Final Project Report

Human Health Science Building Geothermal Heat Pump Systems

DOE Award #: DE -EE0002970

Awardee: Oakland University, Rochester, Michigan

Report Date: December 22, 2014
Revised Report: August 31, 2016

Project Period: *October 2011 through December 2014*

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Acknowledgement

This material is based upon work supported by the Department of Energy under Award Number DE -EE0002970. Many thanks to the SmithgroupJJR and The Christman Company for their deidication and hard work to design and construct this facility. Many items in this report were provided by the SmithgroupJJR.

Disclaimer

Table of Contents

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Executive Summary

The grant objectives of the DOE grant funded project have been successfully completed. The Human Health Building (HHB) was constructed and opened for occupancy for the Fall 2012 semester of Oakland University. As with any large construction project, some issues arose which all were overcome to deliver the project on budget and on time.

The facility design is a geothermal / solar-thermal hybrid building utilizing both desiccant dehumidification and variable refrigerant flow heat pumps. It is a cooling dominant building with a 400 ton cooling design day load, and 150 ton heating load on a design day. A 256 vertical borehole (320 ft depth) ground source heat pump array is located south of the building under the existing parking lot. The temperature swing and performance over 2013 through 2015 shows the ground loop is well sized, and may even have excess capacity for a future building to the north (planned lab facility).

The HHB achieve a US Green Building Counsel LEED Platinum rating by collecting 52 of the total 69 available LEED points for the New Construction v.2 scoring checklist. Being Oakland's first geothermal project, we were very pleased with the building outcome and performance with the energy consumption approximately 1/2 of the campus average facility, on a square foot basis.

Technical Innovations – Cooling Dominated Building in a Cold Climate

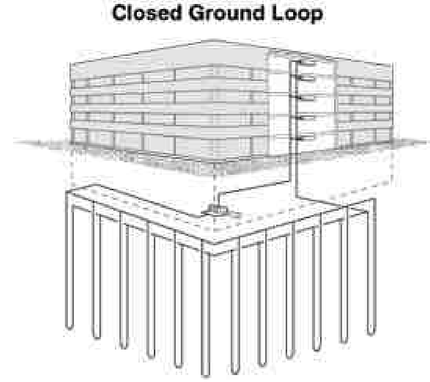
- Variable Refrigerant Flow (VRF) heat pumps
    - Refrigerant side energy recovery within the each heat pump system zones
    - Condenser water side energy recovery within the building
- Thermally regenerated desiccant dehumidification of outdoor air supply
    - Solar thermal system for activation energy

1st Michigan Higher Ed. LEED Platinum Rated Project

Introduction

This project consisted of a public university classroom and health science lab facility new construction project including of a ground sourced heat pump, heating, ventilation, air conditioning (HVAC) and solar energy systems. The facility is located on the NW corner of Oakland University's campus and is named the Human Health Sciences Building (HHB). This DOE grant funds enhanced the energy efficiency of the building, substantially reducing both operating cost and the building carbon footprint. The design is one of the most efficient geothermal heat pump systems available, making use of variable refrigerant flow heat pumps, solar-thermally activated desiccant outdoor air supply, and multiple methods of waste heat recovery. The design showcases a USGBC LEED Platinum facility, which is the first for a college campus in the State of Michigan.

Closed Ground Loop



Specific goals were to supplement the base project HVAC systems budget to allow for a full geothermal system (as opposed to the planned partial, hybrid system planned in the non-grant funded design) as well as add an innovative solar thermal driven desiccant dehumidification system to the outdoor air supply. The system makes use of variable refrigerant flow heat pump units, including both refrigerant side and condenser water side heat recovery. The DOE grant provided additional capital cost to the base $62M HHB project budget.

The scope of this five year project includes the engineering and design of the enhanced system components, equipment and material costs, construction and commissioning, followed by a three year monitoring and verification phase. The efficiency and performance of this innovative building design will be fully monitored and recorded for review.

The 160,260 square foot Human Health Building is now home to the School of Health Sciences and the School of Nursing. Collectively, this new enterprise is part of Oakland University's vision of better preparing today's health care students by creating an innovative partnership in one structure. With this new building, growth in undergraduate and graduate enrollment can be doubled in response to vital shortages in nursing and heavy demand for health science professionals.

The DOE grant funds allowed for a scope of work including:

- The deletion of the conventional, evaporative cooling tower from the roof.
- The increase in the size of the ground source well field from approximately 70 boreholes to 256 boreholes (320 feet deep).
- The modification of the dedicated outdoor air supply systems (qty 2) from a simple heat recovery unit, to a thermally activated desiccant air supply unit.
- The addition of a solar thermal hot water array to the roof of the building for use in summer desiccant dehumidification of outdoor air and supplemental winter space heating.
- Monitor and verify the HVAC system performance and efficiency for three years.

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BUILDING AT A GLANCE

Name Oakland University Human Health Building

Location Rochester, Mich. (30 miles NW of Detroit)

Owner Oakland University

Principal Use Mixed use university building including classrooms, offices, teaching labs

Employees/Occupants Undergraduate and graduate students, teachers and general public

Expected (Design) Occupancy 4,259 undergraduate and graduate students
Percent Occupied Nearly 100% (approximately 70% during summer term)

Building Efficiency Ratio 59.5%

Gross Square Footage 160,260

Distinctions/Awards
LEED NC 2.2 Platinum, 2013; Professional Projects Award of Merit—Architectural Engineering Integration Category, Architectural Engineering Institute (AEI), 2014

Total Cost $47.8 million (construction)/ $62 million (total project)
Cost per Square Foot $298 (construction)/$387 (total project)*

Substantial Completion/Occupancy
August 2012

* Total project cost includes soft costs including programming, planning, design and furniture costs.

Project Tasks (PHASES)

Phase I – Feasibility Study and Engineering Design
Following the award of the project which is anticipated in 2009, the detailed design process began. Although the main building heat pump systems using a hybrid, partial design will be well underway, or perhaps complete by then, the grant supported activities will supplement the base project and base design.

All work proposed here will be additive in nature and will be installed on the exterior of the building or in the ground loop well field as outlined above.
A geothermal heat pump specialty consultant will be brought on board with the existing design team to assist with design of the geothermal array.

Energy modeling has already been done on the building and preliminary designs have been worked up for this highly cooling dominant building. If this grant is not approved, a hybrid geothermal heat pump system will be sized based on the much smaller heating load. Summer needs would then be met by the addition of a conventional evaporative cooling tower in series with the ground loop. The grant supported design will up-size the ground well field to handle the entire summer cooling load.

Calculated heating load:	150 ton in winter (1.8 million BTU / hr)
Calculated cooling load	400 ton in summer

A geothermal ground thermal conductivity test was already performed in July 2009, and conditions were found to be with in normal ranges and are acceptable.

Phase II – Installation and Commissioning of Equipment

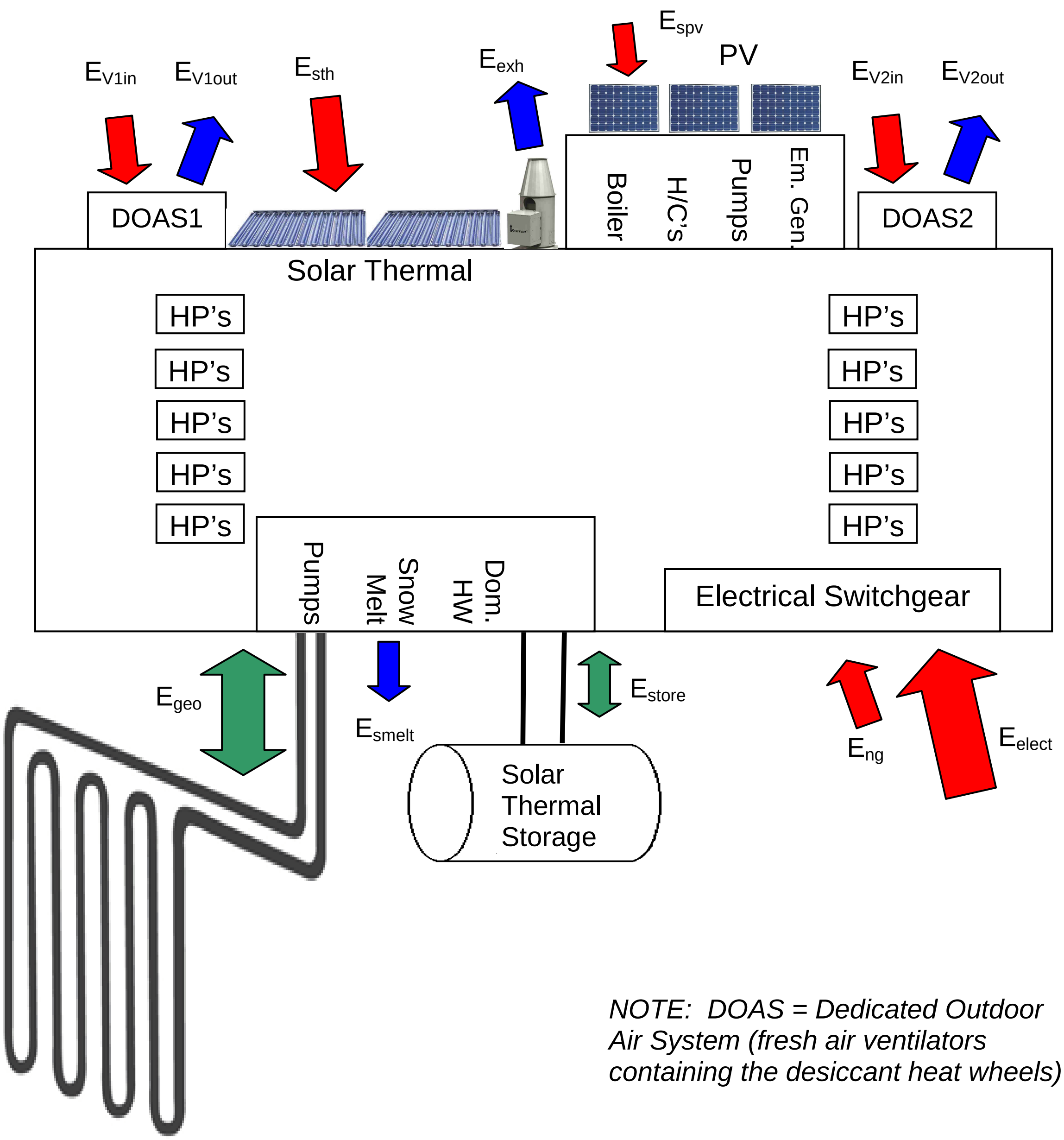
The project schedule started with site selection and programming in Spring 2009, through design, engineering and construction, and concluding with Occupancy in August of 2012 by the health science departments. The third party commissioning agent continued work through 2013 to verify all systems and oversee the completing of remaining punch-list items.

Phase III – Operation, Data Collection, and Marketing

Three years of operational data were logged and reviewed with the assistance of CDH Energy Corp. This phase began during building commissioning in 2012, and continued through 2014. A dedicated Tridium metering network was utilized for this function with power meters and ultrasonic BTU / flow meters networked back to a Tridium JACE data portal via Modbus communications. See the energy model below for more information on the type of data metered and collected. Not all HVAC temperatures and flow were logged, but the ground loop and HVAC power meters were all monitored.

Energy Model

Below is a schematic of the energy flows into and out of the HHB. A 50kW solar electric (PV) systems in addition to a large solar thermal array provides some renewable energy fraction to the building energy supply. The solar thermal array consists of 117 sets of 30 evacuated tube collectors (Solar Panels Plus, SPP-30A). This is a total of 3,510 tubes capable of producing in excess of 3.5 million BTU per day under sunny conditions for use in the desiccant dehumidification regeneration.



