2018
ASHRAE AWARD OF ENGINEERING EXCELLENCE

A Journey From Worst To Best Energy Efficiency

Heritage Hall uses less energy now than when it was "mothballed."

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PHOTO CREDIT JUSTIN MACONOCHIE

Upgrading to geothermal from steam helped transform an old, obsolete midwest university building into the most efficient building on campus. The renovated building saves nearly 80% over the Standard 90.1-2010 baseline, with an EUI of 33.27 kBtu/ft^2·yr (378.2 MJ/m^2·yr).

The 1904 building, the first constructed at Western Michigan University (WMU), has been reborn as the Heritage Hall Alumni Center. (See "History and Re-Imagining of Heritage Hall Alumni Center.")

Energy Efficiency

The State of Michigan's energy code at design was based on ASHRAE Standard 90.1-2007, but the team's goal was to exceed the ASHRAE Standard 90.1-2010 baseline by 50%.

The building's original, non-insulated structure was furred-out on the inside surface with 3 in. (76 mm) of spray applied, closed-cell insulation, providing a foundation for peak performance. Five inches (127 mm) of rigid polyiso insulation was applied to the roof, and the original single-pane windows were replaced and upgraded to the highest performance window available that met historic preservation requirements.

A geothermal system is the heart of Heritage Hall's mechanical system. The building is more than half a mile from the university's cogeneration power/steam plant. More than 600 ft (183 m) of steam and condensate piping would have needed to be replaced to serve Heritage Hall with campus steam, making a geothermal system financially feasible.

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Heritage Hall is the second building to use geothermal on campus, and the university is assessing the power plant/steam system and the future of geothermal power on campus.

The four-module geothermal heat pump system generates both heating water and chilled water. The geothermal side of the heat pump consists of 56 vertical bore wells, totaling more than 8.5 miles (13.7 km) of below-grade piping. The geothermal system is piped in a self-balancing reverse-return arrangement with variable, primary-only pumping.

The system includes a geothermal load-side bypass at the heat pump and a three-way mixing valve at the source side of the field, allowing the building control system to modulate flow to the field, as required, based

Building at a Glance

Heritage Hall Alumni Center

Location: Kalamazoo, Mich.

Owner: Western Michigan University

Principal Use: Alumni center, offices, meeting areas, ballroom

Employees/Occupants: 45

Gross Square Footage: 53,079

Conditioned Space Square Footage: 53,079

Substantial Completion/Occupancy: October 2015

Occupancy: 100%

on demand. The vertical bore wells were collected into a central utility vault to allow for future expansion. Additional taps with valves and blind flanges were added, allowing for future expansion from the vault.

The heat pumps simultaneously generate 130°F (54.4°C) heating water and 44°F (6.7°C) chilled water. Both hot water and chilled water loops are piped in a variable-primary arrangement with source-side and load-side minimum flow bypass valves and two-way control valves at all building loads. This arrangement allows the direct digital control (DDC) system to monitor feedback from all valves and reset the heating water and chilled water loops, so the most critical valve in the system maintains at least 95% open.

PHOTO CREDIT JUSTIN MACONOCHIE

The heart of the mechanical system is a four-module geothermal heat pump system, generating both heating water and chilled water. The geothermal system consists of 56 vertical bore wells, totaling more than 8.5 miles of below grade piping.

PHOTO CREDIT TOWERPINKSTER/MIDWEST GEOTHERMAL

Fifty-six vertical bore wells were installed beneath the parking lot. The well field is designed for future expansion to pick up additional buildings around the site.

Heating water is reset in 5°F (9°C) increments from 130°F (54.4°C) down to 90°F (32.2°C) while chilled water is reset in 2°F (3.6°C) increments from 44°F up to 60°F (6.7°C to 15.6°C). In tandem with the supply temperature reset, the system loop pressure is also reset dynamically to maintain critical valves at 95% open, further reducing pump horsepower. With this aggressive reset strategy, it is common to witness the 120°F (48.9°C) heating system water maintain the building at 70°F (21.1°C) on all but the coldest of days. Similarly, it is common to see the chilled water temperatures operating at 50°F (10°C) and still maintain cooling and humidity control.

A dual-wheel dedicated outdoor air unit (DOAS) located in the attic penthouse (*Figure 1*) provides energy recovery and ventilation air for the entire building. By using dual wheels, the DOAS can provide dehumidified air with "free" reheat at room-neutral conditions. This ventilation air is then provided to variable-speed, four-pipe fan coils via pressure-independent air terminal units (*Figure 2*).

The variable-speed fan coils and the terminal units are controlled by both the building schedule and space occupancy sensors. The ventilation terminal units are turned off to unoccupied spaces, while the associated fan coil unit cycles, as required, to maintain the unoccupied setback temperatures. Once a space registers as occupied, the terminal units open to minimum flow, and the fan coils operate continuously at low speed to maintain the occupied space temperature.

