Primary Topic Areas

- Outdoor Air Intakes
- System Cleanliness
- Controls for Outdoor Air Supply
- Air Distribution
- Exhaust Systems
- Quantity of Outdoor Air
- How to Measure Air Flow

Instructions

Read this section before completing the Ventilation Checklist.

Background Information for Ventilation Checklist

The Ventilation Checklist offers in-depth guidance to schools for inspecting ventilation systems. Typical schools have multiple ventilation units and central HVAC systems. Perform the activities and complete a checklist for each unit and system.

The following process is recommended for completing the checklist:

Activities 1–3
Perform these activities for all outdoor air intakes while outside the building; mark the results on the Ventilation Checklist for each unit.

Activities 4–12
Perform these activities as a set on each ventilation unit or air handling unit while you're in the appropriate room with the unit turned on.

Activities 13–16
Perform these ventilation control system activities as necessary.

Activities 17–21
Perform these air distribution activities as necessary.

Activities 22–23
Perform these activities regarding the quantity of outdoor air on all units while you have the airflow measurement equipment available.

For more detailed information see *IAQ Building Education and Assessment Model* (EPA 402-C-01-001), listed in **Appendix L:** "Resources" in the ***IAQ Reference Guide***.

There are two primary types of ventilation systems in schools:

- Mechanical systems—unit ventilators, central HVAC (e.g., air cooled packaged rooftop HVAC unit, chilled water air-handling unit), and central exhaust.
- Passive ventilation—operable windows, air leaks, wind, and the stack effect (the tendency of warm air to rise).

Most checklist activities apply to mechanical systems and are designed to ensure that the ventilation system is clean and that outdoor air is adequately supplied to the appropriate areas. The checklist is designed for individuals who are properly trained in mechanical systems and safety procedures. Basic tools are required for most activities (see **Appendix B:** "Basic Measurement Equipment" in the ***IAQ Reference Guide***). Skip checklist items that do not apply to your system. (See diagram of a Typical HVAC System on reverse side of this sheet.)

OUTDOOR AIR INTAKES

Blocked or clogged outdoor air intakes can result in reduced amounts of outdoor air, which can lead to stuffy air and health problems from exposure to accumulated pollutants. Proper location of outdoor air intakes can minimize the entrance of contaminated air. Problems due to pollutants near intakes may be resolved by:

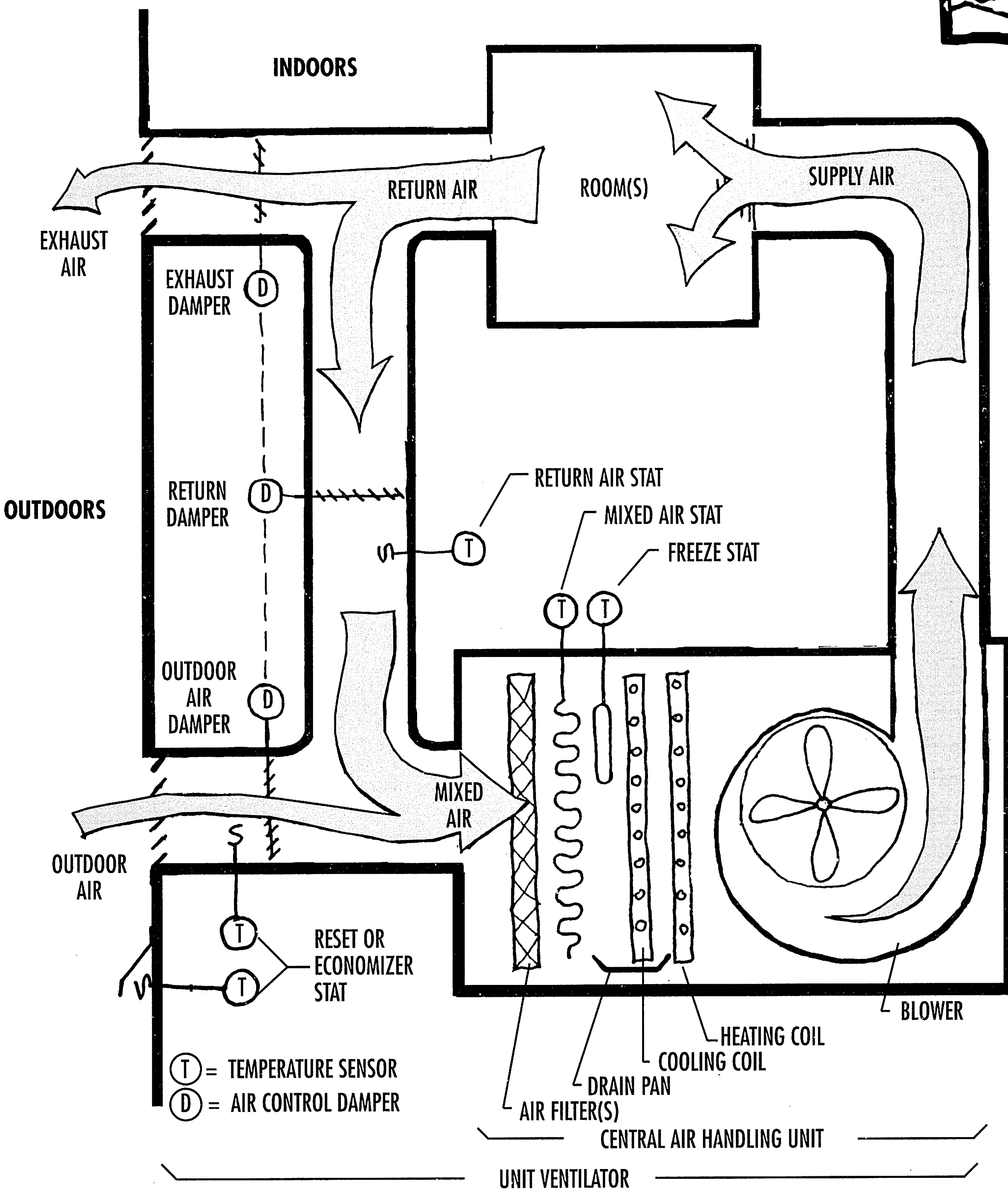
- Removing the source (such as relocating a dumpster).
- Separating the source from the intake (such as extending a pipe to raise a nearby exhaust outlet above the intake).
- Changing operating procedures (such as not allowing buses and delivery trucks to idle).

