The Health and Human Services building at Saginaw Valley State University, Saginaw, Mich., was sited specifically to maximize daylighting by orienting the building's long dimension east to west.

Aquathermal Systems

By Camille Sylvain Thompson and **Wayne E. Kerbelis,** Associate Member ASHRAE

Saginaw Valley State University's (SVSU) new Health and Human Services (HHS) building uses one of the largest pond closed loop geothermal (aquathermal) systems ever developed in Michigan. The system has provided SVSU with 40% annual savings in heating and cooling costs, equating to $85,000 annually, as compared to an ASHRAE/IESNA Standard 90.1-2004 level conventional boiler and chiller system.

About the Authors Camille Sylvain Thompson is a marketing communications coordinator, and Wayne E. Kerbelis is a mechanical engineer and principal with the engineering firm of Peter Basso Associates in Troy, Mich. Kerbelis is a member of ASHRAE's Detroit chapter.

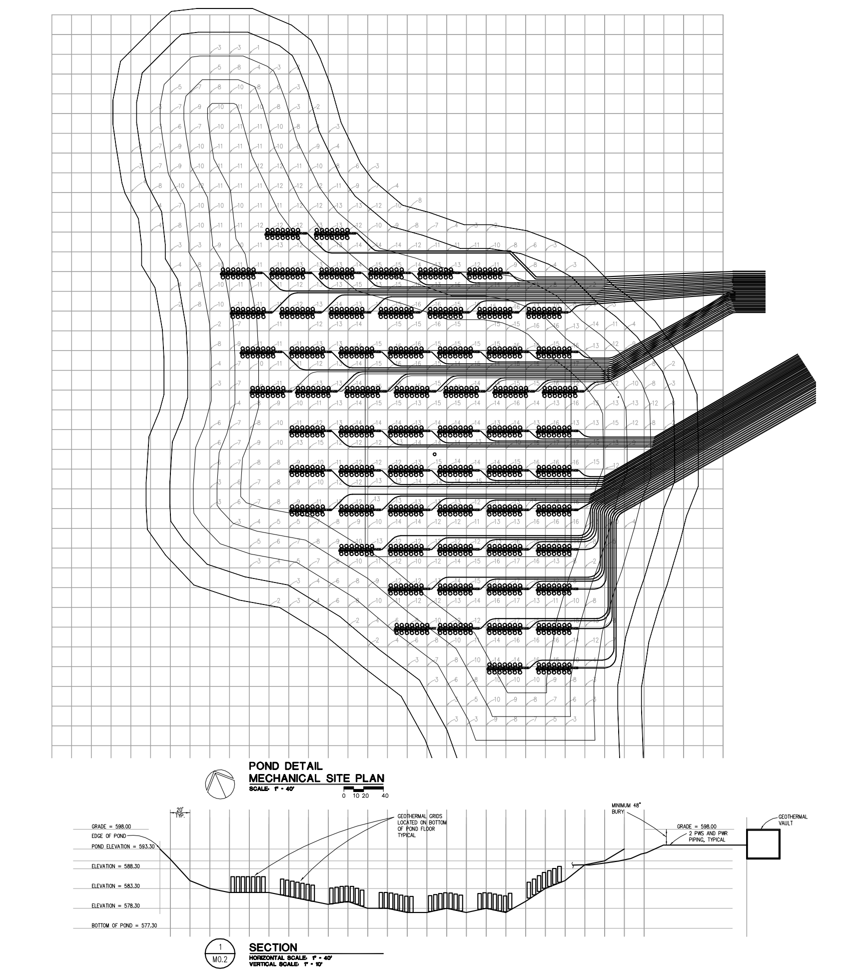

Figure 1: Aquathermal pond heat exchanger layout.

Building at a Glance

Saginaw Valley State University

Health and Human Services

Location: Saginaw, Mich.

Owner: Stephen L. Hocquard

Principal Use: Health occupations classroom and lab building

Includes: Classrooms, laboratories, occupation training facilities, vivarium, offices, conference rooms, gymnasium, student lounge

Employees/Occupants: 800

Occupancy: 100%

Gross Square Footage: 95,975

Conditioned Space: 91,500 ft^2

Substantial Completion/Occupancy: August 2010

The 95,975 gross ft^2 (8900 m^2) building houses nursing, kinesiology, occupational therapy, health sciences and social work programs. The mission of the new building is to provide new facilities for student instruction and training in Health and Human Services, along with presentation skills, and technology integration.

