PDHonline Course M384 (2 PDH)

HVAC Ventilation for Indoor Air Quality

Instructor: Fred W. Dougherty, P.E.,B.A.E, M.M.E

2012

PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone & Fax: 703-988-0088
www.PDHonline.org
www.PDHcenter.com

An Approved Continuing Education Provider

HVAC Ventilation for Indoor Air Quality

Fred W. Dougherty, P.E., B.A.E., M.M.E.

COURSE CONTENT

1. Scope

This course will describe finding and applying the required minimum ventilation of buildings and air handler zones using outdoor air.

2. Important Terms

The following terms will be used throughout this course. They have specific meanings in connection with HVAC systems, ventilation, and indoor air quality.

A **building** is a roofed and walled structure with controlled environment, built for human occupation and use.

The **thermal envelope** of a building is the physical separation between the conditioned space and the unconditioned environment. It holds the primary insulation layer of the building where resistance to heat transfer is the greatest.

The **pressure envelope** is the primary air barrier of the building, which is sealed to provide the greatest resistance to air leakage from the unconditioned environment.

A **system** is a group of spaces within the thermal and pressure envelopes which are served by a single air handling zone.

A **sub-zone** is a group of spaces within a zone that may be served by a single terminal component such as a variable air volume unit.

A **space** is a single room, with or without a ceiling plenum.

A **czone** is a space or group of spaces within a zone having the same **occupancy category**

An **occupancy category** is a designation that defines the activity and use of a space or group of spaces. (This will be clarified later in the course)

Ventilation is the introduction of outdoor air into a conditioned zone after passing through cooling/heating apparatus either mixed with return air or independently.

Supply air is the all of the air delivered by the cooling/heating apparatus to the supply air diffusers in the zone.

Return air is the portion of the supply air that is recirculated after being collected by the return grilles in the zone.

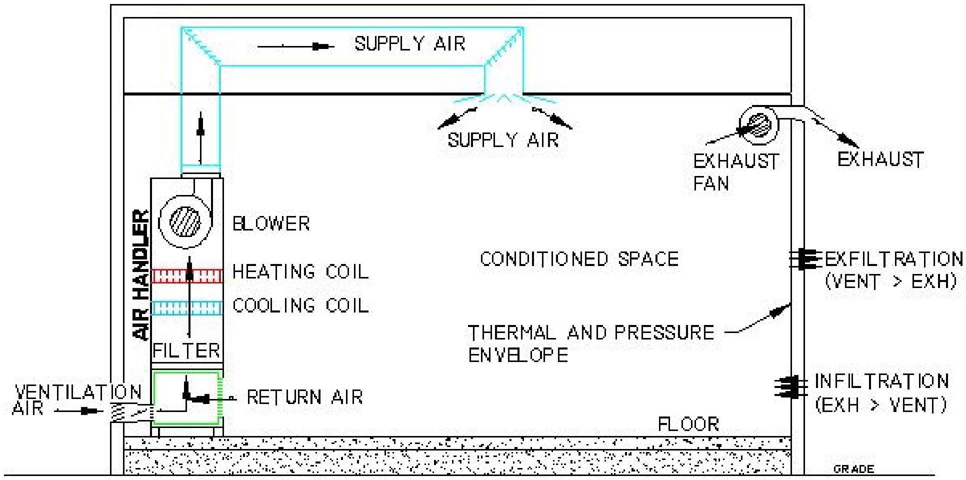
Exhaust, or **exhaust air**, is the portion of the supply air that is discharged from the zone to outdoors after passing through the zone.

Infiltration is outdoor air that enters the conditioned space without passing through cooling/heating apparatus. It enters through cracks in the building envelope, leaks in the return air ductwork, or window and door openings.

3. What is Ventilation?

Ventilation is the introduction of outdoor air into a conditioned zone after passing through cooling/heating apparatus either mixed with return air or independently. To understand this requires a brief refresher of the process of mechanically heating and cooling a building.

Figure 1 illustrates the motion of air within a zone consisting of a single conditioned space, and the exchange of air between the zone and outside (shown) or between the zone and an adjacent zone within the building. During the summer, cool, dry **supply air** passes through the room and picks up heat and moisture. Most of this air is returned to the air handler where it may be mixed with **ventilation air** before passing over a cooling coil to be cooled and dehumidified. Some of the **supply air** is **exhausted** directly from the zone. Air from outdoors or adjacent spaces may **infiltrate** if the rate of ventilation air flow is less than the rate of exhaust air flow. If the ventilation air flow is greater, then the excess air will leak out of the zone, or **exfiltrate**.



CONDITIONED SPACE - AIR MOTION AND TRANSFER

Figure 1

During the winter, supply air warmed by the heating coil carries heat into the room to replace the heat lost through the building envelope (or ductwork) to outdoors. Otherwise, the air motion and exchange are identical with the cooling mode.

