PRACTICAL APPLICATIONS FOR INNOVATIVE HVACR MECHANICAL SYSTEMS ENGINEERS

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At this lakefront digital library, a university combines radiant heating and cooling with natural ventilation to elevate performance to the next level.

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Lakefront Library:

Radiant Systems Meet Natural Ventilation

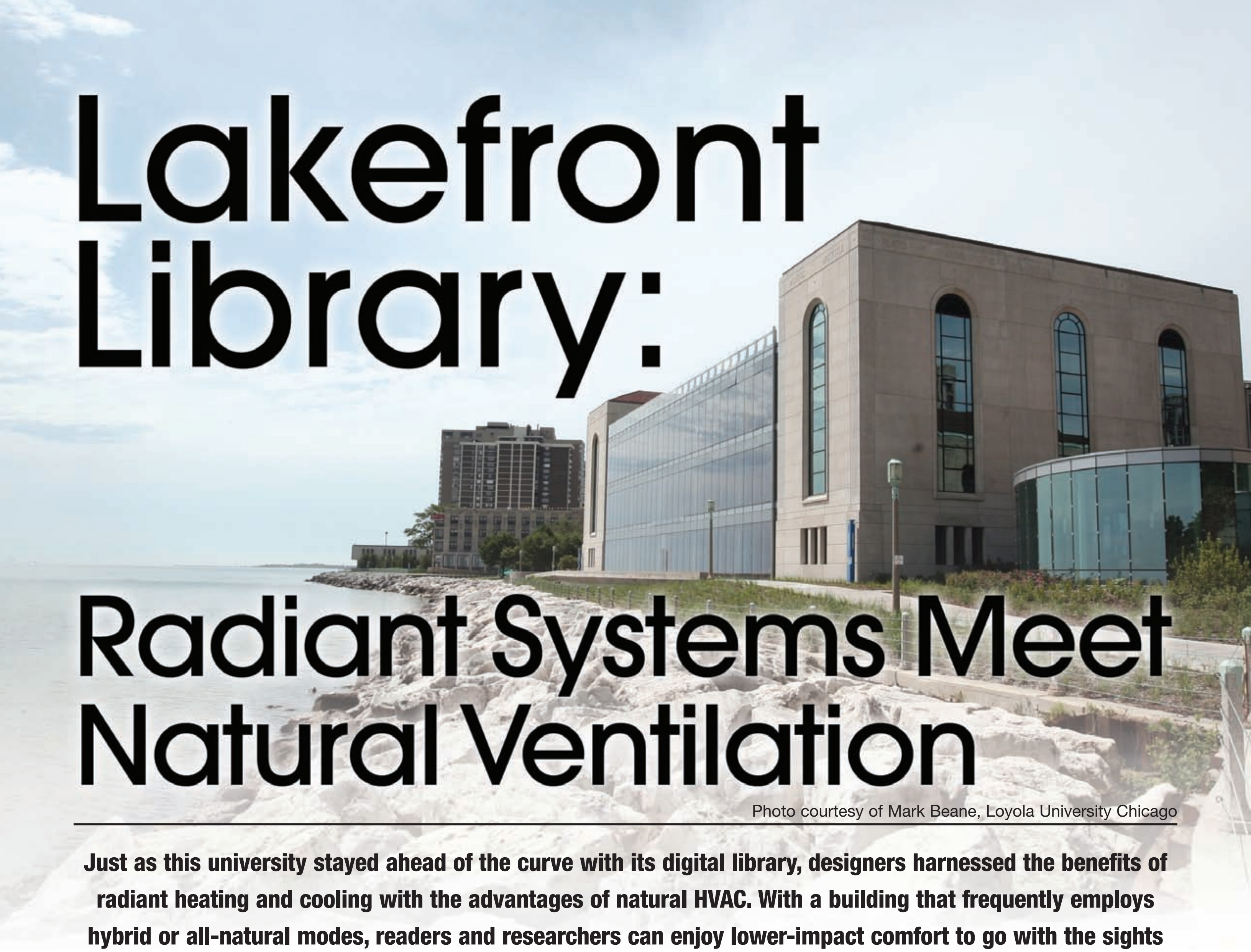

Photo courtesy of Mark Beane, Loyola University Chicago

Just as this university stayed ahead of the curve with its digital library, designers harnessed the benefits of radiant heating and cooling with the advantages of natural HVAC. With a building that frequently employs hybrid or all-natural modes, readers and researchers can enjoy lower-impact comfort to go with the sights and sounds of Lake Michigan.

