Gaia Geothermal

Ground Loop Design
Version 2012

GLD Training

Welcome!

Presenting: David Henrich
VP – Thermal Dynamics, Inc.
Daniel Bernstein
President - Gaia Geothermal, llc.

- Presented by:
- Gaia Geothermal and Thermal Dynamics

Gaia Geothermal

Ground Loop Design
Version 2012

Course Overview

- **How can GLD Software help you?**
- Brief introduction to GLD
- Why Use GLD Software?
- System Design Inputs and Their Impact
- How to use GLD
- What to Look For in a Good Design
- Practice!

Gaia Geothermal

Ground Loop Design
Version 2012

How Can GLD Help You?

- Easily design loop fields
- Easily select equipment
- Easily design piping
- Easily determine costs and savings
- Design a loop field in three minutes!

Gaia Geothermal

Ground Loop Design
Version 2012

Course Overview

- How can GLD Software help you?
- **Brief introduction to GLD**
- Why Use GLD Software?
- System Design Inputs and Their Impact
- How to use GLD
- What to Look For in a Good Design
- Practice!

Gaia Geothermal

Ground Loop Design Version 2012

What is GLD Software?

- **1997:** Version 1.0 – Training tool for engineers
- **2000:** Version 2.0 – Introduced at IGSHPA
- **2001:** Version 2.7 – Horizontal module release
- **2003:** Version 3.0 – Dongle-based license system
- **2005:** Version 4.0 – Development tool
- **2007:** Version 5.0 – Lund University model added
- **2008:** Version 5.0 – Residential Edition
- **2009:** Version 6.0 – Finance/Emissions Module
- **2010:** Version 7.0 – Piping/Pressure Drop Module
- **2012:** Version 7.5 – Grid Builder; G-Function Generator

Today: Used in over 54 countries,
1000's of engineering customers world wide

Gaia Geothermal

Ground Loop Design Version 2012

What is GLD Software?

Goal: To turn research advances into practical design tools

Developed in conjunction with:

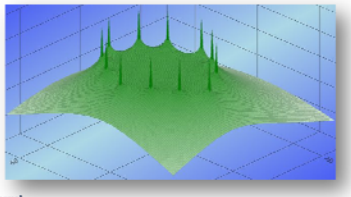
- Oakridge National Lab
- University of Alabama
- Oklahoma State University
- Lund University, Sweden
- Oregon Institute of Technology- "GeoHeat Center"
- Major Heat Pump Companies- ClimateMaster
- Design and engineering firms

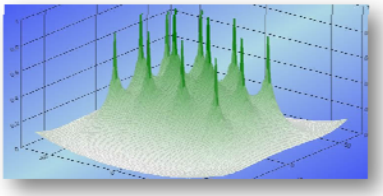
Gaia Geothermal

Ground Loop Design Version 2012

What is GLD Software?

- GLD takes the mystery and complexity out of geothermal design and enables designer to:
  - a) Quickly match pumps to loads
  - b) Estimate loopfield size and drilling requirements
  - c) Estimate installation costs
  - d) Optimize the most cost effective design and piping layout
  - e) Avoid rule of thumb designs that can be too expensive to install
  - e) Perform a comprehensive lifecycle costing analysis

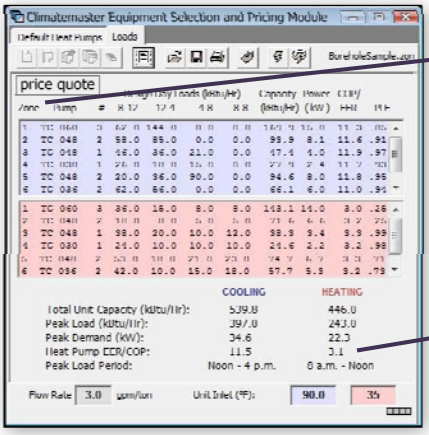




Gaia Geothermal

Ground Loop Design Version 2012

What is GLD Software?



Automatic pump selection across multiple zones

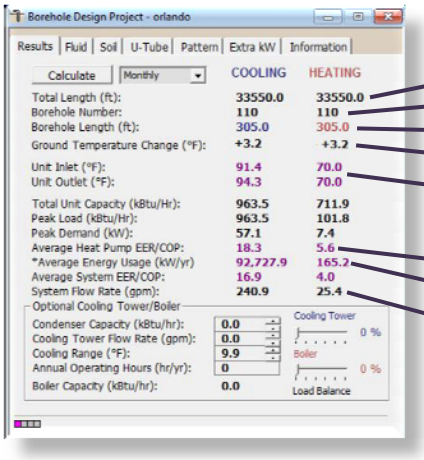
Dynamic pump performance calculations based on fluid temps/flow rates, etc.

Gaia Geothermal

Ground Loop Design Version 2012

What is Ground Loop Design Software?

- Basic Outputs include:



Total Drilling
Borehole Quantity
Borehole Length
Soil Temp Change
Fluid Temperatures
Pump Performance
Energy Use
Flow Rates

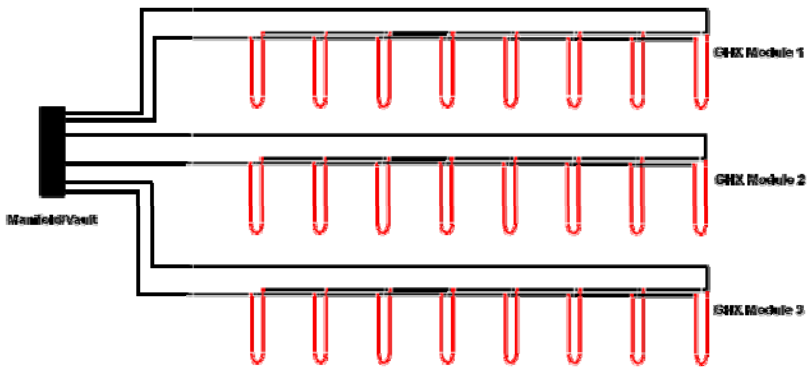
Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

What is GLD Software?