Mathematically, these relationships, shown on Figure 1, can be stated as follows:

	supply air – exhaust air = return air + leakage
	ventilation + return air = supply air
therefore	**ventilation + return air – exhaust air = return air + leakage**
and	**ventilation – exhaust air = leakage**
therefore	**if ventilation > exhaust air then leakage is positive (exfiltration)**
	if ventilation < exhaust air the leakage is negative (infiltration)

Infiltration is always undesirable, but it is particularly so in summer, when outside air may be laden with moisture. Infiltration does not pass through a cooling coil before entering the room, and so adds directly to the room cooling and dehumidifying loads, and therefore to the supply air flow which must remove the room heat and moisture. Ventilation, on the other hand, passes through a cooling and dehumidifying coil before being introduced into the room, allowing control of room relative humidity without increasing supply air flow.

4. Principles of Ventilation

For any space within a zone, the conditioned air supplied to that zone must equal the air removed by return, exhaust, or leakage. As noted in Section 3, if exhaust is greater than supply, then the return will be made up by leakage into the space. This principle also applies to two zones within a building, because an each air handler can only supply as much air as is returned to it.

In order to control the zone relative humidity, ventilation air should always be set greater than exhaust so that leakage is always out of the zone, and the zone is thus at greater pressure than outdoors. This principle also applies to spaces within a zone, so that air can be transferred between spaces by adjusting the exhaust proportionately between "downstream" spaces.

There are codes and standards for minimum required ventilation and exhaust. These are dependent on the use and occupancy of the pertinent spaces in the project, and will be explained in more detail presently.

Thus, a building may be divided into different occupancies, each with specific requirements for ventilation and exhaust. For example, building codes prohibit air from restrooms and janitor closets from entering occupied rooms. Another example, explained in detail later in the course, is commercial kitchens, where heat and odors from the kitchen must not be carried into the dining area. The direction of air flow within a building or zone can be controlled by regulating the ratio of supply to exhaust for each space within the zone . Exhaust from a space can reduce the pressure in that space relative to other spaces in the zone, while maintaining the entire zone at a positive pressure relative to outdoors.

5. Basic Rules

Before cooling and heating loads for a building can be estimated, the amount of outdoor air that will need to be supplied by the building air handlers to each zone must be determined.

In any climate, but most particularly in humid climates such as the Southeast, all buildings must be under positive internal pressure, as described in Sections 3 and 4, when the cooling systems are operating. There is no standard for the degree of positive pressurization, but in general, an excess of 25% of outdoor ventilation air over exhaust air is considered good practice.

$$\mathbf{Qoav = 1.25 \times Qexh} \qquad \mathbf{(1)}$$

An exception to this general rule would be if there is a very small amount of minimum required exhaust air, coupled with a relatively small requirement for ventilation air, as may be the case for a small office, or in a zone with no exhaust required. In such a case, outdoor air could exceed exhaust by multiple factors, since the excess air would readily leak out of the building. This would be up to the designer's judgment. Another exception would be if the amount of required exhaust is very large, in which case the ratio of outdoor air to exhaust could be reduced, but never below 1.2. In general, then, exhaust in excess of that required by code is only required to limit pressure loading on exterior doors. In order to limit exterior door pressure loading to five pounds or so, pressure differential should not exceed about .05 inches of water. In any case, however, ventilation air should never fall below 1.2 times exhaust air.

There are two ways to determine the minimum ventilation air that must be mechanically supplied to the building and both must be calculated for each zone of a project. One is by adding the required exhausts and multiplying by 1.25 The other is by determining the minimum "Ventilation for Acceptable Indoor Air Quality" as calculated based on use and occupant load using ASHRAE Standard 62.1.[1] The designer should make sure that he or she has the latest issue, since that standard continuously evolves. Both methods must be calculated, and the minimum ventilation air required will be the larger of the two.

The sum of ventilation, exhaust, and leakage must of course equal zero. Figure 2 is a simplified representation because the windward side of a building may experience infiltration while the downwind side has outward leakage. By pressurizing the building with an excess of induced ventilation over mechanical exhaust, infiltration is minimized if not eliminated. Also, the possibility of excess internal pressure causing problems such as heavy door loads is remote, because the excess ventilation air will never exceed .5 air changes per hour (ACH), which would be a tight building.

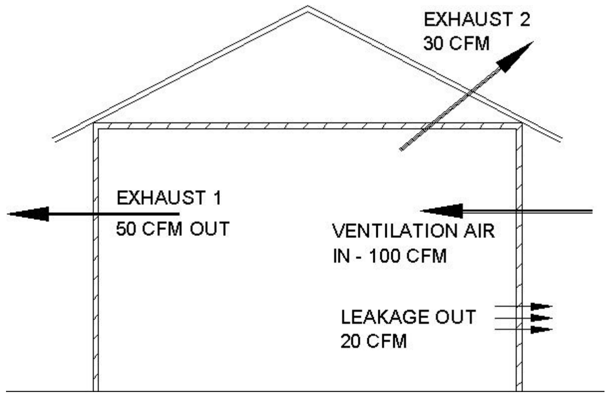


Figure 2, Building Air Balance
Mechanical Ventilation and Exhaust

6. Ventilation Based on Required Exhaust

All local codes have requirements for minimum exhaust from restrooms, lockers, janitor closets, scullery areas, and kitchen fume/grease hoods. Examples from the Florida Uniform Building Code:

Locker Rooms	.5 cfm/sf
Shower Rooms	20 cfm/shower head (continuous)
Toilet Rooms	50 cfm per water closet or urinal
Non-commercial kitchen	100 cfm (intermittent)

Commercial kitchens are a special category that are discussed below. If there is no commercial kitchen, then the minimum outdoor air based on required exhaust is found by adding the total of required exhausts and multiplying by 1.25.