NOTE: DOAS = Dedicated Outdoor Air System (fresh air ventilators containing the desiccant heat wheels)

Table of Energy Model Tags and Meter Devices

TAG	Description	Units	Media	Dirctn.	Meter
E_{elect}	Electrical utility	kWhr	Electricity	In	Nexus 1262
E_{spv}	Solar photovoltaics	kWhr	Electricity	In	Shark 200
E_{ng}	Natural gas utility	MCF	Natural gas	In	Roots
E_{sth}	Solar thermal system	BTU	Solar hot water	In	Ultrasonic BTU
E_{geo}	Ground loop	BTU	Ground loop water	Bi-dir	Ultrasonic BTU
E_{store}	Solar ground storage	BTU	Solar hot water	Bi-dir	Ultrasonic BTU
E_{V1in}	DOAS intake air	BTU	Outdoor air	In	Air flow & temp
E_{V1out}	DOAS intake exhaust	BTU	Exhaust air	Out	Air flow & temp
E_{V2in}	DOAS intake air	BTU	Outdoor air	In	Air flow & temp
E_{V2out}	DOAS intake exhaust	BTU	Exhaust air	Out	Air flow & temp
E_{exh}	Laboratory exhaust	BTU	Exhaust air	Out	None
E_{smelt}	Snow melt system	BTU	Hot water	Out	Ultrasonic BTU

Meter information:

Nexus 1262	Electro Industries, Nexus 1262 utility switchboard electric meter
Shark 200	Electro Industries, Shark 200 multifunction panel electric meter
Roots	Roots, rotary natural gas meter with pulse output
Ultrasonic BTU	Siemens SITRANS FUS1010 ultrasonic flow and energy meter
Air flow & temp	Dedicated Outdoor Air Unit (DOAS) from Innovent, with packaged air flow station and temperature / humidity sensors used by the Honeywell automation system to calculate the air flow energy

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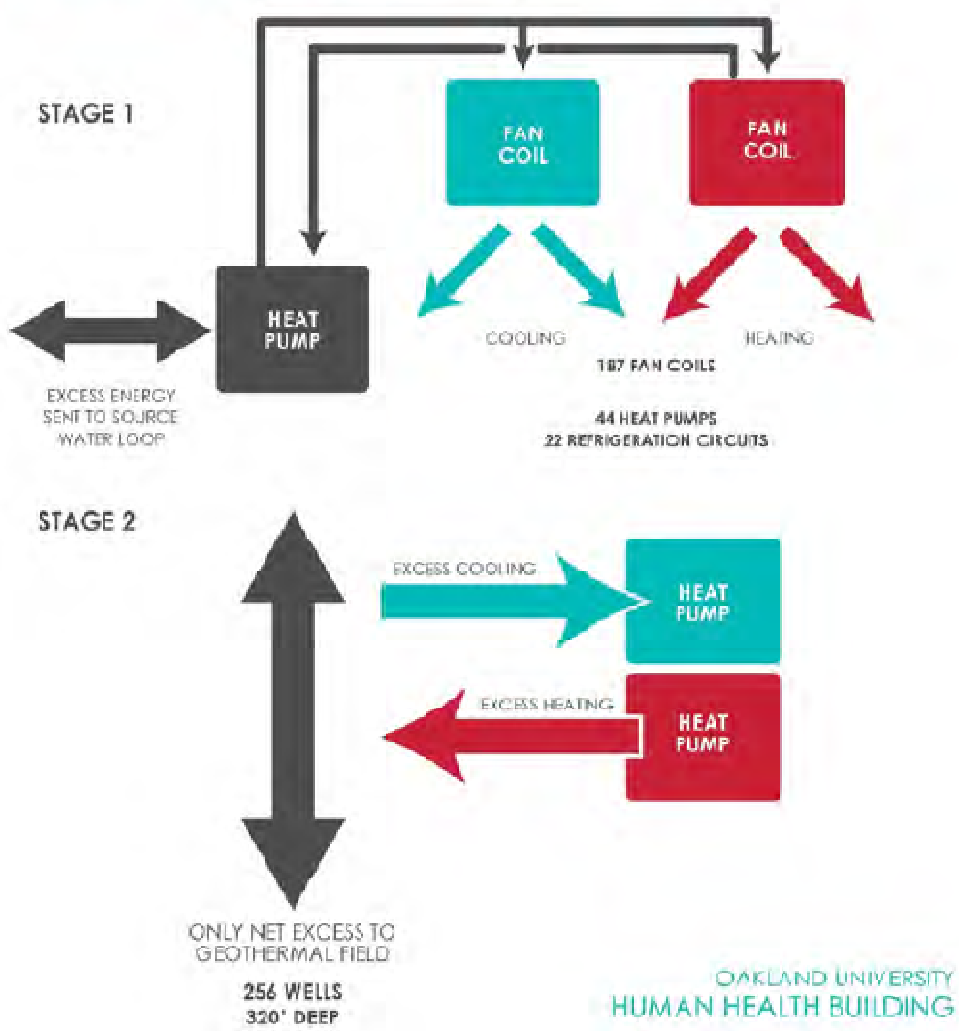
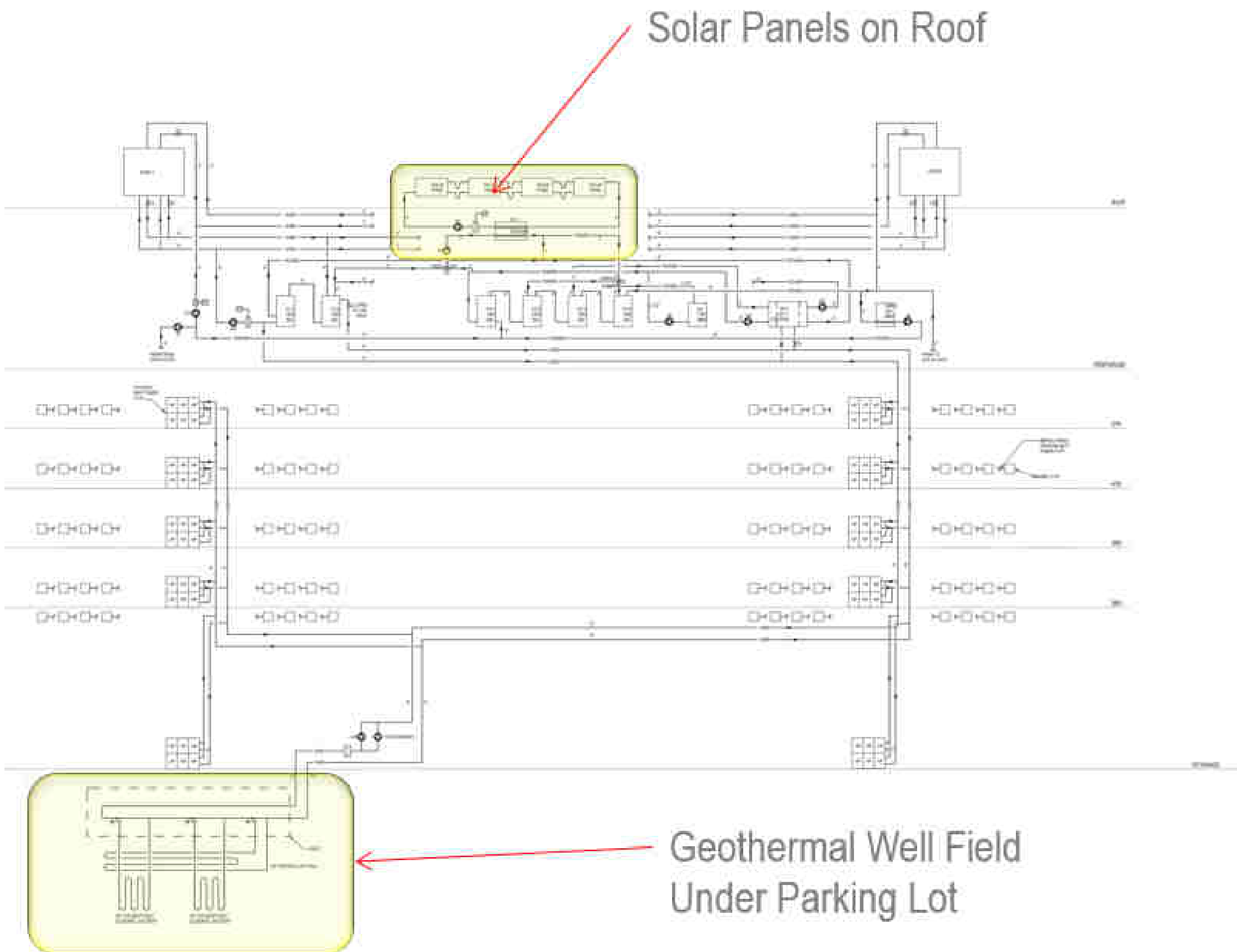
Mechanical System Features

- Ground Source - Water Cooled Geothermal VRF Heat Pumps
- 256 vertical bore hole ground array, 320 feet depth
- 117 sets of solar thermal collectors, each with 30 evacuated heat pipe tubes
- Mini-Mech Rooms, 2 “closets” per floor
- 187 fan coils, 44 heat pumps, 22 refrig circuits
- Dedicated Outside Air Units (DOAS) in lieu of Variable Air Volume (VAV)
- Energy Savings: smaller fans moving less air, with exhaust energy recovery
- Smaller Duct Sizes: Avoided High Rise Classification

Heat Pump Heat Recovery is accomplished on two levels. First stage, heat recovery (or zone to zone heat transfer) may be done on the refrigerant side of the system. Second stage, heat recovery is accomplished as in all heat pumps systems on the hydronic level between heat pump compressor units. There are only 44 units in the building serving 187 refrigerant zones.





