# Indoor Environmental Quality

The entire indoor environment impacts employee productivity, including indoor air quality, acoustics, lighting, ergonomics and thermal comfort. The dynamics of integrating these elements within the building design must assure that they work in conjunction with one another to eliminate the impediments to a productive work environment. Almost 25 percent of the LEED® points earned for this building project encompass factors that were designed to assure good IEQ.

## Building Orientation

The most important factor in the design of a green building, once an appropriate site has been selected, is the orientation of the building on the site. HVAC and lighting, all impacting energy consumption and building operating costs, can be significantly reduced if the building orientation balances daylight penetration for optimal ambient lighting and shading to prevent glare and accompanying radiant heat gain.

The primary building facades are oriented to face north and south to maximize the use of windows while minimizing east and west exposures to develop a relatively narrow floor plate. The floor plate is split into two wings, slightly skewed from true southern orientation. One wing is 10 degrees east of south, the other 10 degrees west of south. This orientation reduced summer solar loads and increased opportunities for daylighting and solar control.

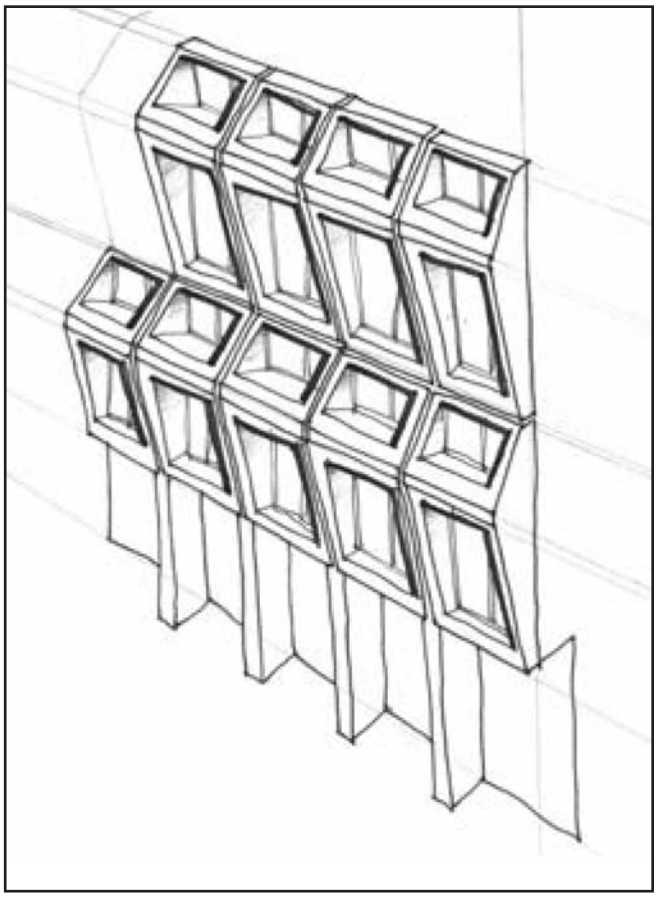
## Daylighting

The orientation of the building is primarily east/west elongated which provided the best shading control and daylighting potential. Elevations oriented east and west were minimized, eliminating unnecessary radiant heat gain from low solar angles. The depth of each wing allows for good daylight penetration, ranging from 60 feet to 80 feet at maximum penetration.

