The bar was raised high for the building, also known as Block 225, before construction began. The California Department of General Services wanted a green building, and the design-build team set a goal of achieving LEED Gold certification—a relatively new green standard in 1999.

Block 225 is the first California state office building to use an underfloor air-distribution system and is the first design-build office building in the state’s history. The integrated approach to design and construction resulted in the building’s completion 10 months ahead of schedule. The design-build team and Department of General Services also received the Design-Build Excellence Award, Public Sector Over $15 Million, Design-Build Institute of America, 2003.

This article was published in High Performing Buildings, Fall 2009. Copyright 2009 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. Posted at www.hpbmagazine.org. This article may not be copied and/or distributed electronically or in paper form without permission of ASHRAE. For more information about High Performing Buildings, visit www.hpbmagazine.org.
spaced at relatively large intervals, UFAD systems deliver fresh air through a larger number of floor dif-
fusers strategically placed near each occupant. This system improves
thermal comfort while saving energy and generating less demand on
building operations and fewer main-
tenance calls.

A raised floor system forms the
low pressure underfloor plenum,
which supplies air to the floor dif-
fusers. The raised floor system
also serves as a cable manage-
ment raceway and allows for easy
maintenance on underfloor fan-coil
units. The ease of repositioning
floor diffusers reduces life-cycle
costs associated with maintenance
and reconfiguration of HVAC and
electrical services. Block 225 took
advantage of these potential savings
when the building was reconfigured
in 2003 to accommodate 250 addi-
tional workers.

Improved energy efficiency was
another goal of UFAD. In mild
western U.S. climates such as
Sacramento, UFAD energy sav-
ings are usually associated with

**Sustainable Design**

The design-build team developed
145 strategies for sustainable
enhancements, eventually incorporat-
ing 110 that provided the best value.

A sustainable design begins with
a high performance building enve-
lope. A thermoplastic membrane
roofing system is made with 100%
recyclable PVC-free rubber and
reflects over 70% of solar radiation.
It lowers roof temperature to 15°F to
25°F above the ambient temperature
and correspondingly lowers cooling
loads. Exterior glazing (sized at roughly a 40% window-to-wall
ratio), low-e coatings and tinted
glass improve thermal performance
while reducing glare.

A section of Block 225's penthouse
enclosure features a building-inte-
grated photovoltaic system. The 310
photovoltaic panels are integrated
into the exterior envelope design and
are capable of generating up to 2% of
the building’s power.

An underfloor air-distribution
(UFAD) system conditions floors
two to six. In contrast to the con-
tventional grid of overhead diffusers

Price Underfloor Air, Displacement Ventilation, and Radiant Systems Provide Unique Solutions for Improved Air Quality

www.price-hvac.com

The façade of Block 225 resembles a graduation cap. The building houses the California Department of Education headquarters.

A photovoltaic system is integrated into Block 225's mechanical penthouse enclosure. The 310 photovoltaic panels are capable of generating up to 2% of the building's power.

The EPA estimates that the average person spends 90% of their lifetime indoors.

Are you taking care of your most valuable resource?

Price is committed to the continual development of innovative air distribution technologies that promote and facilitate environmentally responsible building design.

Order your Sustainable Building Product Catalog online today at: www.price-hvac.com/green
Plenum Layout
For UFAD floors, conditioned air is distributed through a series of air highways—fabricated ducts consisting of the top of the slab, underside of floor panels, and two sheet metal sides—as shown by red shading in Figure 1. Variable volume dampers, spin-in units are mounted along the sides of the air highways to provide multiple plenum inlet locations across the large (50,000 ft²) floor plate. Figure 2 shows how the system of central corridors and air highways divides the plenum into distinct control zones. Each zone has at least one pressure sensor in the plenum and one thermostat in the conditioned space above. Underfloor variable speed fan-coil units at the building skin are ducted to linear bar grille diffusers located on the windowsills, as shown in Figure 2. These units draw supply air from the plenum and deliver it as needed during cooling operation. They provide heat from hot-water coils during heating.