SYSTEM CLEANLINESS

Accumulated dirt can interfere with the proper operation of the ventilation system and lead to:

- Insufficient ventilation.
- Uncomfortable room temperatures.
- Lowered efficiency (and higher utility bills).
- Additional maintenance.
- Rapid deterioration of equipment.

Typical HVAC System



Air filters must be properly selected and regularly replaced to prevent dirt and dust from accumulating in the HVAC system. Dirty filters restrict airflow. Filter "blow outs" allow dirt in unfiltered air to accumulate on coils, producing a need for more frequent cleaning and reducing the efficiency of the heating and/or cooling plant. It is much less expensive to trap dirt with properly maintained filters than to clean ductwork, coils, fan blades, and other HVAC system components.

WARNING: Do not clean dirty or biologically contaminated system components when the system is operating or when the building is occupied.

WARNING: If there is visible biological growth (such as mold), obtain expert advice about the kind of respiratory protection to use and how to use it.

CONTROLS FOR OUTDOOR AIR SUPPLY

This group of activities is for ventilation systems that use fans or blowers to supply outdoor air to one or more rooms within a school.

Since your **ventilation controls** may be unique, and since there are many different types and brands of control components, you will find it helpful to review controls specifications, as-built mechanical drawings, and controls operations manuals.

Based on your equipment and experience, perform as many of the activities and make as many indicated repairs as possible. Discuss the need for additional help for incomplete activities or repairs with your IAQ Coordinator.

NOTE: If the amount of outdoor air supply measured in Activity 22 of the checklist proves to be inadequate for the number of occupants served, you may have to slightly adjust the minimum outdoor damper setting. Use a nut or a knob to adjust for a larger damper opening. If a larger adjustment on an outdoor air supply is required, contact the HVAC system installer or HVAC maintenance contractor.

AIR DISTRIBUTION

Even when sufficient outdoor air enters the school building, under-ventilation can occur in particular areas of the building if the outdoor air is not properly distributed. Problems with air distribution are most likely to occur if:

- Ventilation equipment malfunctions.
- Ventilation intakes are located too close to ventilation exhausts.
- Room layouts are altered without adjusting the HVAC system.
- The population of a room or zone increases without adjusting the HVAC system.

Unit Ventilators are sometimes specified to operate under one of the following American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) sequences:

Cycle I: Except during warm-up stage (outdoor air damper closed), Cycle I supplies 100 percent outdoor air at all times.