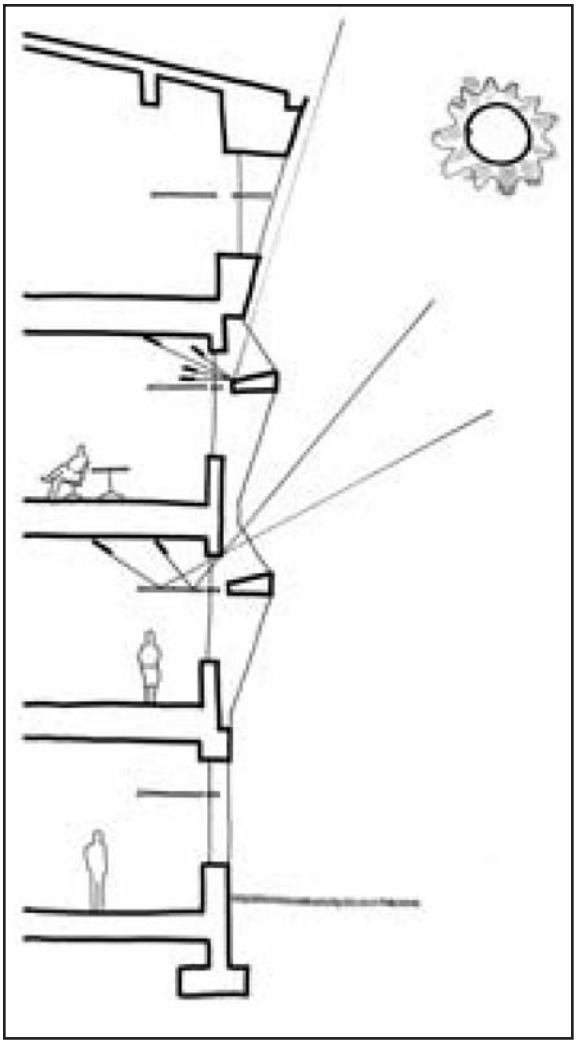
A system of pre-cast in-place vertical fins and horizontal light shelves on the south façade of the building established the means to daylight and shade spaces inside the building on the 2nd and 3rd floors. The 4th-floor shading device relies on the roof overhang and light shelf formed using the exterior galvanized aluminum roof, and column construction material.

Graphic No. 1 shows the 2nd and 3rd floors. During the summer months, sunlight reflects off the external light shelves into the building to daylight occupant work space, and in conjunction with the vertical fins. The external shelves also shade the windows below and to the side to eliminate solar gain.

During the winter months, when the sun is lower in the sky, solar heat is harvested into the building, cutting heating and electrical load and associated costs. Sunlight penetration into the building from the exterior light shelves is dif-



Graphic No. 1: *A system of pre-cast vertical fins and horizontal light shelves were incorporated into the south-facing facade of the Lewis and Clark State Office Building.*



Graphic No. 2: *Depending on the season and sun angle conditions, sunlight is either directed into, or away from, the interior of the facility. At right, the cloth light shelves are absorbing heat, but allowing sunlight to diffuse off the fabric at the top. This allows sunlighting without overheating the southside halls and work areas.*

shelves and the enclosures housing the lower window shades. This redesign and associated reinstallation eliminated 85 percent of the glare problem. The shades are now being moved outward, flush with the wall structure, to eliminate the last vestige of light penetration from the redesigned cloth light shelves.

Architectural firms should pay close attention to the design and installation of internal light shelf systems to make sure that glare is eliminated entirely, especially during winter months when the sun is lower in the sky.

fused by means of internal cloth light shelves installed below 2 ½-foot clerestory windows.

As shown in Graphic No. 2, sunlight reflects off the exterior light shelves or directly into the building off of the internal cloth light shelves. The internal cloth light shelves are made from 70 percent-denier textured polyester and 40 percent-denier bright spandex. Other materials such as aluminum, fiberglass or other hard surface materials were considered but were deemed too inflexible to meet the structural design of columns and the cistern's gray-water pipes found throughout the building.

Light is further reflected off of the internal cloth light shelves onto bright white ceiling surfaces and drop ceiling grids called acoustical "clouds," interspersed evenly throughout the south side of the building.

The entire daylighting system was designed to shade, cool, heat and provide lighting for building occupants without causing glare. However, as reported by several design architectural firms, daylighting systems are still a constant cause of frustration to building occupants. The internal cloth light shelf system was redesigned and remanufactured in the Lewis and Clark State Office Building due to problems with glare between the cloth light

The following article, *Daylit Spaces, Productive Places*, by Ramana Koti of BNIM, appeared in *Solar Today*. Access it on the Web at
www.solartoday.org www.solartoday.org.
The article further defines daylighting using the Lewis and Clark State Office Building design as the model for how proper daylighting has a positive effect on productivity in the workplace.

An additional Department of Natural Resources link is at
www.dnr.mo.gov/greenbldg/docs/daylit-spaces.pdf

## Windows

Glazing, or transparent portions of walls, was installed throughout the building using low-E float glass to maximize daylighting while giving the building a feeling of openness to views outside the structure.