BY DAVID LAVAN AND DON MCLAUCHLAN, P.E., CEM, LEED® AP

Loyola University Chicago's (LUC) new digital library, named Klarchek Information Commons began with very ambitious goals. The university wanted a visually transparent, energy-efficient building built on the shores of Lake Michigan where students could learn and exchange information digitally in a "book-less" library. With the lakeshore location, there was an additional goal of creating an indoor experience similar to being outdoors on a beautiful day. To meet these aggressive goals, Solomon Cordwell and Buenz (SCB, architect) assembled the design team of Transsolar (indoor climate consultant), Elara Energy Services (MEPFP engineer), and Halvorson and Partners (structural engineer). Unlike much traditional construction, this project required a very high level of integration and coordination with all the design elements of the building. The building was complete in January 2007 and has attained LEED® Silver certification.

Typically, the percentage of glass necessary to achieve transparency is not complementary with the goal of energy efficiency. In an effort to maximize the views of the lake, and to further complicate matters, the building was oriented with its primary axis running almost near north-south. This design parameter created additional challenges to control glare and solar heat gain loads on the building.

The building is approximately 70,000 sq ft, with three full floors and a partial fourth floor. There are three floors of large open space in the center of the building, with all-glass east-west facades flanked by traditionally constructed bookends. There are classroom/seminar rooms in the bookends and open study areas with partially glass-partitioned group study areas in the center open area. There is a ground-floor café and connecting links to the existing traditional library and chapel. The main building access is through a "winter garden" entry space on the west side. The roof is partially vegetative.

To meet these considerable challenges the following innovative strategies were implemented.

VENTILATED, DOUBLE FAÇADE WINDOWS WITH INTERSTITIAL SHADING

In order to mitigate solar heat gain on the west side and improve the overall "U" factor of the glass façade, a double skin was selected. The motorized Venetian blinds in the interstitial space deploy when needed to block direct sunlight and control glare. The interstitial space is naturally ventilated with intake air entering through cavity dampers at the bottom and exhausting through awning windows located at the top of the four-story glass stack.

FIGURE 1. The radiant cooling system used in the ceiling at Klarchek Information Commons was designed to meet 60% of the sensible cooliong load with approximately 4 W/sq ft of cooling power at 80% ceiling coverage.

It was determined through CFD modeling that a negative pressure would be created at the top of the glass stack to enhance the chimney effect and naturally ventilate this space, regardless of wind direction

NATURAL VENTILATION

With the building located within a green campus environment and immediately adjacent to the lake, this project was an ideal candidate to take full advantage of nature whenever possible to create indoor comfort. To accomplish this, automatically controlled windows were used on the east façade, as well as on the inner windows on the west double façade (Figure 2). These windows, in conjunction with the motorized awning windows at the top of the glass stack, allows for exceedingly effective natural ventilation throughout the open areas. This effectiveness is achieved with the combination of the negative pressure created by the thermal buoyancy of warm air in the west side interstitial space as well as the effect of the wind blowing across the top of the glass stack. This draws air through the inner west side windows, across the open areas, from the windows on the lakeside of the building to the east. Furthermore, with the inclusion of massive concrete ceilings, the night's "coolness" could be harvested to aid in conditioning the space on the following day. It was predicted through modeling that approximately one-third of the occupied hours of the year, the building would be conditioned naturally.

