vary according to what people are doing and other factors. The standard recommends maintaining a level of carbon dioxide 700ppm below that of the outside air.

"Since purchasing the DCV systems, Grandview High and Meadowmere Elementary have had better IAQ levels and no mold. The IAQ has increased tremendously and students and faculty have had comfortable and safe learning environments," stated Wilson.

Cost savings

The annual energy cost for an average Midwestern school facility's HVAC system totals $20,000.

Since Lennox' L Series with DCV has been installed in Grandview and Meadowmere, Wilson has seen cost efficiency improve 20%.

"Even with increasing gas prices, our HVAC cost has remained the same throughout the schools due to Lennox' L Series with Demand Control Ventilation," stated Wilson.

Customer Satisfaction

Improving the IAQ of school facilities and ensuring that students and faculty are comfortable and healthy requires careful planning and reliable equipment.

"We have been nothing but impressed since installation," stated Wilson, "I would recommend Lennox to improve IAQ to anyone."

APPENDIX A: CASE STUDY #3

Improving Indoor Air Quality With L Series® Units And Humiditrol® Dehumidification System

JUST WHAT THE DOCTOR ORDERED

Lennox' L Series® units prove to be the right prescription to help allergist solve indoor air quality problems

The Challenge

Dr. Alfred Johnson treats patients for allergies and chronic illness. The one thing he didn't want or need was for his patients to get worse while sitting in his office. So when Dr. Johnson opened his new Johnson Medical Associates clinic in the Dallas suburb of Richardson, he turned to Hammack Service Co., a local Lennox dealer, for help.

What Dr. Johnson was seeking was the cleanest indoor environment for his patients; an environment free of harmful chemical odors, fumes, mold and pollen. After listening to Dr. Johnson's requests and surveying the building, Jim Kuhs, Hammock's service manager, knew he would need some advice. He knew he could rely on Lennox to offer the expertise he needed. Kuhs contacted the Lennox' Indoor Comfort & Air Quality team at their Product Development & Research lab in Carrollton, Texas.

The Solution

After reviewing the clinic's needs, Hammack selected four high-efficiency Lennox 5-ton L Series® rooftop units with the Humiditrol® option.

"While providing temperature and humidity control for the offices by using refrigerant reheat technology, the units dehumidify without overcooling the clinic," said Mark Jackson, Lennox Senior Staff Engineer. *"By controlling humidity, mold growth is minimized while additionally reducing dust mites."*

The configuration was also designed to provide multiple comfort zones within the clinic to allow separate temperature control for each section of the building. But that was only part of the battle. One of the biggest challenges to improving indoor air quality (IAQ) is how to keep outdoor contaminants from coming inside. Hammack and Lennox solved this problem two ways. First, by filtering outdoor air through high-efficiency particulate air (HEPA) filters, and second, by treating it with Ultraviolet (UV) light.

"This process not only helps provide clean, fresh ventilation air in accordance with ASHRAE requirements, it also pressurizes the building. The UV light helps reduce the concentrations of mold, bacteria and viruses as well," Jackson said.

Filtering the outside air through HEPA filters reduces the number of particles coming in from the outside by 99.97% microns at 0.3 microns. Even return air is filtered. All return air grills were fitted with MERV 8 (Minimum Efficiency

Reporting Value, per ASHRAE) filters to continuously clean the re-circulated air before entering the ducts.

Lennox' team also assisted with eliminating pollutants at the source and with monitoring the level of pollutants. Hard surface flooring was installed throughout instead of carpeting, and water-based paints, which reduce off-gassing chemicals, were utilized.

HEPA vacuum cleaners were used to clean the building, and only sealed lights were used to prevent air leakage through light fixtures. Lastly, the office was put under positive pressure to minimize leakage of dirty air into the building.

Dr. Johnson even requested that all the metal surfaces having air contact in the system be degreased with soap prior to installation in an effort to minimize the off-gassing from oil on the metal parts. Foil-faced insulation was used, and mounting and wiring holes were sealed to reduce air leaks.

"Even during construction, all supply and return vents were taped off and sealed to prevent any paint and drywall dust from contaminating the air ducts prior to commissioning," stated Steve Attri, Indoor Comfort and Air Quality Manager for Lennox.

"This is an excellent example of looking at the whole building as a system," Attri added. "It's not always as simple as adding another component."

For Lennox and Hammack, the challenging effort was a success. For Dr. Johnson's patients, better indoor air quality translates to a better quality of life.

APPENDIX A: CASE STUDY #4

L Series® Units With The Humiditrol® System Improves Indoor Air Quality

SOLUTIONS THROUGH INGENUITY

Lennox helps resolve the stink over a Florida school's indoor air quality

For months, facility personnel tried to solve the mystery of the schoolroom stench.

Complaints swirled around Bucholz High School of a strong, unpleasant odor in the Gainesville, Florida school's band-and-choir building. Several indoor air quality specialists couldn't figure out what was causing the odor; the facility services manager was sick of the complaints and the smell.

School officials needed to .nd a way to quickly dilute the odor while they sought out its source. School board engineers said bringing 2,000 cubic feet per minute (CFM) of outside air into the band and choir rooms would do the trick, but other personnel worried about introducing so much outside air because of Florida's high heat and humidity.

The school's facility manager called representatives of Lennox Industries for suggestions. Lennox proposed installing two high-efficiency, 10-ton L Series® packaged rooftop units with the Humiditrol® dehumidification system. Each unit would supply 1,000 CFM of outside air. Bypass curbs and mixing boxes would introduce the 1,000 CFM of outside air to the evaporator coil by mixing it with the return air to lower its temperature, hence, lowering the load on the evaporator coil. This duct design was necessary to ensure the unit would function as designed over the entire outdoor air temperature range to which it would be exposed.

This system had been proven effective at pretreating outside air in other applications which is why Lennox felt confident it would meet the requirements of this building. In fact, L Series rooftop units with a bypass air system will deliver as much as 60% latent capacity when the leaving air requirement is 55°F db.

School personnel also appreciated the fact that each L Series rooftop unit came with an Integrated Modular Controller (IMC) that provided multiple control options. Knowing that the IMC adjusts the unit's operation based on room temperature, outdoor air temperature and discharge air temperature provided the reassurance they needed to feel confident about using this rooftop unit in such an unusual application for a packaged heating and cooling rooftop unit.

Immediately after Lennox installed the units, the odor – and the complaints – vanished. The two L Series units are still on the school's roof today, maintaining approximately 50% relative humidity, and school officials say indoor air quality has noticeably improved. The school's facility manager was happy with the results and happier still when six months later, someone accidentally tracked down the source of the smell. Turns out Florida's high humidity had caused felt material inside a piano to decompose.

APPENDIX B: KEY REFERENCES

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

ASHRAE 62.2 Ventilation for Acceptable Indoor Air Quality

ASHRAE 52.1 Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter

ASHRAE 52.2 Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

ASHRAE 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings

ASHRAE Systems and Equipment Handbook

Website - www.ashrae.org

American Lung Association (ALA)

Website - www.lungusa.org

Environmental Protection Agency (EPA)

Website - www.epa.gov

Visit us at www.lennox.com
For the latest technical information, www.lennoxdavenet.com
Contact us at 1-800-4-LENNOX

COMMERCIAL COMFORT SYSTEMS