Alaska Geothermal LLC
Geothermal Heat Pumps

Alternatives for Heating, Cooling & Domestic Hot Water Production

Short Video

Santa Monica Mountains Recreation Area Intern Center

"Geothermal"? – Two Types

- Active geothermal = anything greater than 100 Degrees F
- Passive geothermal OR Heat Pump geothermal = anything less than 100 Degrees F.
  - Also called "Ground Source" heat pumps.

Why a Geothermal Heat Pump?

- Lower operating costs -- reduces energy consumption 30-50%
- Payback period of 3 to 12 years with current tax credit depending on new vs retrofit
- Better aesthetics -- no stack, no make-up air
- Can cover heating and cooling with one system
- Long life, low maintenance
- Safe -- no combustion, no fumes
- No ambient emissions
- Renewable and green technology

Status in the Interior

- About 60 systems currently in the interior
- 6 commercial / industrial systems and 54 residential. 90% is hydronic. 10% is forced air.
- Alaska Geothermal has done 52 systems all handling 100% of building’s space heating
- AK Geothermal has had no system failures and no major problems!!

Outlook for Geothermal in FRBKS

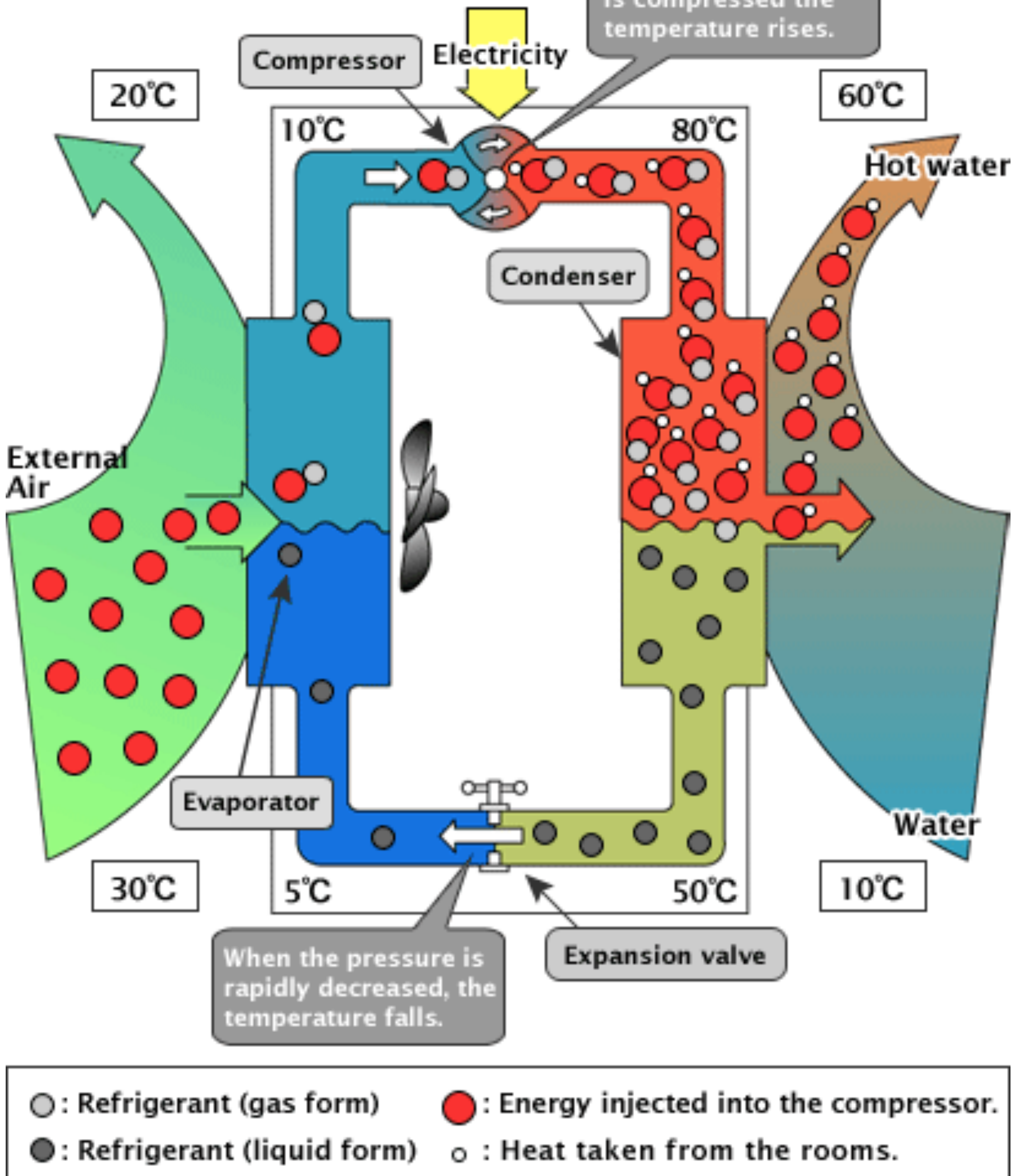
- Outlook is good! Progressively more systems each year.
- 12 systems in 2014
- Largest systems in 2014 and 2015
- More systems on the schedule for 2015 than this time in 2014

What is a Geothermal Heat Pump?

- Three components:
  - Heat pump unit
  - Ground loop heat exchanger
  - Heat distribution system


