Grunenwald Science and Technology Building

Shane Helm
Mechanical Option

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CLARION UNIVERSITY

Presentation Overview

- Building Overview
- Existing Mechanical System
- Geothermal Heat Pump Analysis
  - Sizing Geothermal Wells
  - Construction Breadth
  - Energy Consumption &Payback
- DOAS with Parallel System Analysis
  - Equipment Selection & Sizing
  - Energy Consumption & Payback
- Recommendations

**Architectural Breadth Covered Only in Final Report

Building Overview

- Owner: Clarion University
- Building Size: 108,560 sf
- Function: Educational Facility
  - Laboratories, Classrooms, Offices
- Construction Period Oct. 2006-June 2009
- Delivery Method: Design-Bid-Build
- Total Cost= $34 million

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Overall Design Goals

- Provide State of the Art Laboratories
- Allow for Campus Growth with Additional Classrooms and Offices
- Keep Original Planetarium from Old Pierce Science Center
  - Renovate & Include Large Lecture Hall & Planetarium in New Science and Technology Building

Sustainability

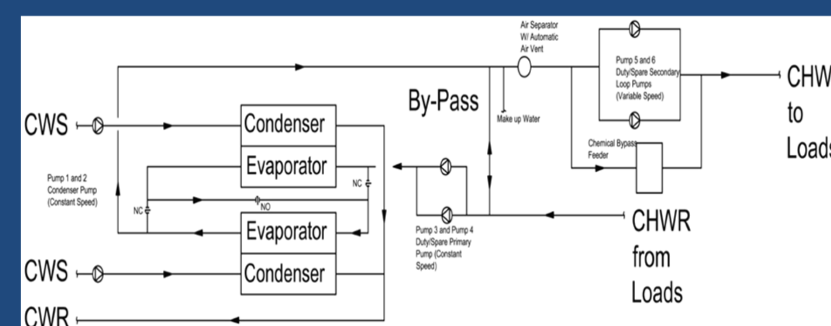
- Achieved LEED Gold Rating
- Sustainable Design Approach
  - Rainwater Collection
  - Micro Turbine, Waste Heat Used to Pre-treat Outdoor Air
  - Photovoltaic Panels, <1% of Energy Load

Existing Mechanical System Overview

- Total Mechanical System Cost=$6.25 million
- 5 VAV Modular Air Handling Units
  - 3 100 % Outdoor Air VAV Units to Serve Laboratories
  - Range in Size From 23,000 to 42,000 CFM
- Include Energy Recovery Wheels
- Glycol Runaround Coil to Pre-condition Outdoor Air

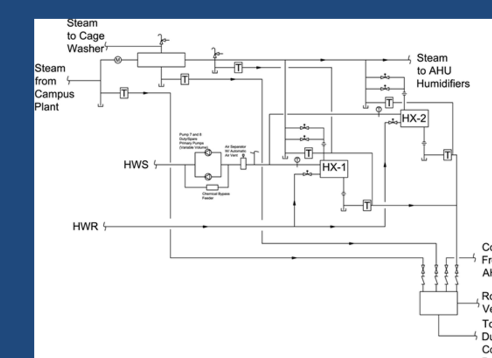
Chilled Water

- Chilled Water Produced by (2) Centrifugal Chillers in Series
  - Temperature Entering Coil= 44˚F
- (2) 750 gpm Cooling Towers



Hot Water

- (4) Natural Gas Boilers
  - Campus Central Plant
- (2) Plate and Frame Heat Exchangers
  - Campus Produced Steam Supplies Heat to Water
  - Hot water Leaves at 180˚F and Enters at 140˚F