Overall Mechanical System Schematic

Geothermal System

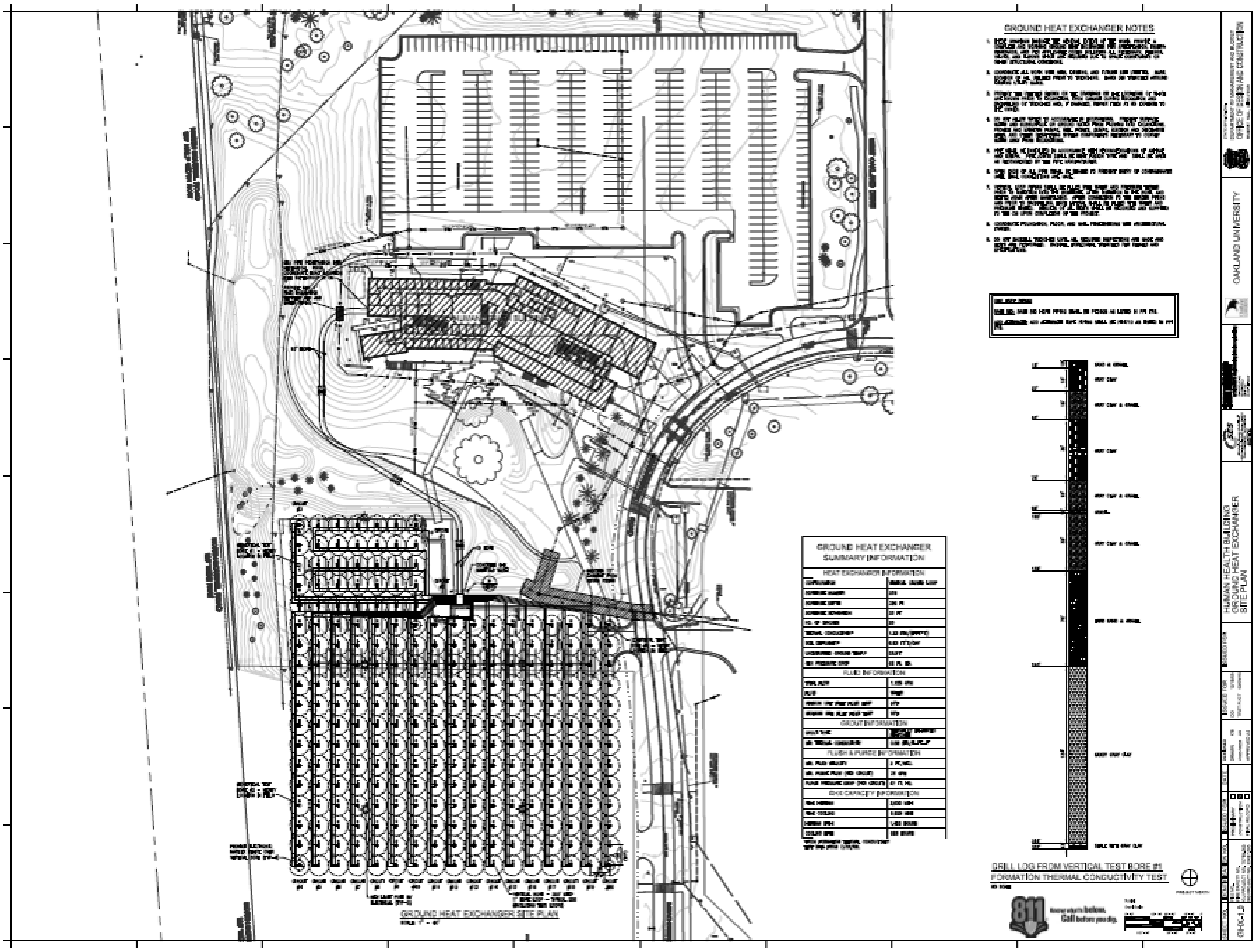
The ground loop is located to the south of the facility beneath the existing asphalt parking lot. Local contractor and geothermal specialist, Frank Rewold and Sons removed the asphalt, subcontracted up multiple drilling rigs to bore the 256, 320 foot depth geothermal wells, and then repaved the lot surface. This was all done in one summer to avoid parking disruptions. Initially, as the drill rigs were lined up side by side, there was caving issues from adjacent rig vibrations. Therefore, a more spread out, random drilling order was implemented and all proceeded smoothly.

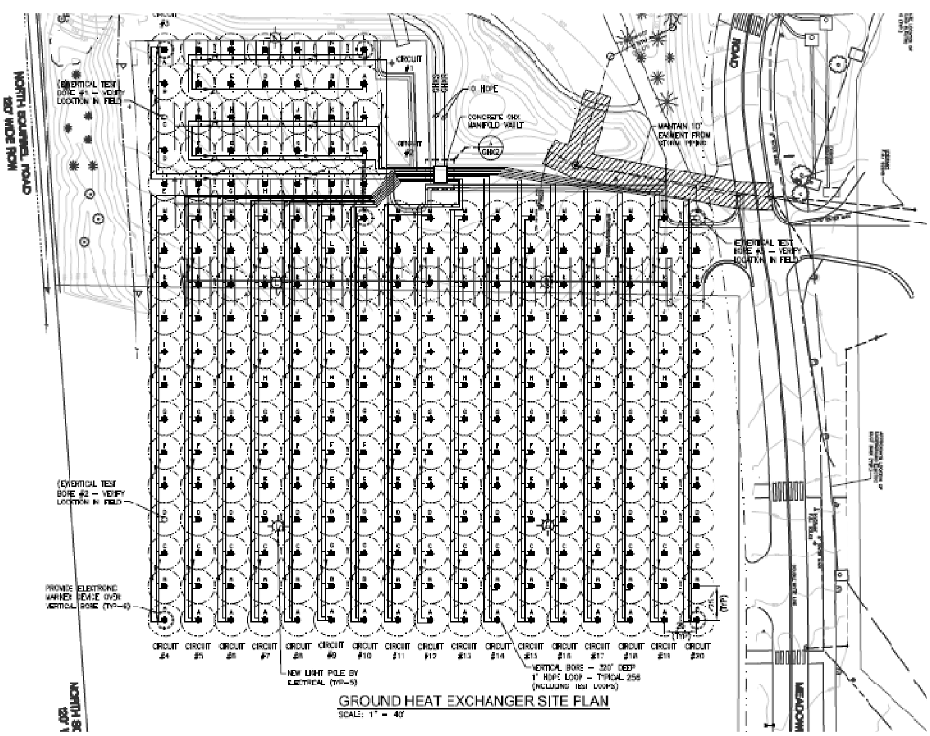
A YouTube video of a borehole installation interview of the project manager can be viewed at *https://youtu.be/-S92ltS--E4*

Also, a time lapse video of the construction project can be viewed at *https://youtu.be/n_ZFlKwj2pA*

This is a photo looking south from the building site, looking at the ground loop drilling operations (on the left) and the installation of the vertical header piping (on the right).

Twenty circuits are brought back via the vertical headers to the single vault shown here. From there, 10 inch HDPE lines travel underground to the pump room located on the NW corner of the building on the lower level. Two 50 HP pumps circulate the "source water" throughout the system. One pump is standby, and one operates the water only system. No freeze protection was needed for our design.





Shown here is a plan view of the 256 bore hole array. Three circuits are located to the west of the vault, and the other 17 are located to the south.

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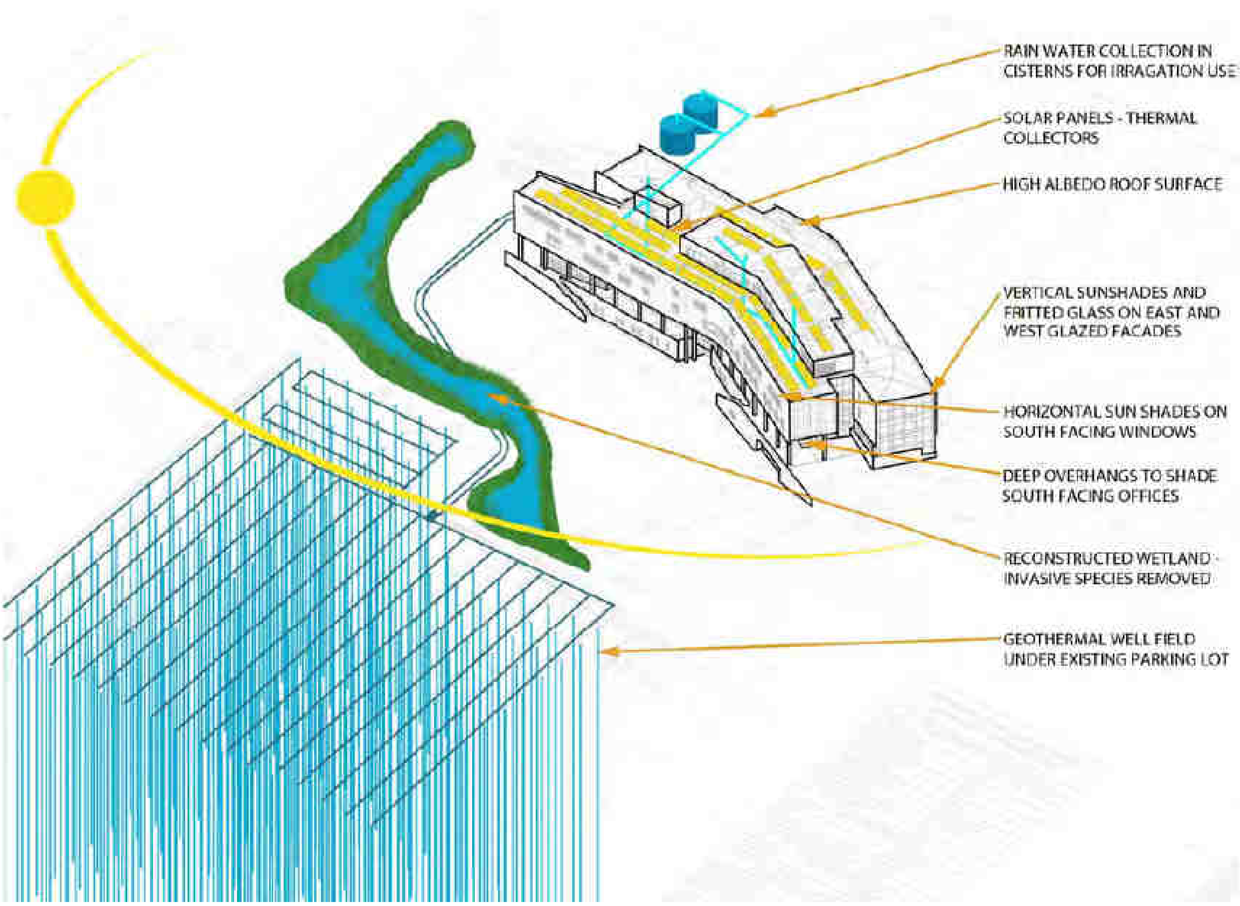
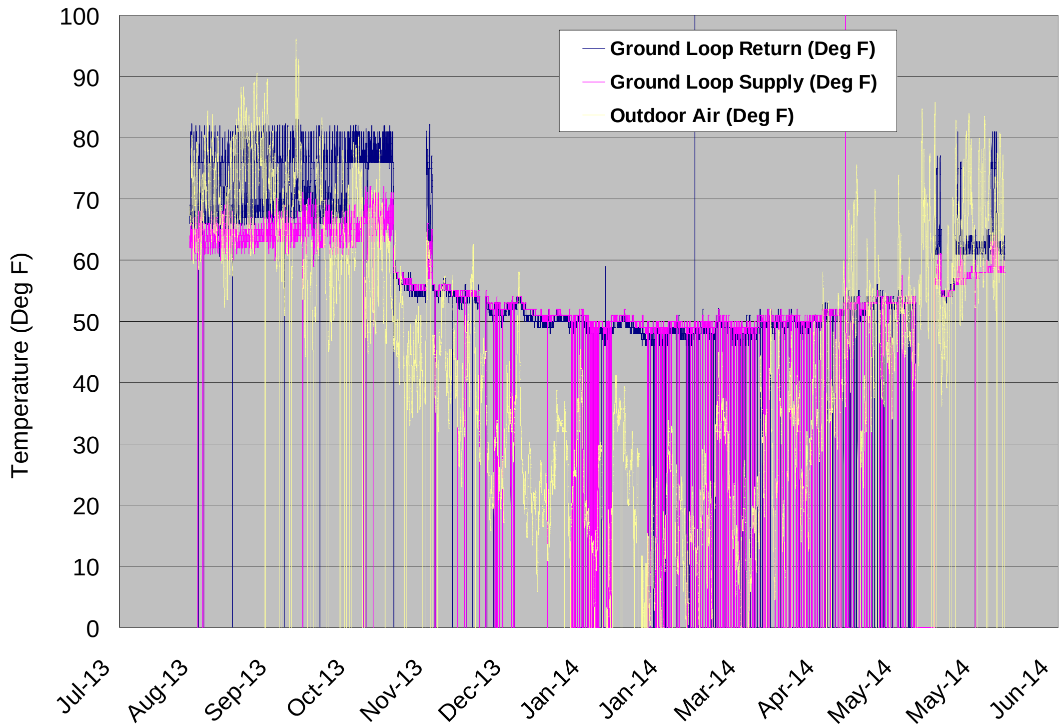
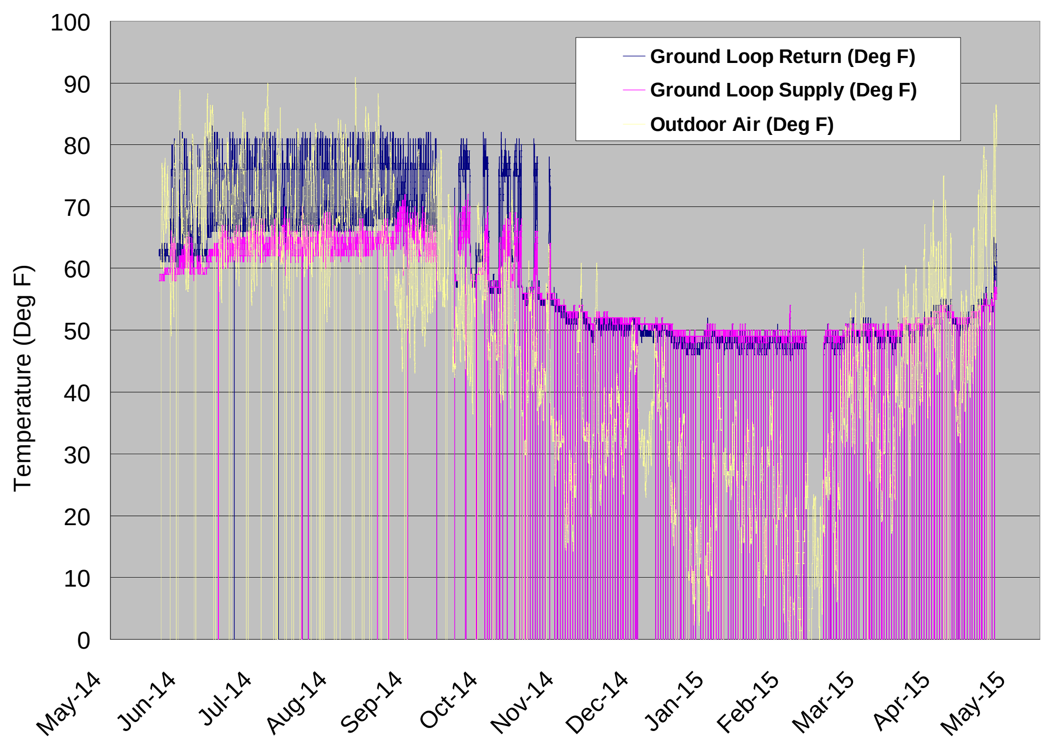


