Explanatory Information for Ventilation Log Items

OUTDOOR AIR INTAKES

If outdoor air intakes are deliberately blocked or become clogged with dirt or debris, areas they serve are likely to get insufficient outdoor air. Students or staff might experience stuffy or stagnant air, or develop health problems from exposure to accumulated pollutants.

❑ On a small floor plan (e.g., a fire escape floor plan), mark the locations of outdoor air intakes, based on mechanical plans (if available) and your observations while performing these activities.

❑ Obtain chemical smoke (or, alternatively, a small piece of tissue paper or light plastic) before performing Activity 3. For more information on chemical smoke, see *How to Measure Airflow*, at the end of this Checklist.

❑ Ensure that the ventilation system is on and operating in "occupied" mode

1. Ensure that outdoor air intakes are unobstructed

❑ Check the intakes from outside the school building for obstructions, such as debris, clogged screens, or make-shift covers (e.g., boards or plastic)

❑ Remove any obstructions

❑ Install corrective devices if snowdrifts or leaves often block an intake

2. Ensure that outdoor air intakes are clear of nearby pollutant sources

❑ Check the intakes from outside the school building to confirm that pollutant sources are not located near outdoor air intakes

- At ground level, look for dumpsters, loading docks, and bus-idling areas
- At roof level, look for plumbing vents, exhaust outlets (such as kitchen, toilet, or laboratory exhaust fans), puddles on the roof, and mist from air-conditioning cooling towers

❑ Resolve problems due to pollutants near intakes:

- Remove sources, where possible (for example, move a dumpster to another location)
- Separate the source from the intake (for example, add another pipe section to raise a nearby exhaust outlet above the intake)
- Change operating procedures (for example, turn off vehicles instead of idling at loading docks and bus stands)

3. Confirm that outdoor air is entering the system intake

❑ Use chemical smoke (or, alternatively, a small piece of tissue paper or light plastic) to show whether air is moving into the intake grille

SYSTEM CLEANLINESS

Accumulated dirt can interfere with the proper operation of the ventilation system and lead to underventilation, uncomfortable temperatures, less efficient operation (higher utility bills), more maintenance, and decreased life expectancy of equipment. Air filters are intended primarily to prevent dirt and dust from accumulating in the HVAC system. If filters are not properly selected and maintained, built-up dirt in coils and ducts could provide a habitat for microbiological growth. Filters that are clogged with dirt restrict the flow of air through the HVAC system. If filters "blow out" and allow the passage of unfiltered air, dirt can accumulate on coils (producing a need for more frequent cleaning) and reduce the efficiency of the heating and/or cooling plant. It is much less expensive to trap dirt with properly maintained filters than to remove it from ductwork, coils, fan blades, and other HVAC system components.

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

WARNING: *If there is visible biological growth, such as mold, minimize your exposure to air in the interior of ducts or other HVAC equipment. Use proper respiratory protection; obtain expert advice about the kind of respiratory protection to use and how to use it.*

4. Inspect air filters on ventilation equipment

- ❑ Install new filters as needed. Shut off ventilation system fans when replacing associated filters so that dirt will not blow downstream. Vacuum the filter area before installing the new filter
- ❑ Confirm that filters fit properly in their tracks, with no major air leaks that would allow air to bypass (flow around) the air filter
- ❑ Confirm that filters are installed in the proper direction for airflow

5. Ensure that condensate drain pans are clean and drain properly

- Drain pans should slant toward the drain so they do not collect and hold water

6. Ensure that heating and cooling coils are clean

7. Ensure that air handling unit(s) (air mixing chambers, coils, and fan blades) and duct interiors are clean

8. Ensure that the mechanical rooms are free of trash and chemicals

- ❑ Check mechanical room for unsanitary conditions, leaks, or spills
- ❑ Confirm that mechanical rooms and air mixing chambers are not used to store trash or chemical products and supplies

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. The primary objectives that you should keep in mind as you perform these activities are:

- Ensure that air dampers are always at least partially open (minimum position) during occupied hours, and
- Ensure that the minimum position provides an adequate amount of outdoor air for the occupants.

These activities are fairly generic, and apply to most ventilation systems. See the figures in the *IAQ Backgrounder* for more information.