GLD makes commercial piping design easy!



Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

What is Ground Loop Design Software?

- More Advanced Outputs Include:

Optimized Headers **GHX Module Pressure Drop** Balanced Flow Rates

GHX Module - Supply-R...	2"	2"	45.57 gpm	45.57 gpm	4.93 ft/s	4.93 ft/s	27.4 ft. hd
Circuit #01	1"	1"	5.74 gpm	5.74 gpm	2.03 ft/s	2.03 ft/s	13.7 ft. hd
GHX Header Section #01	2"	1"	39.83 gpm	5.74 gpm	4.31 ft/s	2.03 ft/s	0.0 ft. hd
Circuit #02	1"	1"	5.68 gpm	5.68 gpm	2.01 ft/s	2.01 ft/s	13.3 ft. hd
GHX Header Section #02	2"	1 1/4"	34.15 gpm	11.43 gpm	3.69 ft/s	2.53 ft/s	0.0 ft. hd
Circuit #03	1"	1"	5.67 gpm	5.67 gpm	2.00 ft/s	2.00 ft/s	13.2 ft. hd
GHX Header Section #03	2"	1 1/2"	28.48 gpm	17.09 gpm	3.08 ft/s	2.89 ft/s	0.0 ft. hd
Circuit #04	1"	1"	5.69 gpm	5.69 gpm	2.01 ft/s	2.01 ft/s	13.3 ft. hd
GHX Header Section #04	2"	2"	22.79 gpm	22.79 gpm	2.47 ft/s	2.47 ft/s	0.0 ft. hd
Circuit #05	1"	1"	5.69 gpm	5.69 gpm	2.01 ft/s	2.01 ft/s	13.3 ft. hd
GHX Header Section #05	1 1/2"	2"	17.09 gpm	28.48 gpm	2.89 ft/s	3.08 ft/s	0.0 ft. hd
Circuit #06	1"	1"	5.67 gpm	5.67 gpm	2.00 ft/s	2.00 ft/s	13.2 ft. hd
GHX Header Section #06	1 1/4"	2"	11.43 gpm	34.15 gpm	2.53 ft/s	3.69 ft/s	0.0 ft. hd
Circuit #07	1"	1"	5.68 gpm	5.68 gpm	2.01 ft/s	2.01 ft/s	13.3 ft. hd
GHX Header Section #07	1"	2"	5.74 gpm	39.83 gpm	2.03 ft/s	4.31 ft/s	0.0 ft. hd
Circuit #08	1"	1"	5.74 gpm	5.74 gpm	2.03 ft/s	2.03 ft/s	13.7 ft. hd

Fluid Velocities **Purge Pump Requirements** Flow State

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

What is Ground Loop Design Software?

- More Advanced Outputs Include:

Optimized Headers GHX Module Pressure Drop **Balanced Flow Rates**

Circuit #01	1"	1"	4.54 gpm	4.54 gpm	2168	2168
Circuit #02	1"	1"	4.49 gpm	4.49 gpm	2146	2146
Circuit #03	1"	1"	4.48 gpm	4.48 gpm	2140	2140
Circuit #04	1"	1"	4.50 gpm	4.50 gpm	2149	2149
Circuit #05	1"	1"	4.50 gpm	4.50 gpm	2149	2149
Circuit #06	1"	1"	4.48 gpm	4.48 gpm	2140	2140
Circuit #07	1"	1"	4.49 gpm	4.49 gpm	2146	2146
Circuit #08	1"	1"	4.54 gpm	4.54 gpm	2168	2168

Fluid Velocities Purge Pump Requirements **Flow State**

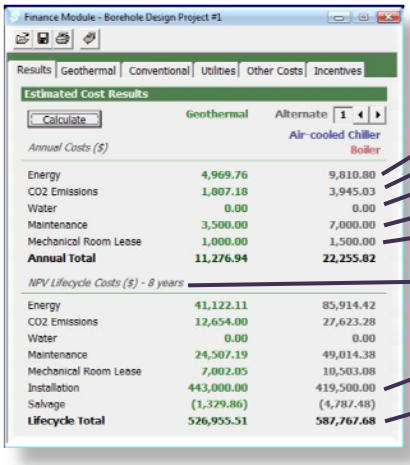
Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

What is Ground Loop Design Software?

- More Advanced Outputs Include:



- Energy Costs
- C02 Emissions
- Water Costs
- Maintenance Costs
- Value of Sq. Footage
- Lifecycle Costing
- Installation Costs
- NPV Calculations

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Course Overview

- How can GLD Software help you?
- Brief introduction to GLD
- **Why Use GLD Software?**
- System Design Inputs and Their Impact
- How to use GLD
- What to Look For in a Good Design
- Practice!

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Why Use GLD Software?

- To avoid risky "rule of thumb" designs
- To efficiently explore scenarios and quickly optimize designs
- To accurately balance installation cost/system performance tradeoffs
- To save your clients money
- To enhance your business success
- To save you time!

