Geothermal Design/ Construction

Lessons Learned

SCARY MONSTERS AND QUICK SAND

February 3, 2015

Presented by:

Dave Hoffman, P.E., LEED-AP,
Certified Geothermal Designer

8719 Brooks Drive, Easton, MD 21601,
410.822.8688
dhoffman@gipe.net
Why Did We Choose a Geothermal HVAC System for Miller Library/Smith Hall?

- No outdoor or rooftop equipment
- Competitive first costs when compared to conventional system.
- Benefit from simultaneous heating & cooling
- Inherent energy recovery
- Eliminates Underground Steam Piping
- Improves comfort and indoor air quality
- Eliminates multiple fuel sources
- Excellent Life-Cycle cost
- No cooling tower / No chiller / No boilers

Case Study: Washington College Miller Library
Miller Library
Life Cycle Cost Comparison

**Total Initial Cost**

<table>
<thead>
<tr>
<th>Conventional System</th>
<th>Geothermal System</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2,160,000.00</td>
<td>$2,221,750.00</td>
</tr>
</tbody>
</table>

**Total Annual Cost**

<table>
<thead>
<tr>
<th>Conventional System</th>
<th>Geothermal System</th>
</tr>
</thead>
<tbody>
<tr>
<td>$163,926.00</td>
<td>$110,054.00</td>
</tr>
</tbody>
</table>
Miller Library
Life Cycle Cost Comparison

Total Life Cycle Cost Over 30 Years

Conventional System: $11,464,440.00
Geothermal System: $8,468,415.00

TOTAL SAVINGS OVER 30 YEARS = $2,996,025!
Warn your clients that Geothermal is messy!

Don’t Forget: Stormwater Control Requirements, Sediment & Erosion Control
*Coordinate with the Civil Engineer on the project.*
Washington College in Chestertown, MD

...But the end result is well worth it!
Heat transfer must be verified via thermal conductivity test at the site.

- Sandy soil: 0.75 to 0.90 ton per borehole
- Rock soil: 1.3 to 2 ton per borehole
- Muddy soil: 0.6 to 0.75 ton per borehole

Note: On the Delmarva Peninsula you do not achieve 1 ton per borehole!
Process Loads:

Do not utilize geothermal for buildings with unbalanced loads or process loads

Data Centers

Emergency Operations Centers

Computer Rooms

In the future watch out for super insulated buildings!
Equipment (Heat Pump) Selection

What is a typical inside design condition for cooling in our region?  
Answer: 75 Dry BULB; 50% Relative Humidity

Selecting equipment at 80°F DB and 67°F WB (50%RH) does not make sense! It is like comparing apples to oranges!

You MUST select equipment at the expected inlet temperature your equipment will be operating at, Why?  
Answer: The higher the inlet temperature, the more capacity the unit will have in cooling due to the greater Delta T between refrigerant and air.

Select equipment based on design:  
- Entering Air Temperature DB°F / WB ºF  
- Design Fluid Temperature ºF  
- Design Flow Rate (GPM)
Multistage Equipment vs Single Stage

What uses less energy? Multi-stage equipment or Single-stage Equipment?

It Depends!

Unless you lower the fluid flow rate and fan speed during single stage operation you will actually use more energy due to pump operation!
Vertical U-tube Fundamentals & Applications

Warning Tape With Metallic Tracer

Minimum Horizontal Bury Depth 4 Ft

To Building

Minimum 20 Ft Separation Between Center Line Of Each Bore Hole (Typ.)

Grout Entire Annular Space And Vertical U-tube With Thermally Enhanced Bentonite Grout.