Controls
Interior zones are controlled using a cascaded control loop. The underfloor pressure setpoint is reset based on (average) interior zone thermostat deviation from setpoint. Similar to interior zones, plenum pressure in perimeter zones is maintained by the adjustable spin-in dampers on the air highways serving that area based on a nearly interior zone thermostat. Signals from column-mounted thermostats at the exterior walls control the variable speed perimeter zone fan-coil units, which operate independently of the plenum pressure setpoint. This arrangement allows the fan coil units to meet high building skin loads even when plenum pressures are reduced due to low interior loads.

At the perimeter, underfloor variable speed fan-coil units are ducted to linear bar grille diffusers located on the windowsills. These units draw supply air from the plenum as needed during cooling operation and provide heat from hot-water coils during heating.

Figure 1
Four plenum dividers were installed on each floor, as shown here for the fourth floor, creating four separate, more manageable control zones for the UFAD.

Figure 2
Plenum Layout

KEY SUSTAINABLE FEATURES

Water Conservation
36% reduction of potable water consumption
67% reduction in irrigation water

Recycled materials
95% of construction waste diverted from landfill
100% of scrap/waste material was recycled
At least 25% of the building includes recycled materials
Up to 60% recycled content used in structural systems
53% recycled content in carpets
82% recycled content in acoustical ceiling tiles
More than 30% recycled content in 50,000 pounds of acoustical insulation, manufactured formaldehyde-free

Daylighting
Daylighting and views available for 90% of the space
Perimeter dimming controls when daylight and electrical loads are at peak
Task lighting at workstations operated by motion sensor
Low-e glazing

Individual Controls
Occupant controlled temperature, ventilation and lighting

Other Features
Up to 2% of electricity use generated on-site for Block 225 (photovoltaics produce 9.3 kW ac)
“Cool” roof (thermoplastic membrane)
Integrated Pest Management—Eco-friendly landscape design
(leading example became a statewide practice in California)
64% reduction in parking, with up to 53% being alternate transit

increased economizer use. Higher supply air temperatures and lower fan energy use due to decreased static pressure through the underfloor plenum contribute to energy savings.

In practice, measuring only the UFAD system’s energy performance is difficult, especially in Block 225, which uses multiple systems (a standard overhead variable-air-volume system was installed on the ground floor) and many energy-saving strategies. Nevertheless, the energy performance of Block 225 (see Energy Use) has been impressive.

Ninety percent of the interior spaces offer natural daylighting and outside views, further contributing to increased user comfort and reduced energy costs. Operable and task lighting (operated by motion sensors) are located at workstations, while perimeter dimming is activated when daylight and electrical loads are at their peak.

Occupancy sensors are used in all closed offices and utility rooms. Monitored electricity use (during occupied hours from September 2007 to August 2008) confirmed these reduced internal loads with average overhead lighting equal to 0.38 W/ft² and plug loads (equipment and task lighting) equal to 0.60 W/ft².

The design-build team worked with manufacturers to improve their processes and reduce volatile organic compound levels on products previously considered indoor eco-friendly. New methodologies relating to materials and testing were established to minimize the impact of source emissions on the interior environment, offering innovative advancements for industry-wide use.
ENERGY USE

The overall building electric and gas energy use for Block 225 is shown in Figure 3. Although a variation exists between years, the use is similar. ENERGY STAR ratings for Block 225 have been tracked through EPA’s Portfolio Manager since 2003. The May 2009 report is shown in Figure 4. The ENERGY STAR rating of 98 and the energy use intensity (EUI) of 43 kBtu/ft²·yr demonstrate exceptionally low energy consumption and prove that the building is operating efficiently. Its energy use is significantly lower than required for an ENERGY STAR label. The EUI has improved by about 15%, most likely because of extensive commissioning conducted since occupancy.