Looking at the summer and winter operation of the ground loop over two seasons, it looks as if the system has ample capacity as expected. (many apologies for not manually removing the lost data points or zeros, which produce the many vertical lines) It cooling mode, the ground loop returns approximately 65 deg F to the building. In heating mode, the ground water return stabilizes around 48 to 50 deg F for winter operation.

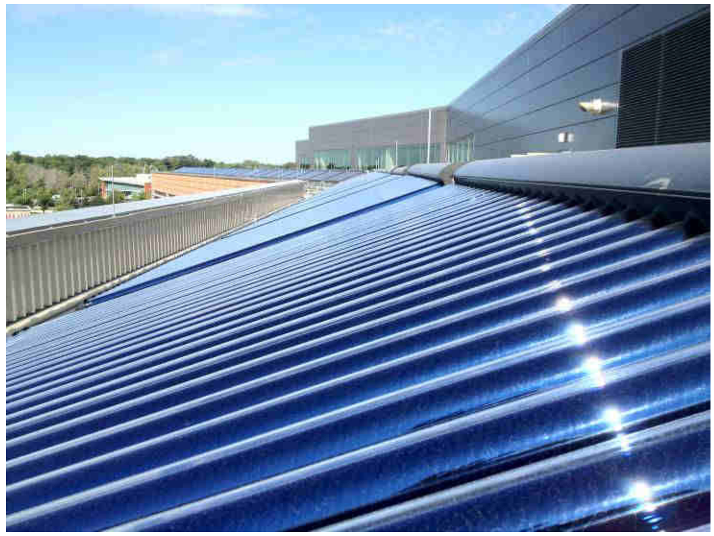
Ground Loop Temperatures for 2013 - 2015





Solar Thermal System

One of the largest solar thermal systems in the Midwest USA is located on the roof of the HHB. 3,510 evacuated tubes are installed a relatively low 20 degree angle for a summer optimized design for a cooling process. The solar thermal is maximized to serve a desiccant dehumidification assist to the heat pumps, by removing the summer latent energy from the incoming ventilation air.



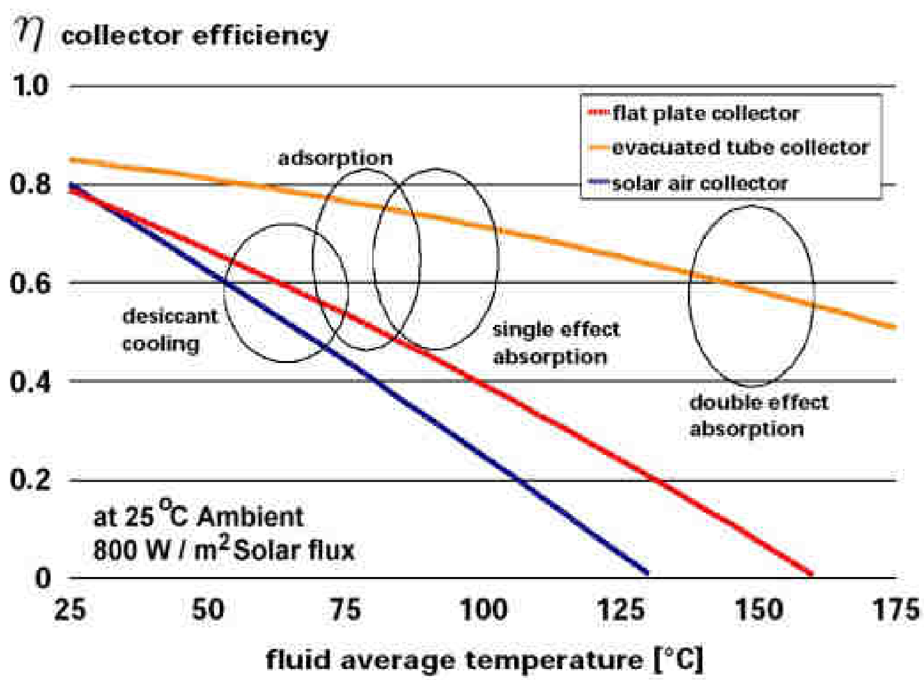
Shown below is the south facing bulk of the solar collectors. On the roof of the penthouse, we also have 50 kW DC of PV, solar electric panels.

There are two solar thermal buffer tanks located in the penthouse. If they are "topped off" thermally, and cannot store any additional heat during times of low demand, the system can exchange thermal energy to these four 250,000 ground thermal storage tanks. During times of low sun, or peak demand times, these will provide thermal energy back to the heating loop.

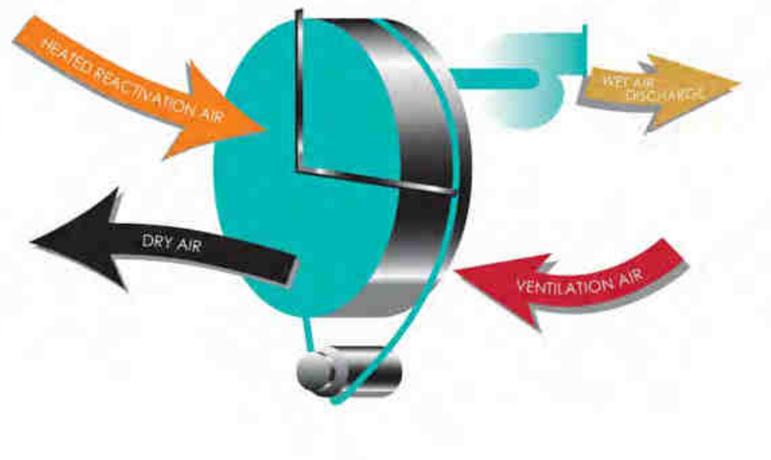
Dedicated Outdoor Air Unit Supply with Desiccant Dehumidification

The sensible temperature required for thermally activated cooling is lowest for a desiccant based system, as shown here. In addition, this type of system has a good match to a dedicated outdoor air unit coupled to a heat pumps design.

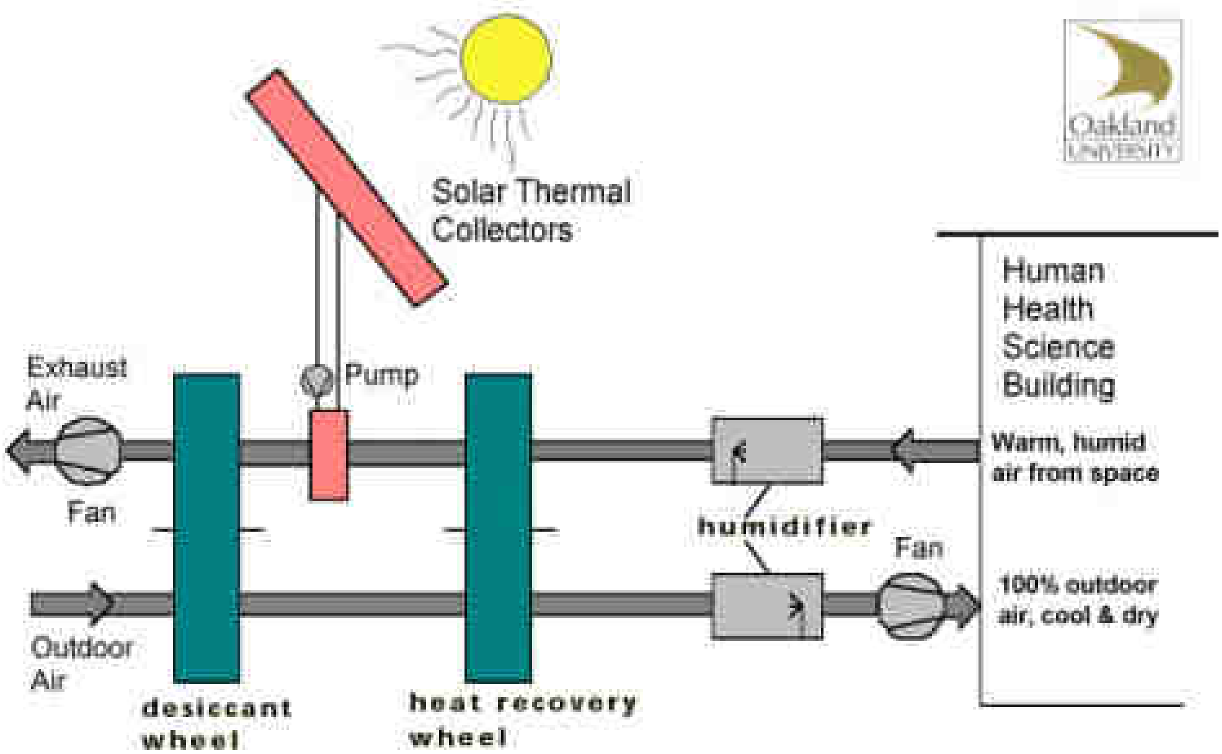
Therefore this type of technology was been chosen. Each DOAS has a sensible heat recovery wheel, and a desiccant dehumidification wheel with solar thermal regeneration.



Shown here is a typical rotating heat recovery wheel. A desiccant impregnated honeycomb structure will adsorb moisture from incoming air, and then desorb in the heated regeneration section.