RADIANT CEILINGS

Radiant heating technologies have long been used in the United States, but only recently has radiant cooling gained increasing acceptance. The following are some of the advantages of radiant heating and cooling.

FIGURE 2. Computational flow dynamics was used to design Klarchek Information Commons at Loyola University Chicago.

Comfort/with more energy temperate setpoints. It has been shown that people are comfortable at lower temperatures in heating and at higher temperatures while in cooling when exposed to radiant ceilings or floors. This is due to the radiant energy exchange between the occupant and surrounding heated/chilled surfaces. For example, depending on the temperature of the ceiling, 68°F may feel like 70° in heating, and 77° may feel like 75° in cooling. This operative temperature is a weighted average of air temperature and average surrounding surface temperatures.

The radiant energy exchange is governed by the Stefan-Boltmann equation. Using an accepted value of 0.87 for the radiation exchange factor, this equation becomes (using equation 5 from the 2008 *ASHRAE Handbook – Systems and Equipment*, page 6.2):

$$Qr = 0.15 \times 10^{-8} [(tp)^4 - (AUST)^4]$$

Where
Qr = radiant cooling, Btuh/sq ft
tp = mean panel surface temperature, °R
AUST = area weighted average temperature of the non-radiant panel surfaces of the room, °R

In addition to the radiant energy exchange, there is also a convective component. This component can be approximated with the following equation (ASHRAE 2008):

$$Qc = 0.31 [tp-ta]^{0.31} (tp-ta)$$

Where
Qc = natural convection from a cooled ceiling, Btuh/sq ft
ta = AUST for ceiling cooled spaces with large proportions of exposed fenestration, °R

Lower distribution energy. Due to the excellent thermal properties of water, the transport energy associated with a radiant system (pump energy) is significantly lower than the equivalent transport energy for an air system (fan energy).

Some of the challenges associated with radiant systems include:

- Controlling the indoor dewpoint in the cooling mode to avoid condensation on the surface of the radiant panels
- The slow response to step loads typical of massive radiant systems

At Klarchek Information Commons, the decision was made to use cross-linked polypropylene (PEX) tubing imbedded in the precast concrete ceiling panels. The 5/8-in. PEX

Green Construction Institute: Advanced Learning For A Sustainable Future

Hill Mechanical Group, part of the team for this project, is a member of the Mechanical Contractors Association (MCA) of Chicago and employs workers from United Association Pipe Fitters Local Union 597, who receive green training from MCA Chicago's Green Construction Institute.

MCA Chicago established the Green Construction Institute to further the cause of sustainable practices in the construction industry. In addition to Local 597 apprentices and journeymen, the Institute also offers educational opportunities to the association's member contractors, as well as engineers, city officials, and building owners, among others.

"Education is a top initiative of the association," said Stephen Lamb, executive vice president of MCA Chicago. "For three years, the association has been instructing our member contractors on sustainable technology. This year, we decided it was time to formalize our efforts by founding the Green Construction Institute."

"Any business in the construction industry that ignores sustainable technology runs the risk of being left behind — and losing market share," stated Dan Bulley, senior vice president of MCA Chicago, executive director of the Green Construction Institute, and a LEED® Accredited Professional (AP).

The Green Construction Institute's educational offerings include the following:

- Introductory course in green building for contractors
- Apprentice and craft training
- Technical, equipment and design: Training on green building methods and materials
- Legal and insurance advice
- LEED AP training
- Marketing: How to promote green building to clients
- CEO training: How business leaders can position their companies
- Owner training: Online seminars for owners on LEED Existing Building (EB) and New Construction (NC)
- Visioning: How green building will intersect in the future with build-B, building information modeling (BIM), and other industry developments
- Green building publications
- LEED consulting services
- Contractor assistance to find financing options on energy payback projects
- Contractor and/or owner assistance to find grants for green projects

This September, MCA Chicago and the Green Construction Institute moved from a suite in downtown Chicago to their new headquarters in a green building in Burr Ridge, IL. The building was built and equipped with low-emitting materials, which contribute to better IAQ by releasing minimal toxins over time.