ENERGY AT A GLANCE

Energy Use Intensity (Site) 43.52 kBtu/ft²·yr
Natural Gas 6.6 kBtu/ft²·yr
Electricity 36.9 kBtu/ft²·yr
Renewable Energy 0.08 kBtu/ft²·yr
Annual Source Energy 130.1 kBtu/ft²·yr
Annual Energy Cost Index (ECI) 1.11 $/ft²·yr
Savings vs. Standard 90.1-2004 Design Building 42%
ENERGY STAR Rating 98

BUILDING ENVELOPE (MOSTLY BASED ON MODEL)

Roof
Type: White Roof – single-ply elastomeric polyurethane roofing
Overall Reflectivity: 0.5 minimum

Walls
Type: Architectural precast concrete, metal panels, stone, curtainwall
Overall Reflectivity: 0.23

Basement/Foundation
Type: Shotcrete and cast-in-place concrete; non-occupied basement

Windows
U-value
GL-1: 0.29 Btu/h·ft²·°F; winter: 0.3 summer;
GL-2: 1.09 Btu/h·ft²·°F; winter: 1.33 summer
Solar Heat Gain Coefficient (SHGC) 0.23

Location
Latitude: 38° 34’ 25.10” N (121° 29’ 20.89” W)

DIAGNOSTIC TOOLS TO MEASURE BUILDING PERFORMANCE

Minneapolis Blower Door™ The Leader in Airtightness Testing

Blower Door tests are used to measure the airtightness level of building envelopes, diagnose and demonstrate air leakage problems, estimate natural infiltration rates, estimate efficiency losses from building air leakage, and certify construction integrity.

For more than 20 years, the Minneapolis Blower Door™ has been recognized as the best designed and supported building airtightness testing system in the world. Combined with new features such as Cruise without a computer, specialized accessories and complete testing procedures developed by The Energy Conservatory, the Minneapolis Blower Door™ is the system of choice for utility programs, energy raters, HVAC contractors, builders, insulation contractors and weatherization professionals.

• Precision Engineered, Calibrated Fan
• Accurate, Powerful 2 Channel Digital Pressure and Flow Gauge
• Lightweight, Durable Aluminum Door Frame and Fabric Panel

For more information about options, price and delivery, please call 612-827-1117. To view and download the product literature and complete owner’s manual visit our website at www.energyconservatory.com.
SUSTAINABLE FEATURES

- Energy and Architecture
- Sustainable Site
- Water and Resources
- Indoor Environment Quality

Articulated columns support a covered arcade that shades visitors and the two-story glass curtainwall.

Solar Section

- Photovoltaic roof
- Energy Star roof reduces heat island and keeps building cool
- Underfloor air distribution for increased ventilation effectiveness
- Shaded arcades and light-colored pavement provide cool surfaces at pedestrian level

A post-occupancy evaluation (POE) survey was conducted in January and February 2003 (N=500). The fourth survey was conducted in October 2007 (N=650). The benchmark data includes 430 buildings (N=47,929).

Four post-occupancy evaluation (POE) surveys have been completed since the building was occupied in July 2002. Figure 5 compares average occupant satisfaction ratings for the most recent POE (October 2007) to those of the first POE (January/February 2003) and the large benchmark database. Response rates for both Block 225 surveys were close to 50% and were a fair, representative sample.

The survey results are generally positive, considering that Block 225 is a large open plan office building. The results for the fourth POE indicate that occupant satisfaction has increased significantly in most categories since the first POE. Three categories (general building, thermal comfort, air quality) were likely influenced by the existence of the UFAD system and the recommissioning and tuning up of the building’s HVAC operation. Floor diffusers give occupants a sense of personal control while increasing air movement and available fresh air.

Three categories (general building, thermal comfort, air quality) were likely influenced by the existence of the UFAD system and the recommissioning and tuning up of the building’s HVAC operation. Floor diffusers give occupants a sense of personal control while increasing air movement and available fresh air.