The new building was sited specifically to maximize daylighting by orienting the building's long dimension east to west. Ample daylighting allows the facility's corridor daylight harvesting system to automatically turn off lights during the day, when daylight is prevalent, to achieve additional energy savings.

The building's envelope features exterior walls constructed of veneer face brick, an air gap, 2 in. (50 mm) of spray foam insulation and a minimum of 8 in. (200 mm) of CMU, allowing for a large mass wall, reducing heat loss by providing an overall wall construction insulating value of R-20. The roof is constructed of a white EPDM membrane with an overall insulating value of R-30. The exterior windows consist of low-e glazing with a U-value of 0.34 at the center of the glass, and an overall U-value of 0.47 when factoring in framing. Sun shade devices, large overhangs, and window shades all provide further heat gain reduction in summer months and heat loss reduction in winter.

Each of these efficient features is factored into the performance of the HHS building, and is part of a comprehensive system design that provides 19% more energy savings than the building code's requirements for the envelope. The construction of the exterior walls and roof was a key component to the energy efficiency of the building.

Spaces within the building are designed to be flexible and versatile, to provide for the diverse and growing field of health and human services. Among the 13 labs are a research-level vivarium, which operates on a 24-hour basis on 100% outdoor air, and a learning lab, which includes five meeting areas clustered around a central observation room, providing space for individual and group instruction, as well as simulation space for patient treatment. Simulation laboratories and meeting rooms provide space for the development of health sciences and social work research. Twelve classrooms feature spaces for nursing, kinesiology, and occupational therapy. Additionally, various student meeting spaces are provided as well as faculty offices, conference rooms and computer classrooms.

The second floor features clustered office suites for faculty and the college's dean, encouraging the use of shared conference and collaboration space, file storage, and support staff space. Pedestrian connections are located at each level between the HHS and Regional Education Center (REC) building for convenience in sharing existing food services, lab spaces, and the REC's auditorium.

At the heart of the complex and versatile HHS building is a massive, concealed aquathermal system. The aquathermal system connects the HHS and REC buildings, providing heating and cooling from an on-site 12 acre (5 ha) manmade pond. The decision to use an unconventional heating and cooling method was critical to the new building's high efficiency design.

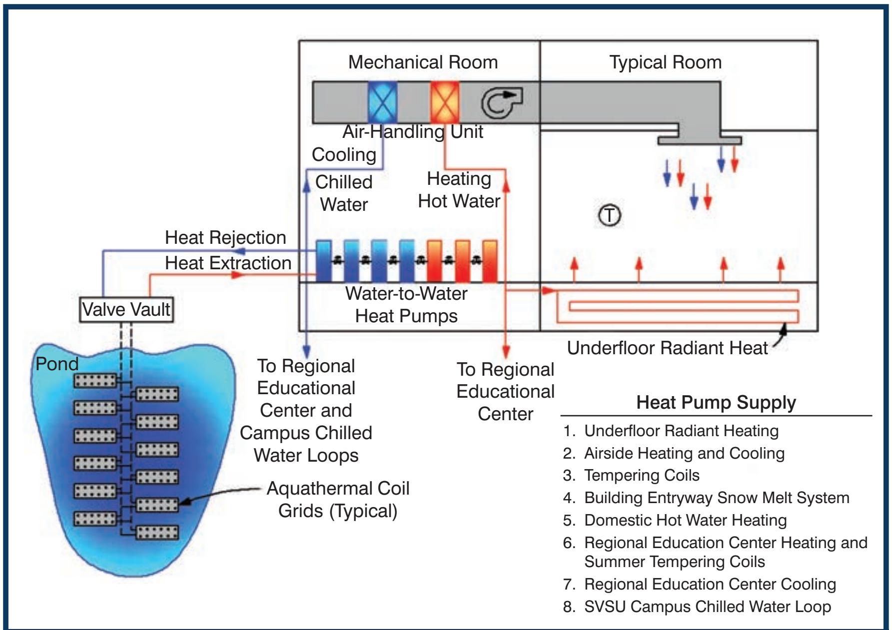

Figure 2: Aquathermal system schematic.

