Indoor Environmental Quality

Americans spend an average of 90% of their time indoors, where levels of pollutants may be two to five times–and occasionally more than 100 times–higher than outdoor levels, according to the U.S. Environmental Protection Agency. In its *1999 Air Quality Guidelines*, the World Health Organization states that most of a person's daily exposure to many air pollutants comes through inhalation of indoor air. Many of these pollutants can cause health reactions in the estimated 17 million Americans who suffer from asthma and 40 million who have allergies, thus contributing to millions of days absent from school and work. The Asthma and Allergy Foundation estimates that asthma cost the U.S. economy $10.7 billion in 1994 alone.

Research over the past decade has increased our understanding of the indoor environment, revealing both problems and potential solutions. Major health disasters such as outbreaks of Legionnaires' disease and sick building syndrome have heightened the awareness of indoor air quality for building owners and occupants. An increasing number of legal cases emphasize the need for optimal indoor environmental quality (IEQ) strategies. Such strategies reduce potential liability for design team members (including building owners), increase the resale value of the building, and increase productivity of building occupants. In fact, case studies suggest that IEQ improvements can increase worker productivity by as much as 16%, resulting in rapid payback for IEQ capital investments (source: *Greening the Building and the Bottom Line*, Rocky Mountain Institute, 1994).

IEQ strategies include issues related to indoor air quality (IAQ) such as increased ratios of filtered outside air, ventilation effectiveness, moisture management, and control of contaminants. Prevention of air quality problems is generally much less expensive than cleaning up after these problems occur. For example, it is inexpensive and sensible to sequence construction activities so that materials are kept dry and those that absorb contaminants are installed after other materials have had the opportunity to off-gas contaminants. Specifying materials that release fewer and less harmful contaminants is even better. Another strategy is to protect air handling systems during construction and perform a building flush-out prior to occupancy. To provide optimal air quality for building occupants over the lifetime of the building, automatic sensors and controls can be integrated with the HVAC system to adjust temperature, humidity, and the percentage of outside air introduced to occupied spaces. Sensors can alert building maintenance staff to potential IAQ problems such as carbon dioxide (CO_2) build-up in occupied space.

Other IEQ issues to consider include daylighting and lighting quality, thermal comfort, acoustics, occupant control of building systems, and access to views. All of these issues have the potential to enhance the indoor environment and optimize interior spaces for building occupants.

Overview of LEED™ Prerequisites and Credits

EQ Prerequisite 1
Minimum IAQ Performance

EQ Prerequisite 2
Environmental Tobacco Smoke (ETS) Control

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 3
Construction IAQ Management Plan

EQ Credit 4
Low-Emitting Materials

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 6
Controllability of Systems

EQ Credit 7
Thermal Comfort

EQ Credit 8
Daylight & Views

There are 15 points available in the Indoor Environmental Quality category.

Minimum IAQ Performance

SS	WE	EA	MR	EQ	ID

Prerequisite 1

Required

Intent

Establish minimum indoor air quality (IAQ) performance to prevent the development of indoor air quality problems in buildings, thus contributing to the comfort and well-being of the occupants.

Requirements

Meet the minimum requirements of voluntary consensus standard ASHRAE 62-1999, Ventilation for Acceptable Indoor Air Quality, and approved Addenda (see ASHRAE 62-2001, Appendix H, for a complete compilation of Addenda) using the Ventilation Rate Procedure.

Submittals

- ❑ Provide the LEED Letter Template, signed by the mechanical engineer or responsible party, declaring that the project is fully compliant with ASHRAE 62-1999 and all published Addenda and describing the procedure employed in the IAQ analysis (Ventilation Rate Procedure).

Summary of Referenced Standard

ASHRAE Standard 62-1999: Ventilation For Acceptable Indoor Air Quality

ASHRAE, www.ashrae.org, (800) 527-4723

This standard specifies minimum ventilation rates and indoor air quality (IAQ) levels to reduce the potential for adverse health effects. The standard specifies that mechanical or natural ventilation systems be designed to prevent uptake of contaminants, minimize the opportunity for growth and dissemination of microorganisms, and filter particulates, if necessary. Makeup air inlets should be located away from contaminant sources such as cooling towers; sanitary vents; and vehicular exhaust from parking garages, loading docks, and street traffic.

A Ventilation Rate Procedure and an Indoor Air Quality Procedure are outlined to achieve compliance with the standard. The Ventilation Rate Procedure prescribes outdoor air quality acceptable for ventilation; outdoor air treatment measures; and ventilation rates for residential, commercial, institutional, vehicular, and industrial spaces. The procedure also includes criteria for the reduction of outdoor air quantities when recirculated air is treated by contaminant-removal equipment and criteria for variable ventilation when the air volume in the space is used as a reservoir to dilute contaminants. The Indoor Air Quality Procedure incorporates both quantitative and subjective evaluation and restricts contaminant concentrations to acceptable levels.

SS WE EA MR EQ ID

Prerequisite 1

Credit Synergies

SS Credit 1
Site Selection

SS Credit 2
Urban Redevelopment

SS Credit 3
Brownfield Redevelopment

SS Credit 4
Alternative Transportation

WE Credit 1
Water Efficient Landscaping

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Prerequisite 1
Storage & Collection of Recyclables

MR Credit 1
Building Reuse

(continued)

Green Building Concerns

Optimal IAQ performance in buildings results in improved occupant comfort, well-being, and productivity. Key components for maintaining superior indoor air quality include using high-quality outdoor air and providing adequate ventilation rates. The referenced standard describes procedures for avoiding the introduction of contaminants such as location of air intakes relative to potential sources of contamination. The referenced standard also outlines general ventilation rates for a variety of building types.

Environmental Issues

Higher ventilation rates are sometimes necessary to optimize IAQ, and this can result in higher energy use to operate the building HVAC system. However, the additional energy cost can be offset by improved occupant productivity and lower absentee rates.

Economic Issues

Increased ventilation rates may result in greater annual energy costs. However, poor indoor air quality can cause occupant illnesses, resulting in increased expenses and liability costs for building owners, operators, and insurance companies. Personnel costs are a significant percentage of operating costs, much greater than energy or maintenance costs, and, thus, actions that affect employee attendance and productivity are significant. A 1991 statistical abstract by the Building Owners and Managers Association estimated employee salaries at $130 per square foot while energy costs were less than $2 per square foot.

ASHRAE Standard 62-1999 has become standard ventilation design practice and may not require additional design effort or cost. Good IAQ reduces potential liability for architects, builders, owners, building operators, and occupants, as well as increases the value and marketability of a building. Additional effort may be required to optimize the integration of the HVAC system with the layout of the structure and surrounding area.

Community Issues

IAQ optimization strategies can lead to a healthier environment for occupants, which typically results in fewer complaints, lower absenteeism and illness, and higher productivity. Improved occupant health results in decreased health care and insurance costs.

Design Approach

Strategies

Evaluate the project site prior to acquisition to avoid choosing a site with potential IAQ problems. These potential problems might include heavy traffic areas, nearby polluting industrial sites, or neighboring waste management sites. In addition, identify possible future uses of nearby sites that may impact outdoor air quality. Obtain ambient air quality data and local wind patterns from the U.S. EPA or local sources to identify sources of pollution most likely to affect the site.

After the building site has been chosen, identify site activities that may have a negative impact on air quality such as construction activities, materials installed in the building, and chemical handling activities during occupancy. Establish air quality standards early in the design process, and clearly state these design criteria in plans and specifications.

Specify, design, and install fresh air intakes away from possible sources of contamination (at least 25 feet is recommended and 40 feet is preferable). Possible sources of contamination include loading areas, building exhaust fans, cooling towers, street traffic, idling cars, standing water, parking garages, sanitary vents, dumpsters, and outside smoking areas.

Locating fresh air intakes appropriately requires coordination between HVAC designers and the project architect.

Ensure that the outside air capacity for the ventilation system can meet the requirements of the referenced standard in all modes of operation. Remember to consider the maximum potential occupancy load when calculating outside air needs in all spaces. Assess changes in occupant loads for renovation or retrofit projects and, where possible, plan for these future requirements. Avoid over-design and under-design of the ventilation system and anticipate future retrofits.

Upon project completion, include operational testing in the building commissioning report. Implement an operations and maintenance plan to maintain an uncontaminated HVAC system.

Synergies and Trade-Offs

Site location and landscape design affect the outdoor air volumes that can be circulated through the building. Dense neighborhoods, adjacent transportation facilities, and existing site contamination can adversely affect the quality of outside air available for ventilation purposes. Increased ventilation rates can solve some indoor air quality problems by diluting contaminant levels, but this strategy may affect indoor thermal comfort and may increase energy use. Building commissioning and measurement & verification processes are tools that can be used to optimize indoor air quality levels while minimizing energy efficiency losses.

During construction and building fit-out, protect building materials from moisture and specify materials and furnishings that do not release harmful or irritating chemicals, such as volatile organic compounds (VOCs) from paints and solvents, to reduce the detrimental effects these substances have on IAQ. Occupant activities such as chemical handling and smoking can reduce the amount of clean air in a space. More often, it is beneficial to reduce IAQ problems at the source, such as specifying low-VOC materials, than to use energy to ventilate the building and to condition a greater volume of air.

Resources

Web Sites

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

www.ashrae.org, (404) 636-8400

Advances the science of heating, ventilation, air conditioning, and refrigeration for the public's benefit through research, standards writing, continuing education, and publications.

Indoor Air Quality Links

outreach.missouri.edu/edninfo/airquality.htm

Web links that address health and building systems issues.

U.S. Environmental Protection Agency's Indoor Air Quality Web Site

www.epa.gov/iaq, (800) 438-4318

Includes a wide variety of tools, publications, and links to address IAQ concerns in schools and large buildings. The downloadable *IAQ Building Education and Assessment Model (I-BEAM)* software program provides comprehensive IAQ management guidance and calculates the cost, revenue, and productivity impacts of planned IAQ activities. Publications include the *Energy Cost and IAQ Performance of Ventilation Systems and Controls Modeling Study*; the *Building Assessment, Survey and Evaluation Study*; and the *Building Air Quality Action Plan*.

Credit Synergies

(continued)

EQ Prerequisite 2
Environmental Tobacco Smoke (ETS) Control

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 3
Construction IAQ Management Plan

EQ Credit 4
Low-Emitting Materials

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 7
Thermal Comfort

Print Media

Air Contaminants and Industrial Hygiene Ventilation: A Handbook of Practical Calculations, Problems, and Solutions by Roger Wabeke, CRC Press & Lewis Publishers, 1998.

Handbook of Indoor Air Quality Management by Donald Moffatt, Prentice Hall, 1997.

Improving Indoor Air Quality Through Design, Operation and Maintenance by Marvin Meckler, Prentice Hall, 1996.

Indoor Air Quality, Construction Technology Centre Atlantic. Written as a comprehensive review of indoor air quality issues and solutions, the report is available for purchase from http://ctca.unb.ca/IAQ/index.htm or (506) 453-5000.

Indoor Pollution: A Reference Handbook (Contemporary World Issues) by E. Willard Miller, et al., ABC-CLIO, 1998.

Definitions

Indoor Air Quality is the nature of air that affects the health and well-being of building occupants.

Sick Building Syndrome is a situation in which a substantial proportion of building occupants experience acute discomfort and negative health effects as a result of exposure to contaminated air in the building.

Ventilation is the process of supplying and removing air to and from interior spaces by natural or mechanical means.

Environmental Tobacco Smoke (ETS) Control

SS | WE | EA | MR | EQ | ID

Prerequisite 2

Required

Intent

Prevent exposure of building occupants and systems to Environmental Tobacco Smoke (ETS).

Requirements

Zero exposure of non-smokers to ETS by EITHER:

- prohibiting smoking in the building and locating any exterior designated smoking areas away from entries and operable windows;

OR

- providing a designated smoking room designed to effectively contain, capture and remove ETS from the building. At a minimum, the smoking room must be directly exhausted to the outdoors with no recirculation of ETS-containing air to the non-smoking area of the building, enclosed with impermeable deck-to-deck partitions and operated at a negative pressure compared with the surrounding spaces of at least 7 PA (0.03 inches of water gauge).
- Performance of the smoking rooms shall be verified by using tracer gas testing methods as described in the ASHRAE Standard 129-1997. Acceptable exposure in non-smoking areas is defined as less than 1% of the tracer gas concentration in the smoking room detectable in the adjoining non-smoking areas. Smoking room testing as described in ASHRAE Standard 129-1997 is required in the contract documents and critical smoking facility systems testing results must be included in the building commissioning plan and report or as a separate document.

Submittals

❑ Provide the LEED Letter Template, signed by the building owner or responsible party, declaring that the building will be operated under a policy prohibiting smoking.

OR

❑ Provide the LEED Letter Template, signed by the mechanical engineer or responsible party, declaring and demonstrating that designated smoking rooms are exhausted to the outdoors with no recirculation of ETS-containing air to the non-smoking area of the building, enclosed with impermeable deck-to-deck partitions, operated at a negative pressure compared with the surrounding spaces of at least 7 PA (0.03 inches of water gauge), and performance has been verified using the method described in the credit requirements.

Summary of Referenced Standard

ASHRAE 129-1997: Measuring Air-Change Effectiveness

ASHRAE,www.ashrae.org, (800) 527-4723

This standard provides a method for measuring air-change effectiveness in mechanically ventilated buildings and spaces. Air-change effectiveness (E) is determined by the pattern of natural airflow within the building's ventilated air spaces along with the effect of mechanical recirculation by ventilation systems. The measurement of air-change effectiveness involves a tracer gas procedure that determines the age of air in building spaces.

SS	WE	EA	MR	EQ	ID

Prerequisite 2

Green Building Concerns

The relationship between smoking and various health risks, including lung disease, cancer, and heart disease, has been well documented. A strong link between Environmental Tobacco Smoke (ETS) or "secondhand smoke" and health risks has also been demonstrated. The most effective way to avoid health problems associated with tobacco smoke is to prohibit smoking in indoor areas. If this is not possible or desirable, indoor smoking areas should be isolated from nonsmoking areas and have separate ventilation systems to avoid the introduction of tobacco smoke contaminants to nonsmoking areas.

Environmental Issues

Separate smoking areas occupy space in the building and may result in a larger building, additional material use, and increased energy for ventilation. However, these environmental impacts can be offset by building occupants who are more comfortable, have higher productivity rates, and have lower absenteeism and illnesses.

