« Back | Print

Greening the Caribbean

In Puerto Rico, engineers integrate commonly used technologies to produce a unique top-rated green building.

By Scott Siddens, Senior Editor -- Consulting-Specifying Engineer, 12/1/2007

Standard Refrigeration Co. Inc.'s Guaynabo, Puerto Rico, facility was getting old. Real estate costs were skyrocketing. The shared office and manufacturing space just wasn't cutting it any more. The mechanical/electrical contracting firm, founded 60 years ago, had to move.

But firm officials didn't want just to build a new facility—they wanted a unique, sustainable building. The firm decided to acquire 5 acres of industrial set-aside land on the outskirts of San Juan. They acquired land in 1999, and completed the permit acquisition in 2004. Construction of the administrative building began in 2005, with occupancy beginning in 2006.

Finally, the crowning glory of the project came on Sept. 21, 2006, when the facility achieved a platinum rating under USGBC LEED NC Version 2.1 for new construction—the first building in Puerto Rico, and the first in the Caribbean, to attain this highest LEED certification level.

“The greatest challenge on the project was complying with requirements for LEED platinum status,” said Jorge Ledon Webster, PE, lead mechanical engineer on the project. “A lot of effort was put into providing a first-class interior environment requiring minimal energy costs. The LEED process requires a lot of documentation.”

The two-story building is a 9,600-sq.-ft footprint with 12,000 sq. ft of air conditioned area for offices, cafeteria and storage areas. In addition to being designed to LEED NC Version 2 requirements, the design process also adhered to ASHRAE 90.1-1999 for energy efficiency, ASHRAE 55-1995 for thermal comfort for human occupancy, and ASHRAE 62.1-2001 standard for ventilation. The main incentive for the new building was to achieve a substantial energy use reduction when compared with the firm's existing facility in Guaynabo.

Conserving energy

Energy conservation measures incorporated into the design including:

Lighting upgrade: With an illumination-level calculation program, and using minimum illumination level requirements of 50 lumens at all desktops, the total Watts per square foot were reduced by 0.78 W/sq. ft. In addition, all offices and open areas have T8 lamps with high-efficiency tubes and occupancy sensors. All walls have a reflectivity of 75% and ceilings have a reflectivity of 85%.

Insulation upgrade: In addition to the minimum requirements of ASHRAE 90.1-1999, the roof insulation was increased from R19 to R30 with a reflectivity of 92% and the walls from U = 0.58 and no R value requirement to a U = 0.089 and an R11.25.

Condensing unit efficiency upgrade: R410A units with dual speed compressors and 60,000 Btuh capacity with an 11.35 EER were installed (ASHRAE 90.1 minimum requirement is 9.7 EER).

Heat recovery: An energy recovery unit (enthalpy wheel) with an 85% efficiency and capable of handling 125% of the required outside air was included in the system. In addition, the hot water for the reheat coil in the air conditioning units is obtained from desuperheaters for each of four compressors. Solar panels are connected in series for additional reheat capacity.

High efficiency fans: The air conditioning unit has an adjustable-pitch vane axial fan with a static efficiency greater than 75%.

ASHRAE 90.1 requires a maximum of 1.7 hp per 1,000 cfm for variable air volume (VAV) systems. The design used 0.675 hp per 1,000 cfm.

Fenestration: Double glass windows with clear glass inside and low-E glass outside with U = 0.26, exceeding ASHRAE 90.1 requirements. In addition, exterior metal shadings cover all glass areas for a substantial improvement on the solar heat gain coefficient requirements.

Exhaust and supply fans: The building exhaust and the outside air make-up use the fans of the energy recovery unit and are both served by variable frequency drives for higher energy efficiencies. Electrical efficiencies

“Our new building consumes so much less electricity than our previous building that the electrical savings alone will pay for the cost of the new building in 10 to 15 years at today's electricity rates,” said Juan S. Quintana, president of Standard Refrigeration. Strategies employed in this project yielded the results for electricity usage shown in Table 1.

Using the LEED-NC Version 2.1 criteria, where receptacles are not considered, the electricity savings is in excess of 70% when compared with ASHRAE 90.1-1999. The building management system of the new facility, along with a separate energy monitoring system, provided the electricity use data shown in Table 2. For the period from July 15, 2006, to July 15, 2007, the results of a comparison between design and actual use are shown in Table 3.

The hours of use and the square footage used in the model defined the difference in design vs. actual use of electricity for the receptacles. The complete building area should have been used in design for the receptacles rather than the air conditioned areas. The building receptacles serve refrigerators, water coolers, vending machines, uninterruptible power supplies, photocopiers, and other electrical units that consume electricity 24 hours per day.

For receptacles design: 12,000 sq. ft x 2,496 h x 0.66 W/sq. ft = 19,768 kWh

For receptacles actual: 19,200 sq. ft x 8,760 h x 0.29 W/sq. ft = 48,776 kWh.