ECONAR
by GeoSystems

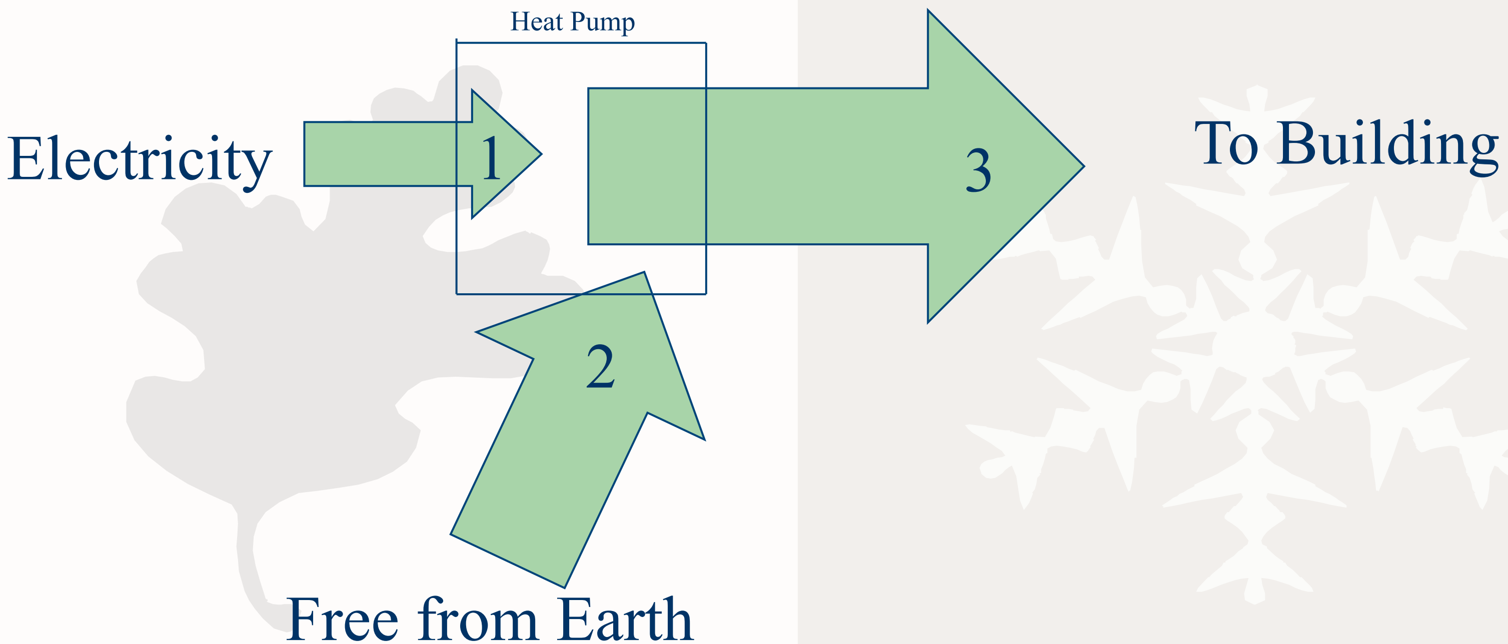
Hot-water supply



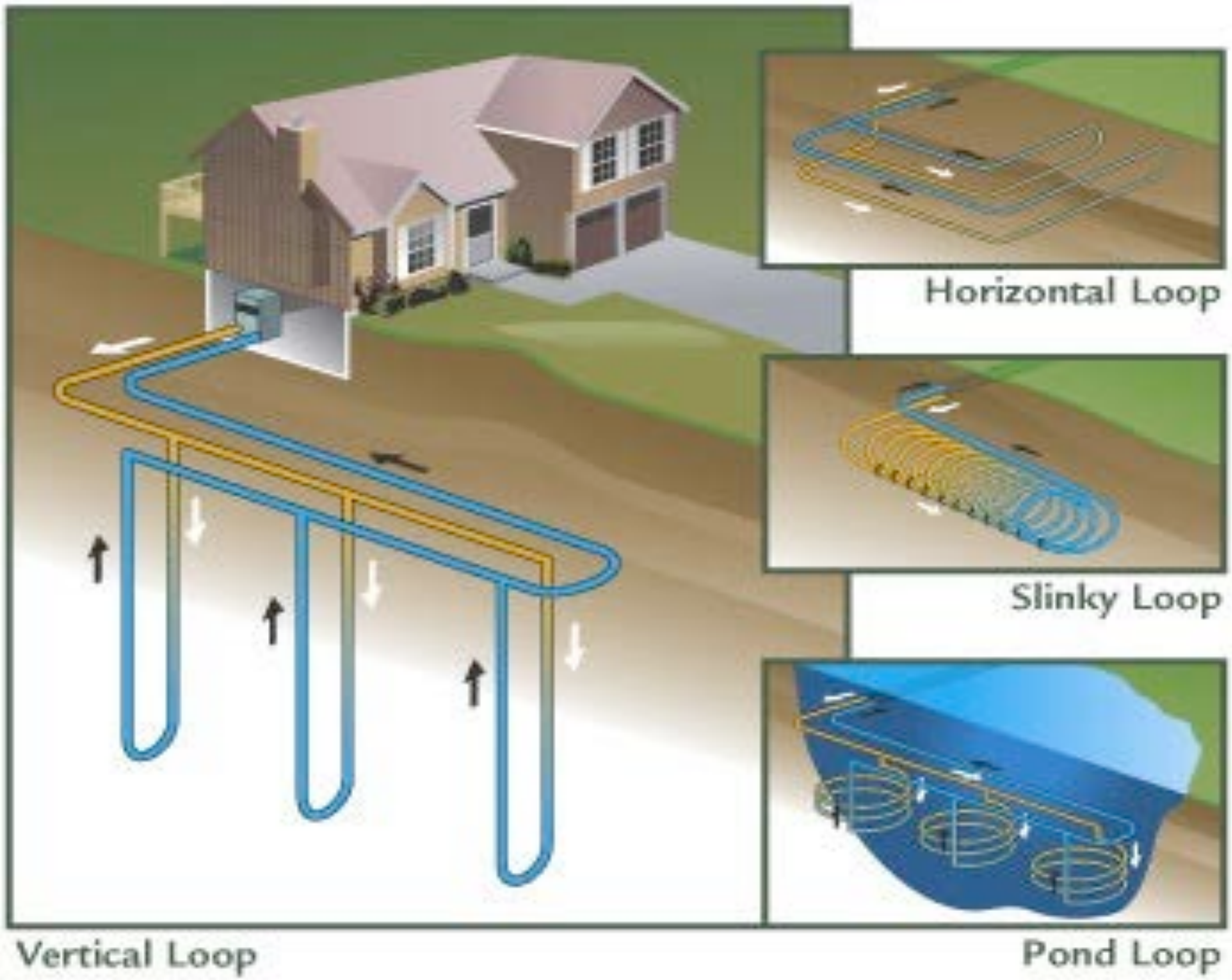
Coefficient of Performance - C.O.P.