The majority of glass is tinted, except for the clerestory or upper level glazed portions along the south façade. Here, sunlight is transferred in abundance off of light shelves to daylight interior occupant spaces not day lit by the lower windows. Many of the windows in the atrium and front entry also are not tinted in order to brighten the expansive space and eliminate the need for abundant electrical lighting.

Windows also are designed along all internal offices, interview rooms and conference rooms, starting 54" above the floor windows and along the top and door handle side of each door. This is designed to assist daylighting enclosed areas of the building. The idea was to provide occupants as much daylighting as possible, regardless of their location throughout the building.

The U-value of all the double pane window assembly units, including glass, frame, weather-stripping and sealants, is between .28 to .30, in order to reduce heat loss.

## Operable Windows

The building provides occupants a mixed-mode environment by combining the natural ventilation of operable windows with a conventional HVAC system. Many studies indicate building occupants will allow wider ranges of temperature if given more control of their thermal comfort, which was the primary reason operable windows were added to the building design. Sixteen percent – every 6th window in the building – is operable.

Building designers and Office of Administration and department project managers discussed operable windows as a means of improving occupant comfort by giving occupants greater personal control of the building environment while reducing energy consumption. The impacts of providing occupants with greater control of comfort using natural ventilation during certain parts of the year include exterior noise levels and the effect on the effi-

*One in six windows can be opened. Temperatures between 50 F to 70 F, combined with humidity levels between 40 percent to 50 percent are optimal for opening windows.*

cient operation of the HVAC system.

The building HVAC system provides a very stable condition within the wings, varying only .02 degrees to .07 degrees between the very east and west ends of each wing. In this particular building, exterior temperature and humidity levels dictate when the windows can be opened by occupants.

***Temperatures ranging between 50 F to 70 F, combined with humidity levels ranging between 40 percent to 50 percent are optimal for opening windows.***

Opening the windows with temperatures and humidity outside these ranges will impact the building HVAC system by requiring systems to work harder to overcome the effects of open windows. This also can affect the comfort of occupants who may suffer from sinusitis and other respiratory problems.

## Lighting Systems

The indirect lighting system combined with the maximum number of daylight and occupancy motion sensors was integrated with daylighting to create a comfortable work environment for occupants. The primary function of integrating these two design components was to eliminate glare from computer screens and desktops thereby reducing eyestrain and fatigue. Two strategies were added to the daylighting component with a uniform ceiling brightness and acoustical fabric "clouds" to create a consistent and uniform lighting environment throughout the building. Providing task lighting in the systems furniture design was also added allowing occupants more control when blinds were shut, cloudy conditions prevailed or when nightfall arrives sooner during winter months.

Reliable equipment for the project such as lamps, ballasts and controls were purchased in order to use energy more efficiently and lower maintenance costs. The following specific lighting design goals were established by the design team, with the assistance of Clanton and Associates, as members of the project team:

- Using T8 and T5 linear fluorescent, compact fluorescent and inductive lamps for interior spaces
- Using high-frequency electronic ballasts in the 25K frequency range to enhance visual performance and reduce occupant fatigue by providing a smooth, non-flickering operational environment
- Selecting luminaries for their lighting effectiveness, distribution characteristics, efficiency, quality con struction, aesthetics and economics
- Providing controls to provide occupants with lighting flexibility in their spaces
- Reducing lighting loads through daylighting and occupancy and dimming sensors

Selecting equipment to minimize required maintenance by:

- Minimizing the number of luminaire and lamp types
- Making all luminaires easily accessible for re-lamping
- Minimizing re-lampings by specifying long-life lamps

Daylighting eliminated almost 50 percent of the lighting fixtures required to illuminate the open floor plan areas in the building. Daylight sensors that respond to small changes in sunlight penetration without distracting occu-

pants with sudden lighting changes were added to dim lights during the day. When excessive amounts of sunlight penetrate occupant space, the dimmers kick in and decrease lighting loads. Enclosed offices, break rooms and other multi-purpose rooms also were designed with occupancy sensors. Hallways and other circulation paths throughout the building are lit using sconce lighting – fixtures that reflect lighting upwards onto walls and ceilings. Sconce lighting provides indirect, ambient lighting in passageways where bright illumination is unnecessary. Motion sensors also are prevalent throughout these areas to eliminate lighting in those passageways where traffic might be lighter than in main hallways.

