Holistic Design Approach For Energy Efficiency

Using LED and fluorescent lighting, the lighting design was modeled to maximize lighting effect while reducing energy use.

BY DEVIN CHEEK, P.E.

The CMTA Lexington Office in Lexington, Ky., is a newly constructed two-story, 11,750 ft^2 (1092 m^2) building designed by architects Sherman Carter Barnhart and the MEP design was done by the owner CMTA Inc. The building achieved LEED Platinum and earned a perfect Energy Star rating of 100. CMTA has an office building of similar size and use in Louisville, Ky., built in 2009 that also achieved an Energy Star rating of 100.

The design team wanted to implement different strategies in the Lexington office so the Louisville and Lexington buildings could be compared and the strategies analyzed for their effect on energy use and first cost. In addition, design engineers wanted to showcase these strategies to future building owners for a better understanding of the available technologies and help them make informed decisions for their projects.

Energy Efficiency

The Lexington building was modeled and predicted to consume 19.5 kBtu/ft^2 yr (222 MJ/m^2·yr). The predicted consumption showed a 63% reduction when compared to the ANSI/ASHRAE/IESNA Standard 90.1-2007, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, baseline case of 37.4 kBtu/ft^2 yr (425 MJ/m^2·yr). The building operated at 15.6 kBtu/ft^2 yr (177 MJ/m^2·yr). after the first year of operation. This was achieved by taking a holistic approach to the building's design (HVAC system, lighting design and the building envelope) and operation. Energy meters were installed for the HVAC, lighting and plug loads so engineers could see the difference that these technologies made in the new building compared to the Louisville office building. The HVAC system design used a single pipe loop that helped reduce the overall installed horsepower of the building while maximizing the efficiency of the system. Lighting design was modeled to maximize the lighting effect while reducing the energy use. This was accomplished with the use of LED and fluorescent lighting due to cost effectiveness of the fixtures at the time this office was built. The lighting design was 0.63 W/ft^2 (6.78 W/m^2); 37% better than the ASHRAE Standard 90.1-2007 code compliance. The building envelope also played an important role in energy conservation. Using

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Building at a Glance

CMTA Lexington Office

Location: Lexington, Ky.

Owner: CMTA Consulting Engineers

Principal Use: Consulting Engineering Offices

Includes: Office space and conference rooms for MEP design work

Employees/Occupants: 38

Gross Square Footage: 11,750

Conditioned Space Square Footage: 11,750

Substantial Completion/Occupancy: July 2012

Occupancy: 100%

PHOTO 1 The newly constructed two-story, 11,750 ft² (1092 m²) CMTA Lexington Office in Lexington, Ky. Using insulated concrete form (ICF) construction provided a high resistivity to heat flow with a value of R-40.

insulated concrete form (ICF) construction provided a high resistivity to heat flow with a value of R-40 and also gave the building significant thermal massing and the ability to hold temperatures during setback and unoccupied schedules. The designers were conscious of the building's tightness and had the building pressure tested. The allowable leakage rate according to the ASTM Standard is 5,488 cfm (2590 L/s). The CMTA building tested at 1,730 cfm (816 L/s), which is a 70% reduction of airflow leaking with just a slightly positive pressurized building.

PHOTO 2 Single pipe loop system. Heat pumps are supplied and returned from a common pipe.

Indoor Air Quality

ANSI/ASHRAE Standard 62.1-2007, *Ventilation for Acceptable Indoor Air Quality,* air quality calculations were performed for the CMTA Lexington office building. This building has an energy recovery ventilator that provides fresh air to the building. The building temperature ranges were set at 75°F (24°C) cooling and 68°F (20°C) heating and a humidity range of 40% to 60% to meet ANSI/ASHRAE Standard 55-2004, *Thermal Environmental Conditions for Human Occupancy*, for thermal comfort. However, most occupants keep their spaces at 72°F (22°C) during occupied hours.

All of the occupants have access to operable windows. Studies were conducted to determine the optimal time that opening the windows would be permitted to achieve occupant comfort without sacrificing energy efficiency. This range was concluded to be 50°F to 70°F (10°C to 21°C) outside air temperature with a maximum outdoor humidity of 50% relative humidity. The occupant's ability to open their windows has been a great amenity in the building. Demand control ventilation was a consideration during design; however, due to the types of spaces and occupancy there were not enough transient areas in the building to warrant the sensors based upon the life-cycle costing. Using the proper amount of ASHRAE Standard 62.1-2007 specified constant outdoor airflow during occupied hours was better for indoor air quality and more cost effective than CO_2 sensors.