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Goal

Improve the Energy Efficiency by Exploring Alternative Mechanical Systems

Geothermal Heat Pump Design

Heat Pump Selection

- Water to Water Floor Mounted
- Capacity up to 35 tons
- Operating Conditions
  - Ground Water Loop, 75 gpm per Heat Pump
    - EWT=85˚F
    - LWT=93.7˚F
  - Load Water Loop, 90 gpm per Heat Pump
    - LWT=44˚F
    - EWT=50˚F
  - Actual Capacity= 259,000Btuh=21.6 tons
- **17 Heat Pumps** Needed to Meet Full Cooling Load

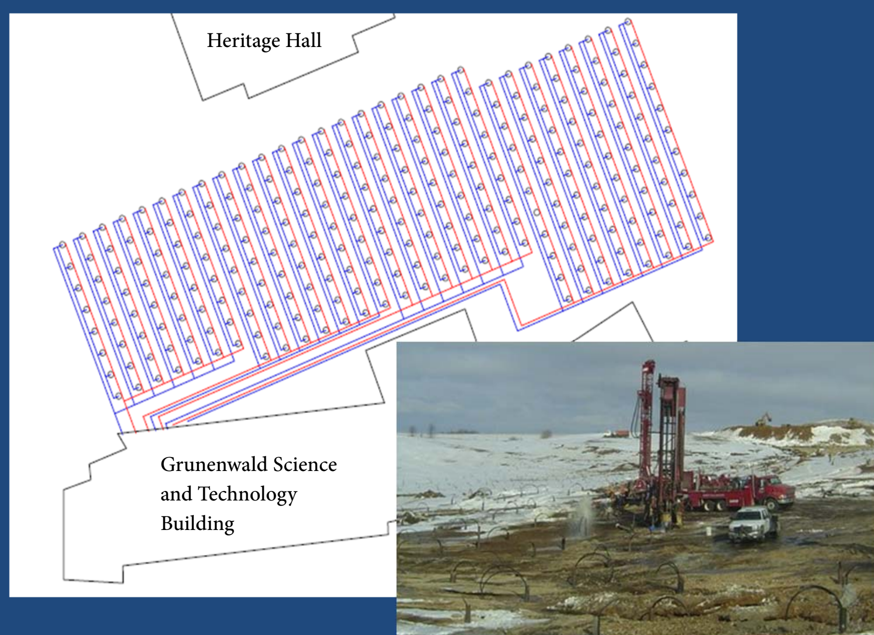
- McQuay Heat Pump Model WRA 420
  - 34 in. x 50 in. x 63.125 in.
- Placed in Mechanical Room
  - In Floor Plan where Chillers Originally Located

Sizing Geothermal For Cooling Only

- Design Implements Vertical Bore Holes
- Based on Process Outlined in Chapter 32 of ASHRAE Handbook 2007: HVAC Applications
- Heating Load met by Campus Natural Gas Boiler Plant
  - Need for More Bore Length when Cooling Only
- **Calculated Total Bore Length= 87,458 ft**

Design Considerations

- Ground Temperature
  - Clarion, PA = 51˚F
- Designed to Meet Full Cooling Load
  - 4,235,700 Btu/hr
- 1" HDPE Pipe for Bore Hole Loop
- 15'x15' Bore Hole Spacing
- Grout & Piping Installed after Hole has been Drilled



Construction Breadth-Geothermal System

- Schedule
  - Dependent on the Bore Hole Depth
  - Installation of Pipes & Grout 1 week after Drilling
    - To Prevent Blow Outs
  - Not on Critical Path
  - Total: 15.6 weeks, over Summer Semesters(14 weeks)
- Location of Wells
  - Lowest Impact on Students
  - North Quad
- Increased Initial Cost by $ 736,019