Economics Issues

Separate smoking areas may result in first costs for increased building space and more extensive mechanical ventilation systems. Smoking within a building contaminates indoor air and can instigate occupant reactions ranging from irritation and illness to decreased productivity. These problems increase expenses and liability for building owners, operators, and insurance companies. A nonsmoking policy avoids these problems and eliminates the need for a separate ventilation system for isolated smoking areas. Prohibition of indoor smoking can also increase the useful life of interior fixtures and furnishings.

Community Issues

Air is a community natural resource, and promoting clean air benefits everyone. Strict no- smoking policies improve the health of the community as a whole, resulting in lower health care and insurance costs.

Design Approach

Strategies

Prohibit smoking in the building. Provide designated smoking areas outside the building in locations where ETS will not enter the building or ventilation system and away from concentrations of building occupants or pedestrian traffic. Post information on the nonsmoking policy for occupants to read.

If interior smoking areas are designed for the building, a separate ventilation system must be installed, and these areas must be tested to ensure that they are isolated from nonsmoking portions of the building. ASHRAE Standard 62-1999 designates outdoor air requirements for smoking rooms. Smoking areas are typically operated at higher ventilation rates than nonsmoking rates to remove contaminants from the conditioned space. In general, buildings that allow smoking require twice the ventilation volumes of nonsmoking buildings. See the standard for more information on designing ventilation for smoking areas.

Synergies and Trade-Offs

The use of separate ventilation systems to physically separate smoking areas from the rest of the building requires additional energy and requires commissioning and measurement & verification attention. Smoking activities, both indoor and outdoor, affect IAQ performance of the building. Smoke can enter the building areas through operable windows and intake vents or through the ventilation system for indoor smokers. It may be advantageous to address smoking loads in the building in conjunction with chemical and pollutant sources in the building.

Credit Synergies

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 6
Controllability of Systems

Resources

Web Sites

Secondhand Smoke: What You Can Do About Secondhand Smoke as Parents, Decision Makers, and Building Occupants

www.epa.gov/iaq/pubs/etsbro.html, (800) 438-4318

An EPA document on the effects of ETS and measures to reduce human exposure to it.

Setting the Record Straight: Secondhand Smoke Is a Preventable Health Risk

www.epa.gov/iaq/pubs/strsfs.html

An EPA document with a discussion of laboratory research on ETS and federal legislation aimed at curbing ETS problems.

Print Media

The Chemistry of Environmental Tobacco Smoke: Composition and Measurement, Second Edition by R.A. Jenkins, B.A. Tomkins, et al., CRC Press & Lewis Publishers, 2000.

The Smoke-Free Guide: How to Eliminate Tobacco Smoke from Your Environment by Arlene Galloway, Gordon Soules Book Publishers, 1988.

Definitions

The **Age of Air** is the average amount of time that has elapsed since a sample of air molecules at a specific location has entered the building.

Air-Change Effectiveness is a measurement based on a comparison of the age of air in the occupied portions of the building to the age of air that would exist under conditions of perfect mixing of the ventilation air.

Environmental Tobacco Smoke (ETS), or secondhand smoke, consists of airborne particles emitted from the burning end of cigarettes, pipes, and cigars, and exhaled by smokers. These particles contain about 4,000 different compounds, up to 40 of which are known to cause cancer.

Carbon Dioxide (CO_2) Monitoring

1 point

Intent

Provide capacity for indoor air quality (IAQ) monitoring to help sustain long-term occupant comfort and well-being.

Requirements

Install a permanent carbon dioxide (CO_2) monitoring system that provides feedback on space ventilation performance in a form that affords operational adjustments. Refer to the CO_2 differential for all types of occupancy in accordance with ASHRAE 62-2001, Appendix C.

Submittals

- ❑ Provide the LEED Letter Template, signed by the mechanical engineer or responsible party, declaring and summarizing the installation, operational design and controls/zones for the carbon dioxide monitoring system. For mixed-use buildings, calculate CO_2 levels for each separate activity level and use.

Summary of Referenced Standard

There is no standard referenced for this credit.

Credit Synergies

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Credit 1
Building Reuse

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 6
Controllability of Systems

EQ Credit 7
Thermal Comfort

Green Building Concerns

Buildings are supplied with outdoor air to flush airborne contaminants and to replenish fresh air on a regular basis. Ventilation rates are conventionally determined using ventilation standards for a particular building design. A better method for determining and maintaining adequate outdoor air ventilation rates in buildings is to measure carbon dioxide (CO_2) concentrations. High CO_2 levels are generally an indication of poor indoor air quality (IAQ). Maintaining low CO_2 concentrations similar to those found outdoors is one strategy by which indoor air quality can be optimized.

Environmental Issues

Optimal IAQ may require higher ventilation rates, increasing energy use in the building. However, these environmental impacts can be offset by a more productive work space that reduces absenteeism and illness for building occupants.

Economic Issues

A permanent air monitoring system enables building owners, maintenance personnel, and occupants to detect air quality problems quickly so that corrective actions can be applied. Potential impacts of air quality problems range from reduced work productivity to temporary or permanent health issues for building occupants. CO_2 monitoring systems increase initial construction costs due to equipment and installation costs. Initial costs typically range from $1,000 to $1,500 per sampling point (depending on the quality of the equipment and number of sampling points), while annual costs for equipment maintenance and calibration procedures are usually less than $2,000 overall. The initial monitoring system cost is offset by reduced absenteeism and increased occupant productivity. Often, the lifetime of the HVAC system is extended and more efficient HVAC operation is achieved as a result of effective air quality monitoring.

Community Issues

A permanent air monitoring system ensures that the means to maintain high-quality indoor air is provided, with the potential to protect the well-being of the building occupants and enhance productivity. Increased occupant health results in decreased health insurance costs and health care costs.

Design Approach

Strategies

Development of an appropriate and effective carbon dioxide sampling methodology is largely dependant upon the type of ventilation system being used. This section seeks to provide guidance on development of an effective sampling methodology.

Carbon dioxide sampling locations must be selected so that they provide representative readings of the CO_2 concentrations in the occupied spaces served by each HVAC system used in a building. Carbon dioxide monitoring locations should be selected such that they are positioned in locations that present the greatest challenges for the HVAC system to adequately ventilate. These spaces include those with variable occupant densities (e.g., conference rooms, auditoriums, training rooms, etc.) and those locations within the space served by the longest lengths of ductwork.

Automatic ventilation control should be provided for all HVAC systems serving a large number of spaces or spaces with variable occupant densities. Manual ventilation control may be used for spaces with static occupant densities, but the most responsive comfort control is provided by an automated system. Spaces with static occupant densities must each be controlled or they can be combined into small groups if the combined floor area of the group is reasonably small. The optimum location for sampling in a room is six to ten feet from the nearest person. Sampling locations should be positioned to avoid low CO_2 concentration air entering the space through open windows and supply air vents.

For HVAC systems that serve multiple spaces with a small combined floor area, the indoor CO_2 sampling point may be located in the return air duct at the junction point where the return air is combined from all of the multiple spaces served, provided this point is far enough away from the location where return air is exhausted or outside air is introduced into the HVAC system. Siting the sampling point in this location will mitigate the risk of diluting the return air. The duct joints should be effectively sealed. Occupant use and schedule changes should be considered when establishing and reassessing ventilation setpoints.

Indoor CO_2 concentrations must be compared to outdoor CO_2 concentrations to determine the differential point at which ventilation rates should be adjusted. The differential CO_2 level that activates ventilation within each space must be based on occupant activity level and the corresponding metabolic rate (MET) defined in ASHRAE Standard 55-1992, Table 4. MET is the rate of energy production of an individual, which varies depending on activity level. For offices where occupants are sedentary, the CO_2 differential level is approximately 530 parts per million (ppm). The maximum CO_2 differential in ppm is equal to: (8,600 cfm of CO_2 per MET) x (MET level)/cfm of outside air per occupant, as adapted from ASHRAE 62-2001 Appendix C.

CO_2 ventilation control systems must be calibrated and tested by the contractor and proper operation must be verified as part of the building commissioning process.

Technologies

Current systems include shared-sensor vacuum-draw systems and distributed sensors. Distributed sensors are either hard-wired or plugged into power circuitry and use carrier wave communication. Once the system is properly calibrated, it is used to assess the adequacy of airflows throughout the building interior. Specify annual calibration activities for sensors per manufacturer instructions in the HVAC system operation manual. Include sensor and system operational testing and initial set point adjustment in the commissioning plan and report.

Synergies and Trade-Offs

CO_2 monitoring requires additional equipment to be installed and requires additional commissioning and measurement & verification (M&V) attention. Building reuse may prohibit optimization of ventilation rates due to inflexible HVAC equipment or inadequate outside air intakes.

Monitoring CO_2 levels has significant impacts on all indoor environmental quality issues, including overall IAQ performance, ventilation rates, chemical and pollutant control, and thermal comfort. Proper ventilation rates are integral to successful energy efficiency and air quality programs. CO_2 monitoring can be used either actively or passively to alter ventilation rates as appropriate.

Resources

Web Sites

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

www.ashrae.org, (404) 636-8400

Advances the science of heating, ventilation, air conditioning, and refrigeration for the public's benefit through research, standards writing, continuing education, and publications.

Building Air Quality: A Guide for Building Owners and Facility Managers

www.epa.gov/iaq/largebldgs, (800) 438-4318

An EPA publication on IAQ sources in buildings and methods to prevent and resolve IAQ problems.

Print Media

Air Handling Systems Design by Tseng-Yao Sun, McGraw Hill, 1992.

ASHRAE Standard 55-1992 (and Approved Addenda of 1995): Thermal Environmental Conditions for Human Occupancy, ASHRAE, 1992.

ASHRAE Standard 62-1999: Ventilation for Acceptable Indoor Air Quality, ASHRAE, 1999.

ASTM D 6245-1998: Standard Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation, ASTM, 1998.

Efficient Building Design Series, Volume 2: Heating, Ventilating, and Air Conditioning by J. Trost and Frederick Trost, Prentice Hall, 1998.

Definitions

Carbon Dioxide (CO_2) is an indicator of ventilation effectiveness inside buildings. CO_2 concentrations greater than 540 ppm above outdoor CO_2 conditions are generally considered to be an indicator of inadequate ventilation. Absolute concentrations of CO_2 greater than 800-1,000 ppm are generally considered to be an indicator of poor breathing air quality.

Return Air is air removed from conditioned spaces that is either recirculated in the building or exhausted to the outside.

Supply Air is air delivered to conditioned spaces for use in ventilating, heating, cooling, humidifying, and dehumidifying those spaces.

Case Study

Brengel Technology Center
Milwaukee, Wisconsin

The Brengel Technology Center is a LEED™ Certified Pilot Project that showcases advanced building controls technologies to maximize energy efficiency and indoor environmental quality. To improve occupant comfort and productivity, the HVAC system in the building includes an integrated comfort component to measure carbon dioxide (CO_2) concentrations in occupied spaces in parts per million (ppm). The monitoring system also measures temperature, humidity, outdoor airflow, carbon monoxide (CO), and total volatile organic compounds (TVOCs). The HVAC system automatically adjusts ventilation rates based on the measured parameters to maintain optimal indoor air quality.

Courtesy of Zimmerman Design Group

Owner
Johnson Controls, Inc.

Ventilation Effectiveness

1 point

Intent

Provide for the effective delivery and mixing of fresh air to support the safety, comfort and well-being of building occupants.

Requirements

For mechanically ventilated buildings, design ventilation systems that result in an air change effectiveness (E_{ac}) greater than or equal to 0.9 as determined by ASHRAE 129-1997. For naturally ventilated spaces demonstrate a distribution and laminar flow pattern that involves not less than 90% of the room or zone area in the direction of air flow for at least 95% of hours of occupancy.

Submittals

❑ For mechanically ventilated spaces: provide the LEED Letter Template, signed by the mechanical engineer or responsible party, declaring that the design achieves an air change effectiveness (E_{ac}) of 0.9 or greater in each ventilated zone. Complete the table summarizing the air change effectiveness achieved for each zone.

OR

❑ For mechanically ventilated spaces: provide the LEED Letter Template, signed by the mechanical engineer or responsible party, declaring that the design complies with the recommended design approaches in ASHRAE 2001 Fundamentals Handbook Chapter 32, Space Air Diffusion. Complete the table summarizing the air change effectiveness achieved for each zone (must be 0.9 or greater).

OR

❑ For naturally ventilated spaces: provide the LEED Letter Template, signed by the mechanical engineer or responsible party, declaring that the design provides effective ventilation in at least 90% of each room or zone area in the direction of airflow for at least 95% of hours of occupancy. Include a table summarizing the airflow simulation results for each zone. Include sketches indicating the airflow pattern for each zone.

Summary of Referenced Standard

ASHRAE 129-1997: Measuring Air-Change Effectiveness

ASHRAE, www.ashrae.org, (800) 527-4723

This standard provides a method for measuring air-change effectiveness in mechanically ventilated buildings and spaces. Air-change effectiveness (E) is influenced by the pattern of natural airflow within the building's ventilated spaces in addition to the effect of mechanical recirculation by ventilation systems. Measurement of air-change effectiveness involves a tracer gas procedure to determine the age of air in ventilated spaces.

Air-change effectiveness is based on a comparison of the age of air in the occupied portions of the building to the age of air that would exist under conditions of perfect mixing of the ventilation air. If the ventilation air within a space is perfectly mixed (E=1), the outdoor airflow rate to the ventilated space should be identical to the required rate of outdoor airflow. The credit requirement specifies a minimum E value of 0.9.

ASHRAE Fundamentals Handbook 2001, Chapter 32: Space Air Diffusion

ASHRAE, www.ashrae.org, (800) 527-4723

This guideline provides descriptions of air diffusion strategies and technologies, methods of evaluation, and system design considerations.

Green Building Concerns

Inadequate ventilation in buildings has a negative effect on occupant comfort and well-being, while overventilation consumes significant amounts of energy without benefiting building occupants. Designing the ventilation system to take maximum advantage of regional climate characteristics can help cut down on energy costs and increase ventilation options. Through proper system design, ventilation rates and energy efficiency can be optimized.

Environmental Issues

Increased ventilation in buildings typically requires additional energy use, which in turn causes additional air and water pollution. However, optimal indoor air quality (IAQ) is beneficial to building occupants, resulting in greater comfort, lower absenteeism, and greater productivity.

Economic Issues

Adequate ventilation in buildings may result in higher worker productivity, which in turn can translate into increased profitability for a company. However, increased ventilation requires more operation energy inputs for increased HVAC operation. Therefore, these operations should be balanced to provide maximum ventilation effectiveness while avoiding overventilation.

Natural ventilation strategies are typically much less expensive to construct and operate than mechanical ventilation strategies, but require an appropriate climate and more comprehensive design analysis.