Restaurant Ventilation With Commercial Kitchens

Commercial cooking appliances are required by NFPA standard 96 and by most local codes to be equipped with a grease hood. The HVAC designer is usually charged with specifying the hood and showing details on the mechanical plans. This is because the requirements for exhaust and make-up air of the kitchen hood system must be integrated into the ventilation air balance of the entire building.

A commercial kitchen includes at least three exhaust air zones, each of which may have it's own exhaust systems. These are: the cooking lineup with NFPA96 grease hood, the scullery with dishwasher and general exhaust, and a bakery with general and bread warmer exhausts. It is important that odors from kitchen operations not be carried into the dining area or other areas of the buildings, so the kitchen pressure must be negative with respect to the rest of the building. At the same time, the kitchen pressure should be positive with respect to outdoors to avoid unwanted infiltration of moisture laden outdoor air.

Figure 4-2 is a typical restaurant layout, with the building ventilation air balance shown by the large dark arrows. All of the ventilation air is brought in through the dining area air handler. Building exhaust is from the rest rooms and the kitchen. If the kitchen has an air handler for heating or cooling, it induces no ventilation air.

The kitchen exhaust consists of the cooking hood and the scullery/dishwasher exhaust. There is no bakery. In this case, the kitchen hood is “compensating”, meaning that outdoor air to make up a portion of the hood exhaust is introduced integrally through the hood system. The total kitchen exhaust is thus the net hood exhaust plus the scullery exhaust.

$$\mathbf{C\ kit\ exh = C\ hood\ exh - C\ hood\ sup + C\ dw\ exh} \qquad \mathbf{(2)}$$

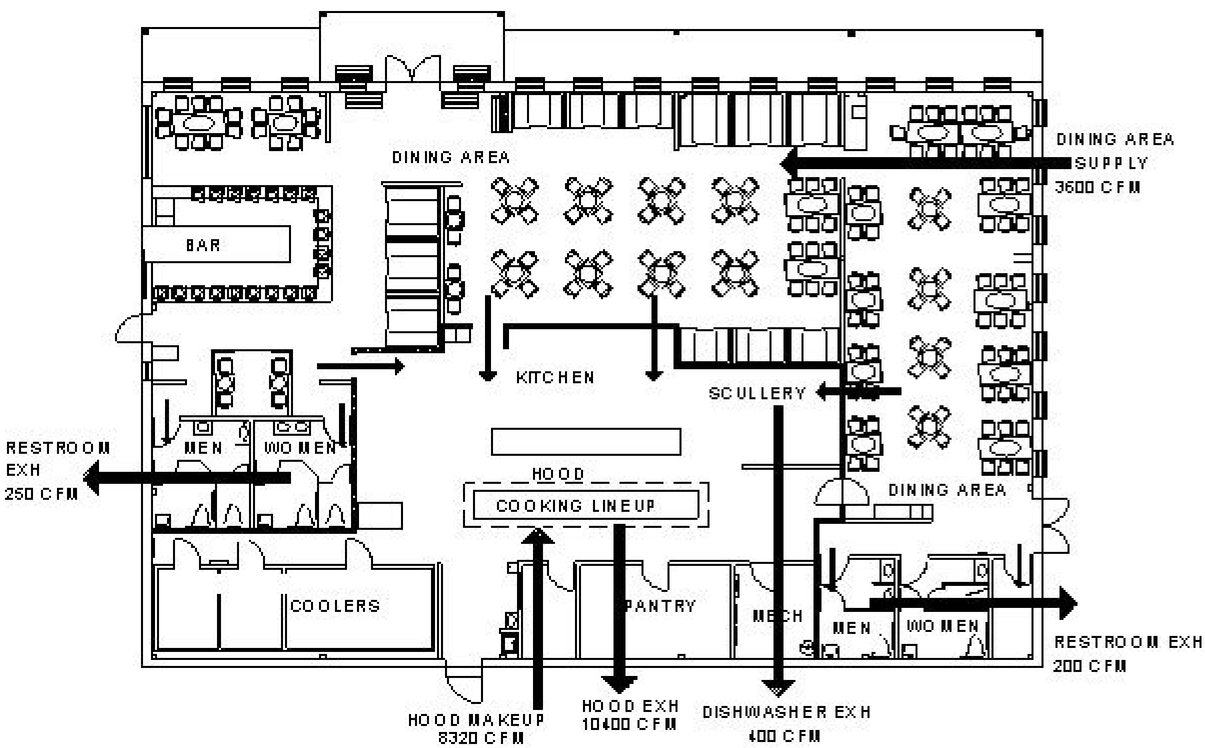


Figure 3 – Typical Restaurant Ventilation Air Balance

This case shows the outdoor air requirement controlled by the net building exhaust. This is because the outdoor air requirement based on ASHRAE standard 62 (occupancy and use) is less than 1.2 times the total exhaust from the building.