Floor diffusers give occupants a sense of personal control while increasing air movement and available fresh air. All categories were rated above zero except acoustic quality in the October 2007 survey. The acoustic quality rating is not surprising for a large open plan cubicle layout and is a contributing factor to the average or below average ratings for general workspace, office layout, and office furnishings. Improvements to the task lighting resulted in a large increase in satisfaction with lighting quality. The decline in satisfaction with cleanliness/maintenance and, to some extent, air quality since the first POE is likely due to the building’s increasing age.
Block 225 was procured as design-build project with a stipulated sum, or best value delivery, of $75 million. The design and construction teams, using an integrated design approach and reinvesting over a half million dollars from a shortened construction schedule, were able to provide additional sustainable features within the budget at no additional cost.

The cost of the sustainable features was estimated at roughly $1.2 million. The costs include additional design fees, materials testing, UFAD and application fees for LEED Gold. The design and construction team also researched and applied for grants to fund additional sustainable features, including the 350 building integrated solar panels, recycled rubberized asphalt street paving, and the daycare playground surface made from recycled sneakers.

The integrated design approach made a significant impact on the design production and construction schedule and costs. The contractor and subcontractors were on board early in the design process. This allowed the architect to work directly with the exterior envelope subcontractors to develop the shop drawings directly from the design intent documents. This streamlined the design document development and shop drawing submittal and review, significantly shortening the process.

The energy model predicted that the sustainable features would yield an average savings of $185,000 a year, resulting in an estimated payback period of less than seven years. However, the design team has been unable to verify the accuracy of the modeled energy cost savings. The building has been in operation since 2002, meaning that in theory, the principal investment has been recouped. The state should continue reaping savings each year from reduced operational costs.

Findings from the UFAD Field Study of Sacramento Capitol Area East End Complex will be posted at http://www.cbe.berkeley.edu/research/briefs-eastend.htm.

The patterned marble used for the stone floors in the main lobby and elevator lobby was recycled and reused from the original Sacramento Library and Courts Building, circa 1923.

Landscape designers for Pocket Park selected plant species that attract beneficial insects and animals, providing natural pest control.
A LEED innovation credit was achieved through a new Green Education Outreach Program. The project team created an educational brochure describing the building’s sustainable features, which is distributed to schoolchildren and tourists. R&D of sustainable design and materials provided the basis for the California Best Practices Manual, which is used statewide as a guide for green building in California. The team also developed Section 01350 of the manual, “Special Environmental Conditions,” for managing the LEED, design, and construction processes for sustainability.

Block 225’s high performing envelope, innovative design features and fully integrated design resulted in a building that outperformed California Title 24-98 energy codes by 43% (based on simulation capabilities in 2002), saving an estimated $185,000 a year in energy costs alone. It reduced potable water consumption by 36%, used recycled content in at least 25% of building materials, and reduced air, light and noise pollution. The exceptional effort to maximize use of low-emitting materials, paired with improved ventilation effectiveness provided by the UFAD system, produced a healthier indoor environment.

As a fast-track design-build project, Block 225 finished 10 months ahead of schedule by using innovative techniques in design production and construction. The design-build team delivered the best value by eliminating 10 months of construction costs (general conditions and overhead costs) and reinvesting the savings—a half million dollars—into sustainable features.

These efforts were rewarded with a LEED Gold certification—the first LEED certified state office building in California.

Thermal decay Performance measurements during the first few years of occupancy revealed larger than expected temperature gain (thermal decay) in the supply air as it traveled through the underfloor plenum in this 50,000 ft² floor plate building. The entire outer ring of the building’s perimeter space was a single open, connected plenum zone at the time. This increased travel distances of supply air before delivery, thereby likely increasing thermal decay. The control of thermal decay was improved by dividing the plenum into smaller zones using plenum dividers or other means (Figure 1), particularly along different exposures of the perimeter zone. This retrofit resulted in higher occupant satisfaction.

Reset strategies Since heating is provided only in the perimeter zones, supply air temperature reset strategies must be carefully considered in plenum zones serving both interior and perimeter spaces. During periods of peak cooling demand at the perimeter, reducing the supply air temperature entering the plenum (to address perimeter loads) must be traded off against overheating occupants in the interior.