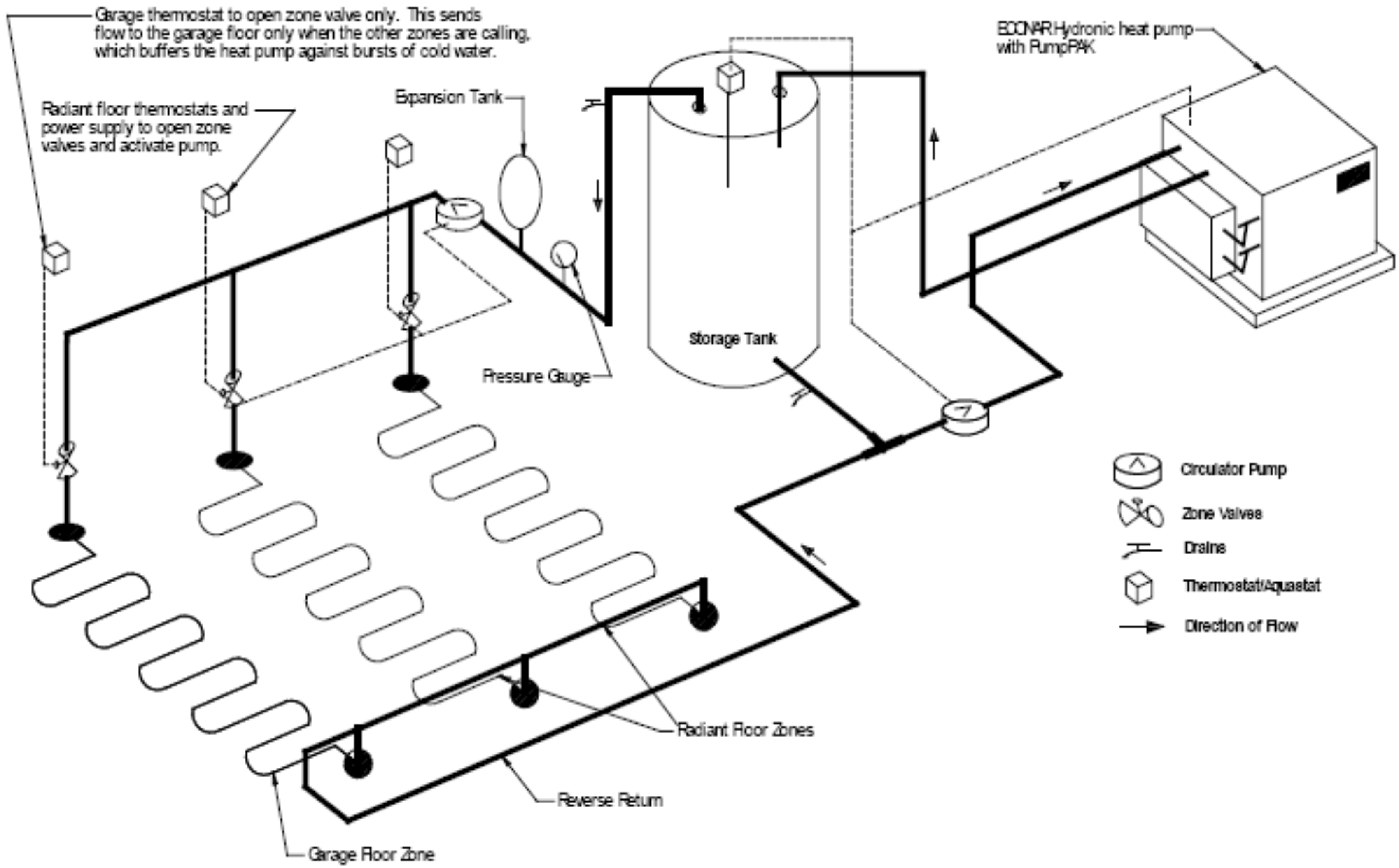
- Ratio of energy delivered to energy purchased

Example: C.O.P. of 3



Geothermal Energy for the Home

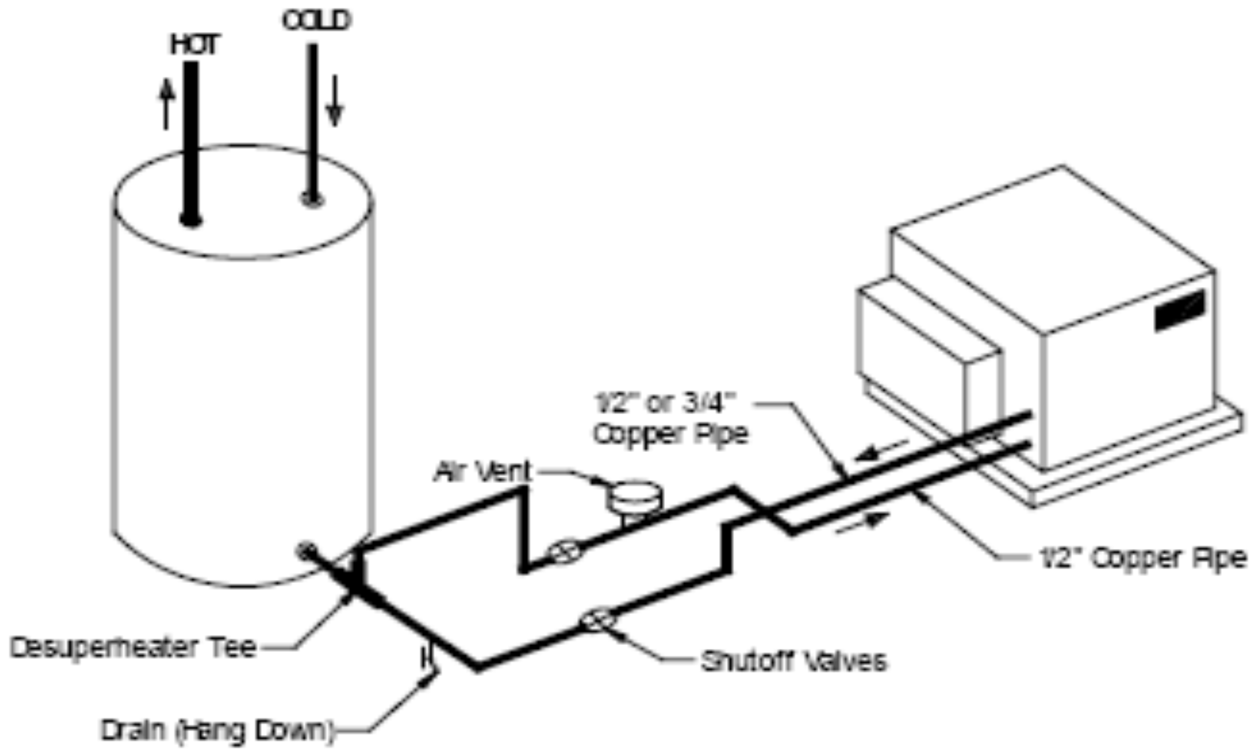




☞**Note** – Always use copper pipe on the hydronic side.

☞**Note** – Conceptual drawing only. Check local codes and use proper plumbing procedures.