The large dark arrows on Figure 4-2 show the ventilation air balance, expressed mathematically as follows:

C vent = C kit exh + C rest exh + C leakage **(2A)**

so **C leakage** = 3600 – 2480 – 450 = 670 cfm (23% of exhaust)

Part of the air drawn into the dining area through the dining area air handler(s) is exhausted through the two restrooms. The remainder, as indicated by the small dark arrows, is allowed to flow freely into the kitchen through serving passageways, architectural openings, and transfer ducts, there to be exhausted by the hood and dishwasher fans. Rules for internal transfer of air within a building, such as through restroom doors, or for kitchen makeup, are discussed later in this course.

The excess outdoor air causes the building to be under positive pressure relative to outdoor ambient, and introducing the air only into the dining area ensures that the dining area will have positive pressure relative to the kitchen and scullery. The desired pressure relations between the dining area, the kitchen and the outdoor ambient must be maintained under all conditions of operation – for example, when the kitchen hood or scullery exhaust is not operating. Special control features may be necessary to maintain pressure differentials under these conditions.

Special System Exhaust Air Flow Rates

Although local codes establish minimum exhaust air flow rates for many occupancy categories, there may be special process exhausts within a zone for which the air flow rate is established by the need to capture fumes, aerosols such as grease, VOCs (volatile organic compounds), or heat. For example, kitchen hood minimum exhaust is established by each hood manufacturer as a function of the hood type, style, size, and cooking surface temperature. These parameters are defined in the kitchen hood design standard, NFPA 96.[2]

In general, the HVAC designer will often be given the required exhaust and maximum make-up supply by the manufacturer's representative of the equipment to be installed, whether it is a kitchen grease hood, manicure station, or gun cleaning station. Guidance for many process exhausts may also be found in the Industrial Ventilation Manual[3] in terms of required capture velocities.

7. Ventilation Based on Occupancy and Use

Up until the 1970's, while it was considered good practice to ensure positive pressurization of buildings, this was usually limited to ensuring that only enough outdoor air was introduced into the air handling systems to slightly offset exhaust. Some government and institutional agencies had outdoor air requirements tied to occupancy. A few quantified excess air, such the Navy Facilities Command, which specified that ventilation air exceed exhaust by 20% in humid climates.

The energy crisis of the 1970's resulted in codes tightening the envelopes of commercial buildings to reduce infiltration and thus save energy. This reduced the de-facto dilution of contaminants in buildings, and resulted in widespread problems of "sick building syndrome" – where a combination of volatile organic compounds (VOCs) and bio-aerosols (mold and bacteria) reached concentrations in a building's air that caused discomfort and distress to many occupants.

ASHRAE addressed this problem with Standard 62.1, "Ventilation for Acceptable Indoor Air Quality" originally released in 1973. This standard was adopted by most local codes, and has undergone significant changes since its original release. The most recent release as of this writing is 62.1-2010. The stated purpose of the standard, set forth in paragraph 1.1 is "to specify minimum ventilation rates and indoor air quality that will be acceptable to human occupants and are intended to minimize the potential for adverse health effects."

Applying Standard 62.1, the designer has the option of using a prescriptive approach or an indoor air quality (IAQ) approach. The prescriptive method specifies minimum "breathing zone" ventilation rates per occupant for various activities, and adds minimum ventilation rates per square foot for various types of spaces. To apply the IAQ approach, the designer may use lower ventilation rates

Table 1

OCCUPANCY CATEGORY	Rp	Ra	Dod
	cfm/person	cfm/sq ft	#/1000 ft
Office Buildings			
office space	5	0.06	5
reception areas	5	0.06	30
conference/meeting	5	0.06	50
main entry lobbies	5	0.06	10

Public Assembly Spaces			
auditorium seating area	5	0.06	150
courtrooms	5	0.06	120
libraries	5	0.12	10
museums/galleries	7.5	0.06	40

but must show that the levels of indoor air contaminants are held below recommended limits. This course will discuss using the prescriptive method. Examples of prescriptive ventilation rates in the "breathing zone" as found in Standard 62.1 are shown in Table 1 above.

The Dod column is "default occupant density". This is the occupant density that must be used unless the designer can verify that a different density is applicable to a particular project. Total outdoor air required for the "breathing zone" is

$$\mathbf{V_{bz} = Rp*(\#\ occupants) + Ra*Area} \qquad \mathbf{(3)}$$

Actual outdoor air required for the zone air handler must be modified to account for **air distribution configuration**, for **multiple occupancy categories** within a zone, for **population diversity** and for **ventilation efficiency**. (Note that in Standard 62.1, the term "system" is used to denote the spaces served by a single air handler, and is equivalent to the term "zone" used in this course. The term "zone" as used in the Standard, means a particular occupancy category within a system served by a single air handler. That will be termed **czone** in this course)

Air Distribution Configuration

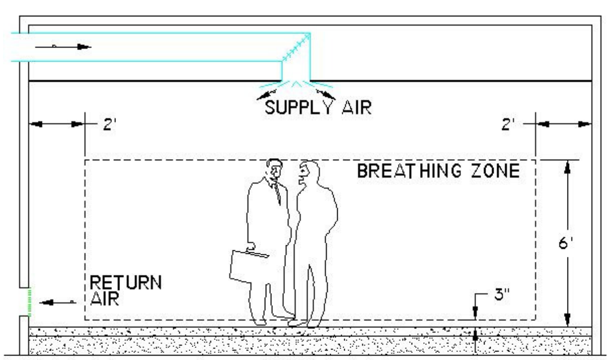


FIGURE 4 - BREATHING ZONE
Ez = 1 (CEILING SUPPLY AND FLOOR RETURN)