Perimeter sill grilles Perimeter sill grilles are architecturally attractive. However, installing perimeter diffusers at floor level reduces the vertical projection (mixing) of supply air in the room, improving stratification and energy performance in the perimeter zones.

Thermal decay Performance measurements during the first few years of occupancy revealed larger than expected temperature gain (thermal decay) in the supply air as it traveled through the underfloor plenum in this 50,000 ft² floor plate building. The entire outer ring of the building’s perimeter space was a single open, connected plenum zone at the time. This increased travel distances of supply air before delivery, thereby likely increasing thermal decay. The control of thermal decay was improved by dividing the plenum into smaller zones using plenum dividers or other means (Figure 1), particularly along different exposures of the perimeter zone. This retrofit resulted in higher occupant satisfaction.

Reset strategies Since heating is provided only in the perimeter zones, supply air temperature reset strategies must be carefully considered in plenum zones serving both interior and perimeter spaces. During periods of peak cooling demand at the perimeter, reducing the supply air temperature entering the plenum (to address perimeter loads) must be traded off against overheating occupants in the interior.

Perimeter sill grilles Perimeter sill grilles are architecturally attractive. However, installing perimeter diffusers at floor level reduces the vertical projection (mixing) of supply air in the room, improving stratification and energy performance in the perimeter zones.

Conclusion The aggressive approach toward Block 225’s green design resulted in energy savings, reduced the building’s impact on the environment and helped establish sustainable building practices for the state of California. Continued maintenance and adjustments to the mechanical systems will help ensure a century of efficient operations.

Conclusion The aggressive approach toward Block 225’s green design resulted in energy savings, reduced the building’s impact on the environment and helped establish sustainable building practices for the state of California. Continued maintenance and adjustments to the mechanical systems will help ensure a century of efficient operations.

Energy efficiency has a new name

Introducing Strategos™ rooftop units, the most energy-efficient units of their kind. Designed to cut energy usage, lower operating costs and reduce environmental impact, Strategos units are a critical element in a successful strategy for sustainable design.

Energy efficiency with continuous ROI

By controlling energy spending, Strategos™ innovative design dramatically reduces HVAC total cost of ownership. Up to 66% more efficient than U.S. Department of Energy regulations with ratings up to 14.3 EER, 16.1 SEER and 16.4 IPLV, Strategos units help meet green building design objectives including the attainment of LEED credits.

Advanced design for a better environment

Lennox continues its legacy of innovation with its MSAVT™ (multi-stage air volume) supply fan. This revolutionary new technology provides up to seven levels of airflow, helping to conserve energy while still meeting comfort requirements. Present at the factory for quick and easy start-up, users can also customize airflow settings using the unit’s Integrated Modular Controller. With units that come standard with a full list of features, Lennox offers the high-quality products to meet your specification requirements.

For more information on how Strategos units can help you increase efficiency and comfort, contact the experts at Lennox.

Curtis Fentress, FAIA, RIBA, is the president and principal-in-charge of design at Fentress Architects.

Greg Gidez, AIA, DBIA, LEED AP is the corporate manager of design services for Hensel Phelps Construction Co. and serves on the DBIA Board of Directors.

Fred Bauman, P.E.; and Tom Webster, P.E.; are research specialists with the Center for the Built Environment at the University of California, Berkeley.

Matt Popowski is the public relations coordinator at Fentress Architects.

Darryl Dickerhoff is a principal research associate at the Lawrence Berkeley National Laboratory.

Leaves have a color/size advantage in the Strategos line. This effective design provides up to 66% more efficiency than U.S. Department of Energy regulations, with ratings up to 14.3 EER, 16.1 SEER and 16.4 IPLV. Strategos units help meet green building design objectives including the attainment of LEED credits.

1-800-9-LENNOX • www.lennox.com

© Lennox Industries Inc., 2009

HPB.hotims.com/26999-12

1-800-9-LENNOX • www.lennox.com

© Lennox Industries Inc., 2009

HPB.hotims.com/26999-12