Aquathermal Central Water-to-Water Heat Pump Systems

Energy savings from the aquathermal system, led the university to an annual energy use intensity (EUI) of 92 kBtu/ft^{2*} for the HHS building. In comparison, the average EUI for similar buildings at universities in the same geographic region is 138 kBtu/ft^2 (based on 2010 data). These savings were met by supplying hot water to various systems including the underfloor heating systems,

*This number only reflects the cost of the renovation project and does not include the property cost or site work.

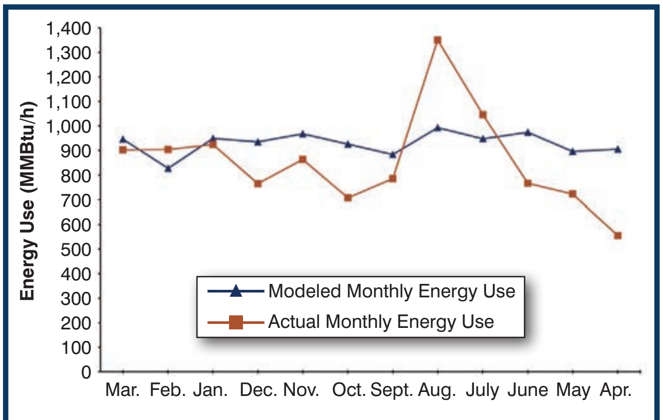

Figure 3: 2011–12 monthly actual, modeled, energy use.

snow melt systems, domestic water heating systems, hot water heat transfer coils and chilled water for cooling all from one central aquathermal heat pump plant location.

Operating similarly to a central boiler and chiller system allows air-handling systems to serve multiple thermal zones (rooms) as opposed to having to install one heat pump per room. Each high-tech central heat pump unit is capable of providing heating hot water at 120°F to 130°F (48°C to 54°C) with a minimum pond temperature of 35°F (1.6°F) and supplying chilled water at a temperature of 42°F (5.5°C) with maximum pond temperatures of 90°F (32°C).

The central aquathermal heat pump system is used to boost the heating supply water temperature with the heat harvested from the earth into a suitable heating temperature range during the winter, while the cool water in the pond acts as condenser water during the hot summer months. The aquathermal system provides 100% of the HHS building's year-round heating and cooling needs. Ten water-to-water heat pumps are connected together where one end of the heat pump system provides chilled water for cooling the building, and the other end provides hot water for heating. Each heat pump is capable of switching between heating and cooling mode in any combination to meet the building's heating and cooling demand.

The aquathermal system distributes hot water to heating coils and chilled water to cooling coils located in two indoor variable volume air-handling units, with an air-to-air heat recovery device that serves the majority of the building. In addition, the heat pump system supplies hot water and chilled water to a 100% outdoor air unit with a runaround energy recovery coil that serves a critical research vivarium space. Spaces served by the air-to-air energy recovery air-handling units are equipped with a carbon dioxide sensor (demand control), which allows ventilation air to be reset based on occupancy in the building. The aquathermal central heat pumps also deliver hot water to the in-floor hydronic radiant heating system located in each space. In addition, the central heat pump system also provides hot water to a domestic water heat

Study area heated by underfloor aquathermal system.

exchanger, serving all plumbing fixtures and snow melting systems at all entrances.

Aquathermal Pond Source Water System

A closed loop aquathermal water system (or source water system) was installed to serve the central heat pump system. There were 868 coils (approximately 1 ton [3.5 kW] per coil) mounted on 62 skids and sunk into the bottom of the pond to exchange (absorb or dissipate), building heat with the pond water for heating and cooling operation.

Extending the Savings and Thermal Comfort

In addition to supporting the HHS building, the aquathermal system, through a series of pipes, is interconnected to the adjoining Regional Educational Center (REC) and the campus chilled water loop system. Therefore, the aquathermal central heat pump system can serve other heating and cooling campus needs with better energy efficiency without firing the boilers in the REC and energizing other campus building chillers. Additional capacity was engineered into the aquathermal central heat pump system to accommodate these extra connected loads.