"Not only do attendees of the Green Construction Institute learn the latest in sustainable technology," Bulley said, "but they also enjoy the comfort of a healthier indoor environment as they learn."

To find out more about MCA Chicago, visit *www.mca.org*.

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tubing was placed a few inches above the surface at 6-in. centers. Due to the contour of the coffered ceiling, care had to be taken to avoid air traps. A spiral pattern of the tubing was incorporated to minimize temperature gradients across the slab. The manifolds were placed underneath the structural raised floor, which was used throughout the building.

The ceiling system was designed to meet 60% of the design sensible cooling load, with approximately 4 W/sq ft of cooling power at 80% ceiling coverage.

An underfloor air system (UFAS) was designed to provide ventilation air and supplemental radiant cooling systems on design days. To improve overall dehumidification and lower indoor dewpoint temperatures, the air handlers that supplied air to the UFAS were custom designed.

In heating mode, the air handlers operate as a variable DOAS with heat recovery (Figure 4). There are individual VAV boxes, which in heating mode respond to measured CO_2 levels in the space.

In cooling mode, a runaround coil was designed to enhance the latent heat/moisture removal of the outside air. A separate return air path was used to further dehumidify the space. The return air path uses a stacked coil arrangement allowing part of the air to be cooled low enough to effectively dehumidify the air. The temperature of the conditioned outside air path and the conditioned return path were set as equal and mixed at the blower. Since these air handlers supply the open areas of the library, the space is treated as one large zone from a CO_2 standpoint. The delivered volume of outside air is controlled by the highest measured CO_2 in the space. The individual boxes in cooling are controlled by measured CO_2 levels with a temperature override. The fan speeds are controlled by static pressure.

To further enhance dehumidification in the space, the bookend seminar/classrooms are conditioned by a traditional VAV ceiling supply system to respond to the anticipated step cooling loads. The supply of the air to those spaces was designed at 51.5° to provide good de-humidification. Since there is no significant vapor barrier between the bookends and the open areas this lowers the overall humidity in the building. Sensors are embedded in the ceiling to monitor the actual ceiling surface temperature. The BAS maintains the ceiling temperature in cooling between 62° to 67° as required for cooling, or 3° higher than the measured indoor dewpoint. In cooling mode, the space temperature is trimmed with the UFAS.

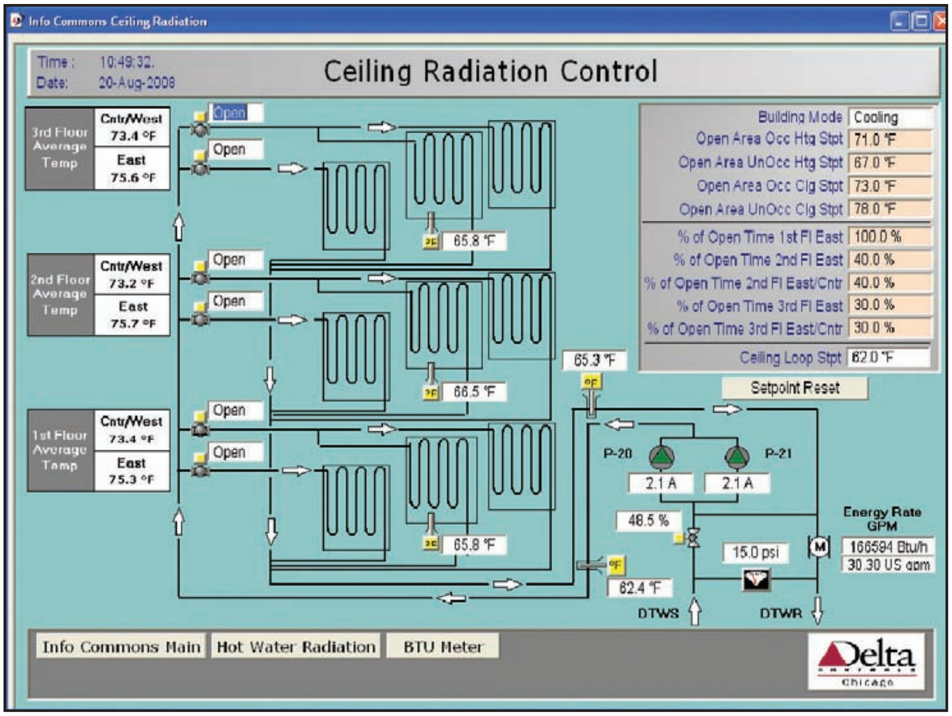
Improved plant efficiency. Since the ceiling is maintained between 62° to 67° in cooling, 56° to 58° return water to the central plant is used to chill the ceilings. This increases the return water temperature to the central chilled water plant and increases the overall efficiency of the chillers. Another benefit is that no additional primary chilled water is used and the additional hydronic pressure drop of the chillers and associated auxiliaries is avoided. In heating mode, this same dual-temperature loop supplies warm water from the central plant for the radiant ceiling and the other systems requiring hot water.

