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GEOEXCHANGE™
Comfort from the ground up

3962 Alpine Valley Circle
Sandy, Utah 84092

Geothermal Resources Council
&
Utah Natural Resources

Geothermal Heat Pump Workshop

April 29 & 30, 2009

GX Loop Heat Pumps and Design Considerations

Hybrid Designs

Special Thanks To:

Andrew Chiasson
Geo-Heat Center
Oregon Institute of Technology

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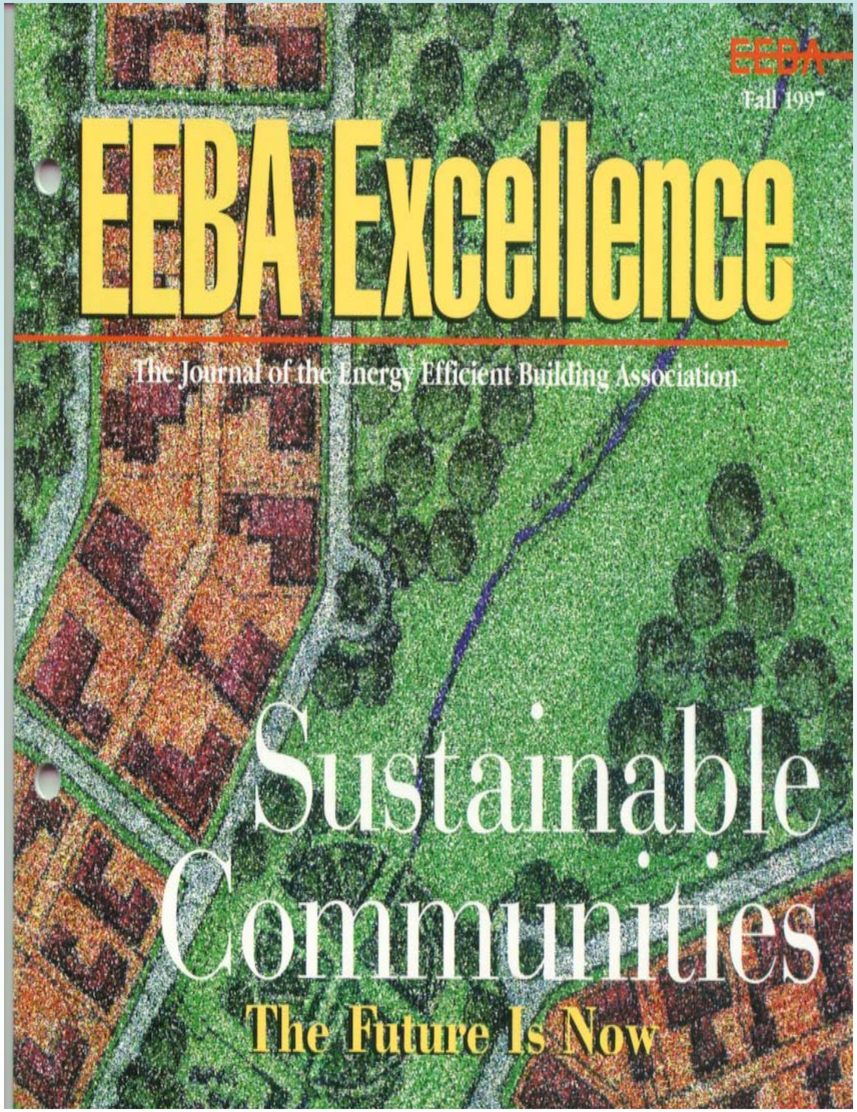
Presentation Outline

- Overview of geothermal heat pump (GHP) systems
  - aka: GeoExchange (GX), ground-source, ground-coupled
- GX Design
  - Thermal Conductivity
  - Loop Design Considerations
- Hybrid Systems

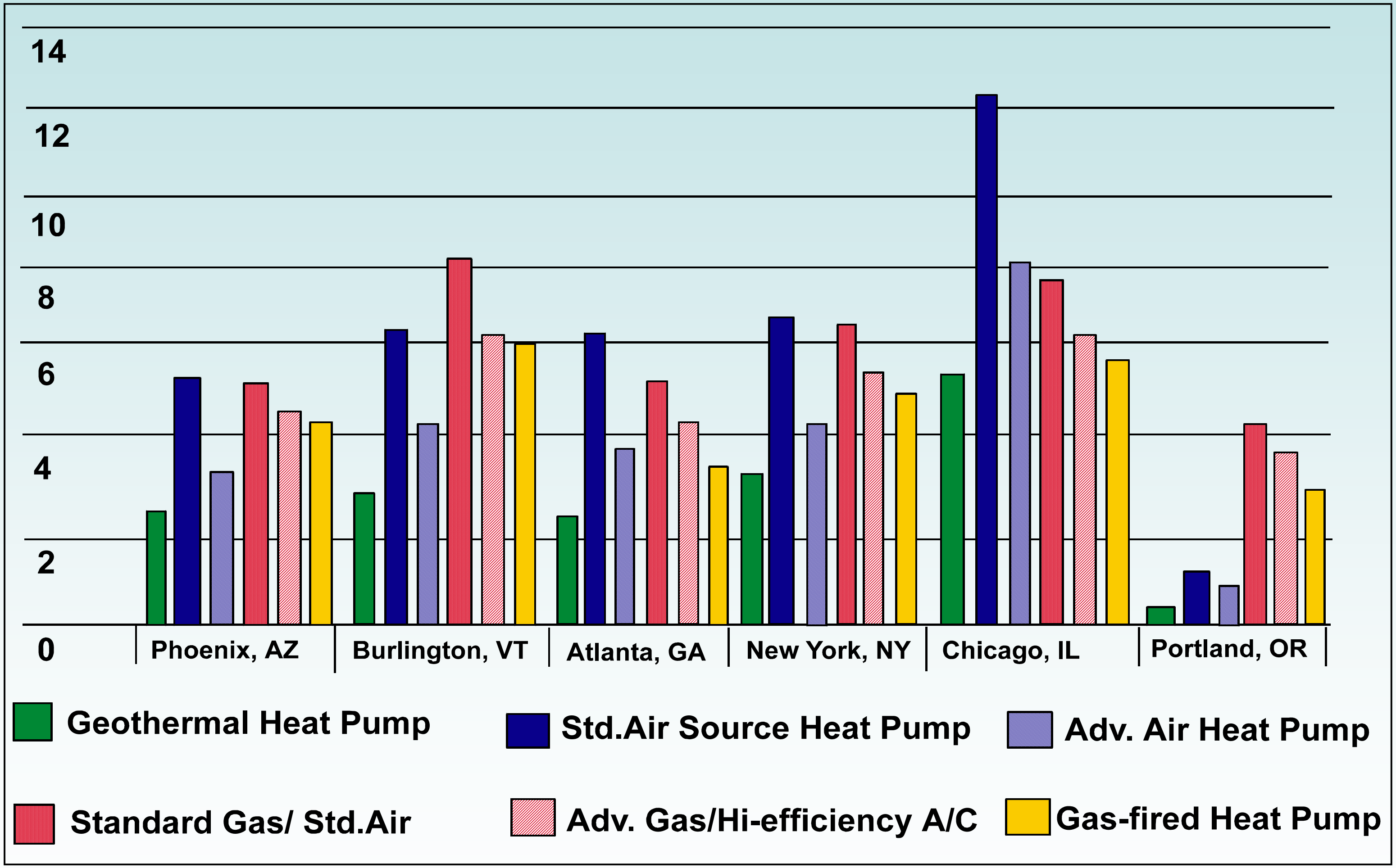
Growing Interest in Sustainable, Green Design

- **Owners**
- **Architects**
- **Government**
- **Patrons**
- **Utilities**
- **Students**



Environment

Annual Carbon Dioxide Emissions from Space Conditioning Equipment by Region



(In thousands of kilograms per year)

Federal and State Incentives:

Utah: Tax Credit

Residential: 25% of the cost of the GeoExchange system, up to $2,000

Commercial: 10% of the cost of the GeoExchange System up to $50,000

Federal Tax Credit:

Residential: 30% of the cost of the GeoExchange system – no limit. GX equipment must meet Energy Star requirements.

Commercial:

10% of the cost of the system.
5 year accelerated depreciation
May elect to take credit as a grant – paid within 60 days of completion.
50% Energy reduction up to $1.80/ sq. ft.

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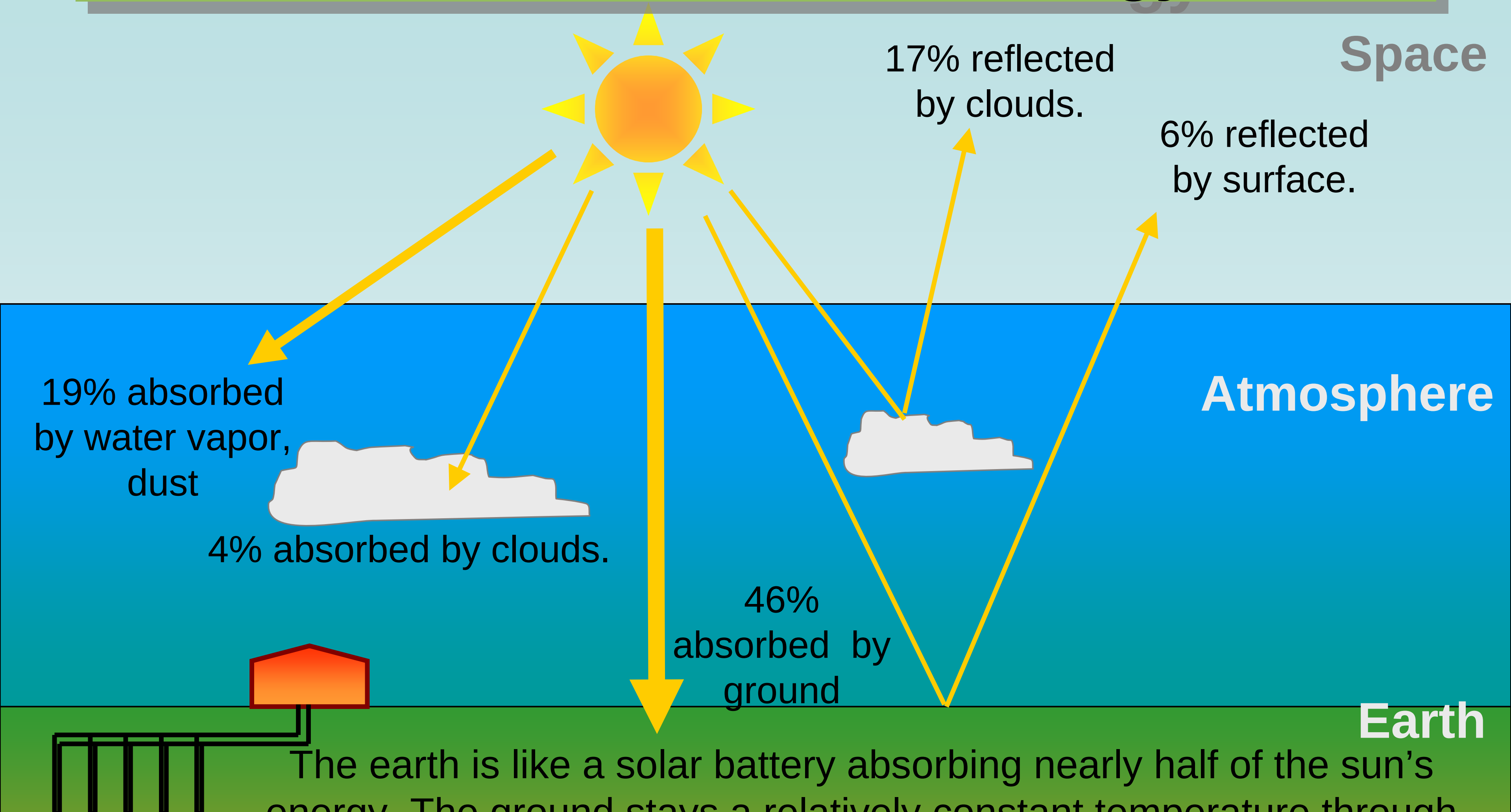
Overview:
What do GHP systems provide?

- Heating
- Cooling
- Hot water
- Humidity control
- Ice making

…but also…

- Energy efficiency
- Decreased maintenance
- Decreased space needs
- Low operating costs
- No outdoor equipment (no noise or outdoor maintenance)
- Comfort & air quality
- Reduced peak electrical loads for air conditioning

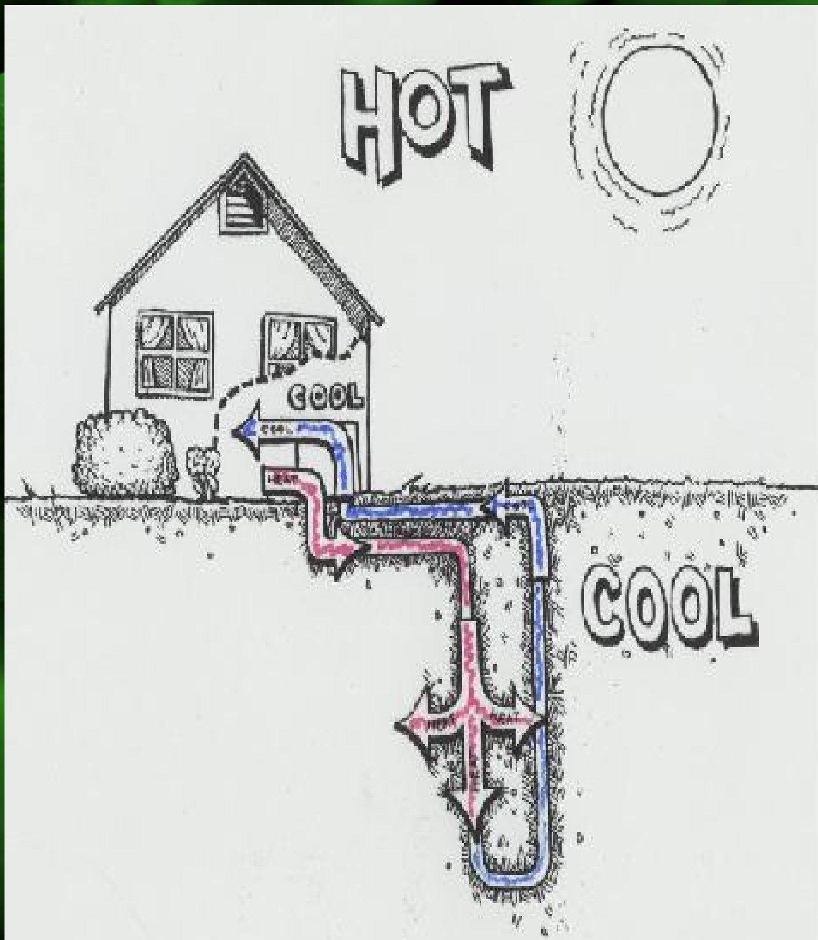
Geothermal & Solar Energy

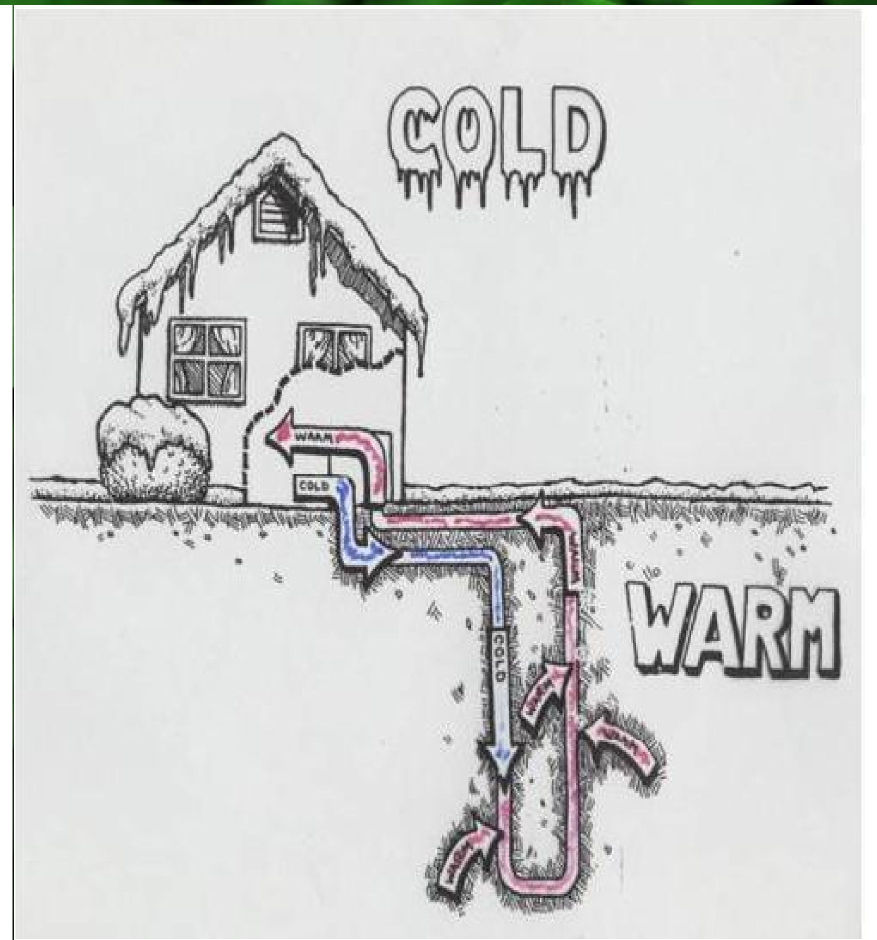


The earth is like a solar battery absorbing nearly half of the sun's energy. The ground stays a relatively constant temperature through the seasons, providing a warm source in winter & a cool heat sink in summer.

