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Dream Big, Think Small: Innovative System Has All

When mechanical engineers, installers, architects, and building owners have the rare luxury of designing a new facility specifically to meet or exceed energy efficiency and indoor comfort needs, big dreams become a reality. Remarkably — with the influence of a tough economy and highly scrutinized energy consumption — an ambitious, imaginative plan came to fruition. The key: smaller, smarter mechanical systems that wrench every last Btu from super-efficient ground-source heating and cooling systems.

"I don't know that you'll find a smarter, more efficient mechanical system than the one now installed at the new Penn Foundation facility," professional engineer Glenn Snyder said. Snyder was one of several professionals who, in October 2012, were literally living the dream as hundreds of mechanical components were brought together and connected by a modular control network to serve as the building's central nervous system.

The planning for the new 36,000-square-foot, two-story addition to the mental health facility not far from Allentown, Pa., began in 2004. Much of it existed only in the minds of several forward-thinking experts, but as the planning moved forward, the dream of an innovative mechanical system started to take shape. It wasn't until 2009 that the technology began to emerge to help bring the innovative system into being.

"Geothermal systems were installed that harvest energy from the earth, but the real uniqueness of this job is the way Btu are removed from or delivered to enclosed spaces," said Greg Cunniff, application engineering manager for Taco Inc. "Different water temperatures are readily available for a variety of terminal units throughout the facility from a single-pipe system because we're using new, off-the-shelf injection mixing blocks that blend supply and return water temperatures from the main.

"Injection mixing provides the perfect balance of everything designers, installers, and building owners most want," he added. "Their master list of essential needs included performance, efficiency, compact size, quiet operation, comfort, and IAQ — an especially important facet for a health facility."

Underground to Overhead

Penn Foundation's freshly-paved parking lot conceals 48 bore holes, each 6 inches in diameter and containing a 1-inch diameter pipe. The holes are on 20-foot centers and each circulate fluid to a depth of 300 feet. The well field uses Taco's KS Series vertical in-line pumps to save space in the mechanical room.

The bore holes provide ground-temperature water to five 28-ton water-to-water geothermal heat pumps housed side by side in the main mechanical room. The units stage on and off, depending on current load requirements. "Commercial geothermal jobs are always noteworthy because it points to a large investment in energy and resource stewardship," Cunniff said. "What makes this system so exceptional are the terminal units that were specified and installed to deliver an extraordinary level of performance."

The big water-to-water units feed a total of 176 Semco chilled beams (88 zones), eight Carrier fan coil units to condition high-load interior spaces, and 10 water-to-air heat pumps to handle entry doors with high infiltration. A single-pipe distribution system tied to Taco's LOFlo injection mixing blocks saves space, installation time, initial cost, and long-term operating expense.

Taco's iWorX control system carefully monitors room temperature, supply water temperature, ever-changing dew point, and circulators connected to the stainless steel mixing blocks. The new building automation system also controls circulation in the geothermal exchange field, water-to-water units, dedicated outdoor air system (DOAS), and all remote heat pumps.

The facility's fresh air is supplied through the chilled beams, via the DOAS, which in turn increases the capacity of the beams. Active chilled beams use a combination of air supplied from the DOAS and the airflow from natural convection to either heat or cool the space.

Active chilled beam systems, like those installed by mechanical contractor IT Landes at the Penn Foundation, can approach 400 Btuh per square foot. In passive configurations, where only natural convection provides movement of air through the coil, capacity is closer to 150 Btuh per square foot.

"Coupling the LOFlo distribution system with iWorX controls and geothermal equipment provides the most energy efficient HVAC system available today," Cunniff said.

Challenges: Overcome

"We've worked with Penn Foundation on six projects before this one. The trust we've earned is apparent when it came to designing this system with relatively new technology," Snyder said.

Phillip C. Lederach, president of the architecture and engineering firm Lederach Associates, did the architectural work at Penn Foundation, Snyder said, while he and his associate, Jason Lutchendorf, did the mechanical system design.