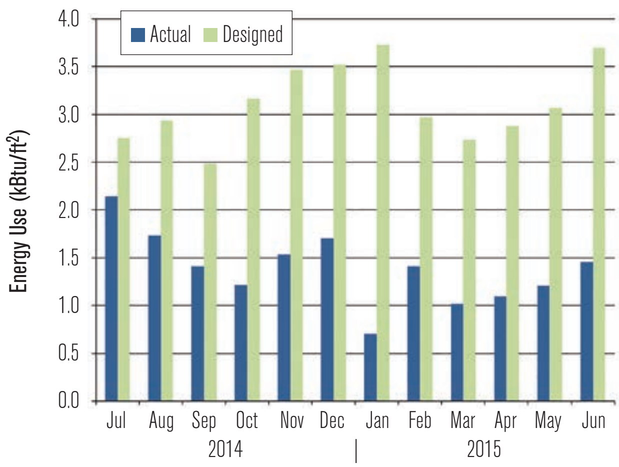

FIGURE 1 The Lexington building was modeled and predicted to consume 19.5 $kBtu/ft^2 \cdot yr$ (222 $MJ/m^2 \cdot yr$). The building operated at 15.6 $kBtu/ft^2 \cdot yr$ (177 $MJ/m^2 \cdot yr$). after the first year of operation.

PHOTO 3 Geothermal entrance and centralized variable speed loop pump. Easy access to well field isolation.

To ensure occupant comfort a thermal comfort survey was developed. Targeting especially cold winter days, mild fall/spring days, and hot summer days, the survey was distributed to staff. It was concluded that less than 5% of occupants were dissatisfied and thermal comfort and air quality complaints have been reduced, and absenteeism has improved as a result of meeting and or exceeding Standard 55-2004.

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Innovation

The HVAC system for the building is a geothermal ground loop system. However, this building uses a single condenser loop throughout with individual electronically commutated motor (ECM) pumps for each heat pump that only has head pressure to pump the water through the heat pump. Using these low-pressure pumps with ECMs allows these pumps to operate up to 82% efficient.

The building has a main variable speed centralized pump that circulates the water through the geothermal well field and the building. Traditional design would vary the speed on the pump based upon the differential pressure in the hydronic system. In this design, the pump is controlled on the condenser water temperature to maximize operating efficiency of the heat pumps. In a typical geothermal design, the loop temperature would operate between 40°F to 95°F (4°C to 35°C) depending on the season. These two temperatures are not where the heat pumps operate at maximum efficiency. Rather than let the well field loop temperature (condenser water) fluctuate, designers tried to optimize the number of hours the heat pumps have 65°F to 80°F (18°C to 27°C) condenser temperatures to achieve energy efficiency ratios (EER) over 40. With this design, the total installed horsepower in the building was decreased significantly and was 40% to 50% less than that of similar geothermal buildings.

PHOTO 4 Easy to access heat pumps and one common filter size makes operation and maintenance easier.

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This building has a total installed horsepower of 1.3 hp (0.97 kW). Engineers compared the Lexington, Ky., building to a recent high efficiency, LEED Gold, geothermal office building with similar function and occupancy schedule but with centralized pumping and found that the distributive pumping strategy alone showed a decrease in 25% horsepower.

Another innovation happened on the domestic hot water side. The geothermal heat pumps are equipped with a domestic water desuperheater that uses waste heat from the heat pumps' refrigeration cycle. Rather than rejecting the waste heat back to the geothermal loop the desuperheater uses that energy for domestic water heating, taking demand from the electric water heater. On the air side, solar powered linear slot diffusers were used in private offices along the perimeter of the building. A motorized damper, powered by solar energy, changes the throw pattern of the diffusers depending on the discharge air temperature. If the supply air is cool it is distributed toward the occupant, if that air is warm it is directed toward the exterior walls and windows.

These innovative features allowed for the building to become a learning lab, with the purpose to collect real measured data from various high-performance features of the building. These results will be shared among employees and clients of the building's owner, as well as the building owners, architects and engineers throughout the industry. The actual data of specific systems will help determine true performance, energy use, savings and return on investment.

Operation and Maintenance

As the designers, owners and tenants of the building, the maintenance of the CMTA Lexington office was highly important to the occupants. The majority of the heat pumps were installed in a second floor mechanical room versus installation above the ceiling, which allows for easier maintenance. In addition, all heat pump filters were similarly sized to prevent the need for stocking different sizes, allowing for the use of more efficient filters, which contributes to better indoor air quality. On typical geothermal well field installations, well field isolation valves and access are located in a buried vault but for ease of access we provided the geothermal entrance in the building. All geothermal well isolation and valving is located on a basement wall for easy maintenance and operation.