Activities 9-11 generally serve multiple ventilation units, while activities 12-16 are related and performed at each individual ventilation unit. 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 any uncompleted activities or repairs with your IAQ Coordinator.

9. Gather controls information

Your ventilation controls may be uniquely designed, and since there are many different types and brands of control components, it can be very helpful if you:

- Gather and read any controls specifications, as-built mechanical drawings, and controls operations manuals that you may have
- Contact the system installer or HVAC maintenance contractor to obtain controls information that is missing from your files

10. Check Clocks, Timers, and Seasonal Switches

- ❑ Confirm that summer-winter switches are in the right position
- ❑ Confirm that time clocks read the correct time
- ❑ Confirm that time clock settings fit the actual schedule of building use (night/weekend set-back and set-up)

11. Check pneumatic control system components (if any)

- ❑ Test the line pressure at both the occupied (day) setting and the unoccupied (night) setting to determine whether the overall system pressure is appropriate
- ❑ Confirm that the line dryer is preventing moisture buildup
- ❑ Check the control system filters. The filter at the compressor inlet should be changed periodically in keeping with the compressor manufacturer's recommendation (for example, when you blow down the tank)
- ❑ Ensure that the line pressure at each thermostat and damper actuator is at the proper level (no leakage or obstructions)
- ❑ Repair or replace defective components

12. Check outdoor air damper operation

Before continuing, the air temperature in the indoor area(s) served by this outdoor air damper must be within the normal operating range, and ensure that the outdoor air damper is visible for your inspection

- ❑ Turn off the air handler connected to the outdoor air damper and confirm that the damper fully closes within a few minutes
- ❑ Turn on the air handler and confirm that the outdoor air damper opens at least partially with little or no delay
- ❑ Set the room thermostat as follows, and observe the damper for movement (damper should go to its minimum position, but not completely closed):
  - If in heating mode, set the room thermostat to 85°F
  - If in cooling mode, set the room thermostat to 60°F, mark the current setting of the mixed air thermostat, and set it to a low setting (about 45°F)

If the outdoor air damper does not move:

- Confirm that the damper actuator is linked to the damper shaft and that any linkage set screws or bolts are tight
- Confirm that rust or corrosion are not preventing free movement
- Confirm that either electrical wires or pneumatic tubing is connected to the damper actuator
- Reset thermostat(s) to appropriate temperature(s)

Proceed to Activities 13-16 if the damper seems properly operating

> ***NOTE:*** *The minimum damper setting, adjusted with a nut or a knob, may have to be adjusted to allow a larger damper opening if the amount of outdoor air supply measured in Activity 22 is not adequate for the number of occupants being served.*

Unit Ventilators are sometimes specified to operate under one of the following ASHRAE sequences:

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

Cycle II: During the heating stage, Cycle II supplies a set minimum quantity of outdoor air. Outdoor air is gradually increased, as required for cooling. 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 adaptions for mechanical cooling.)

The following four items may be responsible for keeping outdoor air dampers closed during the normal occupied cycle.

13. Confirm freeze-stat condition

HVAC systems with water coils need protection from freezing. The freeze-stat may close the outdoor air damper and disconnect the supply air when tripped. The typical trip range is 35°F to 42°F.

- If the freeze-stat has a manual reset button (usually red), depress the button. If a click is heard, the freeze-stat was probably tripped. Consider replacing manual reset freeze-stats with automatic reset freeze-stats
- If the freeze-stat has an automatic reset, disconnect power to the controls and test for continuity across the terminals

14. Check mixed air thermostat

- The mixed air stat for heating mode should be set no higher than 65°F
- The mixed air stat for cooling mode should be set no lower than the room thermostat setting

15. Check air economizer setting

Economizers use varying amounts of cool outdoor air to assist with the cooling load of the room or rooms. There are two types of economizers, dry-bulb and enthalpy. Dry-bulb economizers vary the amount of outdoor air based on outdoor air temperature, and enthalpy economizers vary the amount of outdoor air based on outdoor air temperature and humidity level.

- ❑ Confirm proper settings based on design specifications or local practices (dry-bulb setting typically 65°F or lower)
- ❑ Check the sensor to make sure that it is shielded from direct sunlight

16. Confirm that fans operate continuously during occupied periods

- Any fan that helps move air from outdoors to indoors must operate continuously during occupied hours, even though the room thermostat is satisfied.
- If the fan shuts off when the thermostat is satisfied, change the control cycle to prevent underventilation.