Gaia Geothermal

Ground Loop Design Version 2012

Course Overview

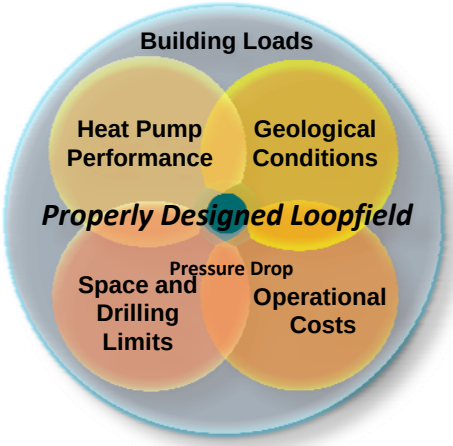
- How can GLD Software help you?
- Brief introduction to GLD
- Why Use GLD Software?
- **System Design Inputs and Their Impact**
- How to use GLD
- What to Look For in a Good Design
- Practice!

Gaia Geothermal

Ground Loop Design Version 2012

What is Ground Loop Design (GLD) Software?

- An advanced software suite that helps to properly size a closed loop ground heat exchanger by considering the interplay among:



Geothermal Training Institute

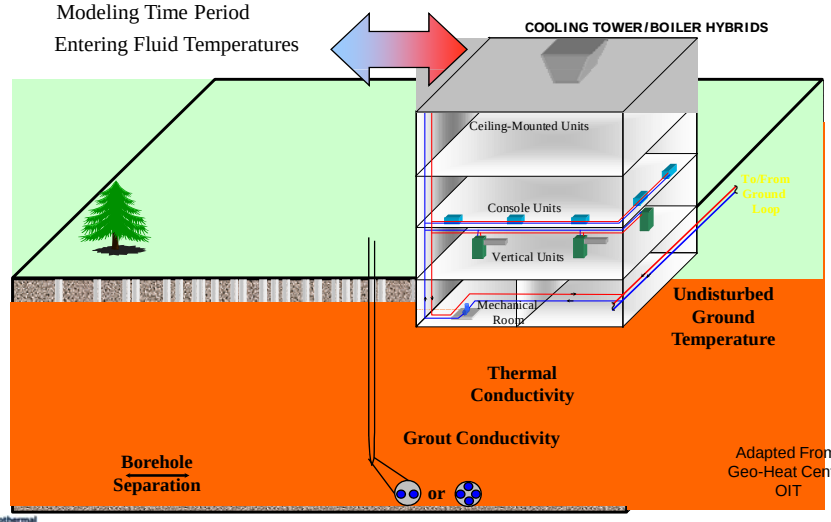
Gaia Geothermal

Ground Loop Design Version 2012

System Design Inputs and Their Impact

Modeling Time Period

Entering Fluid Temperatures



Adapted From: Geo-Heat Center OIT

Geothermal Training Institute

System Design Inputs and Their Impact

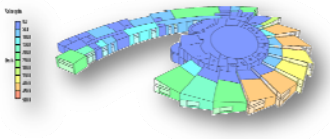
Key Components:

- Loads
- Entering Water Temperatures
- Pipe/Borehole Spacing
- Field Layout
- Ground Temperature
- Thermal Conductivity
- Grout Conductivity
- Modeling Time Period

Gaia Geothermal
Ground Loop Design
Version 2012

Loads: Residential vs Commercial

- Residential loads determined by climate/bin data
- Commercial loads determined by climate, structure and building use/internal gains/diversity
  - Oftentimes cooling dominated



Geothermal Training Institute

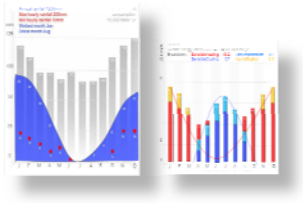
Gaia Geothermal

Ground Loop Design Version 2012

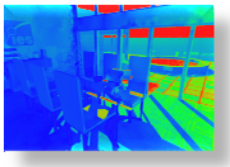
Loads

Loads are THE foundation of a geothermal system:

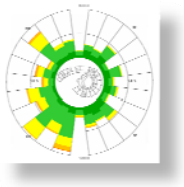
- Loads Overview
- Required Loads Data



Monthly Energy Output*



Daylight contours



Climate Understanding

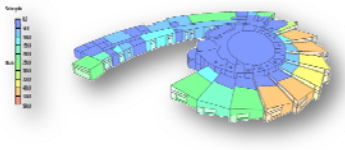
Gaia Geothermal

Ground Loop Design Version 2012

Loads: Overview

A thorough understanding of the loads is essential for determining how much energy must be transferred to and from the ground. The designer must consider:

- Climate and Structure
- Energy Reclamation
- Internal gains (occupancy, electrical, process)
- Solar gains
- Energy loads
- Energy Balance

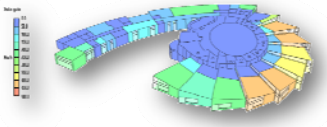


Gaia Geothermal

Ground Loop Design
Version 2012

Loads: Overview

- Conventional loads calculations require only the cooling load on the hottest day of summer when the building is fully occupied.
- Conventional loads calculations require only the heating load on the coldest night of the year
- With these two numbers, the building will have the "right" conventional equipment capacity



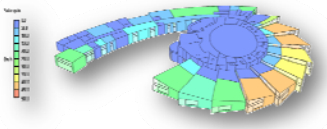
Geothermal Training Institute

Gaia Geothermal

Ground Loop Design
Version 2012

Loads: Overview

- For a geothermal system to function, the design must guarantee that the equipment can utilize the ground all year round.
- Designing a geothermal system involves the design of a system and an energy source. The GHX must be the right size.
- If it is too big it costs too much. If it is too small it underperforms and gives geothermal technologies a bad reputation.
- More detailed loads data are required. They take more time to calculate and are more valuable. Designers should charge clients for these calculations.



