Second Place: Industrial Facilities or Processes, New

Photo: Paul Howell

Texas Medical Center in Houston is the largest medical center in North America. It has a chilled water system of 160,000 tons.

Big Plant in a Small Space

By Blake E. Ellis, P.E., Member ASHRAE; and **Raymond J. Mosier, P.E.,** Member ASHRAE

Everything is big in Texas, including the Texas Medical Center in Houston (the largest medical center in North America) and the plant that provides its energy.[1] Thermal Energy Corporation (TECO) was operating an 80,000 ton (281 360 kW) chilled water system in 2007 that served the Texas Medical Center. Planning efforts indicated cooling load demand would double to 160,000 tons (562 720 kW) over the next decade. An area just east of the existing central plant was identified as available for expansion. This area was less than half the size of the existing plant, but it was the only land available for expansion.

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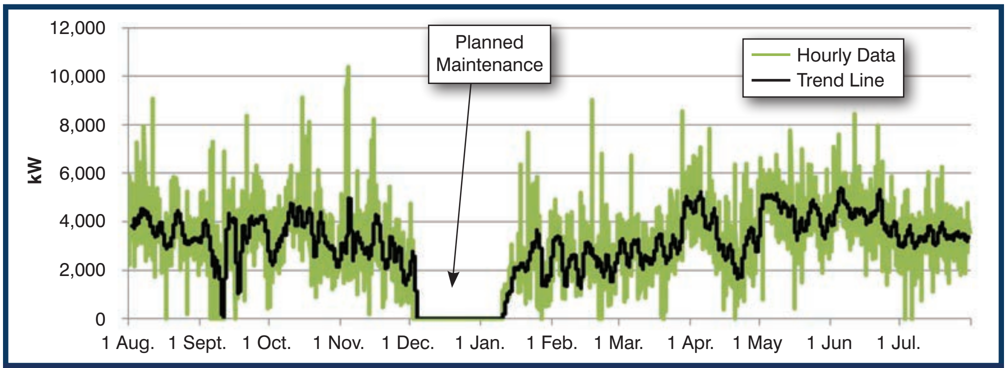

Figure 1: Hourly energy savings in kW.

Analysis of several options suggested a two-step approach to meet the increased cooling load demand. The first step was to add 8.8 million gallons (33.3 million L) of thermal energy storage (TES), which became operational in January 2010. The second step was the addition of the new East Chilled Water Building (ECHB), which became operational in May 2011 with 32,000 tons (112 544 kW) of chilled water production, bringing the system total to 120,000 tons (422 040 kW) of production. The ECHB has provisions for an ultimate production capacity of 80,000 tons (281 360 kW).

Energy Efficiency

Modern chilled water plant design philosophy uses variable speed drives (VSDs) for the major pieces of equipment such as chillers, cooling tower fans and pumps to optimize energy efficiency. However, at the time this project was being designed, VSDs had never been applied to the 8,000 ton (28 136 kW) chillers required for this project.

Several chiller options were analyzed including constant speed 5 kV and 15 kV motors and VSDs serving 5 kV motors. After several iterations, the configuration selected was to use VSDs with a 15 kV input to reduce the electric cable costs and a 5 kV output to drive the 7,000 hp (5220 kW) motors on each chiller. VSDs were also used on the 24,000 gpm (1514 L/s) chilled water pumps and the cooling tower fans. In addition to the VSDs, the efficiency of the new chillers was 0.094 kW/ton (0.027 kW/kW) lower than the existing chillers.

The result of the all variable speed chilled water plant design was an average reduction in energy use of 3.4 MW during the first year of operation. *Figure 1* shows the energy savings in kW for every hour from August 2011 through July 2012. During this period, a total of 303 million ton-hours of chilled water was produced with the new chillers saving a total of 26.1 GWh of electricity. This is an average decrease of 12.7% in annual energy use.

The project site is extremely compact. (*Figure 2*) Consequently, a project goal was established to maximize the potential chilled water production capacity on the space-constrained site. This resulted in the cooling towers being located on the roof of the plant to provide the most compact arrangement.

