

## 2014 ASHRAE TECHNOLOGY AWARD CASE STUDIES

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Most science buildings consume a lot of energy. But, the Davis Building at the University of Findlay has a site EUI of only 64 kBtu/ft<sup>2</sup> (202 kWh/m<sup>2</sup>), which is significantly lower than most similar buildings that include labs with many fume hoods.

### FIRST PLACE

EDUCATIONAL FACILITIES, NEW

# Low Energy Science Building

CREDIT: ANNE RISSER LEE, THE UNIVERSITY OF FINDLAY

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### BUILDING AT A GLANCE

#### Davis Building

University of Findlay

**Location:** Findlay, Ohio

**Owner:** The University of Findlay

**Principal Use:** Houses university-level science education

**Includes:** 19 science laboratories, a 112-seat lecture hall, one computer lab, 15 faculty offices, one conference room and one student lounge

**Employees/Occupants:** Maximum occupancy of 827

**Gross Square Footage:** 42,000

**Substantial Completion/Occupancy:** June 2012

**Occupancy:** 100%

Science buildings with multiple fume hoods and high ventilation rates are often the highest net energy-consuming buildings per square foot on a campus. However, the Davis Building at the University of Findlay in Findlay, Ohio, which is made up of lab and classroom spaces, offices, conference rooms and support spaces, has a site EUI of only 64 kBtu/ft<sup>2</sup> (202 kWh/m<sup>2</sup>).

The design process began with extensive energy modeling as the architect worked through early concepts of massing, fenestration and wall construction types. The final envelope design consisted of high mass walls (concrete blocks with cores filled with sand) enveloped with exterior insulation covered by architectural metal.

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ABOVE Science lab with fume hood.

LEFT Student lounge.

This insulated thermal mass was leveraged in the design of the HVAC system, enabling the interior to absorb peak heating and cooling loads in a manner that “time shifted” the peak loads by several hours.

This strategy also allowed a reduction in the peak load seen by the central plant—the capacity of the central heat pump is nominally 60 tons (211 kW) or equivalent to 700 ft<sup>2</sup>/ton (18.5 m<sup>2</sup>/kW)—again extremely low for this type of building.

The design of the HVAC system commenced in parallel to the architectural design process. A central geothermal heat pump system (a 60 ton [211 kW] magnetic-bearing chiller that can produce up to 90 tons [317 kW] under certain conditions) providing chilled water and hot water was selected as it allowed for an innovative method of coupling sensible cooling devices directly to the geothermal earth heat exchanger (GHX). This would not have been possible with traditional distributed unitary water-to-air geothermal heat pumps. The central geothermal energy plant simultaneously makes hot (95°F [35°C]) and chilled (45°F [7°C]) water for heating and cooling, feeding the outdoor air system as well as the chilled beams, reheat coils and thermally massive radiant heating/cooling system.

A hybrid wet/dry closed-circuit cooling tower (nominal 30 ton [105 kW] capacity) was selected to provide both daily and seasonal preconditioning of the GHX. Three hydraulically separated geothermal earth heat exchangers using vertical HDPE loops were sized, and are controlled, to provide different fluid temperatures and to provide direct sensible cooling via radiant cooling and active chilled beams. When the building cooling load exceeds the heating load the control system determines whether to direct the surplus thermal energy into the GHX for later use/later rejection or to reject it to the closed-circuit cooling tower if that process consumes

less energy or costs less. If the heating load exceeds the cooling load, the heat deficit to the central heat pump is taken from the GHX.