Relatively Constant Earth Temp

Ground Source Heating and Cooling…

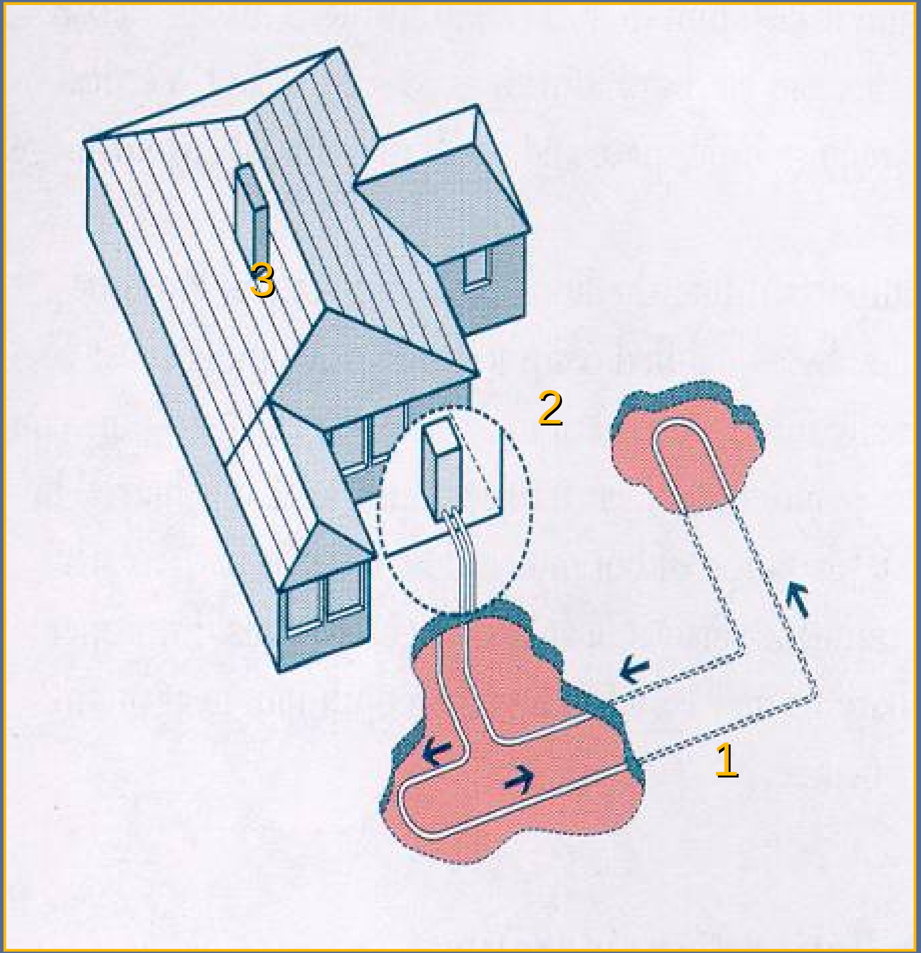




Uses a Heat Pump to move energy from a space into the ground or, energy from the ground into a space.

Components of GHP Systems

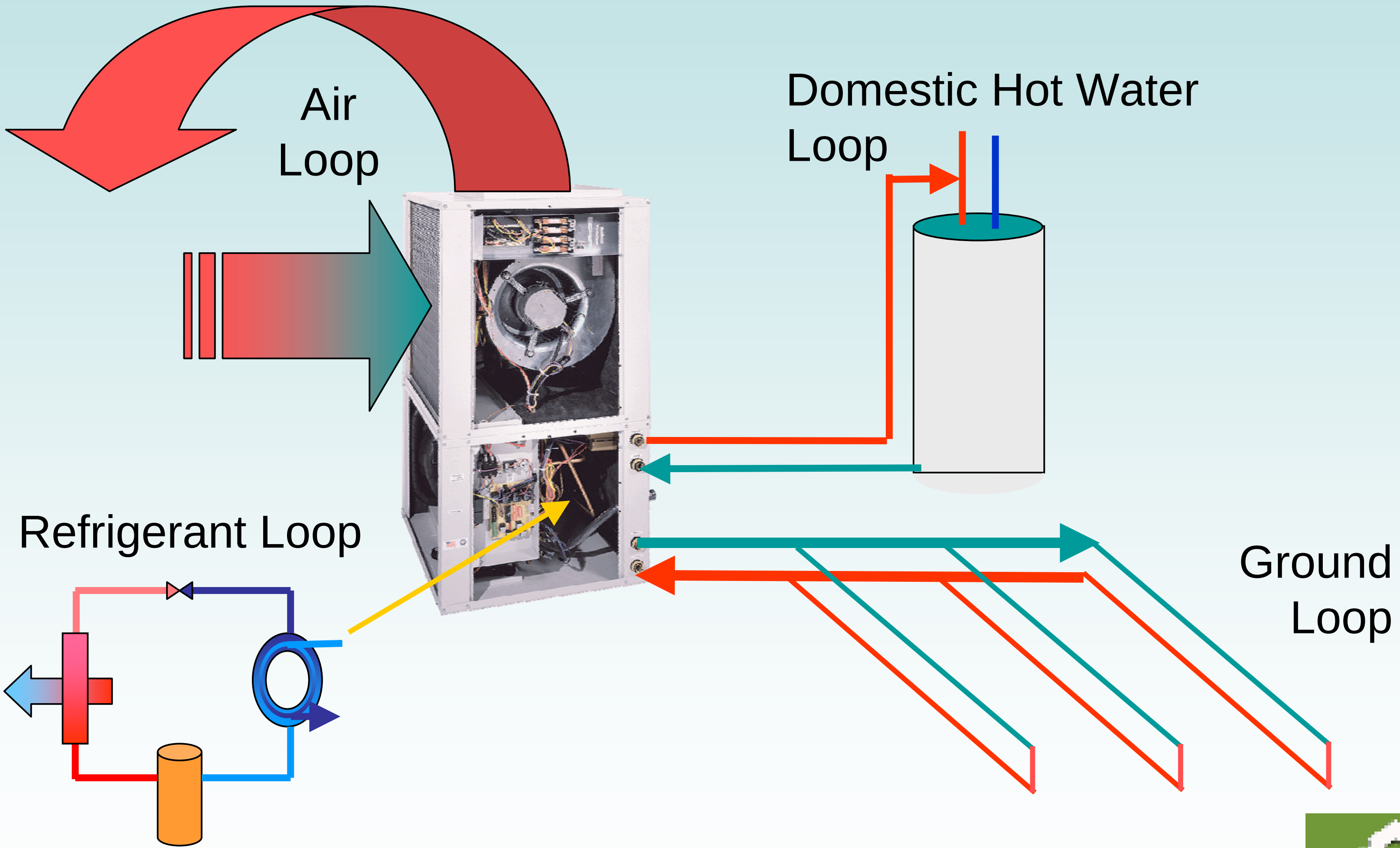
1. Earth connection
   - Closed-loop
   - Open-loop
2. Water-source heat pump
3. Interior heating/ cooling distribution subsystem
   - Forced air
   - Radiant



Components: Water-Source Heat Pump

- Water-to-air or water-water heat pump
- ¾ to 10 ton units are most common
- Up to 50 tons commercial

Ground Source Heat Pump



Heat Pumps

- **How do heat pumps work**

  Moves heat = A/C or refrigerator

- **Why are they more efficient that conventional equipment**

  Heating – Moving not creating

  Cooling – **T**hermal **C**onductivity of water vs.

Residential Water-to-Water

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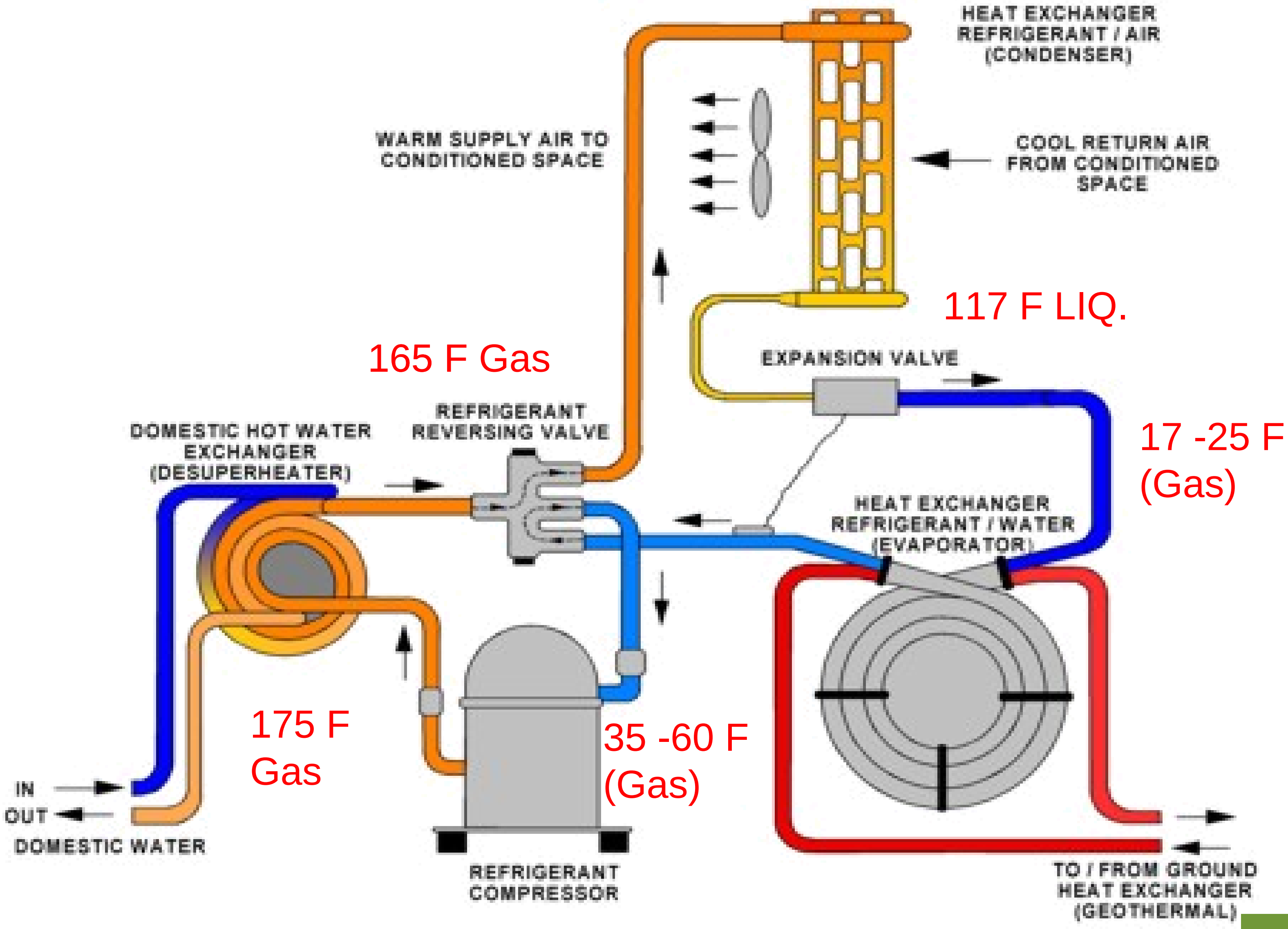
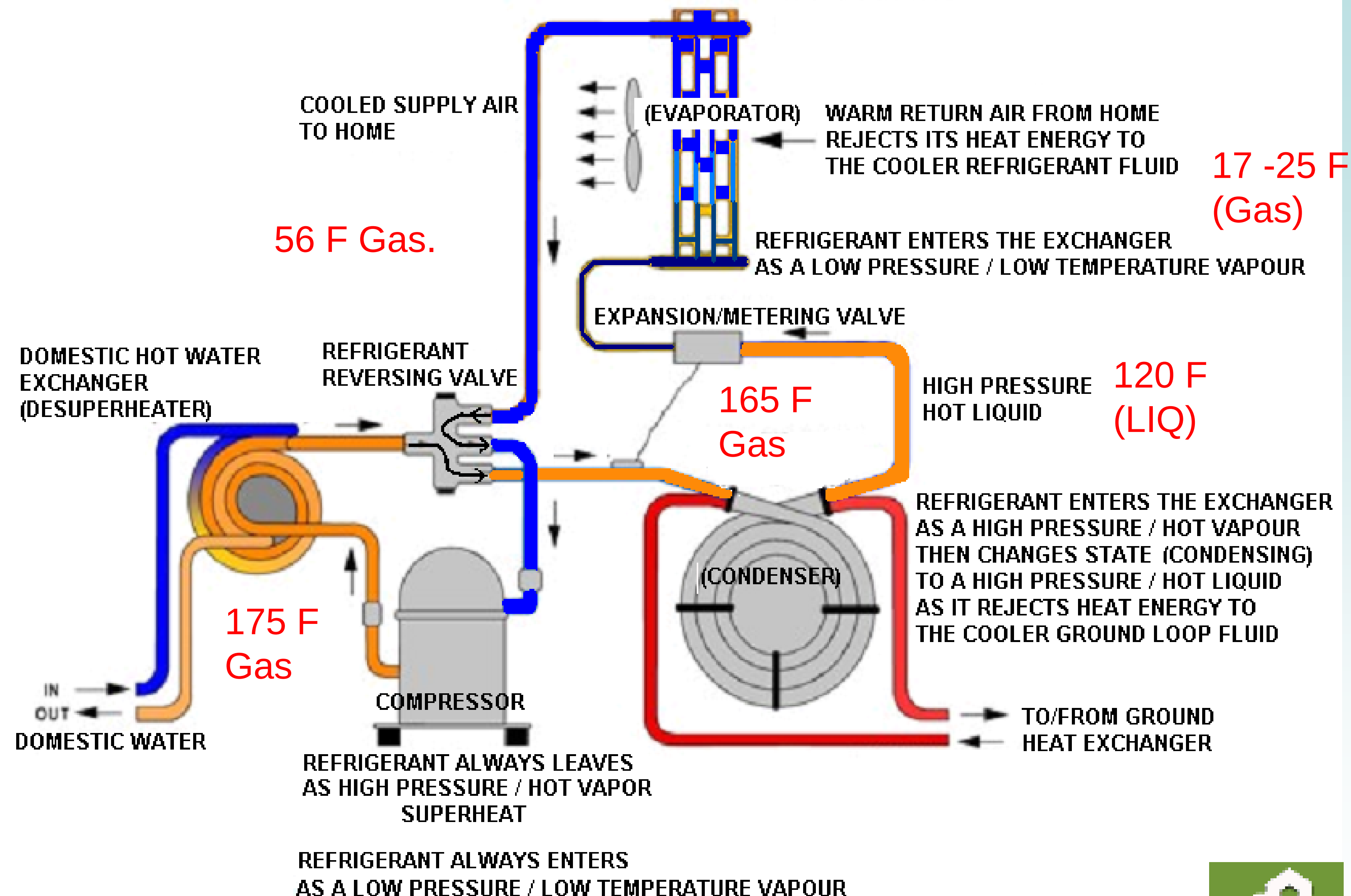
Ground Source Heat Pump Heating Operation



IGSHPA

Ground Source Heat Pump Cooling Operation



Geoexchange Potential

- Heating Efficiency
  - 80-96% AFUE vs. 4.0 COP (400%)
- Cooling Efficiency
  - 13-15 SEER vs. 38 SEER (Up to 30 EER)
    - (11 EER) up to (30 EER)
- Consumer satisfaction > 95%
- Owner savings
  - 30%-70% $ in heating mode
  - 20%-50% $ in cooling mode