Figure 5 – ECONAR Hydronic Heat Pump – Multizone System



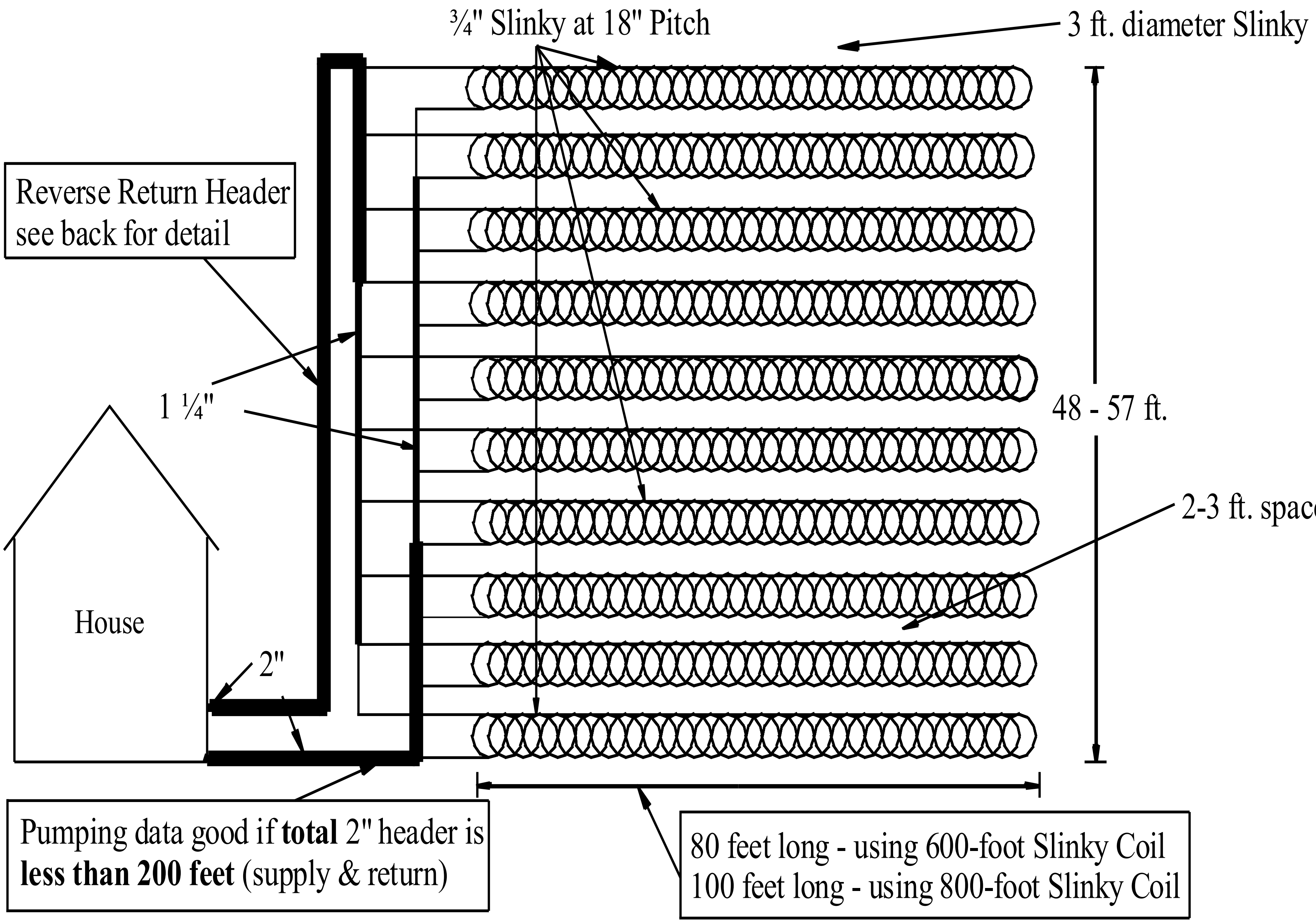
☛**Note –** Always use copper pipe. Check local codes and use proper plumbing procedures.

Figure 6 – Preferred Desuperheater Installation

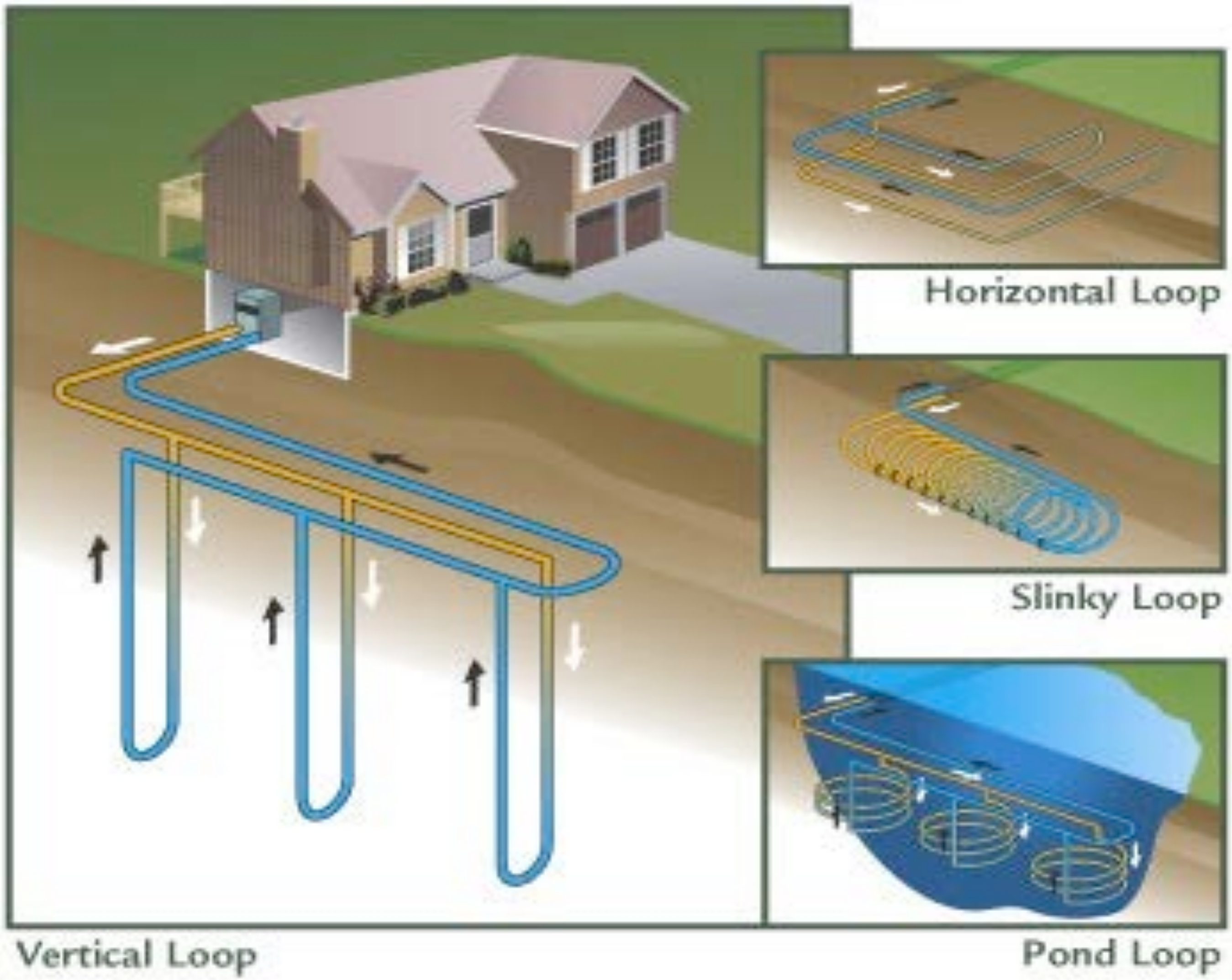
Installations of GHEX

- All horizontal slinky loops prior to 2011
- 90% Vertical or Directional Drilled since 2011
- Reduced bore hole length per ton in some valley applications

Typical 10-ton Horizontal System



Geothermal Energy for the Home



Commercial / Industrial Examples

- WV Builders - Office and Shop
- NLC General - Office and Shop
- Peterbuilt Truck Garage
- GHU WWTP Addition
- CCHRC Retrofit

WV Builders Office and Shop

- Built in 2012 on University Ave
- 6,000 sq ft office, shop and residential appt.
- 10 ton heating system with domestic h.w.