Initial desires were to locate the condenser water basins at grade; however, given the condenser water pump energy requirement, locating the basins as high as possible was desired to reduce the required net static head on the pumps. The final location saved nearly 3 MW of condenser water pumping energy versus condenser water basins located at grade. The savings are nearly equal to the energy saved by the variable speed chiller plant concept.

Innovation

Maximizing the amount of chilled water production per square foot of the project site was a project goal because TECO did not have additional property on which to expand. Capacity of the chilled water plant was constrained by the footprint of the cooling towers on the roof. Several plant arrangements were studied, but single inlet counter flow cooling towers with a 15°F (8.3°C) range for the condenser water temperature provided the highest heat rejection per square foot of tower footprint while using only slightly more energy (2%) than the most efficient cooling towers.

Locating the cooling towers on the roof with no room for a basin to extend beyond the tower, and a roof that could not extend beyond the basin presented a unique challenge. The solution was to design an integral basin/roof structure. Counter flow cooling towers were placed directly on the roof with water cascading onto the roof structure. The water then flows across the roof where

Building at a Glance

East Chilled Water Building

Location: Houston

Owner: Thermal Energy Corporation

Principal Use: Chilled water production

Includes: Roof mounted cooling towers, condenser water sumps, chiller level, electrical distribution and pumping systems.

Employees/Occupants: Unoccupied

Gross Square Footage: 104,000

Conditioned Space: 104,000 ft^2 (tempered to 85°F [29°C])

Substantial Completion/Occupancy: May 2011

Occupancy: 40% of total chilled water capacity is built out

National Distinctions/Awards: 2012 ACEC Honor Award it is collected in a series of basins. The roof system is designed to absorb the constant pounding of the water and can be repaired or re-roofed two cells at a time while maintaining the other eight cells in operation (*Figure 3*).

Other innovative ideas include the first variable speed 8,000 ton (28 136 kW) chillers mentioned in the Energy Efficiency section, a crane system and the chilled water pumping scheme.

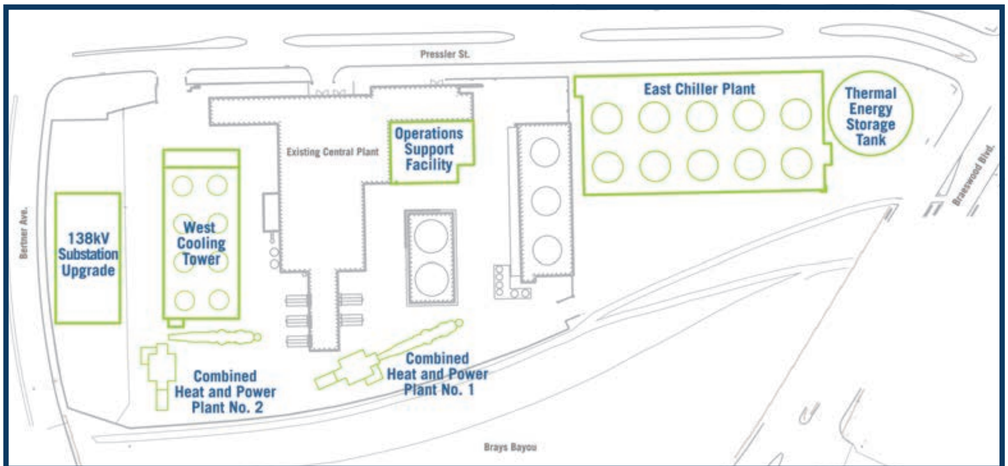

Figure 2: Project site.

Operation & Maintenance

Chilled water production at this site began in 1969 and TECO has maintained a 0.99998 reliability factor, being down only seven hours since inception. Providing reliable chilled water to the medical center is a priority, and this project revised the operating strategy to integrate the function of all three chilled water plants and the new TES tank. This strategy provides increased flexibility to adapt to emergencies while maximizing energy efficiency.

Figure 3 (left): Cooling tower with sumps below walkway; **(right):** Integral basin/roof (viewed from the walkway above the sumps).