The actual number of hours increased because they had to start up the unit two hours earlier every day, used the unit during the lunch hour, and used it for two additional hours every day in the afternoon, which lead to the difference between design and actual electricity use for the air conditioning system. The number of hours used in the design model is 2,496, but the actual number of hours is 4,400: 4,400/2,496 x 51,885 kWh = 91,464 kWh

Mechanical integration

The air conditioning system consists of an air-handling unit (AHU) with a VAV adjustable-pitch vane axial fan with variable volume boxes to maintain static pressure and variable volume diffusers in every location. The AHU has a DX cooling coil that is vertically split intertwined and has a double circuit, top and bottom. The AHU is a draw-through type, and each coil section closest to the fan has an individual 5 TR (tons of refrigeration) condensing unit connected to it that runs continuously while the fan is operating. Each of the other coil sections of the split coil is connected to a variable speed 5 TR condensing unit and responds to leaving air temperature (set at 53 F).

The variable speed condensing units are not allowed to cycle more than six times per hour. If the building temperature drops below 73 F, the VAV reheat water pump operates to raise the building return air temperature through the reheat coil. This combination of sequences allows the A/C system to maintain 72 F +/-1 F and 50% +/-5% relative humidity.

Outside air is forced into the AHU return plenum by a VAV energy recovery unit that is capable of 125% of the required air for ventilation. The AHU has (MERV 14) 85% efficient permanent filters and 40% throw away pre-filters. It also has UV-C lights in the return air plenum using the intensity recommendations from “Immune Building Systems Technology” (Wladyslaw Jan Kowalski, McGraw-Hill, 2002).

All ductwork in the building is galvanized sheet metal double-wall with solid interior liner and fiberglass insulation sandwiched between duct walls. Additionally, the inner duct liner is covered with a technology that liberates silver ions and prevents bacterial growth inside the ducts.

All VAV diffusers (thermafusers) were placed so as to achieve an air diffusion performance index of 90 or greater. Areas with more than one occupant have a thermostat that can bypass the VAV serving the area and convert the VAV to temperature-controlled for a period of 3 hours. A Web-based monitoring system samples seven different areas of the building for temperature, relative humidity, carbon monoxide, carbon dioxide, VOCs, and particulate. This continuous sampling process also reports to the energy management system.

In order to verify the particulate reported by the monitoring system, the engineers brought in a particle counter and the area sampled at random reported as ISO class 8 clean room. The ratio is maintained at a maximum of 1.0 cfm/sq. ft and a minimum of 0.7 cfm/sq. ft by the VAV system. The ratio of exhaust air to intake air is controlled using VAV units in both supply and exhaust fans to achieve positive building pressurization, adequate exhaust control, and minimum ventilation requirements at all times. Only if the carbon monoxide in the building exceeds 800 parts per million will the minimum ventilation rate be exceeded while always maintaining building pressurization.

Not only did the design team create a high-performance facility in terms of energy efficiency, but they also maximized efficiencies with respect to operation and maintenance. The AHU, energy recovery unit, condensing units, desuperheaters, reheat water tank, reheat pump and domestic solar hot water collectors all are located on a single pad outside the building for ease of maintenance. And the commissioning process verified each and every item of the HVAC and plumbing system.

Design uniqueness

“The positive environmental impacts that result from the design of our new building are significant and many,” Quintana said, “including condensing units that use R-410A refrigerant; electrical savings of 70% that substantially reduce carbon dioxide generation; and recycling of materials such as glass, paper, aluminum, cardboard, electrical lamps, printer cartridges, car batteries, oil, cellular phones, sheet metal, car tires, wood pallets, and grass.”

In addition, light pollution is eliminated by keeping the illumination within the site; all storm water is strained for removal of oil residue and some phosphorus; rain water is used for toilets and urinals; and the facility's own sewage treatment plant operates on evapotranspiration, which does not impact acquifer recharging. Storm water is retained in an underground rechargeable tank that slowly releases water during a 72 h timeframe so that water will not affect the level of the creek close to our site.

“We feel that our building is really unique,” Quintana said. “It is located in Puerto Rico without the benefits of using cold outside air for air conditioning at any time during the year. Yet still, we have achieved 750 sq. ft/ton.

“The greatest reward was that project goals were accomplished, and that the owner obtained substancial savings from energy and water measures that were implemented during the design process,” he said. “The coordination between the owner, which in this case was the contractor, and the rest of the design team was a great plus for implementing all the energy savings into the project.”

Because the owners of the facility are in the MEP business themselves, they began this project with a strong notion of what could be achieved, and challenged their design team with the task of far surpassing their existing building in energy use reduction. And the design team did a “platinum” job of meeting the challenge.