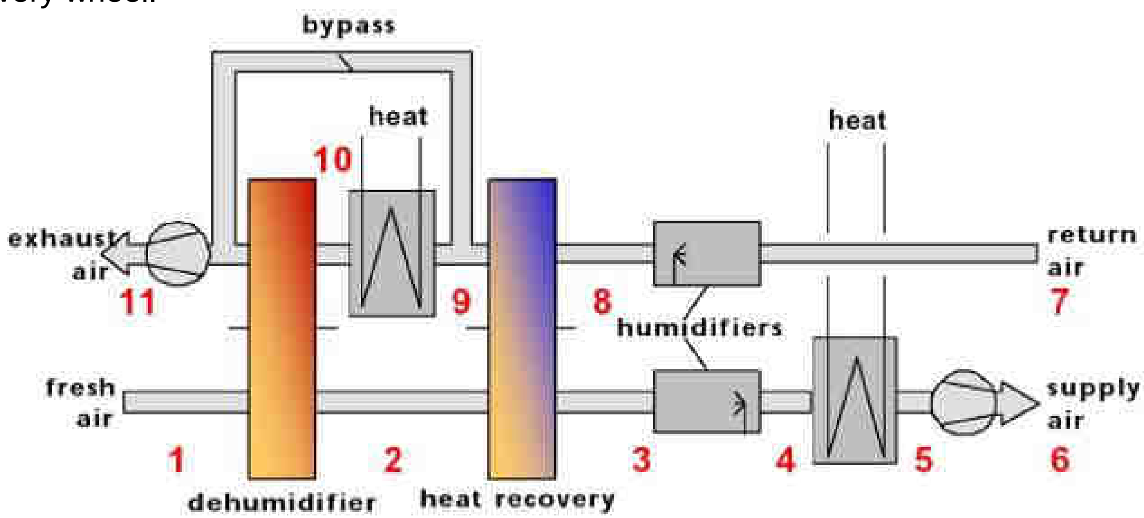
The solar thermal system serves the DOAS units as schematically shown here. Solar energy will drive out the summer humidity, removing this latent load from the heat pump system and directly supporting the operation of the ground source well field.

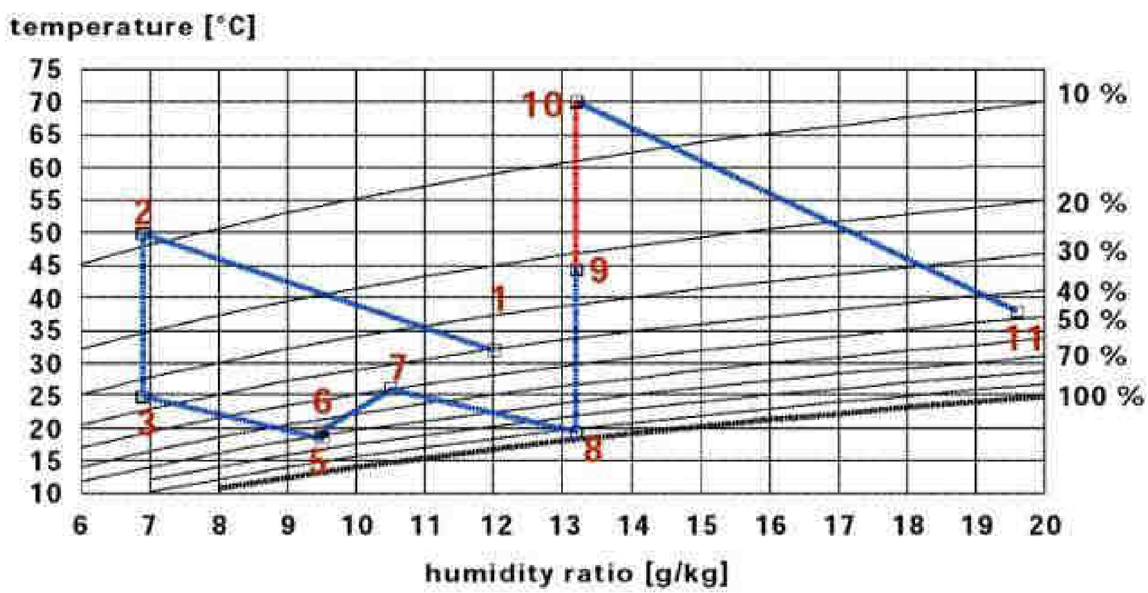


Dedicated Outdoor Air Suppy Unit

A typical system is illustrated below, using a sensible heat recovery wheel in series with the desiccant dehumidification wheel.

The system psychometric process is shown here, below. The desiccant dehumidifcation path from point 1 to 2, followed by a sensible cooling path from points 2 to 3 by the heat recovery wheel.





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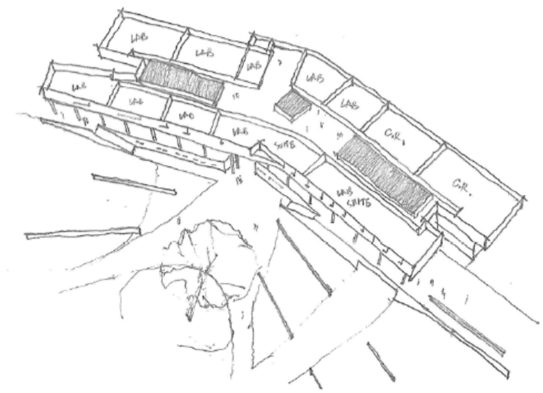
Additional Sustainable Features



- 50 kW solar PV system on penthouse roof
- Educational displays within the building
- Electric vehicle charging stations
- Access to public transportation
- Low Maintenance / Long Life Materials
- Locally Sourced Materials and Products
- Low VOC paints and sealants
- Use of Rapidly Renewable Materials.
- Rain water collection cistern
- Restoration of Wetland
- Recycling of construction waste
- Wood from Managed Forests – Forest Stewardship Council certified wood products
- Hardy landscaping that requires little irrigation
- Providing Bike Racks and showers to encourage Bike use

KEY SUSTAINABLE FEATURES

Water

Storm water harvesting for landscaping: 10,000 gallon cisterns below-grade collect rainwater from the roof and store it for later irrigation use.

Storm water management: Storm water runoff from parking lots and other areas is controlled by the natural wetland.

Low flow plumbing fixtures: 0.125 gallon flush urinals; dual flush (1.1/1.6 gpf) water closets.

Native trees and grass.

Materials

Recycled materials used in metal castings, manholes, exterior concrete, reinforcing and structural steel, insulation, waterproofing, metal flashing, brick and other various components.

A total of 22.8% combined recycled content value as a percentage of total materials cost.

95% of building construction material diverted from landfills by recycling.

Use of rapidly renewable materials.

Forest Stewardship Council certified wood products.

Classroom furniture is locally sourced, has low chemical emissions and includes a high percentage of pre-consumer and post-consumer recycled content.

Low VOC paints and sealants.

Lighting

All of the perimeter areas are illuminated by natural light.

The atrium uses clerestory windows, a highly reflective ceiling, and glass walls to illuminate the atrium and adjoining spaces.

Occupancy sensors provide lighting control and daylight harvesting.

LED lighting for roadways and parking; no lighting pollution into the sky; time clock and photocell with override switches were provided.

Individual Controls

Provided for most spaces except private offices. Up to five private offices with similar load profiles share a thermostat.

Transportation Mitigation Strategies

Two dual electric charging stations for four electric and hybrid vehicles on site.

Bike racks, showers and lockers.

Other Major Sustainable Features

Geothermal wells, solar collectors, photovoltaic panels, variable refrigerant flow fan coil units, heat pumps, high performance building envelope with high insulation values.

BUILDING ENVELOPE

Roof

Type Concrete pavers on pedestal support system over continuous 3 in. high density polystyrene insulation (R-18), roofing membrane, sloped concrete "topping," structural concrete slab, and metal roof deck.
Overall R-value 22
Reflectivity 55 (light colored pavers)

Walls

Type Terra-cotta rain screen system with 3 in. closed-cell spray foam insulation (R-18), vapor barrier, and 8 in. masonry unit back-up wall.
Overall R-value 20
Glazing Percentage 32%

Basement/Foundation

Slab Edge Insulation R-value R-10
Basement Wall Insulation R-value R-10

Windows

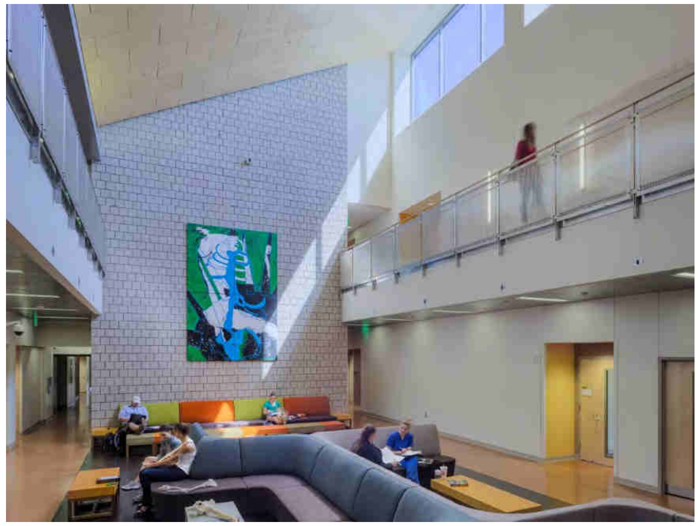
Effective U-factor for Assembly
Estimated and average 0.4 (center of glass 0.29)
Solar Heat Gain Coefficient (SHGC) 0.29
Visual Transmittance 62%

Location

Latitude 42° 40' 22.7244"N
Orientation The building is oriented in an east/west direction to take advantage of the solar position and the sloping hillside.

Day-Lighted Interiors

- Large overhang to shade south glass curtain wall
- Shading devices to shade south window
- Clerestory Lets sliver of direct light deep into atrium



BUILDING TEAM

Building Owner/Representative
Oakland University

Architect, Mechanical Engineer, Electrical Engineer, Energy Modeler, Structural Engineer, Civil Engineer, Landscape Architect, Lighting Design, LEED Consultant SmithGroupJJR

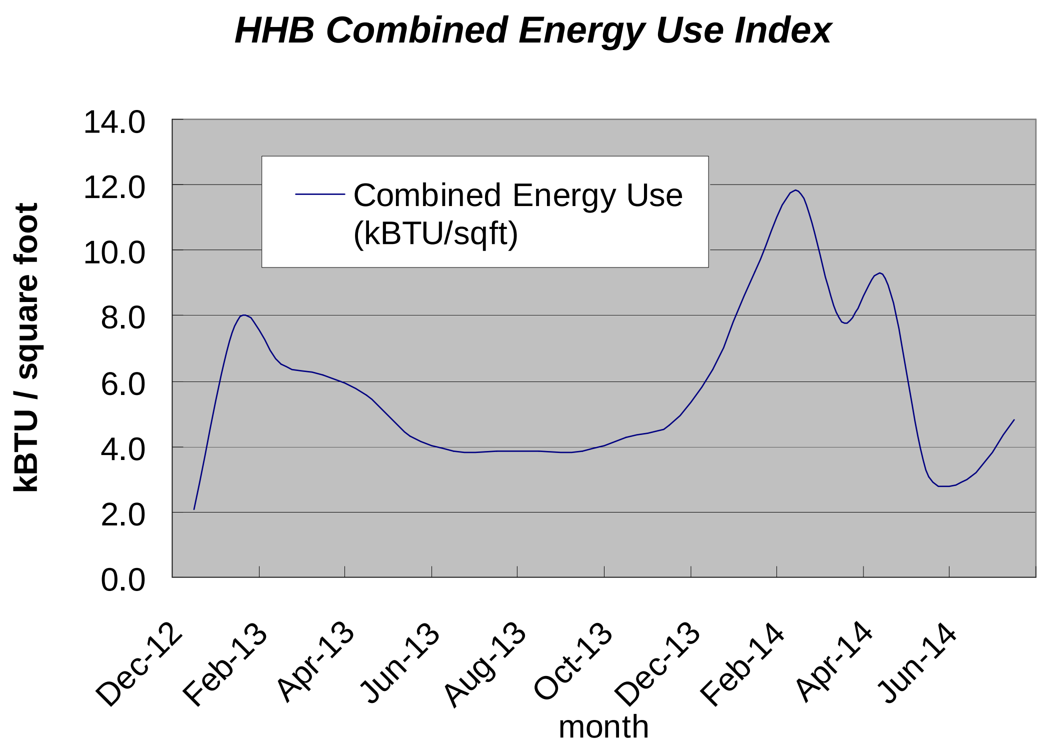
General Contractor The Christman Company (Construction Manager)

