ASHRAE Journal

Lake-Source Cooling

Exterior view of the completed heat exchange facility showing many of the architectural features.

By Tim Peer, P.E., Associate Member ASHRAE, and
W. S. (Lanny) Joyce, P.E., Member ASHRAE

The Lake-Source Cooling (LSC) Project at Cornell University uses the deep, cold waters of nearby Cayuga Lake, as a non-contact cooling source for the campus chilled water system. It began providing 16,000 tons (56 300 kW_{th}) of cooling in July 2000 with an 86% reduction in energy use versus conventional cooling alternatives. Cornell's deep-water-source cooling project is the first to use a deep inland lake's renewable cold water. (All heat gained each year is fully released to the environment by midwinter. LSC's contribution is equivalent to an additional two hours of sunlight each year.) Two technically challenging issues of this project were heat exchanger selection and distribution system hydronics.

Campus District Cooling System

Most research universities boast physical plants large enough to serve a small city. Cornell's nearly 40-year-old central chilled water system has more than 75 buildings connected to a looped distribution-piping network of more than 10 miles (16.1 km). Three central plants with eight chillers and an aboveground 4.4-million-gallon (16.7×10^6 L) stratified chilled water thermal storage tank[1] provided cooling before LSC. Load growth, phase out of CFC refrigerants, aging equipment and rising energy costs all contributed to the need for major change. Six of the eight chillers could not be economically retrofitted to new refrigerants, requiring their replacement before 2005.

Lake-Source Cooling

LSC is designed to provide more than 20,000 tons (70 400 kW_{th}) of peak cooling capacity, circulating up to 32,000 gpm (2020 L/s). It has reduced chiller energy use by 86% with associated reductions in emissions of pollutants produced in the generation of electricity in regional power plants. LSC also offers a 75- to 100-year system life, versus 30 to 40 years typical for chillers.

The project begins physically with a screened intake structure located in a water depth of 250 ft (76.2 m) near the southern end of Cayuga Lake, which is the second largest of the Finger Lakes in New York. This glacial lake is roughly 38-miles (61 km) long, 1 mile (1.6 km) wide, up to 425 ft (130 m) deep with 2.5 trillion gallons (9.48×10^{12} L) volume.

A variable flow of up to 32,000 gpm (2020 L/s) of 39°F (4°C) lake water (which has the highest density for fresh water) enters the intake and travels through nearly 2 miles (3.22 km) of 63 in. (1.6 m) high-density polyethylene (HDPE) plastic pipe to arrive at a wet well in the heat exchange facility. In the plant, the water is pumped out of the wet well by up to three 350 hp (261 kW_e) variable speed vertical turbine pumps, and pushed through up to seven plate and frame heat exchangers piped in parallel. The lake water then returns to the lake through a 100 ft (30.5 m) diffuser section, which ends 500 ft (152 m) off shore in about 14 ft (4.27 m) of water depth.

Chilled water flows from campus distribution piping through five interconnection points that combine into 42 in. (1.07 m) of coated welded steel transmission piping that extends 2.5 miles (4.02 km) to the lakeshore heat exchange facility. The closed loop of campus water is pulled through the heat exchangers and then pushed by the pumps back to campus to minimize operating pressures in the plant. The five 600 hp (447 kW_e) variable speed centrifugal pumps and transmission piping are designed for high static pressure due to the nearly 600 ft (183 m) height between the top of campus loads and the plant.

System Performance

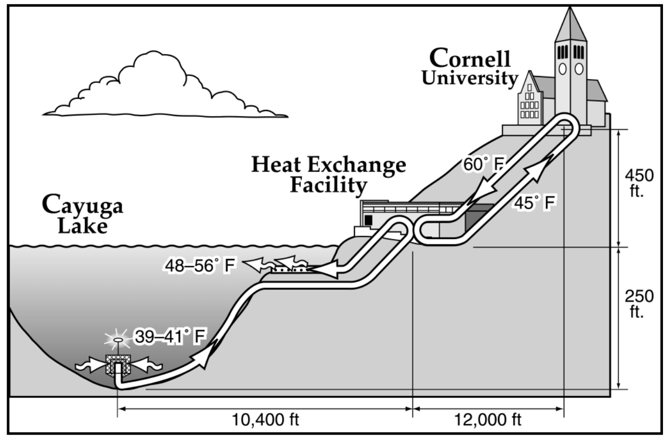
The system started operation in July

About the Authors

Tim Peer, P.E., is heat exchange facility project engineer at the Utilities Department, Cornell University, Ithaca, N.Y.

W. S. (Lanny) Joyce, P.E., is lake-source cooling project manager at the Utilities Department, Cornell University, Ithaca, N.Y.

Interior view of the completed heat exchange facility.



Schematic of the lake-source cooling process.