NLC OFFICE AND SHOP

- 7,000 sq ft building near Mitchell Expressway
- 60% office space and 40% shop
- 10 ton hydronic heating and cooling system
- 10 bore holes to 160’


GEOSOURCE

Peterbuilt Semi-Truck Garage

- Currently being built off Van Horn Rd
- 16,800 sq ft of heated garage space
- 20 ton heating system
- 20 bore holes to 160’

GHU WWTP Addition

- 6 ton heat pump
- Uses effluent channel as heat source
- HX is one 4x8 Slim Jim
- Effluent channel is 2000 gpm at 50 Deg F


FAIRBANKS WASTEWATER TREATMENT FACILITY


GEOSOURCE

CCHRC Retrofit

- 6 ton heating system
- Horizontal Slinky loop
- Completely monitored with electrical and BTU meters
- Measured C.O.P. of 3.4 to 3.6!!!
- Same system as all Alaska Geothermal Residential systems

Quote From CCHRC Report

"Owner Satisfaction:

The surveyed homeowners reported that their heat pumps are generally meeting their expectations.

Many respondents noted substantial energy savings over using oil heat. Additionally, homeowners felt

that the low maintenance requirements of the heat pump are an advantage, likening it to a refrigerator.

Other noted advantages include not relying on the fluctuating prices of fuel, no on-site combustion, and

no on-site fuel storage."

CCHRC Ground Source Heat Pumps in Interior Alaska – Lessons Learned From Installed Systems


ECONAR
by GeoSystems

GHP vs Heating Oil in Fairbanks

- Cost for Mbtu with heating oil at $4.12 and 85% eff. Boiler = $34.95
- Cost for Mbtu with GHP with C.O.P of 3.1 and elec rates of $0.217 Kwhr = $20.52
- GHP saves 41% with current prices for energy

EPA’s Take

A 1993 study by the U.S. Environmental Protection Agency showed geothermal heat pumps:

- Provide the lowest cost heating & cooling, even when higher initial costs are factored into analysis
- Geothermal Heat Pumps had the lowest CO_2 (greenhouse gas) emissions and the lowest over all environmental cost
- Can be highly cost-effective for utility conservation programs
- Can save home / business owners 30 to 70% annually over conventional heating systems

Greenhouse Gas Emissions

- Average installation saves 5 tons per year over heating oil

$$GHG\ Savings = HL\left(\frac{FI}{AFUE \times 1000\frac{kg}{ton}} - \frac{EI}{COP \times 3600\frac{sec}{hr}}\right)$$

HL = seasonal heat load ≈ 160 GJ/yr for a modern house in Alaska
FI = emissions intensity of fuel = 50 kg(CO_2)/GJ for natural gas, 73 for heating oil
AFUE = furnace efficiency ≈ 95% for a modern condensing furnace
COP = heat pump coefficient of performance ≈ 3.4 seasonally adjusted for Alaska heat pump
EI = emissions intensity of electricity ≈ 600 ton(CO_2)/GWh, Alaska power grid

Greenhouse Gas Emissions

- Average installation in Alaska saves 5 tons per year over heating oil
- This is equivalent in the savings achieved by replacing 4 to 5 conventional cars with electric cars

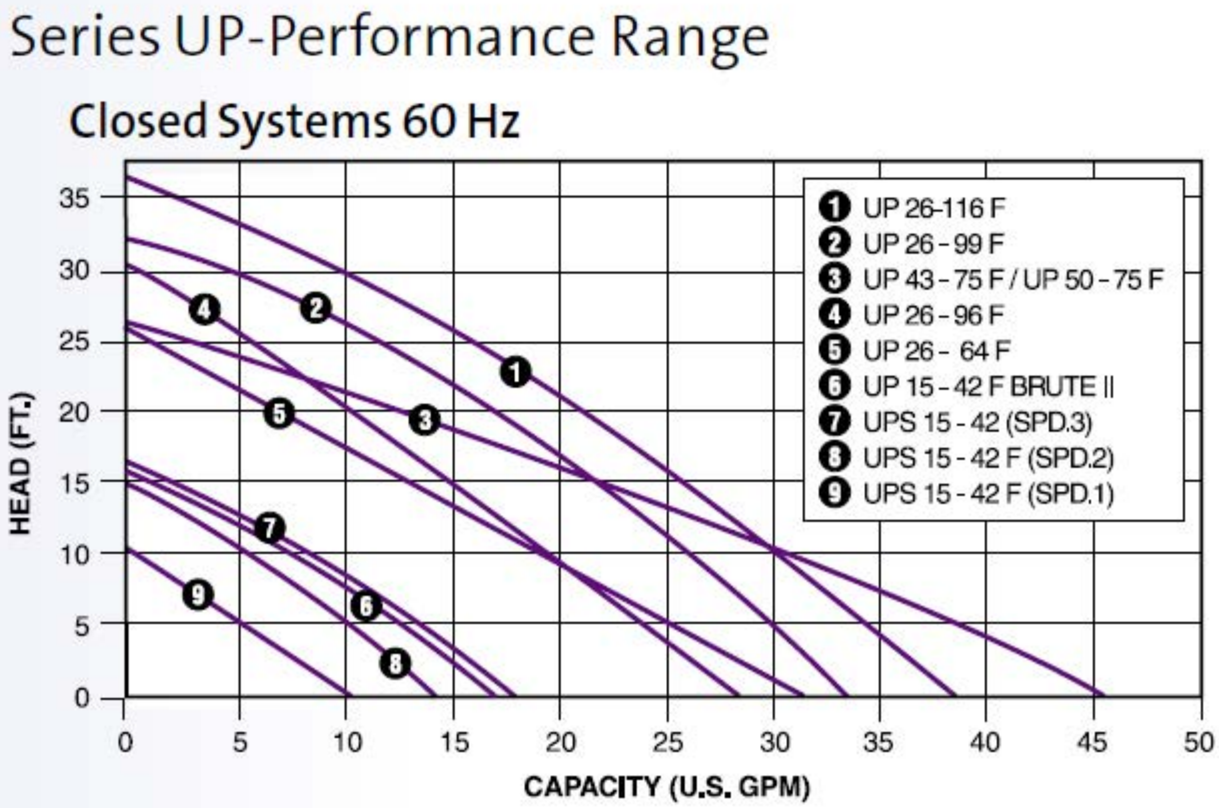
System Design

- Interior Design
- GHEX Design

Interior Design Considerations

- C.O.P. is improved with lower hot water temps
  - Increase flow with more tubing and or slightly larger circ pumps
  - Consider floor coverings that do not insulate
  - Use outdoor reset controls
  - Noise control
  - Electrical requirements

Pump Curves



Series UP-Performance Range
Closed Systems 60 Hz
HEAD (FT.)
CAPACITY (U.S. GPM)
0
5
10
15
20
25
30
35
40
45
50
1 UP 26-116 F
2 UP 26-99 F
3 UP 43-75 F / UP 50-75 F
4 UP 26-96 F
5 UP 26- 64 F
6 UP 15-42 F BRUTE II
7 UPS 15-42 (SPD.3)
8 UPS 15-42 F (SPD.2)
9 UPS 15-42 F (SPD.1)