Community Issues

Optimal ventilation rates improve IAQ, thus protecting the well-being of the building occupants. Increased occupant health may result in decreased health care and insurance costs.

Design Approach

Strategies

The minimum values for ventilation air rates in a space are determined by ASHRAE 62-1999 as part of IEQ Prerequisite 1. IEQ Credit 2 enhances the minimum indoor air quality requirements by ensuring that superior ventilation is delivered to the building occupants. In general, this credit rewards the employment of architectural and mechanical system design strategies that increase ventilation effectiveness and prevent short-circuiting of airflow delivery. Ventilation effectiveness refers to the movement of the supply air (that contains fresh outdoor air) through the occupied space.

There are two approaches to ventilating buildings: mechanical ventilation and natural ventilation. Mechanical ventilation strategies use fan energy to ventilate occupied spaces. Mechanical systems provide the most reliability and control. Natural ventilation strategies take advantage of physical properties of the building design and site such as stack effects, operable windows, and site wind patterns to ventilate occupied spaces. Natural ventilation strategies provide a connection to the outdoors and have low operation and maintenance costs. Project teams should evaluate the strengths and weaknesses of the two approaches, including building location, regional climate patterns, and enthalpic conditions, as well as client preferences in the final decision for ventilation systems.

ASHRAE 129-1997 describes a test method for quantifying the air-change effectiveness (E) for a given room design. The measured value is influenced by the shape of room, the extent of mechanical recirculation, the location of heat-generating objects, and air motion. Because these variables are highly specific to each design, a full-scale mock-up is the most effective way to verify E with a high level

Credit Synergies

SS Credit 1
Site Selection

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Credit 1
Building Reuse

EQ Prerequisite 1
Minimum IAQ Performance

EQ Prerequisite 2
Environmental Tobacco Smoke (ETS) Control

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 6
Controllability of Systems

EQ Credit 7
Thermal Comfort

of confidence. See the referenced standard for more information on the prescribed testing procedure.

It is important to note that testing under ASHRAE 129-1997 is suitable mainly for laboratory-based conditions and is not appropriate in most field applications. ASHRAE states "the test method has been used successfully in laboratory test rooms to study the performance of different ventilation systems, but there is considerably less experience in the field where many factors can complicate the measurement process and increase measurement uncertainties. Therefore, the standard places strict limitations on the characteristics of the spaces that can be tested with the method. While the test method will not be usable in all field situations, it is generally applicable in laboratory test rooms."

ASHRAE also states that the data set of current test results is very small, and the test requires very close attention to the protocol described in the standard, in addition to factors that contribute to some uncertainty when evaluating test results. Therefore, the standard is generally used as a design guide for ventilation effectiveness.

Credit compliance may also be achieved by following the recommended design approaches in the ASHRAE Fundamentals Handbook 2001, Chapter 32: Space Air Diffusion.

Technologies

Conventional ventilation design (that locates supply and return air vents in the ceiling) is not preferred. Instead, consider displacement ventilation (that locates air supply vents at the bottom of the occupied space and return vents at the top of the space) and natural ventilation.

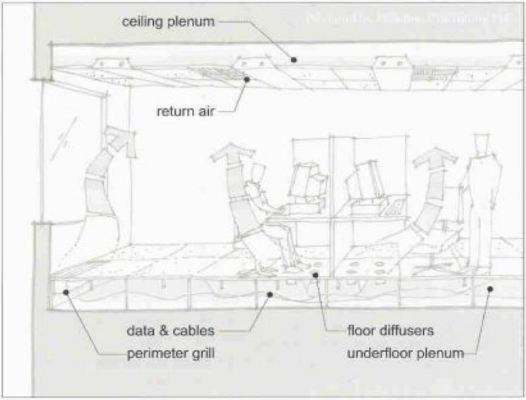
For mechanical HVAC systems, the ASHRAE Fundamentals Handbook 2001, Chapter 32, Space Air Diffusion lists the five major types of outlet types: **Group A**, mounted near the ceiling discharging horizontally; **Group B**, mounted in or near the floor discharging a vertical non-spreading jet; **Group C**, mounted in or near the floor discharging a vertical spreading jet; **Group D**, mounted in or near the floor that discharge horizontally; and **Group E**, mounted in or near the ceiling projecting vertically. Each of these types has strengths and weaknesses depending on the load conditions. See the ASHRAE handbook for details.

There are several new applications for mechanical ventilation systems in the market today that are very effective at preventing short-circuiting of airflow delivery. These applications include the use of displacement ventilation, low velocity ventilation, and plug flow ventilation such as underfloor or near-floor delivery.

Figure 1 illustrates an underfloor ventilation system. Supply air is introduced through diffusers and grills in the floor. The air travels upward through the occupied space and is exhausted in return grills in the ceiling. The underfloor plenum can also be used as a cabling conduit.

Natural ventilation strategies rely on openings in the building envelope to develop airflows. Operable windows are the most common architectural strategy employed to create natural ventilation, cross ventilation, and stack effects. Application of operable windows and other openings as elements of the ventilation system requires analysis of inlet and outlet location, size, and regional climate patterns. Operable windows combined with fan-powered mixing boxes **do not** qualify under this credit without a demonstrable architectural strategy for natural ventilation. Other factors to consider in the building ventilation design scheme include windows, doors, non-powered ventilators, and building infiltration. Computer models are helpful to predict ventilation processes and determine the best location for ventilation elements. Computational Fluid Dynamics (CFD) modeling tools

Figure 1: Example of Underfloor Ventilation System



are becoming available to designers and show great promise.

Synergies and Trade-Offs

Regional climate characteristics of the selected project site may dictate whether mechanical or natural ventilation strategies can be used. Ventilation strategies influence the overall energy performance of the building and require commissioning as well as measurement & verification (M&V). Reuse of existing buildings may preclude the use of natural ventilation strategies because the overall airflow is already determined. In some locations it may not be possible to employ natural ventilation schemes due to poor outdoor air quality, prevailing airflows, undesirable outdoor temperatures, or security concerns.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. There are two compliance paths for mechanically ventilated buildings.

The first compliance path is to field-test the completed HVAC system. Testing must be performed as described in ASHRAE 129-1997 after the building is constructed to demonstrate that air-change effectiveness of 0.9 or greater is achieved in all regularly occupied areas.

The second compliance path is through design verification. The designer must prepare a detailed narrative illustrating the design approaches that were used per the ASHRAE Fundamentals Handbook 2001, Chapter 32: Space Air Diffusion. To demonstrate the ventilation design, the mechanical engineer must describe the essential elements of the ventilation system in a narrative. If this credit is audited during the LEED certification review, provide a section and plan drawings of each major room type, showing inlets, outlets, furniture, and occupants specific to the following system types:

- Mixing Systems: the outlet types, the characteristic room lengths, the return/exhaust openings, all air velocities, and the predicted Air Diffusion Performance Index (ADPI).
- Displacement/Unidirectional Systems: the outlet types, the return and exhaust openings, all air velocities, and the predicted distribution of the upper and lower stratification zones.

Airflow patterns must be graphically illustrated to scale. Cut sheets and specification tables for all terminal vents, grills, and registers must be provided and cross-referenced to the drawings.

For naturally ventilated spaces, conduct airflow simulations for each zone and summarize the results. Provide a narrative describing system operation and sketches or graphics that indicate air flow patterns.

Resources

Web Sites

Air Change Effectiveness Measurements in Two Modern Office Buildings

www.fire.nist.gov/bfrlpubs/build94/PDF/b94024.pdf

A case study on ventilation effectiveness.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

www.ashrae.org, (404) 636-8400

Advances the science of heating, ventilation, air conditioning, and refrigeration for the public's benefit through research, standards writing, continuing education, and publications.

Mixed Mode Ventilation: HVAC Meets Mother Nature

www.esmagazine.com (see May 2000 archive)

A May 2000 article in *Engineered Systems* about various options for building ventilation.

Print Media

ASHRAE Handbook: Fundamentals, ASHRAE, 1997.

ASHRAE Handbook: HVAC Systems and Equipment, ASHRAE, 2000.

Heating, Ventilating, and Air Conditioning: Analysis and Design, 4th Edition, by Faye McQuiston and Jerald Parker, John Wiley & Sons, 1993.

Definitions

The **Age of Air** is the average amount of time that has elapsed since a sample of air molecules at a specific location has entered the building.

Air-Change Effectiveness is a measurement based on a comparison of the age of air in the occupied portions of the building to the age of air that would exist under conditions of perfect mixing of the ventilation air.

Conditioned Space is the portion of the building that is heated or cooled, or both, for the comfort of building occupants.

Natural Ventilation is the process of supplying and removing air without mechanical ductwork in building spaces by using openings such as windows and doors, non-powered ventilators, and infiltration processes.

A **Tracer Gas** is a gas that can be mixed with building air in small amounts to study airflow patterns and measure the age of air and air-change rates.

Ventilation is the process of supplying and removing air by natural or mechanical means in building spaces.

Ventilation Effectiveness refers to the movement of the supply air (that contains fresh outdoor air) through the occupied space.

Case Study

PNC Firstside Center
Pittsburgh, Pennsylvania

The PNC Firstside Center is a LEED™ Silver Project that functions as a banking facility. The building incorporates a hybrid local ventilation system that combines underfloor air distribution with a conventional VAV system. Air is introduced through floor diffusers at each workstation to deliver fresh air directly to building occupants. Natural air convection is used to create upward air movement in conditioned spaces and air is exhausted through ceiling vents. This ventilation strategy creates temperature stratification about six feet from the floor. The zone below the stratification is cool and provides a comfortable working environment for building occupants. The zone above the stratification acts as a reservoir for warmer air. This ventilation pattern is effective at providing optimal conditioned temperatures to building occupants, resulting in increased productivity while decreasing HVAC operating costs.

Courtesy of Paladino Consulting LLC

Owner
PNC Bank

Construction IAQ Management Plan

SS	WE	EA	MR	EQ	ID
Credit 3.1					

During Construction

1 point

Intent

Prevent indoor air quality problems resulting from the construction/renovation process in order to help sustain the comfort and well-being of construction workers and building occupants.

Requirements

Develop and implement an Indoor Air Quality (IAQ) Management Plan for the construction and pre-occupancy phases of the building as follows:

- During construction meet or exceed the recommended Design Approaches of the Sheet Metal and Air Conditioning National Contractors Association (SMACNA) IAQ Guideline for Occupied Buildings under Construction, 1995, Chapter 3.
- Protect stored on-site or installed absorptive materials from moisture damage.
- If air handlers must be used during construction, filtration media with a Minimum Efficiency Reporting Value (MERV) of 8 must be used at each return air grill, as determined by ASHRAE 52.2-1999.
- Replace all filtration media immediately prior to occupancy. Filtration media shall have a Minimum Efficiency Reporting Value (MERV) of 13, as determined by ASHRAE 52.2-1999 for media installed at the end of construction.

Submittals

- ❑ Provide the LEED Letter Template, signed by the general contractor or responsible party, declaring that a Constuction IAQ Management Plan has been developed and implemented, and listing each air filter used during construction and at the end of construction. Include the MERV value, manufacturer name and model number.

AND EITHER

- ❑ Provide 18 photographs—six photographs taken on three different occasions during construction—along with identification of the SMACNA approach featured by each photograph, in order to show consistent adherence to the credit requirements

OR

- ❑ Declare the five Design Approaches of SMACNA IAQ Guideline for Occupied Buildings under Construction, 1995, Chapter 3, which were used during building construction. Include a brief description of some of the important design approaches employed.

SS | WE | EA | MR | EQ | ID

Credit 3.2

1 point

Construction IAQ Management Plan

After Construction/Before Occupancy

Intent

Prevent indoor air quality problems resulting from the construction/renovation process in order to help sustain the comfort and well-being of construction workers and building occupants.

Requirements

Develop and implement an Indoor Air Quality (IAQ) Management Plan for the pre-occupancy phase as follows:

- After construction ends and prior to occupancy conduct a minimum two-week building flush-out with new Minimum Efficiency Reporting Value (MERV) 13 filtration media at 100% outside air. After the flush-out, replace the filtration media with new MERV 13 filtration media, except the filters solely processing outside air.

OR

- Conduct a baseline indoor air quality testing procedure consistent with the United States Environmental Protection Agency's current *Protocol for Environmental Requirements, Baseline IAQ and Materials, for the Research Triangle Park Campus, Section 01445.*

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, general contractor or responsible party, describing the building flush-out procedures and dates.

OR

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, declaring that the referenced standard's IAQ testing protocol has been followed. Include a copy of the testing results.

Summary of Referenced Standards

IAQ Guidelines for Occupied Buildings Under Construction

Sheet Metal and Air Conditioning National Contractors Association (SMACNA), www.smacna.org, (703) 803-2980

This standard provides an overview of air pollutants associated with construction, control measures, construction process management, quality control, communications with occupants, and case studies. Consult the referenced standard for measures to protect the building HVAC system during construction and demolition activities.

ANSI/ASHRAE 52.2-1999: Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

ASHRAE, www.ashrae.org, (800) 527-4723

This standard presents methods for testing air cleaners for two performance characteristics: the ability of the device to remove particles from the air stream and the device's resistance to airflow. The minimum efficiency reporting value (MERV) is based on three composite average particle size removal efficiency (PSE) points. Consult the standard for a complete explanation of MERV value calculations. Filtration media used during the construction process must have a MERV of 13. **Table 1** summarizes the requirements for a MERV value of 13.

EPA Protocol for Environmental Requirements, Testing for Indoor Air Quality, Baseline IAQ and Materials for Research Triangle Park Campus, Specification Section 01445

www.epa.gov/rtp/new-bldg/environmental/specs.htm, (919) 541-0249

This specification section was a part of the construction documents for the EPA's Research & Administration Facility at Research Triangle Park. The section addresses baseline indoor air quality testing and materials testing.

Table 1: Requirements for a MERV Value of 13

Composite Average Particle Size Efficiency [%]			Minimum Final Resistance	
0.30-0.10 µm	1.0-3.0 µm	3.0-10.0 µm	[Pa]	[in. of water]
< 75%	≥ 90%	≥ 90%	350	1.4

SS WE EA MR EQ ID
Credit 3

Credit Synergies

MR Credit 2
Construction Waste Management

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 4
Low-Emitting Materials

Green Building Concerns

Building construction processes invariably include activities that contaminate the building during construction. Often, these activities result in residual building contamination that continues to impact indoor air quality over the lifetime of the building. HVAC systems are especially prone to contamination from particulate matter generated during construction activities. This particulate matter can include dust, volatile organic compounds (VOCs), microorganisms, and other contaminants that remain in HVAC systems for years. Building occupants may experience reduced productivity and adverse well-being effects as a result.