End use	**Design case (kWh)**	**Budget case (kWh)**
Electrical receptacles	19,740	19,740
Lighting	29,823	48,232
Space cooling	42,168	116,703
Fans/pumps	9,717	110,028

Date	**Receptacles**	**First floor**	**Second floor**	**A/C**
07/15/2006	40 x 106 W	6 x 106 W	6 x 106 W	44 x 106 W
07/15/2007	88 x 106 W	17 x 106 W	18 x 106 W	83.5 x 106 W

Use	**Design (kWh)**	**Actual (kWh)**
Lighting	29,823	23,000
Receptacles	19,740	48,000

A/C	51,885	83,500

Natural ventilation makes this library coolest building on campus

Architecture rules at this new Judson University building, which houses an expanded library and the division of art, design, and architecture. “Seeking a facility worthy of an evolving architecture program that is seeking accreditation, the university conducted an international design competition,” said Norm Bower, KJWW public relations coordinator. London-based architect Alan Short of Short and Assocs., a pioneer in low-energy, naturally ventilated, and passively cooled buildings, designed the facility.

The design team's challenge was to treat light and humidity issues in a library and art environment, where these factors could seriously damage the contents of the 88,000-sq.-ft building. Dominant energy-conscious features of the building are its photovoltaic, natural ventilation, and natural daylighting systems. Optimizing solar gains in the spring and fall is intended to allow the building to run naturally, with little or no mechanical intervention, for six or more months of the year. The building is expected to earn a USGBC LEED silver rating.

“The greatest challenge as an HVAC engineer on this project was taking the vision of placing a naturally ventilated building in the middle of the Midwest,” said Wade Ross, PE, lead mechanical engineer on the project. “Although the system works well in Northern Europe, we had to not only adapt it to the harsh Midwest climate, but also justify its viability.”

Ross also points to the vital need for teamwork. “Another struggle for the engineering firm was to design an exterior concrete precast structure with multiple openings. Extremely close coordination had to take place between engineering disciplines, architect, and the precast contractor,” he said.

Designing a naturally ventilated building that conformed to local code also challenged the team. For example, when it came to smoke evacuation strategies, “computational fluid dynamics analyses were commissioned to show that smoke could be effectively vented from the structure,” said architect of record Rick McCarthy, AIA, of Burnell Cassell Assocs., Elgin, Ill.

Natural ventilation is probably the most innovative aspect of the design. The building draws cool air at the lower level, circulates it throughout the building through various routes, and exhausts the air through roof terminals. Because of the extreme Midwest climate, a fully natural ventilation system was not possible. Consequently, mechanical engineers designed a hybrid system that minimizes the use of conventional heating and cooling, with operation in the natural mode for as much of the year as possible, but engaging the mechanical mode when the need arises.

There is a significant amount of engineering involved in the design of such a system, and the end product is a building that behaves as a single integrated system.

High school makes the lifecycle grade

Kinard Junior High School's design almost makes you want to go back to school just to check out the building. The facility incorporates thermal advanced insulating systems, daylighting, lighting controls, and geoexchange heat pump technology with exhaust air heat recovery ventilation systems. A building automation system monitors and controls engineered systems throughout the 117,000-sq.-ft building.

“Poudre School District (PSD) is very sensitive to total lifetime cost impacts of the design, construction, operation, and maintenance requirements, keeping in mind the total lifecycle costs rather than focusing primarily on the lowest first costs,” said Eric Young, PE, president of EMC Engineers Inc. and lead mechanical engineer on the project.

This was the fourth project that project architect, RB+B Architects, Fort Collins, Colo., designed under PSD sustainability guidelines. EMC was selected to provide three separate areas of service for this project: energy analysis, mechanical design, and commissioning. PSD selected EMC's energy team to help establish energy and sustainable goals for the facility, to create an energy model, and to update the model and advise the design team throughout the design process as relevant architectural and MEP systems features were determined. EMC also was selected for its experience in designing high-performance geoexchange systems. Finally, the firm was responsible for co-commissioning the building, working closely with Architectural Energy Corp., Boulder, Colo.

The district challenged the design team not only to explore ways to make this project even more energy efficient than previous schools, but also to make it exceptionally easy to build and maintain.

"The budget for the entire project was $17.45 million and the building was completed for a total cost of $17.5 million," Young said. "The cost of the mechanical and plumbing portions of the project, including the geoexchange borefield, was $2.2 million, It came in on budget, equaling $18.86/sq. ft, a very competitive construction cost for this type of system."

PSD documented the energy performance of this school for one complete year from July 2006 through June 2007, and tracked its performance against another conventional, similar-sized junior high school in the district. Electrical and gas savings can be summarized by the amount of energy used in one year per square foot for each school: Kinnard's 24.8 kBtu/sq. ft/yr compared to 55 kBtu/sq. ft/yr for the other school—an energy cost savings of approximately $30,000 in the first year of operation.

Stu Reeve, energy manager for PSD, echoes the excitement in the performance results. "Based on previous high-performance schools in PSD, we increased our expectations and performance goals for this project and EMC exceeded them all," Reeve said.

« Back | **Print**