DESIGNING GROUND-LOOP HEAT EXCHANGERS FOR COMMERCIAL HVAC SYSTEMS

Presenter: Bruce E. Beddow, PE, CEM, GBD

B2E Consulting Engineers, PC

Bruce E. Beddow, PE, CEM, GBD, a graduate of Virginia Tech has over 30 years of experience as a professional Mechanical Engineer. He has worked as a mechanical design engineer and energy consultant in the U.S.A., Germany and Switzerland. He has extensive practical experience in new construction, renovation and retrofit projects for sustainable energy efficient buildings. Mr. Beddow has managed the design and administered the construction of more than 500 million dollars in MEP construction cost over his career.

As Project Director , Mr. Beddow is responsible for the planning, evaluation, design and commissioning of all projects. He developed the **Geo-Solar Heat Pump System** which heats and cools buildings using the sun and earth, maximizing the use of renewable energy. This system combines solar and geothermal technologies to increase energy savings in public and commercial buildings. **B2E** specializes in educational and municipal building types. Most of his building designs since 2001 are LEED Silver or LEED Gold.

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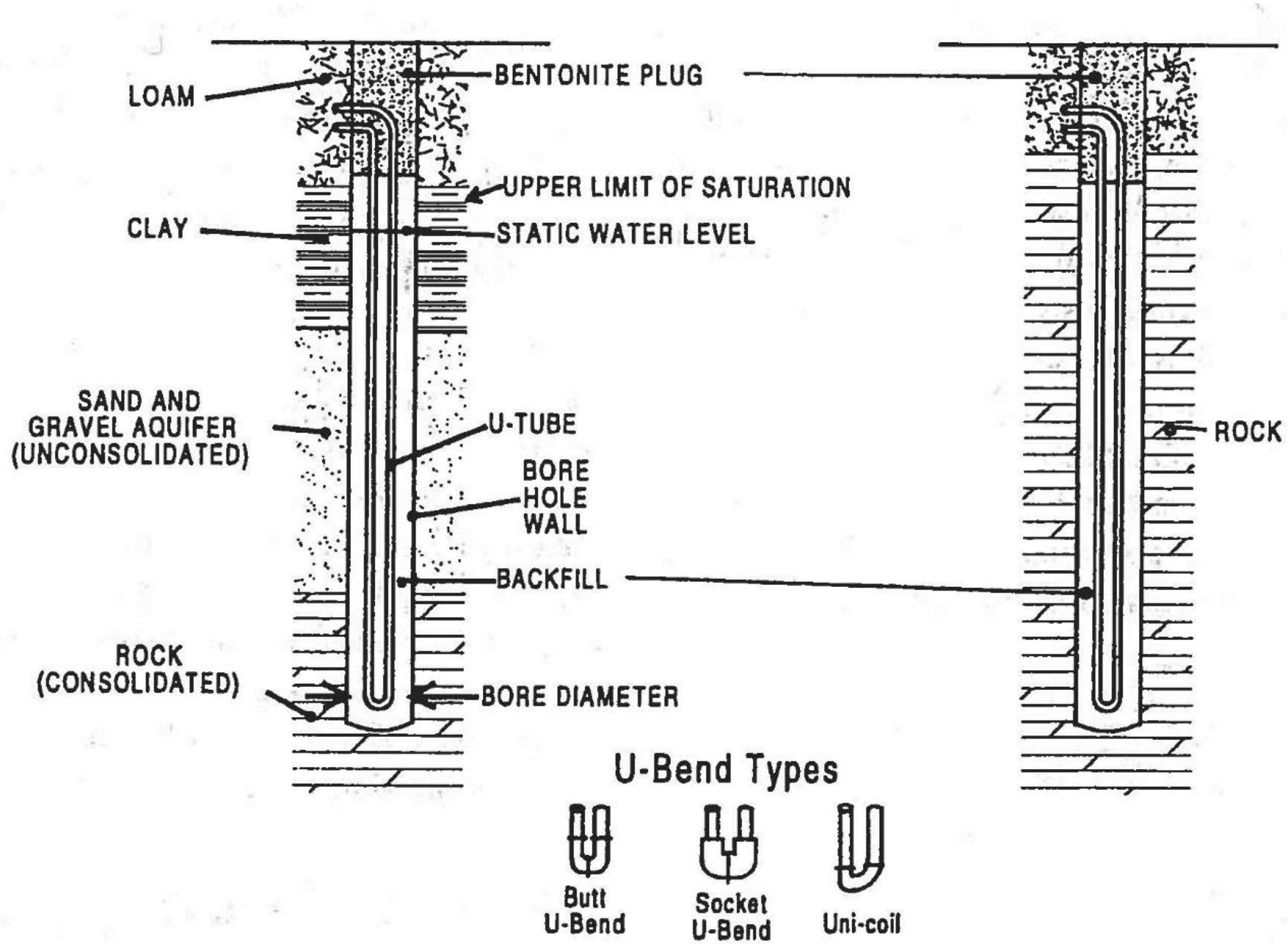

Typical U-tube installations for unconsolidated and consolidated formations.

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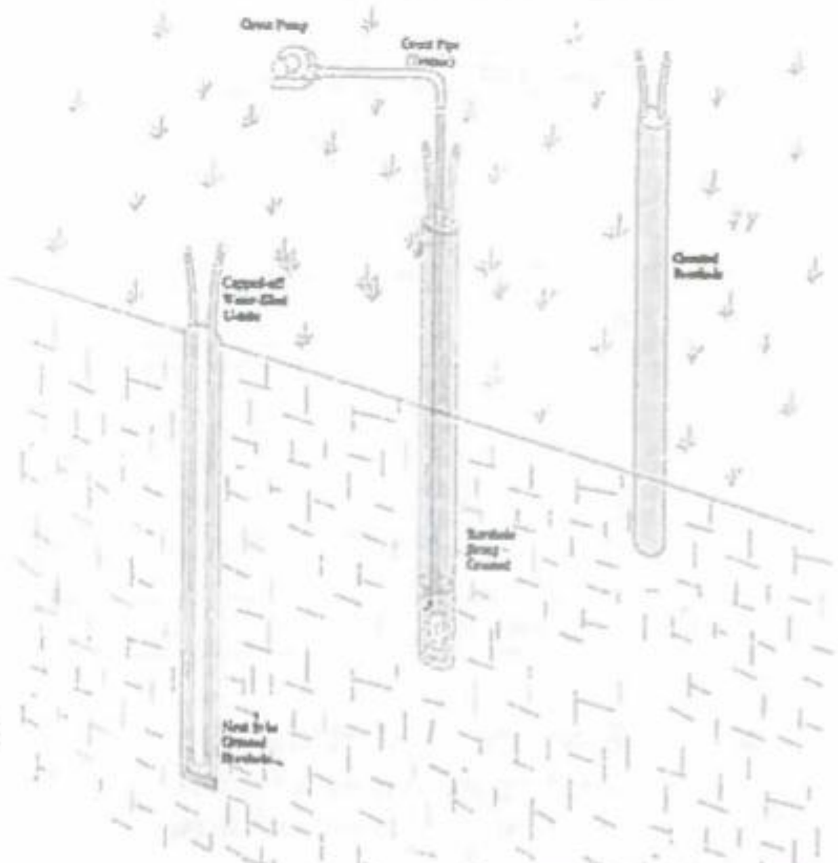
1.0 – GROUND LOOP HEAT EXCHANGERS (GLHX) (CON'T)

A. BACKGROUND – CLOSED LOOP SYSTEMS

- Design complicated by variety of geological formations and properties that affect thermal performance.
- Identification of materials, moisture content and water movement is an involved process.
- Thermal conductivity tests are performed for larger systems to document the formation and restivity of the soil.
- Rock depth is noted to help determine probable GL HX cost.
- Define if and how much steel (or PVC) casing may be required.
- When the boreholes are concentrated in close proximity the affect of cooling dominant or heating dominant building loads becomes more important.
- The affect of building load (heating or cooling) must be simulated to determine the long term affect on the ground temperature.
- Detailed energy modeling and simulations must be performed to determine the correct size of the ground-loop HX (# boreholes, pipe diameter, pipe length).