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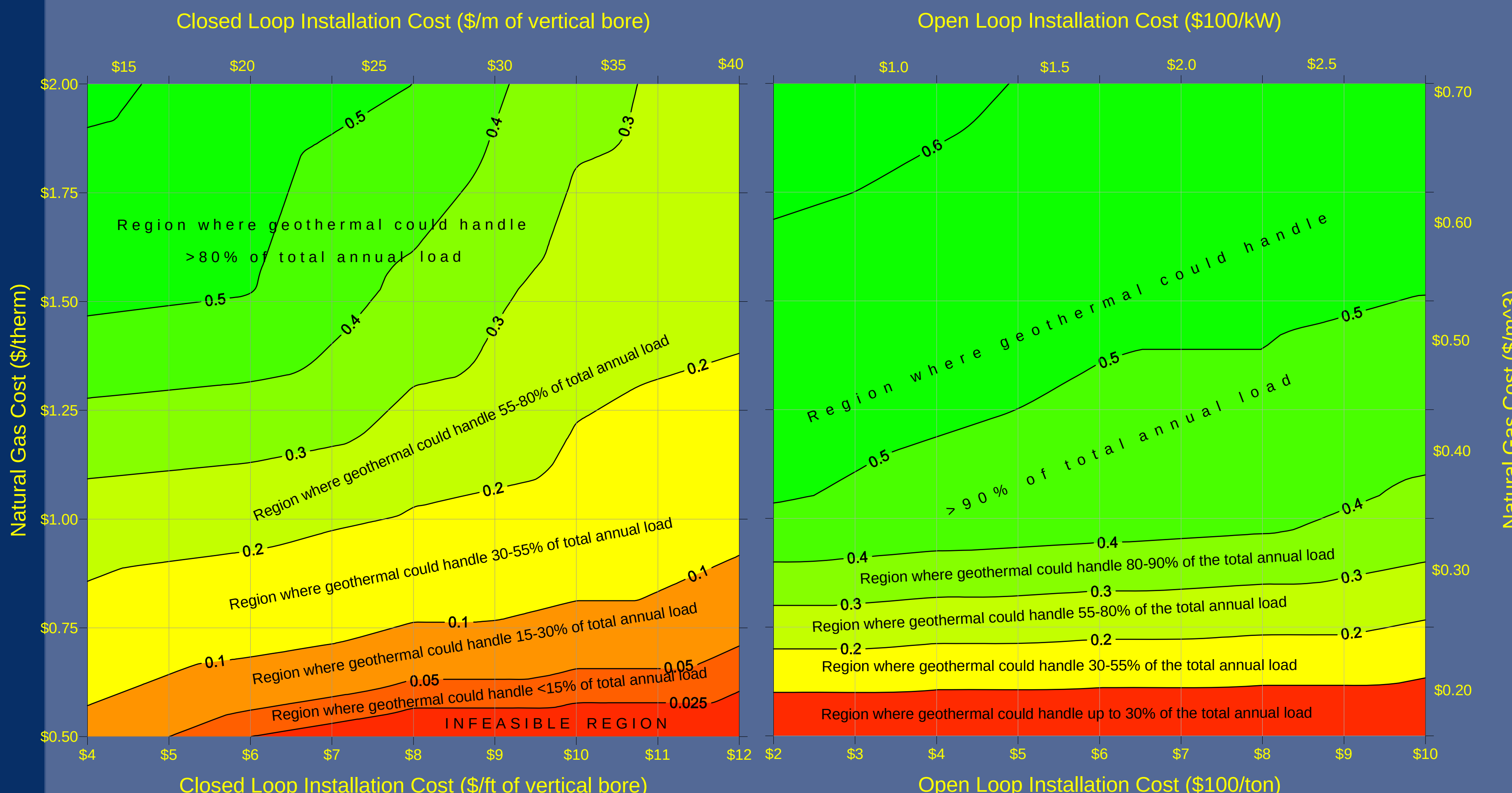
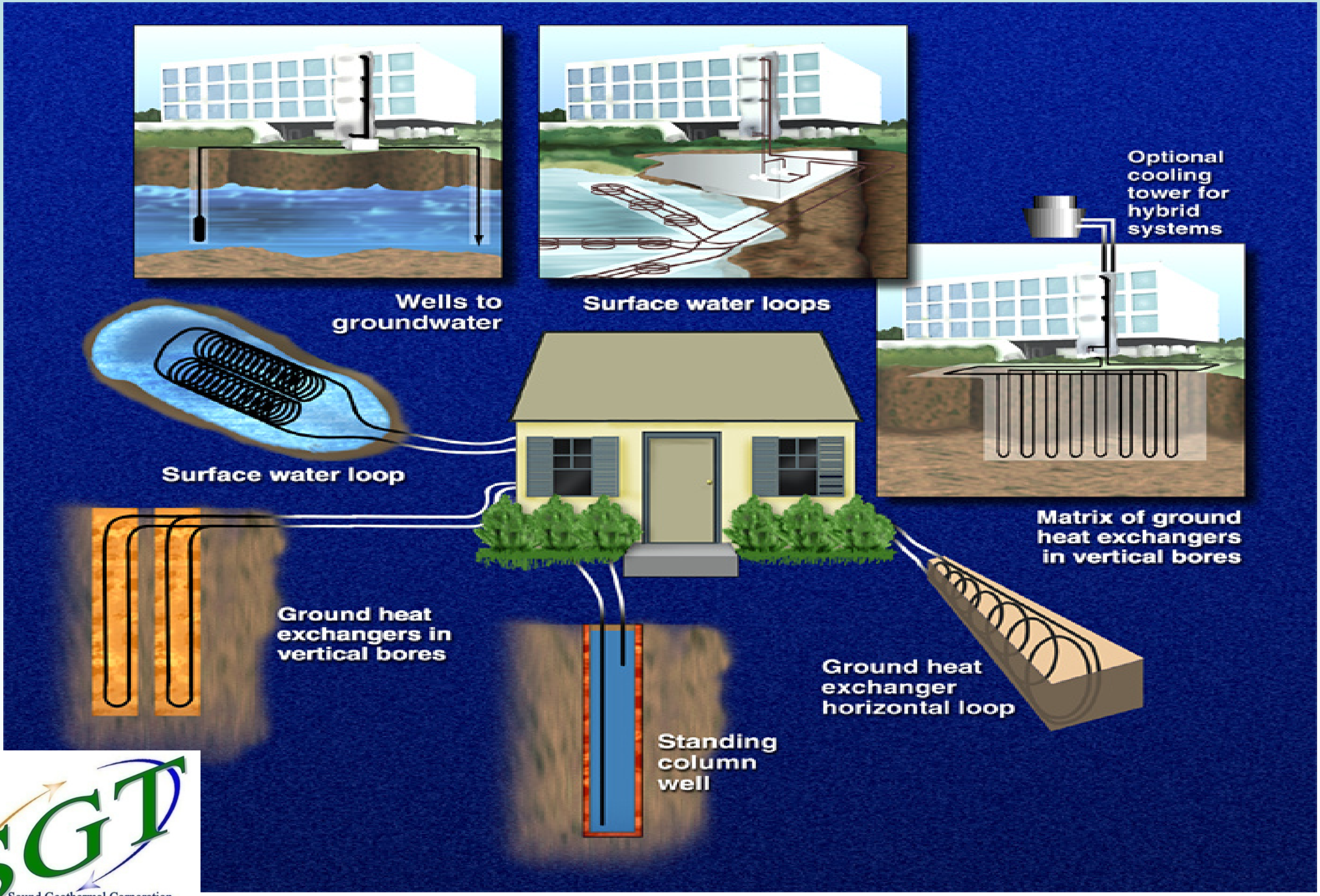
GHPs and Aquaculture: Feasibility



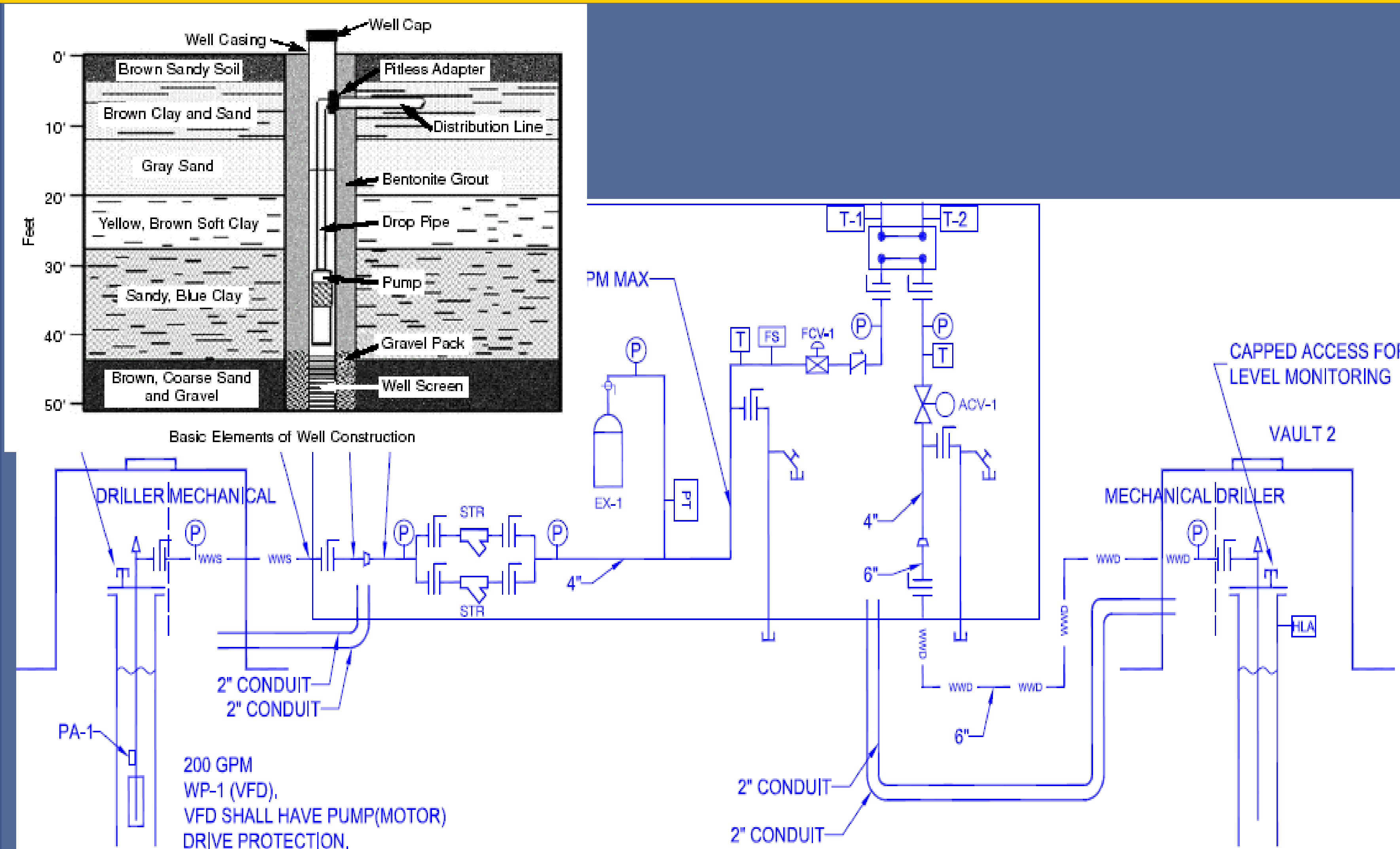
Contours represent fraction of geothermal capacity to the peak hourly heating load

Full article available at http://geoheat.oit.edu/bulletin/bull26-1/art3.pdf

GHP system options

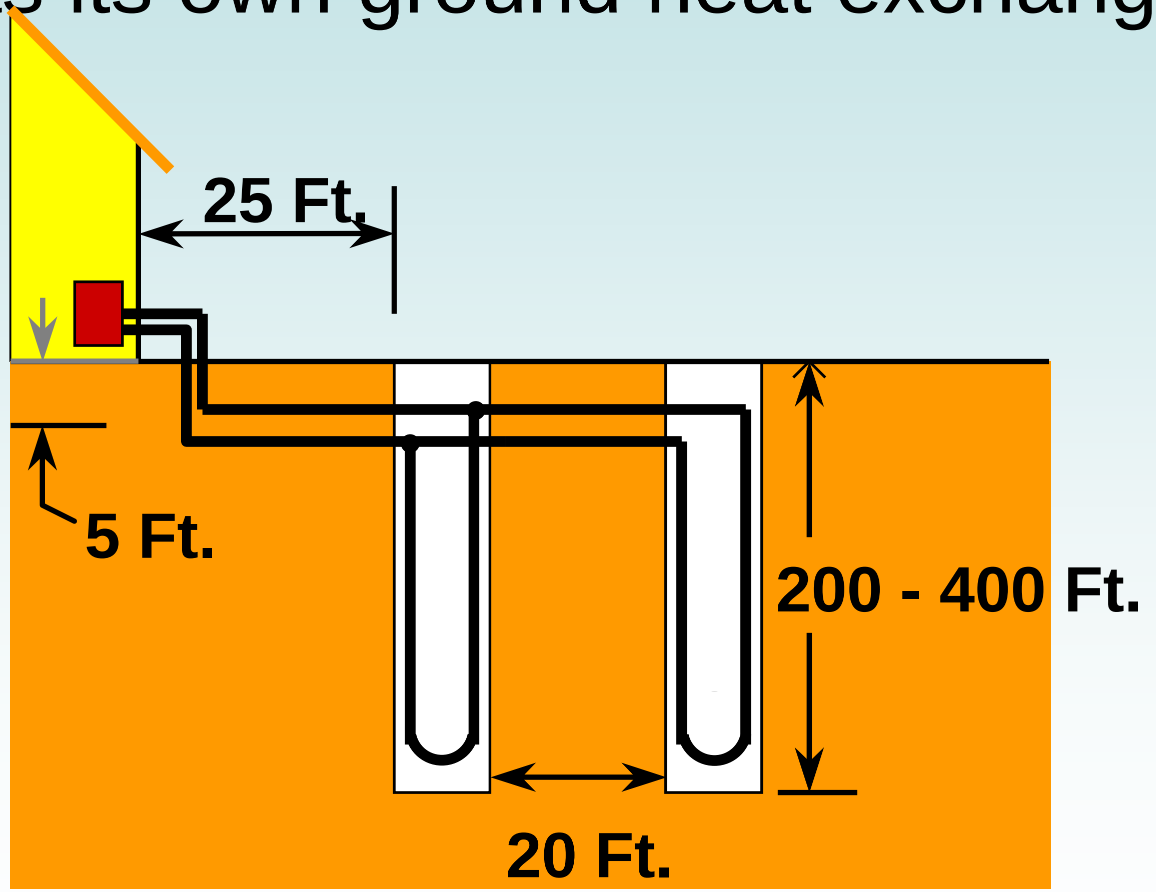


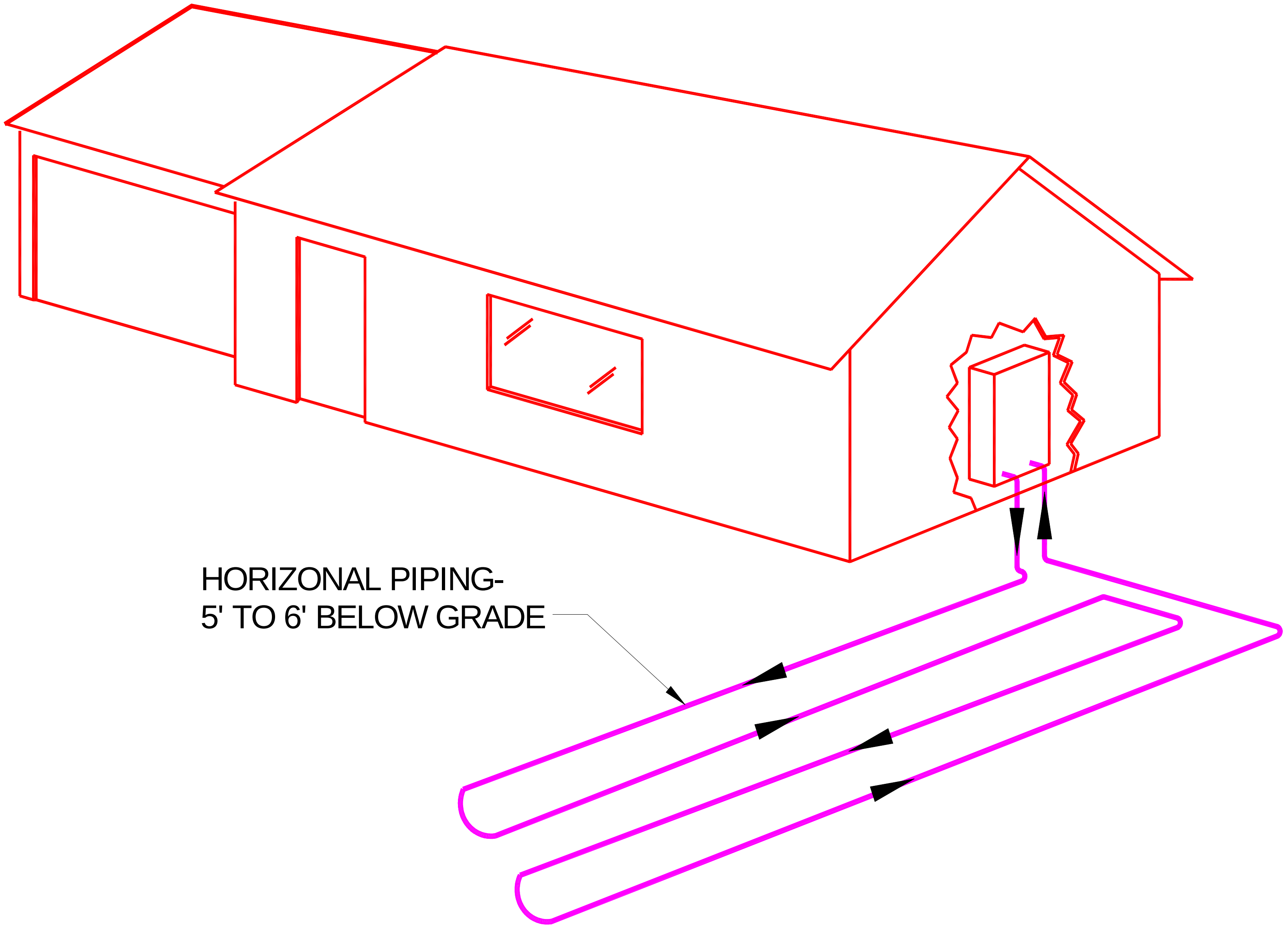
Open-Loop



Basic Elements of Well Construction

Residential systems: Each home typically has its own ground heat exchanger





HORIZONTAL SYSTEM

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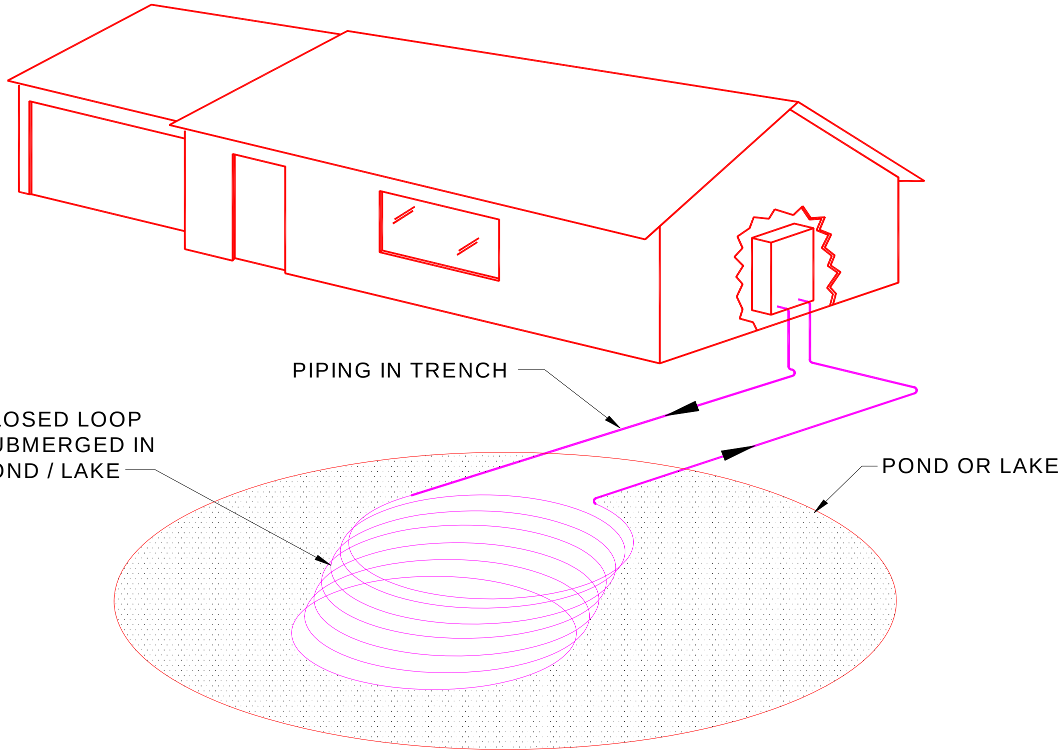

POND / LAKE SYSTEM

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Other Residential and Commercial Applications

- Black Water Heat Exchangers
- Fountain Heat Exchangers
- PV Hot Water Recirculation Systems
- Solar Hot Water Recharge