Schedule and Location Optimization

Length (ft)	# of Bores	Bore Depth	ft/day	day/Bore	Days	Weeks	Drilling Cost	Location of Site
87458	170	514	900	0.572	97.2	19.4	$329,619.48	N Quad
87458	210	416	900	0.463	97.2	19.4	$329,619.48	N Quad
87458	250	350	900	0.389	97.2	19.4	$329,619.48	N Quad
87458	270	324	1200	0.270	72.9	14.6	$216,312.79	N Quad
87458	310	282	1200	0.235	72.9	14.6	$216,312.79	N&S Quad
87458	350	250	1200	0.208	72.9	14.6	$216,312.79	N&S Quad
87458	380	230	1200	0.192	72.9	14.6	$216,312.79	N&S Quad
87458	390	224	1800	0.125	48.6	9.7	$118,457.00	N&S Quad
87458	430	203	1800	0.113	48.6	9.7	$118,457.00	N&S Quad

Initial Cost

Equipment/Material	Cost for Location	Equipment	Cost for Location
Drilling	$216,312.79	(2) Centrifugal Chillers	$209,244.00
Grout	$196,019.48	Cooling Tower	$54,000.00
Heat Pumps	$448,800.00		
Piping	$78,967.52		
Pumps (Hydraulic)	$55,389.50		
Welding	$3,774.10		
		Initial Cost Increased by	$736,019.37

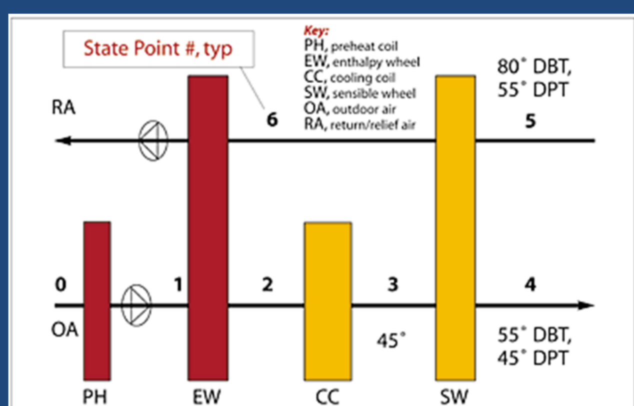
Energy Use Comparison Geothermal Heat Pumps vs. Existing VAV Design

	Original Design (VAV)	Geothermal High Efficiency	Geothermal Regular Efficiency
Energy Consumption (kWh)	2,962,304	2,400,184	2,445,493
Electricity Cost	$138,141	$111,158.38	$113,333.77
Total Saving (Energy)		562,120 kWh	516,811 kWh
Total Cost Saving per Year		$26,982.62	$24,807.23
Payback Period (years)		27.28	29.67

- Total Energy Savings
  - High Efficiency Saves 562,120 kWh each year
    - Saves ~$27,000
  - Regular Efficiency Saves 516,811 kWh each year
    - Saves ~$25,000
- Calculated Simple Payback Periods
  - High Efficiency- 27.23 years
  - Regular Efficiency- 29.67 years

- Reduction in Energy Cost
  - High Efficiency Saves 19.6%
  - Regular Efficiency Saves 18.1%
- Added Construction Cost
  - Increase Mechanical System Costs from $6.25 million to $6.98 million
  - Increase of 11.7% in the Initial Mechanical Budget

Dedicated Outdoor Air System Design



DOAS Roof Top Unit Selection

- Sized Based on Ventilation Air Requirement for Each Zone
- Laboratory Air Handling Units Replaced by DOAS
  - System 1 Sized at 7,450 CFM OA
  - System 2 Sized at 8,800 CFM OA
  - System 3 Sized at 2,100 CFM OA
- DOAS Unit meets Entire Latent Load and Part of the Sensible Loads
- Roof Top Unit Contains an Enthalpy Wheel and Sensible Wheel
  - Supply Temperature = 55˚F
- Remaining Sensible Load to be met by Parallel System
  - System 1- 336,000 Btu/hr
  - System 2- 432,000 Btu/hr
  - System 3- 47,000 Btu/hr
- Parallel Systems Implemented
  - Maximum Ceiling Area of ~50% for Each System
  - Radiant Ceiling Panels
  - Active Chilled Beams
  - Passive Chilled Beams