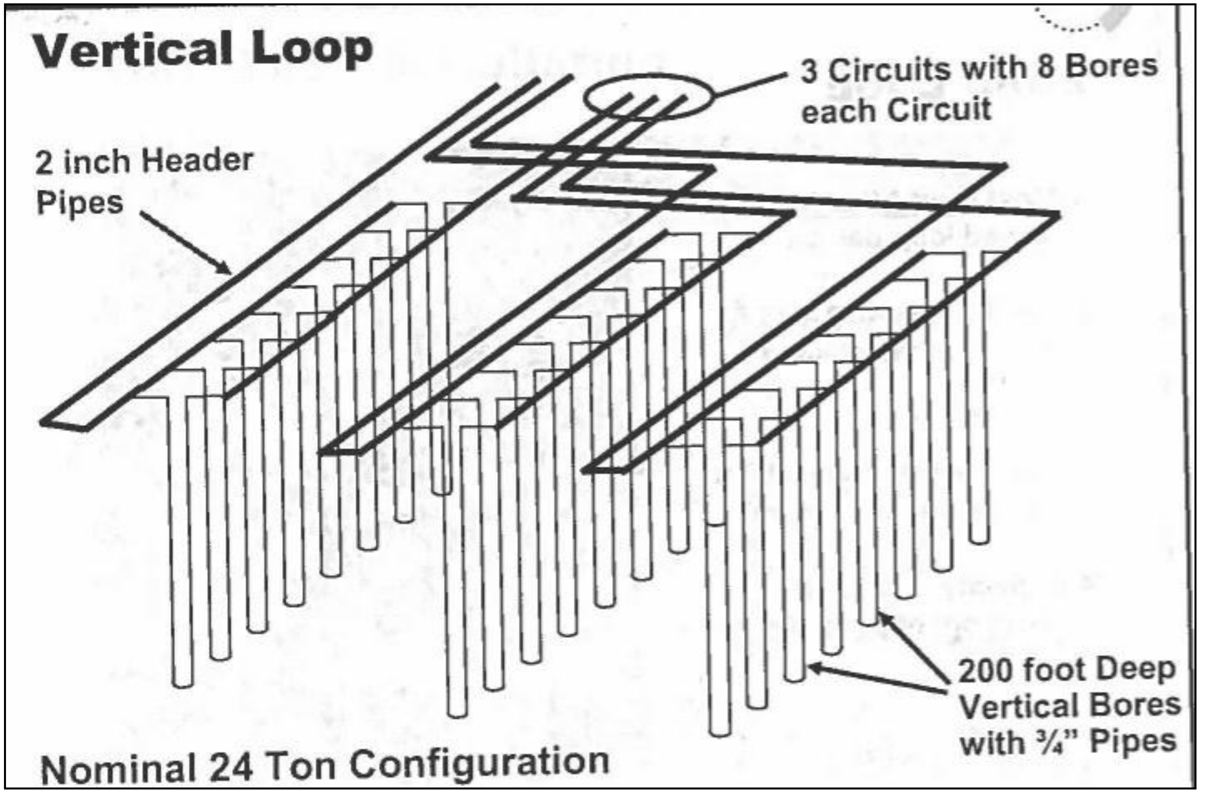
Vertical Bore Grouting

- Grouting of Vertical Bore Holes Required
  - Seal Borehole to Protect Underground Aquifers
  - Maintain Thermal contact between pipe and ground
  - Allow movement of pipe
- Grout Types
  - Bentonite Based
  - Thermally Enhanced
  - Cement Based
- Pressure Grouting from the bottom up recommended



Courtesy ASHRAE GSHP Engineering Manual

1.0 – GROUND LOOP HEAT EXCHANGERS (GLHX) (con't)



- Typical GLHX Piping From Buildings Using 2" Header
- Header to Branch Main Circuits Using Reverse Returns
- Branch Main Circuits to Borehole Using ¾" Vertical V-Bends
- Larger Systems Use 2 ½" or 3" Headers

1.0 – GROUND LOOP HEAT EXCHANGERS (GLHX) (con't)

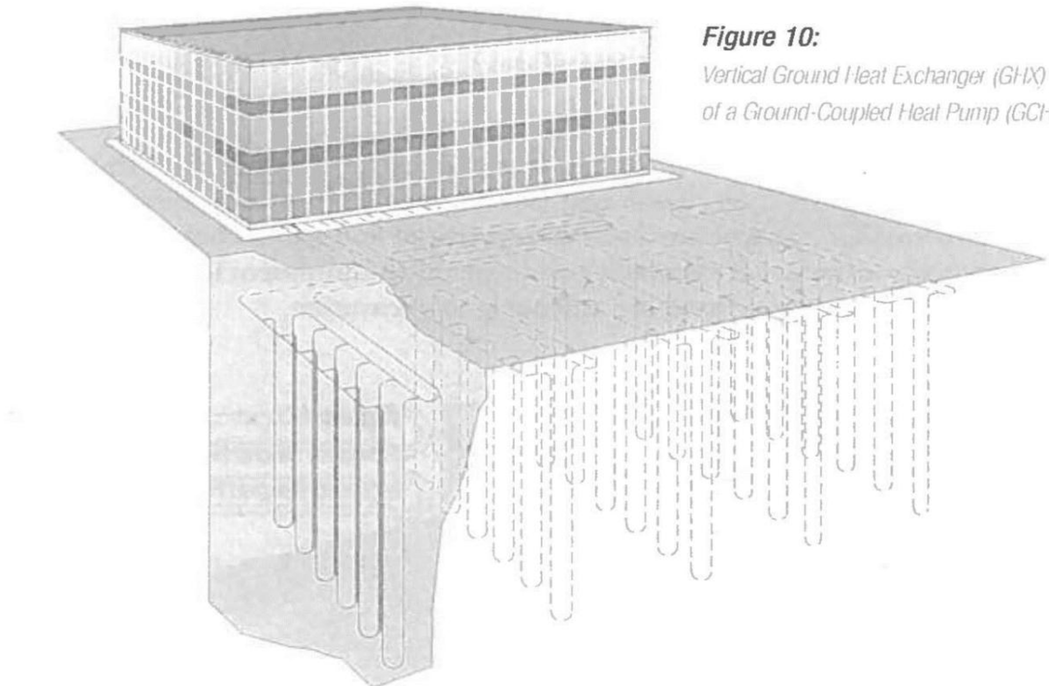


Figure 10:
Vertical Ground Heat Exchanger (GHX) of a Ground-Coupled Heat Pump (GCHP) System.