Figure 4 is a graphic representation of the "breathing zone" as defined in Standard 62.1. Also shown on Figure 4 is one of the ten **air distribution configurations** described in the standard. The parameter E_z is the "**Czone Air Distribution Effectiveness**". Applying E_z results in the Czone Outdoor Air Flow, modifying V_{bz} as follows"

$$\mathbf{V_{oz} = V_{bz} / E_z} \qquad \mathbf{(4)}$$

The configuration shown, ceiling supply and floor return of both cooling and heating supply air, results in E_z of 1.0. Other common values of E_z are:

ceiling supply and ceiling return of cool and warm air,	$E_z = .8$
floor supply and floor return of cool and warm air,	$E_z = 1.0$
floor supply and ceiling return of cool and warm air	$E_z = .7$

Equation (4) is the ventilation air required for an air handler serving a zone with only one occupancy category, as may be the case for an assembly occupancy such as an auditorium with a dedicated system.

Multiple Occupancy Categories

Most air handler systems will serve spaces with different occupancy categories – called zones in the Standard. For example, an office system may include a conference room, a reception area, and six offices. The Standard designates this as a **Multiple Czone Recirculating System**. The procedure for computing a required minimum ventilation for these systems is intended to provide the needed ventilation to each czone without unnecessary energy use and moisture loads by excessive ventilation. An example calculation will be carried out for the office system cited above.

Diversity Factor and Ventilation Efficiency

The conference room may be designed for a capacity of eight, the reception for six, and each office for one each. However, when the offices are occupied, it may be assumed that the conference room is unoccupied, and it may also be assumed that the normal occupancy of the reception area will only be the receptionist. The Standard allows the designer to compute a **diversity factor** , D, defined as

$$\mathbf{D = P_s/\Sigma P_z} \qquad \mathbf{(5)}$$

where P_s = The normal population of the zone = 7
P_z = The maximum expected population of a czone
ΣP_z = 17 (three offices unoccupied)

(Again, "zone" as used in the Standard means a particular occupancy category within a system served by an air handler.) For the example cited, the diversity factor will be

$$D = 7/17 = .41 \quad \text{(5ex)}$$

In order to compute **ventilation efficiency**, it is necessary to first compute the **primary outdoor air fraction** (Z_p) for each czone.

$$Z_p = V_{oz} / V_{pz} \quad \text{(6)}$$

where V_{oz} is from equation (4)
and V_{pz} is the czone primary air flow

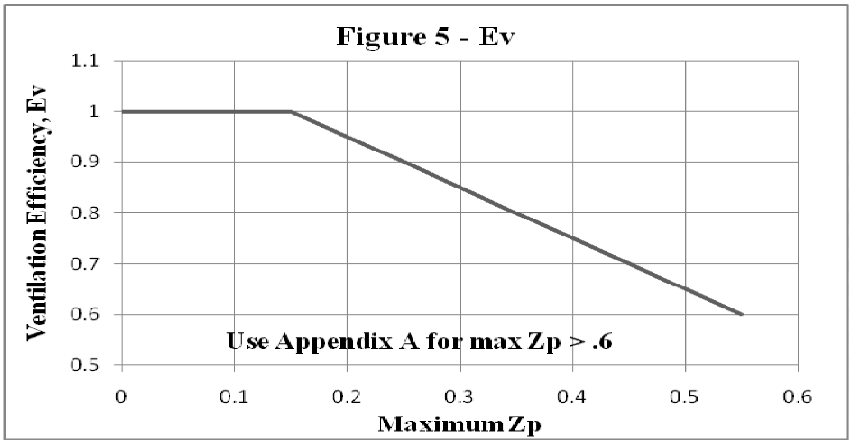
When the course opened, it was stated that the required minimum ventilation must be computed for each air handler zone before cooling and heating loads can be calculated. Yet here is a situation where the supply air flow to each zone must be known in order to calculate the required ventilation.

In this case a preliminary load calculation will be needed to estimate the supply air flow (called the primary air flow in the Standard) for each czone. Since in general, the envelope and internal parameters will be known at this point in a project, it is only necessary to estimate a ventilation rate and a primary supply air flow to the zone in order to proceed with a preliminary load calculation. An estimated sensible room load must be calculated for each czone, and an estimated total air flow based on the zone. The preliminary load calculation is beyond the scope of this course, but let us assume that it has been performed for the example, with the following results:

Table 2

czone	Pz	Az	Ez	Voz (Eq 4)	Vpz	Zp (Eq 6)
offices	6	600	0.8	83	450	0.18
reception	6	400	0.8	68	300	0.23
conference	8	315	0.8	74	270	0.27

Ventilation efficiency can now be found using Table 6-3 in Standard 62.1, or by reading from a graphical version of Table 6-3as shown in Figure 5.