## Raised-Access Flooring System

Most sustainably designed office buildings today, including those constructed by "value-added conscious" federal General Services Administration guidelines, are designed with raised-access flooring systems. Air flow from below-floor plenums is a much more comfortable means of providing air flow to occupant spaces. One of the primary complaints of occupants in the built environment is the discomfort of air blowing downward. It can create an uncomfortable environment where cold air tends to stiffen neck and spine areas. Ceiling plenums also create habitat for dust, mold, bugs and spiders, is a source of heat and provides a wasteful escape for heating and cooling in many buildings.

*A raised-access flooring system has many benefits, including putting the heating or cooling closer to the occupant than via ceiling vents. Computer and phone cabling also runs through the subfloor, making access for changes, upgrades or maintenance faster and less disruptive.*

The Interface AR C-Tec Series access panel flooring system used in the Lewis and Clark State Office Building combines the tensile strength of steel with the compressive strength of concrete to create a composite structure much like that of a concrete slab. The two-foot by two-foot panels, installed eighteen inches above grade, provide a strong and quiet floor structure with easy access to cables and utilities.

Floor cooling registers are mounted within the raised-floor panel structure throughout the open floor plan design. Registers can be moved with moderate ease to shift registers within cubicle workstations allowing employees to change the location of registers for more comfort. Floor registers can be turned up or down and in several directions, depending upon the need for cooling. Also, air coming from the floor plenum infiltrates the workstation area allowing cooling to moderate along a plane closer to where employees sit and work.

Computer and telecommunications network cabling and electrical wiring systems, as well as pipes operating the chilled loop heating and cooling system are much more easily maintained without being disruptive to employees. Pipe leaks do not drop onto desks causing damage to computers and can be cleaned easily off of the below concrete floor without creating mold problems on carpeted floor and gypsum panel wall structures.

Essentially, a raised-access flooring system eliminates problems created by a ceiling plenum, cools occupant space more comfortably, provides easier access to wiring and pipe structures and is a major deterrent to mold.

## Indoor Air Quality

Numerous factors contribute to the degradation of air quality in the indoor built environment where employees spend one-third of their daily life. Substandard construction processes, deficient mechanical system design and

VOC-laden building materials, finishing products such as high-emitting solvents, caulking products, carpet, adhesives, sealants, paints and other coatings, glues, composite wood and agrifiber products and environmentally unfriendly cleaning products can all have harmful effects on occupants.

A primary concept in the design and construction process, including the development of material specifications, was to eliminate VOCs from entering the building and being emitted as the building envelope was completed prior to occupancy.
Several LEED® credits are available that establish strategies to eliminate many of the common causes of indoor air quality problems during and after building construction.

**These factors should be developed as strategies throughout the design phase and include:**

- daylighting
- raised flooring system promoting greater comfort via air rising into the space rather than descending from a ceiling plenum
- temperature comfort using adjustable floor registers
- consistent temperature control throughout the building without hot and cold spots
- indirect lighting systems with use of motion and light sensors
- a percentage of windows should be operable
- use of environmentally friendly cleaning products within the facility
- implementation of a smoking ban inside the building and away from exterior in take systems

Plans and specifications should be developed during the construction bid process requiring submittal of a construction indoor air quality plan prior to work beginning. The plan should specify that flush-out procedures be developed at an appropriate time during construction. It also must stipulate that CO2 monitoring be performed within the equipment management system and require low- or no-VOC materials and finishing products during construction. There also are other factors that can enhance employee satisfaction with the indoor environment.

## Indoor Air Quality Plan – Construction

The selected prime construction contractor was to submit a construction indoor air quality management plan, as was required in bid documents for this particular LEED®-certified building project. Bid documents indicated the plan was due within 45 days after the bid opening. However, the winning bid construction company president presented bid officials with a completed air quality plan with their bid documents. The company's commitment to the mission and specific objectives of the project was quickly evident and gave project planners and architects an immediate indication that the selected contractor had done the appropriate research prior to the bid opening. The construction contractor became mission-driven, as did collaborative members of the design and construction team. With their dedication to the project mission, the ultimate success of the entire project was assured.

Of particular note, it is highly recommended that the indoor air quality management plan follow SMACNA guidelines, which are listed in Section 01360 3.1B: HVAC Protection, Source Control, Pathway Interruption, Housekeeping, Scheduling and Building Flush-Out.