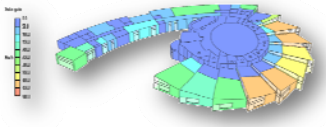
Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Loads: Overview

- We recommend advanced energy simulators such as Trane Trace, IES, eQuest and Carrier HAP.
- Standard mechanical equipment loads calculation tools do not provide the necessary loads data and should not be used.



Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Loads: Overview

- Example: Church vs. Office

- Same peak load, same location, same geology
- Church used 2x a week
- Office used 12 hours a day, 5 days a week
- Office loopfield >> Church Loop

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Loads: Required Loads Data

- Minimum (Design Day Method)
- Better (Monthly Simulation Method)
- Best (Hourly Simulation Method)

Gaia Geothermal

Ground Loop Design Version 2012

Loads: Required Loads Data

Minimum Required Loads Data (Design Day Method)

Peak Loads (btu/hr, kbtu/hr, kW)

Annual Energy Loads (total btu, total kbtu, kwH)

Annual energy loads are converted into Annual Equivalent Full Load Hours (AEFLH) by dividing:

Annual Energy Load/Peak Load

For example:

Peak Cooling: 1440kBtu/hr (~120 tons)

Annual Cooling Energy Load: 1,414,080kBtu

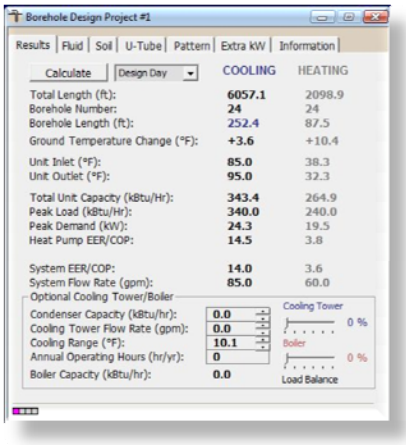
AEFLH = 1,414,080/1440 = 982 hours cooling

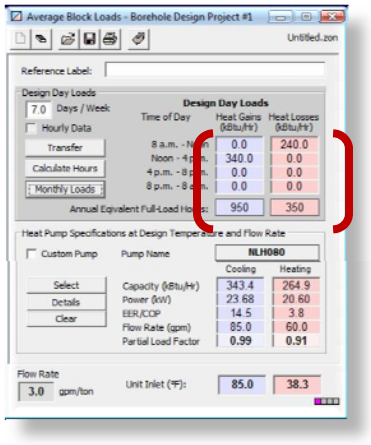
Gaia Geothermal

Ground Loop Design Version 2012

Loads: Required Loads Data

Minimum Required Loads Data



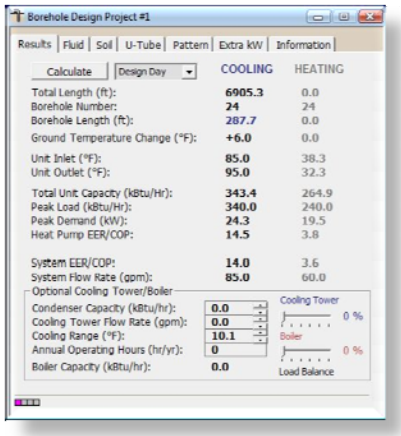


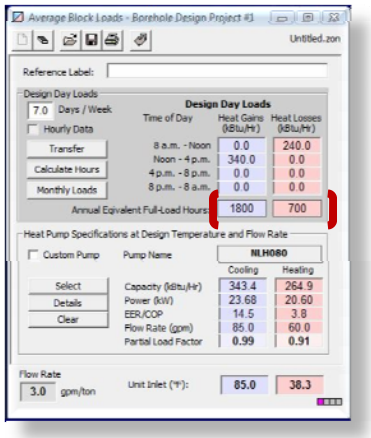
Gaia Geothermal

Ground Loop Design Version 2012

Loads: Required Loads Data

What happens if you guess the AEFLH?



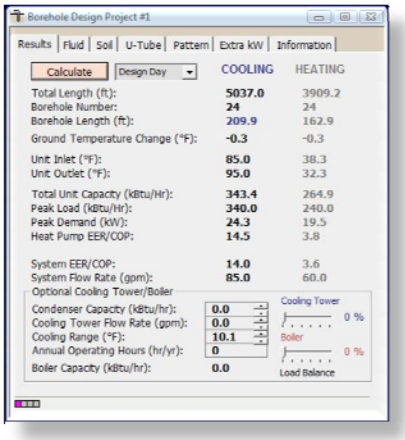


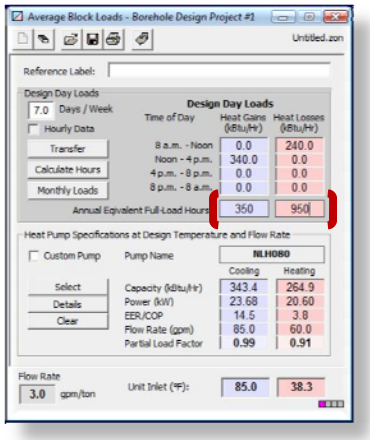
Gaia Geothermal

Ground Loop Design Version 2012

Loads: Required Loads Data

What happens if you guess the AEFLH?