- **Vertical Boreholes Result in More Efficient Heat Pump Systems Than Horizontal**
- **Vertical Boreholes Require Less Overall Pipe Length Than Horizontal**
- **Vertical Boreholes Are More Suitable For Larger Buildings With Less Area Required**
- **Parking Lots or Ball Fields Make Good Locations Using Vertical Boreholes**
- **Use Areas That Are Typically Graded Relatively Flat**
- **Locate Where No New Construction Will Be Added For Roughly 50-Years**

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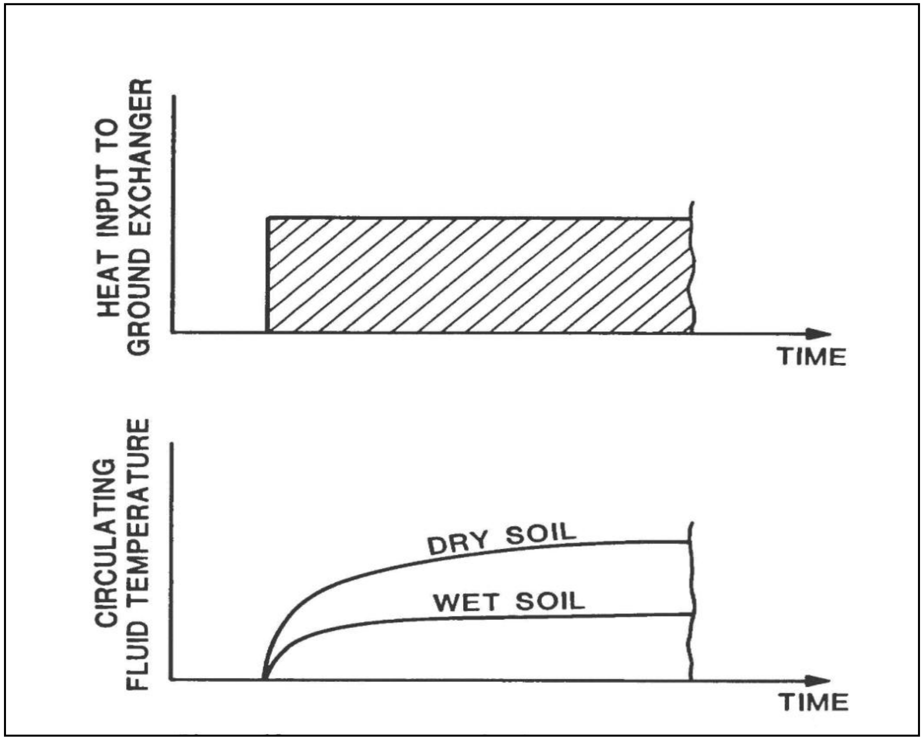
2.0 – CALCULATION METHODS



- **Heat From Building Rejected By GLHX Into Earth (Massive Thermal Storage**
- **Warm Fluid Flowing into a GLXH Cooling Down (cooling dominant)**
- **Thermal Storage Temperature Increases Over Time**
- **Circulating Fluid Temperature Increases Over Time**

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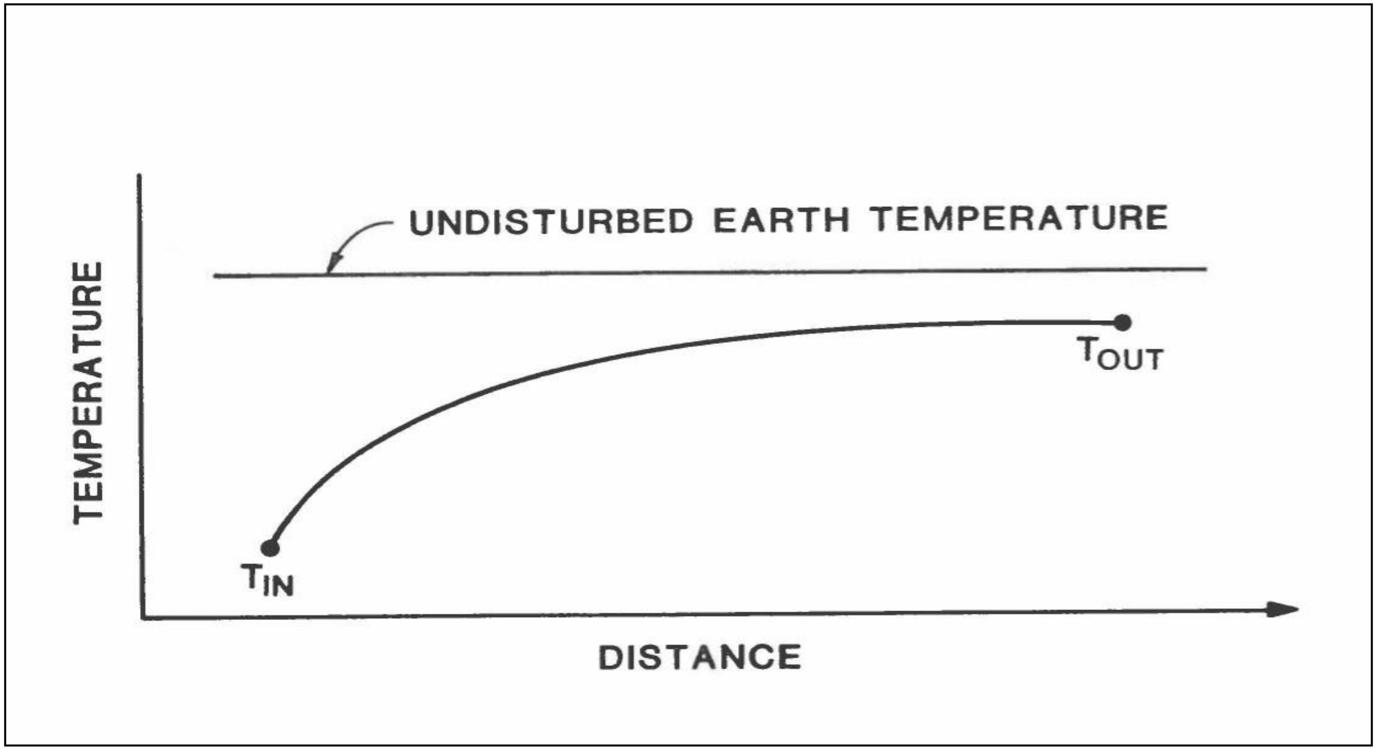
2.0 – CALCULATION METHODS (CON'T)



- GLHX Hybrid Systems Sized For Heating Loads Will Need to Provide Heating at Design Conditions
- Circulating Fluid Temperature Change as Flows through GLHX
- Cold Fluid Flowing into a GLHX Heating up (heating mode)
- Cannot Heat Fluid Higher Than Earth Massive Thermal Storage Temperature