Within the plant, the chillers are arranged in a variable primary pumping arrangement with dedicated primary pumps. A bypass piping loop was installed to allow any chilled water pump to serve any chiller. This configuration will allow future installation of chillers with differing pressure drops without having to match the head of the machine with the largest pressure drop (as would be required if the pumps were installed in a headered arrangement) (*Figure 4*).

Maintenance issues were addressed with an overhead crane system on the chiller level (third floor) capable of removing a compressor or a motor from a chiller and transferring it through openings in the second and third floor slabs to load it directly onto the bed of a truck on the first floor. The truck can then transport the part to be repaired without it ever touching the floor (*Figure 5*).

The pump suction and discharge piping on the first floor was also arranged to allow a minimum of 10 ft (3 m) of clearance below the piping with clear aisles provided between the pump lineups. This arrangement allows forklift access to any pump for motor or pump casing removal. Monorails are provided above each pump to facilitate this process.

This was especially noteworthy given the condenser water, and chilled water pumps are 600 hp and 1,000 hp (447 kW and 746 kW), respectively (*Figure 6*). In addition, this plant is tempered to 85°F (29°C) to provide a more habitable work environment in the summer for the maintenance staff. A big improvement during the Houston summers over the existing central plant, which is unconditioned. Finally, many vendors for equipment such as valves, pumps, controls, chillers and cooling towers were chosen to match the existing vendors to minimize spare parts inventories and the number of new components the maintenance staff would be required to maintain.

Cost Effectiveness

Designing a cost effective project requires the evaluation of the interrelationship of all project costs including first costs, operational costs and maintenance costs.

First Costs

One intriguing aspect of this project was the extremely high cost of the surrounding land, which has a tremendous impact on TECO's ability for future expansion of the plant. This con-

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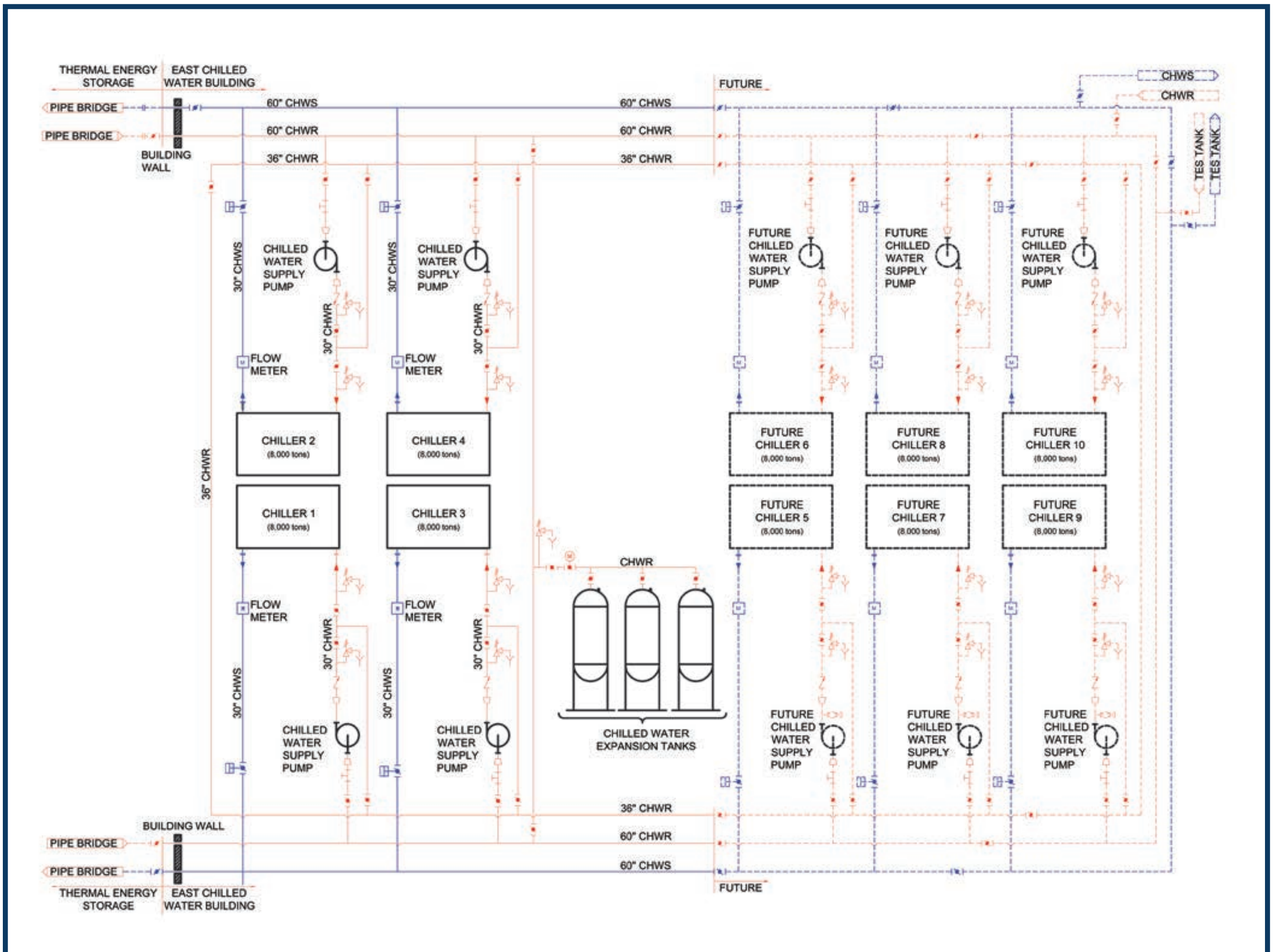