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Are all the valves in good shape? Are they going to let you fix the whole system so that everything talks to everything else, or are you just installing a new boiler?

I'm thinking that the only way to really prove savings in any building is to install the new high-efficiency equipment and then keep track of what happens during the next year or so. But who will keep track of this? Will it be the building owner? And is he just tracking the amount of fuel burned? Does that define high efficiency? Just fuel savings? If that's all it is, we could keep the old equipment and shut it off for part of the day. Hey, nothing is more efficient than a burner that's not running.

But shutting down the system will probably affect human comfort, right? So should human comfort come into play when we're talking about high efficiency? And if we do that, who is going to step up to be the standard of comfort? Some folks like it warm while other folks like it cool. And now we're really talking systems, which includes the building envelope, windows, doors, insulation, controls, piping layouts, terminal units, circulators, and on and on. We're not just talking about a high-efficiency boiler when we're talking about human comfort.

So how do you test for comfort? Do you conduct polls? Who will pull that together? Do we need to get Gallup involved in this? And who's going to pay for this?

This is getting complicated. Maybe high efficiency is a comparison of the building we're working on to a similar nearby building that we're not going to work on (if there is such a place). If you can make an improvement in your building you get bragging rights. But how can you prove that things got much better once you're done? Will the folks in the other building show you their fuel bills and tell you about their level of comfort? And what if they decide to make changes to their building, but at less cost than what you charged? Maybe they just sealed the cracks and made some adjustments to the burner or gave their boiler a good cleaning.

If we're going to define high efficiency as a comparison to some other similar building, any improvements they make will take away from what you achieved. So subjective, this high efficiency business.

Perhaps high efficiency is really just a state of mind, based on how much the customer wants to spend and how he perceives the return on investment. Whatever he gets is probably going to be better than what he has now. Is that high enough? Beats me, but who knows what the tuna will be tomorrow?

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Dream Big

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In the past, churches and long-term care facilities have been a staple for Lederach's business, but more recently, they've moved into the municipal and medical markets. Since the project is an addition to the existing Penn Foundation facility, Lederach wanted to match ceiling heights between the new and old portions of the building. But this limited the space for mechanical components between the first and second floors.

According to Snyder, an all-air ducted system was out of the question because of the space required for larger ducts. They also evaluated a conventional four-pipe hydronic system centered on fan-coil units, but even that was too much for the restricted space.

"We offered the single-pipe, LOFlo system as an alternative," Cunniff said. "This reduced the number of pipes from four to two — one for heating, and one for cooling — and because of its low flow, we can use a very large delta T, which shrinks the size of the pipes needed.

"When compared to a conventional chilled beam system, we're able to decrease the flow rate by almost 75 percent. Over a conventional four-pipe system, we're able to cut the flow rate by about 50 percent," Cunniff continued. "So, not only were we able to cut the number of pipes in half, but we were also able to significantly reduce the size of the pipes."

The result was adequate space for the engineer to fit the piping and the DOAS ductwork into the available ceiling space. Also, lower horsepower pumps were put to work in the main mechanical room.

Putting it on Paper

"We were speaking with Penn Foundation about this project several years before anything materialized, but the actual design process started in 2009," said Lutchendorf, engineering project manager for Lederach. "Since it was our first facility to incorporate chilled beams, we were glad to have some help from the experts at Taco and the manufacturer's rep firm, BJ Terroni."

Jeff Pitcairn, Taco's commercial regional manager, oversaw the project from design to commissioning and start-up, and Sean Connor, commercial sales manager for BJ Terroni, helped with equipment selections and estimating.

For the engineers at Lederach, learning about the chilled beam concept and how it would work within the design concepts and requirement of the facility was an interesting challenge. Before Taco got involved with the project, initial design for the facility overshot the budget.

It took some time, effort, and collaboration with manufacturers to redesign the project in line with the available funding. The redesign, including some modifications to the building itself, came in at nearly 10 percent under the initial cost mark.

According to Lederach engineers, Penn Foundation will see a return on additional investment of the geothermal and chilled beam system — when compared to operation of conventional heat pumps — within 16 months.