2000. By the end of the month, it was handling all campus-cooling load with a summer peak that year of 15,500 tons (54 600 kW_{th}). The peak sustained demand in 2001 was more than 16,000 tons (56 300 kW_{th}). Since startup, LSC has been operating at an annual average of 0.10 kW/ton (0.028 kW_e/kW_{th}). With a typical annual production of more than 30 million ton-hours (106 × 10^6 kW_{th}), LSC will save more than 22 million kWh of electricity.

The plant is fully automated and integrated into the overall utilities control system for monitoring by operators 3 miles (4.83 km) distant from the LSC plant. A fiber-optic link allows the operators to see plant functions instantly. Today, the campus return temperature allows 18,000 tons (63 400 kW_{th}) of peak heat rejection, and as the campus return temperature rises, the ultimate capacity will be 20,000 tons (70 400 kW_{th}).

Heat Exchanger Design and Selection

As stated earlier, heat is transferred from the chilled water system to the lake water system through seven plate and frame heat exchangers. The 300 psi (2069 kPa) rated exchangers are located on the suction side of the chilled water pumps where the normal operating pressure is typically 200 to 250 psi (1380 to 1720 kPa). The heat exchangers are designed to provide 42°F (5.6°C) chilled water at a 3°F (1.7°C) approach. Campus loads are designed as primary-secondary variable flow mixing loops providing 47°F (8.3°C) chilled water in the summer and 50°F (10°C) during the winter to the buildings.

Total load on the plant includes the buildings and heat gain to the 5 miles (8.05 km) of transmission piping that accounts for 800 tons (2820 kW_{th}) at peak. With peak flow and all but lake return temperature fixed, surface area was determined by balancing heat transfer coefficient and water pressure drop. Fouling factor was included by adding one spare unit.

All vendors were requested to supply a base bid and two alternates (less quantity of exchangers) to allow optimization based on guaranteed vendor data during the review process. The optimization process included evaluation of heat transfer coefficient versus pressure drop. More surface area increases first cost but decreases operating costs. The project team developed a model to "run" the heat exchangers with the expected annual load profile and create a "cost of ownership." Final selection was made on present value.

The present value of reducing pressure drop across the plate heat exchangers by 1 psi (6.9 kPa) was estimated for a 10-year period. Because of the large savings potential, a design 10 psi (69 kPa) pressure drop across the PHE was selected for the base bids. During the optimization process, the vendor guaranteed data and costs drove the selection to a 14 psi (96.5 kPa) pressure drop, increasing available thermal capacity for the few short hours each year the plant will run at peak flows, with minimal extra operating costs during off-peak conditions.

Campus Distribution Study

The previous Cornell system had three chilled water plants located on the periphery of the campus looped distribution system. The LSC system feeds directly into the center of the existing system, significantly changing the system hydraulics. A campus distribution study using a flow analysis program determined the optimal tie-in of the LSC transmission pipeline, the sections of the distribution system requiring upgrading, and the required LSC chilled water pump head. The following constraints were used when performing the hydraulic analysis:

- The minimum supply and return differential pressure at any building connection would be 5 psid (34.5 kPa).
- The maximum supply and return differential pressure at any building connection would be 30 psid (207 kPa).
- The maximum supply pressure would not exceed 140 psig (965 kPa).
- Fluid velocities would not exceed 10 ft/s (3.0 m/s).
- The return system pressure at the makeup point would be 60 psig (414 kPa).

Base demands and system configurations were determined and modeled for 2000, 2015 and 2029. Modifications were made to the base models to optimize the tie-ins and determine upgrades to the existing distribution system.

Booster Pump Station

A challenge arose due to a 3,000 ft (914 m) radial spur feeding the east side of campus. The minimum differential pressure requirements could not be met using pumps at LSC without exceeding the maximum differential pressure requirements in the core campus.

A series pump booster station was added, reducing core campus pressures and overall pumping horsepower by 350 hp (261 kW_e), or more than 10%. High system flow turndown reduces the pump's duty to less than 500 hours per year.

The pump is a single-stage, horizontal split-case, double-suction pump rated for 10,000 gpm (631 L/s) at a head of 47 ft (140 Pa). The high-flow, low-head condition required a creative pump and motor selection to purchase standard products. A 900 rpm, 120 hp (89.5 kW_e) pump design point is met through the use of a 1200 rpm, 200 hp (149 kW_e) motor on a variable speed drive. The drive is configured to operate at a maximum speed of 900 rpm matching the rated speed of the pump. The pump impeller is uncut to provide the greatest efficiency.

The flow rate of the pump is controlled by a variable frequency drive that regulates the speed according to the differential pressure at the most remote load. The pump operates continuously throughout the year (much of it at minimum speed), eliminating the need to provide space heating and ensuring proper bearing lubrication.

See www.utilities.cornell.edu /lsc for more information.

References

1. Bahnfleth, W.P. and W.S. Joyce. 1995. "Stratified storage economically increases capacity and efficiency of campus chilled water system." *ASHRAE Journal* 37(3):46–49.