HVAC - Domestic and Industrial Ventilation Systems

An Online Continuing Education Course for Engineers

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HVAC – DOMESTIC AND INDUSTRIAL VENTILATION SYSTEMS

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Ventilation can simply be described as the process of changing air in the enclosed space. Fresh air is introduced and circulated throughout the building and the vitiated or stale air is removed or diluted. Ventilation is necessary in:

1. Preventing depletion of the oxygen content of the air;
2. Preventing undue accumulation of carbon dioxide and moisture;
3. Preventing an undue concentration of body odors and other contaminants such as kitchen or tobacco smoke;
4. Preventing an undue concentration of particles carrying bacteria;
5. Removing body heat and heat liberated by the operation of electrical, mechanical and process equipment (e.g. artificial lighting and machinery)

The rate of ventilation, measured in cubic foot per minute (CFM) or liters of air per second (lps) must be sufficient to satisfy the following three requirements:

1. Sufficient air movement throughout the space to prevent the formation of pockets of stale air.
2. Sufficient fresh air supply and foul air exhaust to limit the level of air pollution from all sources in the building, including humidity.
3. Reduction of air temperature, within the limits set by the climate, by the removal of heat generated within the building or supplied by the sun.

This course will discuss the basic guidelines and prudent practices in the design of ventilation systems. The course is divided into 6 sections:

Section -1: General Purpose Ventilation

Section -2: Types of Ventilation Systems

Section -3: Ventilation Strategies for Indoor Air Quality

Section -4: Estimating Ventilation Rates

Section -5: Industrial Ventilation

Section -6: General System Design Considerations

SECTION -1: GENERAL PURPOSE VENTILATION

General Purpose Ventilation involves removing heat, odors, and/or contaminated air from inside the building and replacing it with outside air. It may be provided by natural draft, by exhaust fans, by supply fans or by a combination of supply and exhaust fan/s. Although natural ventilation is often relied, its effects are uncertain, unreliable and difficult to control. Mechanical ventilation system using fans have become an essential part of good ventilating systems for the following reasons:

1. They operate irrespective of internal temperature and external winds.
2. They can be more easily and accurately controlled.
3. They can often be used for either extract or intake, and therefore cater for a wider variety of winter and summer conditions more easily.
4. On extract much smaller inlet openings are necessary in building structures for air replacement, due to the greater suction pressure provided by a fan.
5. On intake they give positive air movement for relief from radiant heat, can incorporate filters for use in dusty atmospheres, and heaters if required during cold weather to augment the normal heating system of the building.

General or dilution ventilation is not an adequate alternative to containment of an impurity at source. This is done by local exhaust ventilation. However, it may be necessary to dilute the impurity to an acceptable level where complete control at source is not reasonably practical. These aspects are discussed in detail in section# 5.

Factors Affecting Ventilation Rates

The need for fresh air in the workplace is influenced by a number of factors; in particular the space available per occupant, the work activity, the habits of the occupants (e.g. smoking) and the presence of other sources of airborne contaminants such as process plant, heaters etc.

Quantity and Distribution of Air: The fresh air supply is required to maintain an acceptably non-odorous atmosphere (by diluting body odors and tobacco smoke) and to dilute the carbon dioxide exhaled. The quantity may be quoted per person and is related to the occupation density and activity within the space. The proportion of fresh air introduced into a building may be varied to achieve economical operation. When the fresh air can provide a useful cooling effect, the quantity is controlled to balance the cooling demand. However, when the air is too cool, the quantity is reduced to a minimum to limit the heating load. Similarly, when the air is too warm or humid, the quantity is reduced to minimum to reduce the cooling load.

Transfer of heat/moisture: Air circulation is required to transfer the heat and humidity generated within the building. In simple systems, the heat generated by the occupants, solar heat and heat from electrical and mechanical equipment may be removed by the introduction and extraction of large quantities of fresh air. In more elaborate systems air may be recirculated

through conditioning equipment to maintain the desired temperature and humidity. The air circulation rates are decided in relation to the thermal or moisture loads and the practical cooling or heating range of the air.

Air movement: Air movement is desirable, as it contributes a feeling of freshness, although excessive movement should be avoided as this leads to complaints of draughts. The speed of an air current becomes more noticeable as the air temperature falls, owing to its increased cooling effect. The design of the air-distribution system therefore has a controlling effect on the quantity and temperature of the air that can be introduced into the space. The quantity of fresh air should not be increased solely to create air movement; this should be affected by air recirculation within the space or inducing movement with the ventilation air stream.

Air flows within the building should be controlled to minimize transfer of fumes and smells, e.g. from kitchens to restaurants and the like. This is achieved by creating air pressure gradients within the building, by varying the balance between the fans introducing fresh air and those extracting the stale air. For example, the pressure should be reduced in a kitchen below that of the adjacent restaurant. Care should be taken, however, to avoid excessive pressure differences that can cause difficulty in opening doors or cause them to slam. In other cases, such as computer rooms, the area may be pressurized to minimize the introduction of dust from adjacent areas.

Fire and smoke control: Air circulation system may be designed to extract smoke in the event of a fire, to assist in the fire fighting operations and to introduce fresh air to pressurize escape routes.