Figure 4: Chilled water flow.

straint factored into several decisions including the decision to maximize the potential chilled water capacity on the available site.

Cost effective decisions were made in several areas including constructing the plant building in one phase versus two, saving construction overheads and inefficiencies. Cooling towers were changed from concrete to field-erected fiberglass to minimize the weight on top of the building and eliminating a building expansion joint during construction to ensure structural integrity with a 120 mph (193 kmh) wind loading. Finally, the net result of making cost effective decisions was that the project was constructed $15 million under budget.

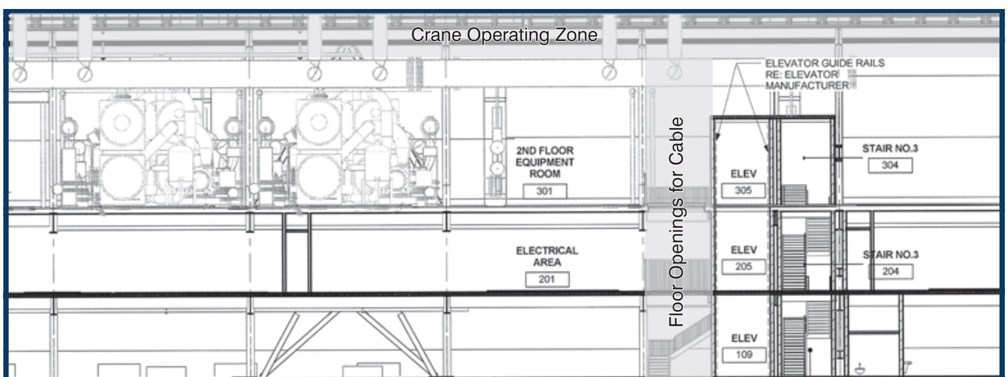

Figure 5: Overhead crane system.

Operation Costs

The first portion of this article highlights some of the energy efficiency improvements. These improvements resulted in more than $1 million energy savings during the first year of operation. The real-time electricity pricing made large energy savings possible during peak days of the year. *Figure 7* shows this energy savings on an hourly basis, peaking at more than $16,000 that was saved in a single hour when electricity was selling at $3,000/MWh.

Environmental Impact

When this plant is fully built out, it will have an 80 MW electrical service. Therefore, reducing the amount of electrical energy this plant consumes provides its greatest positive environmental impact. Efforts to reduce energy use have been described in other sections.