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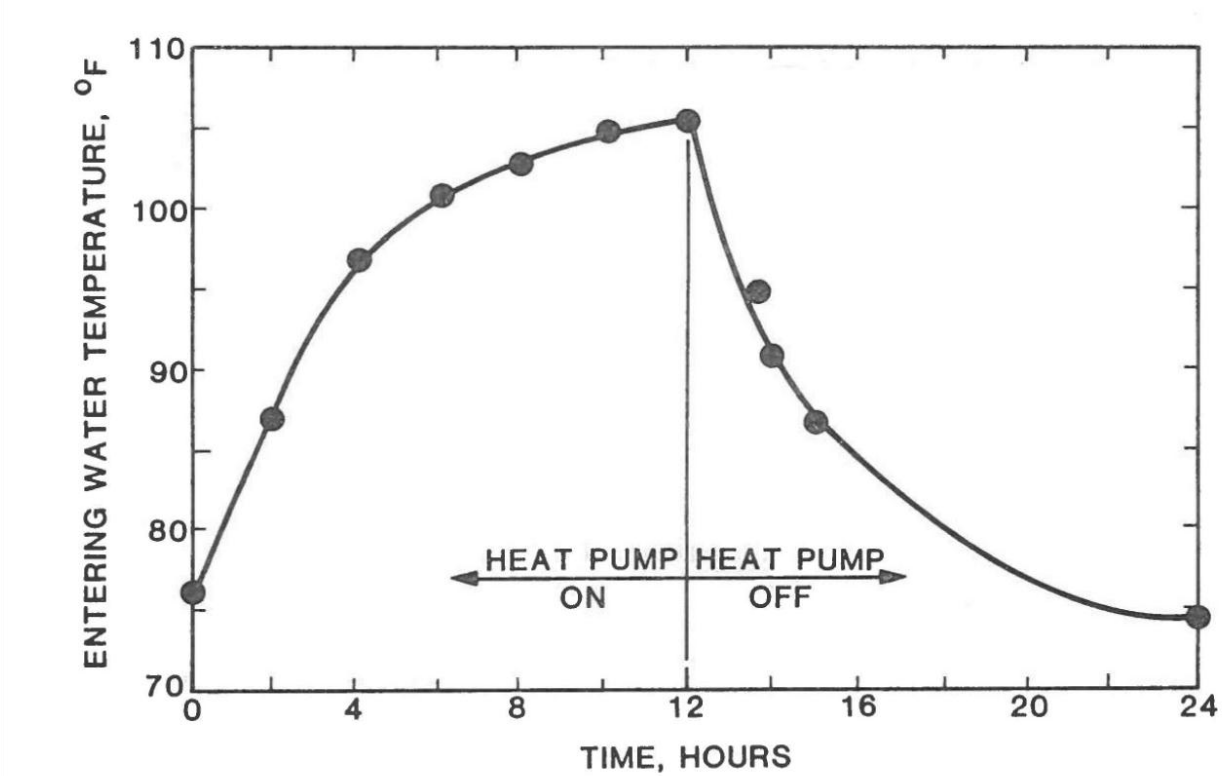
2.0 – CALCULATION METHODS (CON'T)



- Cooling Dominant: Circulating Fluid Temperature Entering the GLHX Over Typical Day
- Cooling Mode: Fluid Temperature Leaving System Rises throughout Day
- Night Setback Mode: Fluid Temperature Leaving System Declines Overtime

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2.0 – CALCULATION METHODS (CON'T)

A. SIMPLIFIED CALCULATION METHOD

This method considers a steady state heat transfer equation

$$q = L\,(t_g - t_w)\,/\,R$$

where,

q = rate of heat transfer for the heat exchanger length (BTU/hr)
L = length of heat exchanger (bare length) (ft)
t_g = temperature of the ground (°F)
t_w = average temperature of the fluid in the pipes (°F/BTU)
R = thermal resistance of the ground (h · ft · ° F/BTU)

- **This calculation method can be performed on a simple spreadsheet**
- **It is useful for quick estimating for preliminary field sizing**
- **Only need reasonably good calculation of peak heating and cooling loads**
- **Does <u>not</u> predict eventual GLHX thermal storage temperature over time**
- **Is helpful to develop preliminary construction cost budgets**
- **Should <u>not</u> be used for final system sizing.**

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2.0 – CALCULATION METHODS (CON'T)

Table 3.1
Equivalent Diameters and Thermal Resistances (R_b) for Polyethylene U-tubes*

U-tube Dia. (Eqv. Dia.)	SDR or Schedule	Pipe (Bore) Thermal Resistance (h·ft·°F/Btu)			
		For Water Flows above 2.0 gpm	20% Prop. Glycol Flow 3.0 gpm	20% Prop. Glycol Flow 5.0 gpm	20% Prop. Glycol Flow 10.0 gpm
¾ in. (0.15 ft)	SDR 11	0.09	0.12	NR	NR
	SDR 9	0.11	0.15	NR	NR
	Sch 40	0.10	0.14	NR	NR
1.0 in. (0.18 ft)	SDR 11	0.09	0.14	0.10	NR
	SDR 9	0.11	0.16	0.12	NR
	Sch 40	0.10	0.15	0.11	NR
1¼ in. (0.22 ft)	SDR 11	0.09	0.15	0.12	0.09
	SDR 9	0.11	0.17	0.15	0.11
	Sch 40	0.09	0.15	0.12	0.09
1½ in. (0.25 ft)	SDR 11	0.09[1]	0.16	0.15	0.09
	SDR 9	0.11[1]	0.18	0.17	0.11
	Sch 40	0.08[1]	0.14	0.14	0.08

*Based on using borehole cuttings for backfilling around U-tube. Use Table 3.2 corrections for other conditions

[1]Water flow must be at least 3.0 gpm to avoid laminar flow for these cases.

- Thermal resistances for HDPE tubing
- Avoid laminar flow for size of pipe used
- Values used in GLHX sizing calculations

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2.0 – CALCULATION METHODS (CON'T)

Table 3.2
Thermal Resistance Adjustments for Other Borehole Backfills or Grouts
(Add Values to Base Resistances in Table 3.1)

Natural Soil Cond.	0.9 Btu/h·ft·°F		1.3 Btu/h·ft·°F			1.7 Btu/h·ft·°F	
Backfill or Grout Conductivity	0.5 Btu/ h·ft·°F	2.0 Btu/ h·ft·°F	0.5 Btu/ h·ft·°F	1.0 Btu/ h·ft·°F	2.0 Btu/ h·ft·°F	0.5 Btu/ h·ft·°F	1.0 Btu/ h·ft·°F
4 in. bore ¾ in. U-tube 1 in. U-tube	 0.11 (NR) 0.07	 –0.05 –0.03	 0.14 (NR) 0.09	 0.03 0.02	 –0.02 –0.02	 0.17 (NR) 0.13 (NR)	 0.05 0.04
5 in. bore ¾ in. U-tube 1 in. U-tube 1¼ in. U-tube	 0.14 (NR) 0.11 (NR) 0.06	 –0.06 –0.04 –0.03	 0.18(NR) 0.14(NR) 0.09	 0.04 0.03 0.02	 –0.04 –0.02 –0.02	 0.21 (NR) 0.16 (NR) 0.12 (NR)	 0.06 0.05 0.04
6 in. bore ¾ in. U-tube 1 in. U-tube 1¼ in. U-tube 1½ in. U-tube	 0.18(NR) 0.14(NR) 0.09 0.07	 –0.07 –0.06 –0.04 –0.03	 0.21 (NR) 0.17 (NR) 0.12 (NR) 0.09	 0.04 0.03 0.03 0.02	 –0.05 –0.04 –0.02 –0.02	 0.24 (NR) 0.21 (NR) 0.15 (NR) 0.11 (NR)	 0.07 0.06 0.05 0.04

(NR) = Not Recommended → For low thermal conductivity grouts, use small bore.

Air Gaps add 0.2 to 0.4 h·ft·°F/Btu to Bore Resistance.

Note: some adjustments are negative, which indicates a thermal enhancement and a lower net thermal resistance compared to natural backfills.