Gaia Geothermal

Ground Loop Design Version 2012

Loads: Required Loads Data

Minimum Required Loads Data (Monthly Method)

Peak Loads (btu/hr, kbtu/hr, kW)

and

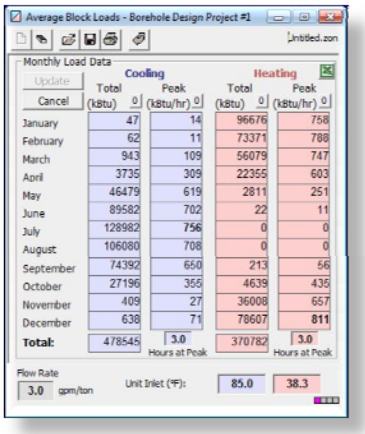
Monthly total loads (total btu, total kWh) for each month of the year for heating and cooling.

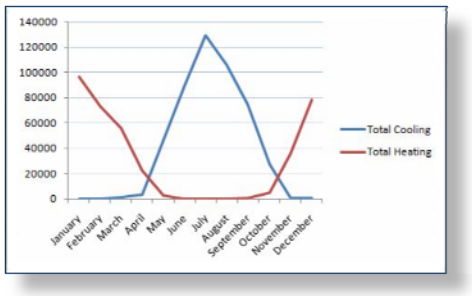
Gaia Geothermal

Ground Loop Design Version 2012

Loads: Required Loads Data

Required Loads Data (Monthly Simulation Method)





Gaia Geothermal

Ground Loop Design Version 2012

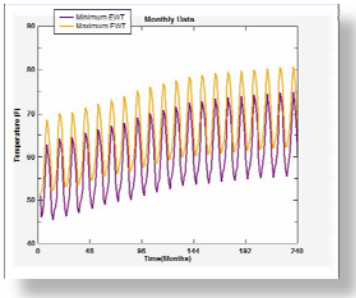
Loads: Required Loads Data

What can you do with Monthly Simulation Method Loads Data?

Predict the interplay of heating and cooling loads to estimate fluid temps over time, average COPs/EERs and annual power consumption.

For some loads profiles you can reduce your drilling based on the predicted thermal storage benefits arising from balanced loads.

	COOLING	HEATING
Total Length (ft):	14658.0	14658.0
Borehole Number:	60	60
Borehole Length (ft):	244.3	244.3
Ground Temperature Change (°F):	0.0	0.0
Peak Unit Inlet (°F):	80.5	45.5
Peak Unit Outlet (°F):	88.8	36.5
Total Unit Capacity (kBtu/Hr):	708.8	640.6
Peak Load (kBtu/Hr):	708.8	640.6
Peak Demand (kW):	10.0	9.2
Average Heat Pump EER/COP:	18.4	4.4
Avg. Annual Power (kWh):	25,974.2	24,671.4



Gaia Geothermal

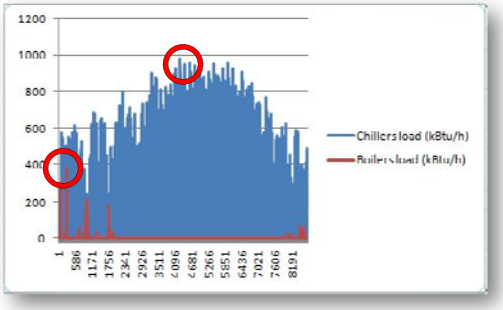
Ground Loop Design Version 2012

Loads: Required Loads Data

Required Loads Data (Hourly Simulation Method)

Hour	Chillers load (kBtu/h)	Boilers load (kBtu/h)
1	0	1.932
2	0	1.929
3	0	1.976
4	0	2.35
5	0	3.217
6	0	3.16
7	0	2.963
8	0	810.514
9	1.205	124.741
10	13.375	76.599
11	29.916	38.911
12	46.029	11.067
13	62.112	4.25
14	77.821	0.009
15	87.88	0
16	96.815	0
17	100.01	0
18	100.082	0.19
19	105.067	2.846
20	0.024	0
21	0.605	0
22	2.384	0
23	5.343	0
24	6.568	0

Hourly Data



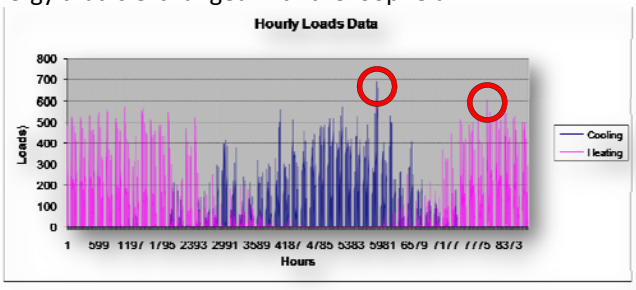
Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Loads: Required Loads Data

- Peak Loads
  - The loads normally calculated for commercial buildings using boiler/chillers plants etc.
- Energy Loads
  - For Geothermal, we need energy loads to determine the total annual energy that is exchanged with the loopfield.



Data calculated with IES <VE>

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Loads: Required Loads Data

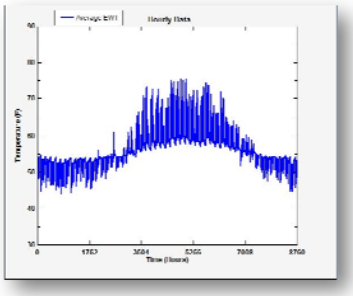
What can you do with Hourly Simulation Method Loads Data?