Air purity and filtration: A ventilation or air-condition system installed in a building should clean, freshen or condition the air within the space. Special air filters may be required to remove contaminants or smells when air is recirculated. Positions of air inlets and extracts to the system are most important and care should be taken in their location. Inlets should not be positioned near to any flue outlets, dry cleaning or washing machine extraction outlets, kitchens, WC's etc. When possible, air inlets should be at high level so as to induce air from as clean an area as possible. If low level intakes are used, care should be taken to see that they are positioned well away from roadways and car parks.

Climatic Conditions: Ventilation systems must be considered for three climatic conditions that occur during the year--winter, summer, and spring-fall. A high rate of ventilation is required in summer to deal with the build-up of heat from solar radiation, production processes and high internal heat load, whereas in winter a very low air changes per hour (ACH*) is required, simply to prevent vitiation of the air and to remove odors and water vapor. This variation in requirements may range from 6-15 ACH in summer and 2 ACH in winter.

* ACH - The number of air changes per hour is the number of times one volume of air is replaced in the space per hour.

Winter Ventilation

A heating system with adequate capacity is needed in the winter to maintain environmental conditions inside the building. Even during the coldest part of the winter, when the heating system is running at full capacity, some ventilation is still required. Fresh, outside air must be introduced into the building to remove the warm, moisture-laden air. If moist air is not removed, high humidities and excessive condensation will occur. Studies have shown that humidities over 90% foster rapid deterioration of structural components, and damp, uncomfortable environmental conditions.

Condensation occurs when warm, humid air comes into contact with a cold surface, such as glass or structural members. The air in contact with the cold surface is cooled to the temperature of the surface. If the surface temperature is below the dew point temperature of the air, then water vapor in the air will condense onto the surface. For example, condensation occurs, if indoor air at 70° F and 70% relative humidity comes in contact with a surface that is 60° F or colder. *This tendency is increased with low ambient temperatures, high wind velocities and high internal humidities.*

Exhausting moist air and replacing it with heated outside air is effective in eliminating condensation and other problems resulting from high humidities. *Whenever ventilation rates are increased in the winter, the heating requirements also increase. Consequently, it is necessary to determine a ventilation rate that will maintain humidities below the damaging level and, at the same time, keep the heating requirements as low as possible. Ventilation requirements in winter are generally on the order of two to three air changes per hour. The higher the inside temperature, the lower shall be the air exchange rate that is required to maintain humidities below the damaging level.* Besides controlling humidity, this minimum ventilation rate is required to remove any gases of combustion that may be present as a result of leakages around the heater and ducting when a direct-fired heating system is used.

To conserve energy in winter, the ventilation shall operate under reduced flow to take advantage of increased air infiltration. The ventilation fans could be equipped with a flow controller such as a two-speed fan. A manual switch or an indoor humidistat could be used to increase flow for quick removal of odors, moisture, and fumes. In addition, an outdoor temperature controller could be installed to increase air flow in mild weather.

Summer Ventilation

The main purpose of a ventilation system during the summer is to prevent the air temperature rising too high above the outside air temperature. The reason for the higher air temperature indoors may be because of the large influx of solar radiation and large dissipation of heat by power and process equipment. The amount of sensible heat gain is essentially from four components:

- Q1 = Solar heat gain through structure
- Q2 = Heat from the electrical apparatus/machinery
- Q3 = Heat dissipation from other equipment/processes

- Q4 = Body heat of occupants

The total heat gain is Σ Q = Q1 + Q2+ Q3 + Q4

The ventilation rate can then be calculated from equation:

V = Q / (1.08 * ΔT)

Where:

1. Q = sensible heat load (Btu/h)
2. V = volume flow rate of outdoor air introduced in cubic feet per minute (cfm)
3. ΔT = temperature difference between outdoor and indoor air °F
4. 1.08 = A constant derived from the density of ai… *u ft* under average conditions, multiplied by the … to raise 1 lb of air 1°F), which is 0.24… …ant are Btu min/*cu ft* °F h.

The ventilation calcu… …ables V and ΔT. Setting different values of ΔT… …ically setting the value of indoor air temperatur… …obtained from ASHRAE handbook of fundame… …ographical location. As the temperature differe… …decreases the ventilation rates increases. *Regar… …mer, the inside air temperature during the… …ature.* The inside air temperature can at the … …ry high ventilation rates. But the disadvan… …cost for fans and accessories, as well as … …aintaining an inside air temperature below o… …some other means of refrigeration must be us…

A generally accepted ve… …range from one air change every three minu…

Spring-Fall Ventilation

The recommended ventilation rates for the spring-fall seasonal periods will be somewhere between rates required for summer temperature control and those required for winter-humidity control. The spring-fall periods are characterized by sometimes being relatively cool and cloudy and other times that are warm and sunny. No special provisions are necessary for maintaining ventilation rates during this period except for the temperature and humidity controls that will determine the amount of ventilation necessary.

Ventilation for Air Quality

The sources for odor are many: body odors, tobacco smoke, vehicle exhaust, food preparation, garbage, finishing materials, furnishings and even the wetted coils of air conditioning systems as they become dirty. There are a number of other items that can affect indoor air quality. From