Cycle II: During the heating stage, Cycle II supplies a set minimum quantity of outdoor air. For cooling, outdoor air is gradually increased as required. During warm-up, the outdoor air damper is closed. (Typical sequence for northern climates.)

Cycle III: During the heating, ventilating, and cooling stages, Cycle III supplies a variable amount of outdoor air as required to maintain a fixed temperature (typically 55°F) entering the heating coil. When heat is not required, this air is used for cooling. During warmup, the outdoor air damper is closed. (Typical sequence for southern climates, with adaptations for mechanical cooling.)

- Differences in air pressure move contaminants from outdoors to indoors then transport them within buildings, or from bathrooms to hallways and classrooms.

In schools with mechanical ventilation equipment, fans are the dominant influence on pressure differences and airflow. In schools without mechanical ventilation equipment, natural forces (wind and stack effect) are the primary influences on airflow.

Air moves from areas of high pressure to areas of low pressure. To prevent infiltration of outdoor air and soil gas (for example, radon), mechanically ventilated buildings often maintain a higher air pressure indoors than outdoors. This is known as **positive pressurization**. At the same time, exhaust fans control indoor contaminants by keeping some rooms—smoking lounges, bathrooms, kitchens, and laboratories—under negative pressure compared to neighboring spaces (for example, another room, a corridor, or the outdoors). **Negative pressurization** of buildings may cause problems with natural draft combustion appliances or cause outdoor pollutants, such as pollens or vehicle exhaust in loading docks, to be drawn into the building through openings and cracks in the construction.

To determine whether a room is positively or negatively pressurized—or neutral—release puffs of smoke near the top and bottom of a slightly opened door or window. Observe the direction of flow. If the smoke flows inward at both the top and bottom of a slightly opened door, for example, the room is negatively pressurized when compared to the space on the other side of the door.

EXHAUST SYSTEMS

Exhaust systems remove contaminated air and odors. Some HVAC designs also rely on the operation of exhaust fans to create negative pressure that draws outdoor air into the building through windows and gaps in the building envelope. If insufficient air flows toward the exhaust intake when the fan is running, check the following:

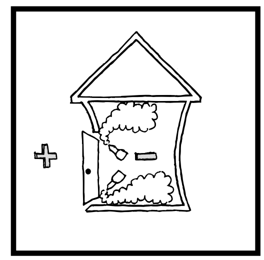
- The backdraft damper at the exhaust outlet may be stuck open.
- Obstructions may be clogging the ductwork.
- The ductwork could have leaks or be disconnected.
- The fan belt may be broken.
- The motor may be installed backwards.
- The fan may supply insufficient quantities of air for room capacity (i.e., improper design).

QUANTITY OF OUTDOOR AIR

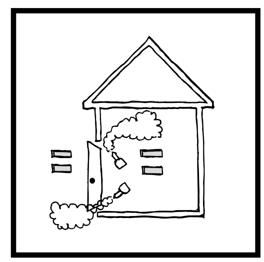
To maintain good indoor air quality, you must ensure that acceptable quantities of outdoor air enter the building. ASHRAE's ventilation recommendations are located in Table 1:

1. In the first column of Table 1, find the listing for the type of area served by the unit you are evaluating.
2. Check the second column to see if the occupancy for each 1,000 square feet that the ventilation unit serves is no greater than the occupancy assumed for the recommendations.
3. Compare the recommended ventilation in the third column of Table 1 to the calculated outdoor air per person from Activity 22 of the Ventilation Checklist.
4. If the calculated airflow falls below the recommendations in Table 1, the school may have been designed to meet a lower standard that was in effect when the school was built. If you have design specifications for the system or know code requirements in effect at the time of construction, compare the measured outdoor air to this specification. Repair the system to meet the design specification, if necessary.