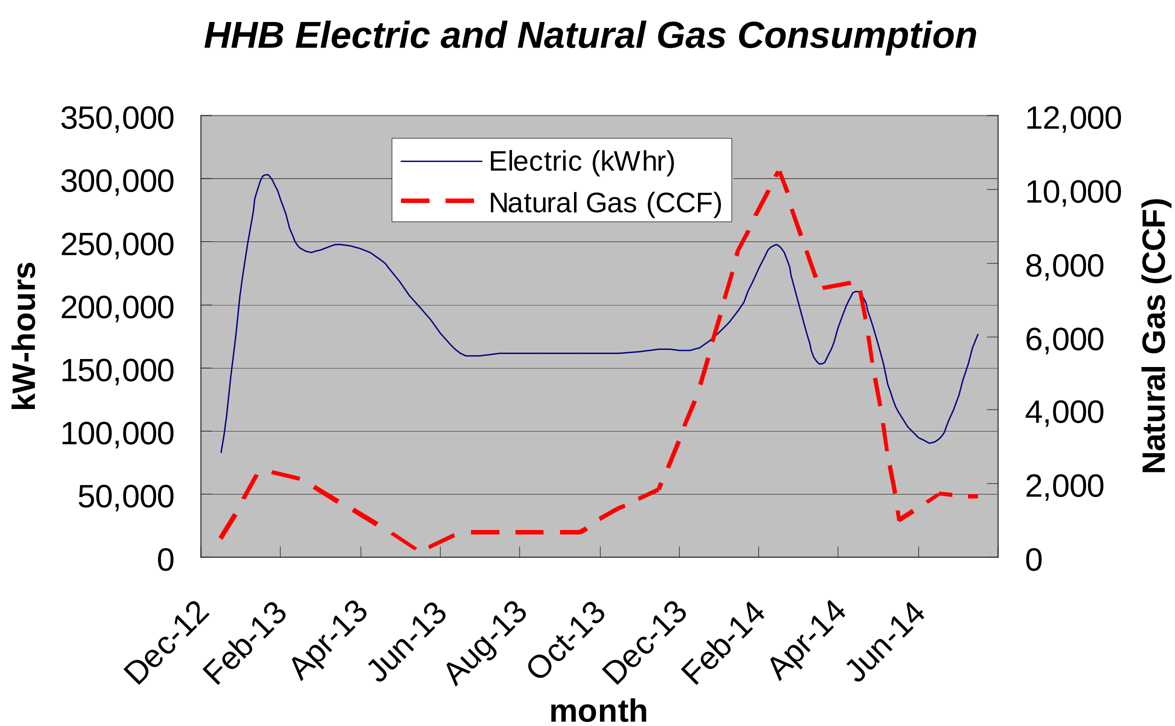
Environmental Consultant Testing Engineers & Consultants, Inc. (geotechnical engineer) and Strategic Energy Solutions, Inc. (geothermal consultant)

Commissioning Agent
LL Catey Engineering

Energy Performance

Manual meter readings of the building for the past year average a combined gas and electric usage of 4.9 kBTU / square foot of building space as shown below. This is 58.4 kBTU / sq foot annual average, or about half of the campus average.





Lessons Learned

Soffits and Stack Effect. Ideally, building pressurization is maintained at a slight positive pressure. However, such control cannot overcome effects of strong winds, and may also be challenged by the chimney effect of a five-story 70°F building in a 10°F environment. Although the large soffit under the student levels was well-detailed and observed during construction, one spot leaked enough air to freeze sprinkler pipes above adjacent heated space sharing a common plenum, though fortunately without rupture. The lesson learned here is to pay close attention to soffit details and actual construction, especially in similar weather conditions.

VRF Controls. Though VRF manufacturers have recently improved the ability to accommodate some customization, at the time of design, control capabilities and flexibility were limited and varied between manufacturers. The VRF system was not able to communicate directly with associated VAV boxes providing ventilation air to each space as initially planned. Adding a second parallel BAS network throughout the building was not in the budget. As a result, the VAV boxes were installed with “stand alone” controls and no ability exists for the BAS to remotely monitor the ventilation VAV box operation. Also, VRF fan coil units may shut off and stop heating when return air temperatures are too low (a safety feature of the VRF system that the design team was not aware of until after it happened). When the soffit leak mentioned above reached nearby VRF fan coils, rather than adding heat, they shut off.

Down to the Details. A row of solar thermal panels was installed on the roof at a lower elevation than intended, creating more winter shading by a portion of the penthouse. There are no plans to make adjustments to this installation though, due to the associated costs of moving and reinstalling the panel equipment.

Complexity and Cost. The owner and design team recognized this would be a more complex project than most, in part because the DOE grant for geothermal-related aspects of the HVAC system allowed the owner to add other energy-related sub-systems. And as expected for this relatively sophisticated owner, operation of the system was picked up right in stride. Nevertheless, other project funding scenarios, owners and designers will vary, and simpler may indeed be better.

Solar Thermal System: This is a complex system with very little contractor / designer experience in the USA. Systems of this size should have the oversight and assistance of an experienced solar thermal provider, which is very rare in the USA. More effort should have been undertaken to located a solar thermal specialist or experienced installer to avoid the significant learning curve encountered for this subsystem.

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Awards and Publications

Publications

- "Flagship for Health: Oakland University Human Health Building", *ASHRAE High Performing Buildings Magazine*, Winter 2015
- "Oakland University Human Health Building", *Technology Century (ESD)*, Summer 2014
- "A Golden Opportunity for Platinum", *Environmental Design + Construction*, March 2014
- "Halls of Ivy Keep Getting Greener and Greener", *Building Design + Construction (online)*, November 11, 2015
- "Building a Healthy Building for the Healing Sciences", *CAM Magazine*, February 2013
- "Critical Mass", *CAM Magazine*, January/February 2012

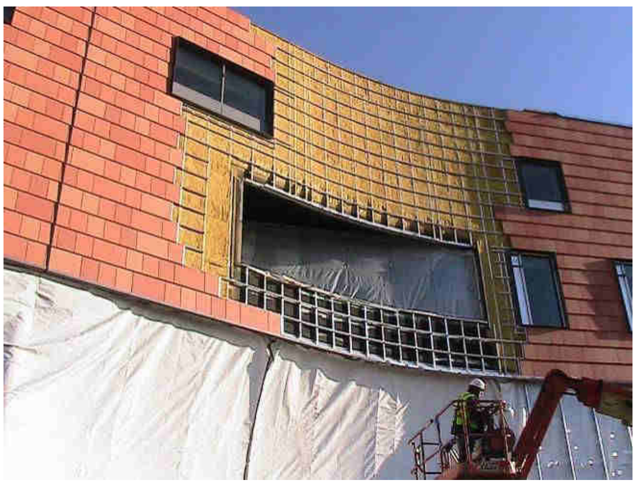
Awards

- Honor Award - Building, AIA Michigan, 2015
- Award of Merit - Architectural Engineering Integration Category, Architectural Engineering Institute, 2014
- Second Place - New Educational Facilities, ASHRAE Region V Technology Award, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2014
- Construction & Design Award, Engineering Society of Detroit, 2014
- Honor Award - Building, AIA Detroit, 2013
- Best of Michigan Construction, *CAM Magazine*, 2013
- Construction Project of the Year, *CAM Magazine*, 2013

Construction Photos from 2012

View of solar thermal system from the east, looking west.

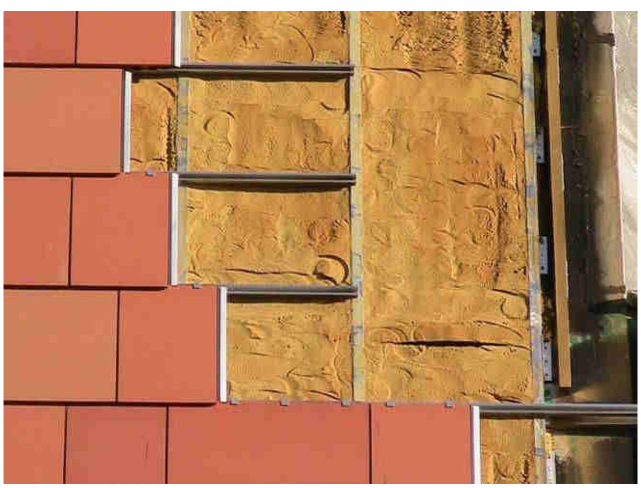
February 20, 2012



View of the building envelope structure, under construction.

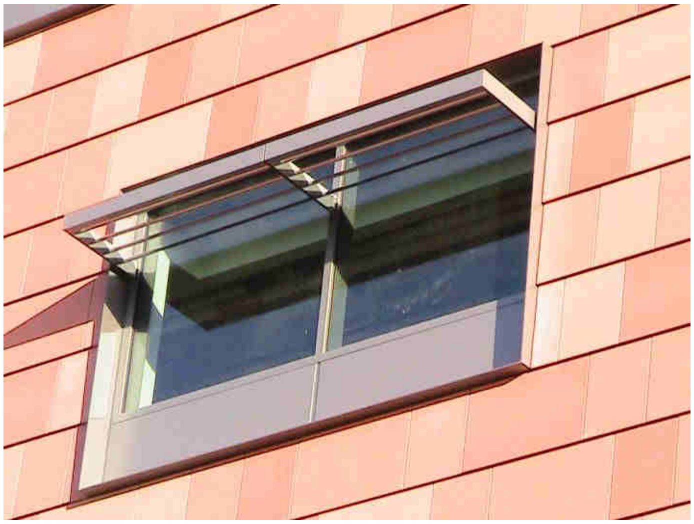
German tile system is a unique structure.

February 20, 2012



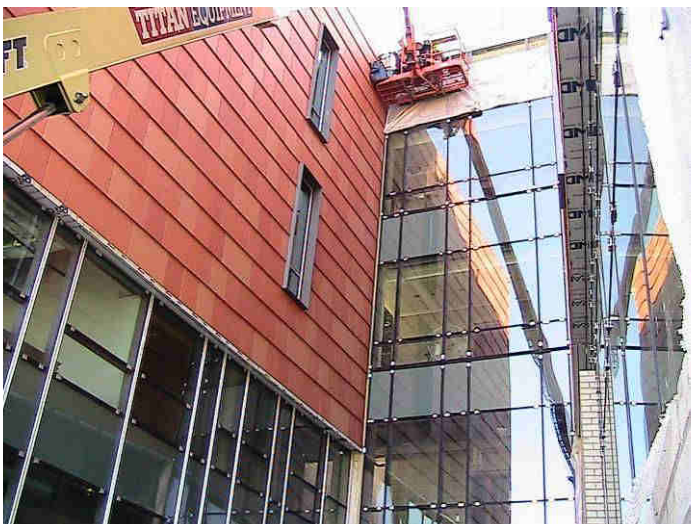
Building envelope tile system.

February 20, 2012



Small solar shade features on the south facing windows.

February 20, 2012



West façade under construction.