Typical Vertical U-tube 1” Diameter

Typical Bore Depth 200-500 Ft

Finished Grade

Minimum Vertical U-tube Diameter = 1 inch
Grout Type
Grout Thermal Conductivity

SAMPLE PROBLEM

ASSUMPTIONS:
COOLING LOAD = 120 MBH
HEATING LOAD = 120 MBH
GROUND THERMAL CONDUCTIVITY = 1.0 BTU/HR-FT-OF
THERMAL DIFFUSIVITY=0.80 FT²/DAY

STANDARD GROUT = 0.55 BTU/HR-FT-OF
2,770 FEET OF PIPING REQUIRED

THERMALLY ENHANCED GROUT=1.0 BTUH/HR-FT-OF
2,370 FEET OF PIPING REQUIRED
(15% REDUCTION)

THERMALLY ENHANCED GROUT=1.3 BTUH/HR-FT-OF
2,260 FEET OF PIPING REQUIRED
(18.5% REDUCTION)
REYNOLDS NUMBER

\[ R_e = \frac{\vec{V} \times D}{\nu} \]

Where: \( R_e \) = Reynold's Number (no dimension)
\[ \vec{V} = \text{Velocity of Flow (Ft/sec)} = \frac{q(\text{gpm})}{d^2} \times 0.4085 \]
\( D = \text{Inside Diameter of Pipe (feet)} \)
\( \nu = \text{Kinematic Viscosity [Ft}^2/\text{sec]} \)

GPM REQUIRED TO AVOID LAMINAR FLOW
(LAMINAR FLOW = REYNOLDS # < 2000
TRANSITIONAL FLOW = 2000 < REYNOLDS # < 4000
TURBULENT FLOW = REYNOLDS # > 4000)

<table>
<thead>
<tr>
<th>FLUID TYPE</th>
<th>70°F FLUID TEMPERATURE</th>
<th>40°F FLUID TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>¾”  1”  1-1/4”</td>
<td>¾”  1”  1-1/4”</td>
</tr>
<tr>
<td>Water</td>
<td>1.1  1.4  1.7</td>
<td>1.7  2.1  2.7</td>
</tr>
<tr>
<td>30% Propylene</td>
<td>3.1  3.9  5</td>
<td>6.1  7.6  9.6</td>
</tr>
</tbody>
</table>
GEOTHERMAL VAULTS

Key Components:
- Lighting
- Light colored surface on the inside (for concrete)
- Grating at the floor
- HDPE vs. Concrete
- Tracer lines
Excellent use of waste energy…. But,

Verify, that the unit will produce enough hot gas re-heat to achieve neutral air when the geothermal water temperature is cold such as the spring time.
What is the Most Efficient Pump?

You must verify during unoccupied modes, weekends, and nighttime that pumps that are supposed to be “off” are in fact “off”.

The Pump that is “OFF”!

<table>
<thead>
<tr>
<th>Outside Air Temperature (°F)</th>
<th>Variable Night Set Back Temperature</th>
<th>Space Night Set Back Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50°F</td>
<td>40°F</td>
<td></td>
</tr>
<tr>
<td>10°F</td>
<td>65°F</td>
<td></td>
</tr>
</tbody>
</table>
Future Additions

- If you have a project with provision for future additions, physically verify that the bypass valve at the end of corridors is actually closed once the flow has been verified!
Pipe Pressure Loss

- Dimensional ratio or SDR
- Make sure if the horizontal mains are supposed to be SDR-13.5 that they are!

Why is this important??
Pipe Friction & Pump Energy

<table>
<thead>
<tr>
<th>PUMP POWER (HP/100TONS)</th>
<th>GRADE (PER KAVANAUGH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 OR LESS</td>
<td>A-EXCELLENT</td>
</tr>
<tr>
<td>5 TO 7.5</td>
<td>B-GOOD</td>
</tr>
<tr>
<td>7.5 TO 10</td>
<td>C-MEDIocre</td>
</tr>
<tr>
<td>10 TO 15</td>
<td>D-POOR</td>
</tr>
<tr>
<td>GREATER THAN 15</td>
<td>F-BAD</td>
</tr>
</tbody>
</table>

SDR-13.5
Less Wall Thickness

SDR-11
Thicker Wall Pipe
Large System Pumps

- For very large projects operate pumps in parallel and use water to wire efficiency to stage pumps.