Daylighting. An automatic digitally controlled dimming system harvests natural daylight and reduces required artificial light energy.

Demand controlled ventilation. CO_2 sensors were installed throughout the space to control the volume of outside air required while maintaining the space IAQ.

Heat recovery. The system recovers approximately 45% of the available energy from the exhaust air to precondition the outside air needed for ventilation (Figure 4).

External/internal shading. The west-side façade has motorized Venetian blinds that are controlled by the BAS. The blinds are only



Info Commons Ceiling Radiation

Ceiling Radiation Control

Time : 10:49:32.
Date: 20-Aug-2008

3rd Floor Average Temp: Cntr/West 73.4 °F; East 75.6 °F
2nd Floor Average Temp: Cntr/West 73.2 °F; East 75.7 °F
1st Floor Average Temp: Cntr/West 73.4 °F; East 75.3 °F

Building Mode	Cooling
Open Area Occ Htg Stpt	71.0 °F
Open Area UnOcc Htg Stpt	67.0 °F
Open Area Occ Clg Stpt	73.0 °F
Open Area UnOcc Clg Stpt	78.0 °F
% of Open Time 1st Fl East	100.0 %
% of Open Time 2nd Fl East	40.0 %
% of Open Time 2nd Fl East/Cntr	40.0 %
% of Open Time 3rd Fl East	30.0 %
% of Open Time 3rd Fl East/Cntr	30.0 %
Ceiling Loop Stpt	62.0 °F

Energy Rate GPM: 166594 Btu/h; 30.30 US gpm

FIGURE 3. A BAS graphic of the radiant ceiling.