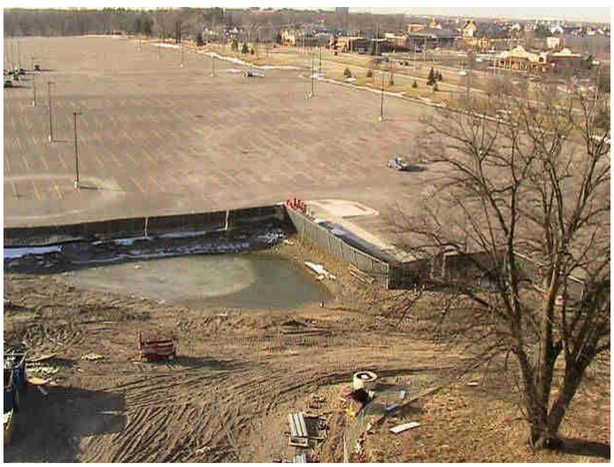
February 20, 2012

One of the heat pump mechanical rooms showing five VRF heat pump units.

February 20, 2012

VRF compressor.

February 20, 2012



View looking south from the roof. The 256 bore holes are under the new asphalt parking lot beyond the construction fence.

February 20, 2012

Honeycomb structure of the desiccant dehumidification wheels that will be regenerated by the solar thermal hot water system.

February 20, 2012

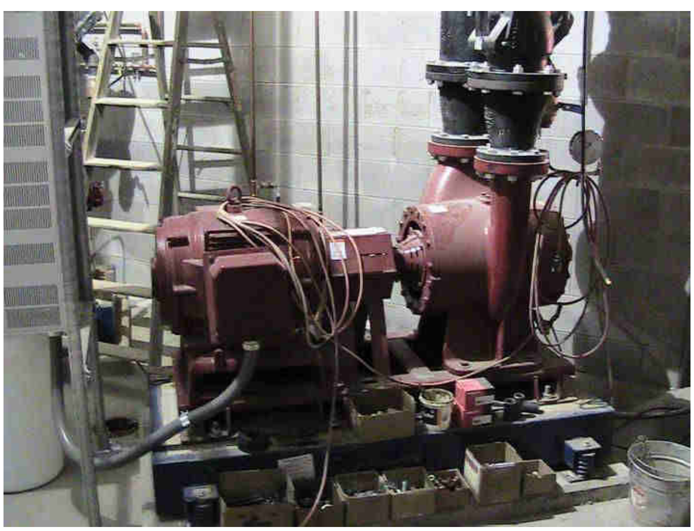
Penthouse heater – chiller (heat pump) units that provided chilled water & backup hot water to the solar thermal system. These supply HW & CHW to the main ventilation units as well as building vestibule fan coils and unit heaters.

Solar thermal is stage one, these heater/chillers are call for heat 2, and a backup gas fired boiler is stage 3.

February 20, 2012

Backup 2MMBTU/hr natural gas boiler in penthouse.

February 20, 2012



Ground water supply pumps.

Typical of two.

February 20, 2012

Electrical meters located in the main substation.

All HVAC circuits as well as all hydronic BTU flows are monitored to allow for a full and complete energy monitoring system.

February 20, 2012

View from the south on June 15, 2012. Below the asphalt is the256 borehole geothermal array. Bores are 320 feet deep and 25 feet apart, center to center.

View from the southeast corner looking west. August 5, 2012. Landscaping is well underway, and faculty are moving into the building.

On the penthouse roof is a 50 kW solar photovoltaic system.

Solar thermal tube racks are located below on the main roof.

July 2012

Solar PV inverters.

July 2012

Installation of solar thermal, evacuated tubes.

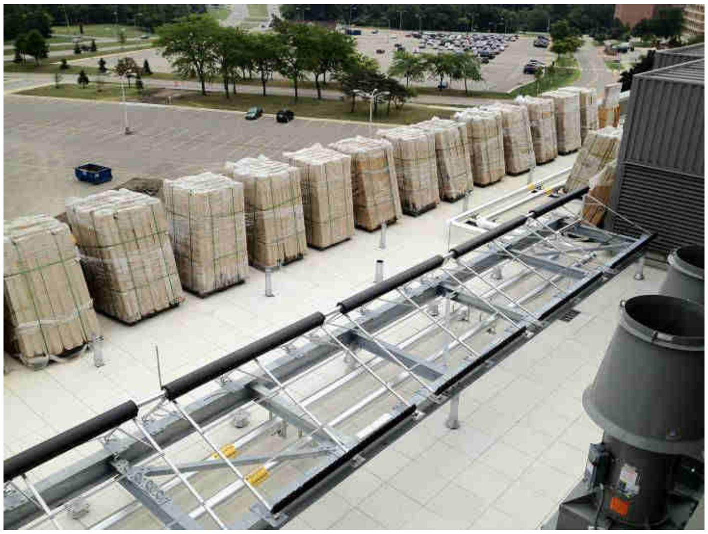
This system will supplement the heat pump cooling & heating.

Cooling support will be aided by the latent heat removal of the two large desiccant wheels. Less energy will be needed by the geothermal system as a result.

July 2012

Solar tubes were craned to the roof on palletized boxes. There was some breakage, but abundant spares accounted for this.

July 2012



View from the penthouse roof of the solar tube boxes.

July 2012

Solar tubes being unpacked.

July 2012

Engineered wetlands on the west side of the building site.

July 2012

Fully installed solar thermal evacuated tube arrays.

View looking west.

August 2012

Approximately 12 Siemens flow computer / BTU meters are used throughout the basement and penthouse mechanical rooms.

A clamp-on transit time ultrasonic flow meter as well as supply and return water temperature sensors connect to each flow computer where the BTU rate is calculated and totalized.

All electric and BTU meters communicate via Modbus back to a Tridium JACE controller.

The JACE controller is part of the whole campus metering system, from which the DOE data communications will take place.

August 2012

Detailed Building Description

A. General

Mechanical systems for the Oakland University – Human Health Building will be designed in accordance with applicable codes, regulations, OU Building Construction Standards. The mechanical system design will emphasize safety, a healthy environment free from indoor and outdoor pollutants, but at the same time will optimize energy conservation and low maintained cost. The mechanical systems will be designed to minimize acoustical and vibration impacts within the building spaces.

The state-of-the art controls will optimize energy conservation but also will maintain comfort levels throughout the day and night.

B. Design Criteria

The building mechanical systems will be designed to maintain the following indoor space temperatures at the given ambient weather conditions:

Summer : At 91 ºF dry bulb / 73ºF wet bulb – Outdoor air design conditions
75 ºF dry bulb / 50 %RH - General Indoor Spaces

Winter : At 3 ºF dry bulb - Outdoor air design conditions
72 ºF dry bulb - General Indoor 60 ºF dry bulb

C. Utilities

The following mechanical utilities will be brought to the new HHS Building from their respective campus service mains:

City Water: combined 8” fire protection, 4” domestic split off from fire inside the building.
Storm Sewer: Number of outlets and sizes as indicated on utility drawings.
Sanitary Sewer: Number of outlets and sizes as indicated on utility drawings.
Natural Gas: Gas company furnished and installed gas meter outside of the building.

D. Fire Protection

A combination wet pipe sprinkler/standpipe system will be provided throughout the building. Loading dock, service areas, storage spaces, and mechanical equipment rooms will be designed for ordinary hazard occupancy. Office, instructional areas, patient / client facilities, lobbies, and corridors will be designed for light hazard occupancy. All parts of the system will be designed and installed in accordance with State of Michigan Office of Fire Safety requirements, NFPA 13 and NFPA 14.

The system will consist of a wet standpipe riser in each exit stair with hose valves located at each intermediate landing in accordance with NFPA 14. A combination sprinkler/standpipe riser located at one stair will supply sprinklers from zone control valves located adjacent to the riser based on NFPA 13 coverage requirements. Water supply for the fire protection system will come from a new combination domestic/fire protection water line extended from an existing city main located on campus. A fire pump will be required to maintain the required 100 psig at the highest hose valve per NFPA 14. A backflow preventer will be provided at the inlet to the fire pump.

E. Plumbing

Storm
A roof drainage system consisting of roof sumps and indoor rain conductors designed to flow by gravity into the site storm system. A storm overflow drainage system will be provided to back-up the primary system and will discharge above grade as required per code. A drain tile system will be provided around the basement mechanical room foundation walls and will gravity drain to the existing wetland area.

Sanitary
A complete system of sanitary drainage and vent piping will be provided to serve plumbing fixtures and floor drains throughout the building. The sanitary drainage system will be extended to the site sanitary system. Floor drains in the 1st Level mechanical room will be routed by gravity to a “grey water” duplex sump pump unit, which will discharge into the sanitary drainage system. Other 1st Level plumbing fixtures will be routed by gravity to a “black water” duplex sump pump unit, which will discharge into the sanitary drainage system. The emergency generator will power these pumps. (These pumps and sumps will be omitted from the design upon verification that the site sanitary depth and size are adequate for gravity drainage.)
Drainage from laboratory sinks using chemicals will be routed through sink mounted neutralization traps prior to discharging into the campus sanitary system. The intent of this system is to protect piping from spills of corrosive fluids. Chemical waste within the facility must be disposed of properly.

Domestic Water
Water for the domestic system will come from a new combination domestic/fire protection line extended from an existing city main located on campus. A new water meter will be provided inside the building and piping extended from the meter to all building fixtures and equipment. A domestic water pressure boosting system will boost water pressure for Levels 3 through the penthouse. A duplex set of domestic backflow preventers will be provided down stream of the water meter. Additional backflow preventers will be provided as required for domestic connections to condenser water and heating hot water make-up. Small near point of use electric domestic water heaters will provide 120ºF domestic hot water where required. Where required, emergency showers and combined emergency shower/ eyewash

units will be provided with hot/cold water fail safe mixing valve to temper the water to each shower. A floor drain will also be provided near each shower.

Natural Gas
Natural gas service will be provided to the building by the local natural gas utility company. The gas service piping upstream of the meter and meter will be furnished and installed by the gas utility. The gas meter and pressure reducing valves will be located on an outside wall of the building and the service will enter the building above grade. Natural gas will be piped from the meter to the emergency generator and the laboratories requiring gas. Natural gas will be delivered at 0.5 psig to the laboratories. An emergency shut-off valve within a recessed valve box will be provided outside of each laboratory requiring gas.

Laboratory Compressed Air
A central system will not be provided.

Laboratory Vacuum
A central system will not be provided.

Laboratory Pure Water
A central system will not be provided. If high purity water is required, local polishing units will be provided by the user and not contractor purchased.

F. Heating, Ventilating, and Air Conditioning Systems

General Heating and Cooling

Calculated heating load:	150 ton in winter (1.8 million BTU / hr)
Calculated cooling load	400 ton in summer

The building will be served by a variable refrigerant volume (VRV) water source heat pump system. Heating/cooling fan-coil units located in (or near) each space or zone will provide heating and cooling. Water source heat pumps located in mechanical rooms on each floor will be connected via refrigerant piping to fan-coil units. The water source heat pump units will utilize variable speed scroll compressors to efficiently circulate refrigerant.

The heating/cooling water source for the VRV heat pumps will be a hybrid geothermal system. A vertical well field, sized for the peak heating load requirements, will provide a “heat sink” in which the heat pumps can obtain and release heat energy. A roof-top evaporative cooler will pre-cool the source water in the summer time to provide the additional cooling capacity when cooling loads exceed the capacity of the well field. Two (2) variable speed end-suction pumps will circulate the source water between the heat pumps and the well field (and evaporative cooler). A polypropylene heat transfer fluid will be utilized for freeze protection during extreme cold conditions.

Heating Hot Water System
The heating hot water system will consist of two (2) water-to-water heat pumps, each sized for 100% capacity, an air separator, expansion tank, and two (2) variable speed base in-line pumps each sized for 100% capacity. The variable speed heating hot water pumps will pump hot water from the water-to-water heat pumps to unit heaters in mechanical rooms and service areas, and cabinet unit heaters near entry doors and in stairwells.