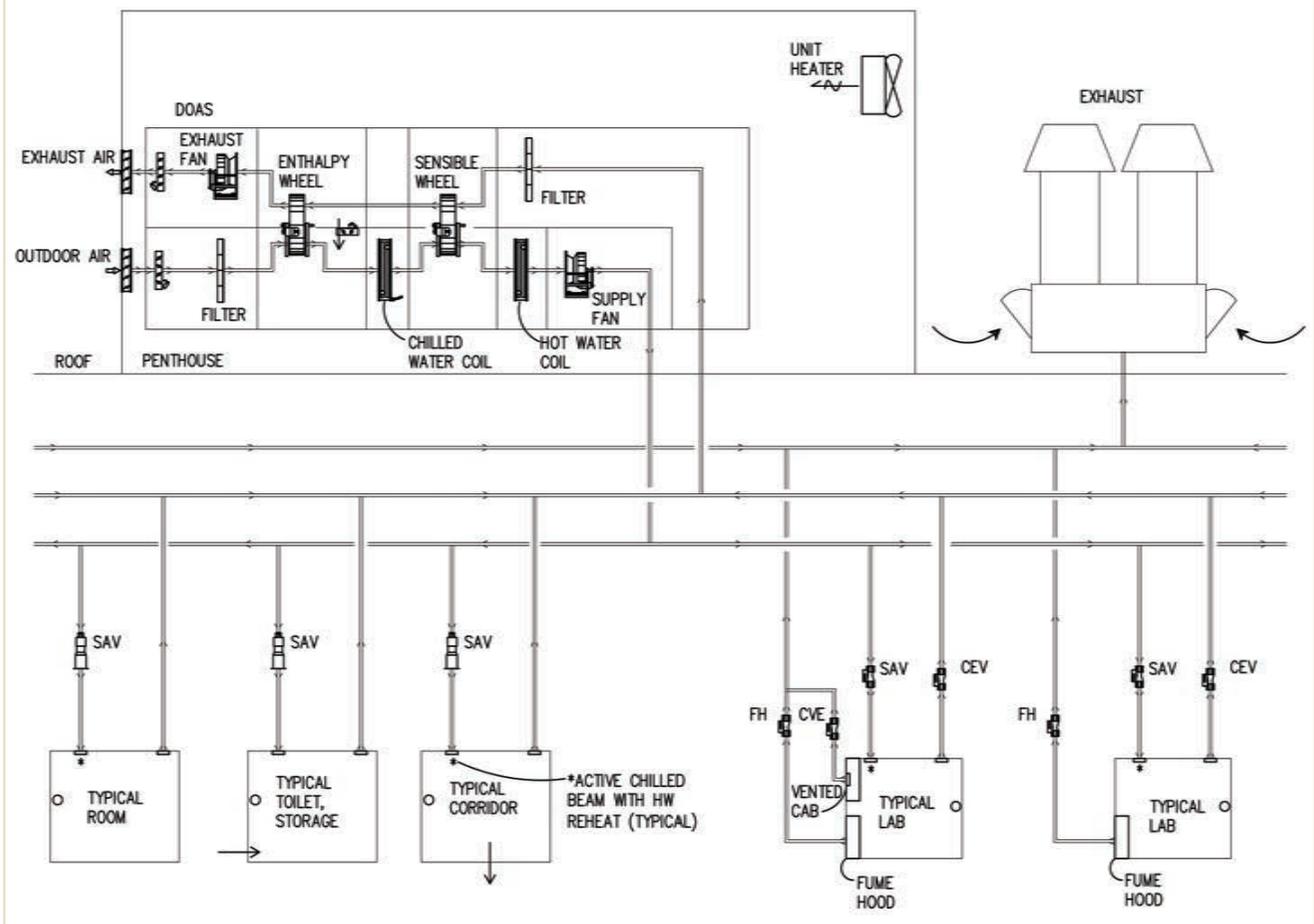
An 18,000 cfm (8495 L/s) variable volume dedicated outdoor air system (DOAS) using dual energy recovery wheel technology (one total energy wheel, one sensible energy only wheel) supplies conditioned outside air to the active chilled beams and hot water reheat coils for each space. This system recovers energy and moisture, heats, cools and dehumidifies the ventilation air as required.

Thermally massive radiant heating and cooling using embedded PEX tubing in the concrete floors and the active chilled beams can use fluid directly from the geothermal loops for sensible cooling without engaging chiller operation. A seven zone geothermal variable refrigerant flow system was used for stairwell and vestibule conditioning.

An air quality monitoring system tracking VOCs, CO<sub>2</sub>, particle counts and wet-bulb air temperature to ensure that the air quality within the spaces is being maintained. The air quality monitoring system takes air samples from each space on a rotating basis and conveys the samples to a central air quality testing station where the air is analyzed for CO<sub>2</sub>, volatile organic compounds (VOC), and wet-bulb temperature. Should one of the monitored items exceed a setpoint, the ventilation rate in the space is automatically increased. In the event of a solvent spill in a lab area, the system automatically initiates a high air volume flush mode to rapidly remove the contaminants.

