WASHINGTON STATE UNIVERSITY
ENERGY PROGRAM

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Good Ventilation is Essential for a Healthy and Efficient Building

Our Mission

To advance environmental and economic well-being by providing unmatched energy services, products, education and information based on world-class research.

About Us

Our staff of over 100 people (energy engineers, energy specialists, technical experts, software developers, energy research librarians, and more) work out of our Olympia, Spokane and satellite offices. Operating similar to a consulting firm, the WSU Energy Program is a self-supported department within the University.

Within WSU

We are part of the College of Agricultural, Human and Natural Resource Sciences. We report directly to the WSU Vice President of Agriculture and Extension.

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Most of us spend about half of our waking hours in office or school buildings. It follows that the quality of air in these buildings can affect the health, productivity and comfort of the occupants. Measures that protect air quality, such as adequate ventilation, should be taken seriously.

Indoor air quality (IAQ) is determined by:

- Concentrations of contaminants in the air, and
- How effectively the ventilation system brings in appropriate volumes of fresh air and distributes it to people throughout the building.

The information presented here is designed to:

- Help facility managers understand the importance of continually monitoring a building's ventilation rate to ensure adequate IAQ is maintained as the number of people in each area of a building (or zone) changes throughout the day.

- Explain how much outside air (OSA) should be brought into a building.
- Describe symptoms of ventilation problems.
- Discuss the importance of assessing pressure differentials (inside to outside and zone to zone).
- Provide guidance for controlling indoor air pollutants.

See the companion factsheet, *"Measuring Carbon Dioxide Inside Buildings – Why is it Important?"** to learn how carbon dioxide (CO_2) levels in a building can be used to monitor IAQ and for guidance about obtaining accurate CO_2 measurements.

Bringing fresh air inside

Scientific studies clearly show that people who work in buildings where adequate fresh air is provided and properly delivered to the building occupants are more productive than those who work in buildings that are inadequately ventilated.

Good ventilation is essential for a comfortable, healthy and productive indoor environment, so a top priority for facility managers should be to understand and tune the building's heating, ventilation and air conditioning (HVAC) system so it meets the needs of the building occupants throughout the day.

The ventilation rate is the flow of outside air (OSA) into a building per unit of time.

** Available on the Washington State University Energy Program website: http://www.energy.wsu.edu/PublicFacilitiesSupport/ResourceConservation.aspx.*

Symptoms of ventilation problems

- Stuffy or stale conditions
- Noticeable odors from outdoors or other areas in the building
- Very low or high relative humidity, dampness or window condensation
- Pressure imbalances between the inside and outside, which can make it difficult to open or close doors
- Noise or drafts from air delivery vents
- Spillage or back-drafting of combustion equipment
- Dust and dirt accumulation
- Reports of comfort or health issues
- Unusually high utility costs

As workers and students come and go throughout the day, the air quality in the building changes. People continually generate CO_2, so CO_2 levels can build up throughout the day unless OSA is brought in through the HVAC system to dilute the CO_2. As the CO_2 builds up, so can other potentially serious indoor air pollutants.

Bringing in OSA that has been filtered and heated or cooled to the appropriate temperature is essential to control odors, reduce exposure to indoor air pollutants, and purge moisture and contaminants in a building.

How much OSA is too much?

It is important to bring only enough OSA into the building as needed to maintain healthy conditions. To accomplish this, the facility manager needs to monitor and control the building's ventilation rate.

If too much OSA is brought in, the HVAC system will have to work harder to heat or cool the OSA to the appropriate temperature, resulting in wasted energy and excessive utility payments.

If too little OSA is brought in, the CO_2 concentrations will rise throughout the day, as will concentrations of pollutants and odors. These impacts are exaggerated in buildings where the HVAC system re-circulates 70 to 80 percent of the indoor air.

If just enough OSA is brought in, the levels of CO_2, pollutants, odors and moisture will more likely be within appropriate guidelines and the HVAC system will not have to work harder than necessary to maintain a comfortable temperature.

However, ventilation is not a cure-all for IAQ issues. Strong pollutant sources in the building, including occupant-created pollutants and those emitted from carpets and other building furnishings, can overwhelm typical fresh air exchange rates, so a practical IAQ policy that works to limit pollutant sources should also be implemented.

