ENGINEERED SYSTEMS

A Complex Organism

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The Centers for Disease Control and Prevention (CDC) is undergoing significant changes at its Atlanta campuses. With many of its buildings constructed in the 1950s and '60s, the main campus now requires facility upgrades to improve its ability to fulfill its missions, which include being a national leader in research and response to the threat of bioterrorism.

An ambitious modernization and expansion effort is ongoing, and a project design has recently been completed to provide significant mechanical and electrical infrastructure upgrades. These upgrades were designed to support the campus on a continuous basis throughout construction, as well as provide for the future. This article focuses on the challenges and decisions made during the design of the upgrades and modifications to the central chilled water systems while in this robust period of construction and demolition.

A Revitalized Campus

The changes to this urban campus are essential and have been swift. Many of the older buildings are worn from heavy use and are not well positioned on the site to allow maximum use of the remaining land. Over the past five years, the campus has expanded to the west with four new buildings totaling areas of over 980,000 sq ft and construction costs over $300 million.

These changes include a modern BSL-4 laboratory space, visitor's center, headquarters office building, and a new west campus chiller plant. Demolition and new construction continues. Over the next four years, the east campus (containing the older buildings) will be revitalized with a new 450,000-sq-ft laboratory/vivarium, an office building, trans-shipping facility, and a new electrical switchgear building. The long-range plan for the east campus also includes another major laboratory building, office building, and a 1,600-car parking deck.

Prior to revitalizing the east campus, the CDC developed a master plan for the campus chilled water system that included a new west campus chiller plant with high-efficiency chillers (0.55 kW/ton) using a 17ºF chilled water supply-to-return water temperature difference (Δ T) and a primary-distributed secondary pumping system. Chilled water TES was also considered. The challenge was implementing that master plan and designing a way of integrating the new chiller plant and anticipated thermal storage system with an existing older chiller plant such that the ultimate combined system provides a single, reliable, and energy-efficient source of chilled water for the campus.

Connecting Chiller Plants: New and Old

A single chiller plant, now called the East Campus Central Utility Plant (East Campus CUP), served the original campus buildings. At the time of its construction, the plant was on the southern edge of the campus. To provide chilled water to campus buildings, a major utility tunnel extended from the plant to the north. As the campus grew, the original single plant became overstressed and less centrally located. In 2003, in the midst of the western campus expansion, a West Campus CUP was completed.

The CDC team designed the new central plant with an eye toward the future. Rather than matching the 10º Δ T used in the East Campus CUP, they designed the new West Campus CUP for a 17º Δ T to allow for significant reductions in piping and pump sizes. This higher ΔT also improved the economics for the possible implementation of TES because of the greater storage capability.

Furthermore, the pumping system in the new plant utilized a primary-distributed secondary system in lieu of the direct pumped "primary only" system used in the older plant. The benefit of the primary-distributed secondary system was that future buildings would have their own local dedicated chilled water pumps that could be connected to the new west campus system in what could be described as a "plug and play" arrangement; a complete system rebalancing would not be necessary as each new building came online.

The two campus plants are currently operating independently. However, the CDC master planners have envisioned all along that the two plants will one day work together. (This was considered in the determination of capacity for the west campus plant.) Although the new approach used in the West Campus CUP had several advantages over the older plant, there was such a disparity in the designs that a five-step approach was developed to ultimately interconnect the two plants.

Install Building Pumps in East Campus Buildings

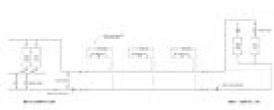
The East Campus CUP delivers chilled water to buildings through large 200-hp primary chilled water pumps located in the plant. Individual building pumps are not necessary because the large distribution pumps were sized to overcome the chiller plant pressure losses as well as piping system losses to the farthest cooling coil in all connected buildings.

The system has worked well, although balancing issues have surfaced in recent years due to the addition of a major laboratory building in close proximity to the plant that is "stealing" water from smaller loads farther away.