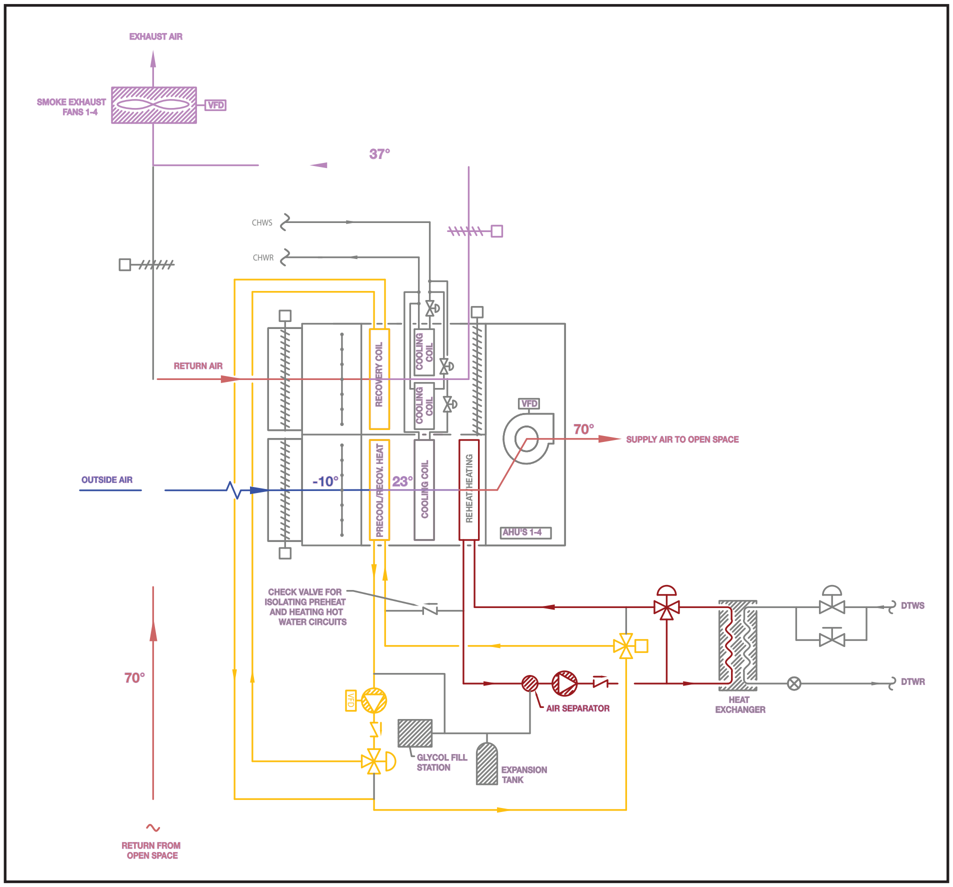


FIGURE 4. Heat recovery mode.

deployed when both the celestial calculations of the sun position and the ambient external light sensor determine that external shading is required. When required, the blinds are lowered and the angle of the 4-in. slats is adjusted based on the angle of the sun's rays. On the east façade, there are motorized rollup shades that are controlled in a similar manner except that there is only one degree of motion.

Hybrid mode. To further reduce cooling and fan energy, the building has a hybrid mode where the system is in natural ventilation (all the fans are off and the windows are open) and the radiant chilled ceiling is activated. In this mode, the outdoor dewpoint is equal to the indoor dewpoint, requiring additional precautions to avoid condensation. The ceiling temperature is kept 5° above the outdoor/indoor dewpoint in this mode.

Intelligent control. It was imperative that all these dynamic systems be integrated into the BAS. BACnet® was used as the backbone to integrate standalone system protocols. The BAS was integrated into the campus-wide network to allow the monitoring and operation of the building. Electric submeters and Btu meters were installed and connected to the BAS to provide real-time monitoring of the energy usage and long-term trending.

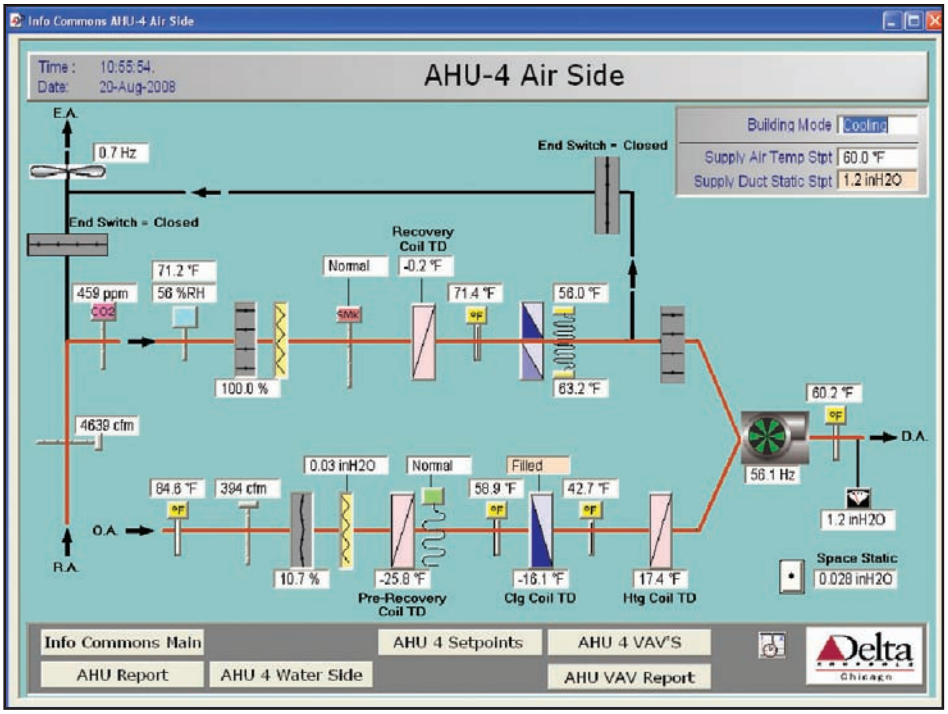
Energy model and actual results. The design model predicted 52% less energy usage than an ASHRAE 90.1-base building, excluding computer/plug loads. Figure 3 provides a summary of the design energy model with computer/plug loads based on 24/7 operation.