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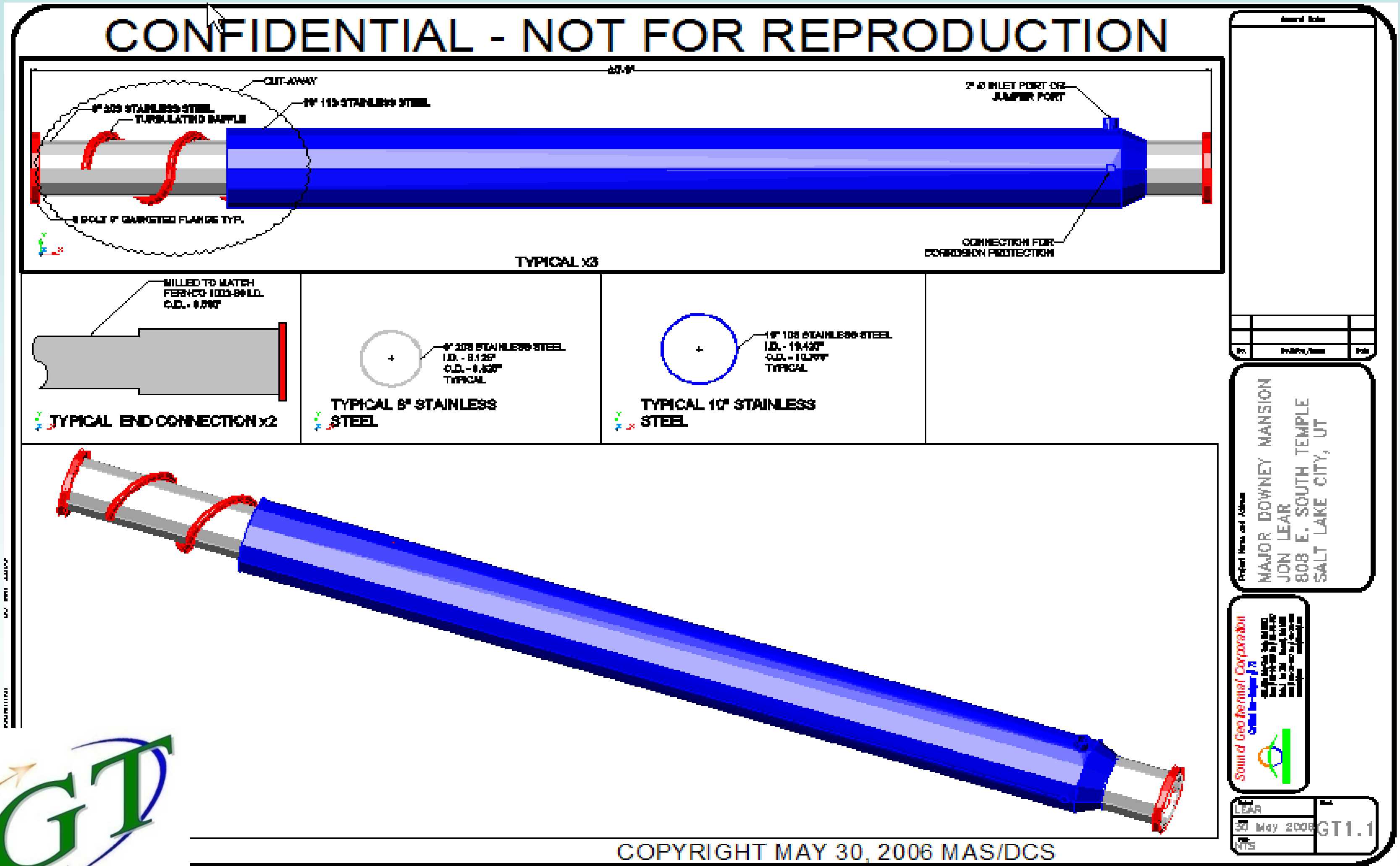
Black Water Heat Exchanger
Major Downey Mansion



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OVERVIEW

DESIGN CONSIDERATIONS
- Thermal conductivity testing
- Loop design parameters
- Physical loop design considerations

HYBRID SYSTEMS
- Overview

Economics

Renewable Utilities

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What we need to know about the earth before design of the loop.

- –Soil properties – Type of soil
- –Earth temperature
- –Formation Thermal Conductivity (k - Btu/hr-ft-°F)
  - •A measure of a material's ability to conduct heat.
- –Formation Thermal Diffusivity (α=k/ρc - ft2/day)
  - •Ratio of heat conduction rate to heat storage capacity.
- –Excavation or drilling characteristics

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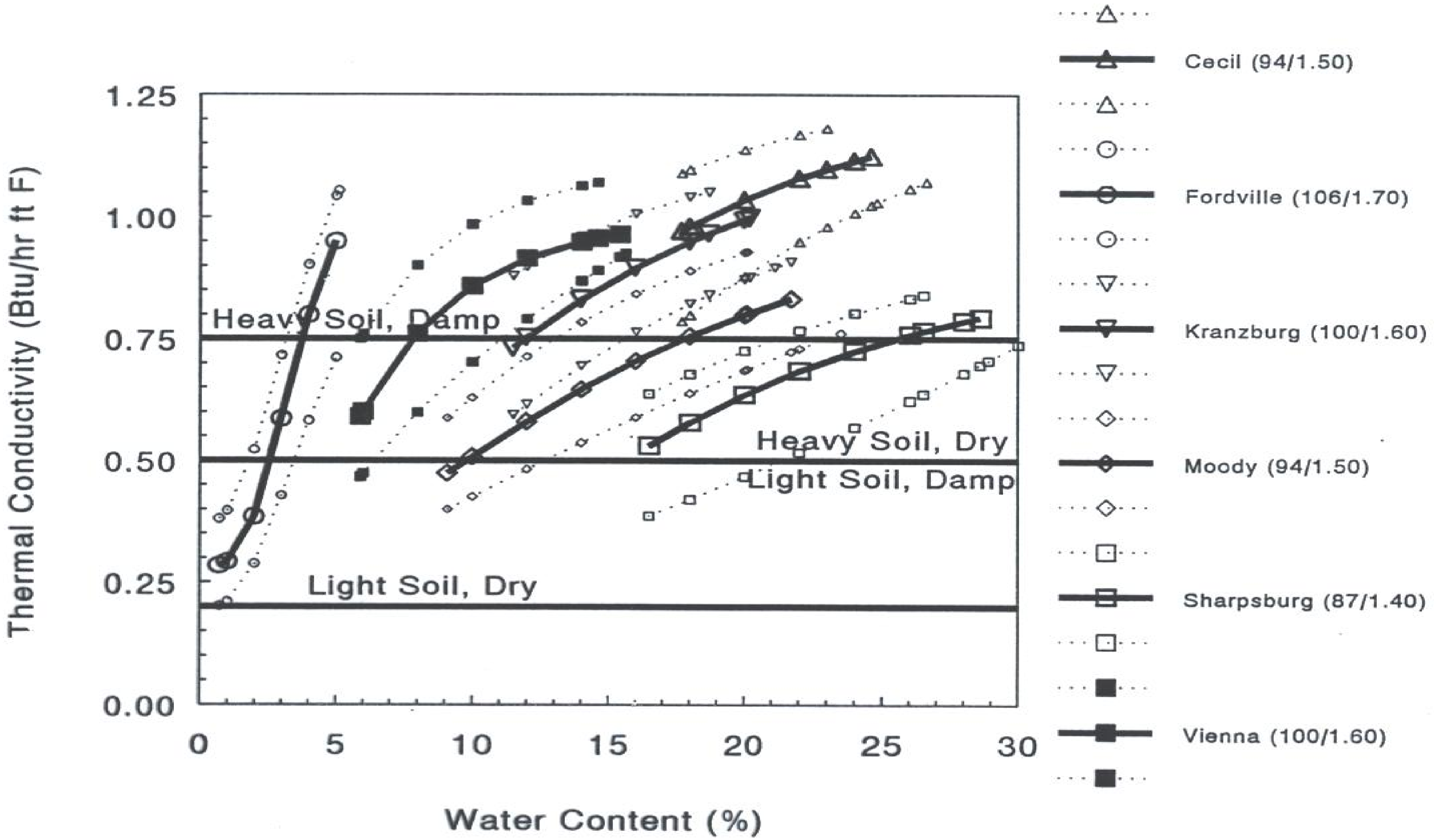
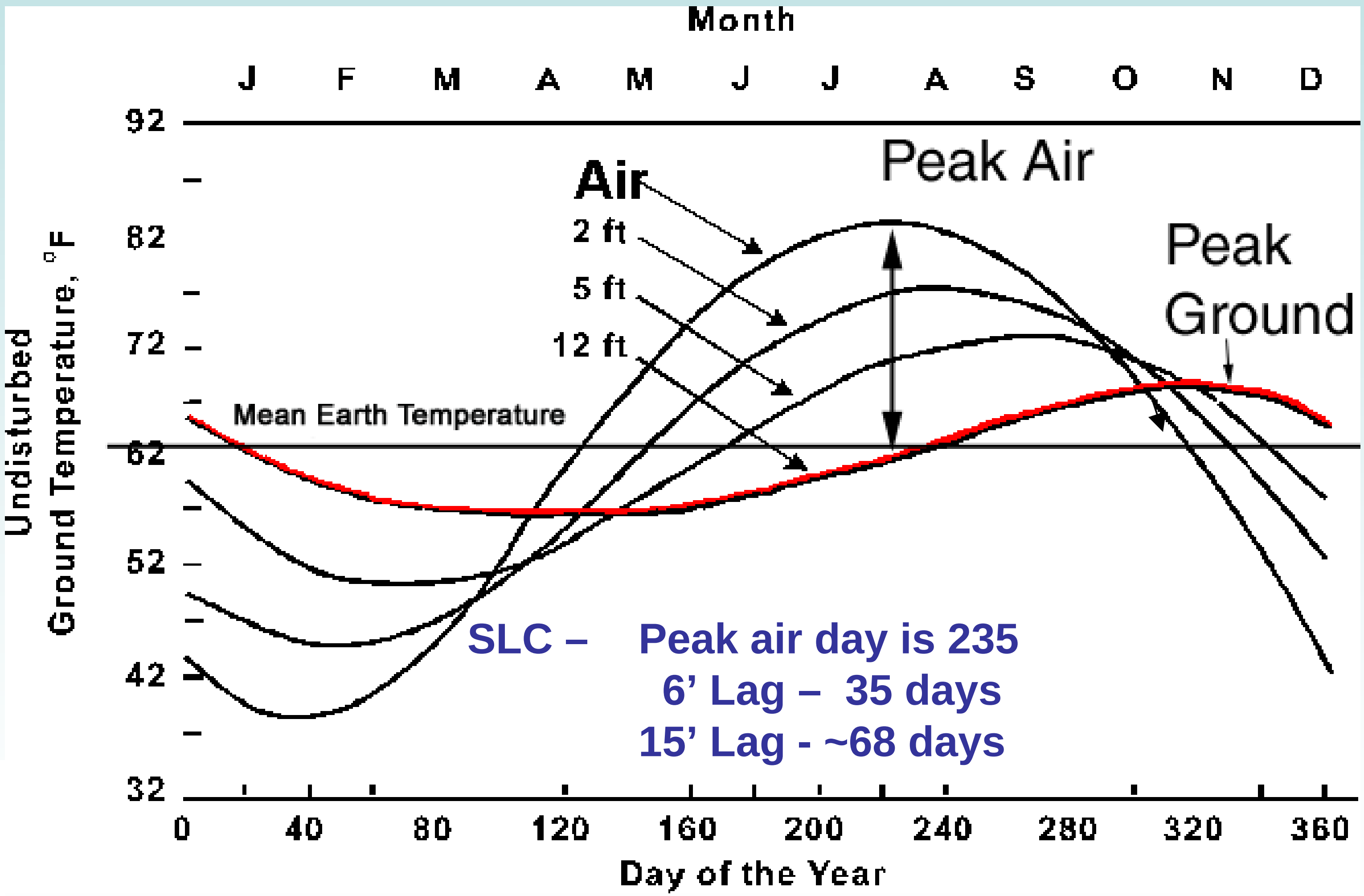
Shallow Loops- Soil Thermal Groups

- Coarse-Grained
  - Water content has large effect
  - Higher values of thermal conductivity if dirty
- Fine-Grained
  - Silt or Clay
  - Silts have higher thermal conductivity values
- Loam
  - Mixture of sand, silt and clay

Moisture content is very important:



Constant Earth Temperatures Compared to Air



Vertical Boreholes

Most of the GX sites in Utah will fall into one of three hard-rock categories.

However, thermal conductivity is highly variable.

T-3.5

Petrologic Groups

Petrologic Group Number	Principal Rock Type
1	Pumice, obsidian, perlite
2	Basalts
3	Andesite, rhyolite
4	Mudstones
5	Granite, granodiorite, quartz, monzonite, diorite, diabase, gabbro, peridotite
6	Schist, amphibolite, gneiss, phyllite
7	Limestone, dolomite, marble
8	Sandstone and tuff

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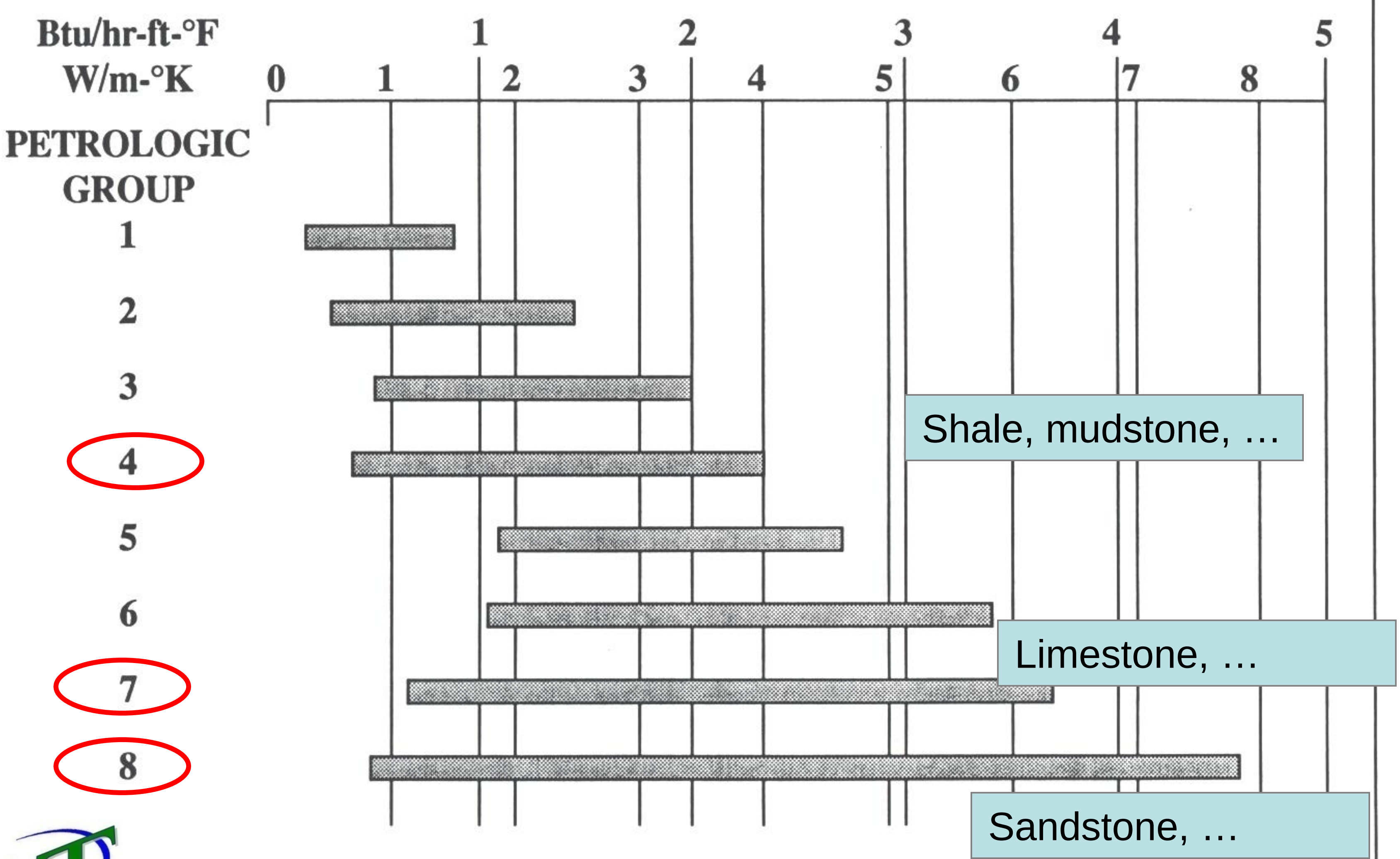
Thermal Conductivities of Petrologic Groups



T-3.4

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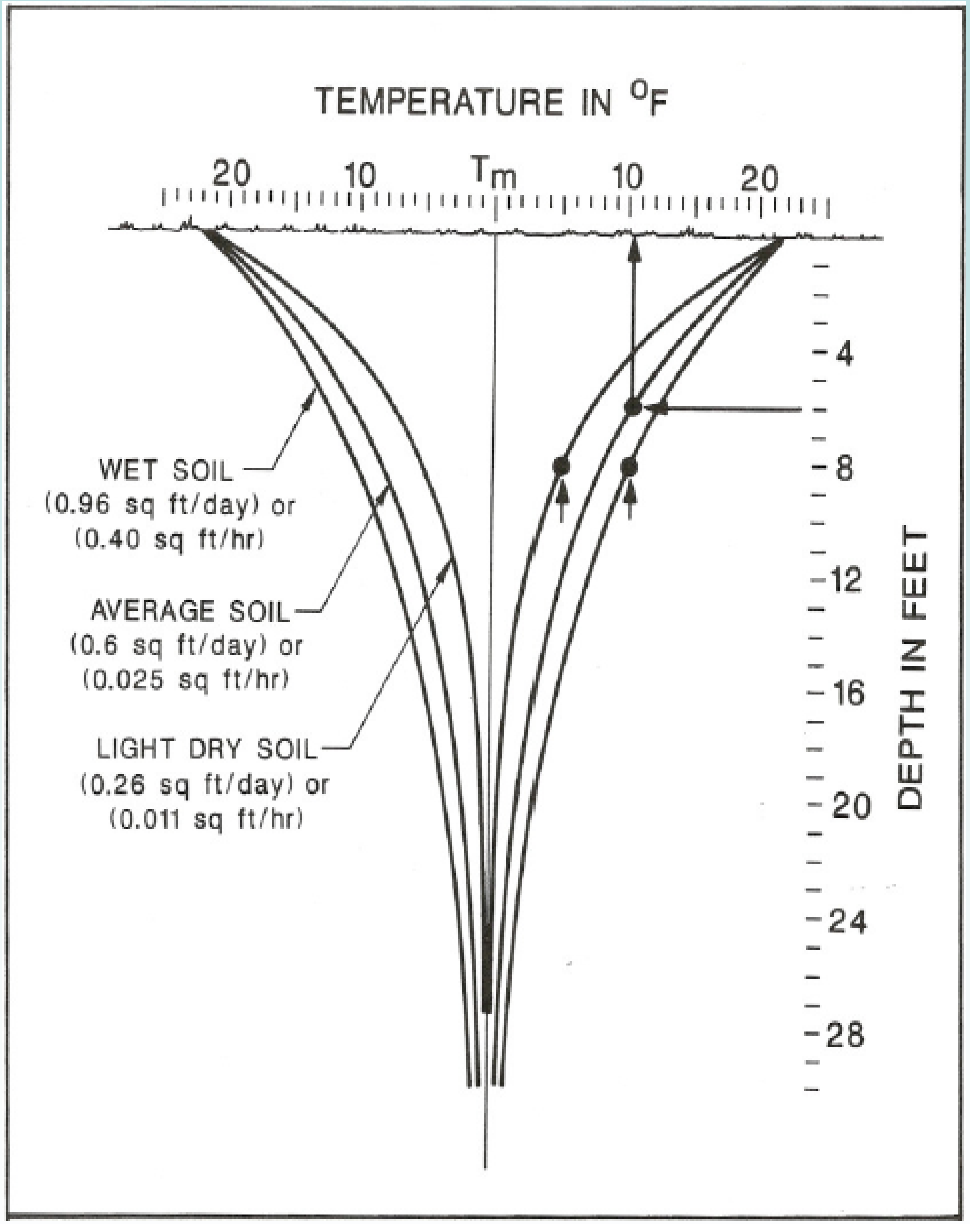
Soil Temperature

- Soil temperature is variable to about 26 feet.
- At ~26 feet the temperature is +/- 2^{o} F of the mean surface air temperature.
- Generally, below ~26' to approximately 1,000', the earth temperature will remain constant.
- Geologic anomalies (faults, thermal intrusions, etc.) may change this rule of thumb.