The project team discussed all aspects of the air quality plan and how it impacted each phase of the project. The plan also was enhanced throughout the project as conditions changed or opportunities arose that warranted that the plan be revised to improve its effectiveness to eliminate VOCs from entering the building.

Three situations stand out as examples of how the plan was revised during the project. Smoking was prohibited inside any enclosed area or where a finished product was installed not requiring immediate enclosure. Construction contract employees were continually monitored during the project due to new subcontractors arriving weekly.

*Excellent indoor environmental quality starts at the beginning of the project. LEED® certification for indoor air quality requires the development of a construction indoor air quality plan. Here, duct work and other materials are covered onsite until needed. This eliminates the infiltration of construction dust to the building's interior during startup and operation of the HVAC system.*

As winter arrived, it was suggested the contractor utilize LPG in heaters rather than gasoline to eliminate fumes that could well attach to building materials. Gasoline odors that are attached to building materials during installation can be emitted into the occupied indoor environment for many years.

Surface cleaning was required during final stages of the project. Constant monitoring during this phase by the department's project manager caught several instances where a cleaner emitted odors not consistent with the indoor air quality plan. As a consequence, possible harmful ammonia and other solvent odors were being emitted as wood and glass were being cleaned for project closure. Alternative products were found to be as effective in cleaning surfaces while eliminating odors in the indoor environment.

## Indoor Air Quality Plan – Pre-Occupancy Air Flush-Out

A building air flush-out was performed for the entire building in three separate phases starting with the east wing only (duration: 38 days, 24 hrs/day), then the west wing only (duration: 74 days, 24 hrs/day) and ending with the atrium (duration: 34 days 24 hrs/day). The LEED® requirement for an air flush-out is 14 days. However, due to the following issues, the duration for air flush-outs had to be lengthened.

Testing and balancing was completed as the commissioning agent was completing their work, systems furniture was completed and moved into the building and the prime contractor completed punch lists, allowing the flush-out to begin on the east wing. As the east wing flush-out ended, further testing and balancing was completed, systems furniture was moved into the building and punch lists were completed. Subsequently, air flush-out of the west wing was scheduled to begin. As the atrium construction ended, during the final stages of the west wing flush-out, and after all systems furniture was installed, flush-out began in the atrium.

MERV 13 filtration media was replaced after construction in each portion of the facility. The filtration media replacements occurred at the start of each flush-out phase.

The LEED® requirement for flush-out is 14 days, 24 hrs/day, using 100 percent fresh air. However, problems existed in meeting the LEED® flush-out requirements.

**1.** Designing a high efficient, low electric use system with the capacity to use 100 percent fresh air was too costly when the building would never operate on 100 percent fresh air.

**2.** The atrium was not designed with its own HVAC system, as it shares HVAC from the east and west wings, to eliminate mechanical and material costs and energy usage.

**3.** Modular systems furniture manufacturing had to be completed to get the remaining furniture in the building prior to flush out allowing it to off-gas, as required by LEED®.

**4.** The prime contractor was entering the final stages of substantial completion on the wings which meant punch lists were being performed requiring use of paints, glues and material installations.

Therefore, the building flush-out was performed for the entire building in three separate stages starting with the east wing only (38 days, 24 hrs/day), then the west wing only (74 days, 24 hrs/day) and ending with the atrium (34 days, 24 hrs/day). Testing and balancing was completed to calculate how much fresh air could be supplied to the flush-out in each stage to meet the requirement, which is allowed by LEED® to meet this requirement.

Testing and balancing was completed as the commissioning agent was completing their work, modular systems furniture shipment was received and the prime contractor completed punch lists allowing the flush-out to begin on the east wing. As the east wing flush-out ended, further testing and balancing was completed, modular systems furniture were moved into the building and punch lists were completed allowing flush-out of the west wing to begin. As the atrium construction ended, during the final stages of the west wing flush-out, and after all modular systems furniture were installed, flush-out began in the atrium.