- On Dover High School in Dover, Delaware the installed pump sizes went from 150 hp each to 60 hp each.

\[
\text{WWE}\% = \frac{\text{Water horsepower (Whp)} \times 0.746 \times 100}{\text{Kw}}
\]

Where \( \text{Whp} = \frac{\text{gpm} \times \text{total head}}{53.08 \times \text{Kw}} \)
## VARIOUS HEAT TRANSFER FLUIDS

<table>
<thead>
<tr>
<th>Antifreeze Fluid Type</th>
<th>K - Factor</th>
<th>Comments</th>
<th>Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>500</td>
<td>Ideal viscosity &amp; heat transfer characteristics</td>
<td>• None</td>
</tr>
</tbody>
</table>
| Alcohol Based         | 500        | Good viscosity & heat transfer characteristics | • Very flammable,  
• Do not use in any coils located within airstream |
| Propylene Glycol      | 470        | Poor viscosity & poor heat transfer characteristics | • Will require replacement in 8 to 10 years  
• Very expensive  
• Low concentrations (<25%) can result in water treatment issues |
| Ethylene Glycol       | 455        | Poor viscosity & poor heat transfer characteristics | • Will require replacement in 8 to 10 years  
• Very expensive  
• Low concentrations (<25%) can result in water treatment issues  
• Toxic |

ONLY UTILIZE WHEN ABSOLUTELY NECESSARY
Geothermal Fluid
Antifreeze Concentration

- Must check with a refractometer, if glycol based.
- Must check with independent lab if alcohol based.
Heat Pumps Alarms

Condensate Over Flow Switches

Filter Dp Switches

Test them Both!
75% of these components on projects we commission do not operate!
Heat Pumps Pressure Drops

\[ \Delta P = \text{Inlet Pressure} - \text{Outlet Pressure} \] (Must correct for gauge elevations)

- Do not Just Rely on Auto Flow Valves for Flow Measurement
- Compare field pressure drop across heat exchangers versus manufacturer’s data
System Flushing/Strainers

Strainers should be pulled at project completion and once again at 6 months/year after project completion.

We find plastic pipe shavings, potato chip bags, sludge, and joint material in strainers.
Variable Speed Pumps

**Triple Duty Valve**

- Never install triple duty valves on variable speed pumps! Why??

**Variable Speed Pump**

- Use the drive to prevent excess flow not a triple duty valve
Autoflow Valves & Variable Frequency Drives

Use VFD to Reduce Resistance of Most Demanding Auto Flow Valve
Building Voltage

- Voltages above 500 volts are too high and should be dropped at the building transformer taps.

- Excess or high voltage tends to push the magnetic portion of motors into saturation. This causes the motor to draw excessive current in an effort to magnetize the iron in the motor.

High Voltage Causes:
- Increase in starting amps.
- Increase in full load amps.
- Increase in starting and maximum torque.
- Decrease in efficiency.
- Decrease in power factor.
Factory/Field Insulation

- All of the heat exchangers, piping, and valves within a heat pump must be insulated to prevent condensation.

- This is really important where water to water units are stacked!
Flush Purging

- Indicate purge values on each circuit
- Design for no more than 10 boreholes per circuit
- Indicate main purge valves
- Minimum velocity during purging per IGSHPA = 2 feet / second

4 feet /second is better!
And consider independent flushing/purging

Balance Valve: Select based on flow rate not pipe size!

¾” Circuit Purge/Drain Valve

Supply Header
What Should be Commissioned?

Everything! 100%!

- Pumps
- Ground Loop System
- Fans
- Flow Measuring Stations
- Sensors
- Water to Air Heat Pumps
- Where Applicable, Hot Gas Re-heat Coils
- Pump Variable Frequency Drives
Excellent Resources for Geothermal Design & Construction:

Dr. Steve Kavanaugh

The Well Drillers
Questions & Answers