Fortunately, construction management strategies can be instituted during construction and before occupancy to minimize the potential for building contamination and to remediate or clean up any contamination that has occurred. Protection of HVAC systems during construction, IAQ testing, and flush-out of the building prior to occupancy are effective methods to mitigate the impact of construction activities and products on IAQ.

Environmental Issues

A ventilation flush-out prior to occupancy may require additional energy use, which is associated with air and water pollution. However, contaminant reduction is beneficial to building occupants, resulting in greater comfort, lower absenteeism, and greater productivity.

Economic Issues

Superior indoor air quality is likely to increase worker productivity, translating to greater profitability for companies. Additional time and labor may be required during and after construction to protect and clean ventilation systems. However, these actions can extend the lifetime of the ventilation system and improve ventilation system efficiency, resulting in reduced energy use. The sequencing of material installation may require additional time and could potentially delay the date of initial occupancy. Early coordination between the contractor and subcontractors can minimize or eliminate scheduling delays.

Community Issues

Contaminants from the construction process can affect the health of construction workers during construction and building users during occupancy. If these contaminants remain in the building after occupancy commences, they may affect the quality of indoor air, leading to expensive and complicated clean-up procedures. Construction worker health issues are addressed by federal and state regulations, primarily those of the Occupational Safety and Health Administration (OSHA). However, building occupants are not covered under these regulations.

Design Approach

Strategies

This credit hinges on performance by the builder. Regardless of the project delivery mechanism, be it design/bid/build or design/build, it is imperative that the general contractor implement an IAQ Management Plan for the construction process. In some cases the architect may provide a draft plan that the contractor then tailors to the situation. In other cases, the contractor is charged with creating the plan in order to keep the roles and responsibilities perfectly clear.

The plan should address the protection of the ventilation system components during construction and cleanup of contaminated components after construction is complete. Require temporary ventilation in the General Conditions of the construction contract.

Include construction-related IAQ procedures in the pre-construction and construction progress meeting agendas. Also, make efforts to ensure that all participants in the construction process are aware of the IAQ procedures and understand the importance of the goals of the IAQ Management Plan. If necessary, identify an owner's representative as the IAQ Manager to identify IAQ problems and require mitigation as necessary.

The referenced SMACNA standard recommends control measures in five areas: HVAC protection, source control, pathway interruption, housekeeping, and scheduling. The second portion of this credit provides an additional point for a sixth control measure: building flush-out or IAQ testing. For each project, review the applicability of each control measure and include those that apply in the final IAQ Management Plan. The control measures are as follows:

HVAC Protection—Shut down the return side of the HVAC system (which is, by definition, ductwork under negative pressure) whenever possible during heavy construction or demolition. The return side should also be isolated from the surrounding environment whenever possible. For example, all ceiling tiles for the ceiling plenum should be in place and all leaks in ducts and air handlers should be repaired promptly. If the ventilation system must be operated during construction, it should be fitted with temporary filters that can be replaced with clean media just prior to completion and occupancy.

The return side of the HVAC system should be dampered off in the heaviest work areas and return system openings should be sealed with plastic. Upgraded filter efficiency is recommended where major loading is expected.

Source Control—Specify finish materials (such as paints, carpet, composite wood, adhesives, and sealants) that have low toxicity levels, or none at all. Low-toxic materials selection is covered under IEQ Credit 4. Materials that are potentially noxious should be identified by the project architect, and control measures specified (options as described in the SMACNA guidelines).

Pathway Interruption—During construction, isolate areas of work to prevent contamination of clean or occupied spaces. Depending on the climate, ventilate using 100% outside air to exhaust contaminated air directly to the outside during installation of VOC-emitting materials. Pressure differentials between construction areas and clean areas can be utilized to prevent contaminated air from entering clean areas. Such strategies often require the erection of temporary barriers between work areas and non-work areas.

Housekeeping—Institute cleaning activities concentrating on HVAC and building spaces to remove contaminants from the building prior to occupancy. Building materials should be protected from weather and stored in a clean area prior to unpacking for installation. All coils, air filters, and fans should be cleaned before performing testing and balancing procedures and especially before conducting baseline air quality tests.

Scheduling—Specify construction sequencing to reduce absorption of VOCs by porous materials. Complete applications of wet and odorous materials such as paints, sealants, and coatings before installing absorbent "sink" materials such as ceiling tiles, carpets, insulation, gypsum products, and fabric-covered furnishings. Materials directly exposed to moisture through precipitation, plumbing leaks, or condensation from the HVAC system are susceptible to microbial contamination and should be replaced.

Flush-out—Conduct a minimum two-week building flush-out with MERV 13 filtration media and 100% outside air after construction ends and prior to occupancy. After flush-out, new MERV 13 filters must replace all filters except those solely processing outside air.

IAQ Testing—For each building area where the maximum concentration limits are exceeded, identify and mitigate pollutant sources (if possible) and conduct a partial building flush-out for a maximum of two weeks. Retest for any contaminant concentrations that were exceeded. Repeat this process until appropriate concentration levels are achieved.

Synergies and Trade-Offs

Proper construction waste management procedures can minimize the possibility of building contamination. It is also important to choose building materials that have a low potential for contaminating the building, such as low-VOC paints, adhesives, and sealants.

Resources

Web Sites

EPA Baseline IAQ Specifications

www.epa.gov/rtp/new-bldg/environmental/specs.htm, (919) 541-0249

These specifications were used for the EPA's Research Triangle Park Campus and include baseline IAQ testing and materials testing procedures.

EPA Fact Sheet: Ventilation and Air Quality in Offices

www.epa.gov/iaq/pubs/ventilat.html, (800) 438-4318

This EPA publication addresses IAQ issues for office buildings.

Sheet Metal and Air Conditioning National Contractors Association (SMACNA)

www.smacna.org, (703) 803-2980

Professional trade association that publishes the referenced standard as well as *Indoor Air Quality: A Systems Approach*, a comprehensive discussion of the sources of pollutants, measurement, methods of control, and management techniques.

Print Media

Indoor Air Quality, Construction Technology Centre Atlantic. Written as a comprehensive review of indoor air quality issues and solutions, the report is available for purchase from ctca.unb.ca/IAQ/index.htm or (506) 453-5000.

Definitions

A **Construction IAQ Management Plan** is a document specific to a building project that outlines measures to minimize contamination in the building during construction and to flush the building of contaminants prior to occupancy.

HVAC Systems include heating, ventilating, and air-conditioning systems used to provide thermal comfort and ventilation for building interiors.

Case Study

Greater Pittsburgh Community Food Bank
Pittsburgh, Pennsylvania

The Greater Pittsburgh Community Food Bank is a LEED™ Silver Pilot Project serving local food banks in Western Pennsylvania. The building houses distribution, warehouse, and processing facilities and is designed to utilize site resources and be a positive workspace for building occupants. An indoor air quality management plan was adopted to avoid air contamination in the building during construction activities. VOCs were controlled through source reduction and housekeeping efforts. Particulate contamination was reduced by physically separating the HVAC system from construction activities and by cleaning the HVAC system before occupancy. Combustion was controlled by limiting combustion activities on site and locating combustion sources away from air supply intakes. Finally, cleaning agents were specified to contain no chlorine or ammonia.

Courtesy of Gardner + Pope Architects

Owner
Greater Pittsburgh Community Food Bank

SS	WE	EA	MR	EQ	ID
Credit 4.1					

1 point

Low-Emitting Materials

Adhesives and Sealants

Intent

Reduce the quantity of indoor air contaminants that are odorous, potentially irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

The VOC content of adhesives and sealants used must be less than the current VOC content limits of South Coast Air Quality Management District (SCAQMD) Rule #1168, AND all sealants used as fillers must meet or exceed the requirements of the Bay Area Air Quality Management District Regulation 8, Rule 51.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, listing the adhesives and sealants used in the building and declaring that they meet the noted requirements.

SS WE EA MR EQ ID

Credit 4.2

1 point

Low-Emitting Materials

Paints and Coatings

Intent

Reduce the quantity of indoor air contaminants that are odorous, potentially irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

VOC emissions from paints and coatings must not exceed the VOC and chemical component limits of Green Seal's Standard GS-11 requirements.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, listing all the interior paints and coatings used in the building that are addressed by Green Seal Standard GS-11 and stating that they comply with the current VOC and chemical component limits of the standard.

Low-Emitting Materials

Carpet

1 point

Intent

Reduce the quantity of indoor air contaminants that are odorous, potentially irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

Carpet systems must meet or exceed the requirements of the Carpet and Rug Institute's Green Label Indoor Air Quality Test Program.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, listing all the carpet systems used in the building and stating that they comply with the current VOC limits of the Carpet and Rug Institute's Green Label Indoor Air Quality Test Program.

SS | WE | EA | MR | EQ | ID

Credit 4.4

1 point

Low-Emitting Materials

Composite Wood

Intent

Reduce the quantity of indoor air contaminants that are odorous, potentially irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

Composite wood and agrifiber products must contain no added urea-formaldehyde resins.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, listing all the composite wood products used in the building and stating that they contain no added urea-formaldehyde resins.

Summary of Referenced Standards

South Coast Rule #1168 by the South Coast Air Quality Management District

South Coast Air Quality Management District, www.aqmd.gov/rules/html/r1168.html, (909) 396-2000.

The South Coast Air Quality Management District is a governmental organization in Southern California with the mission to maintain healthful air quality for its residents. The organization established source specific standards to reduce air quality impacts.

The South Coast Rule #1168 VOC limits for adhesives are summarized in **Tables 1a and 1b.**

Table 1a: South Coast Rule #1168 VOC Limits

Welding & Installation	VOC Limit [g/L]	Welding & Installation	VOC Limit [g/L]
Non-vinyl backed installation	150	PVC welding	510
Carpet pad inatallation	150	CPVC welding	490
Wood flooring installation	150	ABS welding	400
Ceramic tile installation	130	Plastic cement welding	350
Dry wall & panel installation	200	Cove base installation	150
Subfloor installation	200	Adhesive primer for plastic	650
Rubber floor installation	150	All others	250
VCT & asphalt tile installation	150		

Table 1b: Substrate VOC Limits

Substrates	VOC Limit [g/L]
Metal to metal	30
Plastic foams	120
Porous material except wood	120
Wood	30
Fiberglass	200

Regulation 8, Rule 51 of the Bay Area Air Quality Management District (January 7, 1998)

Bay Area Air Quality Management District, www.baaqmd.gov, (415) 771-6000

This California regulatory agency develops and enforces air pollution regulations in its seven-county jurisdiction. **Tables 2** and **3** summarize Regulation 8, Rule 51 limits on VOCs for sealants and sealant primers.

Table 2: Sealant VOC Limits

Sealants	VOC Limit [g/L]
Architectural	250
Roadways	250
Roofing material installation	450
PVC welding	480
Other	420

Table 3: Sealant Primer VOC Limits

Sealant Primer	VOC Limit [g/L]
Architectural (non-porous)	250
Architectural (porous)	775
Other	750

Green Seal Standard GS-11

Green Seal, www.greenseal.org, (202) 872-6400

Green Seal is a nonprofit organization that promotes the manufacture and sale of environmentally responsible consumer products. Standard GS-11 was developed for paints and primers. **Table 4** summarizes limits on VOCs in grams per liter for interior paints from April 1999.

Table 4: Green Seal Limits for Interior Paints

Paint	VOC Limit [g/L]
Non-flat	150
Flat	50

SS WE EA MR EQ ID

Credit 4

Carpet and Rug Institute Green Label Testing Program

Carpet and Rug Institute, www.carpet-rug.com, (800) 882-8846

The Carpet and Rug Institute is a trade organization representing the carpet and rug industry. The organization established the Green Label Testing Program Limits to identify low-emitting carpet products for consumers. The Program established limits on VOCs for carpets, cushion, and adhesives, as summarized in **Table 5**.

Table 5: Carpet and Rug Institute VOC Limits

	Emission Factor Limit [mg/m2 x h]		Emission Factor Limit [mg/m2 x h]
Carpets Total VOCs	**0.50**	**Cushion Total VOCs**	**1.00**
4-Phenylcyclohexene	0.05	4-PC (4-phenylcyclohexene)	0.05
Formaldehyde	0.05	Formaldehyde	0.05
Styrene	0.40	BHT (butylated hydroxytoluene)	0.30
Adhesives Total VOCs	**10.0**		
Formaldehyde	0.05		
2-Ethyl-1-Hexanol	3.00		

Credit Synergies

MR Credit 1
Building Reuse

MR Credit 4
Recycled Content

MR Credit 5
Local/Regional Materials

MR Credit 6
Rapidly Renewable Materials

MR Credit 7
Certified Wood

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 3
Construction IAQ Management Plan

Green Building Concerns

A large number of building products contain compounds that have a negative impact on indoor air quality and the Earth's atmosphere. The most prominent of these compounds, volatile organic compounds (VOCs), contribute to smog generation and air pollution outdoors while having an adverse effect on the well-being of building occupants indoors. By selecting low-emitting materials, both outdoor and indoor air quality impacts can be avoided. This credit targets those building materials that are commonly associated with high-VOC content, including adhesives, paints and coatings, carpet systems, composite wood, and agrifiber products.

Environmental Issues

VOCs are chemical compounds that contribute to air pollution inside and outside of buildings. VOCs are of concern because they react with sunlight and nitrogen in the atmosphere to form ground-level ozone, a chemical that has a detrimental effect on human health, agricultural crops, forests, and ecosystems. Ozone damages lung tissue, reduces lung function, and sensitizes the lungs to other irritants. Ozone is also a major component of smog, which affects agricultural crops and forestland.

Economic Issues

Healthy occupants are more productive and have less illness-related absenteeism. Use of high-VOC content materials can cause illness and may decrease occupant productivity. These problems result in increased expenses and liability for building owners, operators, and insurance companies. As a result, the construction market is driving product manufacturers to offer low-VOC alternatives to conventional building products. Costs for these low-VOC products are generally competitive with conventional materials. However, some low-VOC materials are more expensive than conventional materials, particularly when the products are first introduced to the marketplace. Low-VOC products may also be difficult to obtain for some product types. However, these problems will recede as application of low-VOC products become more commonplace.

Community Issues

VOCs impact indoor air quality and contribute to sick building syndrome, building-related illnesses, and multiple chemical sensitivities. Application of products containing VOCs also affects outdoor air quality, creating smog and producing an unhealthy environment. By using low-VOC products, these problems can be avoided, creating a more favorable environment for building occupants and neighbors.