Predict the interplay of heating and cooling loads to estimate fluid temps over time, average COPs/EERs and annual power consumption.

For some loads profiles you can reduce your drilling based on the predicted thermal storage benefits arising from balanced loads.

Hourly simulations provide more detail that monthly simulations.

	COOLING	HEATING
Total Length (ft):	14640.0	14640.0
Borehole Number:	60	60
Borehole Length (ft):	244.0	244.0
Ground Temperature Change (°F):	0.0	0.0
Peak Unit Inlet (°F):	75.6	43.9
Peak Unit Outlet (°F):	85.4	38.2
Total Unit Capacity (kBtu/Hr):	708.8	640.6
Peak Load (kBtu/Hr):	708.8	640.6
Peak Demand (kW):	42.7	50.2
Average Heat Pump EER/COP:	10.7	4.1
Avg. Annual Power (kWh):	25,571.1	26,516.0
System EER/COP:	16.5	3.7



Gaia Geothermal

Ground Loop Design Version 2012

Loads: Software

- With loads programs, it is easy to have oversized loads
- Avoid oversized loads with geothermal design

With most commercial loads programs:

- the heat gain from the mechanical room is added to cooling load (for example, a chiller plant). This doesn't exist with geothermal systems.
- Lighting must be adjusted for scheduled use to avoid extra loads
- Eliminate any backup heat sources in the loads calculations
- Include energy recovery for outside air ventilation

Gaia Geothermal

Ground Loop Design Version 2012

Loads: Reality Check

PEAK LOADS

New Construction Office Buildings:

20-30 btu/sq ft cooling

Less for heating

Retrofit:

25-30 btu/sq ft cooling

Heating may be as high

ANNUAL HOURS

Cooling annual loads over 2,000 hours = double check

Gaia Geothermal

Ground Loop Design Version 2012

Loads: Conclusion

- **Loads are really important!**
- **Calculate them accurately!**

Gaia Geothermal

Ground Loop Design Version 2012

Entering Water Temperatures

- **Definition:**
  Entering Water Temperatures (EWTs)/Unit Inlet Temperatures are the temperatures coming into the heat pump from the ground source heat exchanger.
- **Range:**
  Cooling: 85-95 F (25-35 above ground temp)
  Heating: 30-40 F (15 below ground temp)
- **Impact**
  Heat Exchanger Length

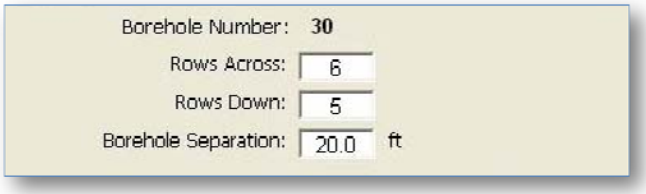
Example 1

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Borehole Spacing



- **Definition:**
  Center-to-center distance between adjacent boreholes
- **Range:**
  15 ft minimum, no maximum
- **Impact**
  more separation = less heat build-up in soil = less drilling
  less separation = more heat build-up in soil = more drilling

Example 1 (cooling dom)
Example 2 (heating dom)

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Borehole Geometry

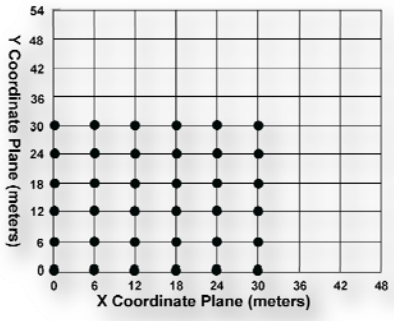
Borehole Number:	100	Borehole Number:	100
Rows Across:	10	Rows Across:	25
Rows Down:	10	Rows Down:	4
Borehole Separation:	8.0 m	Borehole Separation:	8.0 m

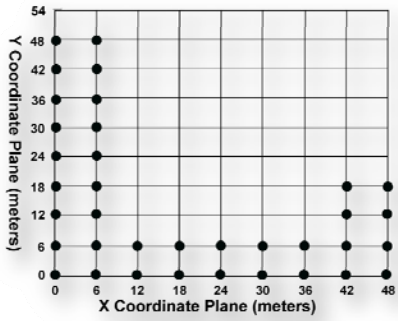
- **Definition:**
  Geometry of the loopfield
- **Range:**
  Depends on space
- **Impact**
  High Density Systems = More Drilling
  Low Density Systems = Less Drilling

Gaia Geothermal

Ground Loop Design Version 2012

Borehole Geometry





36 boreholes x 437ft

36 boreholes x 406ft

~ 1,111 ft less drilling

Gaia Geothermal

Ground Loop Design Version 2012

Ground Temperature

Ground Temperature: 58.0 °F

- **Definition:**
  Subsurface undisturbed ground temperature
- **Range:**
  35F +/- to 68F +/-
- **Impact:**
  Maximize the Delta T between the Soil and EWTs to minimize drilling

Example 1

Gaia Geothermal

Ground Loop Design Version 2012

Thermal Conductivity

Thermal Conductivity: 1.08 Btu/(h*ft*°F)

Thermal Diffusivity: 0.75 ft^2/day

- **Definition:**
  Ability of soil to transport heat
- **Range:**
  0.6 to 1.5 +
- **Impact:**
  higher conductivity = more efficient heat transfer = less drilling