General Ventilation System
Ventiltion air will be delivered to each space or zone via a dedicated outside air system (DOAS). Two (2) DOAS units will be located on the roof and will supply conditioned ventilation air to the facility. The units will be equipped with dehumidification capability, supplying dry air to the building, thus allowing the fan-coils to primarily provide primarily sensible only cooling. The DOAS units will incorporate enthalpy type heat recovery wheels will be utilized to provide “free” pre-heating/pre-cooling of the outside air utilizing the building relief/exhaust air. The enthalpy wheels also provide modest wintertime humidification by transferring moisture in the exhaust/relief air to the ventilation air. Sensible type heat recovery wheels will be utilized to provide “free” reheating when building dehumidification is required. A water source heat pump and direct expansion heating/cooling coil will be utilized to control temperature and provide dehumidification when required.

Each DOAS units will include variable speed supply and relief/exhaust fans, filter sections with 2" pre-filters and 12” final cartridge filters (MERV 7 and MERV 13 efficiency), water source heat pump, and heating/cooling coils with stainless steel drain pans. Airflow from the units will be varied using adjustable frequency motor controllers on the supply and relief/exhaust fans. The units will be equipped with heated side service vestibules to allow typical unit access and maintenance without being exposed to outdoor conditions.

Exhaust Systems
Each instructional lab fume hood will be connected to a dedicated high plume exhaust fan located on the roof. Low velocity constant volume hoods will be utilized. Contaminated fume hood exhaust will not be utilized in the DOAS units. Toilet rooms will be ducted to two (2) central exhaust fans located on the roof. The fans will be interlocked with the air handling systems and will operate under DDC control.

Mechanical and electrical equipment rooms will be exhausted using local exhaust fans controlled by a room thermostat whenever possible.

G. Air Distribution

Ventilation air will be delivered throughout the building to occupancy sensor controlled variable air volume terminal units. Ventilation air will be medium pressure, round spiral sheet metal where space permits.

Supply ductwork downstream of the fan-coil units will be low pressure; rectangular, and acoustically lined.

Return air will be routed back to the fan-coil units through a ceiling plenum or return duct as applicable.

Relief air will be collected at a minimum of two locations per floor within the ceiling plenum and ducted from here to the DOAS units.

H. Instrumentation and Controls

A direct digital (DDC) control system by Honeywell or Automated Logic will control and monitor all functions of the building mechanical systems. The control system will be provided with a local (monitoring only) operator workstation and mobile service tool (laptop computer) with the appropriate software to allow HVAC maintenance personnel to control and diagnose system operation. The DDC control network will connect to the campus energy management network via the OU Campus Ethernet. The DDC will report control alarm conditions to the central campus system.

Recap of Previous Activity Reports for Reference

2011, 4th Quarter Oct 2011 – Dec 2011

All solar thermal racking hardware and piping have been installed. The solar evacuated tubes will not be installed until Summer 2013. The penthouse mechanical room is nearly complete (serving the solar thermal system).

The dedicated outdoor air ventilation units are installed. The VRF heat pumps are installed and the in-building condenser water piping is nearly completed. Refrigerant piping is progressing as well.

The plan is to make the final connections to the ground source piping systems and commission the system in Feb - March 2012 to provide heating to the remainder of the project.

Honeywell was selected as the system controls provider, and work is underway on the data collection system.

2012, 1st Quarter Jan 2012 – March 2012

All solar thermal piping and racking has been installed. The penthouse mechanical rooms are nearing completion.

The basement geothermal mechanical pump room is complete.

Floor by floor commissioning of the geothermal HVAC systems are underway. By the next quarter, all geothermal systems will be fully functional.

Control DDC systems and metering / monitoring commissioning will continue through summer and fall 2012.

The project is on track and academic classes will take place in the fall semester 2012 (Sept 2012).

2012, 2nd Quarter April 2012 – June 2012

All work on this exciting project is on schedule. Final finishings and commissioning is being completed for occupancy throughout July & August 2012.

School starts on Sept 4th, an this building will be open for classes and occupied by the School of Nursing, the Environmental Health & Safety program, the Physical Therapy program, and other general education classes.

Commissioning of the complex system integration will continue through September and most likely into October, but the construction will be complete. In August, landscaping and final outdoor concrete work is being finished.

The geothermal system is online and working well. The solar thermal system will be commissioned in late August or early September. The solar PV system will be online in early August.

All metering systems will be functional and commissioned by late August. The next report will discuss some of the metering system and status of this important element of the project.

2012, 3rd Quarter July 2012 – Sept 2012

All work on this exciting project is on schedule. Final finishings and commissioning is being completed for occupancy throughout July & August 2012.

School started on Sept 4th, and the building was occupied and open for classes.

Commissioning of the complex system controls & integration continues through September and October, but the construction is complete.

The geothermal system is online and working well. The solar thermal system has had some commissioning problems and delays, so this subsystem will hopefully be fully online in late fall 2012. The solar PV system has been functioning well.

Commissioning of the metering & monitoring, and working out some bugs in the HVAC controls and integration of the multiple systems will continue through the fall. Presently, I estimate that the metering & monitoring fully functional in Nov 2012 to start collecting performance and energy balance data.

2012, 4th Quarter Oct 2012 – Dec 2012

School started on Sept 4th, and the building was occupied and open for classes with the heat pump system fully operational and providing space comfort.

Debugging and commissioning of the complex system controls & integration continues.

Specifically, the solar thermal system has had some control and hydronic issues, which are being resolved. Some valves and circuit setters used in the solar thermal array were not of sufficient temperature as per specifications, so these were replaced with 400 deg F rated devices. The solar thermal system BTU meter was inadvertently omitted, so we are waiting for this to be installed. Commissioning this system in the winter is challenging, so work will continue on this thru the winter and into the spring. Specs called for a performance verification, which I will ask for in late spring once the solar radiation levels are higher, the BTU meter is installed, and the system is verified to be fully commissioned and operational.

The geothermal system is online and working well, but due to the time of year for startup, we have the backup boiler adding some heat to the ground loop. Once we pass thru one summer season, this highly cooling dominant ground loop will be a bit warmer, and the next year's operation should be more indicative of the normal operation and efficiency. Fine tuning of the system continues.

Commissioning of the metering & monitoring is behind schedule and continues. We are collecting manual meter readings from the main gas and electric meters, and we plan to have the full system automatically collecting and providing data in Winter 2012.

2013, 1st Quarter Jan 2013 – March 2013

The building has been fully operational and occupied since Sept 2013.

With such a complex facility, there will be a period of time where the geothermal and solar thermal systems and vairous subsystems are fine tuned and fully commissioned properly. At least one fully cycle of seasons will be needed to view and fine tune the solar thermal and geothermal systems.

There are some known issues that remain to be resolved in the solar thermal system before we can make full used of the solar array. The project designers and contractors continue to work on this.

The Daikin heat pump controls are still being optimized, and the start of the cooling season this spring will help fine tune the change-over from winter to summer.

Lastly, there remains some commissioning work on the metering & data collection systems. We will provide and update on this as soon as more detail is available, and we will endevor to get the data live and reporting as soon as possible. Manual meter reads of the major incoming utilitis are being collected.

2013, 2nd Quarter April 2013 – June 2013

The building has been fully operational and occupied since Sept 2013. Systems are functional and the building is comfortable.

However, with such a complex HVAC system with mulitle subsystems and controls integration, full commissioning and fine tuning will likely take the cycle of two full seasons.

The utility metering system is functional, but I have been unable to get meaningful data formatted in a usable way from the Tridium installer. We are also installing a sophisticated EnergyCAP software reporting system, and this will definitely provide a solid user interface and reporting of the Tridium data. However, I will coordinate with Oak Ridge National Laboratory and CDH Energy Corp to see if we can get information directly from the Tridium metering web server. The EnergyCAP system should be providing reports before the next quarterly report.

There are a few significant commissioning issues on the building pressurization / infiltration as well as the solar thermal system.

We hope to resolve some mechanically forced air balance issues, and then do a building envelope pressure test with a new 6 fan blower door system that we have already procured.

2013, 3rd Quarter July 2013 – Sept 2013

The building is occupied and we are in the maintenance and verification phase.

M&V data is being electronically sent to the data consultant firm, CDH Energy Corp. The Oakland campus is transitioning all of its utility meter data to an Energy Cap front end software reporting package. This has been a long process to get perfected, but once complete, we will transition the Human Health Building (HHB) Data to this platform for improved data management and display of data. We anticipate this will be complete in the fall 2013.

2014, 1st Quarter Jan 2014 – March 2014

The building is occupied and we are in the maintenance and verification phase. M&V data is being electronically sent to the data consultant firm, CDH Energy Corp.

Our transition to a new utility metering system, Energy Cap, is nearly complete, and the HHB building data will be available on that platform.

Manual meter readings of the building for the past year average a combined gas and electric usage of 4.9 kBTU / square foot of building space. This is 58.4 kBTU / sq foot annual average, or about half of the campus average.

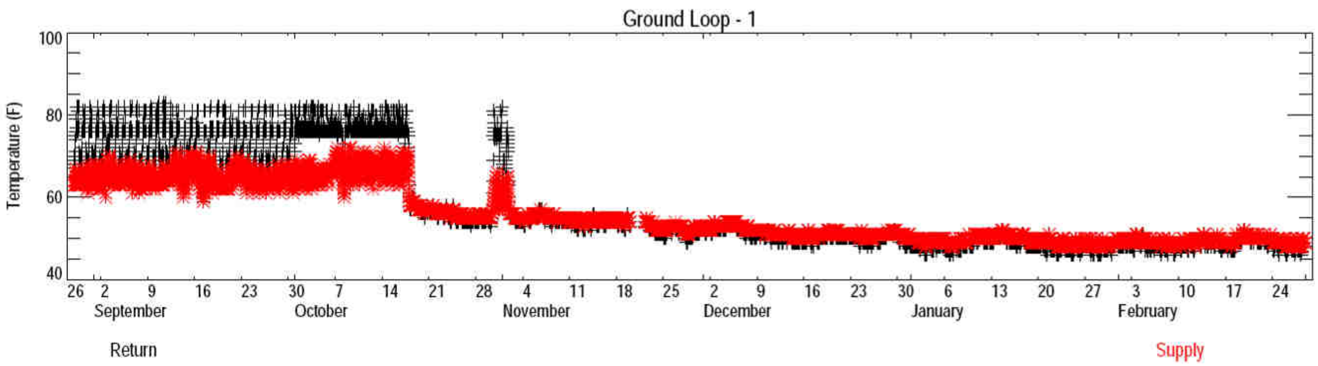
As the large in ground solar storage gets fully up to temperature this next summer, and the building controls are further optimized, this energy usage should improve even further. This should be reflected in the next report as well as in the forthcoming final project report.

2014, 2nd Quarter April 2014 – June 2014

Similar to previous quarter. The building is occupied and performing normally.

The temperatures in the ground loop as well as the relative efficiency of the building will be analyzed in more detail. With the extremely cold winter of 2013/2014, care will be taken to normalize the data for Heating Degree Days and Cooling Degree Days.

Below is a graph of the ground loop temperature supply and return for the past six months.



2014, 3rdQuarter July 2014 – Sept 2014

The project PI, James Leidel, attended a panel discussion at the Baltimore, MD International Ground Source Heat Pump Association meeting. At the requeste of the DOE, James participated in the panel discussion on October 15, 2014.

There are no changes to the building operations. The building has been online & occupied since the Fall of 2012, and we are in the maintenance and verification phase. We will be analyzing the building operation and data for to provide in the final project report due out this fall.

2014, 4th Quarter Oct 2014 – Dec 2014

The grant period has concluded at the end of September 2014. Utility data and other building information will continue to be collected. A final report will be compiled and submitted in January 2015. There are no changes to the building operations.