- Thermal resistance for various grout mix designs
- These values are important and greatly affect the calculations in larger systems
- Sand/Cement grouts have higher conductivity than Cement or Bentonite grouts
- Grout mix typically designed better than soil resistance value

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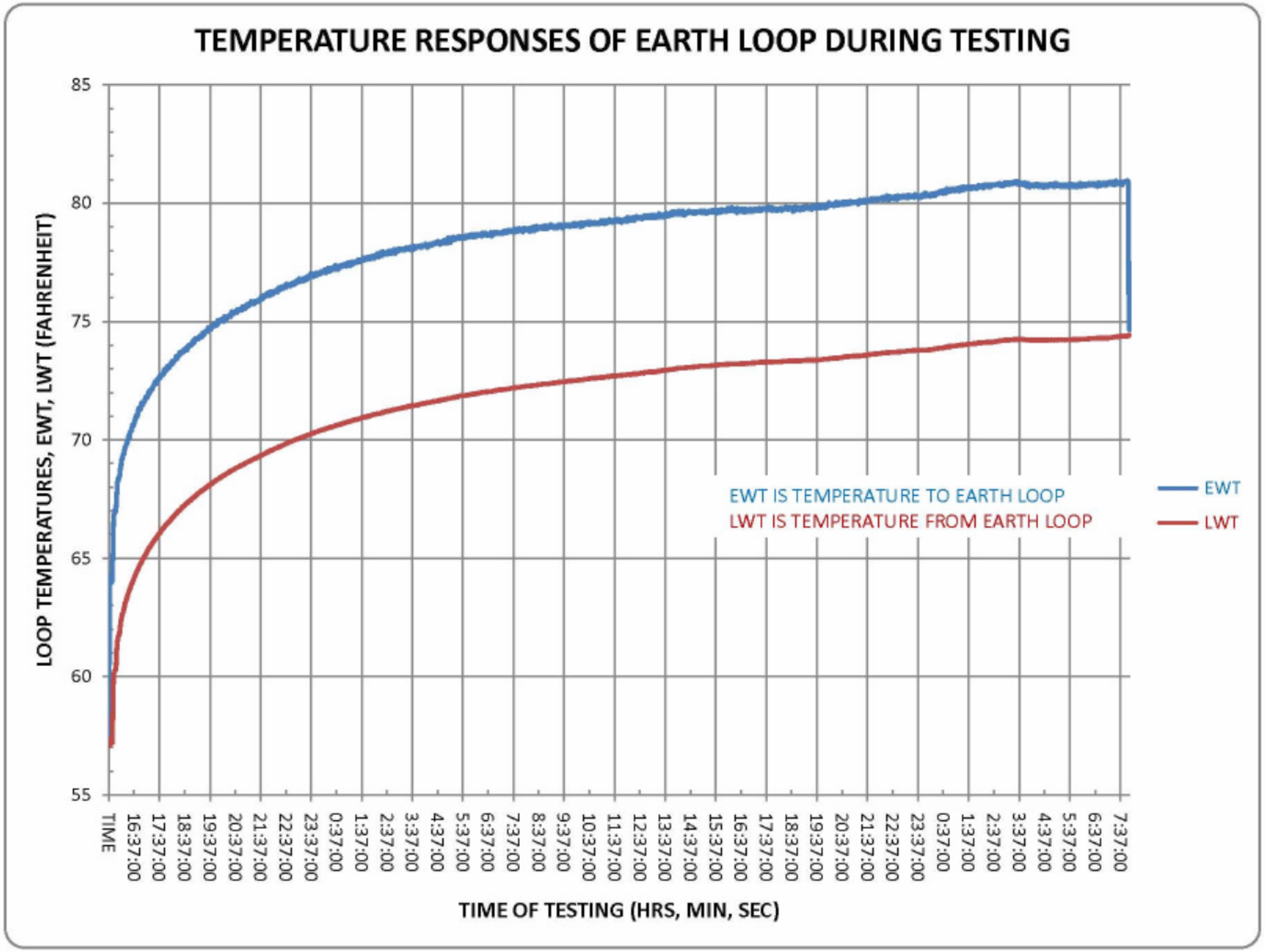
3.0 – COMPUTER SIMULATIONS (CON'T)

AVERAGE CONDUCTIVITY OF BOREHOLE IS 2.3 BTU/hr ft °F



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2.0 – CALCULATION METHODS (CON'T)

Example Spreadsheet for Simplified Calculation Method

CALCULATION THE GEOTHERMAL FIELD

Input
Output

COOLING	HAP VALUE		Heat of REJ		EER
Cooling load	1440	MBH	1,818	MBH	13.0
Total Cooling load	**1,440**	**MBH**	**1,818**	**MBH**	
Formation Thermal Conductivity	1.730	Btu/(h*ft*°F)			(Test-Result from 9/2/2008)
Liquid Temperature differenz at HP (twi-two)	10	°F			
Liquid Temperature differenz at Geothermal (twi-tg)	30	°F			(ASHRAE HVAC 03 / 32.17)
Undistrubed Formation Temperature (Ground Temp.)	60	°F	16	°C	(Test-Result from 9/2/2008)
Liquid Temperature at HP inlet (twi)	90	°F	32	°C	two 100
Liquid Temperature at HP outlet (two)	100	°F	38	°C	twi 90
max. bore length for one borehole	400	ft/hole			tg 60
required bore length for Cooling	**30,026**	**ft**			
required boreholes	**75.1**	**holes**			
diversity factor	80%				
required bore length for Cooling with diversity factor	**24,021**	**ft**			
required boreholes with diversity factor	**60.1**	**holes**			

HEATING	HAP VALUE		Heat of ABS		COP
Heating load	1,355	MBH	1,694	MBH	4.0
Total Heating load	**1,355**	**MBH**	**1,694**	**MBH**	
Formation Thermal Conductivity	1.730	Btu/(h*ft*°F)			(Test-Result from 9/2/2008)
Liquid Temperature differenz at HP (twi-two)	10	°F			(10°F from the DHWST 1)
Liquid Temperature differenz at Geothermal (tg-twi)	15	°F			(ASHRAE HVAC 03 / 32.17)
Undistrubed Formation Temperature (Ground Temp.)	60	°F	16	°C	(Test-Result from 9/2/2008)
Liquid Temperature at HP inlet (twi)	45	°F	7	°C	tg 60
Liquid Temperature at HP outlet (two)	35	°F	2	°C	twi 45
max. bore length for one borehole	400	ft/hole			two 35
required bore length for Heating	**48,952**	**ft**			
required boreholes	**122**	**holes**			
diversity factor	80%				
required bore length for Heating with diversity factor	**39,162**	**ft**			
required boreholes with diversity factor	**98**	**holes**			
elected boreholes	**80**	**holes**			
Power from geothermal field	**1,107**	**MBH**	**324**	**kW**	
Differenz to Total Heating load	**587**	**MBH**	**172**	**kW**	(Power from DHWST)

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C. THE LONG CALCULATION METHOD

This method considers the variable heat note of a ground heat exchanger as a function of load over time.

For Cooling: $L_c = q_a R_{ga} + (q_{1c} - 3.41 W_a)(R_b + PLF_m R_{gm} + R_{gd} F_{su}) / (t_g – (t_{wi} + t_{wo}) / 2 – t_p)$

For Heating: $L_h = q_a R_{ga} + (q_{1h} – 3.41 W_h)(R_b + PLF_m R_{gm} + R_{gd} F_{sc}) / (t_g – (t_{wi} + t_{wo}) / 2 – t_p)$

where,

F_{sc}	-	short circuit heat loss factor
PLF_m	-	part-load factor during design month
q_a	-	net annual average heat transfer to the ground (BTU/hr)
q_{1c}	-	building design cooling block load (BTU/hr)
q_{1h}	-	building design heating block load (BTU/hr)
R_{ga}	-	effective thermal resistance of the ground, annual pulse (h · ft· ºF/BTU)
R_{gd}	-	effective thermal resistance of the ground, daily pulse (h · ft· ºF/BTU)
R_{gm}	-	effective thermal resistance of the ground, monthly pulse (h · ft· ºF/BTU)
R_b	-	thermal resistance of the bore (h · ft· ºF/BTU)
t_g	-	undisturbed ground temperature (ºF)
t_p	-	temperature penalty for interference of adjacent bores (ºF)
t_{wi}	-	liquid temperature at heat pump inlet (ºF)
t_{wo}	-	liquid temperature of heat pump outlet (ºF)
W_c	-	Power input at design cooling load (W)
W_h	-	Power input at design heating load (W)