The zone-level wet-bulb temperature sensing allows monitoring and control of the dew-point temperature to ensure that the radiant cooling and active chilled beams do not enter into a mode where unwanted condensation might occur as well

FIGURE 1 Partial airside system schematic.

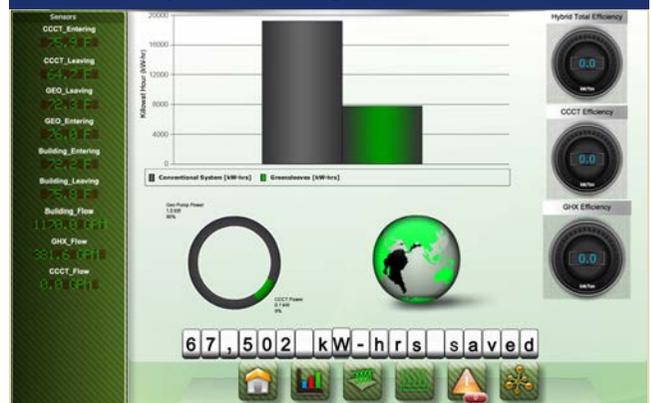


as providing the needed humidity control for thermal comfort. If the potential for condensation is detected, the sensible cooling device in that zone is disabled until the conditions change to allow it to return to normal operation. The above signals are used to reset the DOAS unit supply air humidity levels. The zone-level CO<sub>2</sub> monitoring allows reduction of the ventilation rate when a space is lightly occupied and allows identification of potential under-ventilation if that might occur.

During the past year, the air quality monitoring system took 164,000 air samples and 98.99% of the time all air samples tested at CO<sub>2</sub> levels below 1,000 ppm, indicating good compliance with the design process, which used ASHRAE/IES Standard 62.1-2010. Ninety percent of all samples were at 500 ppm or below, 97% at 700 ppm or below.

This building houses the university’s industrial hygiene program and the faculty is anticipating accessing the indoor air quality data for educational use.

FIGURE 2 Control system display indicating temperatures and performance metrics.



All of the fume hoods have a variable volume fume hood control system that senses an operator standing in the breathing zone and sash position to provide the maximum safety and contaminant capture while minimizing exhaust air volume and energy use. The lab areas with fume hoods have active space pressurization control systems to provide a negative lab space pressure

relative to the corridors for contaminant control.

The control system uses anticipatory predictive algorithms for the geothermal heat exchanger (GHX) seasonal and daily preconditioning. This can minimize heat rejection and compressor energy use as compared to traditional “real-time” control that would initiate closed-circuit cooling tower (CCCT) operation when the GHX temperature simply exceeds a setpoint. This means that the CCCT may operate during the night or during winter to precondition the GHX for summer cooling and to minimize summer daytime CCCT operation. Significant reductions in CCCT energy use and water use can be achieved by operating in winter instead of summer due to lower ambient temperatures.

The control system measures and “learns” the actual building thermal load imposed on the GHX and adjusts the preconditioning algorithms in relation to this intelligent model.

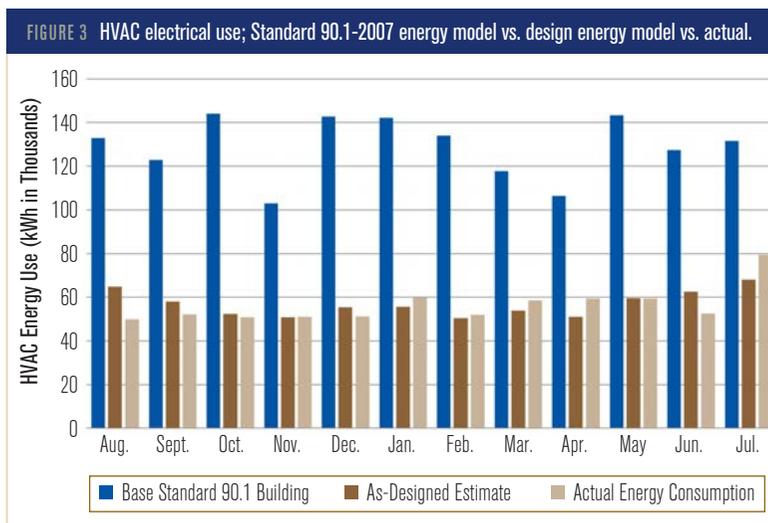
The cooling (chilled water) system energy efficiency ratio (EER or Btus transferred per watt of energy consumed) when using GHX water directly for sensible cooling can approach 150 to 200 EER of pumping energy versus a typical chiller EER of 15 to 20. The GHX predictive control system also allows for an annual reset of the GHX mean earth temperature to prevent temperature “creep” in this cooling-dominant application.