Recommended ventilation rates

Building codes and guidance, such as American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE) Standard 62.1, define ventilation rates and dictate that adequate ventilation should be provided either naturally or mechanically. Ventilation recommendations are continually evolving; it is a good idea to check codes that apply to your building.

Ventilation rates can be determined and maintained through ***prescriptive*** or ***controlled methods***.

The **prescriptive ventilation method** requires specific volumes of OSA in cubic feet per minute of OSA per person (cfm/p) ***plus*** a prescribed volume of OSA per square foot of the space (cfm/sqft). These two values are combined to determine the total ventilation rate for the space at full occupancy.

The prescriptive method also requires up to 20 percent more OSA if the:

- Supply and return systems are both at ceiling level.
- HVAC system does not circulate the air down to the occupant level during heating mode, such as with a variable air volume or multi-zone system.

Prescriptive methods can be difficult to employ because they:

- Require direct measurements of the OSA flow rates per balancing standards, which can be difficult, time-consuming and subject to significant errors.
- Assume full occupancy all the time, which may result in overventilation. For this reason, the prescriptive method is likely not as energy efficient as the controlled method.

Relationship between measured CO_2 and ventilation rate per person

*The CO_2 values in this table are approximate.**

CO_2 (ppm)	Outside Air (ventilation rate)	
2,400	5 cfm/p	Unacceptable
1,400	10 cfm/p	Poor
1,000	15 cfm/p	Classrooms
800	20 cfm/p	Offices
600	25 cfm/p	
~ 380	< - - - - - - - >	Outdoors

The figures given assume:

- A constant number of occupants over an extended period,
- Occupants are sedentary adults,
- The ventilation rate is constant (although occupied spaces are rarely at full occupancy for more than a fraction of an hour), and
- The OSA CO_2 concentration is about 380 ppm.

** Check code requirements for your building; codes and guidance continually evolve.*

ASHRAE recommends that indoor CO_2 levels not exceed the outdoor concentration – which is about 380 ppm – by more than about 650 ppm.

Meeting and maintaining prescribed air exchange rates can be difficult without practical and effective OSA monitoring strategies.

The **controlled ventilation method** recommends using sensors to control the ventilation rate. The most common system of this type is Demand Controlled Ventilation (DCV).

DCV systems use CO_2 sensors to continually adjust the ventilation rate to meet the actual occupant loads and activity levels in the building. DCV systems are especially useful for spaces that experience variable occupancy rates, such as conference rooms, classrooms, auditoriums, dining rooms and open workspaces. As more people occupy a space, they exhale more CO_2. When the DCV system senses that CO_2 levels are rising, it increases the volume of OSA that is brought in through the HVAC system so the CO_2 level is controlled to a pre-set value.

According to the U.S. Department of Energy's Federal Energy Management Program, DCV systems have been demonstrated to save 5 to 27 percent of HVAC energy usage in a typical office environment *(see Resources #16 and 17)*. The cost to implement this feature is minimal and usually results in a very good payback. The return on investment for larger HVAC systems can be less than one year.

The greater the ventilation rate (volume of OSA per person – cfm/p), the more the CO_2 will be diluted. To maintain an optimal CO_2 level in classrooms and offices (approximately 1,035 ppm of CO_2), the ventilation system should be set to bring in OSA at a rate of 15 to 20 cfm/p.

Assessing pressure differentials

Proper air pressure analysis is also important for maintaining an energy efficient and adequately ventilated space.

Pressure differentials are created by the HVAC system and/or air leakage through the building envelope. When differential pressure in one part of a building is greater than in an adjacent area, air will flow toward the area with lower pressure. It follows that CO_2, pollutants and other components of indoor air will also migrate to areas with lower pressure.

Uncontrolled pressure differentials can also hinder the ability of the ventilation system to adequately distribute OSA to all zones in the building.

To determine if a space is over- or under-pressurized, differential readings should be taken in each zone in a building. Flow measurements and subsequent balancing are needed to meet the building's design flow rates and delivery of the appropriate volume of OSA.

Controlling indoor air pollutants

Inadequate ventilation permits potentially harmful air pollutants to build up in some areas of a building. As described in the companion factsheet, CO_2 is easy to measure and can be used as an indicator of ventilation adequacy.