Negative Pressure



Neutral Pressure



Positive Pressure

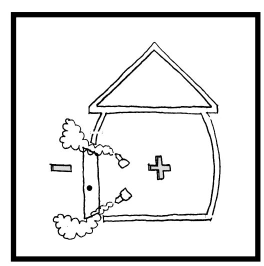


Table 1: Selected ASHRAE Ventilation Recommendations

Type of Area	Occupancy (people/1000 ft^2)	Cubic feet per minute (CFM)/person
Instructional Areas		
Classrooms	50	15
Laboratories	30	20
Music rooms	50	15
Training shops	30	20
Staff Areas		
Conference rooms	50	20
Offices	7	20
Smoking lounges	70	60
Bus garage: 1.5 CFM per square foot of floor area. Distribution among people must consider worker location and concentration of running engines; stands where engines are run must incorporate systems for positive engine exhaust withdrawal. Contaminant sensors may be used to control ventilation.		
Assembly Rooms		
Auditoriums	150	15
Libraries	20	15
Gymnasiums		
Spectator areas	150	15
Playing floor	30	20
Food and Beverage Service		
Cafeteria	100	20
Kitchen	20	15
Additional airflow may be needed to provide make-up air for hood exhaust(s). The sum of the outdoor air and transfer air of acceptable quantity from adjacent spaces shall be sufficient to provide an exhaust rate of not less than 1.5 CFM/square foot.		
Miscellaneous		
Nurse's offices (patient areas)	10	25
Corridors: 0.1 CFM/square foot		
Locker rooms: 0.5 CFM/square foot		
Restroom: 50 CFM/urinal or water closet		

SOURCE: ASHRAE Standard 62-2001, Ventilation for Acceptable Air Quality

If the school's design meets a lower standard and cannot meet the current recommended levels in Table 1, discuss means for increasing ventilation with the IAQ Coordinator. These could include:

- Retrofitting the ventilation system for increased capacity.
- Opening windows. **CAUTION: Consider potential ventilation problems that this may cause in other parts of the building.**
- Making any permanent repairs and taking any other measures that help ensure adequate outdoor air in the future. These improvements will probably require the services of a professional engineer.

HOW TO MEASURE AIRFLOW

There are three activities for evaluating air movement and measuring outdoor air supply:

- Determine airflow direction using chemical smoke.
- Measure quantity of outdoor air supply.
- Take carbon dioxide measurements to estimate outdoor air supply.

1. Determine Airflow Direction Using Chemical Smoke

Chemical smoke can be helpful in tracking air and pollutant movement and identifying pressure differentials. Chemical smoke maintains the temperature of the surrounding air and is extremely sensitive to air currents. This allows for observation of airflow patterns, particularly direction and speed of air movement.

- Release smoke near outdoor air intakes to determine whether air is being drawn in.
- Release puffs of smoke at the shell of the building (by doors, windows, or gaps) to determine whether the HVAC systems are maintaining interior spaces under positive pressure relative to the outdoors.
- Release puffs of smoke near HVAC vents to evaluate supply and return and whether ventilation air actually reaches the breathing zone.
  - For a variable air volume system, consider how the system modulates. It could be on during the test but off for much of the rest of the day.
  - "Short-circuiting" occurs when air moves directly from supply diffusers to return grilles instead of mixing with room air in the breathing zone. In this situation, occupants may not receive adequate outdoor air.

Chemical smoke comes with various dispensing mechanisms, including smoke "bottles," "guns," "pencils," or "tubes." These dispensers allow smoke to be released in controlled quantities and directed at specific locations. It is often more informative to use a number of small puffs of smoke as you move along an air pathway rather than releasing a large amount in a single puff.

CAUTION: Chemical smoke devices use titanium tetra-chloride to produce smoke. While the chemicals forming the smoke are not considered hazardous in the small quantities produced during testing, avoid inhaling smoke; concentrated fumes from smoke devices are very corrosive.

2. Measure Outdoor Air Supply Quantity

Flow hoods or air velocity measurement devices can be used to determine the amount of outdoor air supplied by a single ventilation unit. General instructions for measuring airflow are provided below. Follow the instructions provided by the manufacturer of your measuring equipment if they differ.

Step A: Determine airflow quantity

Flow hoods measure airflow at a diffuser or grille in cubic feet per minute (CFM). Other devices, such as a Pitot tube or

anemometer, are used to measure air velocity and calculate the quantity of outdoor air supply. Follow the instructions supplied with the equipment regarding use, care, and calibration. (See the IAQ Coordinator for help obtaining these devices.)

To determine airflow quantity for a mechanical system:

- Measure air velocity in large ductwork using a Pitot tube with a differential pressure gauge or an anemometer. Calculate the outdoor airflow in CFM at the outdoor air intake of the air-handling unit or other convenient location. For more information on measuring air velocity and calculating outdoor air supply, see the instructions supplied with the Pitot tube or anemometer.