Submetered electrical use by HVAC system, lighting and receptacle loads allows the university to track energy consumption and know specifically where all the energy is going.

Design phase energy modeling indicated an approximately 50% reduction in energy cost from a baseline Standard 90.1-2007 building modeled per Appendix G. Following system commissioning, the energy model was modified to reflect the actual fan and pump heads as well as current temperature setpoints and occupancy schedules. Since the building has come on-line in August 2012, the energy consumption has tracked this

Table 1 2012 actual energy consumption and 2013 actual energy consumption with 12 month total.

CATEGORY (SUBMETERED)	2012					2013							
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	12 Month Total
LIGHTS (KWH)	6,033	6,841	7,732	7,180	6,691	7,411	7,482	7,516	7,369	4,837	4,209	5,903	79,204
RECEPTACLES (KWH)	2,096	1,487	2,933	3,107	2,451	3,098	3,013	3,337	2,999	2,501	2,522	3,783	34,326
HVAC (KWH)	49,796	51,979	50,666	50,934	50,988	59,852	51,756	58,504	59,215	59,266	52,446	79,184	674,585
TOTAL KWH	57,925	61,307	61,331	61,221	60,130	70,361	62,251	69,356	69,582	66,604	59,177	88,870	788,114



model well, with the overall actual energy consumption being 7% less or a total of 57% than the adjusted energy model. Current site energy use intensity (EUI) is 64 kBtu/ft<sup>2</sup> (202 kWh/m<sup>2</sup>); quite low for a science building with many fume hoods.

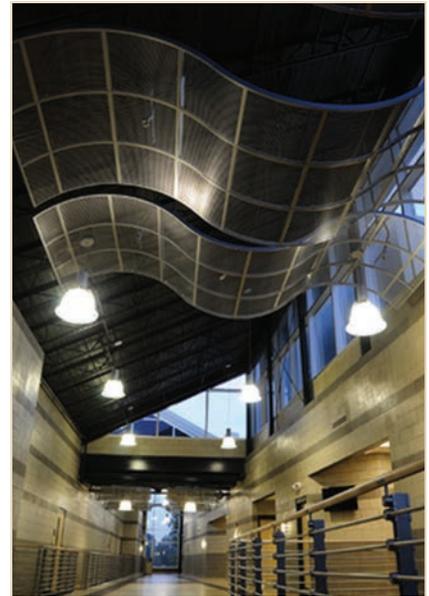
The application of thermally massive radiant cooling and heating increases the thermal comfort by addressing the mean radiant temperature of the space directly through a reset of the radiant surface temperature. To date, no thermal comfort-related complaints have been relayed to the engineer. The control system looks at conditions from the previous day in addition to the current conditions, then predicts when a peak cooling load might occur and then preconditions the radiant cooling slab in anticipation of the cooling event. This allows the floor slab to absorb some of the peak cooling load and

thereby reduce the peak cooling load on the geothermal heat pump energy plant.

The geothermal heat pump energy plant consisting of the magnetic-bearing chiller, pumps, variable speed drives, power

wiring and controls was factory-assembled at an ISO-9001 facility and shipped to the site in five portions for site assembly. This significantly reduced construction and commissioning time as well as risk related to varying

*Advertisement formerly in this space.*



Second floor corridor area with daylight windows and light diffusers.

on-site conditions and quality control.

### Conclusions

Several conclusions can be drawn from this project. First, the application of anticipatory predictive controls on a geothermal HVAC system can provide additional energy saving benefits not possible with traditional real-time control approaches. Additionally, significant system efficiencies and energy cost reductions are possible in climates where the mean earth temperature allows some portion of the cooling load to be addressed directly by GHX loop water without the operation of a chiller. Finally, actual building operation is always different from a design energy model and controls that track, analysis and adapt to these differences will provide more optimum operation over time than a control system that is simply commissioned and left in a static operational condition. ■