What we need to know about the earth before design of the loop.

- Soil properties – Type of soil
- Earth temperature
- Formation Thermal Conductivity (k - Btu/hr-ft-°F)
  - A measure of a material's ability to conduct heat.
- Formation Thermal Diffusivity ($\alpha=k/\rho c$ - ft2/day)
  - Ratio of heat conduction rate to heat storage capacity.
- Excavation or drilling characteristics

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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."

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Formation Thermal Conductivity Testing

Other than building load distribution, soil (earth) conditions are the largest factor in determining the shortest necessary loop length, either conventional or hybrid.

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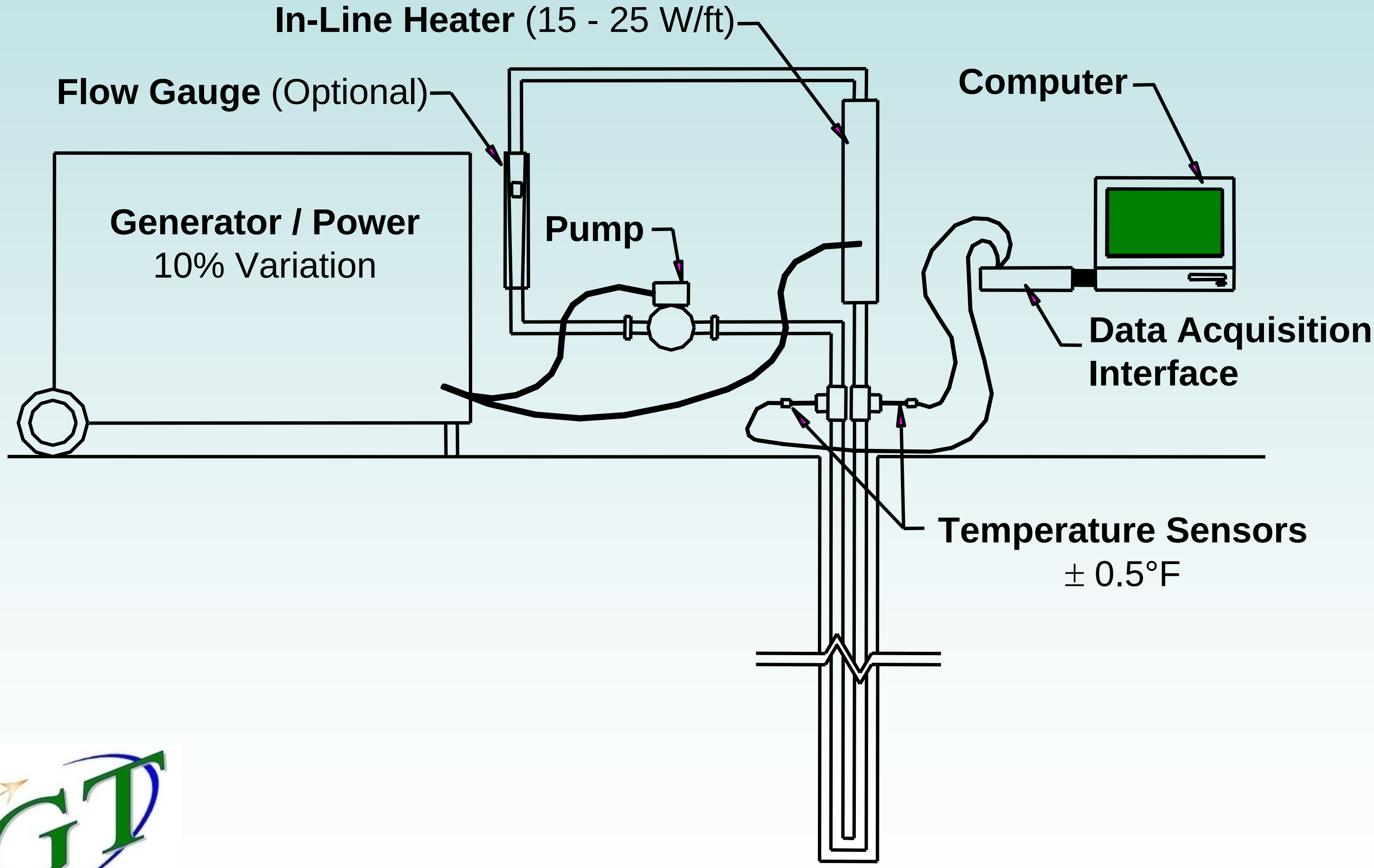
Fundamentals



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ASHRAE Recommended Procedures

ASHRAE's 2003 HVAC Applications handbook, page 32.14

- **Required Test Duration** – 36 to 48 hours.
- **Power**
  - Standard deviation ≤ 1.5% of average.
  - Maximum power variation ≤ 10 % of average.
  - Heat flux rate between 15 W and 25 W per foot of bore.
- **Undisturbed Soil Temperature** – Shall be determined by recording the minimum loop temp. at startup.
- **Installation Procedures** – Bore dia. ≤ 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.

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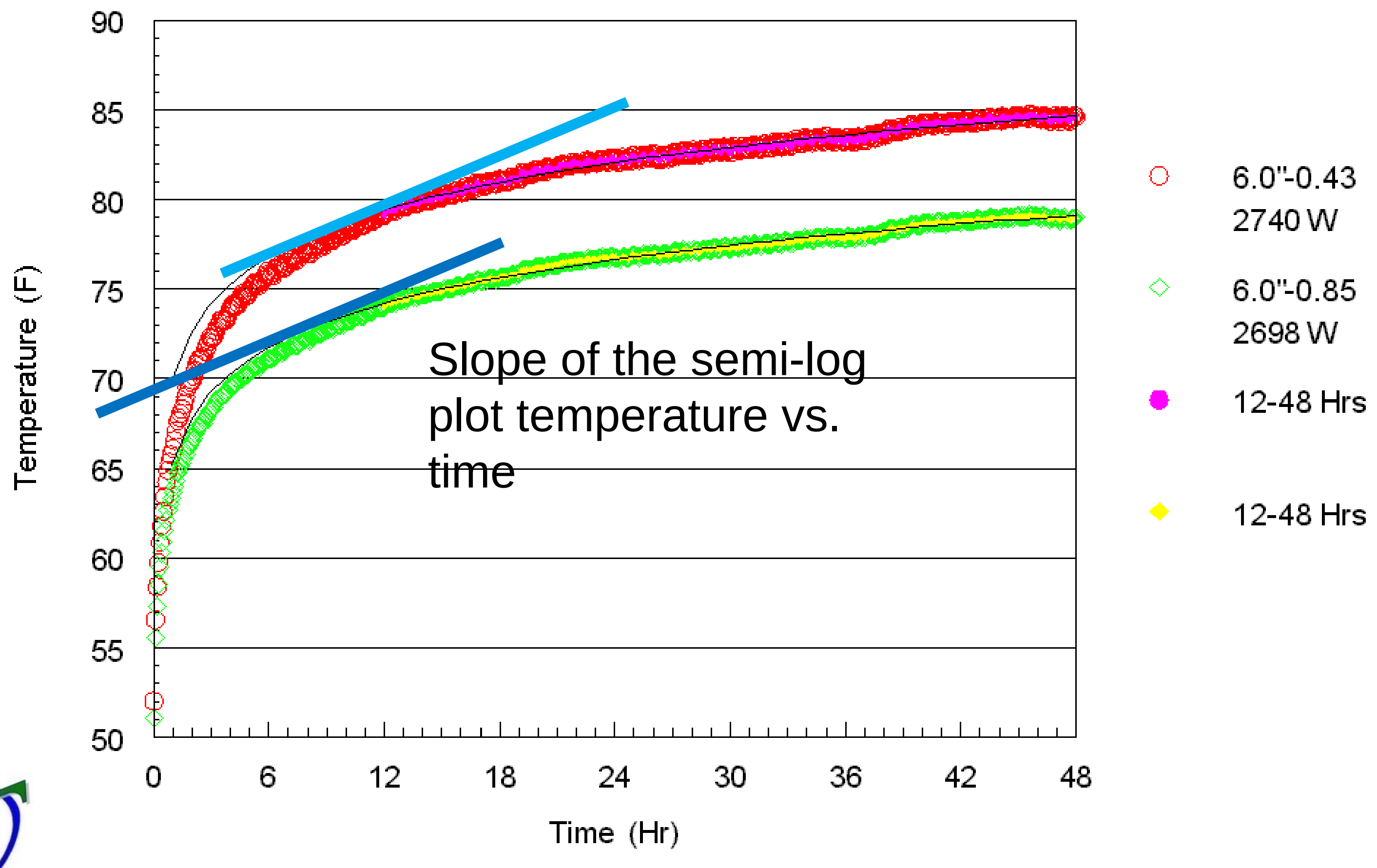
Thermal Conductivity on the FTC Test



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GeoTec Supplied Drill Logs

JUAB SCHOOL DISTRICT
Nephi, UT - New Red Cliffs Elementary School
Geothermal Soil Analysis

DRILLING LOG - Test Borehole #1
3/20/2007

Location:	S, T, R - if known	N1165.17 E943.97, SW corner, 09-13S-1E, SL b&m
	GPS and Elevation:	N 39 41.602 W 111 49.990 NAD27 CONUS
	Nephi, UT	5,151

Driller:	Bertram Drilling			
State License #:	34		24	Joints on rig
Rig:	Mayhew 1000		15'	Length of Kelly
Drilling Fluid:	water based mud			
Loop:	Brand, size, length	Centennial, 1.25", 810		
Grout:	Cetco Geothermal Grout	TC - 0.40		
SPUD/TD	3/20/2007		3/21/2007	
	Spud with Medium Mill Tooth			
	Average ROP - 55-70			

NOTE: Time gaps represent connections or unrelated activity

Surface Water - None encountered

Time Start	End	Activity	Duration Minutes	Depth		Comments
3/20/2007						
9:25	9:27	D	**2**	0-15	A	top soil, silt & clay
9:35	9:37	D	**2**	15-30	L	Change to 4-way blade bit brn. Cly, gravel
9:53	10:35	D	**42**	30-45	L	A/A - Changed to rock bit @ 40' , COH,
					U	cobble fall in, had to re-drill 6-7 feet
					V	Coarse gravel and valley fill+/- 40-45'
					I	Oquirrh rubble- cleaned up ledges 10:35-10:40
10:41	10:49	D	**8**	45-60	A	Oquirrh rubble
10:56	11:01	D	**5**	60-75	L	A/A - clean up ledges

Juab Elementary Drilling Log.xls

Added:

- Drilling times
- Bits used
- General comments
- Additional pertinent data needed for absent drillers to bid.

11:18	11:25	D	**7**	75-90		brn clay w/ bigger gravel/fill clean up ledges
11:41	12:18	D	**37**	90-105	F	POOH @ 95' - bit jet holes pulgged
					A	12:10 - drill again - coarse gravel and fill w/ brn cly
12:21	12:33	D	**12**	105-120	N	Coarse gravel & fill w/ brn cly
12:39	12:54	D	**15**	120-135		A/A
12:59	13:08	D	**9**	135-150	F	A/A
13:10	13:16	D	**6**	150-165	O	A/A
13:21	13:26	D	**5**	165-180	R	A/A - clean up ledges, and fix cable on rig
13:39	13:48	D	**9**	180-195	M	Coarse gravel & fill w/ brn cly @14:02, had to redrill last 8'
14:07	14:20	D	**13**	195-210	A	Coarse sand & gravel
14:26	14:31	D	**5**	210-225	T	A/A (silty)
14:35	14:41	D	**6**	225-240	I	A/A - w/ brn cly
14:44	14:50	D	**6**	240-255	O	Coarse gravel/fill w/ brn cly
14:54	14:59	D	**5**	255-270	N	A/A
15:06	15:15	D	**9**	270-285		A/A - (worked on rig set-up 15:15-15:25)
15:25	15:48	D	**23**	285-300		Coarse cemented sand & gravel
						snappy, slower drilling 290-300' (approx. 15:30)
15:54	16:20	D	**26**	300-315		A/A - snappy, slower drilling
16:28	16:44	D	**16**	315-330		A/A - snappy, slower drilling
16:52	17:06	D	**14**	330-345		A/A - snappy, slower drilling
17:23	17:39	D	**16**	345-360		A/A - snappy, slower drilling
						320' tremie
		Cond Hole	**15**			- POOH 15 bags of grout
Total Drilling Time:			298.00	Minutes		Drilling 0 - 360'
			4.97	Hours		

0 - 40' - Easy drilling through top soil, silt and clay. Balance of hole coarse sand and gravel w/ clay.
Pressure test loop to 115 psi - no leaks.
30 min to POOH. Bit in marginal cond. RIH with U-bend to 355' and tremie to 320'.
RU grout equip, mix grout.

COMMENTS:

Approximately 3500 gallons of water was used for the hole.
The majority of the lithology in test hole was comprised of Oquirrh rubble w/ valley fill and alluvial sand and clay
15 sacks of Cetco Geothermal Grout to 320'

May determine optimum depth.

OVERVIEW

DESIGN CONSIDERATIONS

- Thermal conductivity testing
- Loop design parameters
  - Loads
  - Earth Data
  - Time

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Some GHP Design Considerations: Loop Sizing

- Closed-loop lengths depend on:
  - Peak hourly load
  - Annual heating loads vs. annual cooling loads
  - Optimum loop lengths occur when annual loads are balanced (or the appropriate hybrid length is used).

- Open-loops:
  - Required groundwater flow rate depends on its temperature (usually about 2 gpm/ton)
  - Groundwater quality and regulations!!