Design Strategies

Strategies

This credit applies to products and installation processes that have the ability to adversely affect indoor air quality (IAQ) on site: those that are exposed to interior spaces accessible by occupants. While projects should strive to limit the use of VOC-emitting materials on the building exterior or the project site, their use is not addressed under this credit.

Develop a project outline specification in early design stages, and include criteria for materials with low-VOC characteristics. Materials to address include construction and finishing materials.

Research and specify low-VOC products based on durability, performance, and environmental characteristics. Material Safety Data Sheets (MSDS) from product manufacturers may not include information on VOC content. Thus, it may be necessary to request emissions test data from product manufacturers and compare this test data with comparable products. VOC emissions data should exclude the colorants in paints. Ensure that contaminant limits are clearly stated in Division 1 and in specification sections where adhesives, sealants, coatings, carpets, and composite woods are addressed.

Consider field monitoring for emission levels in the building during installation and prior to building occupancy. Consider implementing an ongoing, periodic review of IAQ over the lifetime of the building.

Synergies and Trade-Offs

Material selection is important to creating interior spaces with low-VOC levels. Locally sourced materials and those materials created with recycled content, rapidly renewable materials, and certified wood may have high VOC content and, thus, may be inappropriate for the project. Use of low-VOC products improves indoor air quality during the construction process as well as over the lifetime of the building.

Calculations

This credit applies to products and installation processes that have the ability to adversely affect indoor air quality (IAQ) on site: those that are exposed to interior spaces accessible by occupants. While projects should strive to limit the use of VOC-emitting materials on the building exterior or the project site, their use is not addressed under this credit.

Documentation for the four subcredits normally consists of recordkeeping. Enter summary VOC data for products in the LEED Letter Template. If this credit is audited during the LEED certification review, provide cut sheets containing VOC data.

Calculations are necessary only when using the "VOC budget," which is an alternative compliance path that allows for specialty applications for which there are no low-VOC product options. Such a budget can be used to demonstrate *overall* low-VOC performance for paints or adhesives (not a combination of both). The applicant must establish a baseline VOC budget based on the appropriate referenced standard and meet the budget based on the amount of each product used and respective VOC concentrations. To develop a VOC budget, define application rates of products and how much of each is necessary for the project. Compare this baseline case to a design case that lists and sums VOCs for the products that are (or will be) specified for the project, for the same areas of application. If the total VOC limit of the design case is lower than the baseline case, the point can be earned.

Resources

Web Sites

Formaldehyde Update

www.cpsc.gov/CPSCPUB/PUBS/725.html

An informational document from the Consumer Product Safety Commission.

GreenSpec

www.greenspec.com, (802) 257-7300

Detailed listings for more than 1,500 green building products, including environmental data, manufacturer information, and links to additional resources.

Master Painters Institute's Environmental Issues Web Page

www.paintinfo.com/green

Ten Basic Concepts for Architects and Other Building Designers

www.buildinggreen.com/elists/halpaper.html, (802) 257-7300

A primer on IAQ basics from *Environmental Building News.*

Zero VOC Paint Manufacturers

www.aqmd.gov/business/brochures zerovoc.html

A listing of paint manufacturers that offer products with no or low VOC content, provided by the South Coast Air Quality Management District.

Print Media

ASTM D5116-97: Standard Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products, ASTM, 1997.

Indoor Air Quality Primer, by Dagmar Schmidt Etkin, Cutter Information Corp., 1993.

"Paint the Room Green" in Environmental Building News, Volume 8, Number 2, February 1999.

Definitions

Formaldehyde, a naturally occurring VOC, is found in small amounts in animals and plants, but is carcinogenic and an irritant to most people when present in high concentrations—causing headaches, dizziness, mental impairment, and other symptoms. When present in the air at levels above 0.1 ppm (parts per million parts of air), it can cause watery eyes, burning sensations in the eyes, nose, and throat; nausea; coughing; chest tightness; wheezing; skin rashes; and asthmatic and allergic reactions. Urea formaldehyde is a combination of urea and formaldehyde that is used in some glues and readily decomposes at room temperature. Phenol formaldehyde, which off-gasses only at high temperature, is used for exterior products, although many of those products are suitable for interior applications.

Volatile Organic Compounds (VOCs) are carbon compounds that participate in atmospheric photochemical reactions (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides and carbonates, and ammonium carbonate). The compounds vaporize (become a gas) at normal room temperatures.

SS	WE	EA	MR	EQ	ID
Credit 5					

1 point

Indoor Chemical & Pollutant Source Control

Intent

Avoid exposure of building occupants to potentially hazardous chemicals that adversely impact air quality.

Requirements

Design to minimize pollutant cross-contamination of regularly occupied areas:

- Employ permanent entryway systems (grills, grates, etc.) to capture dirt, particulates, etc. from entering the building at all high volume entryways.
- Where chemical use occurs (including housekeeping areas and copying/printing rooms), provide segregated areas with deck to deck partitions with separate outside exhaust at a rate of at least 0.50 cubic feet per minute per square foot, no air re-circulation and maintaining a negative pressure of at least 7 PA (0.03 inches of water gauge).
- Provide drains plumbed for appropriate disposal of liquid waste in spaces where water and chemical concentrate mixing occurs.

Submittals

❑ Provide the LEED Letter Template, signed by the architect or responsible party, declaring that:

- Permanent entryway systems (grilles, grates, etc.) to capture dirt, particulates, etc. are provided at all high volume entryways.
- Chemical use areas and copy rooms have been physically separated with deck-to-deck partitions; independent exhaust ventilation has been installed at 0.50 cfm/square foot and that a negative pressure differential of 7 PA has been achieved.
- In spaces where water and chemical concentrate mixing occurs, drains are plumbed for environmentally appropriate disposal of liquid waste.

Summary of Referenced Standard

There is no standard referenced for this credit.

Credit Synergies

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Prerequisite 1
Storage & Collection of Recyclables

MR Credit 1
Building Reuse

EQ Prerequisite 1
Minimum IAQ Performance

EQ Prerequisite 2
Environmental Tobacco Smoke (ETS) Control

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

Green Building Concerns

Some common building activities have a negative impact on indoor air quality. Occupants and visitors entering the building may bring in contaminants on their shoes or clothing that can infiltrate the ventilation system. Other seemingly benign practices such as photocopying, faxing, and mixing housekeeping liquids can contribute significantly to airborne contaminants, affecting the health and productivity of building occupants. By reducing the impacts of these activities, superior indoor air quality can be maintained.

Environmental Issues

Additional materials and energy may be required to provide entryway systems and isolated chemical use areas. This can increase natural resource consumption as well as air and water pollution. However, through proper management of hazardous chemicals used for building operations and maintenance, chemical spills and accidents can be avoided that would otherwise harm wildlife and ecosystems.

Economic Issues

Additional sinks, drains, and separate exhausts for copying and housekeeping areas can increase the project's overall initial cost. However, effective cleaning spaces and systems coupled with good human health initiatives should prove economically sound over the lifetime of the building. Clean air can help support worker productivity, and this translates into increased profitability for the company. Reducing the potential for spills can avoid costly environmental cleanups.

Community Issues

Good housekeeping benefits the community by reducing the potential for chemical spills that can impact neighboring properties. An environmentally sound building also supports the well-being of occupants, which may contribute to lowering health insurance rates and health care costs.

Design Approach

Design all exterior entrances with permanent entryway systems (e.g., grills and grates) to catch and hold dirt particles and to prevent contamination of the building interior. Design exterior stone, brick, or concrete surfaces to drain away from building entrances. The landscape design at building entrances should utilize low maintenance vegetation. Species that drop berries, flowers, and leaves should be avoided in entrance areas so that organic matter does not migrate into the building on occupants' shoes. Plant selection should also be based on an integrated pest management approach to eliminate pesticide applications that have the potential for tracking into the building. Provide a water spigot and electrical outlet at entryways for maintenance and cleaning activities.

Physically isolate occupant activities associated with chemical use through proper building design. Isolation includes adequate and secure storage areas for housekeeping equipment and products. All of these areas should accommodate sinks and drains plumbed for appropriate disposal of liquid waste and separate exhausts vented to the outside that are operated under negative pressure. To ensure that these features remain effective over time, building owners should institute operations and maintenance training programs for chemical usage and storage.

During early blocking and stacking studies, design copy and printing rooms with structural deck-to-deck partitions and dedicated exhaust ventilation systems. Locate high-volume equipment (e.g., copiers, printers, and fax machines) away from regularly occupied areas and provide physical isolation of this equipment. Provide dedicated localized exhaust systems and locate discharge points away from

HVAC system air intakes. Convenience (small) copier and printer use should be minimized where possible. Although encouraged, designing exhaust systems that account for convenience copier and printer use is not a required part of this credit.

Synergies and Trade-Offs

Additional ventilation systems to mitigate contaminating building activities may affect building energy performance and require commissioning and measurement and verification attention. Ventilation system design will also be affected. If an existing building is being reused, the building layout may prohibit deck-to-deck separation and separate ventilation systems for chemical use areas. Recyclable storage areas may be considered to be contaminant sources, depending on the items recycled. Janitorial supplies may impact indoor air quality if not wisely chosen.

Resources

Web Sites

Green Seal

www.greenseal.org/recommendations, (202) 872-6400

Product recommendations for general purpose cleaning solutions.

Janitorial Products Pollution Prevention Project

www.westp2net.org/janitorial/jp4.htm

A governmental and nonprofit project that researches issues and provides fact sheets, tools, and links.

EPA Environmentally Preferable Product Information

www.epa.gov/opptintr/epp/tools/toolsuite.htm

This list of tools includes links to cleaning product information and a database of environmental information on over 600 products, including janitorial and pest control products.

Print Media

Clean and Green: The Complete Guide to Non-Toxic and Environmentally Safe Housekeeping by Annie Berthold-Bond, Ceres Press, 1994.

Controllability of Systems

SS	WE	EA	MR	EQ	ID
Credit 6.1					

Perimeter Spaces

1 point

Intent

Provide a high level of thermal, ventilation and lighting system control by individual occupants or specific groups in multi-occupant spaces (i.e. classrooms or conference areas) to promote the productivity, comfort and well-being of building occupants.

Requirements

Provide at least an average of one operable window and one lighting control zone per 200 square feet for all regularly occupied areas within 15 feet of the perimeter wall.

Submittals

❑ Provide the LEED Letter Template, signed by the architect or responsible party, demonstrating and declaring that for regularly occupied perimeter areas of the building a minimum of one operable window and one lighting control zone are provided per 200 square feet on average.

Controllability of Systems

Non-Perimeter Spaces

Intent

Provide a high level of thermal, ventilation and lighting system control by individual occupants or specific groups in multi-occupant spaces (i.e. classrooms or conference areas) to promote the productivity, comfort and well-being of building occupants.

Requirements

Provide controls for each individual for airflow, temperature and lighting for at least 50% of the occupants in non-perimeter, regularly occupied areas.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, demonstrating and declaring that controls for individual airflow, temperature and lighting are provided for at least 50% of the occupants in non-perimeter, regularly occupied areas.

Summary of Referenced Standard

There is no standard referenced for this credit.

Green Building Concerns

Conventional buildings are sometimes designed as sealed environments with no occupant control over temperature and ventilation and virtually no physical connection to the building grounds and neighboring areas. By providing individual controls such as thermostats, vents, operable windows and shading devices, occupants can customize the indoor environment to their own preferences.

Environmental Issues

Individual control of building systems can increase occupant comfort and save energy by eliminating unwanted or unnecessary space conditioning.

Economic Issues

The most frequent occupant complaint involves thermal discomfort. Greater thermal comfort may increase occupant performance and attendance and, at least, will reduce complaints. Since workers are by far the largest expense for most companies (according to the Rocky Mountain Institute's *Green Developments in Real Estate*, office worker salaries are estimated to be 72 times higher than energy costs, and they account for 92% of the life-cycle cost of a building), this issue has a tremendous effect on overall costs. Case studies have shown productivity increases from 1% to 16%, saving companies millions of dollars per year.

Additional thermostats, operable windows and lighting controls can increase first costs for the building. However, these costs are generally offset by energy savings through lower conditioned temperatures, natural ventilation and less solar gain through proper use of shading devices. Conversely, abuse of personal controls such as setting thermostats too high or leaving windows open during non-working hours increases energy costs. Therefore, it is important to educate occupants on the design and function of system controls.

Community Issues

Building occupants with more control over their environment tend to be more productive and healthier. This may lead to stabilized health insurance rates and decreased health care costs.

Design Approach

Strategies

The credit encourages the design to begin with the occupants in mind. Space planning, lighting schemes and HVAC design must be well integrated early in the design.

Operable windows are perhaps the single most desired feature building occupants request in the programming phase of a project. The design team should be cautioned that the inclusion of this feature raises a host of issues that need to be resolved early in the project design stages. The first decision regarding the window design is whether the opening provides a vision function, a daylighting function, or both. This decision will help determine the preferred size, orientation and aspect ratio of the windows. Next, the ventilation function of the operable sash should be determined. The ventilation characteristics of a window that provides a modest connection to the outdoors are different from a window that can provide a portion of the cooling requirements for the interior space. Once all of these parameters are established, the design of the operable portion of the window can be incorporated into the total fenestration design.

In modern buildings, good engineering practice leads to a positive ventilation scheme for all regularly occupied spaces. In a traditional HVAC mixing system such as variable air volume (VAV), oper-

Credit Synergies

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Credit 1
Building Reuse

EQ Prerequisite 2
Environmental Tobacco Smoke (ETS) Control

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 7
Thermal Comfort

EQ Credit 8
Daylight & Views

able windows are difficult to accommodate. Either operable window designs need to be modest in size and low in quantity, or a control interface with the HVAC system should be specified to prevent counterproductive operation.

A simple control interface might include a light indicating when the HVAC is operating and when closed windows would provide the greatest comfort. An intermediate system might only allow economizer operation when windows are open. A more complex scheme would sense if there were too many windows open, signal the building energy management system to close the windows with actuators, and then start the HVAC system.

The lighting controls required in the perimeter zone go beyond those required by the AHSRAE 90.1–1999 requirements, and simple switching satisfies the credit requirement. However, more sophisticated occupancy and dimming controls may result in increased productivity and energy conservation.

Individual temperature and ventilation controls can increase first costs when implemented in the core of a building plan. As there is no access to operable windows for ventilation, the only system left to control is the mechanical delivery of air. The cost of individual VAV mixing boxes may be prohibitive for conventional HVAC systems, both for the additional boxes and the cost of the extra ductwork. VAV systems for non-perimeter areas can use a 1:1:2 terminal box to controller to occupant ratio to capture this credit.