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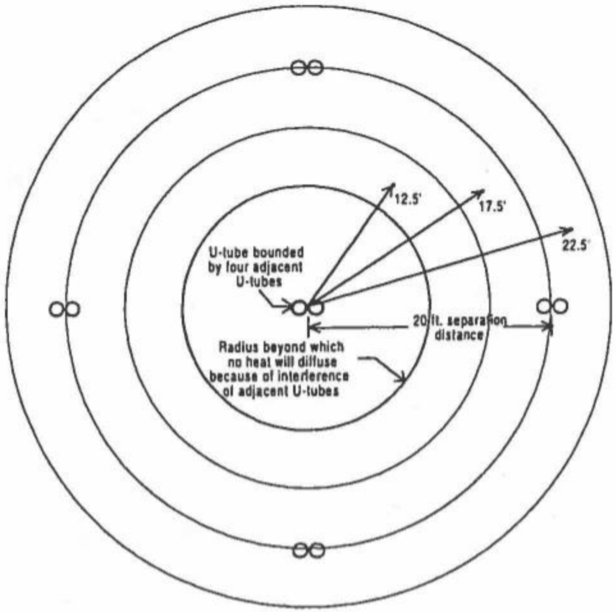
2.0 – CALCULATION METHODS (CON'T)



- Boreholes Spaced in Grid 20-Foot on Center
- Envision a 10-Foot Cylinder Centered on Each Borehole
- Additional Larger Cylinders With 5-Foot Larger Radius Each
- Cylinders Overlap After 10-Foot Radius
- Volume Where Adjacent Cylinders Overlap is Thermally Affected Over Time
- Cooling Dominant Loads Increase GLHX Temperature Over Time
- Heating Dominant Loads Decrease GLHX Temperature Over Time

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2.0 – CALCULATION METHODS (CON'T)

Table 4.1
Long-Term Change in Ground Field Temperature for 10 by 10 Vertical Grid with a 100 Ton Load*

Eqv. Full-Load Hrs. Heating / Cooling	Bore Separation (ft)	Ground Temp. (t_g) & Entering Water Temps. (Htg. & Clg.)					
		t_g = 50°F (EWT = 35/80)		t_g = 60°F (EWT = 45/85)		t_g = 70°F (EWT = 60/95)	
		$k_g = 1.0$	$k_g = 1.5$	$k_g = 1.0$	$k_g = 1.5$	$k_g = 1.0$	$k_g = 1.5$
		Δt_g(ft/ton)	Δt_g(ft/ton)	Δt_g(ft/ton)	Δt_g(ft/ton)	Δt_g(ft/ton)	Δt_g(ft/ton)
1500	15	–4.4°F (318)	–4.4°F (248)	–	–	–	–
500	20	–2.3°F (276)	–2.3°F (216)	–	–	–	–
	25	–1.2°F (258)	–1.2°F (202)	–	–	–	–
1000	10	12.9°F (318)	11.8°F (245)	NR	11.8°F (313)	–	–
1000	15	5.4°F (237)	4.3°F (186)	4.7°F (245)	4.7°F (225)	–	–
	20	3.4°F (220)	1.9°F (172)	2.5°F (263)	2.4°F (206)	–	–
500	15	15.1°F (379)	15.1°F (294)	NR	12.8°F (345)	NR	NR
1500	20	7.8°F (277)	8.0°F (216)	6.7°F (326)	6.7°F (254)	6.7°F (336)	6.7°F (259)
	25	4.1°F (224)	4.3°F (190)	3.5°F (287)	3.5°F (224)	3.5°F (293)	3.5°F (229)
0	15	-	-	NR	NR	NR	NR
2000	20	-	-	10.3°F (406)	10.4°F (316)	10.4°F (414)	10.5°F (322)
	25	-	-	5.4°F (325)	5.5°F (252)	5.4°F (332)	5.5°F (257)

Correction Factors for Other Grid Patterns			
1 x 10 Grid	2 x 10 Grid	5 x 5 Grid	20 x 20 Grid
$C_f = 0.36$	$C_f = 0.45$	$C_f = 0.75$	$C_f = 1.14$

Where $\Delta t_g = C_f \times \Delta t_g$ (10 x 10 Grid)

*$\Delta t_g = -t_p$ in Equations 3.2 and 3.3 worst-case conditions—minimal water movement and percolation.

- Short Method calculation cannot be used to predict future GLXH temperature
- This table is a tool used to estimate future GLHX temperature based on load distribution
- Use long calculation method (computer simulation) to determine affect of cooling or heating dominate loads overtime

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3.0 – COMPUTER SIMULATIONS

STEP 1 : SITE RESTRICTIONS

- ❑ Access suitability of the site and determine preliminary layout for GLHX

STEP 2: THERMAL CONDUCTIVITY TEST BY WELL DRILLER

- ❑ Considers thermal resistance of piping, grout and soil
- ❑ Provides data to better calculate GLHX size and GLHX cost

STEP 3: BUILDING HOURLY LOAD ANALYSIS

- ❑ Considers actual heating and cooling loads over 24-hour period 8,760 hours per year based on owner's operational schedule
- ❑ Considers efficiency of actual heat pumps (by model #)

STEP 4: CLOSED-LOOP HEAT EXCHANGER SOFTWARE

- ❑ Considers the effect of the loads on the ground loop heat exchanger over time. ASHRAE climate zone 4A, cooling dominant.
- ❑ Program sizes ground loop heat exchanger not to exceed design temperature (85ºF) over 20 year or longer time frame

3.0 – COMPUTER SIMULATIONS (CON'T)

GLHX SOFTWARE

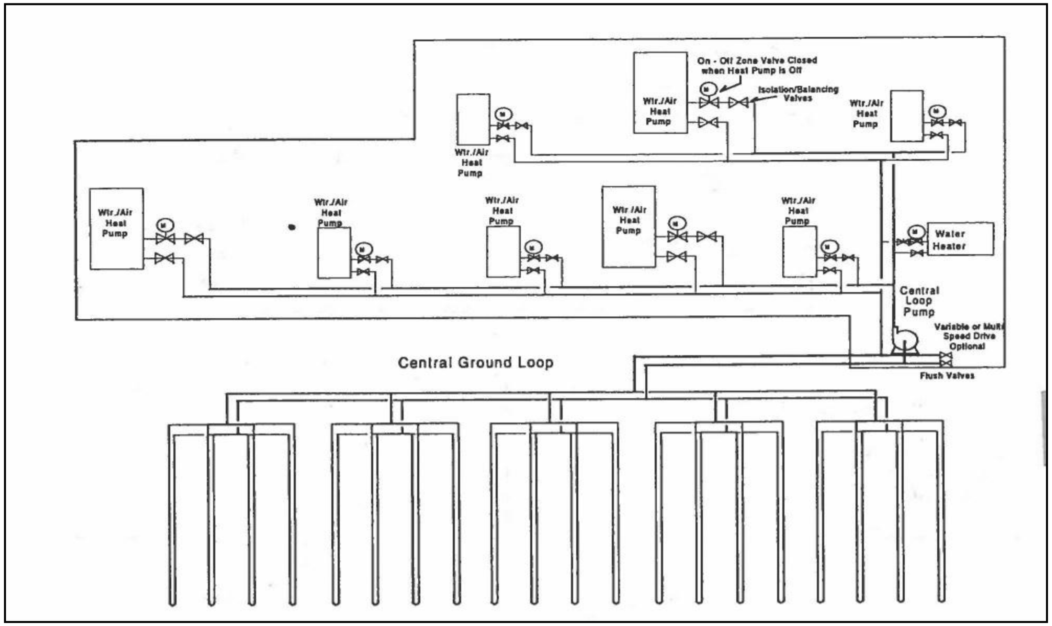
- Geothermal Heat Pump Design Software for Commercial Buildings – "GchpCalc", Steven Kavanaugh, Oklahoma State University
- Program evaluates full GSHP and HYBRID GSHP systems.
- Program allows the use to easily change any input and quickly determine resulting effects on ground coil size and system performance.
- In order to use GLHX software an hourly load analysis is required.
- Use system design load software that calculates loads 8760 hrs per year
- Separate systems should match actual building HVAC design.
- Building envelope thermal performance for walls, windows and roofs must be accurate.
- Ventilation rates and schedules must be accurate.
- Internal occupant and equipment loads and schedules must be accurate.
- Lighting loads and schedules must be accurate.