From Figure 5 we read E_v as .88 for max Z_p of .27 (from Table 2). the ventilation efficiency is applied to the **uncorrected outdoor air intake,** V_{ou}, which is calculated using the **Divesity Factor** from equation (5).

$$\mathbf{V_{ou} = D*\Sigma(R_p*P_z) + \Sigma R_a*A_z} \qquad \textbf{(7)}$$

for the example, using values from equation (5ex) and Tables 1 and 2:

$$V_{ou} = .41*(5*6+5*6+5*8) + .06*600+.06*400+.06*315 \qquad \textbf{(7ex)}$$
$$V_{ou} = 120 \text{ cfm}$$

We're still not done, because we now must modify V_{ou} using E_v to obtain the final minimum design outdoor air intake flow rate, V_{ot}.

$$\mathbf{V_{ot} = V_{ou} / E_v} \qquad \textbf{(8)}$$

or for the example $V_{ot} = 120/.88 = \underline{136 \text{ cfm}}$ **(8ex)**

Earlier it was noted that the "normal" occupancy of the example zone is seven, while the peak occupancy would be 17. So the V_{ot} of 136 cfm is 19 cfm per occupant during normal occupancy, and 8 cfm per occupant during peak occupancy. If equation (3) were applied to each czone, and the results added, the total minimum ventilation air would be 180 cfm, or 10 cfm per occupant. Thus, applying the method of Multiple Occupancy Category reduces the ventilation requirement by 25% relative to simply using the ventilation requirements of Table 1.

Applying Standard 62.1

The preceding exercise is intended to acquaint the student with the fundamentals of applying Standard 62.1. Unless the local code or controlling authority is more restrictive than Standard 62.1, the designer should study and follow the standard to insure a comfortable building and to avoid liability. It is beyond the scope of this course to give comprehensive instructions on application of the Standard, which will vary from project to project. Such details may be found in ASHRAE publications, such as the Standard 62.1 User's Manual[4] which includes a CD with an Excel spreadsheet that can be used to calculate V_{ot}.

Proper application of Standard 62.1 will result in outdoor air rates of 6 to 20 cfm per occupant. In general, rates for assembly buildings such as auditoriums will be on the low end of this range, while rates for classrooms will be near the high end.

8. Variable Air Volume (VAV) Systems

VAV systems have a virtually infinite number of operating points because the air supply is modulated to each sub-zone to follow the sensible cooling load. The largest amount of ventilation air will be required when the "critical" sub-zone is at its lowest load (air flow), because a low sub-zone air flow increases max Z_p – equation (6) - which in return results in a reduced ventilation efficiency (Figure 5). Reference 4 provides methodology to compute the required ventilation for VAV systems.

Another issue with VAV systems is maintaining the minimum required ventilation as zone loads fall and supply air flow is reduced. If the outdoor air is induced by the air handling system, it will decrease as the air demand on the system decreases when cooling load decreases below the design point. To prevent outdoor air from falling below code requirements, and to prevent constant exhaust from causing negative pressurization, a constant, positive outdoor air supply must be provided. To do this requires measuring the outdoor air flow and using the measurement to modulate an outdoor air supply fan or to modulate a damper to throttle the air handler return ahead of the outdoor air intake.

9. Air Transfer Rules

When outdoor air is brought into a zone, it may be necessary to transfer it to an exhaust zone such as a restroom or kitchen. Adequate free area must be provided across doors and walls to allow unrestricted motion of the zone air into the exhaust area. For restrooms, this is done by undercutting the door, by providing a transfer grille in the door or wall, or by providing a transfer grilles and ducts in the ceiling. Two factors determine which of these choices applies. First, free area must be large enough that the air velocity through the opening never exceeds 500 feet per minute. So for a three foot door, a 3/4 inch undercut can only handle 90 cfm of transfer air. Transfer grilles can be selected based on free area to meet this requirement for higher air flows.

The second factor influencing the choice of transfer methods is the fire rating of the wall that the air must travel through or over. Transfer grilles cannot be installed in doors located in fire rated walls. Any solution, while still meeting the 500 fpm maximum velocity requirement, will also have to include a fire damper in the air path at the plane of the fire rated surface.

10. Introducing Ventilation Air into the Zone

The discussion so far has assumed that the ventilation air will be induced by the air handler, as shown on figure 1. Actually, this is only one of several ways to bring ventilation air into the space. Others are

forced induction using a damper in the air handler return

dedicated outdoor air (DOA) unit discharging into the air handler return

DOA unit discharging into the zone

energy recovery ventilator that passes all of the zone exhaust through an enthalpy wheel to cool and dehumidify (or heat) incoming ventilation air which is then discharged into the air handler return

Direct Induction

Direct induction, as by Figure 1, depends on the pressure in the air handler return being low enough, and the intake louvers and ducts being large enough to admit the required amount of outdoor air. The control damper is located in the outdoor air intake duct, and the flow rate is set by a test and balance technician with the system operating at design supply air flow. The designer sizes the intake louvers and ducts for velocities of less than 500 feet per minute at the required ventilation flow rate.

