IAQ Building Education and Assessment Model (I-BEAM)

Text Modules: Heating, Ventilation, and Air-conditioning (HVAC)

This module identifies elements of the heating, ventilating, and air conditioning (HVAC) system that are important to IAQ, as well as information important to developing protocols for the operating set points and schedules consistent with good IAQ performance.

Contents

Heating, Ventilation, and Air Conditioning (HVAC) Systems

Ventilation Systems

There are significant spatial and seasonal variations in the volume of air delivered by most HVAC systems. HVAC Operators must understand the variations to know how to provide occupants with adequate outdoor air in all spaces throughout the year. The ventilation features most important to IAQ are the way in which supply air volume is controlled, and the way in which outdoor air delivery is controlled.

In most HVAC systems a portion of ventilation air supplied to occupied spaces is outdoor air and a portion is recirculated air. The total volume of air is important for two reasons:

- Air movement contributes to thermal comfort. The lack of air movement can create a sensation of hot/stuffy air.
- In many VAV systems (see below), outdoor air is a constant fraction of the total supply air. Thus, the total volume of outdoor air depends on both the outdoor air fraction, and the supply air volume.

There are **two major types of HVAC systems** based upon the use of airflow to control temperature -- the Constant Volume (CV) system, and the Variable Air Volume (VAV) system.

Constant Volume (CV) Systems

In a Constant Volume (CV) ventilation system, variations in the thermal requirements of a space are satisfied by varying the temperature of a constant volume of air delivered to the space. A constant fraction of outdoor air will mean that a constant volume of outdoor air will be delivered to occupied spaces. This volume can be set to satisfy applicable ventilation standards. CV systems are less energy efficient than VAV systems, but controls for outdoor air delivery are simpler to manage.

Variable Air Volume (VAV) Systems

In a Variable Air Volume (VAV) ventilation system, variations in the thermal requirements of a space are satisfied by varying the volume of air that is delivered to the space at a constant temperature. VAV systems reduce HVAC energy cost by 10-20% over CV systems but complicate the delivery of outdoor air. If the fraction of outdoor air is constant, the total volume of outdoor air will be reduced as the supply air volume is reduced. An inadequate outdoor air fraction, combined with an inadequate VAV box minimum setting, may result in inadequate outdoor air flow to occupant spaces. This would occur during part-load conditions. VAV systems also complicate pressure relationships in the building and make testing, adjusting, and balancing more difficult.

Most of the year, the volume of outside air may be reduced to about a third of the outdoor air volume at design load. This could result in indoor air quality problems. Separate controls to insure adequate outside air year round do not increase energy costs. Some new VAV systems incorporate these controls.

Economizer

Economizers are controls of the outdoor air designed to save energy by using cool outside air as a means of cooling the indoor space. When the enthalpy of the outside air is less than the enthalpy of the recirculating air, conditioning the outside air is more energy efficient than conditioning recirculating air.

Economizers can reduce HVAC energy costs in cold and temperate climates while potentially improving IAQ, but are not appropriate in hot and humid climates.

HVAC Components

Many HVAC components are particularly important to maintaining good IAQ. Tips for optimum functioning are listed below.

Coils and Drain Pans

- Malfunctioning coils, including dirty coils, can waste energy and cause thermal discomfort. Leaky valves that allow hot or chilled water through the coil when there is no demand waste energy and create thermal discomfort.
- Cooling coils dehumidify the air and cause condensate water to drip into a drain pan and exit via a deep seal trap.
- Standing water will accumulate if the drain pan is not properly designed and maintained, creating a microbial habitat. Proper sloping and frequent cleaning of the drain pans is essential to good indoor air quality.

Humidification and Dehumidification Equipment

- Potable water rather than boiler water should be used as a source of steam to avoid contaminating the indoor air with boiler treatment chemicals.
- Wet surfaces should be properly drained and periodically treated as necessary to prevent microbial growth.
- Duct linings should not be allowed to become moist from water spray.