Loop Design Load Format - Spitler

BULDING LOAD

- 24 hour load profile
- Peak Monthly H/C load
- Cumulative monthly energy use
- Duration of peak loads

Edit Loads on GLHE

Load on GLHE

Month	Total Heating 1000 Btu	Total Cooling 1000 Btu	Peak Heating 1000 Btu/hr	Peak Cooling 1000 Btu/hr
January	280375	1021551	950.739	1502.966
February	304921	906373	1098.53	1467.549
March	433548	977420	1238.893	1366.674
April	581118	938692	1400.184	1315.121
May	912353	967974	1850.076	1301.04
June	1056029	936749	2076.385	1301.04
July	1263996	967974	2288.328	1301.04
August	1200461	967974	2223.274	1301.04
September	989574	936749	2083.646	1301.04
October	738227	967985	1720.431	1301.996
November	348402	952482	1085.548	1385.772
December	308057	1002320	974.592	1443.149

Duration of Peak Loads

Number of Peak heating hours : 6

Number of Peak Cooling hours : 6

Warning : Changing the Duration of Peak Loads here also changes the Duration of Peak Loads of Heat Pump loads

Clear Loads | Copy | Paste | Cancel | OK

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Loop Design Load Format – Kavanaugh/Peterson

<u>BULDING LOAD</u>

- 24 hour load profile
- Peaks during design day periods
- ASHRAE RP 1120 “Development of Equivalent Full Load Heating and Cooling Hours for GSHPs”

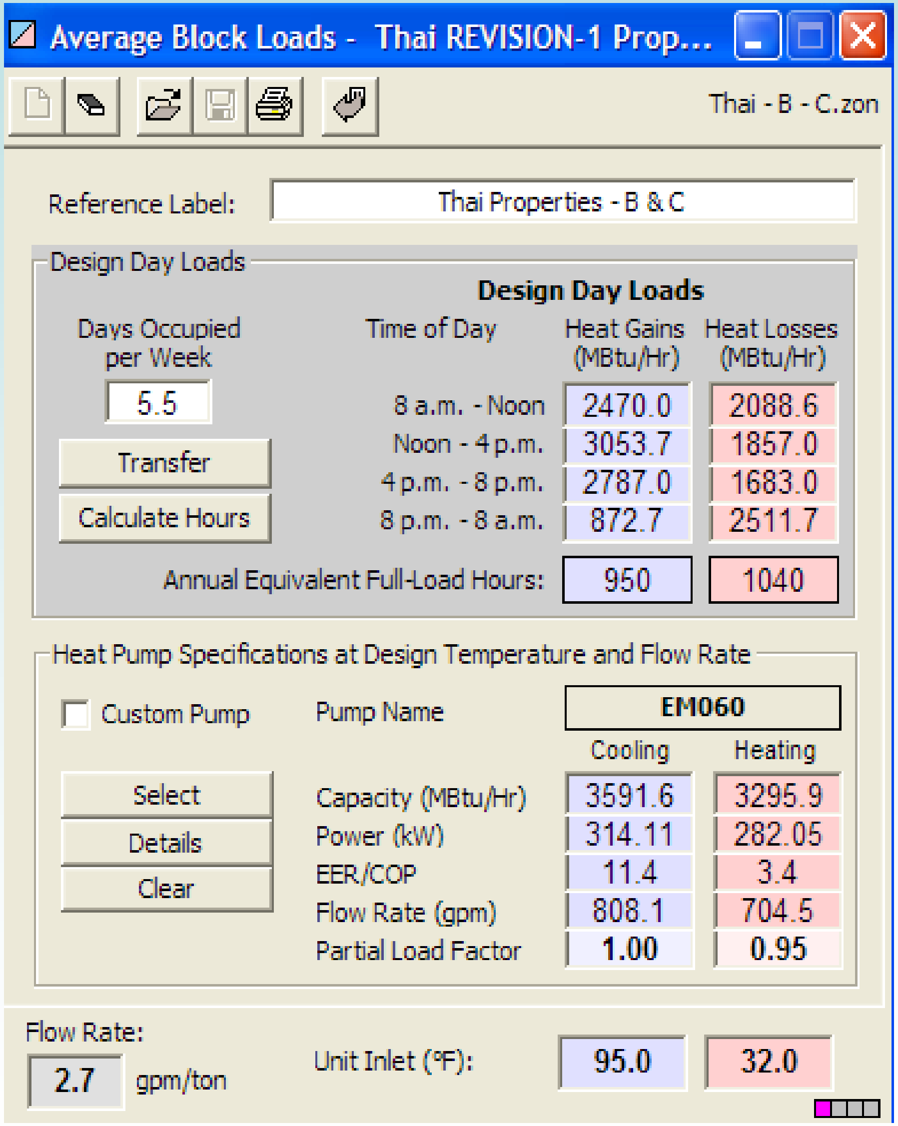

TABLE 6 (Continued)
Equivalent Full-Load Hours for Typical Occupancy with Constant Temperature Setpoints

City	St	EFLH School[1] Occupancy		EFLH Office[2] Occupancy		EFLH Retail[3] Occupancy		EFLH Hospital[4] Occupancy	
		Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling
Nashville	TN	320 - 250	570 - 740	680 - 590	830 - 1,280	590 - 470	1,030 - 1,710	450 - 240	1,490 - 2,620
New Orleans	LA	110 - 67	920 - 990	320 - 230	1,500 - 1,720	260 - 160	1,820 - 2,240	160 - 46	2,500 - 3,280
New York City	NY	440 - 350	360 - 550	870 - 790	540 - 1,040	760 - 630	720 - 1,480	590 - 330	1,160 - 2,440
Omaha	NE	400 - 330	310 - 440	800 - 720	480 - 820	720 - 600	610 - 1,130	570 - 360	920 - 1,780
Phoenix	AZ	110 - 65	950 - 1,020	290 - 210	1,340 - 1,610	250 - 170	1,630 - 2,090	140 - 34	2,220 - 3,040
Pittsburgh	PA	500 - 470	300 - 530	950 - 910	440 - 920	840 - 750	600 - 1,310	650 - 420	960 - 2,160
Portland	ME	480 - 400	190 - 300	980 - 880	310 - 630	870 - 710	410 - 900	690 - 420	700 - 1,520
Richmond	VA	410 - 270	630 - 730	820 - 660	880 - 1,310	710 - 520	1,110 - 1,770	530 - 250	1,650 - 2,760
Sacramento	CA	360 - 220	680 - 850	990 - 640	1,080 - 1,430	830 - 480	1,460 - 2,020	540 - 120	2,250 - 3,180
Salt Lake City	UT	540 - 520	410 - 710	1,060 - 1,040	510 - 1,090	930 - 830	660 - 1,520	720 - 440	1,060 - 2,470
Seattle	WA	650 - 460	260 - 460	1,370 - 1,270	440 - 1,200	1,170 - 960	710 - 1,860	850 - 360	1,340 - 3,270
St. Louis	MO	400 - 280	460 - 550	800 - 710	680 - 1,100	700 - 570	850 - 1,500	550 - 320	1,260 - 2,330
Tampa	FL	58 - 35	1,050 - 1,110	190 - 140	1,800 - 2,000	160 - 100	2,170 - 2,580	90 - 22	2,910 - 3,710
Tulsa	OK	300 - 240	580 - 770	620 - 560	830 - 1,300	540 - 450	1,030 - 1,730	410 - 220	1,470 - 2,630

General Table Notes:
(1) The ranges in values are from internal gains at 0.6 W/ft^2 (6.5 W/m^2) and 2.5 W/ft^2 (27 W/m^2).
(2) Operating with large temperature setbacks during unoccupied periods (effectively turning off the system) reduces heating EFLHs by 20% and cooling EFLHs by 5%.

OVERVIEW

DESIGN CONSIDERATIONS

- –Thermal conductivity testing
- –Loop design parameters
  - •Loads
    - »Earth Data

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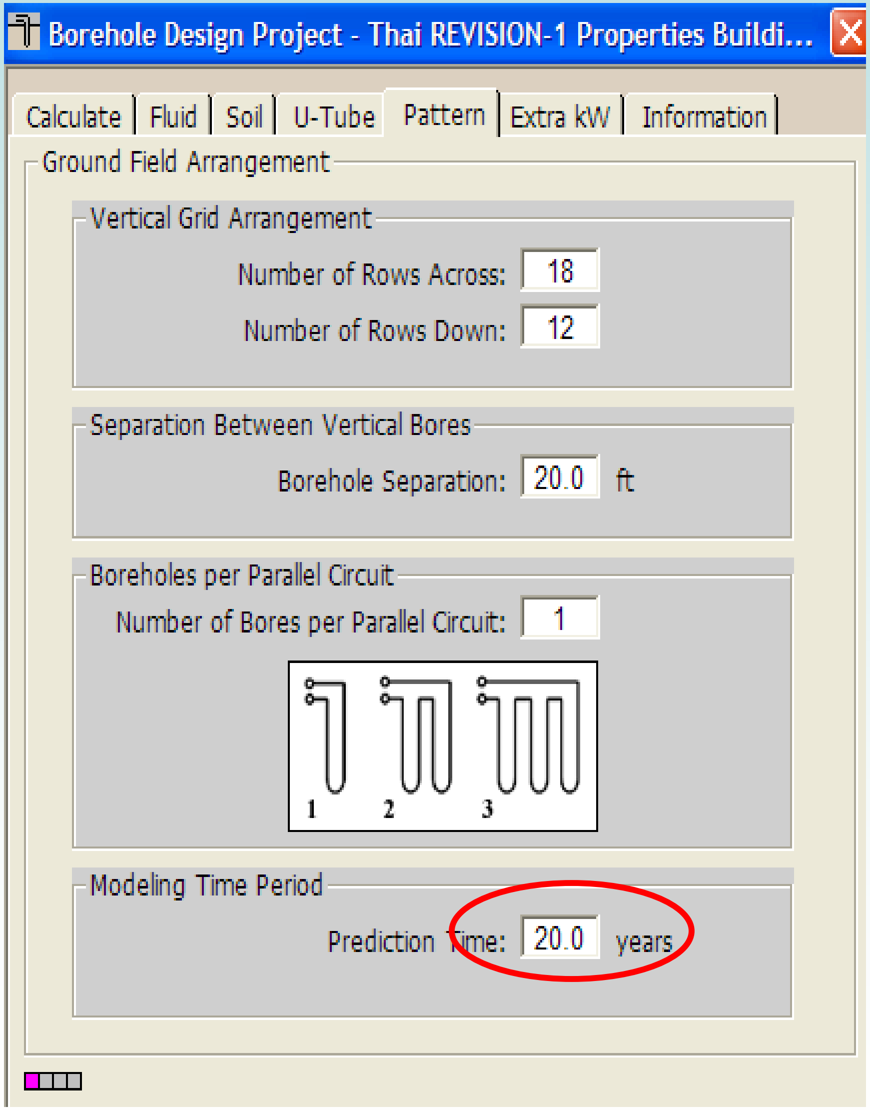
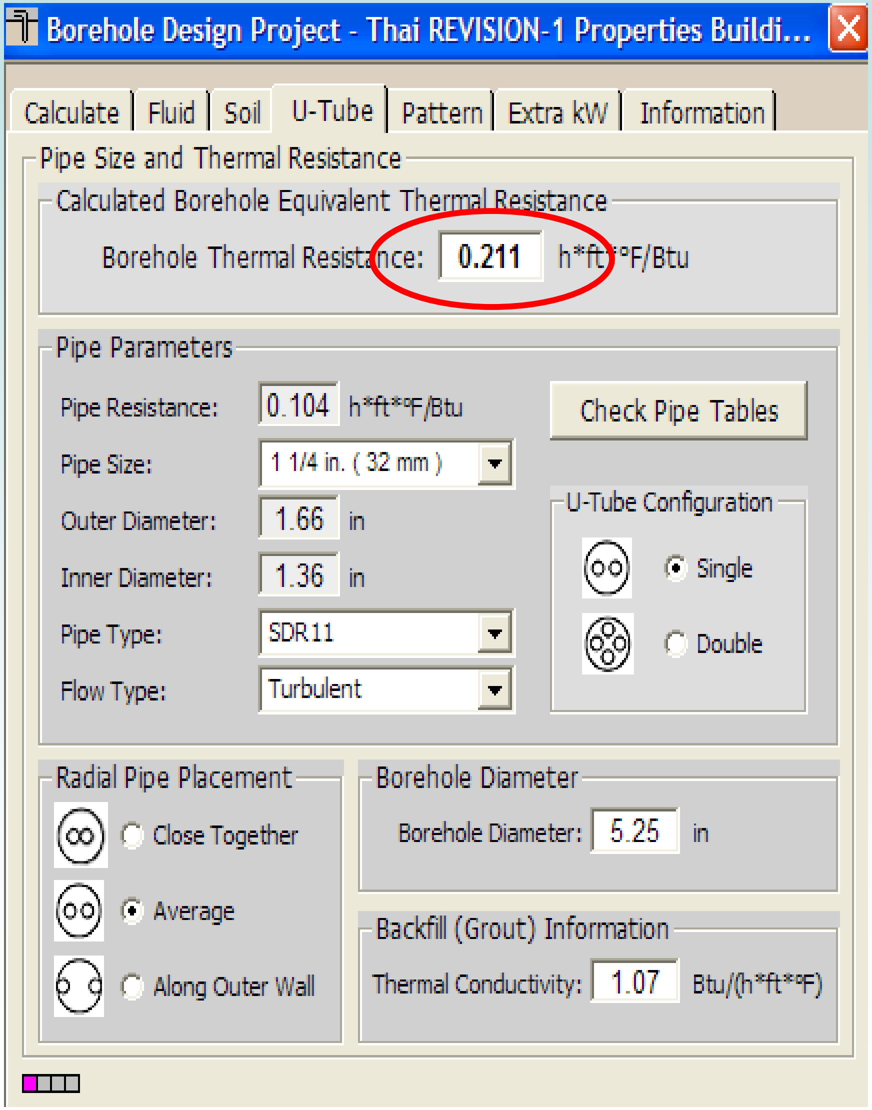
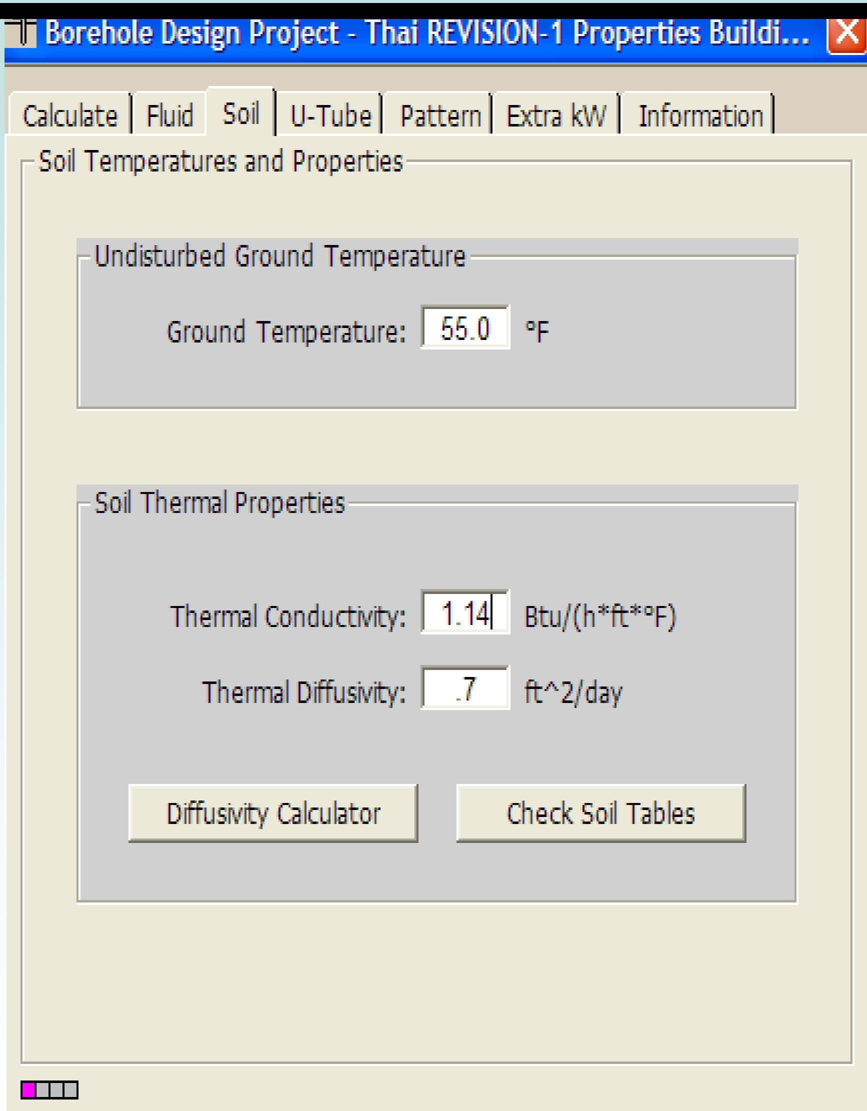
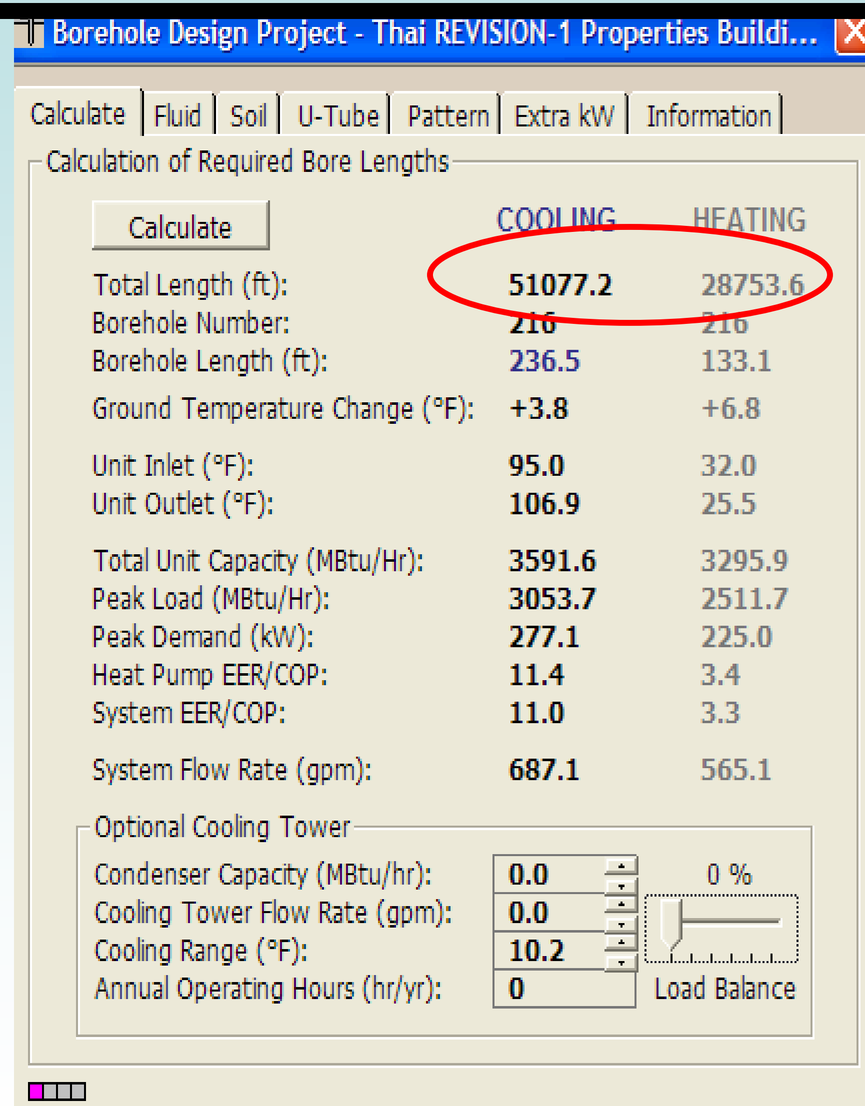
Add Drilling Parameters






Borehole Design Project - Thai REVISION-1 Properties Buildi...
Calculate
Fluid
Soil
U-Tube
Pattern
Extra kW
Information
Soil Temperatures and Properties
Undisturbed Ground Temperature
Ground Temperature: 55.0 °F
Soil Thermal Properties
Thermal Conductivity: 1.14 Btu/(h*ft*°F)
Thermal Diffusivity: .7 ft^2/day
Diffusivity Calculator
Check Soil Tables


Borehole Design Project - Thai REVISION-1 Properties Buildi...
Calculate
Fluid
Soil
U-Tube
Pattern
Extra kW
Information
Calculation of Required Bore Lengths
Calculate
COOLING HEATING
Total Length (ft): 51077.2 28753.6
Borehole Number: 216 216
Borehole Length (ft): 236.5 133.1
Ground Temperature Change (°F): +3.8 +6.8
Unit Inlet (°F): 95.0 32.0
Unit Outlet (°F): 106.9 25.5
Total Unit Capacity (MBtu/Hr): 3591.6 3295.9
Peak Load (MBtu/Hr): 3053.7 2511.7
Peak Demand (kW): 277.1 225.0
Heat Pump EER/COP: 11.4 3.4
System EER/COP: 11.0 3.3
System Flow Rate (gpm): 687.1 565.1
Optional Cooling Tower
Condenser Capacity (MBtu/hr): 0.0
Cooling Tower Flow Rate (gpm): 0.0
Cooling Range (°F): 10.2
Annual Operating Hours (hr/yr): 0
0 %
Load Balance

Sensitivity of loop length to changes in earth thermal conductivity/diffusivity and deep earth temperature.

