SECOND PLACE: INSTITUTIONAL BUILDINGS, NEW

GEOTHERMAL FOR SCHOOL

Whitmore Lake High School in Michigan uses a geoexchange system for HVAC. Daylighting is another energy-saving technique used.

By Robert N. Roop, Member ASHRAE

Whitmore Lake, a nearby suburb of Ann Arbor, Mich., hoped to attract students from outside the district by being a leader in sustainability and building a school with innovative systems. Whitmore Lake High School is the first comprehensive high school in Michigan to achieve LEED Silver certification.

School officials began investigating ways the district could minimize operating costs. After a cost analysis study, the district's project management team chose to use a geoexchange system for HVAC. A detailed value engineering and energy analysis was performed at several milestones of the project. The result was a cost-effective design with major annual energy and operational cost savings. The mechanical systems designed, including the geoexchange system, were installed within the construction budget established by Whitmore Lake Public Schools.

The geoexchange field installed for this facility is comprised of nearly 46 miles (74 km) of high density polyethylene (HDPE) piping installed in a combination of horizontal loops and pond coils. Approximately 70% of the field is buried beneath the soil in a green area to the north of the school building. The ground portion of the field is made up of a series of trenches 2 ft (0.6 m) wide that are spaced 8 ft (2.4 m) on center and excavated to a depth of 6 ft (1.8 m) below grade. Three 1½ in. (38 mm) diameter pipes are laid, evenly spaced, across the bottom of the trench, and approximately 2 ft (0.6 m) of fill material is placed on top of those pipes. The same three pipes are

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Horizontal geoexchange field has nearly 46 miles of HDPE pipe.

Pond loop installation: pipes are floated into place then filled with fluid.

then looped up and routed back and fused into a branch supply and return header.

A variable speed pumping system circulates a glycol solution throughout the building's mechanical spaces, allowing heat rejected to it from one space to be extracted and used in another. A bypass valve permits flow through the geoexchange loop field only when loop temperatures exceed the minimum or maximum design temperatures. By limiting the time the fluid flows through the field and isolating units without a call for heating or cooling, total pump energy is greatly reduced.

The 430-ton (1512 kW) system includes 67 unitary water source heat pumps delivering conditioned air to classrooms and other spaces while providing independent temperature control. Four plate-type air-to-air energy recovery units (ERUs) pretreat all ventilation air. All of the relief air from the building is exhausted through one of the ERUs, pretreating all of the outdoor air introduced into the facility to satisfy ASHRAE Standard 62.1 and state code requirements. Working as a complete system in the winter mode, the energy recovery units take outdoor air that measures 0°F (–18°C), and using waste heat from relief air from the space at 70°F (21°C), pretreat the outdoor air to deliver a temperature of 54°F (12°C). From this point, a water source heat pump integral to the energy recovery unit brings the air temperature up to 60°F (16°C). A similar process occurs in the summer operation where again, pretreated dehumidified outdoor air is delivered from the ERUs to the individual units.

An energy recovery-based dehumidification unit serves the natatorium and consists of an air-to-air plate-type heat exchanger, closed loop water source heat pump with an integral hot gas reclaim coil to provide dehumidification and maintain space temperature. The unit is also provided with a face and bypass damper arrangement on the heat exchanger and an outdoor air enthalpy based dehumidification control sequence to control natatorium humidity levels with pretreated outdoor air whenever outdoor temperature and humidity levels permit.

The air-distribution systems are designed to meet or exceed the guidelines set forth in ASHRAE Standard 62.1 ventilation rates and effectiveness and Standard 55 for occupant comfort. The design criteria for this project specified a summer space temperature of 72°F (22°C) and 50% RH and winter space temperature of 72°F (22°C). Classrooms and office spaces used the "seated, reading or writing" activity level value of 18 Btu/h·ft^2 (57 W/m^2) and the gymnasium areas used a value of 140 Btu/h·ft^2 (442 W/m^2) for basketball, wrestling and leisure activities in the heating and cooling load calculations. Duct systems and outlets were designed to limit air velocities to less than 50 fpm (0.254 m/s) in

Building at a Glance

Name: Whitmore Lake High School

Location: Whitmore Lake, Mich.