AIR DISTRIBUTION

Even if enough outdoor air is brought into a school building, IAQ problems can develop if the outdoor air is not properly distributed. In such cases, underventilation occurs in particular areas of the building rather than being widespread. Problems with air distribution are most likely to occur in areas where:

- Ventilation equipment is malfunctioning
- Room layouts have been altered without adjusting the HVAC system
- The population of a room or zone has grown without adjustment to the HVAC system
- Air pressure differences move air contaminants from outdoors to indoors and transport them within buildings.

In schools with mechanical ventilation equipment, fans are the dominant influence on pressure differences and air flows. In schools without mechanical ventilation equipment, natural forces (wind and stack effect) primarily influence airflows.

To prevent infiltration of outdoor air and soil gas (e.g., radon), mechanically-ventilated buildings are often designed to maintain a higher air pressure indoors than outdoors, which is known as positive pressurization (See "Exhaust Systems" and "How to Measure Airflow" for a description of building pressurization). At the same time, exhaust fans control indoor contaminants by keeping rooms such as smoking lounges, bathrooms, kitchens, and laboratories under negative pressure compared to surrounding rooms. "Negative pressure" and "positive pressure" describe pressure relationships. A room can operate under negative pressure as compared to neighboring rooms, but at the same time it may be positive compared to outdoors.

17. Check air distribution

Verify that air pathways in the original ventilation system design continue to function.

- ❑ Check to see whether operable windows have been replaced by windows that cannot be opened
- ❑ Check to see whether passive gravity relief ventilation systems and transfer grilles between rooms and corridors are functioning. If they are closed off or blocked to meet modern fire codes, consult with a professional engineer for remedies
- ❑ Verify that every occupied space has a supply of outdoor air (mechanical system or operable windows)
- ❑ Confirm that supplies and returns are open and unblocked. If outlets have been blocked intentionally to correct drafts or discomfort, investigate and correct the cause of the discomfort and reopen the vents
- ❑ If you discovered areas with no source of outside air, modify the HVAC system to correct the problem
- ❑ Check for barriers, such as room dividers, large free-standing blackboards or displays, or bookshelves, that could block movement of air in the room, especially if they block air vents

18. Check air flow direction

- ❑ Confirm that the system, including any exhaust fans, is operating on the occupied cycle when doing this activity.
- Where outdoor contaminant sources have been identified, use chemical smoke to determine whether the air flows out of the building through leaks in nearby windows, doors, or other cracks and holes in exterior walls
- Use chemical smoke to determine whether air flows out of the building through below-grade cracks and holes (e.g., floor joints, pipe openings)

EXHAUST SYSTEMS

Exhaust systems are used to remove air that contains contaminants, including 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.

19. Confirm that exhaust fans are operating

- Use chemical smoke to confirm that air is flowing into the exhaust grille(s)

20. Verify that local exhaust fans remove enough air to eliminate odors and chemical fumes

If the fan is intended to exhaust the entire room, stand outside the room with the door slightly open and use chemical smoke to confirm that air is being drawn into the room from locations both high and low in the door opening (see *How to Measure Airflow* below).

If the fan is running, but air isn't flowing toward the exhaust intake (or too little air is moving to do the job), check for the following possibilities:

- The backdraft damper at the exhaust outlet does not open
- Obstructions in the ductwork
- Leaky or disconnected ductwork
- Broken fan belt
- Motor running backwards
- Design problems (e.g., undersized fan)

21. If the exhaust fan is located close to the contaminant source, rather than on the roof, and exhaust air is ducted through the building under positive pressure

- Confirm that the exhaust ductwork is sealed and in good condition.

QUANTITY OF OUTDOOR AIR

22. Measure quantity of outdoor air per person

See *How to Measure Airflow* at the end of this Checklist for techniques on measuring outdoor air supply.

Measure the quantity of outdoor air supplied either to or from each ventilation unit. Use the Ventilation Log to calculate the quantity of outside air per person being provided to occupants (22a. on the Ventilation Log)

Count or calculate the number of occupants served by the ventilation unit under consideration (22b. on the Ventilation Log)

Divide the quantity of outdoor air supplied by the number of occupants served for the ventilation unit under consideration (22a divided by 22b on the Ventilation Log)

ADEQUACY OF OUTDOOR AIR SUPPLY

23. Compare the measured outdoor air per person to Table 1

In the first column of Table 1, find the listing for the type of area that is served by the unit you are evaluating.