3.0 – COMPUTER SIMULATIONS (CON'T)

OTHER GLHX SOFTWARE

- International Heat Pump Association: GLHEPRO
- International Heat Pump Association: CLGS (Smaller Systems)
- Wright Associates: LOOP
- Elite Software, Inc.: ECA
- Water Furnace Int'l, Inc.: WFEA
- Kansas Electric Utility: GL Source
- HVACR Programs: GEOCALC

4.0 - PIPING ARRANGEMENTS



- ❑ Ground – Coupled Heat Pump system with a central loop and pumps
- ❑ GLHX Size: Connected cooling load flow rate
- ❑ Pumping: Constant volume through building and GLHX
- ❑ Operation: 24 x 7 in larger buildings
- ❑ Result: Reduction in overall system efficiency by 15% to run pumps (full flow) at night

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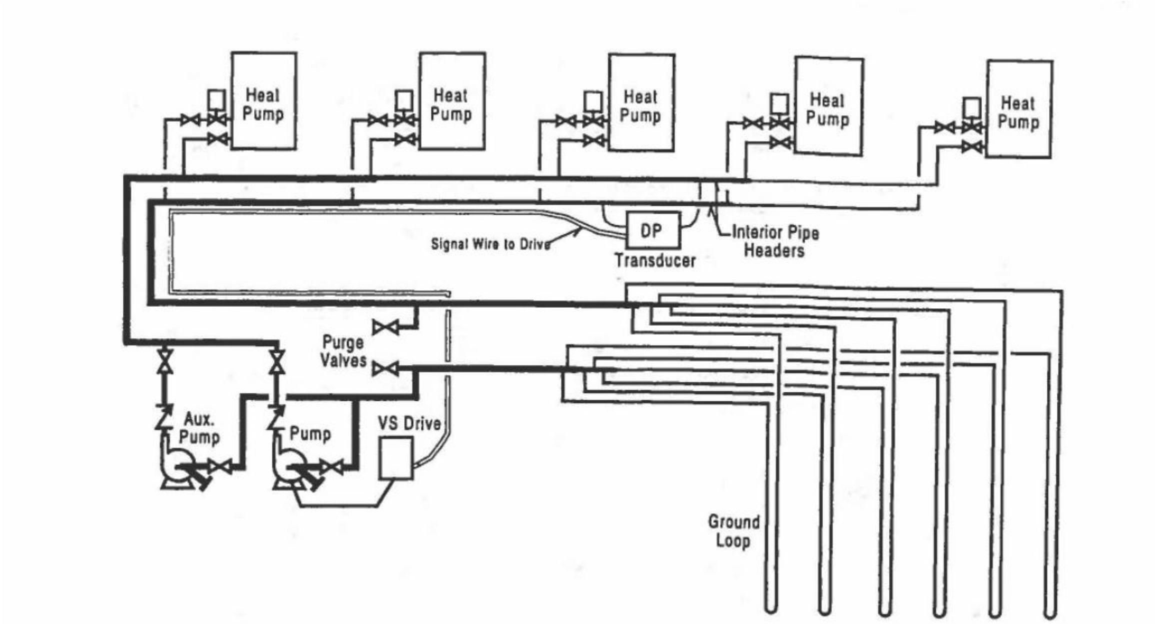
4.0 – PIPING ARRANGEMENTS (CON'T)



- Ground – coupled heat pump system with a central loop and pumps
- GLHX Size: Block cooling load flow rate (up to 30% first cost savings)
- Pumping: Variable speed through building and GLHX
- Pump Flowrate: controlled using pressure transducers and two-way control valves
- Operation: 24/7 in large buildings
- Result (Day): Reduction in pumping energy up to 20% - 30% better than connected load flow rate
- Result (night): No significant reduction in system efficiency to run pumps (low flow) at night

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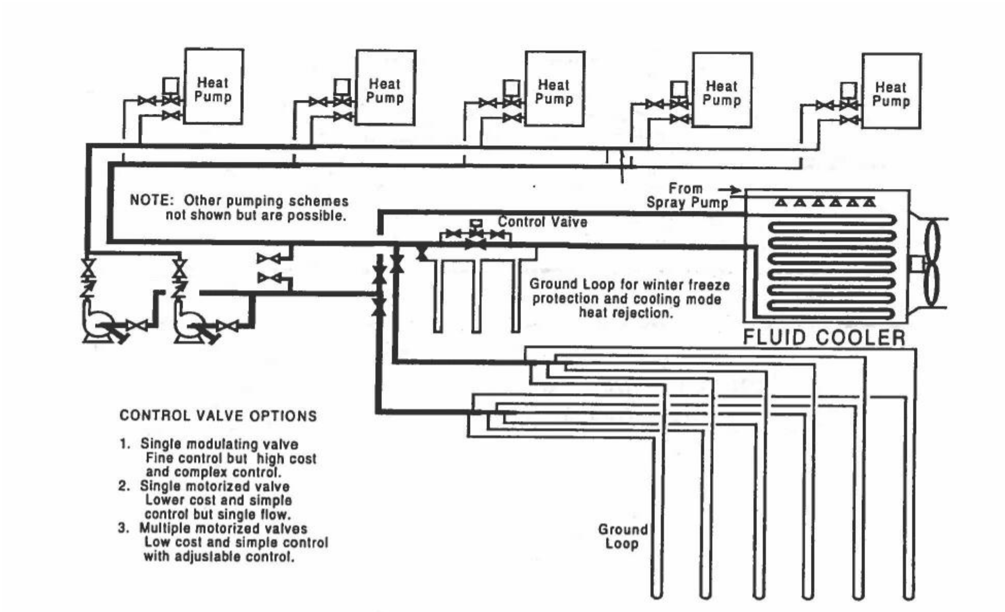
4.0 - PIPING ARRANGEMENTS (CON'T)



- Ground – coupled hybrid heat pump system with a central loop and pumps
- GLHX Size: Connected heating load flow rate (up to 50% first cost savings)
- Pumping: Variable speed thru building and GLHX
- Pump Flow Rate: Controlled using pressure transducers and two-way control valves
- Operation: 24/7 in large buildings
- Result (Day): Reduction in pumping energy up to 25% - 35% better than connected load flow rate
- Result (Night): No significant reduction in system efficiency to run pumps (low flow) at night

4.0 – PIPING ARRANGEMENTS (CON'T)

SUMMARY

Size GLHX for Connected Cooling Load

- ❑ No first cost savings
- ❑ No pump energy savings
- ❑ Loss of system efficiency for running pumps (full flow) at night approx. 15%

Size GLHX for Block Cooling Load

- ❑ Save up to 30% first cost for GLHX (also saves land area)
- ❑ Save 20 to 30% pumping energy
- ❑ No significant reduction in system efficiency to run pumps at night

Size GLHX for Connected Heating Load (Hybrid)