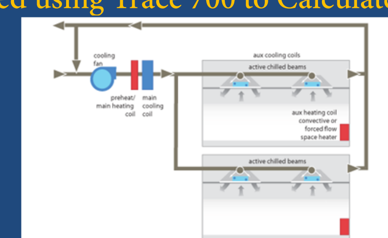
Parallel Systems

Radiant Ceiling Panels

- Capacity of 30 Btu/hr*ft^2
- Required Ceiling Area to Meet Remaining Sensible Load
  - System 1- 54.8% >50%
  - System 2- 86.5% > 50%
  - System 3- 74.2% > 50%
- Since Required Area's are Greater than 50%
  - **Radiant Ceiling Panels are Not a Feasible System**

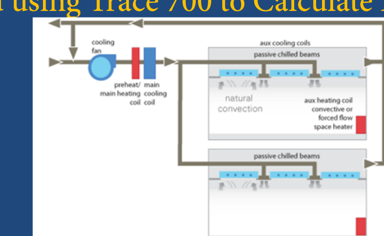
Active Chilled Beams

- Capacity of 3400 Btu/hr for each 12 ft^2 unit
- Required Number of Units to Meet Remaining Sensible Load
  - System 1- 99 units~ 5.8% Ceiling Area < 50%
  - System 2- 128 units~ 9.2% Ceiling Area < 50%
  - System 3- 14 units~ 7.9% Ceiling Area < 50%
- Therefore, **Active Chilled Beams are a Feasible System**
- Modeled using Trace 700 to Calculate Energy Costs



Passive Chilled Beams

- Capacity of 1700 Btu/hr for each 12 ft^2 unit
- Required Number of Units to Meet Remaining Sensible Load
  - System 1- 198 units~ 11.6% Ceiling Area < 50%
  - System 2- 255 units~ 18.4% Ceiling Area < 50%
  - System 3- 28 units~ 15.8% Ceiling Area < 50%
- Therefore, **Passive Chilled Beams are a Feasible System**
- Modeled using Trace 700 to Calculate Energy Costs



Energy Use Comparison DOAS vs. Existing VAV Design

	Original Design (VAV)	DOAS with Passive Chilled Beams	DOAS with Active Chilled Beams
Energy Consumption (kWh)	2,962,304	2,684,445	2,744,816
Electricity Cost	$138,141	$125,877	$128,741
Natural Gas Cost	$3,444	$2,531	$2,560
Total Saving (Energy)		277,859 kWh	217,488 kWh
Total Cost Saving per Year		$13,177	$10,284
Payback Period (Years)		2.48	6.45

- Total Energy Savings
  - DOAS with Active Chilled Beams Save 217,488 kWh
    - Saves $10,284 each year
  - DOAS with Passive Chilled Beams Save 277,859 kWh
    - Saves $13,177
- Calculated Simple Payback Periods
  - DOAS w/ ACB-6.45 years
  - DOAS w/ PCB- 2.48 years

- Reduction in Energy Cost
  - DOAS w/ ACB Saves 7.2%
  - DOAS w/ PCB Saves 9.3%
- Added Construction Cost DOAS w/ ACB
  - Increase Mechanical System Costs from $6.25 million to $6.32 million
  - Increase of 1.1% in the Initial Mechanical Budget
- Added Construction Cost DOAS w/ PCB
  - Increase Mechanical System Costs from $6.25 million to $6.28 million
  - Increase of 0.5% in the Initial Mechanical Budget

Recommendations

Alternative Systems

- Geothermal is Not Feasible Due to High Payback Periods
  - Caused by Large Increase in Initial Cost
  - However, Geothermal System Saves the most Energy Annually
- DOAS with Parallel System had Reasonable Payback Periods between 2.48 to 6.45 years, for PCB & ACB
- Best Possible Alternative Design is the **DOAS w/ Passive Chilled Beams**
  - Payback Period of 2.48 years
  - Initial Cost Increased by $32,000

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Questions?