Chilled water is supplied from a central plant with a measured average efficiency of 0.6 kW/ton, including the tower fans and pump energy. Heating is supplied via the central steam plant, with an average measured steam to fuel efficiency of 82.5%.

During a 30-day period in July/August, the system was in natural or hybrid mode approximately 37% of the time. During one 84° day, it was observed that the building was being cooled with only 32 tons of cooling. It was further observed that the base plug-load energy was higher than anticipated. Field measurements showed that over 50% of the total electric usage (including space cooling) was attributed to computers (over 300 PCs) and plug loads. Currently, the university IT department keeps the computers in ready mode at all times. This has resulted in an average computer plug load of 1 W/sq ft. Even with higher-than-anticipated computer usage, the total building performance is as expected.

LESSONS LEARNED

The natural ventilation system was the most


Info Commons AHU-4 Air Side

Time : 10:55:54.
Date: 20-Aug-2008

AHU-4 Air Side

Building Mode Cooling
Supply Air Temp Stpt 60.0 °F
Supply Duct Static Stpt 1.2 inH2O

Space Static 0.028 inH2O

FIGURE 5. An airside graphic.

challenging to commission. Loyola's project management team is still working through some issues with unreliable window actuators and insect screens on the east facade. Despited these issues, the building has performed better than expected in natural-ventilation mode. Typically, the system is operating in either natural or hybrid when outside air temperatures are between 55° and 75°. The indoor temperature can generally be maintained within 1°F of the outside temperature. This translates to approximately 5 cfm/sq ft of outside air. Further, the audible experience of the rhythm of the waves on Lake Michigan adds to the aesthetic appeal of the facility.

Although we are still optimizing the systems and expect to further improve the facility's energy efficiency, feedback from students and staff has been incredible. The goal of the university was to create an environment that meets the three C's: Collaboration, Connectivity, and Community. All the current feedback suggests that these goals are being met. **ES**

McLauchlan is principal of Elara Energy Services, Inc.. He brings over 30 years of experience in MEP design, construction, and commissioning and has received nine first place Illinois ASHRAE excellence in engineering awards. He is a licensed professional engineer, certified energy manager and LEED® AP. He has authored several technical articles for trade journals and has been a speaker at numerous industry conferences. He holds a bachelor of science degree in mechanical engineering (BSME) from University of Illinois at Chicago.

Lavan is a senior engineer with Elara Energy Services. In addition to his experience in MEP design, he has lectured in the mechanical engineering department at the University of Illinois at Chicago. He has received three first place Illinois ASHRAE excellence in engineering awards. He holds a bachelor of science degree in mechanical engineering from Illinois Institute of Technology, a bachelor of science degree in physics from Northeastern Illinois University and a masters of science degree in mechanical engineering from University of Illinois at Chicago.