- ❑ Save up to 50% first cost for GLHX (also saves land area)
- ❑ Save 25 – 35% pumping energy
- ❑ No significant reduction in system efficiency to run pumps at night

4.0 - PIPING ARRANGEMENTS (CON'T)

BUILDING SYSTEM

- ❑ Pump to heat pumps – to GLHX – Back to pumps
- ❑ Each heat pump must have flushing valves

VALVE ROOM/HOUSE

- ❑ Neatly organize piping manifolds
- ❑ Keep CWS and CWR piping risers next to one another
- ❑ Keep balancing and shut-off valves easily accessible
- ❑ Make blind flange and valves for flushing pump connections

GLHX PIPING

- ❑ Insulated steel piping above ground
- ❑ Uninsulated HDPE 3608 ASTM D2239 SDR-11 underground
- ❑ Branch mains should be set up with 3" branch main headers
- ❑ Each 3" main should have10 borehold circuits
- ❑ Run reverse return piping for each Branch Main Header

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4.0 - PIPING ARRANGEMENTS (CON'T)

BOREHOLE CONFIGURATION

- KEEP IT SIMPLE – RECTANGULAR WORKS FINE
- SET UP ROWS WITH # CIRCUITS TO MATCH CAPACITY OF BRANCH MAIN SIZE (EXAMPLE)
  - 3" Branch main : 10 – 12 circuits
  - 2 ½ " branch main: 6 – 8 circuits
  - 2" branch main: 3 – 4 circuits
- COORDINATE LAYOUT WITH UNDERGROUND SITE UTILITIES
  - Water/Fire
  - Storm sewer and structures
  - Gas Piping
  - Sanitary sewer and structures
  - Electrical power lines and structures
  - Fiber optic cables and structures
  - Telephone and other service provider cables and structures

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4.0 – PIPING ARRANGEMENTS (CON'T)

<u>HORIZONTAL BRANCH MAINS AND BOREHOLES</u>

- ❑ Coordinate installed piping depth below final grade elevation
- ❑ Horizontal piping should be 4 – 6 feet below grade
- ❑ Show sections of piping below final grade elevation
- ❑ Show trenching, bedding and backfill requirements

<u>LOCATING HORIZONTAL MAINS AND BOREHOLES</u>

- ❑ Horizontal mains: magnetic tape above piping in trenches
- ❑ Boreholes: Satellite GPS coordinate as built map
- ❑ Magnetic disk with memory chip to identify borehole number

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5.0 - FLUSHING AND PURGING

FLUSHING AND PURGING THE GLHX

- **AIR PRESSURE TESTING**:
  - Pressure test with air first
  - Each branch main (with # circuits) should be tested separately
  - Test with compressed air to 1.5 times the system operating pressure but not less than 100 psig for 24 hours
  - If leak is found it will be easier to fix unfilled with water

- **FLUSHING DIRT AND DEBRIS OUT OF PIPING SYSTEM**:
  - Cannot be done with system pumps
  - Much more pressure and flow needed
  - Specify flushing procedure with separate flushing equipment
  - Flush pump connection must be at high point in piping

- **CLEANING THE SYSTEM**:
  - Specify cleaning solution and procedure to remove dirt
  - Allow to sit specified time (but not longer) to clean HDPE piping

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5.0 - FLUSHING AND PURGING (CON'T)

PURGING AIR FROM THE SYSTEM

- Use above ground valve room/house
- Make sure high point in piping has manual air vent
- Run water through pumps (min. 2 fps) until air removed from system

SYSTEM PRESSURE

- Set system fill pressure to maintain minimum design pumping pressure
- Install water meter for auto fill system to monitor for leaks
- Glycol solution usually not needed in ASHRAE Climate Zone 4A

SYSTEM IN OPERATION

- With the system in operation, water is flowing through the GLHX
- Tab contractor must set up flows in each branch main for best performance

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6.0 – BALANCING (PEAK – OPTIMIZED – NIGHT)

GLHX WATER BALANCING

- ❑ Balance each branch main to sum of flows of connected circuits
- ❑ Circuits are piped as reverse return for uniform flow

BUILDING PUMPS BALANCING

- ❑ PEAK: Run system at peak connected load flow rate and measure pump difference pressure and power consumption
- ❑ OPTIMIZED: Adjust balance down to block load flow rate and measure differential pressure and power consumption
- ❑ Check number of units tripping on refrigerant pressure (if any)

NIGHT: UNIT SHUT DOWN, VALVES CLOSE PUMPS SLOW DOWN

- ❑ Have approx. 20% of flow on 3-way valves
- ❑ Balance 3-way valve night mode with balancing valve at coil & bypass
- ❑ Verify Verify 20% flow using one pump at night to maximize energy savings

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7.0 - RULES OF THUMB

A. RULES OF THUMB

- ❑ Vertical Loops: 150 to 200 LF/ton for Connected Cooling Load
- ❑ Vertical Loops: 200 – 300 LF/ton for Block Cooling Load
- ❑ Installed Cost: $14 - $15 per Linear Foot Bore Hole Depth
- ❑ Installed Cost: $10 per Linear Foot PVC Casing Depth
- ❑ Minimum Thermal Conductivity Soil (Dry Sand): 0.5 BTU/Hr. Ft. °F
- ❑ Maximum Thermal Conductivity Soil (Rock/Clay): 2.0 BTU/Hr. Ft. °F
- ❑ Minimum Fluid Flow Rate (Water): 2.0 gpm/ton (block cooling load)
- ❑ Maximum Fluid Flow Rate (Water): 3.0 gpm/ton (connected cooling load)
- ❑ Noise from Drill Rigs (Single Muffler): 95 dbA at 10-feet
- ❑ Noise from Drill Rigs (Dual Muffler): 85 dbA at 10-feet (add 2% for diesel surcharge)

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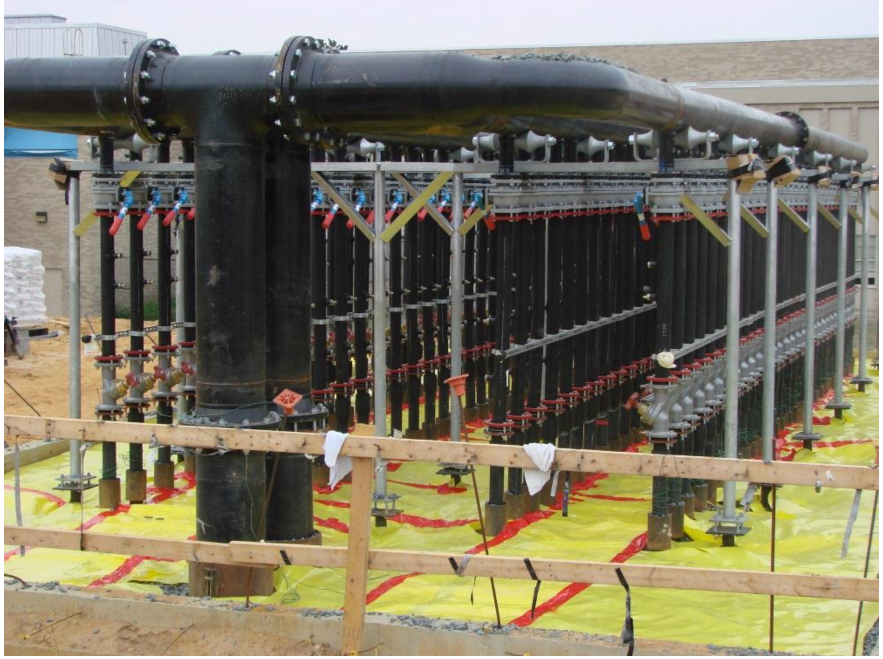

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THANK YOU FOR LISTENING

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