Starting GX Length: 51,077 (ft.)

Parameter	**Change**	**New GX Length**	**% Change**
Thermal Conductivity/Diffusivity	20%	59,309	~16%
Deep Earth Temperature	20%	65,295	~ 27%
Change Both	20%	75,818	~48%

OVERVIEW

DESIGN CONSIDERATIONS

- –Thermal conductivity testing
- –Loop design parameters
- –Physical loop design considerations

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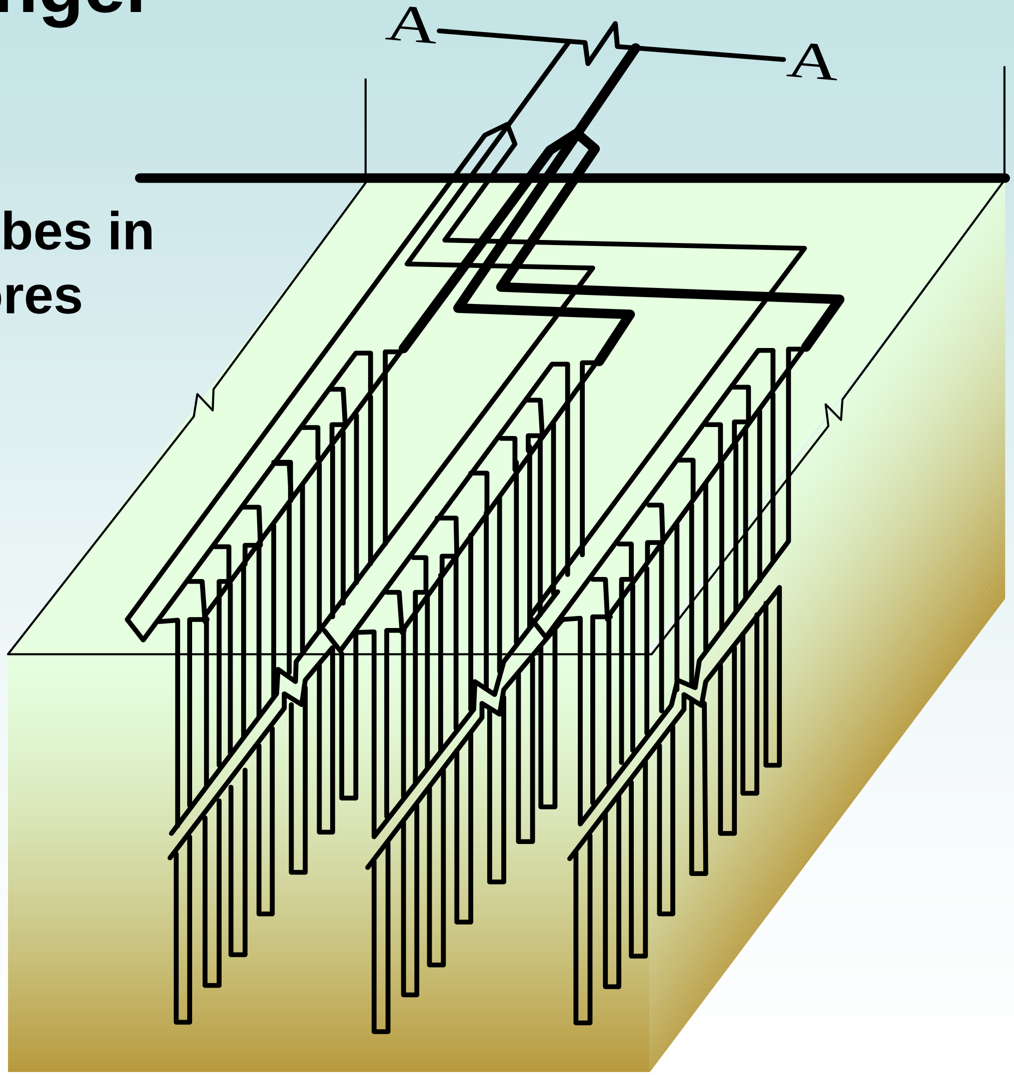
Common loop conditioned by vertical ground heat exchanger



HDPE u-tubes in vertical bores

Generally requires 250-625 ft^2 of land area per ton

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Remember: The object is to reduce energy use, reduce life cycle cost, and increase comfort.

Design boreholes to optimum depth.

Shortening the boreholes to 270 feet could save about $2 – $3 a vertical foot.

~$85,000.

14:54	14:59	D	5	255-270	N	A/A
15:06	15:15	D	9	270-285		A/A - (worked on rig set-up 15:15-15:25)
15:25	15:48	D	23	285-300		Coarse cemented sand & gravel
						snappy, slower drilling 290-300' (approx. 15:30)
15:54	16:20	D	26	300-315		A/A - snappy, slower drilling
16:28	16:44	D	16	315-330		A/A - snappy, slower drilling
16:52	17:06	D	14	330-345		A/A - snappy, slower drilling
17:23	17:39	D	16	345-360		A/A - snappy, slower drilling

May determine optimum depth.

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Design around a vertical pipe size that keeps the loop fluid in turbulent flow <u>at a minimum pressure drop.</u> If possible less than 1 FOH/100'.

1" pipe - <~3.75 gallons/borehole. (water)

1.25" Pipe - <~7.00 gallons/borehole. (water)

Benchmarks for GX System Pumping
@ 2.5 - 3 gpm/ton

Pump Power-Cooling Capacity Watts Input/Ton	Pump Power-Cooling Capacity HP/100 Ton	Grade
50 or less	5 or less	A - Excellent
50 to 75	5 to 7 1/2	B - Good
75 to 100	7 1/2 to 10	C - Mediocre
100 to 150	10 to 15	D - Poor
Greater than 150	Greater than 15	F - Bad

Kavanaugh and Rafferty " Design of Geothermal Systems for Commercial and Institutional Buildings"

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OVERVIEW

DESIGN CONSIDERATIONS

- –Thermal conductivity testing
- –Loop design parameters
- –Physical loop design considerations

HYBRID SYSTEMS

- –Overview

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Hybrid Geothermal

- Geothermal heat pumps provide heating and cooling inside the building
- GHPs reject to ground heat exchangers
- Loop also includes one or more supplemental fluid coolers (dry cooler or cooling tower)
- Can also include supplemental boilers

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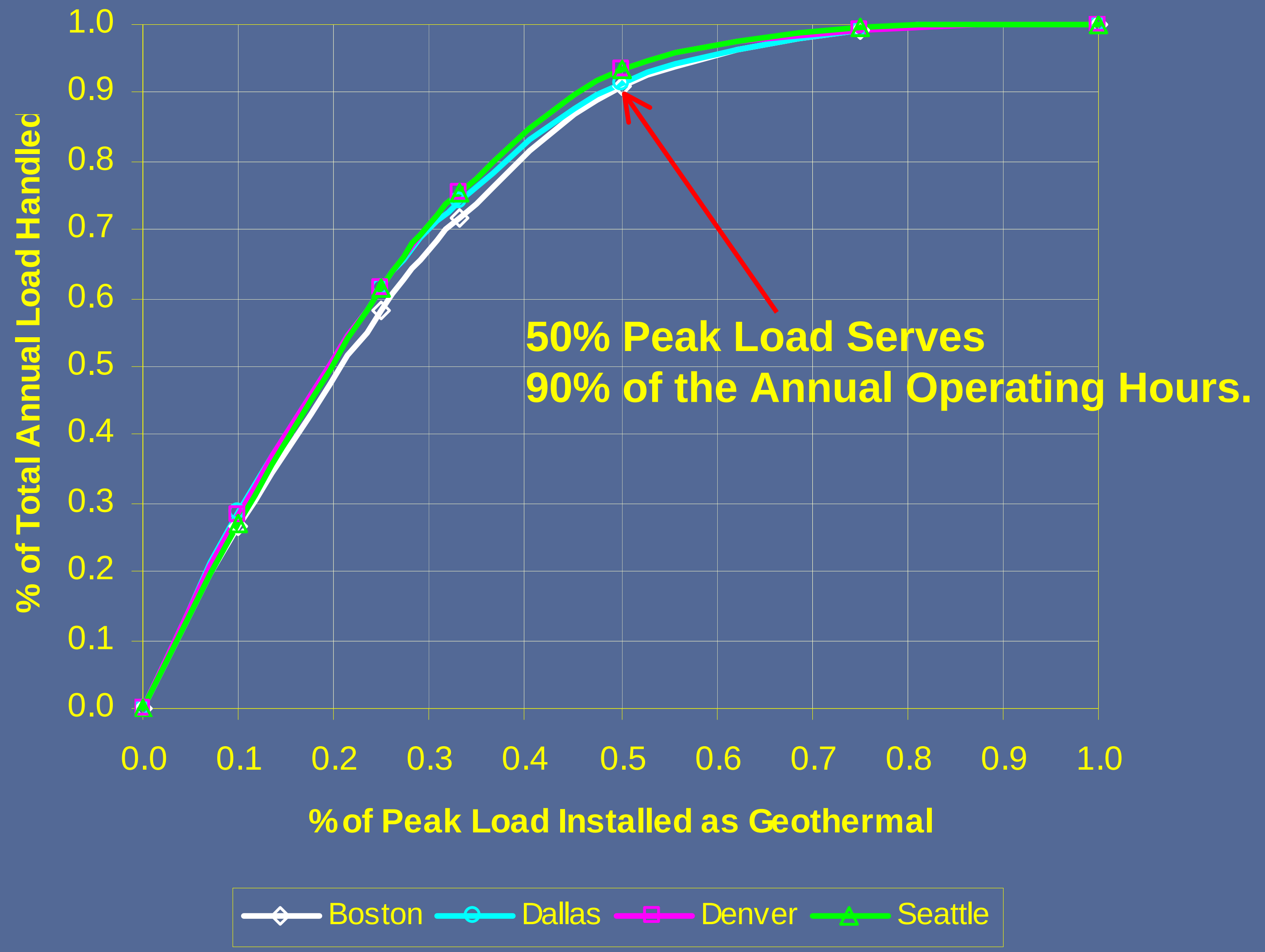
WHY HYBRIDS ARE CONSIDERED

- Ground heat exchanger for GHP is costly
- More imbalanced loads require more ground heat exchanger length
- GHPs can be very expensive in heavily cooling- or heating-dominated climates/applications

- With a hybrid system, the size of the ground heat exchanger can be reduced
  - Fluid cooler provides additional heat rejection capacity in cooling-dominated applications and there is still a significant reduction in water use
  - Overall system cost is reduced
  - Energy use is about the same

Some GHP Design Considerations: Peak vs. Annual Loads



Bin Analysis – Weather Data Example 8,760 hours/year

Building Loads

Heating: 259,000 btu/h

Cooling: 235,000 btu/h

59% of cooling load 139,345 btu/h

57.1% of heating load 148,183 btu/h

Fluid Cooler will run: 249 h/yr

Economizer will run: 2,473 h/yr

GX System will run: 5,660 h/y

Boiler will run: 372 h/yr

Temperature Bin Analysis

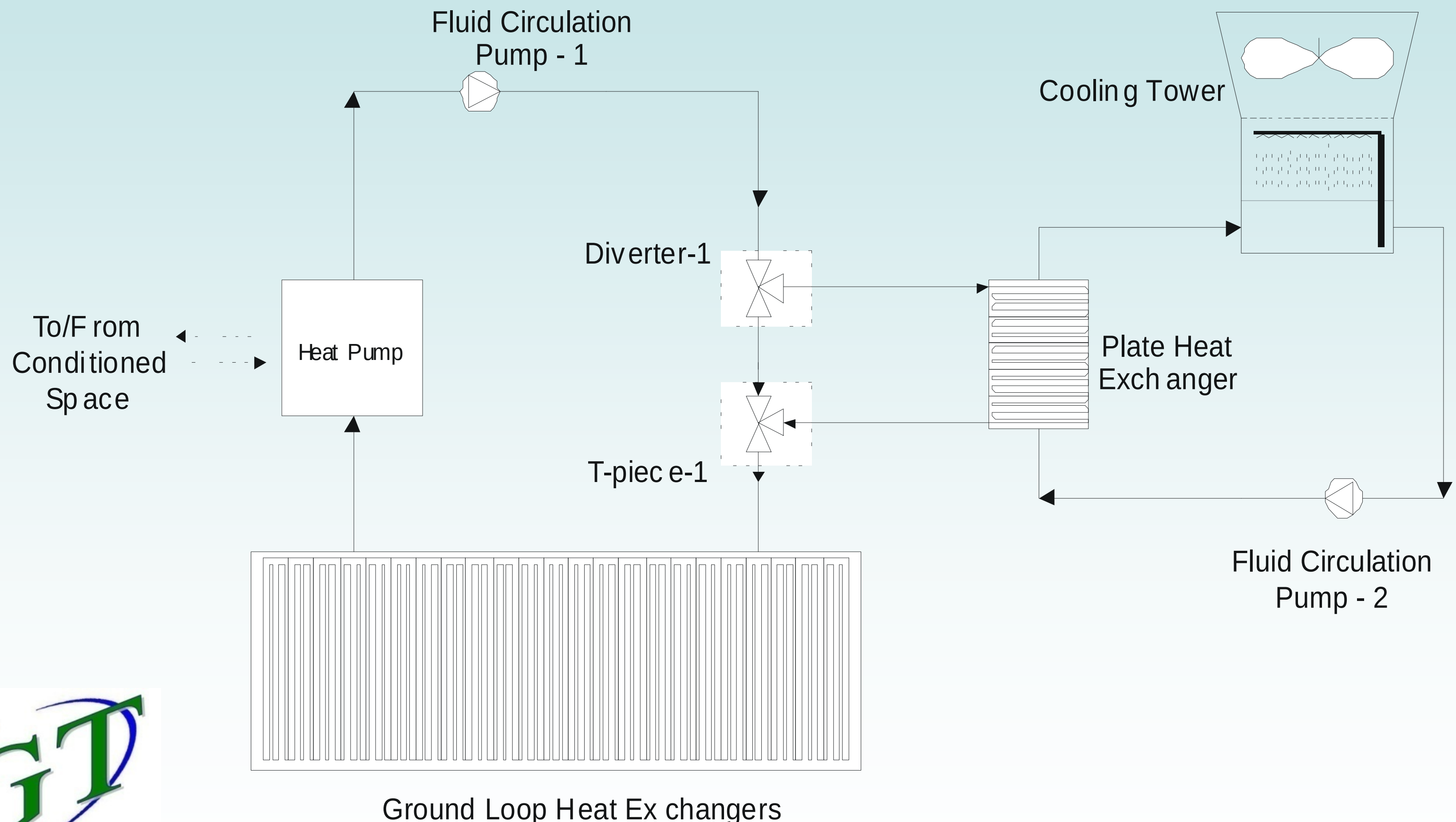
Grand Junction Colorado.

Heating 259,000 btu/h
Cooling 235,000 btu/h.

Outdoor Air Temp	Annual Weather Hours	Space Load Btu/Hr	Hot Water Load Btu/Hr	Geo Source Temp	Air Capacity Btu/Hr	Hot Water Capacity Btu/Hr	Geo Run Time	Geo Operating Cost	Aux Heating Cost	Aux Hot Water Cost
112										
107						Desuperheater only				
102	1	249,716	2,278	80	249,716	2,278	100%	$1.21		
97	51	212,926	2,278	75	237,665	2,542	90%	$48.58		
92	197	176,135	2,278	71	241,972	3,129	73%	$147.00		
87	315	139,345	2,278	66	246,199	4,024	57%	$175.97		
82	405	102,555	2,278	62	250,351	5,560	41%	$157.42		
77	547	65,764	2,278	57	254,433	8,812	26%	$128.75		
72	657	51,048	2,278	56	255,991	8,484	20%	$117.39		$8.46
67	721		2,278							$28.87
62	666		2,278							$26.67
57	615	-8,721	2,278	57	233,796	21,882	4%	$17.73		$11.85
52	588	-28,644	2,278	55	232,134	18,459	12%	$55.29		
47	604	-48,567	2,278	54	234,857	11,014	21%	$93.92		
42	642	-68,490	2,278	52	233,406	7,762	29%	$139.76		
37	686	-88,413	2,278	51	230,543	5,939	38%	$192.51		
32	757	-108,336	2,278	49	227,040	4,773	48%	$260.66		
27	583	-128,259	2,278	48	223,200	3,964	57%	$238.34		
22	353	-148,183	2,278	46	219,164	3,369	68%	$167.36		
17	196	-168,106	2,278	45	215,008	2,913	78%	$105.88		
12	100	-188,029	2,278	43	210,777	2,553	89%	$60.72		
7	47	-207,952	2,278	42	207,952	2,278	100%	$31.78		
2	20	-227,875	2,278	40	227,875	2,278	100%	$15.30		
-3	7	-247,798	2,278	39	247,798	2,278	100%	$5.99		
-8	2	-267,721	2,278	38	267,028	2,278	100%	$1.89	$0.02	
-13										
-18										
-23										
-28										
-33										
	8760							$2,163	$0	$76

74% Load
52%
93.4%
85.3%
52%
64.8%

TYPICAL HYBRID SYSTEM



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There are many possible ways to control a hybrid system

- Operate so as to balance heat rejection/ absorption in ground loop
- Use supplemental heat rejecter whenever water temperature is above a certain setpoint
- Use supplemental heat rejecter whenever it is favorable to do so.
- Optimize rejected energy when WB is lower.