## Indoor Air Quality – Occupancy

Decisions were made internally to move a minimum of furniture into the building that might contain urea-formaldehyde and other VOC-laden wood. Little funding was available to purchase new furniture. This meant that only a small amount of newly purchased wood furniture products would be moved into the building that would not have previously released their VOCs. Space standards were adjusted to eliminate approximately 52 offices in order to derive the greatest effect from daylighting. This meant most offices were able to be furnished using existing furniture that would have previously released its VOCs.

A janitorial service contract was necessary to assure that certified environmentally friendly or eco-friendly cleaning products were used in the building and that green-cleaning programs were developed to use the products effectively. Staff were trained to apply certified green-cleaning products as prescribed by manufacturers. Cleaning products can contain various toxic chemicals that emit VOCs, causing respiratory and dermatological problems, among other adverse effects. Under Green Seal guidelines, green cleaning also describes the means that cleaning products should be manufactured, packaged and distributed. If the manufacturing process is environmentally friendly and the products are biodegradable, then the term “green” or “eco-friendly” can be used.

The department had been working with BG Service Solutions for many years. The janitorial company had worked for the department in other facilities it leased. BG also was hired by the construction contractor to provide clean-up services, based on its past experience with BG in Columbia, Mo. A service contract bid was de-

veloped for the building using contract language previously developed for other department janitorial contract bids. Much of the contract language was based on janitorial contract service bids used by the Office of Administration, Division of Purchasing and Materials Management for other state janitorial agreements. The contract bid was subsequently awarded to BG Service Solutions. This award was offered due to several reasons, including BG's use of Green Seal certified cleaning products. Their method of performance was well developed and documented within the bid. BG also established a training program which was assured by written procedures. BG's good performance in other state facilities on the behalf of the department and other state agencies was noted and helpful in justifying the contract award to the company.

Building guidelines were developed by a team of department employees as a code of conduct in the building. Among the subjects contained in the guidelines, use of potpourri candles and other fragrances were banned from use in the building. The guidelines do not ban the use of perfume and cologne but indicate that employees should be aware that fragrances are triggers to the environmentally sensitive and that alternatives should be sought, if possible, to eliminate odors from impacting indoor air quality.

Bugs and spiders occur frequently due to the building being constructed a few hundred feet away from and above the Missouri River. Bugs and spiders are controlled by Office of Administration janitorial contract supervision staff. For many years, OA has been extremely sensitive to indoor air quality problems caused by the use of products containing VOCs. All bug and spider control is eliminated using eco-friendly products that do not contain VOCs or emit odors that are offensive or potentially dangerous to occupants.

Indoor air quality is so good in the Lewis and Clark State Office Building that occupants or facility management personnel can determine the odor and its source almost instantly upon arrival to a building wing. Occupants are cognizant of how odors are emitted, apply perfume and cologne judiciously, for the most part, prepare food in a manner that takes others into consideration and are quite aware of how odors affect others. The building air exchange system is also excellent at eliminating odors, especially in the food service court, where various entrees are served in the morning and afternoon.

## $CO_2$ Monitoring

The project originally had $CO_2$ monitoring in the conference center only. However, a decision was made to increase the number of permanent automated sensors and additional monitoring throughout the building to include the atrium and all wings to more adequately protect employees. $CO_2$ monitoring was added to the automated Equipment Management System to allow the system to be monitored online and report problems in real time if they occurred. $CO_2$ monitoring is designed to provide information about space ventilation performance while also allowing immediate operational adjustments when needed.

All the factors that met the IEQ mission of the project were integrated into the design and construction of the building from conceptual planning, throughout the design phase and into the construction management and administration. Building designers and planners, construction and state oversight managers and work group participants for the project worked in a partnership throughout the project. This cooperation and coordination assured that indoor air quality was a primary focus and met a specific mission of the building design and construction.

Post-occupancy studies have shown that employees are very pleased with the building's indoor air quality and it adds to their positive experience in the building.

## Conclusion

Ongoing post-occupancy studies indicate that there is more work to be done to better understand the effects of integrated building design strategies on occupants, especially in terms of indoor environmental quality. Many design firms are continuing to have problems with daylighting strategies, privacy and acoustic issues, as well as thermal comfort. Learning to maintain HVAC systems to optimize use of operable windows, occupant education, noise reduction dependent upon changes in occupant behavior and mechanical masking strategies are ongoing targets of improvement. A continual assessment of problems and possible solutions to window glare has also shown to be important to improving occupant satisfaction.

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