Heat Pump in Alaska:
should be sized for 110% of design load

Water-To-Water (GSW) Series

Performance Data — GSW060 - Heating

SOURCE				LOAD																					
EWT	Flow			EWT	Flow 7.5 gpm							Flow 11.3 gpm							Flow 15.0 gpm						
	GPM	WPD			HC	Power	HE	LWT	COP	WPD		HC	Power	HE	LWT	COP	WPD		HC	Power	HE	LWT	COP	WPD	
°F		PSI	FT	°F	MBtuh	KW	MBtuh	°F		PSI	FT	MBtuh	KW	MBtuh	°F		PSI	FT	MBtuh	KW	MBtuh	°F		PSI	FT
20	15.0	7.9	18.2	60	36.8	2.53	28.2	69.8	4.26	1.6	3.7	37.2	2.44	28.9	66.6	4.48	3.1	7.1	37.4	2.39	29.3	65.0	4.58	5.0	11.6
				80	35.0	3.17	24.2	89.3	3.24	1.3	3.0	35.2	3.04	24.9	86.2	3.39	2.6	5.9	35.4	2.98	25.2	84.7	3.48	4.2	9.7
				100	33.9	4.01	20.2	109.0	2.48	0.9	2.1	34.0	3.86	20.9	106.0	2.59	1.9	4.5	34.1	3.78	21.2	104.5	2.64	3.5	8.1
				120	33.6	5.08	16.3	129.0	1.94	0.6	1.5	33.6	4.89	17.0	126.0	2.02	1.6	3.6	33.6	4.79	17.3	124.5	2.06	2.9	6.7
30	7.5	3.1	7.2	60	38.2	2.55	29.5	70.2	4.39	1.6	3.7	38.7	2.46	30.3	66.8	4.62	3.1	7.1	38.9	2.41	30.7	65.2	4.73	5.0	11.6
				80	36.3	3.19	25.4	89.7	3.34	1.3	3.0	36.6	3.06	26.1	86.5	3.50	2.6	5.9	36.7	3.00	26.5	84.9	3.58	4.2	9.7
				100	35.2	4.04	21.4	109.4	2.55	0.9	2.1	35.4	3.88	22.1	106.3	2.67	1.9	4.5	35.4	3.81	22.4	104.7	2.73	3.5	8.1
				120	35.0	5.12	17.5	129.3	2.00	0.6	1.5	34.9	4.92	18.1	126.2	2.08	1.6	3.6	34.9	4.83	18.5	124.7	2.12	2.9	6.7
	11.3	5.0	11.5	60	40.5	2.57	31.7	70.8	4.61	1.6	3.7	41.0	2.48	32.5	67.2	4.84	3.1	7.1	41.2	2.43	32.9	65.5	4.96	5.0	11.6
				80	38.5	3.22	27.5	90.3	3.50	1.3	3.0	38.8	3.09	28.2	86.9	3.68	2.6	5.9	38.9	3.03	28.6	85.2	3.76	4.2	9.7
				100	37.3	4.08	23.4	109.9	2.68	0.9	2.1	37.4	3.92	24.1	106.6	2.80	1.9	4.5	37.5	3.84	24.4	105.0	2.86	3.5	8.1
				120	37.0	5.16	19.4	129.9	2.10	0.6	1.5	37.0	4.97	20.1	126.5	2.18	1.6	3.6	37.0	4.87	20.4	124.9	2.23	2.9	6.7
	15.0	7.4	17.0	60	42.3	2.58	33.5	71.3	4.80	1.6	3.7	42.8	2.49	34.3	67.6	5.04	3.1	7.1	43.0	2.44	34.7	65.7	5.16	5.0	11.6
				80	40.2	3.23	29.2	90.7	3.65	1.3	3.0	40.5	3.10	29.9	87.2	3.82	2.6	5.9	40.7	3.04	30.3	85.4	3.92	4.2	9.7
				100	39.0	4.09	25.0	110.4	2.79	0.9	2.1	39.1	3.93	25.7	106.9	2.91	1.9	4.5	39.2	3.86	26.0	105.2	2.98	3.5	8.1
				120	38.7	5.18	21.0	130.3	2.19	0.6	1.5	38.7	4.99	21.6	126.8	2.27	1.6	3.6	38.7	4.89	22.0	125.2	2.32	2.9	6.7

Design of Closed Loop Ground Heat Exchangers

- Understand piping material used, including physical characteristics, pressure ratings, flow rates for flushing and flow characteristics
- Understand antifreeze mixtures and properties important to GHEX design
- Lay out GHEX to allow ease of flushing and minimize pumping power requirements
- Choose best type of GHEX for site – Vertically bored or horizontally trenched
- For GHEX over 20 tons, have a design done by a IGSHPA certified GeoExchange designer or mechanical engineer
- For GHEX over 20 tons, conduct a FTC test
- Have all systems installed by an IGSHPA certified installer

Determination of 3 Main Design Components

- Undisturbed Formation (Ground) Temperature
- Formation (Ground) Thermal Conductivity (k)
  - A measure of a material's ability to conduct heat.
- Formation (Ground) Thermal Diffusivity (a=k/pc)
  - Ratio of heat conduction rate to heat storage capacity

ASHRAE Recommended Procedures

ASHRAE's 2007 HVAC Applications handbook, page 32.12 – 32.13

- **Required Test Duration**
  - 36 to 48 hours.
- **Power**
  - Heat flux rate between 15-25 W per foot of bore.

Table 1: Power requirements for performing conductivity test based on bore depth

Test Bore Depth Range	**80'-133'**	**160'-267'**	**240'–400'**	**320'-533'**
Elements Turned "ON"	1	1 & 2	1, 2 & 3	1,2,3, & 4
Watts @ 240 V	2000	4000	6000	8000
kW @ 240 V	2	4	6	8
Recommended Minimum Generator Size	15 kW	15 kW	15 kW	20 kW
Required Minimum Line-Voltage Service	10 Amp	20 Amp	30 Amp	40 Amp

- **Undisturbed Soil Temperature**
  - Determined by recording the minimum loop temp. at startup.
- **Installation Procedures**
  - Bore dia. $\leq$ 6"
  - Bore should be grouted bottom to top.
- **Time Between Installation and Testing**
  - 5 days if grout TC is low (< 0.75 Btu/hr ft °F), otherwise 3 days.