As the first step in the interconnection of the plants, each existing east campus building was retrofitted with a building chilled water pump. Each pump has a VFD to maintain a minimum differential pressure within each building. (This approach should resolve most of the current balancing problems.) These pumps, which will serve as the secondary pumps in the eventual primary-distributed secondary system, will not operate initially but will be necessary once the East Campus CUP primary loop is established. New east campus buildings will be designed with building chilled water pumps as part of their original design.

An issue that had to be resolved was how to install the pumps such that they could be disabled and then ultimately enabled when the interconnection is complete. Operating the pumps before they are needed may cause over pressurization of the existing system and would waste energy. Waiting to install the pumps at a later date would not work well with other ongoing construction on campus. The team deployed a check valve bypass around each pump, and pumps will be simply disabled until they are needed. In the few pumps that have already been installed, this proved to be a simple, low-cost, and effective solution.

Lower Chilled Water Supply Temperature



The next step in the interconnection process was to lower the chilled water supply temperature from the East Campus CUP. The new West Campus CUP was designed to deliver 42º supply chilled water. New west campus buildings connected to the plant, of course, have cooling coils selected for this entering water temperature. Conversely, the older East Campus CUP has chillers designed to produce 45º. When an interconnection is complete, an undesirable situation of the "warmer" chilled water reaching west campus buildings will result if the east campus chillers are not retrofitted to decrease their supply water temperature.

The implications of this discrepancy are not immediately obvious. After all, can 3º make that much of a difference? The answer is ‘yes,' and here is why: Not only does the warmer water reduce dehumidification capability, but it also decreases the ability of the cooling coils to transfer heat, thereby requiring additional flow to satisfy the load. The end result of increasing flow for the same load is that the coil Δ T will significantly decrease. A Δ T decrease of 4º was expected for the conditions of this project. Therefore, the increased supply temperature will cause a low Δ T problem with the classic symptoms of increased water flow and an inability of chillers to load to full capacity. To avoid this, the east campus chillers are being retrofitted to produce 42º supply chilled water.

Retrofitting the east campus chillers for lower supply water temperature will require internal modifications by the chiller manufacturer to eliminate the possibility of chiller surge, and it will also decrease chiller tonnage by about 5%.

Converting to Low-Pressure Distribution

A significant difference between the operation of a direct-pumped primary system (East

Campus CUP) and a primary-distributed secondary system (West Campus CUP) is the pressure gradient in the distribution piping of each system. A direct-pumped system with a compression tank located at the suction of the primary pumps will always have greater pressure in the supply main as compared to the pressure in the return main.

On the other hand, a primary-distributed secondary system with a compression tank at the suction of the primary pumps will have a greater pressure in the return main as compared to supply. This extreme difference in the operating pressure in the supply piping of the two plants created the need to convert the east campus pumps to the "low-pressure" distribution of the west campus.

Several options were considered to reduce the pump head of the existing east campus primary pumps and thereby create a low-pressure distribution. The option of simply replacing the pumps with new pumps correctly sized for the new load was considered to be the best choice. Engineers considered retrofitting the pumps with VFDs, but found that to not be cost-effective because replacement of the existing motors with inverter duty motors and additional controls would also be required. Replacing pump impellers was also considered but was found to place the pumps at a very inefficient operating point.

Additionally, designers specified new primary pumps with less flow rate than the existing pumps due to the expectation that the campus chilled water Δ T will increase as new construction continues. New campus buildings are being constructed using cooling coils designed for a 17º Δ T (or greater). Therefore, as old 10º Δ T buildings are demolished and new 17º Δ T buildings are built, the campus Δ T will increase. Calculations have shown that the ultimate Δ T of the campus will be 15.3º. (Resolutions are being considered to create a better match between the projected Δ T of the campus and the Δ T of the two chiller plants.)

A primary loop in the east plant was established by modifying an existing chiller bypass control valve that originally provided minimum chiller flow during low loads to act as a decoupler loop in the new primary distributed secondary arrangement.