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

Compare the recommended ventilation in the third column of Table 1 to the calculated outdoor air per person from Activity 22.

If the calculated airflow is below the recommendations in Table 1, it may be that the school was designed to meet a lower standard that was in effect at the time 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.

If the school was designed to a lower standard and cannot meet the recommended levels in Table 1, discuss with the IAQ Coordinator means for increasing ventilation:

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

Table 1: Selected ASHRAE Ventilation Recommendations

Type of Area	Occupancy (people/1000 ft²)	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	70	20
Smoking lounges	7	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	20
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 provice 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 62-1989, Ventilation for Acceptable Air Quality

HOW TO MEASURE AIRFLOW

This section provides basic guidance and options for determining air movement and measuring outdoor air supply. It is divided into three sections:

- Using chemical smoke to determine air flow direction
- Measuring airflow to determine outdoor air supply quantity
- Estimating outdoor air quantity using carbon dioxide measurements

1. Using Chemical Smoke to Determine Air Flow Direction

Chemical smoke can be helpful in evaluating HVAC systems, tracking air and pollutant movement, and identifying pressure differentials. Chemical smoke moves from areas of higher pressure to areas of lower pressure if there is an opening between them (e.g., door, utility penetration).

Because it is the same temperature as the surrounding air, chemical smoke is extremely sensitive to air currents. Investigators can learn about airflow patterns by observing the direction and speed of smoke movement. Smoke released near outdoor air intakes will indicate whether air is being drawn into the intake. Puffs of smoke released at the shell of the building (by doors, windows, or gaps) will indicate whether the HVAC systems are maintaining interior spaces under positive pressure relative to the outdoors.

Chemical smoke is available with various dispensing mechanisms, including smoke "bottles," "guns," "pencils," or "tubes." The 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 tetrachloride to produce smoke. While the chemicals forming the smoke normally are not hazardous in the small quantities produced during testing, avoid inhaling smoke from smoke devices. Concentrated fumes from smoke devices are very corrosive.*

Determining Air Movement From Diffusers And Grilles

Puffs of smoke released near HVAC vents give a general idea of airflow. (Is it in or out? Vigorous? Sluggish? No flow?) This is helpful in evaluating the supply and return system and determining whether ventilation air actually reaches the breathing zone. (For a variable air volume system, be sure to take into account how the system is designed to modulate. 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. If a substantial amount of air short-circuits, occupants may not receive adequate supplies of outdoor air and source emissions may not be diluted sufficiently.

2. Measuring Outdoor Air Supply Quantity

This section describes methods for determining the amount of outdoor air being supplied by a single ventilation unit using either a flowhood or air velocity measurement device. These are general instructions for measuring airflow. Follow the instructions provided by the manufacturer of your measuring equipment.

Step 1. Determine Airflow Quantity

Using a Flow Hood

Flowhoods measure airflow in cubic feet per minute (CFM) at a diffuser or grille. Taking the measurement is simply a matter of holding the hood up to the diffuser and reading the airflow value. Follow the instructions supplied with the flowhood regarding use, care, and calibration.

Using Velocity Measurements

For information on measuring air velocity using a Pitot tube or anemometer and calculating outdoor air supply, see the instructions supplied with the equipment.

Airflow in large ductwork can be estimated by measuring air velocity using a Pitot tube with a differential pressure gauge or an anemometer. (See the IAQ Coordinator for sources of these devices.)

- Measure the air velocity in the ductwork and calculate the outdoor airflow in cubic feet per minute (CFM) at the outdoor air intake of the air handling unit or other convenient location
- Enter the calculated outdoor air supply in the Ventilation Log

For Systems Without Mechanically-Supplied Outdoor Air

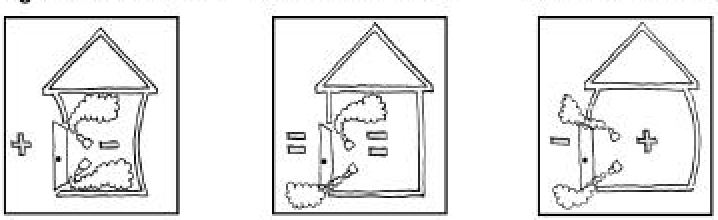
If your system does not have mechanically supplied outdoor air, you can estimate the amount of outdoor air infiltrating the area. Estimate air infiltration by measuring the quantity of air exhausted by exhaust fans serving the area.