Owner: Whitmore Lake Public Schools

Principal Use: Comprehensive High School

Includes: Gymnasium, Cafeteria, Natatorium, Media Center, "Main Street" commons area and classrooms

Employees/Occupants: 450 Students

Gross Square Footage: 150,000 ft^2

Conditioned Space: 150,000 ft^2

Substantial Completion/Occupancy (date): August 2007

National Distinctions/Awards: LEED Silver; Engineering Society of Detroit, 2007 Excellence in Design Awards competition for *PM Engineer Magazine*

the occupied zone. Humidity levels are maintained in the natatorium and other building spaces to achieve compliance with the design intent. Low level return air inlets are used in spaces with large volumes and/or high occupancies to increase ventilation effectiveness.

A design quantity of pretreated outdoor air is delivered to each heat pump through a pressure independent variable air volume box. All variable air volume boxes are connected to the building management system (BMS), which allows the owner to easily change the outdoor airflow to any heat pump through a change in airflow value in the BMS. Outdoor air quantities are also modulated in response to feedback from the space CO_2 sensors. Occupancy sensors provided in most spaces to satisfy the lighting control requirements of Standard 90.1 also provide feedback to the building management system, commanding the equipment to standby mode if occupancy is undetected.

The energy recovery based air-handling units serving the gymnasium and the auditorium have a CO_2 demand control ventilation strategy and necessary components to modulate the air handler toward 100% outdoor air on a rise in CO_2 levels. Prior to its distribution, ventilation and mixed air is filtered through 30% efficient pre-filters and 65% efficient cartridge filters. Return air for each individual heat pump passes through a 30% efficient filter prior to mixing with ventilation air.

The building layout (with varied classroom conditions, large common spaces, individual administration offices and large program spaces such as the gymnasiums, natatorium and auditorium) dictated special attention be given to the zoning of the building. To provide desirable thermal comfort, each type of space and each exposure of large open spaces was provided with its own individual space sensor and zone temperature control to closely follow the heating and cooling requirements of the spaces.

Using many unitary heat pumps that operate in response to space occupancy and internal loads, in lieu of large conventional air handlers, is key to reducing overall fan energy. By locating that equipment near the spaces they serve to reduce ductwork and required clearances, installation costs were held to a minimum and service access to all equipment is provided. Also, the reduced ductwork distribution system is a less expensive, low pressure construction and reduces overall fan static pressure requirements. Locating the heat pumps within the mezzanines and routing the distribution ductwork through ceiling spaces (both of which also serve as a return air plenum) allows the elimination of duct insulation, reducing overall installation costs further.

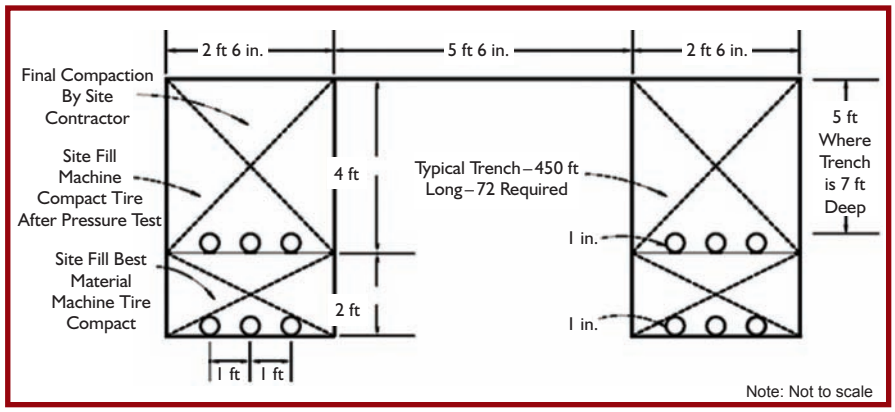

Figure 1: Geothermal cross-section detail.

Energy at a Glance

Energy Use Intensity (Site): 75.033 kBtu/ft^2

Natural Gas: 0.013 kBtu/ft^2

Electricity: 75.02 kBtu/ft^2

Annual Source Energy: 261 kBtu/ft^2

Savings vs. Standard 90.1-2004 Design Building: 35%

The installation cost of moisture-resistant fabric ductwork with an antimicrobial coating in the natatorium was 30% less than the installation of chemical resistant fiberglass or galvanized ductwork with a protective paint finish applied. The much lighter weight of the fabric duct system reduced the loading of the roof support structure, again reducing cost.

Efforts to reduce the impact on the environment first took shape during the planning stage while considering site clearing and building orientation. A turn of the century farmhouse and livestock barn stood on the building site and had to be removed for the construction. The district sought interested parties and found an individual who relocated both the original house and livestock barn to a vacant piece of land approximately a mile away where that individual now lives. Through construction waste management and monitoring, the project received two LEED credits for diverting more than 75% of construction waste from disposal. Active recycling efforts exist in the occupied school building and serve as a constant teaching tool for all students.