GeoCube™ Thermal Conductivity Test Equipment

Example 1

Gaia Geothermal

Ground Loop Design Version 2012

Thermal Conductivity Testing

- What?
  - A test to determine the average thermal conductivity of the ground.
  - Usually for vertical systems. Can be performed for horizontal systems as well;
  - Measures:
    - Ground temperature (undisturbed)
    - Borehole Thermal Resistance
    - Conductivity (k)
      (how much heat flows through the soil)
- Why?
  - Allows you to design accurately
  - Test loop can be used in finished system

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Thermal Conductivity Testing

Perform a Thermal Conductivity (TC) test if the cost of the TC test is less than the cost difference between the best case and worst case design scenarios

For example: Difference in Soil Conductivity (SC)

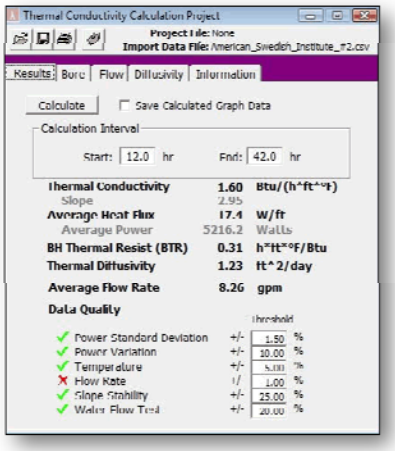
- Drilling footage if SC is 0.80 Btu/(hr●ft.●°F) – 3,500 Ft.
- Drilling footage if SC is 1.40 Btu/(hr●ft.●°F) – 2,500 Ft.
- Drilling cost per vertical foot - $12 / ft.
- Total cost difference - $12,000
- Cost of TC test - $7,500

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design
Version 2012

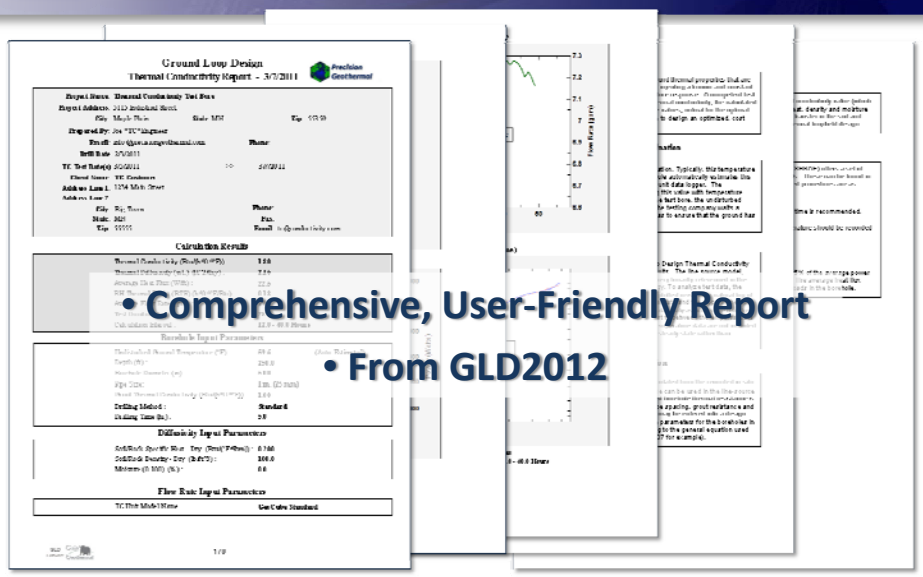
Thermal Conductivity



Geothermal Training Institute

Gaia Geothermal

Ground Loop Design
Version 2012



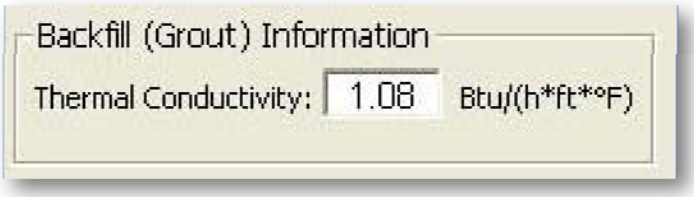
- Comprehensive, User-Friendly Report
- From GLD2012

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Grout Conductivity



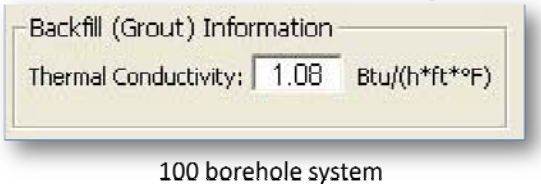
- **Definition:**
  Ability of grout to transport heat
- **Range:**
  varies
- **Impact**
  higher conductivity = more efficient heat transfer = less drilling

Example 1

Gaia Geothermal

Ground Loop Design Version 2012

Grout Conductivity



100 borehole system

Grout Conductivity	Bore length	Total length	Cost ($12/ft)
0.00	6039ft	603900ft	$7,246,800
0.45	369ft	36900ft	$442,800
0.57	350.3ft	35030ft	$420.360
0.69	341ft	34100ft	$409,200
0.79	335ft	33500ft	$402,000
0.88	329ft	32900ft	$394,800

Example 1

Gaia Geothermal

Ground Loop Design Version 2012

Modeling Time Period

Prediction Time: 15.0 years

- **Definition:**
  The length of time required for the ground temperature to stabilize
- **Range:**
  Vertical system: 10-25 years
  Horizontal system: 1-5 years
  Pond system: N/A
- **Impact:**
  Balanced systems, ground temperature stabilizes quickly
  Unbalanced systems: required stabilization time increases