Over a seven month period, the aquathermal central heat pump system supplied heating hot water to the adjoining REC building. During that time, the university managed to save $15,000 by keeping the REC boilers out of operation. It is anticipated the savings will be higher in future years as heating hot water is provided to the REC building year-round.

With the construction of multiple new buildings on campus over the past six to eight years, the existing campus standby chilled water loop capacity was depleted below functional levels. By connecting the aquathermal central heat pump system to the existing campus chilled water loop, additional standby capacity was increased to functional levels. In addition, the existing chilled water loop relied on seasonal cooling towers to be dewinterized before campus chilled water was available. The aquathermal central heat pump can produce chilled water to the campus throughout the year. In Michigan, temperatures of 20°F and 80°F (–7°C and 27°C) in a single month or even a week are common and having chilled water available when needed substantially increased the overall comfort level in campus buildings.

Operation & Maintenance

Operation and maintenance with the central heat pump system is superior to conventional systems with boilers and chillers and condensers due to the reduced amount of equipment to maintain year-round. Air-to-air energy recovery heat exchangers in the air-handling units have no motorized parts to maintain. All mechanical equipment has direct digital controls

Lessons Learned

The top five lessons learned after two years of operation of the system are as follows:

Get the dirt out. The central water-to-water heat pumps are equipped with 60 mesh filter screens. If dirt from the piping system collects and clogs the screens, the bank of heat pumps will de-energize. A thorough flushing and cleaning of the piping system is a must.

Get the air out. Pond source water coils will have high points where air pockets will reside and reduce heat transfer abilities. Circulating water through the system at high velocity to push the air pockets out will allow the source water loop to operate at its peak efficiency.

Functional test (commission) systems at all extremes. The source (earth) water will range in cold climates from 35°F (1.6°C) in the winter to 85°F (29°C) in summer. Heat pump setpoints and safety limits must be properly adjusted or continuous alarms and faults will be a common occurrence.

Size heat transfer devices for EWT of 120°F (48°C). The heat pump system is capable of supplying 130°F (54°C) hot water, but because it is a compressor fed system, supply hot water temperature set points will fluctuate. Choosing heating coils with a 120°F (48°C) entering water temperature will allow some safety on those very cold days.

Pond pre-freeze conditions. In late fall prior to when the pond surface freezes over, the surface water and water at the bottom of the pond will equalize at around 32°F to 34°F (0°C to 1.1°C). Until the pond freezes over and heat is trapped in the pond from the earth, the heat pump system will be operating at its peak cooling load.

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monitored through the energy management system (EMS). The EMS monitors runtimes of the mechanical equipment as well as static pressure drop across unit filters. This allows for preventative maintenance scheduling based on unit operation. The EMS system notifies users of sudden changes in the system, such as loss of temperature or pressure. Alarms aid in system troubleshooting and quick responses before a serious event occurs.

The HHS building's HVAC systems were fully commissioned, resulting in a number of enhancements being identified, which further improved system operations, efficiency, and maintainability.

Sustainable Elements

The mechanical, electrical and architectural systems for the building embrace the concepts of sustainability and green design practices. Among the key concepts are the following:

• Equipment and systems were designed for low life-cycle cost, high durability and ease of maintenance. All mechanical equipment was designed with ample clearance to allow access for maintenance, which keeps the equipment running at its peak performance while extending its useful life.

• During occupancy the air-handling system delivers 10% more outside air ventilation, which exceeds ASHRAE Standard 62.1-2004. The additional ventilation enhances the building occupant's performance and productivity as well as overall comfort. During unoccupied periods, the ventilation is reduced though the use of CO_2 sensors, which also reduce energy consumption.

Vivarium energy recovery unit and heat pump source water pipes from and to pond.

• Fans and pumps use premium efficiency motors. The distribution pumping system for heating hot water uses variable flow control and variable frequency drives. The pump and fan flows are controlled by the building's direct digital control system based on actual building heating and cooling demand further optimizing energy efficiency.

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• All three of the building's mechanical HVAC systems use energy recovery to minimize energy use.