Outdoor Air Dampers

Screens and grilles can become obstructed. Remove obstructions, check connections, and otherwise insure that dampers are operating to bring in sufficient outdoor air to meet design-level requirements under all operating conditions.

Air Filters

- Use filters to remove particles from the air stream.
- Filters should be replaced on a regular basis, on the basis of pressure drop across the filter, or on a scheduled basis.
- Fans should be shut off when changing the filter to prevent contamination of the air.
- Filters should fit tightly in the filter housing.
- Low efficiency filters (ASHRAE Dust Spot rating of 10%-20%), if loaded to excess, will become deformed and even “blow out”, leading to clogged coils, dirty ducts, reduced indoor air quality and greater energy use.
- Higher efficiency filters are often recommended as a cost-effective means of improving IAQ performance while minimizing energy consumption. Filtration efficiency should be matched to equipment capabilities and expected airflows.

Ducts

A small amount of dust on duct surfaces is normal. Parts of the duct susceptible to contamination include areas with restricted airflow, duct lining, or areas of moisture or condensation. Problems with biological pollutants can be prevented by:

- Minimizing dust and dirt build-up (especially during construction or renovation)
- Promptly repairing leaks and water damage
- Keeping system components dry that should be dry

- Cleaning components such as coils and drip pans
- Good filter maintenance
- Good housekeeping in occupied spaces.

Duct leakage can cause or exacerbate air quality problems and waste energy. Sealed duct systems with a leakage rate of less than 3% will usually have a superior life cycle cost analysis and reduce problems associated with leaky ductwork. Common problems include:

- Leaks around loose fitting joints.
- Leaks around light Troffer-type diffusers at the diffuser light fixture interface when installed in the return plenum.
- Leaks in return ducts in unconditioned spaces or underground can draw contaminants from these spaces into the supply air system.

Exhaust Systems

In general, slightly more outdoor air should be brought into the building than the exhaust air and relief air of the HVAC system. This will insure that the building remains under slight positive pressure.

- Exhaust intake should be located as close to the source as possible.
- Fan should draw sufficient air to keep the room in which the exhaust is located under negative pressure relative to the surrounding spaces, including wall cavities and plenums.
- Air should flow into, but not out of, the exhaust area, which may require louvered panels in doors or walls to provide an unobstructed pathway for replacement air.
- The integrity of walls and ceilings of rooms to be exhausted must be well maintained to prevent contaminated air from escaping into the return air plenum.
- Provisions must be made for replacing all air exhausted out of the building with make-up outside air.

Return Air Plenum

- Space above the ceiling tiles is often used as a return air plenum.
- Strictly follow code which restricts material and supplies in the plenum to prevent contamination and insure that airflow is not interrupted. Remove all dirt and debris from construction activity.
- All exhaust systems passing through the plenum must be rigorously maintained to prevent leaks, and no exhaust should be released into the plenum.
- Avoid condensation on pipes in plenum area. Moisture creates a habitat for microbial growth.

VAV Boxes

In a VAV system, a VAV box in the occupied space regulates the amount of supply air delivered to the space, based on the thermal needs of the space. Malfunctioning VAV boxes can result in thermal discomfort and fail to prevent buildup of indoor air contaminants. It is important to insure that VAV box minimum settings (e.g., 30% of peak flow) combined with the outdoor air fraction provide enough supply air so that sufficient outdoor air enters the space at partial loads.

Cooling Towers

Water is a convenient incubator for microbial growth, with potentially fatal consequences, such as Legionnaires Disease, for building occupants. Periodically monitoring water quality and chemical treatment to prevent microbial growth is essential. Physical cleaning to prevent sediment accumulation and installation of drift eliminators may also be necessary.

Boilers

Fossil fuel combustion boilers provide the potential for contamination with carbon monoxide or other combustion by-products.