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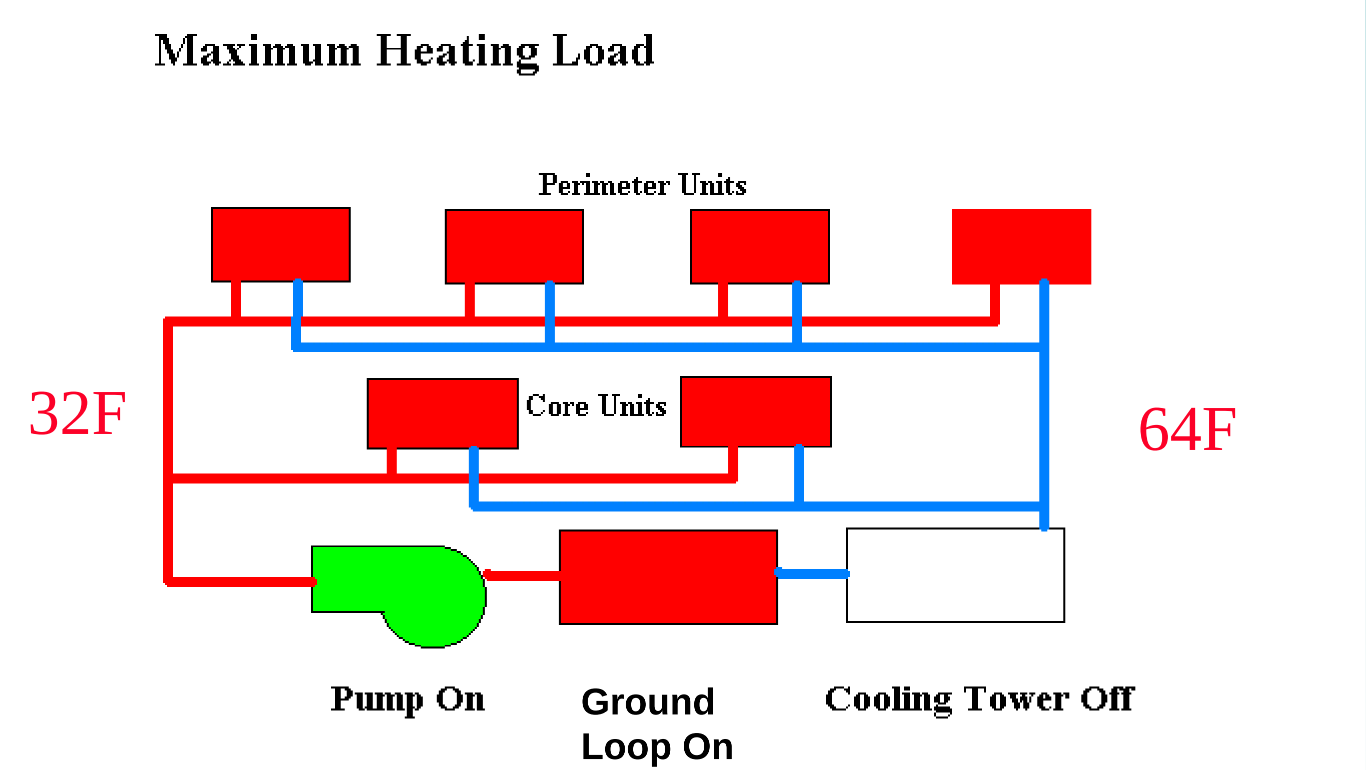
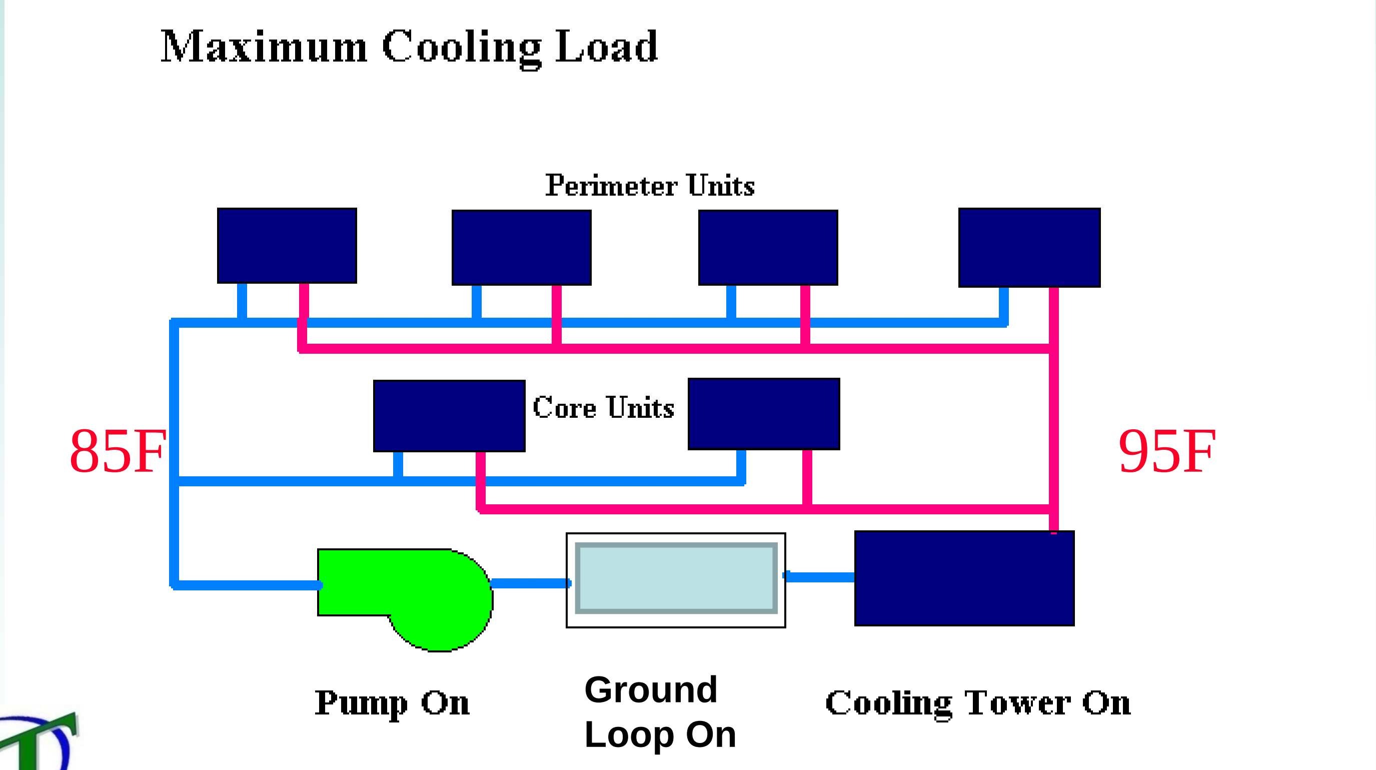
TYPICAL HYBRID SYSTEM

System Operation – Loop sized for heating mode



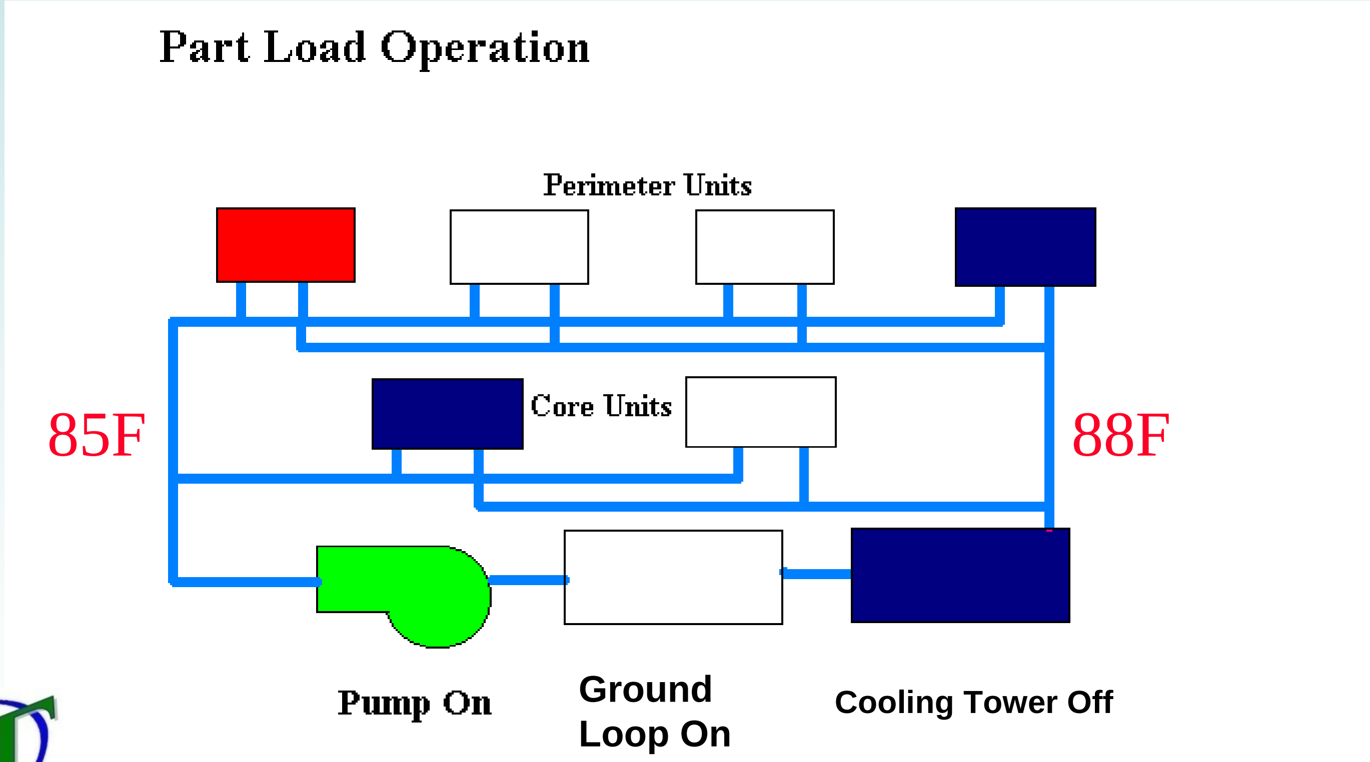
TYPICAL HYBRID SYSTEM

System Operation – Loop sized for heating mode



TYPICAL HYBRID SYSTEM

System Operation

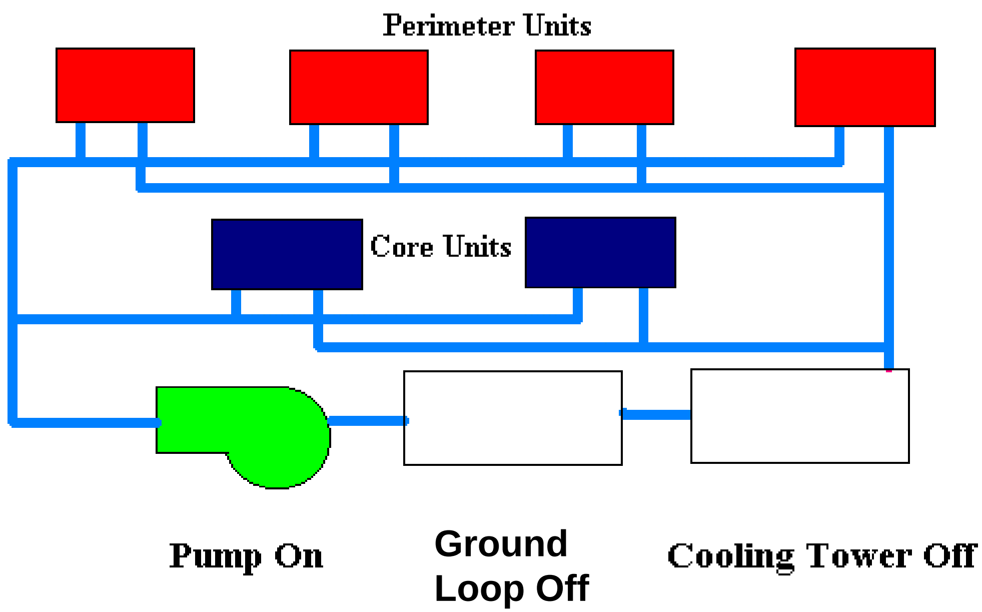


TYPICAL HYBRID SYSTEM

System Operation

Balanced Load

40F
to
85F



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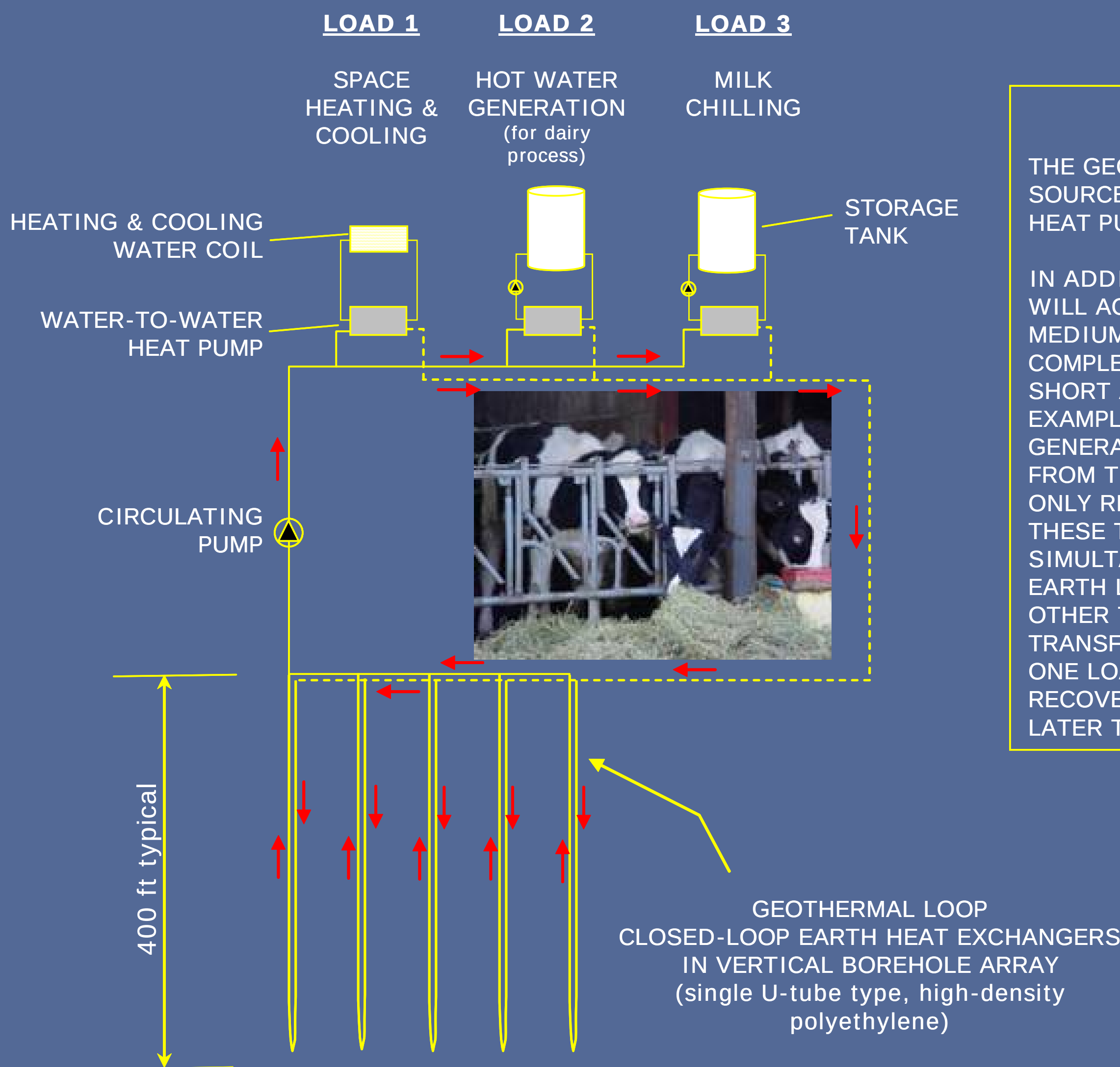
GHPs Applied to a Dairy Farm



PROCESS DESCRIPTION

THE GEOTHERMAL LOOP ACTS AS A HEAT SOURCE AND SINK FOR WATER-SOURCE HEAT PUMPS.

IN ADDITION, THE GEOTHERMAL LOOP WILL ACT AS A THERMAL STORAGE MEDIUM, ALLOWING LOADS 2 AND 3 TO COMPLEMENT EACH OTHER ON BOTH SHORT AND LONG TIME SCALES. FOR EXAMPLE, LOAD 2 (HOT WATER GENERATION) WILL ONLY EXTRACT HEAT FROM THE LOOP WHILE LOAD 3 WILL ONLY REJECT HEAT TO THE LOOP. WHEN THESE TWO LOADS ARE IN DEMAND SIMULTANEOUSLY, THE NET LOAD ON THE EARTH LOOP APPROACHES ZERO. AT OTHER TIMES, THERMAL ENERGY WILL BE TRANSFERRED TO/FROM THE EARTH BY ONE LOAD AT CERTAIN TIMES, AND THEN RECOVERED BY THE OTHER LOAD AT LATER TIMES.

Concluding Summary

- Geothermal heat pumps are an energy-efficient technology
- Large Commercial installations are few, but potential is large
- More cost effective in some situations than others
  - Simultaneous heating and cooling loads
  - Low closed-loop cost
  - Low open-loop cost
  - High conventional fuel costs
  - Reduced greenhouse gas emissions

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Geothermal

GEOEXCHANGE

Comfort from the ground up

3962 Alpine Valley Circle, Sandy, UT 84092

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