- Using a small floor plan, such as a fire escape map, mark the areas served by each exhaust fan
- Measure airflow at grilles or exhaust outlets using a flow hood. Determine the airflow in ductwork 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 Log

A room can be positively or negatively pressurized when compared to the spaces surrounding it. These spaces include another room, a corridor, or outdoors. 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, and observe the direction of flow. Example: If the smoke flows inward at both the top and bottom of a slightly opened door, the room is negatively pressurized when compared to the space on the other side of the door.

Negative pressurization 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.

Negative Pressure **Neutral Pressure** **Positive Pressure**



Step 2. Determine Occupancy

Count the number of students and staff located in areas served by the air handling unit (called the occupied zone). If you are estimating infiltration using exhaust fan airflows, count individuals in the area you have determined are affected by the fan(s) in Step 1.

- Using a small floor plan, mark the occupied zone served by the unit. In areas served by unit ventilators, an occupied zone is probably an individual classroom. In areas served by large air handling units, an occupied zone may include several rooms. A large gymnasium or other room may be served by several air handling units.

- Estimate the number of occupants in the occupied zone, including students, teachers, other staff members, volunteers and visitors.

Step 3. Calculate Outdoor Air Per Person

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

- Use the equation below (the equation also appears on the Ventilation Log) to calculate average ventilation rates in CFM/person

3. Estimating Outdoor Air Using Carbon Dioxide Measurements

Carbon dioxide (CO_2) is a normal constituent of the atmosphere. Exhaled breath from building occupants and other sources increase indoor CO_2 levels above that of the outdoor air. CO_2 should be measured with a direct-reading meter. Use the meter according to manufacturer's instructions. Indoor CO_2 concentrations can, under some test conditions, be used to access outdoor air ventilation. Comparison of peak CO_2 readings between rooms and between air handler zones may help to identify and diagnose various building ventilation deficiencies.

Step 1. Estimate quantity of outdoor air supply.

CO_2 readings, with minimal delays between readings, can be taken at supply outlets or air handlers to estimate the percentage of outdoor air in the supply airstream.

The percentage or quantity of outdoor air is calculated using CO_2 measurements as shown below.

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

Where: CS = ppm of CO_2 in the supply air (if measured in a room), or in the mixed air (if measured at an air handler)

CR = ppm of CO_2 in the return air

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

All these concentrations must be measured, not assumed.

To convert the outdoor air percentage to an amount of outdoor air in cubic feet per minute, use the following calculation:

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

The number used for 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. However, the actual amount of airflow in an air handler is often different from the quantity in design documents. Therefore only measured airflow is accurate.

Step 2. Measure CO_2 levels in the area served by a given unit or exhaust fan(s) or 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.

- Measurements taken to evaluate the adequacy of ventilation should be made when concentrations are expected to peak. It may be helpful to compare measurements taken at different times of day. Classroom CO_2 levels will typically rise during the morning, fall during the lunch period, then rise again, reaching a peak in mid-afternoon. Sample in the mid- to late-afternoon

- Take several CO_2 measurements in the area under consideration. CO_2 measurements for ventilation should be collected away from any source that could directly influence the reading (e.g., hold the sampling device away from exhaled breath)
- Take several measurements outdoors
- For systems with mechanically supplied outdoor air, take one or more readings at the following locations:
  - At the supply air vent
  - In the mixed air (if measured at an air handler)
  - In the return air

Step 3. Note whether CO_2 levels are high.

- Note locations with CO_2 concentrations of 1,000 ppm or higher. Elevated CO_2 indicates that there is not enough outdoor air for the number of people in the space (based on ASHRAE Standard 62, see **Appendix I** of the IAQ Coordinator's Guide)
- Note that there may still be underventilation problems in rooms with peak CO_2 concentrations below 1,000 PPM. CO_2 is produced by human respiration (breathing), and concentrations can change rapidly as people move in and out of a room. Four to six hours of continuous occupancy are often required for CO_2 to approach peak levels.