- Maintain gaskets and breaching to prevent carbon monoxide from escaping.
- Maintain the room in which the boiler is located under sufficient positive pressure relative to the outside to prevent back drafting of flue gases. Back drafting occurs when flue gases fail to be drawn up the the flue and spill out into the room. Provide combustion air directly from the outside to prevent back drafting. A smoke tube can be used to check for back drafting.
- Provide high enough exhaust stacks to prevent re-entrainment into the building, and maintain fuel lines to prevent leaks.

HVAC Operations and Standards

ASHRAE Standard 62-1999, *Ventilation for Acceptable Indoor Air Quality*

ASHRAE Standard 62-1999, *Ventilation for Acceptable Indoor Air Quality*, is the generally-accepted standard for commercial buildings in the United States. Table 2 in that Standard provides ventilation requirements for various spaces.

Table 2.1 Selected Ventilation Recommendations

	Occupancy		

Application		(people / 1000 ft^2)	Cfm / person	Cfm / ft^2
Food and Beverage Service	Dining rooms Cafeteria, fast food Bars, cocktail lounges Kitchen (cooking)	70 100 100 20	20 20 30 15	-
Offices	Office space Reception areas Conference rooms	7 60 50	20 15 20	-
Public Spaces	Smoking lounge Elevator	70 -	60 -	- 1.00
Retail Stores, Sales Floors, Showroom Floors	Basement and street Upper floors Malls and Arcades Smoking lounge	30 20 20 70	- - - 60	0.30 0.20 0.20 -
Sports and Amusement	Spectator areas Game rooms Playing floors Ballrooms and discos	150 70 30 100	15 25 20 25	-
Theaters	Lobbies Auditorium	150 150	20 15	-
Education	Classrooms Music rooms Libraries Auditoriums	50 50 20 150	15 15 15 15	-
Hotels, Motels, Resorts, Dormitories	Bedrooms Living rooms Lobbies Conference rooms Assembly rooms	- - 30 50 120	- - 15 20 15	30 cfm/room 30 cfm/room - - -

Since indoor air quality depends on many factors, including source strengths, moisture control, and thermal parameters, these ventilation requirements cannot guarantee good indoor air quality, but meeting these requirements is a sign of managing for good indoor air quality, where unusual countercurrents or sources are present, they should be controlled at the source.

The outdoor air flow requirements of ASHRAE Standard 62-1999 are usually specified as cfm/occupant. The occupancy value should be the actual occupancy of the space or, for new buildings, the design occupancy. The total outdoor airflow is given by:

OA = (cfm / occupant) X (number of occupants)

The required outdoor air fraction is the fraction of outdoor air required so that the total outdoor airflow in the supply air is sufficient to provide the amount of outdoor air per occupant required in the Standard. However, the outdoor air fraction in the supply air is NOT equivalent to the outdoor air requirements specified in Table 2 of the Standard. That is, if the Standard requires 20 cfm of outdoor air per occupant, that does NOT mean that the outdoor air fraction should be 20%. The best way to determine outdoor air flow is to measure it.

For VAV systems, the outdoor air fraction will change as the supply air volume changes in response to changing loads. In the case of control systems that provide a constant outdoor air fraction and meet outdoor air requirements at design (peak) loads, outdoor airflow into the building at part-load will reduce the outdoor air to between one-half to two-thirds the design flow. This may be a cause of indoor air quality complaints. Manufacturers offer controls for VAV systems that can vary the outdoor air fraction to satisfy Table 2 of the Standard under all load conditions.

Existing Buildings

For existing buildings, the HVAC system should be operated to meet, at a minimum, operating parameters for providing thermal comfort and outdoor air ventilation flow as specified in design documents. However, provided that capacity is available in older buildings, it is a good idea to go beyond design requirements where feasible, and program the operating controls to satisfy the outdoor air ventilation requirements of ASHRAE 62-1999.

Should the outdoor air flow rates of ASHRAE Standard 62-1999 exceed the system's design flow rates, a careful load analysis at these elevated flow rates should be undertaken to insure that the system has sufficient capacity for the added load at peak load conditions. Failure to perform such an analysis could result in deterioration of IAQ and/or coil freezing during extreme weather conditions.