Equalizing MakeUp Water System Pressures

The height of campus buildings varies greatly, and the distinction of being the tallest building on campus is passing from one building to another as new construction continues. When the chiller plants are ultimately interconnected, the makeup water pressure in each plant will be coordinated and adjusted to maintain adequate system pressure in the building that places the greatest static pressure head on each plant (typically the tallest building on campus).

Consideration was given to eliminating the makeup water in one of the plants; however, it was decided this may remove a redundancy that may prove beneficial. If having two makeup water sources proves problematic, one can be manually closed.

Design Load Priority Sequencing

The final challenge in the design of the interconnection was to develop a method of distributing campus cooling load between the two interconnected plants. That is, it would be desirable to have the ability to distribute greater load to the more efficient chillers located in the West Campus CUP concurrent with operating a chiller or two in the East Campus CUP to satisfy the overall campus demand.

Figure 1 illustrates one solution. The design philosophy is that the primary loop of each plant generates chilled water and circulates it within the plant, making it available to the connected buildings. The building pumps of the connected buildings draw water from the primary loop, deliver it to the building, and then push it back to the plant. In the absence of any control valves, the building pumps will draw water from whichever plant offers the least resistance. The plant that offers the least resistance to the greatest number of buildings will assume a greater proportion of the total campus cooling load.

Based on this operation, the proposed solution to distributing load is to provide a "load allocation" control valve at each chiller plant that modulates to increase resistance and force water to the other plant. For example, to increase chiller plant loading in the West Campus CUP, the load allocation valve in the East Campus CUP will modulate toward the closed position.

Thermal Storage Reduces On-Site Standby Power

The operation of this research campus must continue even under extreme circumstances. Implemented security measures include physical barriers, as well as stout wall and glass construction designed to counteract the forces of evil. Additionally, the CDC desired substantial on-site generation of electrical power to operate key laboratory buildings and provide cooling for the occupants during a loss of normal utility power for any reason. The design goal was to provide 100% of building power and 60% of the maximum cooling demand for each laboratory building.

Minimizing the amount of power required in the emergency condition was imperative for a few reasons. Not only was there limited campus space to house engine generator sets, but also the analysis of the campus net emissions of NO_x showed levels approaching a "maximum modification" in accordance with EPA/EPD policy.

Because the driver of the standby power calculation is the energy necessary to operate the campus electric centrifugal chillers, the CDC studied chilled water thermal storage as a means of reducing the peak emergency power demand. Implementing a 3-million-gal chilled water TES tank with pumping designed to provide 4,000 tons of cooling will yield a reduction of 3.4 MW of standby power equipment. A lesser quantity of diesel generators was desirable not only from a space planner's perspective due to fewer exhaust stacks, louvers, acoustical considerations, and less fuel oil storage, but it also improved the NO_x emissions situation, which was a major concern.

The additional tonnage of the chilled water tank also allowed the quantity of future chillers to be reduced. This directly benefited the campus by reducing the CDC's ultimate contract kW demand with Georgia Power Company (GPC). There would also be energy savings from shifting the cooling load to the nighttime hours due to the GPC's time-of-use rate. Because the installation of the chilled water storage tank is integral to the long-term master plan for the campus, a 100% complete design has been included in the chilled water system upgrades; however, the tank installation is not currently funded.

Next Step

The federal government continues to provide tremendous support for the expansion and modernization of this CDC campus. The investment in infrastructure systems to provide a comfortable, energy-efficient, and safe campus is a testament to this support. The chilled water system interconnection and TES system, along with electrical infrastructure upgrades, are major components of this modernization plan. **ES**

Severini is an associate partner with Newcomb & Boyd, a multi-discipline consulting and engineering firm located in Atlanta. During his 18 years with the firm, Severini has designed 17 chiller plants and has been responsible for several other chiller plant retrofit and commissioning projects. Additional information can be found at www.newcomb-boyd.com.