Throughout the design process, energy modeling was used for energy cost and return on investment analysis.

As a result of the energy design innovation, Heritage Hall operates at a site energy use index (EUI) of 33.27 kBtu/ft^2·yr (378.2 MJ/m^2·yr) based on 2016–2017 energy consumption (*Figure 3*), far exceeding the

FIGURE 1 All ventilation air for Heritage Hall is provided by a dual-wheel dedicated outdoor air system (DOAS). By using dual wheels, the DOAS can provide dehumified air with "free" reheat at room neutral conditions.

DIAGRAM CREDIT TOWERPINKSTER

performance goals set early in design. The energy use resulted in an Energy Star score of 97, and the project earned all 19 Optimize Energy Performance points, contributing to Heritage Hall's LEED Platinum certification. This is greater than a 50% reduction over the LEED energy model estimate, and nearly an 80% reduction over the Standard 90.1-2010 baseline. Heritage Hall operates at a lower EUI than while in a mothballed state, when it was heated only to prevent freezing.

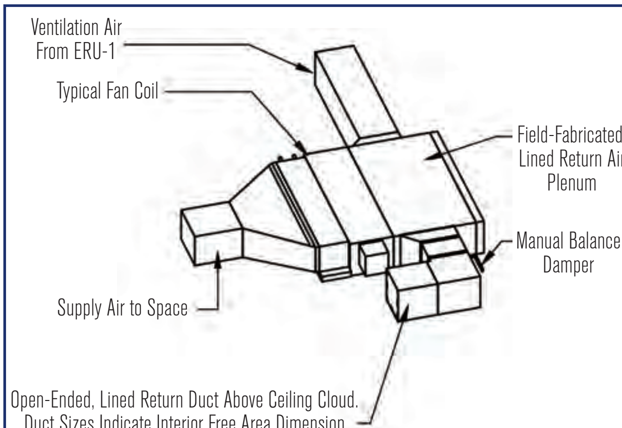

FIGURE 2 Four-pipe fan coils provide heating and cooling for the majority of the building. The fan coils are completely variable speed and include pressure-independent air valves for ventilation from the dedicated outside air unit.

DIAGRAM CREDIT TOWERPINKSTER

Indoor Air Quality

To start, indoor air quality (IAQ) was addressed by removing items from the existing building that contributed to poor IAQ, including significant amounts of asbestos and lead. Only low and no-VOC products were used in the design and construction, and all spaces are ventilated per ASHRAE Standard 62.1-2007 or better.

Ventilation modeling software was used to determine actual outdoor rates required to deliver ventilation to the breathing zone. A ventilation effectiveness of 1.0 was used for cooling, and 0.8 for heating. The outdoor air fraction at the fan coil units ranged from 0.13 to 0.25. IAQ is maximized using the DOAS, which provides outdoor air to all fan coil units and minimum outdoor air to one VAV air handler. MERV 13 filters, CO_2 demand control ventilation, and active outdoor airflow measurement ensure compliance with the standard.

By using pressure-independent air terminals at fan coils in combination with occupancy and CO_2 sensors, ventilation air is dramatically reduced on a per-room basis as space occupancies fluctuate. Finally, the effect on IAQ is considered for indoor activities; a green cleaning plan is used, and smoking is prohibited throughout the university's campus.

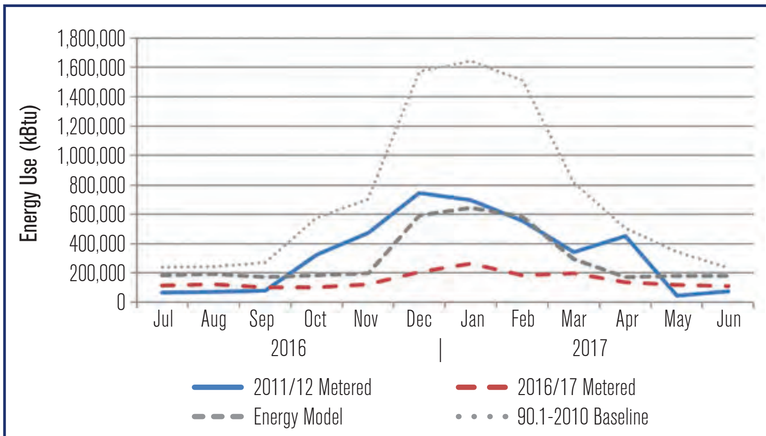

FIGURE 3 Heritage Hall Alumni Center energy use.

Thermal Comfort

Heritage Hall was designed with thermal comfort in mind, following ASHRAE Standard 55-2004. The forced-air systems are designed for no greater than 40 fpm (0.2 m/s) at the height of 3 ft (914 mm) above the floor. Also, the graphical method from Standard 55-2004, and the operative temperatures shown in Figure 5.2.1.1, were used to determine an acceptable temperature and humidity range.