FTC Testing

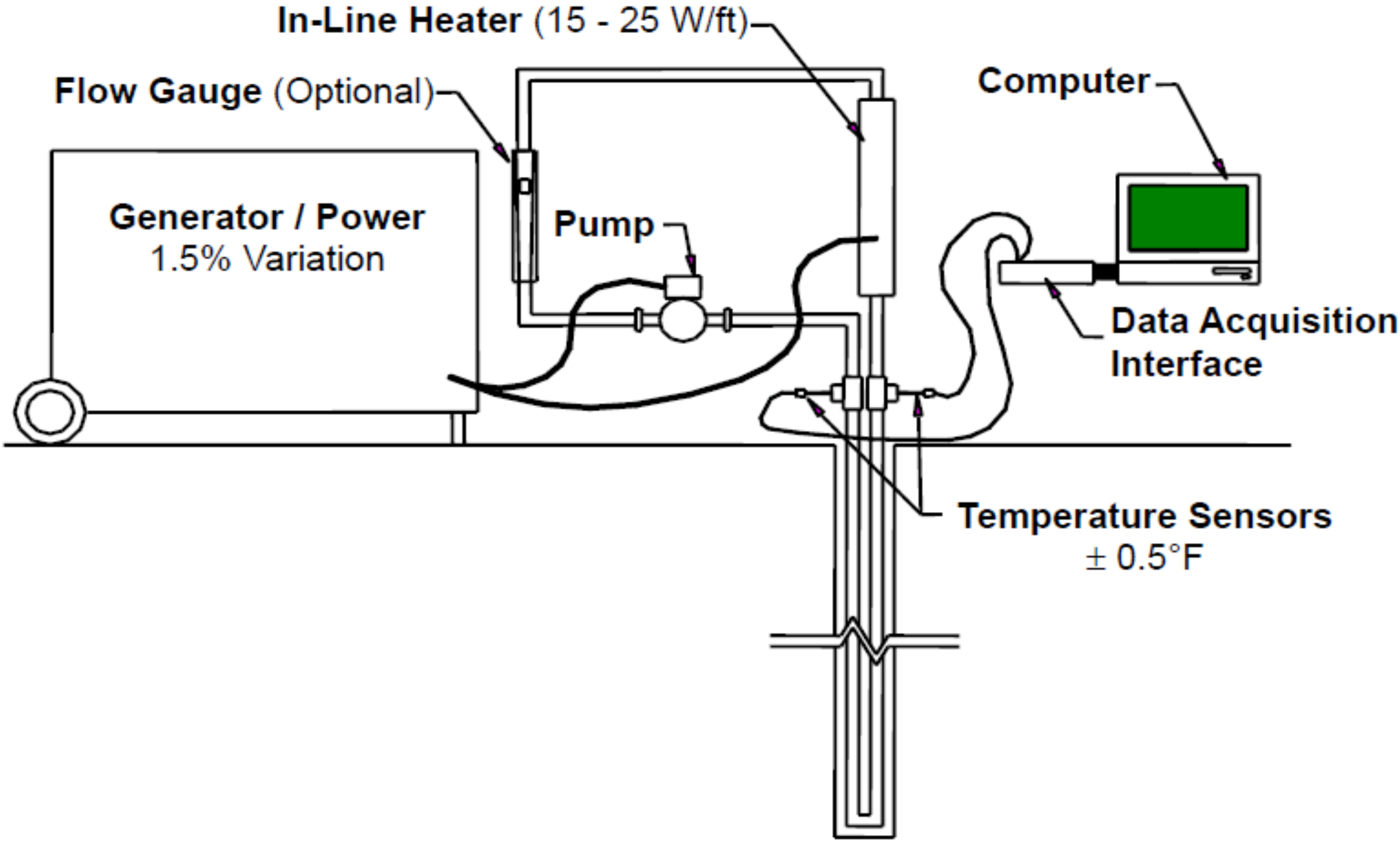
Also known as:

- In-situ Testing
- Thermal Conductivity Testing

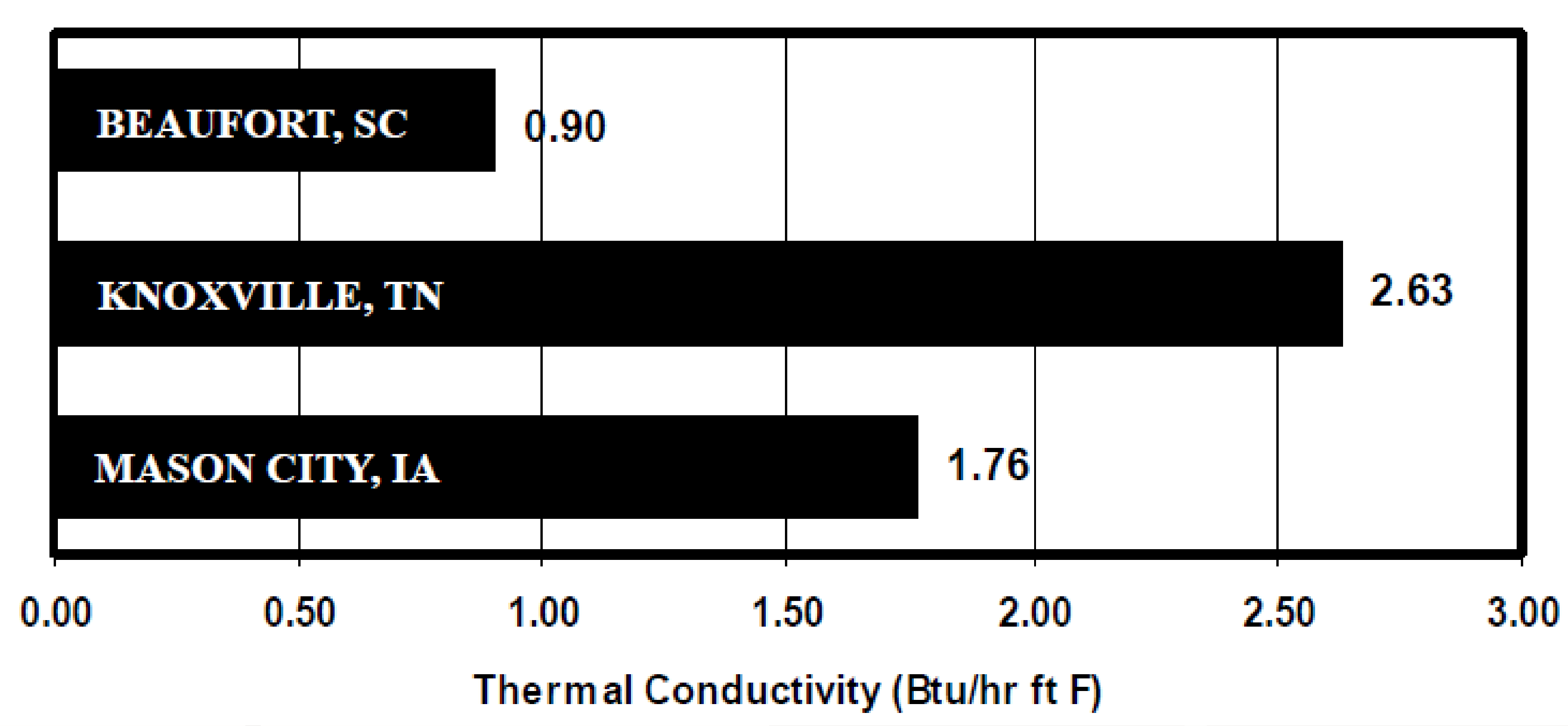
"A field test to determine the average thermal conductivity of the formation throughout the entire length of the vertical bore column"