Forced Induction

If the outdoor air is a significant percentage – say more than 30% - of the total supply air flow, or if it is impractical to make the ventilation air intake large

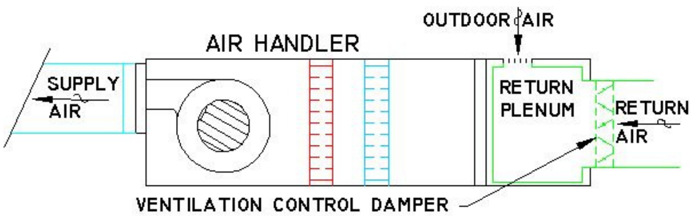


FIGURE 6 - FORCED OA INDUCTION

enough to allow unforced induction, a damper placed in the return ahead of the fresh air intake can be used to drop the pressure as needed. Figure 6 shows a typical arrangement. As the damper is closed, the pressure in the return plenum is dropped, forcing the induction of more outdoor air. Of course, in order to maintain return air, the air handler blower speed must be increased, and if the ventilation requirement is constant, the return and outdoor air flow would be set up during test and balance. If the system is variable air volume, then the damper can be modulated by an air flow sensor to maintain constant minimum ventilation air flow, as required by code.

Dedicated Outdoor Air Units

Ventilation air can be injected directly into the air handler return by a dedicated outdoor air (DOA) unit either pre-conditioned or un-tempered. An example of an un-tempered DOA unit would be a blower, similar to the system shown in Figure 7. In this case the system cooling or heating system must handle the ventilation load in addition to the zone loads, just as in the case of induced ventilation air. The advantage is that the ventilation air flow rate can be set precisely and the air handler blower external static pressure is not adversely affected as in the case of forced induction.

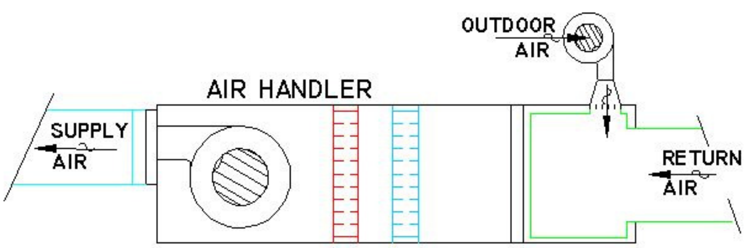


FIGURE 7 - DOA BLOWER

Instead of a simple blower, as shown on Figure 7, the DOA unit may have refrigeration, heating, and hot gas reheat to allow the DOA unit to handle all or part of the heating and cooling load of the ventilation air. In some cases, the DOA unit would have sufficient refrigeration for cooling and dehumidifying the ventilation air, and the zone air handler would have cooling capacity sized only for the zone cooling load and heating capacity sized to handle the ventilation heating load as well as the zone heating load.

Ventilation air from a DOA can also be ducted into the zone and discharged through diffusers without passing through the zone air handler. In this case the zone air handler is sized only for the zone loads and the DOA unit must have refrigeration and heat to allow introducing the air into the zone at near the zone design conditions. This method has the disadvantage of requiring a complete second ductwork system, so would be used only if the building configuration or other problems make it impractical to introduce the ventilation into the air handler return.

Energy Recovery Ventilator

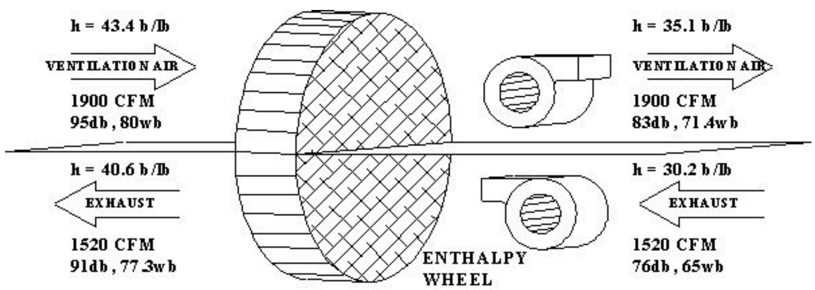


FIGURE 8,ENERGY RECOVERY VENTILATOR
crossflow neglected, casing and filters not shown

An energy recovery ventilator consists of a slowly rotating enthalpy wheel and two blowers, one for ventilation air and one for exhaust. The enthalpy wheel transfers heat and moisture from the ventilation air to the exhaust, as shown on Figure 8. In cooling mode (shown), the ventilation air is cooled and dehumidified by transferring its heat and moisture to the cool, dry exhaust. The unit shown thus reduces the outdoor air load on the air handler by nearly 80%. Of course, in order to do this, all or most of the non-hazardous exhaust from the zone must be collected and ducted to the exhaust intake of the ERV. The ventilation air discharge is ducted to blend with the return of the zone air handler.