A metabolic rate of 1.0 met was used for all office and general-use spaces (seated, reading, writing), and 2.4 met was used for the upper floor ballroom (dancing, social activities). Insulation factor provided by clothing was calculated at 0.61 to 1.0 clo.

PHOTO CREDIT JUSTIN MACONOCHIE

The restrooms feature natural light through frosted glazing. Radiant floors keep the space warm, while original steam radiators are repurposed to remind visitors of the building's history.

All closed offices and shared, multi-occupant spaces have dedicated temperature controls, allowing occupants to adjust the temperature based on individual comfort levels.

Operation and Maintenance

Efficient operation and maintenance procedures were key throughout the design and construction process. To aid in maintenance, the entire building was designed using BIM Level of Development 500. (This is the level of development required for facilities management use for tracking preventative maintenance.) All pertinent maintenance data, from filter sizes to pump installation and maintenance logs, were added into the model for post-construction use, allowing trades personnel to determine equipment placement within the building and immediately access key data for operating and maintaining Heritage Hall.

In addition to the BIM aspects, equipment was strategically positioned to be easily accessible for future maintenance and service visits. Above-ceiling equipment was minimized as much as possible; much of the equipment is located in the building's lower-level mechanical room, or the penthouse.

History and Reimagining of Heritage Hall Alumni Center

Western Michigan University (WMU) was founded as Western State Normal School in 1903 and built its first building, East Hall (now Heritage Hall Alumni Center), on Prospect Hill overlooking the City of Kalamazoo. Dubbed the "Acropolis of Kalamazoo" by humorist Will Rogers, East Hall was the birthplace of the University. Over the next 100 years, East Hall functioned in various capacities, from housing administrative offices in its early days and later converting to classrooms and art studios, to most recently serving as the repository for the university's archives. The building eventually became obscure and obsolete, settling into a mothball state and only heated to prevent freezing.

East Hall was reimagined as the new Heritage Hall Alumni Center, designed to be a touchstone for alumni and the Kalamazoo community, as well as the most sustainable and energy efficient building on campus.

The focus on celebrating the birthplace of the university meant uncovering and re-imagining many of the original design elements that shaped the university's first building. Many of the building's major additions over the years were stripped back to the elemental pieces of the shell and structure. From there, the building was reconstructed from the inside-out, allowing modern technology, light, and general functions to be built into the space, while retaining the building's original character.

The approach to design involved selective demolition, restoration, and additions. New public spaces include a library and café area, allowing visitors to reminisce and connect with the campus. Spaces that were previously used as classrooms were converted to alumni offices, meeting rooms, and on the upper level, a ballroom.

Innovation

The project team incorporated the original building's thermally massive concrete structure into the renovation design; a 5 ft (1524 mm) wide band of in-floor radiant heating was installed around the perimeter of the building. Once the building is brought up to temperature, the mass of the structure retains heat, and slowly releases it, minimizing temperature swings. This warm thermal mass provides a consistent, even heat to building occupants and minimizes the airside heat load.

Another innovation included retrofitting original light fixtures to LED, incorporating both dimming and daylighting control. The lights' historical aesthetic was maintained while improving energy efficiency and yielding a 60% reduction in lighting energy over traditional systems.

The design team worked to blend the mechanical systems seamlessly into the historic building. The existing ventilation chimneys were repurposed to hide the large amount of ductwork required for building relief air. Ductwork was sleeved down from the top, then connected to ductwork from the DOAS within the penthouse. The decorative metal caps at the chimneys were restored as part of the historic preservation.

Cost-Effectiveness

From the beginning, the university challenged the design team to be innovative and cost-effective in design. The site had been served by the campus steam system for over 100 years and was in poor condition. The team evaluated the cost of repairing existing steam infrastructure and quickly discovered that a geothermal system would be a lower first cost.

As a comparison, restoring the steam system was expected to cost roughly $820,000, while the installation of the geothermal system cost less than $750,000, resulting in an immediate payback to the university. Innovative design decisions resulted in reduced energy costs and made the project eligible for utility rebates and tax deductions. The university realized $54,202 in utility rebates and $1.80/ft^2 ($19.38/m^2) from the EPAct tax deduction to help offset the $24 million construction cost.

Conclusion

Heritage Hall links the new and the old by housing WMU's alumni services and telling the story of the university, including its history of sustainability, throughout the building.

Visitors to the reimagined Heritage Hall give it compliments, both for the ability to tell the story of the evolution of the building, site, and university, and to evoke memories of individual experiences. The transformation from the least energy-efficient building on campus to the most energy-efficient can now be added to that story. ■