There are a number of new systems that combine an underfloor air system with individual controls at the desktop. These Personal Environmental Control (PEC) systems transfer a large portion of the HVAC system control from the capital improvement budget to the furnishing budget. This can create challenges or opportunities, depending on the financial structure of the project.

Individual lighting control in core locations of a floor plan is a relatively straightforward installation. Further control is then provided at the individual level with task lighting. For example, furniture systems can include built-in task lighting. For finer control, larger ambient lighting zones can be sub-switched or controlled by occupancy sensors to provide smaller lighting zones.

Educate occupants on individual control of their office space environment. A monitoring system can be implemented to maintain proper system operation and signage if effective to remind occupants of their responsibilities (e.g., turning down the thermostat at night and closing windows).

Synergies and Trade-Offs

Conventional HVAC systems have a cost structure that drives building design towards larger ventilation zones with fewer controls. To successfully integrate controllability of systems into building design, the economic benefits of user satisfaction and productivity should be compared with first costs.

Alteration of the ventilation and lighting scheme may change the energy performance of the building and may require commissioning and measurement and verification attention. Controllability of systems may not be possible for occupants in existing buildings being rehabilitated, especially with regard to operable windows. The degree of occupant controls will affect the performance of the ventilation system. Daylighting and view strategies are affected by the window design.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first pages of this credit. To calculate the degree of occupant control, follow the calculation methodology as outlined in the following paragraphs. The methodology is separated into perimeter calculations and non-perimeter calculations for regularly occupied spaces. Multi-occupant group spaces, such as conference rooms and classrooms, should be accounted for separately in the calculations, following the special requirements for these spaces. Exclude zones such as hallways and lobbies, which are non-regularly occupied spaces, and non-occupied areas such as storage rooms.

Identifying Perimeter and Non-Perimeter Areas

1. On a plan drawing of the building, draw an offset line 15 feet from the outer wall of the building. This 15-foot boundary represents the typical ASHRAE 90.1 method of calculating thermal loads in perimeter zones; it is used in this credit to distinguish between the type of controls in perimeter and non-perimeter spaces.

2. Perimeter areas of the building include all regularly occupied areas that are 15 feet or less from a perimeter wall and share a physical connection with the exterior of the building.

3. Non-perimeter areas of the building are all regularly occupied areas that are greater than 15 feet from a perimeter wall.

4. For rooms that are intersected by the 15-foot line (offset from the perimeter wall) and share a physical connection with the building exterior, the area of the entire room must be included as perimeter if 75% or more of the room is contained within the 15-foot offset line. If less than 75% of the room is contained within the 15-foot offset line—e.g., in **Figure 1**, Room 1—then only the area within the 15-foot boundary is considered perimeter space (area 1A), and the remaining area is factored into the non-perimeter space calculation (area 1B).

5. For group multi-occupant spaces, perimeter calculations are used if 75% or more of the floor area falls within the 15-foot offset line and the space shares a physical connection with the building exterior. Non-perimeter calculations are used if less than 75% of the floor area falls within the 15-foot offset line OR if the space is not connected to the building exterior. In an instance where less than 75% of the floor area falls within the 15-foot offset line but the space shares a physical connection to the building exterior, the space must meet the requirements outlined in non-perimeter calculations in addition to providing an average of one operable window per 200 square feet of perimeter floor area.

Perimeter Space Calculations for Credit 6.1

Occupant controls to consider in perimeter areas include operable windows and lighting.

1. Using the method described above, identify all perimeter areas for the building.

2. Identify the number of operable windows and lighting controls in each perimeter room. Task lighting is applicable only if hardwired. For group multi-occupant spaces, meet the requirements for operable windows according to Perimeter Space Calculations and meet the requirements for lighting controls according to Group Multi-Occupant Space Calculations.

3. The credit requires one operable window and one lighting control on average for every 200 square feet of perimeter floor area.

Table 1 provides an example of the LEED Letter Template's perimeter calculations for the partial office building floor plan presented in **Figure 1**. The table includes all perimeter rooms that are regularly occupied.

Non-Perimeter Space Calculations for Credit 6.2

Occupant controls to consider in non-perimeter areas include airflow, temperature and lighting.

1. Using the method described above, determine the total non-perimeter floor area of all regularly occupied spaces.

2. Determine the total number of non-perimeter occupants based on each space's usage type by referencing the occupancy densities in ASHRAE 62–2001, Table 2. Exceptions to standard occupancy loads (e.g., executive suites and office space used partially for special purposes) must be justified in a narrative attached to the LEED Letter Template.

3. Identify the total numbers of airflow, temperature and lighting controls for this non-perimeter area. Task lighting is applicable only if hardwired.

4. The credit requires that the number of airflow, temperature, and lighting controls provided must each represent 50% or more of the non-perimeter occupants in aggregate. These controls must be provided in areas where corresponding occupants regularly work. Controls in corridors and other non-work areas are not included in the calculations.

It is acceptable for thermal and ventilation control to be provided by a single device. For example, an individual could have control of an underfloor air diffuser

Figure 1: A Sample Floor Plan Indicating Perimeter and Non-Perimeter Spaces

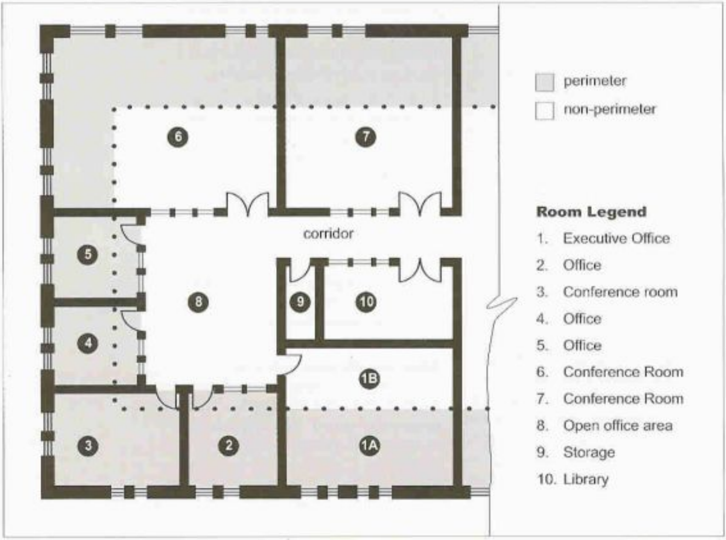


Table 1: Sample Calculations for Space 1A and Rooms 2, 4 and 5

Perimeter Spaces (where 75% or more of a room is within the 15-foot offset line)				
Perimeter Area	Operable Windows		Lighting Controls	
[SF]	[Qty]	Pass?	[Qty]	Pass?
1,290	10	Yes	8	Yes

that adjusts the airflow and also the temperature of his or her personal space.

5. For group multi-occupant spaces, meet the requirements for airflow, temperature and lighting controls according to the Group Multi-Occupant Space Calculations outlined below.

Table 2 provides an example of the LEED Letter Template's non-perimeter calculations for the partial office building floor plan presented in **Figure 1**. Room 9 and the corridor are not regularly occupied and are therefore excluded from the calculation.

Group Multi-Occupant Space Calculations for Credits 6.1 and 6.2

For group multi-occupant spaces, meet the requirements for operable windows according to the Perimeter Space Calculations. Each perimeter and non-perimeter group multi-occupant space must meet the following lighting control requirements. Each non-perimeter group multi-occupant space must also satisfy the following airflow and temperature control requirements.

1. For each space less than or equal to 10,000 square feet in floor area, provide at least three separate lighting controls, one airflow control and one temperature control each for every 2,500 square feet.

2. For each space greater than 10,000 square feet in floor area, provide at least three separate lighting controls, one airflow control and one temperature control each for every 10,000 square feet.

The following lighting controls can each be counted as two separate controls: occupancy sensor, daylighting control, dimming control and manual on/automatic off switch. Other lighting controls, such as an on/off switch, are each counted as one separate control. For example, for a room with one occupancy sensor, one daylighting control and one on/off switch, "5" would be entered in the lighting control's column of the LEED Letter Template.

Airflow and temperature controls must be devices that allow occupants to actively control the space's thermal conditions. Control devices must be easily adjustable (i.e., less than six feet above the floor) and

Table 2: Sample Calculations for Space 1B and Room 8

Non-Perimeter Spaces (where less than 75% of a room is within the 15-foot offset line)							
Non-Perimeter Area	Occupants	Airflow Controls		Temperature Controls		Lighting Controls	
[SF]		[Qty]	Pass?	[Qty]	Pass?	[Qty]	Pass?
1,020	3	3	Yes	3	Yes	6	Yes

Table 3: Sample Calculations for Room 3

Group Multi-Occupant Perimeter Rooms (where 75% or more of a room is within the 15-foot offset line)					
Number of Rooms	Total Area	Operable Windows		Lighting Controls	
[Qty]	[SF]	[Qty]	Pass?	[Qty]	Pass?
1	500	4	Yes	3	Yes

Table 4: Sample Calculations for Rooms 6, 7 and 10

Group Multi-Occupant Perimeter and Non-Perimeter Spaces (where less than 75% of a room is within the 15-foot offset line)											
Room Size Range	#	Per. Area	Non-Per. Area	Operable Windows		Airflow Controls		Temperature Controls		Lighting Controls	
[SF]	[Qty]	[SF]	[SF]	[Qty]	Pass?	[Qty]	Pass?	[Qty]	Pass?	[Qty]	Pass?
<2,500	3	1,330	1,420	10	Yes	3	Yes	3	Yes	9	Yes
>=2,500 and <5,000											
>=5,000 and <7,500											
>=7,500 and <=10,000											
>10,000											

readily accessible (i.e., not locked in an enclosure) by the occupants.

Tables 3 and 4 provide examples of the LEED Letter Template's perimeter and non-perimeter calculations for group multi-occupant spaces in the partial office building floor plan presented in **Figure 1**. The spreadsheet in **Table 3** is used for rooms that share a physical connection with the building exterior and 75% or more of the room is within the 15-foot offset line. These rooms are treated as 100% perimeter space.

The spreadsheet in **Table 4** is used for group multi-occupant rooms where less than 75% of the space is within the 15-foot offset line—such as 100% non-perimeter rooms and rooms that contain both perimeter and non-perimeter space. The example in **Table 4** indicates that three rooms, each less than 2,500 SF, account for a total of 1,330 SF perimeter area and 1,420 SF of non-perimeter area. Based on the perimeter area, seven operable windows are required (1,330/200 = 6.65, rounded up). Ten operable windows are provided, thus meeting this particular credit requirement for rooms 6 and 7. According to the Group Multi-Occupant Space Calculations, rooms that are less than 2,500 SF must each have one airflow control, one temperature control and three separate lighting controls. The example shows that these requirements are met for all three rooms.

Resources

Web Sites

Center for the Built Environment

www.cbe.berkeley.edu

This University of California, Berkeley research center provides information on underfloor air distribution technologies and other topics. See the publications page for articles such as "A Field Study of PEM (Personal Environmental Module) Performance in Bank of America's San Francisco Office Buildings."

Environmental Design + Construction

www.edcmag.com (see archives)

"Do Green Buildings Enhance the Well Being of Workers? Yes," an article by Judith Heerwagen in the July/August 2000 edition, quantifies the effects of green building environments on productivity.

Print Media

Controls and Automation for Facilities Managers: Applications Engineering by Viktor Boed, CRC Press, 1998.

Definitions

Group Multi-Occupant Spaces include conference rooms, classrooms and other indoor spaces used as a place of congregation for presentations, trainings, etc. Individuals using these spaces share the lighting and temperature controls.

An **Individual Multi-Occupant Space** is typically an open office plan. These spaces normally contain standard workstations where each individual must have comfort controls to earn Credit 6.2.

Non-Occupied Spaces include all rooms used by maintenance personnel and not open for use by occupants. Included are janitorial, storage and equipment rooms, and closets.

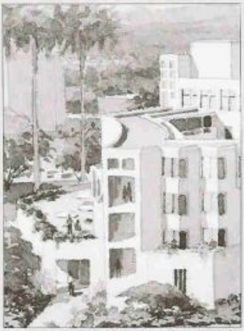
Non-Regularly Occupied Spaces include corridors, hallways, lobbies, break rooms, copy rooms, storage rooms, kitchens, restrooms, stairwells, etc.

Regularly Occupied Spaces are areas where workers are seated or standing as they work inside a building.

Case Study

Donald Bren School of Environmental Science and Management
Santa Barbara, California

The University of California at Santa Barbara's Donald Bren School of Environmental Science and Management is a LEED™ Version 1.0 Platinum Pilot Project housing campus facilities including research and teaching laboratories, and offices. The ventilation system incorporates operable windows for flow-through ventilation that can be controlled by occupants. The operable windows interface with the heating elements and the elements are automatically turned off when the windows are open. The lighting plan includes occupant-controlled energy-efficient fixtures.



Courtesy of Zimmer Gunsul Frasca Partnership

Owner
University of California at Santa Barbara

Thermal Comfort

SS	WE	EA	MR	EQ	ID
Credit 7.1					

Compliance with ASHRAE 55-1992

1 point

Intent

Provide a thermally comfortable environment that supports the productivity and well-being of building occupants.

Requirements

Comply with ASHRAE Standard 55-1992, Addenda 1995, for thermal comfort standards including humidity control within established ranges per climate zone. For naturally ventilated buildings, utilize the adaptive comfort temperature boundaries, using the 90% acceptability limits as defined in the Collaborative for High Performance Schools (CHPS) Best Practices Manual, Appendix C – A Field Based Thermal Comfort Standard for Naturally Ventilated Buildings, Figure 2.

Submittals

- ❑ For mechanically ventilated spaces: provide the LEED Letter Template, signed by the engineer or responsible party, declaring that the project complies with ASHRAE Standard 55-1992, Addenda 1995. Include a table that identifies each thermally controlled zone, and that summarizes for each zone the temperature and humidity control ranges and the method of control used.

OR

- ❑ For naturally ventilated spaces: provide the LEED Letter Template, signed by the engineer or responsible party declaring that the project complies with the 90% acceptability limits of the adaptive comfort temperature boundaries in the Collaborative for High Performance Schools (CHPS) Best Practices Manual Appendix C – A Field Based Thermal Comfort Standard for Naturally Ventilated Buildings, Figure 2.

SS | WE | EA | MR | EQ | ID

Credit 7.2

1 point
in addition to
EQ 7.1

Thermal Comfort

Permanent Monitoring System

Intent

Provide a thermally comfortable environment that supports the productivity and well-being of building occupants.

Requirements

Install a permanent temperature and humidity monitoring system configured to provide operators control over thermal comfort performance and the effectiveness of humidification and/or dehumidification systems in the building.