Make sure air filters are not clogged so the ventilation system can work properly. Photo: Rich Prill

Many indoor air pollutants are generated by materials used in the building itself, such as carpets, furnishings, cleaning chemicals and stored materials; office equipment; and air entry from areas such as contaminated utility tunnels and connections to the soil.

To control indoor air contaminants:

- **Keep pollutants out of the building**
  - Choose furnishings and finish materials carefully and adopt "green cleaning" practices.
  - Make sure OSA intakes are located away from vehicle exhausts, building exhausts, cooling towers, plumbing vents and generators.
  - Install and correctly maintain the most efficient filters based on the air-handing system capacities.
  - Test ducts to determine if they are meeting design tightness criteria.
  - If necessary, seal ductwork to prevent cross-contamination. Leaky ductwork allows pollutants to move from zone to zone within a building and can carry moisture or pollutants (such as radon and methane) from groundwater or soil into a building.
- **Use exhaust fans to capture and remove pollutants** introduced by people, such as perfumes; from equipment, such as copiers and printers; and from localized sources in storage areas. Be sure to control pressures between zones to keep pollutants from migrating to areas of low pressure.
- **Use integrated pest management measures** to keep rodents, birds and insects out of the space without using chemicals.

Summary

Good ventilation is essential to maintain a comfortable, healthy and productive indoor environment. Facility managers need to understand their building's HVAC system and tune it to achieve the optimal mix of OSA. Ventilation settings should adapt to the building's occupant load to save energy while maintaining a comfortable working environment.

Resources

1. "ASHRAE Standard 62.2.2012: Ventilation for Acceptable Indoor Air Quality," American Society of Heating Refrigerating and Air Conditioning Engineers, Atlanta, GA.
2. "Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation," ASTM Standard D-6245 – 12, May 2012.
3. "Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution," ASTM Standard Guide E741-11.
4. *IAQ Diagnostics Reference Manual: Hands-On Assessment of Building Ventilation and Pollutant Transport*, University of Tulsa, College of Engineering and Applied Sciences, Department of Chemical Engineering.
5. Indoor Air Quality Scientific Findings Resource Bank, Lawrence Berkeley National Laboratory: http://energy.lbl.gov/ied/sfrb/.
6. *1994 Manual for Ventilation Assessment in Mechanically Ventilated Buildings*, National Institute for Standards and Technology, NISTR #5329-1994.
7. U.S. Department of Energy, Energy Efficiency and Renewable Energy: www.eere.energy.gov.
8. "Demand-Controlled Ventilation Using CO2 Sensors," U.S. Department of Energy, Federal Energy Management Program: http://www1.eere.energy.gov/femp/pdfs/fta_co2.pdf.
9. "Energy Efficiency," U.S. Small Business Administration: http://www.sba.gov/category/navigation-structure/starting-managing-business/managing-business/running-business/energy-efficiency .
10. *Guidelines for Design and Construction of Health Care Facilities,* Facility Guidelines Institute: http://www.fgiguidelines.org/.
11. ASHRAE Standard 62, Ventilation for Acceptable Indoor Air Quality: www.ashrae.org.
12. Building Energy Codes Resource Center, Commercial Ventilation Rate Procedure: http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter/article/1587.
13. Washington State University, Environmental Health and Safety – Ventilation: http://ehs.wsu.edu/labsafety/manual/s3cventilation.html .
14. Integrated Pest Management primer, Washington State University Extension: http://ipm.wsu.edu/. *(Check with your state for specific recommendations to manage pests.)*
15. Radon primer, Washington State Department of Health: http://www.doh.wa.gov/communityandEnvironment/Contaminants/Radon.aspx. *(Check with your state for specific recommendations to manage radon.)*
16. *Demand-Controlled Ventilation: A Design Guide,* Northwest Energy Efficiency Alliance: http://www.oregon.gov/ENERGY/CONS/BUS/DCV/docs/DCVGuide.pdf.
17. *Energy Savings and Economics of Advanced Control Strategies for Packaged Air-Conditioning Units with Gas Heat,* Pacific Northwest National Laboratory: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20955.pdf.

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WSUEEP13-004 • January 2013