Meters were installed in the building to separate the energy use of the plug load, lighting load and HVAC loads of the building. This allows users to manage the energy and understand what factors increase or decrease energy use. Engineers and occupants can then review these areas with employees or make temperature/schedule changes as needed to reduce energy and get the building back in line for optimum operation. Engaging the tenants gives them ownership of energy reduction strategies. Modifying human behavior (i.e., turning lights off or shutting down computers) allows for higher energy savings.

Environmental Impact

The building is equipped with an 8.58 kW monocrystalline solar PV system that offsets approximately 17% of the building's energy use. After the first full year of operation the PV system was producing 11% more electricity than what was predicted through the modeling process during design. A portion of the building's electricity was served by Green Power through an agreement reached with the local utility company. This guarantees that some of the electricity consumed from the utility company was produced by a renewable resource to help conservation of natural resources. Typically, PV systems are associated with a modern or contemporary architectural aesthetic but designers wanted to show that a building with a traditional and historic design could be paired with modern PV technology in an appealing way. The PV system has a payback of approximately 12 years. The 30% federal tax refund and selling of solar renewable energy certificates (RECs) helped achieve faster than normal paybacks. (One block of RECs were purchased with a two-year enrollment.) The building has parking spots near the front door dedicated to low-emission vehicles that encourage the use of that mode of transportation. During construction, silt barriers were erected around the site to eliminate soil runoff to adjacent areas and municipal utilities. About 70% of the building's waste

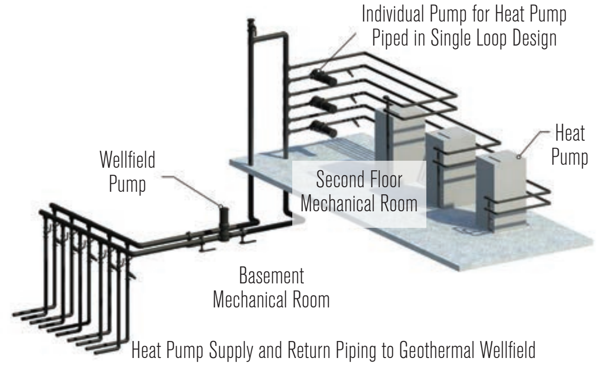

FIGURE 2 Hydronic piping schematic.

material is recyclable, so a recycling program was established with recycle bins in each work area and printing room.

Cost Effectiveness

The single pipe design of the HVAC system reduces the first cost installation by reducing half of the hydronic piping typically needed in a standard geothermal system. However, due to the size of the building and current layout designers were not able to achieve a significant reduction of piping. However, this could be achieved on larger buildings to reduce the first cost of the installation. It was important to right size the geothermal well field taking into consideration all of the energy efficiency features of the building.

The well field design consisted of ten 300 ft (91 m) deep geothermal wells with a total designed cost of $35,000. This was estimated to be equal to that of a comparable water source heat pump system, with all the energy benefits of the geothermal system without the increased mechanical room space and exterior equipment. Since the owner was not a tax-exempt organization, this opened up additional tax savings generated by the renewable energy certificates that other buildings may not be able to receive. These renewable energy credits drastically accelerated the payback for the solar photovoltaic panels. The initial cost of the 9 kW system was $36,000, by applying for the Renewable Energy Tax Credit, the liquidation of Solar Renewable Energy Credits, and by using accelerated depreciation the owner was able to achieve a payback of five years for this system. Designers also looked at other energy saving opportunities and elected not to pursue some of these based upon the life-cycle costing.

The first opportunity analyzed was the lighting control system. Using the similar Louisville building as a comparison opportunity designers wanted to determine the effect of active daylighting control systems on the overall energy use of the building. The Louisville building is two-stories with top lighting strategies that allow for the lights to be off a majority of the time. However, with the evolution of LED lighting, designers were able to get the installed wattage down to 0.63 W/ft^2 (6.78 W/m^2). Analyzing an active daylight control system versus the use of individual occupancy sensor controls, indicated a payback exceeding 40 years for this system.

Designers also looked at using an active demand control ventilation system that would vary the amount of ventilation air based upon the current occupancy. However, with a fairly consistent occupancy, schedule designers were unable to take advantage of this system and the life-cycle costing indicated a net savings of $300 per year for this system, which equated to a payback that also exceeded 40 years.

Conclusion

All buildings are different and these strategies may not fit the needs of every design, however, there are some conclusions that can be drawn from this the CMTA building.

- Importance of the building envelope and pressure testing. A thermal massing coupled with a tight building construction is a cost–effective way to achieve significant energy savings.
- Importance of pump strategy and control. Distributed variable speed pumping drastically reduces the overall pumping horsepower in a building and controlling well field temperature maximized heat pump efficiency.
- Importance of cost effective design. Performing life-cycle cost analysis is paramount in determining when a “cutting edge” energy saving measure actually pays off. ■