Submittals

- ❑ Provide the LEED Letter Template, signed by the engineer or responsible party, declaring that a permanent temperature and humidity monitoring system will operate throughout all seasons to permit control of the building zones within the seasonal thermal comfort ranges defined in ASHRAE 55-1992, Addenda 1995. Confirm that the temperature and humidity controls were (or will be) tested as part of the scope of work for Energy and Atmosphere Prerequisite 1, Fundamental Building Systems Commissioning. Include the document name and section number where the commissioning work is listed.

Summary of Referenced Standards

ASHRAE 55–1992: Thermal Environmental Conditions for Human Occupancy

ASHRAE, www.ashrae.org, (800) 527-4723

This standard identifies the range of design values for temperature, humidity and air movement that provide satisfactory thermal comfort for a minimum of 80% of building occupants. The acceptable range of operative temperatures for the winter and summer, for people performing light, primarily sedentary activities, at 50% relative humidity and a mean air speed of 30 fpm (0.15m/s), are summarized in **Table 1**.

The standard includes specific details for occupant thermal comfort and provisions for building occupants at various activity levels and non-uniformity in air temperatures. It also describes appropriate instruments and procedures for measurement of thermal environment conditions. An addendum to the standard was released in 1995.

Table 1: Operative Temperatures

Room	Temperature Range [°F]	Optimum Temperature [°F]
Winter	68 - 74	71
Summer	73 - 79	76

The Collaborative for High Performance Schools (CHPS) Best Practices Manual, Appendix C–A Field Based Thermal Comfort Standard for Naturally Ventilated Buildings, Figure 2

www.chps.net/manual/index.htm

The result of research funded by ASHRAE, this standard provides an updated approach to thermal comfort using an adaptive model. Occupants of naturally ventilated buildings were found to prefer a wider range of temperatures that extend beyond the comfort zones defined in ASHRAE Standard 55–1992. Refer to the CHPS Best Practices Manual's Appendix C for an in-depth description.

Credit Synergies

SS Credit 7
Landscape & Exterior Design to Reduce Heat Islands

WE Credit 1
Water Efficient Landscaping

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Credit 1
Building Reuse

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 6
Controllability of Systems

Green Building Concerns

A green building provides the desired indoor climate while reducing the amount of energy required for ventilation. The building envelope must be designed to manage the flow of air, moisture and heat.

Temperature and humidity are important parameters in maintaining optimal environmental conditions for occupant comfort. Optimal temperature set points depend on occupant activity levels as well as air movement in the space. Another important environmental consideration in buildings is humidity. Spaces with low humidity create static electricity, which has detrimental effects on office equipment, human respiratory systems and certain types of furniture. Conversely, spaces with high humidity provide conditions conducive to mold and mildew growth on furnishings and interior surfaces, creating potential health hazards and increased maintenance requirements. A properly designed building can provide optimal temperatures and humidity levels throughout the year.

Environmental Issues

HVAC components use fuel and electricity to provide an indoor climate that is different than the outdoor climate and thereby contributes to the environmental impacts of producing and distributing these resources. In fragile climates, such as those with permafrost, conditioning buildings may damage the local environment. Conversely, a comfortable and healthy indoor environment may increase occupant productivity and reduce illnesses and absenteeism.

Economic Issues

Providing the thermal conditions set forth in ASHRAE 55–1992 or CHPS Appendix C may increase or decrease the cost of designing, constructing and operating the building. Designing the envelope and mechanical systems in an iterative process that includes occupant needs, desires and activities can result in lower loads, smaller conditioning and distribution equipment, and consequently reduced fuel consumption while providing greater thermal comfort. Natural ventilation has the likely potential to reduce first costs and operating costs.

Designers generally select one set of thermal conditioning criteria for the entire year. ASHRAE 55–1992 recommends that designers adjust thermal conditions to address seasonal clothing levels of occupants. This strategy would reduce energy used for summer cooling and winter heating.

The most frequent occupant complaint involves lack of thermal comfort. Greater thermal comfort may increase occupant performance and attendance and, at least, will reduce complaints. Since workers are by far the largest expense for most companies (according to the Rocky Mountain Institute's *Green Developments in Real Estate*, office worker salaries are estimated to be 72 times higher than energy costs, and they account for 92% of the life-cycle cost of a building), this issue has a tremendous effect on overall costs. Case studies have shown productivity increases from 1% to 16%, saving companies millions of dollars per year.

Community Issues

Optimal building operation creates a positive work space for building occupants, resulting in higher productivity rates and lower absenteeism and illness. Such results may be used to present a case for lower health insurance rates based on lower health care costs.

Design Approach

Strategies

The environmental parameters that combine to create human thermal comfort include air temperature, air velocity, humidity, clothing, activity and the temperature of surrounding materials. The referenced standards provide ranges of expected values for these various parameters that in combination provide a comfortable environment. To narrow the parameters for a particular building design, it is necessary to make a realistic assessment of the clothing and activity level of occupants. If these parameters can be fixed, or at least limited to a narrow range, the remaining parameters can be manipulated to create design comfort levels.

To provide thermal comfort while avoiding increased energy use, the building envelope must first be designed so that:

- it is airtight enough to prevent the comfort, condensation and excessive energy use problems caused by unplanned and undesired airflows. Return air and supply plenums must be particularly well detailed;
- it uses shading, insulation and thermal mass to manage interior surface temperatures of walls, ceilings, floors and windows;
- it diverts rainwater safely away from moisture-sensitive materials in the building; and
- it manages the flow of water vapor by combining the thermal conductivity, vapor resistance and vapor storage capacity properties of materials well enough to prevent accidental humidification of interior spaces and condensation within the building shell.

In a mechanically ventilated building, equipment must be able to efficiently heat, cool, humidify and dehumidify the spaces in a building as necessary. Using envelope design to reduce loads is an important design strategy that not only conserves energy, but also improves the surface temperatures of the inner envelope surfaces and is resource-efficient in that it reduces the amount of material that is needed for the equipment and distribution systems.

An important consideration in envelope design is internal heat and moisture gains. For example, as the insulating value of the envelope increases and air leakage decreases, internal heat gains from lights, plug loads, and occupants begin increasing cooling loads.

If the gains are not well understood and accounted for, thermal comfort may be difficult to maintain, especially in interior rooms and perimeter rooms without operable windows. For example, if the cooling system for a conference room is designed for a maximum of 20 people seated at a table, and yet the occupants add an outer circle of 25 more chairs, the room will overheat and likely become too humid.

Use of dehumidification and humidification must be considered carefully. It is crucial to dehumidify and to minimize accidental outdoor airflows in buildings when the indoor temperature is maintained below the outdoor air dewpoint. Otherwise condensation problems can become unavoidable. To address this problem, mechanical systems must be designed to deal with part-load cooling conditions in ways that maintain dehumidification. Dehumidification can be enhanced using run-around-loops, split-face staged cooling coils and desiccant systems—all with or without energy and latent recovery.

As outdoor air temperature drops below the indoor setpoints, the ventilating air begins to dehumidify and cool a building. At times, this is a particularly energy-efficient way to provide thermal comfort. Without proper controls, air-side economizers become the source of comfort problems by bringing in too much humidity. As outdoor air temperatures continue to drop, the ventilating air may dehumidify the building to the point of discomfort for the occupants. The greatest discomfort comes to those who have dry skin problems, like eczema, and those who are acclimated to higher humidity levels. People from humid climates have a great deal of trouble in dry climates until they physically acclimate to a new moisture regime, while natives experience no such problems.

Active humidification systems that are used to maintain humidity levels per ASHRAE Standard 55 can contribute to condensation problems in buildings. The problems may occur in the building envelope or in the mixing and distribution system. In Section 5.1.3 Humidity, Standard 55 states that other ASHRAE Standards (e.g., 62, 90.1 and 90.2) may have other requirements and "special precautions may be required to assure overall occupant acceptability even though the conditions of Standard 55 have been met." It further advises that biological air contaminants, whose production depends on humidity levels, are outside the scope of Standard 55. Section 5.1.3 provides a basis for carefully controlling humidification systems to maintain humidity levels at the lower boundary of the Standard 55 comfort zone or for avoiding active humidification altogether. Psychometric analysis can be used to provide a basis for not including active humidification systems in a building.

Complex combinations of envelope and mechanical system strategies can be evaluated by computer simulation. Natural ventilation strategies may be modeled using methods that incorporate interzonal airflow modeling such as TAS and CONTAMW.

Appendix C of the CHPS Standard allows greater latitude in defining thermally acceptable conditions for naturally ventilated buildings. For conditions to not just be acceptable, but preferable, the occupant must have control over them—by adjusting the extent of cool breezes, warm air and, in some climates, humidity level. Accordingly, an operable window is a design feature that can help provide this control.

The second portion of the credit can only be earned with active controls. Projects utilizing natural ventilation strategies cannot earn the second portion of this credit because humidity control is not achievable in naturally ventilated buildings.

Technologies

A wide variety of temperature and humidity control devices are available. These devices can be stand-alone units or may be integrated into the building control system to automatically control temperature and when required humidity levels. Seasonally programmable thermostats can be set to automatically adjust winter and summer temperature conditions to respond to ASHRAE Standard 55's seasonal clothing levels. Humidity monitors can also be used to alert building operations personnel to unusual moisture conditions within a building, which, if left uncontrolled, could lead to mold growth or moisture problems and also cause an active dehumidification system to run unnecessarily and waste energy.

Synergies and Trade-Offs

The interdependence of a mechanical system (size, type and distribution) with envelope characteristics (for moisture, heat and air flow control) can be used to:

- minimize energy use;
- maximize the effectiveness of mechanical systems;
- make better use of renewable energy sources; and
- design the structure to provide non-fan powered ventilation and cooling.

The design of the project site impacts the thermal comfort of building interiors. Sites that minimize heat islands and have landscaping that shades building surfaces tend to reduce temperature peaks. Addition of temperature and humidity monitoring equipment can affect the energy performance of the building and requires commissioning and measurement & verification attention. Buildings that are reused may not be as amenable to temperature and humidity monitoring and control because the building systems are already in place. Thermal and humidity measures can be integrated with CO_2 sensors, ventilation systems and occupant controls.

Resources

Web Sites

Advanced Desiccant Cooling & Dehumidification Program

www.nrel.gov/desiccantcool

A research and development program of the U.S. Department of Energy that works with industry to realize the potential of desiccant systems for reducing energy consumption and improving indoor air quality and comfort.

NIST Multizone Modeling Software

www.bfrl.nist.gov/IAQanalysis/Software.htm

The National Institute of Standards and Technology provides software such as CONTAMW, a multizone indoor air quality and ventilation analysis computer program designed to predict airflows and contaminant concentrations.

The Whole Building Design Guide

www.wbdg.org

The Indoor Environmental Quality section provides a wealth of resources including definitions, fundamentals, materials and tools.

Print Media

ASHRAE Guideline 1–1989: Guideline for the Commissioning of HVAC Systems, ASHRAE, 1989.

ASHRAE Standard 52–76: Method of Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter, ASTM, 1976.

ASHRAE Standard 62–1989: Ventilation for Acceptable Indoor Air Quality, ASHRAE, 1989.

ASHRAE Standard 111–1988: Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air-Conditioning and Refrigeration Systems, ASHRAE, 1988.

Dehumidification Enhancements for 100-Percent-Outside-Air AHUs: Parts I, II and III by Donald Gatley, *Heating Piping and Air Conditioning Magazine*, September, October and November, 2000 (available as fee-based downloads at HPAC.com)

Humidity Control Design Guide by L. Harriman, G.W. Brundett and R. Kittler, ASHRAE, 2000.

The Impact of Part-Load Air-Conditioner Operation on Dehumidification Performance: Validating a Latent Capacity Degradation Model by Hugh Henderson, Conference Proceedings IAQ and Energy 98, ASHRAE, 1998.

"The New Comfort Equation For Indoor Air Quality" by P.O. Fanger, *ASHRAE Journal*, October, pp. 33-38, 1989.

Selecting HVAC Systems for Schools by Arthur Wheeler and Walter Kunz, Jr., Maryland State Department of Education, 1994.

Thermal Comfort, by P.O. Fanger, McGraw Hill, 1973.

Thermal Delight in Architecture by Lisa Heschong, MIT Press, 1979.

"Unplanned Airflows and Moisture Problems" by T. Brennan, J. Cummings and J. Lstiburek, *ASHRAE Journal*, November, 2000

Definitions

Natural Ventilation provides acceptable air-change effectiveness and thermal comfort without the use of mechanical heating and cooling equipment. The natural effect of wind, stack effect and interior/exterior temperature differentials induce air circulation and replacement. Airflow is fan-assisted only when necessary.

The **Occupied Zone** is the region in an occupied space from 3 inches above the floor to 72 inches above the floor and greater than 2 feet from walls or fixed air conditioning equipment.

Relative Humidity is the ratio of partial density of water vapor in the air to the saturation density of water vapor at the same temperature.

Thermal Comfort is a condition of mind experienced by building occupants expressing satisfaction with the thermal environment.

SS	WE	EA	MR	EQ	ID

Credit 8.1

1 point

Daylight and Views

Daylight 75% of Spaces

Intent

Provide for the building occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.

Requirements

Achieve a minimum Daylight Factor of 2% (excluding all direct sunlight penetration) in 75% of all space occupied for critical visual tasks. Spaces excluded from this requirement include copy rooms, storage areas, mechanical plant rooms, laundry and other low occupancy support areas. Other exceptions for spaces where tasks would be hindered by the use of daylight will be considered on their merits.

Submittals

- ❑ Provide the LEED Letter Template signed by the architect or responsible party. Provide area calculations that define the daylight zone and provide prediction calculations or daylight simulation.

1 point

Daylight and Views

Views for 90% of Spaces

Intent

Provide for the building occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.

Requirements

Achieve direct line of sight to vision glazing for building occupants in 90% of all regularly occupied spaces. Examples of exceptions include copy rooms, storage areas, mechanical, laundry and other low occupancy support areas. Other exceptions will be considered on their merits.

Submittals

- ❑ Provide the LEED Letter Template and calculations describing, demonstrating and declaring that the building occupants in 90% of regularly occupied spaces will have direct lines of site to perimeter glazing. Provide drawings highlighting the direct line of sight zones.

Summary of Referenced Standard

There is no standard referenced for this credit.

SS WE EA MR EQ ID

Credit 8

Green Building Concerns

Daylighting improves the indoor environment of buildings by exposing occupants to natural light. Studies have demonstrated that productivity increases dramatically for those building occupants working in daylit areas. In addition, daylighting decreases energy costs for buildings by providing natural solar lighting. A well-designed daylit building is estimated to reduce lighting energy use by 50% to 80% (*Sustainable Building Technical Manual*, page IV.7).