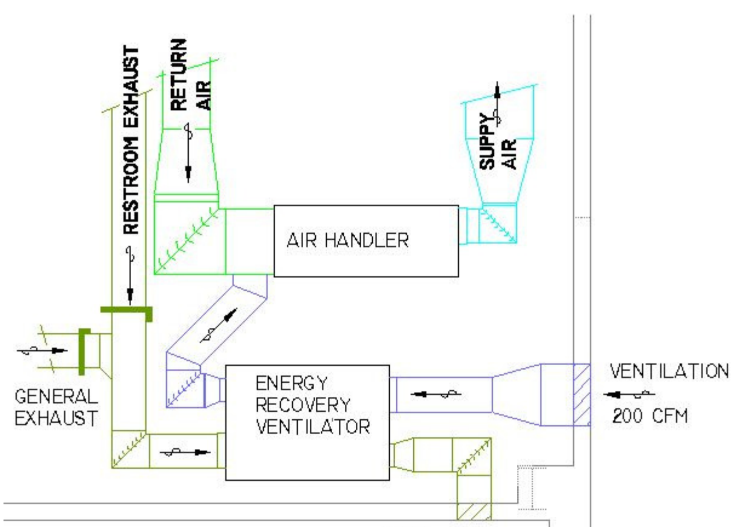


FIGURE 9
TYPICAL ERV LAYOUT

Figure 9 shows a typical layout with an ERV tempering the ventilation air for a zone air handler. Ventilation air is induced from outside by the ERV ventilation blower. The zone exhaust, after passing over the ERV enthalpy wheel, is exhausted to outside by the ERV exhaust blower. The ERV in the system shown is larger than the air handler, and this is often the case. ERV's are large, and the designer must ensure that there will be adequate space for installation and for ductwork connections to the air handler.

11. Ventilation Controls

There are two objectives of ventilation controls. First, to ensure that the minimum ventilation air flow is maintained under all conditions of cooling and heating operation. Second, to ensure that no element of the system can operate in such a way as to bring un-tempered outdoor air into the zone.

Maintaining Minimum Ventilation

For a constant volume system the minimum air flow can be set at test and balance, along with the air handler supply air flow, using the tools provided by the designer – dampers, speed taps for small blowers, and adjustable pulleys for belt-drive blowers. No active control will be needed, although flows should be confirmed periodically as part of normal maintenance.

For VAV systems, active minimum air flow controls that respond to direct air flow measurement will be needed. As noted in the preceding section, the air flow signal can modulate a forced induction damper or vary the speed of a DOA blower.

Under Standard 62.1ventilation air volume can be controlled to maintain a maximum CO2 level. This may be desirable when ventilation air volume is very large, as for a gymnasium at full occupancy. When occupancy is low, ventilation air can be reduced to maintain CO2 at the same or lower concentration than full occupancy, and in fact, Standard 62.1-2010 mandates ventilation modulation when the full occupancy ventilation flow rate exceeds 3000 cfm. However, care must be taken to ensure that the ratio of ventilation to exhaust never falls below 1.2, to maintain building pressurization.

Avoiding Unscheduled Entry of Outdoor Air

Unscheduled outdoor air can enter the conditioned space in three ways: 1) infiltration; 2) operation of the zone air handler without operating the cooling system; and 3) operation of exhaust fan(s) when the cooling system is not operating.

Infiltration is not directly controlled, but is mitigated by maintaining the building internal pressure, using the 25% excess of ventilation air over exhaust .

If the air handler is allowed to operate without the cooling system – condensing unit or chiller – outdoor air will be induced without being dehumidified. The designer needs to specify controls that will prevent this from happening. For example, on a simple DX system, the thermostat fan "on" switch should be disabled.

If exhaust fans are allowed to operate after the cooling system is shut down during unoccupied periods, the building pressurization will be lost because the air handler is not operating and no ventilation air is being induced. To avoid this, the designer must specify that fans be interlocked to shut down when the cooling system serving the zone is shut down.

12. Summary

Prior to performing final cooling and heating load calculations, the minimum required ventilation air must be determined. Local and national codes and standards set minimum exhaust requirements for categories such as restrooms, showers, medical isolation rooms, and restaurant food service. Other codes and standards such as ASHRAE Standard 62 set minimum requirements for outdoor air needed to ensure acceptable indoor air quality. Finally, even if there were no codes regulating exhaust or intake, it would be necessary to induce enough outdoor air through the air handlers to pressurize a building and inhibit infiltration.

In general, outdoor air must exceed exhaust by a factor of about 1.25 in order to pressurize the building and mitigate infiltration. In some cases, particularly if the building has a commercial kitchen, required exhausts will be large enough that the required offset outdoor air will exceed the outdoor air required to maintain air quality standards. If required ventilation air is larger than the required exhaust offset, then supplemental exhaust may be required to prevent over-pressurization of the building.

To make these determinations, the designer should perform an air balance showing all required exhausts, required outdoor air for air quality, and supplemental exhaust or outdoor air as needed to provide pressurization. If the building has a commercial kitchen, then air balances should be performed for all expected operational configurations of kitchen exhaust fans. Special controls may be needed to prevent over pressurization or negative pressure. The pressure in the dining areas of a restaurant must always exceed the pressure in the kitchen, and the kitchen pressure must always exceed outside ambient pressure.

Once the required amount of ventilation air is determined, the designer must decide on a method to induce the required air, and must set up compatible controls to ensure that ventilation air is neither excessive nor insufficient regardless of the zone operating conditions. Controls must also be specified that will prevent unscheduled entry of outdoor air into the conditioned space, especially during unoccupied periods.

---

[1] ***Ventilation for Acceptable Indoor Air Quality,*** ANSI/ASHRAE Standard 62.1-2010

[2] ***NFPA 96, Standard for Ventilation Control and Fire Protection of Commercial Cooking Applications,*** National Fire Protection Association, Quincy, MA

[3] ***Industrial Ventilation – A Manual of Recommended Practice***, American Conference of Governmental Industrial Hygienists

[4] ***62.1 User's Manual – ANSI/ASHRAE Standard 62.1-2010***