Another feature of this plant that has a positive environmental impact is that the condenser water sumps were used for storm water retention for the building footprint. The cooling tower basins were sized to provide full storage capability for a 25 year, 24-hour storm event. By collecting the rainwater in the sumps, this water can be used in the condenser water system, reducing demand on the city water system, as well as reducing the flow to the storm water system, even during large rain events.

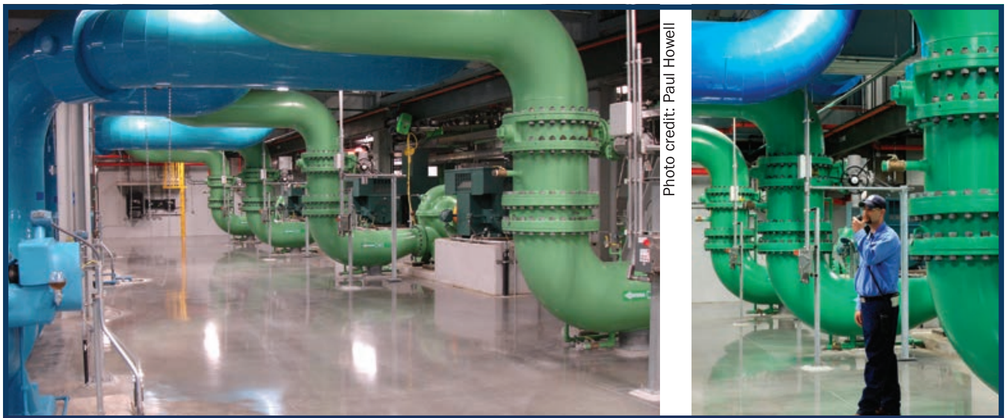

Figure 6: Pump maintenance access.

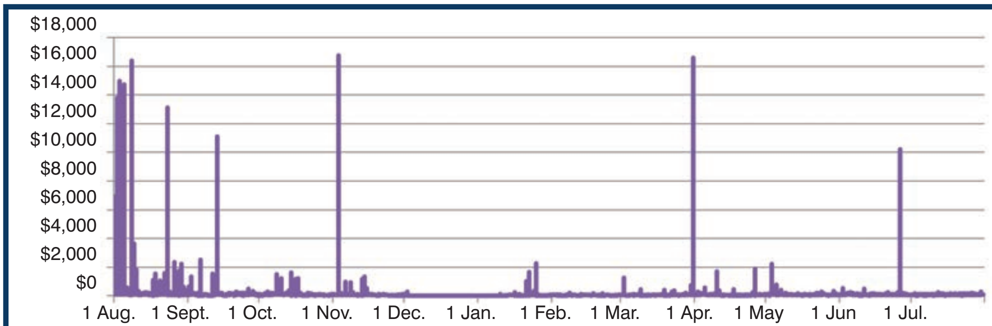

Figure 7: Hourly energy savings.

Conclusion

New chilled water production plants are fairly commonplace, but not at this scale or under such extreme site constraints. A strong focus on the configuration and arrangement of components on the site was crucial to the success of the project. These integration benefits included:

- Reduced condenser water pumping costs resulting from elevated condenser water sumps;
- Recycling of all rainwater falling on the building footprint;
- Accommodation for moving large equipment directly to grade by the provision of a crane system; and
- Provision of adequate maintenance access to the equipment and maintaining consistency of plant equipment eliminated the need for additional maintenance staff.

However, with a future electrical load of nearly 80 MW in the building, minimizing energy consumption was of utmost importance to the operating costs for the owner as were the environmental benefits. The result of reducing electricity consumption by 3.4 MW every hour is that this plant operates for a total of 26.1 GWh of electrical energy savings for the year of operation, resulting in more than $1 million in savings. This is an increase in energy efficiency of 12.7% for the entire first year of operation.

References

1. Ellis, B. 2012. “TES for medical center.” *ASHRAE Journal* 54(11):28. ■