Step 1 – Install Test Bore

FTC Testing Unit Schematic

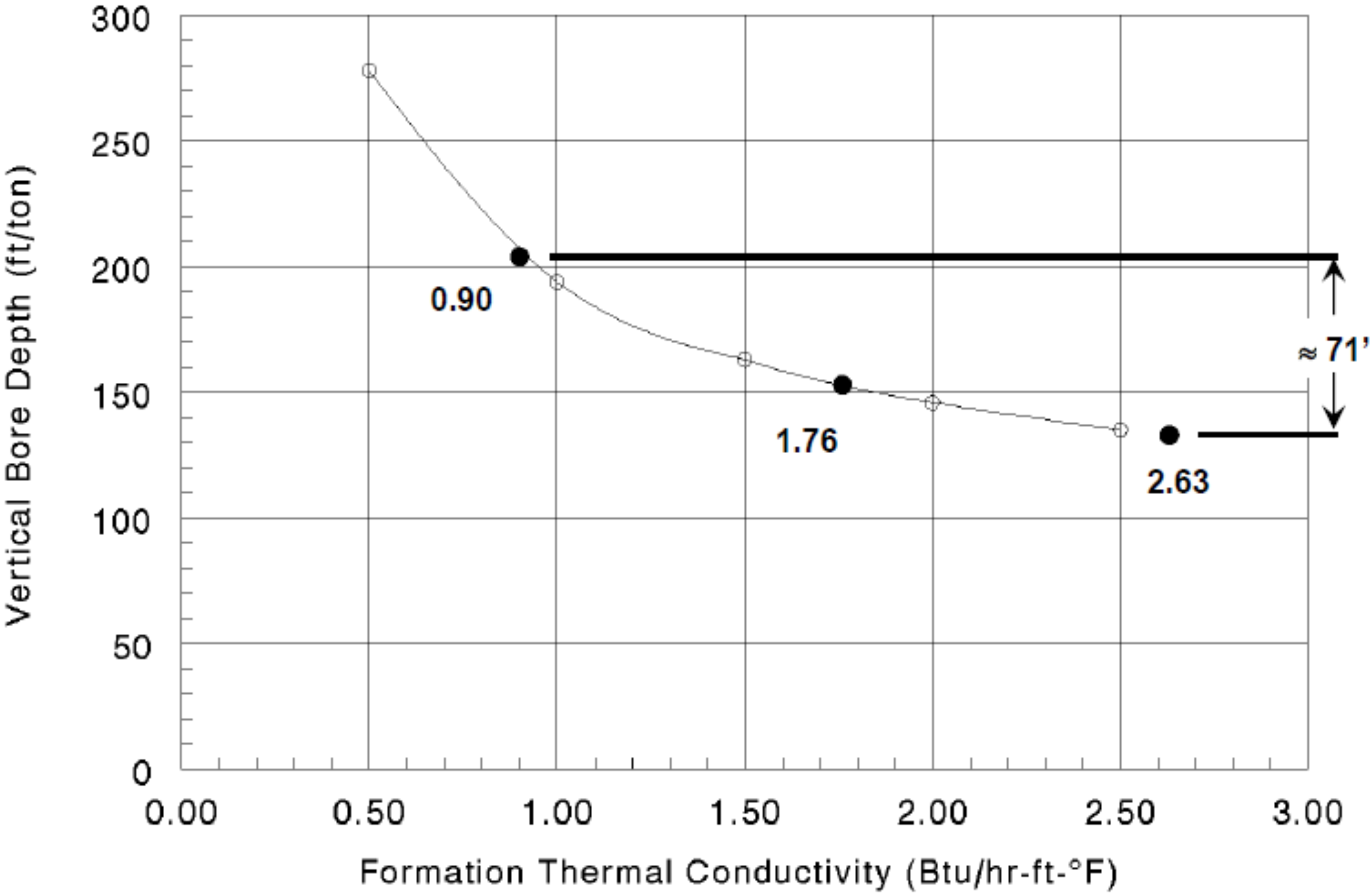


Calculated (reported) Thermal Conductivity Values



Effects of the Formation TC

Hypothetical 100 Ton Project (1200 MBH), 10 x 10 grid, 20'



Different Antifreezes have Different Properties

- Methanol
  - Inexpensive
  - Excellent thermal conductivity
  - Somewhat toxic
  - Low viscosity
- Propylene Glycol
  - Safest
  - Thick at cold temps
  - Poor thermal conductivity
  - Expensive

Flow in GHEX

- Want a flushing flow rate greater than 2 ft/sec in pipe to purge all air.
- Want turbulent flow during normal system operation to maximize heat transfer
  - Reynolds Number > 2500
  - Use Reynolds Number tables for HDPE pipe sizes with proper antifreeze correction factors to decide min flow rate
  - Use the greater flow rate between this value and heat pump flow requirement

General GHEX Design Procedure

- Select a GHEX configuration for the site
- Configure the GHEX for proper flow and ease of flushing
- Estimate the length of each flow path in the GHEX
- Calculate the head loss to size the pumping system
- Evaluate the economics of the design
- Redesign, if necessary or consider other configurations

Vertical Heating Design Equations

$$L_{ht} = \frac{HC_D \times ((COP - 1)/COP) \times R_B + R_G \times F_H}{T_G - ((EWT_{min} + LWT_{min}) / 2)}$$

- L_{ht} = total borehole design length for heating (below header trench), ft
- HC_D = heat pump heating capacity at design heating conditions, *Btu/hr*
- COP_D = coefficient of performance at design heating conditions, dimensionless
- R_B = borehole thermal resistance, hr ft F/Btu
- R_G = steady-state thermal resistance of ground surrounding the borehole, hr ft F/ Btu
- F_H = run fraction in heating mode during heating design month (Jan) dimensionless
- T_G = average ground temperature along borehole length, F
- EWT = minimum entering water temperature at heating design conditions, F
- LWT= minimum leaving water temperature at heating design conditions, F

Horizontal heating Design Equation

$$L_{HP} = \frac{HC_D \times ((COP_D - 1)/COP_D) \times (R_P + R_S \times P_M \times S_M \times F_H)}{T_{SL} - ((EWT_{min} + LWT_{min}) / 2)}$$

- L_{HP} = total pipe design length for heating, ft
- HC_D = heat pump heating capacity at design heating conditions, *Btu/hr*
- COP_D = coefficient of performance at design heating conditions, dimensionless
- R_P = pipe thermal resistance, hr ft F/Btu
- R_s = steady-state thermal resistance of soil, hr ft F/Btu
- P_M = multiplier to account for pipe diameter other than ¾”
- S_M = multiplier to account for trench spacing
- F_H = run fraction in heating mode during heating design month (Jan) dimensionless
- T_{SL} = design soil temperature for heating at average GHEX pipe depth, F
- EWT = minimum entering water temperature at heating design conditions, F
- LWT= minimum leaving water temperature at heating design conditions, F

Many Different Options Available

- Hydronic -- low temp heat & chilled water.
- Stand alone domestic hot water.
- Forced air -- vertical, horizontal
- Forced air / on demand domestic hot water.
- Forced air / hydronic combination.
- Forced air / two stage compressor.
- Accessories for turn key installations.

Thank You for Your Time

References

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- www.econar.com (public website)
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- www.heatspring .com