Cooling towers on roof of Central Utilities Plant No. 1 at the University of Alabama at Birmingham. The towers are part of a system that serves a 900-bed hospital, and a medical research complex.

Chilled Water Distribution System For an Urban University Campus

The University of Alabama at Birmingham (UAB) is an urban campus located in downtown Birmingham. The central chilled water system at UAB was constructed in 1972 and 1975 having a nameplate capacity of 14,000 tons. This system provides chilled water service to the 900-bed medical center and the 1,000,000 ft² (92,900 m²) research complex.

In 1988, the University began the planning to increase system chilled water production capacity to meet the continuing growth of the medical research complex. However, before adding capacity, the University wanted to investigate the chronic problem associated with the system: low differential pressure and low system Delta-T. These two problems required the operation of most of Plant #1 chiller and system pumps even at low system loads. Hot gas bypass was often required to maintain the 4,000-ton (14,000 kW) chillers in operation.

Plant #1 is comprised of two 4000-ton, one 2000-ton (7,000 kW) and four 1000-ton (paired in series) centrifugal chillers. Later additions to the system included Plant #3 (one 4000-ton and one 2100-ton chillers) which is not covered by this project. Plant #1 pumping system is configured with three 350-HP (263 kW) system pumps (8500 gpm at 110-feet) (536 L/s at 33.5 m), decoupled production pumps for each chiller, and tertiary pumps at each building. The tertiary pumps ranged from 75 to 15 HP (56.3 to 11.3 kW).

The distribution system is comprised of a 30-inch (76.2 cm) diameter north loop and a 30-inch diameter south loop which are interconnected with a 20-inch (50.8 cm) diameter supply and return approximately two blocks from Plant #1. The use of this looped piping in conjunction with the large diameter results in minimal pressure drop in the distribution system.

About the Author

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The Project

Initial field surveys of the distribution system were performed to develop a concise, single-line diagram. The University had undertaken numerous extensions to the distribution piping system and no single drawing illustrated all connections.

These surveys yielded a number of “short-circuit” connections where the supply was brought into a building then looped directly to the return and exiting the building, often without any valves on the direct connection. In the winter of 1989-90, many of these short circuits were removed. The results were immediate and significant. The system differential pressure increased and the Delta-T showed marked improvement.

Based on the increase in system differential pressure, consideration was given to removing or bypassing the tertiary building pumps and converting the air handling unit three-way valves to two-way type. The use of elaborate pressure-controlled or temperature-controlled building to system interfaces was reviewed but not considered. These type of systems would require the continued use of the building pumps and, with the temperature controlled system, often allow higher chilled water supply temperatures to be circulated inside the building.

During the summer of 1990, building pumps were shut down and the performance of the building’s HVAC systems monitored. A majority of the air handling systems were found to operate satisfactorily without the building pump operating.

During the summer of 1991, a survey was conducted of the over 200 air handling units served from Plant #1 to document the type of controls, control valve, nameplate data (where available), design data, coil face area and condition of equipment. A majority of the air handling units were found to contain 3-way valves. With a plant differential pressure of 30 psi (207 kPa), simply closing the 3-way bypass was not an option. Also, many units equipped with two-way valves were found to have inadequate close-off ratings.

Based on the results of this survey, plans were developed to replace a majority of the control valves with industrial quality two-way valves equipped with positioners. Additional work included installation of bypasses around all building pumps, or removing the building pump entirely.

The construction was initiated in the fall of 1991 with most units converted during the winter of 1991.

This project has resulted in significant improvements to the system Delta-T. The Delta-T in 1990 was no greater than 7° F (-14° C). The Delta-T during summer now exceeds 10° F (-12° C).

Energy Efficiency

Energy savings have been achieved through three areas:

1. Savings from elimination of building pumps.
2. Savings from reduced operation of plant system pumps.
3. Savings from increased chiller efficiency associated with higher Delta-T.

The savings associated with building pumps was tabulated and computed by using the scheduled gpm and head. The number of pump operating hours was obtained by interviewing plant personnel. On the average, building pumps were operated 8 to 10 months per year except for critical facilities which operated 12 months per year. The discontinued operation of the building pumps resulted in a savings of 460 hp (343 kW) and 1.2 million kWh.

The savings associated with plant system pumps was tabulated similar to the building pumps. The daily operating logs for all three system pumps were reviewed and total yearly hours compiled. The installation of two-way valves reduced the system pump operation by 4000 hours resulting in a savings of 900,000 kWh.

The savings associated with the improved chiller operation due to the Delta-T increase was not computed. Compilation of chiller operating logs for the seven machines would be a time consuming task and actual chiller efficiency improvements would be difficult to document. However, two of the chillers at Plant #1 are 4000-ton nameplate capacity with evaporators designed for 15° F (-9° C) chilled water drop. The increase in system Delta-T has increased both the available capacity and efficiency of these two machines.
Innovation

The UAB campus has numerous large air handling systems. In 1986, a project was completed at the Boshell Diabetes Hospital to provide a staged-coil approach in lieu of a single-control valve. The approach at Boshell used a modulating two-way valve at each of the three coil banks. The operation of this unit was monitored and compared to an identical unit with one two-way valve.

Based on this success experience, a similar concept was used at Basic Science and Education (BSE). BSE contains two air handling units with each at: 139,000 cfm (65 330 L/s), 1,000 ton (3 500 kW), 100% outside air containing ten 33 by 108 in. (84 by 274 cm) - 8-row cooling coils. Each unit was controlled by a single two-way control valve. The campus chilled water metering system was used to trend the building flow vs Delta-T.

The trend data indicated the building Delta-T became unstable at approximately 40% flow. The instability was caused primarily by a loss of turbulent flow in the coil tubes which affected the heat transfer.

As part of this project, each of the 10 coils for both air handling units was equipped with a 2-in. (5.08 cm) diameter, slow close, two-position solenoid valve. Two new two-way modulating valves were installed per unit to provide trim between coil stages. The existing pneumatic commercial grade control systems were replaced with high-quality industrial loop controllers. The building flow versus Delta-T stability has been significantly improved. A similar approach was used at other air handling units.

IAQ and Thermal Comfort

Improvement of indoor air quality (IAQ) and thermal comfort was not an specific original goal of this project. Consequently, no field data was obtained to compare IAQ. However, IAQ was improved.

Several large air handling units were revised to a staged-coil control with trimming two-way valves to allow for improved coil heat transfer. The instability at lower loads degraded IAQ due to lack of sensible and latent cooling capacity. The staged coil concept improved cooling coil part-load performance and resulted in improved IAQ.

Additional improvement to IAQ resulted from replacement of numerous three-way valves which no longer functioned with new industrial quality valves. The installation of new control valves allowed for maintaining the original design supply air temperature to the space.

Operation and Maintenance

This project included the removal or bypassing of 44 chilled water pumps and removal of one R-11 chiller. This resulted in a significant reduction in both preventive and emergency maintenance requirements. Installation of new control valves improved the performance of many of the air handler systems, resulting in fewer complaints from building occupants.

Cost-Effectiveness

Total annual electric energy savings as a result of reduced pump operations is $341,227. Total project cost, including construction and fees, was approximately $800,000. Simple payback is 2.2 years.

Conclusion

The approach used to convert the UAB chilled water system from constant flow to variable flow was successful. Plant pumping and maintenance costs were reduced and system operation was improved. Cost avoidance to install additional chillers if the constant flow system had been maintained was accomplished.

The use of the three system pumps to distribute chilled water through the entire system is possible due to the large looped distribution piping. Conversion of large chilled water distribution plants must be tailored to match the unique features of each system.