"Not only are energy costs substantially lower, but so are the maintenance costs," Lutchendorf said. The iWorX, chilled beam, and geothermal combination is estimated to provide $12,000 in annual energy savings over a standard water-source heat pump system. An annual-maintenance savings of $3,000 is also estimated.

"Using Taco's HSS [Hydronic Solution Software], we designed the majority of the system piping and cascading temperatures throughout the entire system. We were pleased with how easy the program was to use," Lutchendorf said. "The software produces clear, detailed schematics and blueprints for the mechanical contractor to follow."

According to Lutchendorf, the design temperature for the building's chilled water supply buffer tank is 45°F, and 125° on the hot side. Return temperatures are 58° and 110°, respectively. The iWorX modules use the LOFlo mixing blocks and mix water supply to get the water passing through the beam to the exact temperature needed. In cooling mode, water circulating through the beams is 2° above dew point to avoid condensation.

Supply water temperatures cascade as they make their way past each terminal unit. While the beams call for mixing to hit ideal water temperatures, temperatures to the building's fan coils aren't as exact. For the coils, longer run times easily accommodate the varying supply temperatures.

Mechanical contracting firm IT Landes is located only a few miles from Lederach's office. The 83-year-old mechanical installations firm, which employs more than 100 people, routinely balances both commercial and residential work. They've completed a number of Lederach's larger projects through the years, many of which incorporate leading-edge technology.

"This was our first chilled beam project, and the construction schedule was very aggressive," IT Landes co-owner Chris Landes said. "But we have a very talented team, and they worked flawlessly to complete the HVAC system, bringing it together ahead of schedule."

Beams: Best if Chilled or Warmed

The Penn Foundation facility addition uses a total of 98 LOFlo mixing blocks, 88 of which are coupled to chilled beams in the 1,000-6,000 Btu size range.

"A project like this is simplified only when the control system is ideally suited to all of the components that must work in tandem," said Pitcairn. "IWorX modules are designed for specific functions, including chilled beam and geothermal system operation; this was exactly what Penn Foundation needed."

While the fan coils in the building may call for 40-45° supply water, the beams are more likely to only need 55-60°. "Not only are the chilled beams more efficient than any other means of heating or cooling a building, they're also quieter, more comfortable, and provide optimal IAQ," Cunniff said.

"In addition to the five large water-to-water heat pumps, Landes's technicians installed remote water-to-air heat pumps to condition the space inside entry doors and air locks," Snyder said. "Doors opening in the summertime allow too much hot, humid air in to avoid condensation on the chilled beams." For the same reason, all the building's low-E windows do not open, and the entire building is constructed of poured concrete walls using an insulated concrete form system (ICF) that produces a very tight building.

"High ceilings in the meeting rooms required more air volume than chilled beams are intended for," Snyder said. "Tucked above ceiling tiles, the water-to-air heat pumps draw from the same 3-inch line (that serve the fan coils and chilled beams) coming from the ground-source water-to-water heat pumps located in the basement mechanical room."

Smart Controls

"My guess is that some engineers would've been hesitant to adopt and learn a new control platform, but Taco has been our primary specification for hydronic components for over 20 years, so we've come to expect good things," Snyder said. "Their field engineers, like Tom Polansky, have always helped us whenever there's a need."

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Part of the whole chilled beam recipe was the control platform's new CHB chilled beam controller, which monitors system needs and provides a variable-speed output to the cold-and-hot supply-injection circulators connecting the supply streams with the injection mixing blocks.

The modulated output from the CHB controller protects against condensation in the chilled beams on a zone-by-zone basis. At the same time, it reduces the control cost associated with these systems by reducing the number of controllers needed and virtually eliminating commissioning time.

As with all iWorX controllers, the new CHB controllers are completely self-configuring network devices. The Web-based network displays all system functionality, allows full system access in a password-protected format over the Internet, and features alarm capabilities via any Web-enabled device. "The project is a great example of what can be accomplished when manufacturers, engineers, and contractors all work together for a common goal," Snyder said. Ⓝ