Since all of the building's heating and cooling needs are met with the geoexchange system, there is very little consumption of natural gas. Only domestic water heaters and a natural gas fired pool water heater use any fossil fuel. Since the operation of the pool is funded through a separate recreation millage, the community and district felt it was important to meter natural gas use separately for heating pool water. No CFC-based refrigerants are used in any of the equipment on this project. To reduce water consumption, low flow water closets and waterless urinals are installed throughout the facility. The combination of these systems, working together with the geoexchange system, has helped to reduce energy costs by an estimated 35% compared to a conventional system.

Because of the rural setting for the new school, there is no municipal water supply, sanitary sewer or storm sewer system.

Geoexchange supply and return branch mains lined up in the main mechanical room.

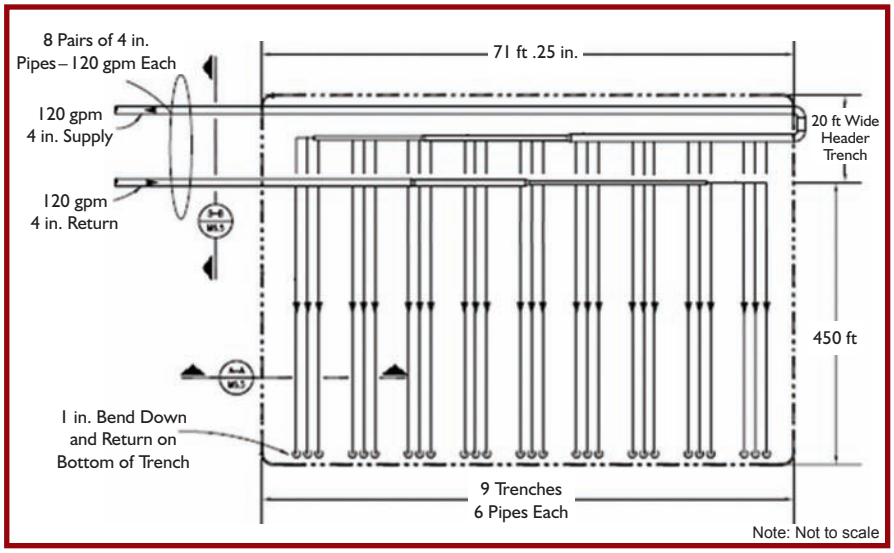

Figure 2: Geothermal loop field piping circuit detail.

Mechanical mezzanine showing individual heat pumps with air terminal units providing measured quantity of ventilation air.

Because of the lack of utility infrastructure, storm water runoff and a water supply for the building fire protection system provided challenges. The design team combined the two needs, resulting in the creation of an on-site pond, covering approximately 14 acres (5.67 ha). This created the opportunity to use the water as a portion of the heat sink/source for the geoexchange field; approximately 30% of the field is submerged in the pond. A separate well and pond level controller maintain the pond water at the level required to provide sufficient fire protection water supply. Ponds provide better heat transfer than loop systems, so we took advantage of what we had to construct anyway to further improve the efficiency of the geoexchange system.

Another innovative feature of the systems at Whitmore Lake High School is the connection of the refrigeration equipment serving the school kitchen's walk-in cooler and freezer to the geoexchange system. All of the heat rejected by the compressors serving the cooler and freezer is then available for space heating wherever needed in the building. Not only does this contribute to the heating of the building, but also picks up the added efficiency of water cooled equipment over air cooled equipment.

Data collected by Whitmore Lake Public Schools supports the achievement of high levels of indoor air quality and thermal comfort. According to their records, student and teacher attendance has risen from 87.5% attendance in their previous building to nearly 95% attendance in the new facility. The ACT test scores by Whitmore Lake High Schools students have also improved since moving into the new building. Prior to the move, Whitmore Lake students' ACT scores had never exceeded the state average.

With a specific goal in mind, the backing of the community, and an efficient HVAC system, Whitmore Lake has built its dream school. The school serves as a flagship for a growing community and a testament to their environmental mind-set. "Now that we've earned our LEED certification, the new school has created a buzz in the community; it has people excited," said Tom DeKeyser, principal of Whitmore Lake High School. "Everyone from members of the community to prospective students and visiting sports teams are witnessing what Whitmore Lake has to offer. We're very pleased with the result."