Daylighting design involves a careful balance of heat gain and loss, glare control and variations in daylight availability. Shading devices, light shelves, courtyards, atriums and window glazing are all strategies employed in daylighting design. Important considerations include building orientation, window size and spacing, glass selection, reflectance of interior finishes and locations of interior walls.

Environmental Issues

Daylighting reduces the need for electric lighting of building interiors, resulting in decreased energy use. This conserves natural resources and reduces air pollution impacts due to energy production and consumption. Daylit spaces also increase occupant productivity and reduce absenteeism and illness.

Economic Issues

Specialized glazing can increase initial costs for a project and can lead to excessive heat gain if not designed properly. Glazing provides less insulating effects compared to standard walls and requires additional maintenance. However, offices with sufficient natural daylight have proven to increase occupant productivity and comfort. In most cases, occupant salaries significantly outweigh first costs of incorporating daylighting measures into a building design. Studies of schools and stores have shown that daylighting can improve student performance and retail sales (see the Resources section).

Daylighting can significantly reduce artificial lighting requirements and energy costs in many commercial and industrial buildings, as well as schools, libraries and hospitals. Daylighting, combined with energy-efficient lighting and electronic ballasts, can reduce the lighting power density in some office buildings by up to 30%.

Community Issues

Daylighting and outdoor views provide a connection with the building site and adjacent sites, creating a more integrated neighborhood. Daylit spaces increase occupant productivity and reduce illness and absenteeism.

Design Approach

Strategies

Determine if daylighting and direct line of sight to the outdoors is feasible and appropriate for the building. Some buildings cannot utilize natural daylighting goals due to site constraints or specialized building uses that prohibit sunlight penetration.

Orient the building on the project site to maximize daylighting options and adopt a building design with shallow floor plates to maximize daylit areas. Courtyards, atriums, clerestory windows, skylights, interior light shelves, exterior fins, louvers and adjustable blinds used alone or in combination are effective strategies to achieve deep daylight penetration. **Figure 1** illustrates various daylighting strategies.

The desired amount of daylight will differ depending on the tasks occurring in a daylit space. Daylit buildings often have several daylight zones with differing target light levels. In addition to light lev-

Credit Synergies

SS Credit 1
Site Selection

SS Credit 2
Urban Redevelopment

SS Credit 5
Reduced Site Disturbance

WE Credit 1
Water Efficient Landscaping

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 2
Renewable Energy

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Credit 1
Building Reuse

EQ Credit 6
Controllability of Systems

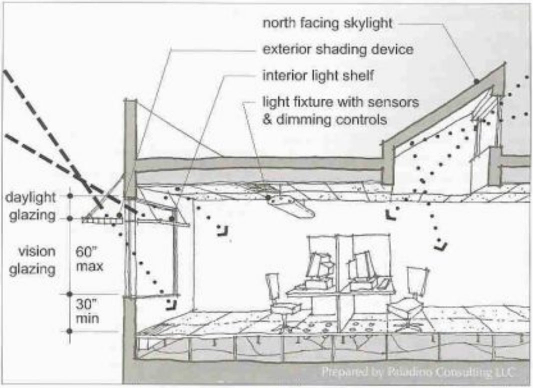


Figure 1: An Illustration of Various Daylighting Strategies

els, daylighting strategies should address interior color schemes, direct beam penetration and integration with the electric lighting system.

Glare control is perhaps the most common failure in daylighting strategies. Glare is defined as any excessively bright source of light within the visual field that creates discomfort or loss in visibility. Large window areas provide generous amounts of daylight to the task area. If not controlled properly, this daylight can produce unwanted glare. Measures to control glare include light shelves, louvers, blinds, fins and shades.

Technologies

Computer modeling software can be used to simulate daylighting conditions. Daylighting software produces continuous daylight contours to simulate the daylighting conditions of interior spaces and to account for combined effects of multiple windows within a daylit space.

Photo-responsive controls for electric lighting can be incorporated into daylighting strategies to maintain consistent light levels and to minimize occupant perception of the transition from natural light to artificial light. These controls result in energy savings by reducing electric lighting in high daylight conditions while preserving footcandle levels on the task surface.

Synergies and Trade-Offs

Project site selection and building orientation have a significant effect on the success of daylighting strategies. Vertical site elements such as neighboring buildings and trees may reduce the potential for daylighting. Reused buildings may have limited daylighting potential due to their orientation, number and size of building openings and floor plate dimensions. Finally, light sensors and automatic controls will affect the energy performance of the building and will require commissioning and measurement & verification attention.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. The calculation methodology is divided into two sections: daylighting and views.

The **daylighting** calculation methodology below can be applied to approximate the daylight factor for each regularly occupied room in the building. The Daylight Factor (DF) is the ratio of exterior illumination to interior illumination and is expressed as a percentage. The variables used to determine the daylight factor include the floor area, window area, window geometry, visible transmittance (T_{vis}) and window height. This calculation method aims to provide a minimum 2% DF at the back of a space.

Areas to include in the daylighting calculations include all regularly occupied spaces such as office spaces, meeting areas and cafeterias. Areas that should not be considered include support areas for copying, storage, mechanical equipment, laundry and restrooms.

The daylighting calculations for this credit may be determined by either using daylighting simulation software or by following the methodology outlined in the following paragraphs:

1. Create a spreadsheet and identify all regularly occupied rooms. Determine the floor area of each applicable room using construction documents.

2. For each room identified, calculate the window area and use **Table 1** to indicate the acceptable window types. Note that window areas above 7'6" are considered to be daylight glazing. Glazing at this height is the most effective at distributing daylight deep into the interior space. Window areas from 2'6" to 7'6" are considered to be vision glazing. These window areas are primarily used for viewing and lighting interior spaces close to the building perimeter. Window areas below 2'6" do not contribute to daylighting of interior spaces and are excluded from the calculations.

3. For each window type, insert the appropriate geometry and height factors as listed in **Table 1**. The geometry factor indicates the effectiveness of a particular aperture to distribute daylight relative to window location. The height factor accounts for where light is introduced to the space.

4. For each window type, indicate the visible transmittance (T_{vis}), a variable number that differs for each product. T_{vis} is the recommended level of transmittance for selected glazing.

5. Calculate the Daylight Factor for each window type using **Equation 1**. For rooms with more than one window type, sum all window types to obtain a total Daylight Factor for the room.

6. If the total daylight factor for a room is 2% or greater, then the square footage of the room is applicable to the credit.

7. Sum the square footage of all applicable rooms and divide by the total square footage of all regularly occupied spaces. If this percentage is greater than 75%, then the building qualifies for the first point of this credit.

8. Note that glare control is also required for each window. **Table 1** provides best-practice glare control measures for different window types. Create a second spreadsheet that identifies the type of glare control applied to each window type.

Equation 1:

$$\text{Daylight Factor} = \frac{\text{Window Area [SF]}}{\text{Floor Area [SF]}} \times \text{Window Geometry} \times \frac{\text{Actual } T_{vis}}{\text{Minimum } T_{vis}} \times \text{Window Height Factor}$$

Table 1: Daylight Design Criteria

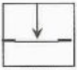
Window Type	Geometry Factor	Minimum T_{vis}	Height Factor	Best Practice Glare Control
 sidelight daylight glazing	0.1	0.7	1.4	Adjustable blinds Interior light shelves Fixed translucent exterior shading devices
 sidelighting vision glazing	0.1	0.4	0.8	Adjustable blinds Exterior shading devices
 toplighting vertical monitor	0.2	0.4	1.0	Fixed interior Adjustable exterior blinds
 toplighting sawtooth monitor	0.33	0.4	1.0	Fixed interior Exterior louvers
 toplighting horizontal skylights	0.5	0.4	1.0	Interior fins Exterior fins Louvers

Table 2 provides an example of daylighting calculations for an office building. All of the offices are considered to be regularly occupied spaces, while support areas such as hallways, foyers, storage areas, mechanical rooms and restrooms are not considered to be regularly occupied.

The example qualifies for the first point of this credit because it exceeds the minimum square footage for daylit area and includes glare control on all windows in daylit rooms.

Views are required for at least 90% of all regularly occupied rooms in order to achieve IEQ Credit 8.2. Use the following steps to perform view calculations.

1. Note if it is possible to view vision glazing in each regularly occupied room. Windows below 2'6" and windows above 7'6" (including daylight glazing, skylights and roof monitors) do not qualify for the credit. For best results use a copy of the floor plans and highlight areas of regularly occupied rooms that have a direct line of sight. Construct line of sight geometries at each window to identify non-view areas in each room (see **Figure 2** for guidance). Remember to take into account the wall thickness when determining oblique angles of sight through windows. Visually inspect each room and

Table 2: Sample Daylighting Calculations

Room	Floor Area	Glazing Area	Window Geometry		Transmittance (T^{vis})		Window Height	Daylight Factor		Daylit Area	Glare Control
	[SF]	[SF]	Type	Factor	Actual	Minimum	Factor	Each	Room	[SF]	
A	820	120	vision	0.1	0.9	0.4	0.8	2.6%	3.3%	820	2
		40	daylight	0.1	0.7	0.7	1.4	0.7%			3
B	410	75	vision	0.1	0.9	0.4	0.8	3.3%	4.1%	410	2
		25	daylight	0.1	0.7	0.7	1.4	0.9%			3
C	120	36	vision	0.1	0.4	0.4	0.8	2.4%	2.4%	120	2
D	95	25	vision	0.1	0.4	0.4	0.8	2.1%	2.1%	95	2
E	410	75	vision	0.1	0.9	0.4	0.8	3.3%	4.1%	410	2
		25	daylight	0.1	0.7	0.7	1.4	0.9%			3
F	820	75	vision	0.1	0.9	0.4	0.8	1.6%	2.1%	820	2
		25	daylight	0.1	0.7	0.7	1.4	0.4%			3
G	600	36	vision	0.1	0.4	0.4	0.8	0.5%	0.5%	0	2
H	120	36	vision	0.1	0.4	0.4	0.8	2.4%	2.4%	120	6
I	95	32	vision	0.1	0.4	0.4	0.8	2.7%	2.7%	95	6
J	95	32	vision	0.1	0.4	0.4	0.8	2.7%	2.7%	95	1
K	410	36	sawtooth	0.33	0.4	0.4	1.0	2.9%	2.9%	410	4
TOTAL	**3,730**									**3,395**	

Percentage of Daylit Area **85%**

Glare Control Chart

Type	Description
1	Fixed Exterior Shading Devices
2	Light shelf, exterior
3	Light Shelf, interior
4	Interior Blinds
5	Pull-down shades
6	Fritted glazing
7	Drapes
8	Electronic black-out glazing

compare areas with access to views against areas without access. If the view area is greater than or equal to 90% of the room area, then the square footage of the **entire** room is applicable to the credit.

In cases where it is difficult to determine the percentage visually, measure the actual square footage on the plans more precisely. For non-perimeter spaces with vision glazing, include a narrative and detailed building section drawing to explain access to views.

2. Sum the square footage of all applicable rooms and divide by the total square footage of all regularly occupied spaces. If this percentage is greater than 90%, then the building qualifies for the second point of this credit.

Resources

Web Sites

Analysis of the Performance of Students in Daylit Schools

www.innovativedesign.net

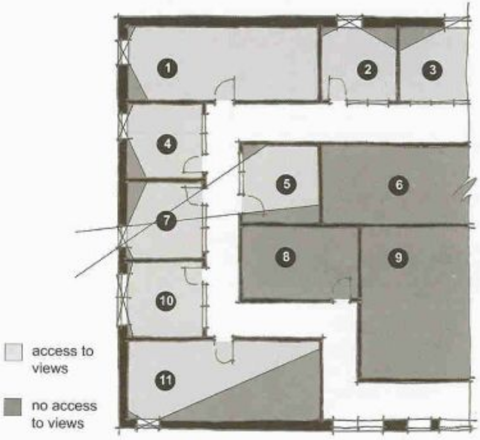
Nicklas and Bailey's 1996 study of three daylit schools in North Carolina.

The Art of Daylighting

www.edcmag.com (see Jan/Feb 1998 archive)

This *Environmental Design & Construction* article provides a solid introduction to daylighting.

Figure 2: An Illustration Showing Access to Views



Prepared by Paladino Consulting LLC

New Buildings Institute's Productivity and Building Science Program

www.newbuildings.org/pier

Provides links to case studies and reports on the benefits of daylighting.

Radiance Software

radsite.lbl.gov

Free daylighting simulation software from the Lawrence Berkeley National Laboratory

Tips for Daylighting with Windows

eande.lbl.gov/BTP/pub/designguide/download.html

A daylighting comprehensive guide from Lawrence Berkeley National Laboratory

The Whole Building Design Guide

www.wbdg.org

The Daylighting and Lighting Control section provides a wealth of resources including definitions, fundamentals, materials and tools.

Print Media

"Daylighting Design" by Benjamin Evans, in *Time-Saver Standards for Architectural Design Data*, McGraw-Hill, Inc., 1997.

Daylighting for Sustainable Design by Mary Guzowski, McGraw-Hill, Inc., 1999.

Daylighting Performance and Design by Gregg D. Ander, John Wiley & Sons, 1997.

Sustainable Building Technical Manual, Public Technology, Inc., 1996 (www.pti.org).

Definitions

Daylight Factor is the ratio of interior illuminance at a given point on a given plane (usually the workplane) to the exterior illuminance under known overcast sky conditions. LEED uses a simplified approach for its credit compliance calculations.

Daylighting is the controlled admission of natural light into a space through glazing with the intent of reducing or eliminating electric lighting. By utilizing solar light, daylighting creates a stimulating and productive environment for building occupants.

Visible Transmittance (T_{vis}) is the ratio of total transmitted light to total incident light. In other words, it is the amount of light passing through a glazing surface divided by the amount of light striking the glazing surface. A higher T_{vis} value indicates that a greater amount of incident light is passing through the glazing.

Case Study

NW Federal Credit Union
Seattle, Washington

Courtesy of Paladino Consulting LLC

Owner
NW Federal Credit Union

The NW Federal Credit Union building is a commercial office facility that houses a financial institution. The building was designed to harvest site resources and create a positive work atmosphere for building occupants as well as showcase environmental measures for banking patrons. The building is oriented on an east-west axis, and the floor plates are elongated to maximize solar access into the building interiors. Exterior shading devices and interior light shelves direct sunlight into the space without causing undesirable glare. Window glazing was selected to reduce glare on computer monitors while allowing natural light into the occupied spaces. Finally, interior finish colors were chosen to bounce light to the deep interior spaces, creating a vibrant and positive workspace.