  OR

- If you are using a flow hood, simply hold the hood up to the diffuser and read the airflow value.
- Enter the calculated outdoor air supply in the Ventilation Checklist.

If your system does not have mechanically-supplied outdoor air (i.e., if it is a passive system), you can estimate the amount of outdoor air infiltrating the area by measuring the quantity of air exhausted by fans serving the area:

- Use a small floor plan, such as a fire escape map, to mark the areas served by each exhaust fan.
- Measure airflow at grilles or exhaust outlets using a flow hood. Determine the airflow in ductwork, if present, by using a Pitot tube with a differential pressure gauge or an anemometer.
- Add the airflows (in CFM) from all exhaust fans serving the area you are measuring and enter the measurement in the Ventilation Checklist.

Step B: Determine the occupied zones

Count the number of students and staff located in each area served by an air-handling unit to determine the "occupied zone." A unit ventilator's occupied zone is likely an individual classroom. In areas served by large air-handling units, an occupied zone may include several rooms. In some cases (such as a gymnasium), several air-handling units may serve a single room.

- Use a small floor plan to mark the occupied zone served by each unit.
- Estimate the number of occupants in each zone.

Step C: Calculate Outdoor Air Per Person

Use the equation below to calculate average ventilation rates in CFM/person.

$$\frac{\text{Outdoor Air (CFM)}}{\text{Number of Occupants}} = \text{Outdoor Air (average CFM/person)}$$

3. Estimate Quantity of Outdoor Air Supply Using Carbon Dioxide Measurements

Indoor carbon dioxide (CO_2) concentrations can be used to estimate outdoor air ventilation. Exhaled breath of building occupants and other sources can raise CO_2 levels indoors above levels outdoors. Measure CO_2 with a direct-reading meter (following manufacturer's instructions) and compare peak CO_2 readings between rooms and between air-handler zones to identify and diagnose various building ventilation deficiencies.

Step A: Measure CO_2 levels

Measure CO_2 levels in each area served by a specific unit or exhaust fan(s) and in an area without any mechanical ventilation. The number of occupants, time of day, position of windows and doors, and weather should be noted for each period of CO_2 testing.

- Take several CO_2 measurements with minimal delays between readings in the area under consideration. Avoid measurements near any source that could directly influence the reading (for example, hold the sampling device away from exhaled breath).
- Compare measurements taken at different times of day. Classroom CO_2 levels typically increase during the morning, fall during the lunch period, then peak in mid-afternoon. Therefore, measure CO_2 levels in the mid- to late-afternoon (when concentrations are expected to peak).
- Take several measurements outdoors.
- For systems with mechanically-supplied outdoor air, take one or more readings:
  - At the supply air vent.
  - In the mixed air (if measured at an air handler).
  - In the return air.

Step B: Estimate Quantity Outdoor Air Supply

- Calculate the percentage of outdoor air in supply air using CO_2 measurements taken in Step A:

  Outdoor air (%) = (CR-CS) ÷ (CR-CO) x 100

  CS = ppm of CO_2 in the supply air (room measurement) or in the mixed air (air-handler measurement)

  CR = ppm of CO_2 in the return air

  CO = ppm of CO_2 in the outdoor air (typical range is 300-450 ppm)

- Convert outdoor air percentage to an amount of outdoor air in cubic feet per minute:

  Outdoor air (CFM) = Outdoor air (%) ÷ 100 x total airflow (CFM)

  Total airflow may be the air quantity supplied to a room or zone, the capacity of an air handler, or the total airflow of the HVAC system. The actual amount of airflow in an air handler, however, is often different from the quantity in design documents. Therefore, only measured airflow is accurate.

Step C: Note high CO_2 levels

Based on CO_2 measurements from Step A, note areas with CO_2 concentrations more than 700 ppm above the outdoor air concentration. Elevated CO_2 indicates an insufficient supply of outdoor air for the number of people in the space. (See Table 1 in this section, **Appendix C**, and *Ventilation for Acceptable Indoor Air Quality* (ASHRAE Standard 62-2001) in **Appendix L**: "Resources" in the ***IAQ Reference Guide***.)

A primary source of CO_2 indoors is human respiration (exhaled breath). As people move in and out of a room, CO_2 levels can change rapidly. Note that problems with low ventilation rates may still occur in rooms with peak CO_2 concentrations less than 700ppm above the outdoor air concentration. Frequently, 4 to 6 hours of continuous occupancy are required for CO_2 to approach peak levels.