Multiple Space Systems

In multiple zone systems, different spaces within a system will call for different outdoor air fractions. This is because loads (and therefore supply air requirement) are different, and/or occupant densities (and therefore outdoor air requirements) are different.

For multiple space systems, even when the total outdoor air volume equals the sum of the requirements of individual spaces, many of the spaces may be under-ventilated most of the time. For example, even with uniform occupant densities, systems servicing both the perimeter and core zones will leave the core zone with only a third to a half of the outdoor air required by Table 2 throughout the year, while the south zone will be over ventilated most of the time. This may result in indoor air quality complaints.

Thus, multiple space systems require higher overall outdoor air fractions. This is calculated by considering the outdoor air fraction required to satisfy the critical zone. The critical zone is the zone with the highest outdoor air fraction requirement. The calculation for the outdoor air fraction required at the air handler is as follows:

Y=X / (1 + X - Z)

where:

Y = adjusted outdoor air fraction required for the system
X = unadjusted outdoor air fraction for the system calculated from the Standard
Z = outdoor air fraction in the critical zone

Unfortunately, both the critical zone and the outdoor air fractions will be different at full load and at part-load. Some manufactures do offer DDC/VAV control systems that dynamically calculate the correct outdoor air fraction at the air handler as the space load requirement changes.

Short-circuiting of the supply air into a space directly to the exhaust should be avoided (ASHRAE, 1989, Section 6.1.3.3). If short-circuiting does occur, building engineers may wish to increase the outdoor airflow rate to insure good indoor air quality.

Intermittent Occupancy

Conference rooms or training spaces often have intermittent occupancies. Provided that peak occupancies are of less than three hours duration, the Standard allows that the outdoor air requirement of the space be calculated on the basis of the average occupancy. However, the outdoor air may never be below one-half the maximum. (ASHRAE, 1989, Section 6.1.3.4)

Alternatively, ventilation in these spaces may be increased and decreased as occupancy increases or decreases, but even when unoccupied, the outdoor air ventilation should never be less than necessary to dilute building related contaminants. (ASHRAE, 1989, Section 6.1.3.1)

Pre-Occupancy Purge

Delivery of outdoor air should precede occupancy to purge the air of contaminants that built up prior to occupancy. (ASHRAE, 1989, Section 6.1.3.4)

Control of Temperature and Relative Humidity

The thermal requirements of the space are designed to provide thermal comfort to occupants during all hours of occupancy. Requirements for temperature, relative humidity, and air movement during all seasons should be established and monitored to insure that thermal comfort requirements are met.

ASHRAE Thermal Comfort Requirements

ASHRAE Standard 55-1992, *Thermal Environmental Conditions for Human Occupancy*, identifies many factors that influence thermal comfort and the perception of thermal conditions. Among them are temperature, radiation, humidity, air movement, vertical and horizontal temperature differences, temperature drift, personal activity and clothing.

As a practical matter, maintaining a building within the following ranges of temperature and relative humidity will satisfy thermal comfort requirements of this standard in most cases.

Table 2.2 Acceptable Temperature and Humidity Ranges

Measurement Type	Winter	Summer
Dry Bulb at 30% RH	68.5°F - 76.0°F	74.0°F - 80.0°F
Dry Bulb at 50% RH	68.5°F - 74.5°F	73.0°F - 79.0°F
Wet bulb maximum	64°F	68°F

Relative humidity *	30% - 60%	30% - 60%
* Upper bound of 50% RH will also control dust mites.		

Humidity and Microbial Growth

In addition to thermal comfort, the control of relative humidity is important to limit the growth of microorganisms such as mold and dust mites. To control microorganisms, it is best to keep relative humidity below 60% (to control mold) and 50% (to control dust mites) at all times, including unoccupied hours. High relative humidity can foster proliferation of mold and dust mites. See also www.epa.gov/mold