• To minimize the new building's footprint, the facility's 12 new classrooms include two pairs of classrooms with moveable walls, allowing for a large computer testing area. In addition, five conference rooms in the new facility have multi-use functions, and double as examination rooms, with an adjacent storage area for exam equipment.

• An aquathermal geothermal system was used as a building heating and cooling source to the HVAC systems.

• Underfloor radiant heating was provided to offset perimeter heating losses, providing superior comfort and allowing unoccupied night setback without cycling air-handling equipment to conserve energy.

• Alternative transportation measures were designed as part of the project, including: bike racks for a percentage of the building occupants as well as shower facilities; preferred parking for low-emitting vehicles and the ability to walk less than 0.25 miles (0.4 km) to gain access to two bus station lines serving the surrounding metro areas.

• Low water flow and automatic sensor operated plumbing fixtures were used to minimize water use.

• Carbon dioxide sensors (demand ventilation) were provided in each room to reset outdoor air ventilation quantities when spaces are unoccupied.

• Energy-efficient lighting, including T-8 fluorescent lamps and electronic ballasts, are used and controlled by occupancy sensors in each space.

• Site water run-off is captured from the site through several retention swales and is drained into the aquathermal ponds to aid in the efficiency of the aquathermal system.

• Registered with the U.S. Green Building Council, the facility is on track with points necessary to achieve LEED certification.

• The photovoltaic system, located on grade near the north building entrance, was installed to generate between 15,000 to 16,500 kWh annually, representing approximately 0.73% of the building's annual usage and 0.2% of the current annual electrical power consumption for the university's entire campus.

• The actual building's energy efficiency far exceeds the requirements of ASHRAE/IESNA Standard 90.1-2004 by 40%.

• The site was restored with native or adapted vegetation to incorporate natural habitat and to significantly reduce the need for irrigation. Where plant water was required, irrigation was supplied by the aquathermal pond.

• Exterior light fixtures and interior light fixtures were strategically selected and located so as to reduce light pollution of the building site.

• Commissioning and functional testing were performed at seasonal weather changes to ensure peak system operation and indoor comfort.

• Indoor air quality is maintained by using low VOC paints, sealants, adhesives and agrifibers.

• A green housekeeping program was implemented by the university.

User Satisfaction Survey

A thermal environment survey was provided to faculty by the university to assess their overall level of comfort in the new HHS building, focusing in particular on the university's decision to use in-floor heat and aquathermal central heat pumps. The faculty was asked to rate their overall satisfaction of four different subjects: temperature, humidity, airflow and comfort. The rating system started at –3 (very dissatisfied) to +3 (very satisfied). More than 80% of the faculty expressed an overall satisfaction of +1 or higher with the new building's unique heating systems and overall thermal comfort level.

Finance

A detailed value engineering and energy modeling process was performed on the HHS building. The aquathermal system cost $330,000 more than a conventional typical heating and cooling system that uses natural gas and electricity for heating and cooling. An annual energy and operational cost savings resulted in a four-year payback for the added investment of the energy-efficient systems over less efficient conventional systems.

The annual energy savings result in a 40% cut in heating and cooling costs compared to conventional systems, which is equivalent to approximately $85,000 to $90,000 a year in savings.

The energy-conscious decision to connect the aquathermal system to other campus buildings and systems including the REC and the South Campus was a financial success as well.

Using the existing SVSU pond for the new heat pump source system saved substantially on installation costs. The cost to install 22 miles (35 km) of source water coils in the existing pond was approximately $800 per ton ($2800 per kW), in comparison to vertical or horizontal buried systems that cost in the range of $3,000 to $4,000 per ton ($10,500 to $14,000 per kW). Coils are filled with 10,000 gallons (37 900 L) of an environment-friendly propylene glycol product. The glycol is fed in and out of the pond through two 10 in. (250 mm) lines that run from the building to the water.

Conclusion

The team's decision to incorporate a heating and cooling system using geo- and aquathermal resources has proven to be an financial, thermal and energy-saving benefits to the university, its staff, students and faculty. The sustained ease of operating and maintaining the facility and its systems continues to impress the university, while the flexibility and versatility of the lab, classroom and office spaces, exceeds the user's needs. ■

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