Example 1

Gaia Geothermal

Ground Loop Design Version 2012

Modeling Time Period

Prediction Time: 15.0 years

100 borehole system

Time	Bore length	Total length	Ground Temp Change
1 year	304.0 ft	30,400ft	0.9˚F
3 years	311.5 ft	31,150ft	1.8˚F
5 years	319.3 ft	31,930ft	2.2˚F
10 years	329.0 ft	32,900ft	2.8˚F
15 years	336.7 ft	33,670ft	3.2˚F
25 years	344.1 ft	34,410ft	3.6˚F
35 years	347.2 ft	34,720ft	3.8˚F

Example 1

Gaia Geothermal

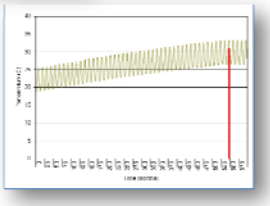
Ground Loop Design Version 2012

Modeling Time Period

Prediction Time: 50 years

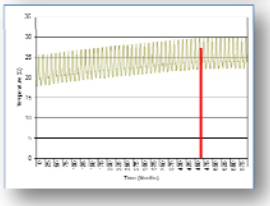
Unbalanced Load

Cooling Load	Heating Load
1,324 kBtu/2,222 hours	1,159 kBtu/1,333 hours



Balanced Load

Cooling Load	Heating Load
1,324 kBtu/2,222 hours	1,248 kBtu/2,205 hours



Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Course Overview

- How can GLD Software help you?
- Brief introduction to GLD
- Why Use GLD Software?
- System Design Inputs and Their Impact
- **How to use GLD**
- What to Look For in a Good Design
- Practice!

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

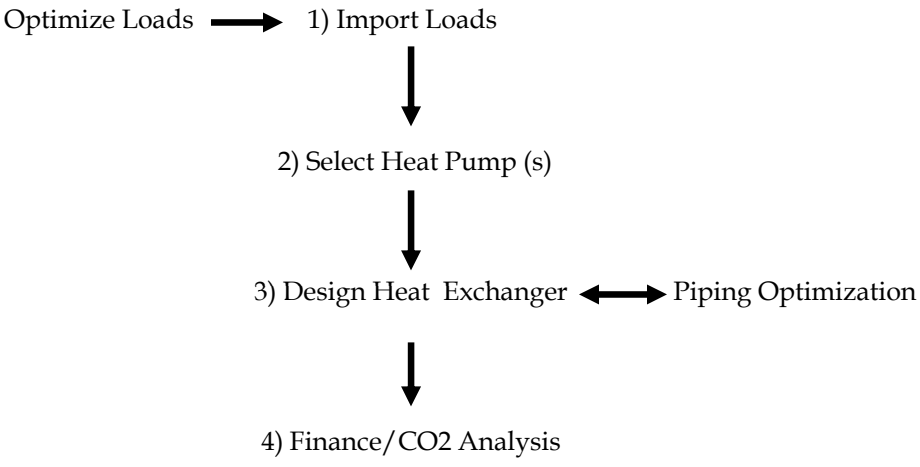
GLD Methodology

- Step 1: Calculate loads with maximum accuracy
- Step 2: Import loads into the software
- Step 3: Select heat pumps
- Step 4: Vertical, Horizontal, Pond or Hybrid?
- Step 5: Input location-specific soil parameters
- Step 6: Design loopfield based on space constraints
- Step 7: Iterate and Optimize Design
- Step 8: Optimize design for PD/Purging
- Step 9: System economics/LEED Submittals

Gaia Geothermal

Ground Loop Design Version 2012

GLD Methodology



Gaia Geothermal

Ground Loop Design Version 2012

Sample GLD Project

- Input loads
- Select heat pump
- Set EWTs
- Design loop system
- Optimize

Gaia Geothermal

Ground Loop Design Version 2012

What are we Trying to Accomplish?

- We want to design geothermal heat exchangers that are easily purged and perform well.
- We want a system that is easily purged so that we can get all the air bubbles out and ensure stable performance.
- We want a system that performs well so that the circulation pumps do not consume unnecessary energy.

Pump hp/100 tons of load	Efficiency
< 5	Excellent
5 – 7 ½	Good
7 ½ - 10	Ok
10-15	Poor
> 15	Bad

Gaia Geothermal

Ground Loop Design Version 2012

What are we Trying to Accomplish?

A sample system:

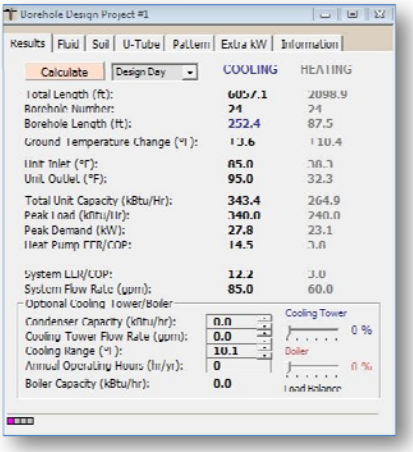
- 22,000kWh cooling
- 5,000 kWh heating

Well Designed piping system:

- 12 x 2 borefield
- 10 ft. hd @ 45gpm
- ~ 0.5 hp pump w/ 85% efficiency = 3,504 kWh
- Pump penalty = 11%

Poorly Designed System:

- 12 x 2 borefield
- 34 ft. hd @ 45 gpm
- ~ 1 hp pump w/ 85% efficiency = 7,884 kWh
- Pump penalty = 22%

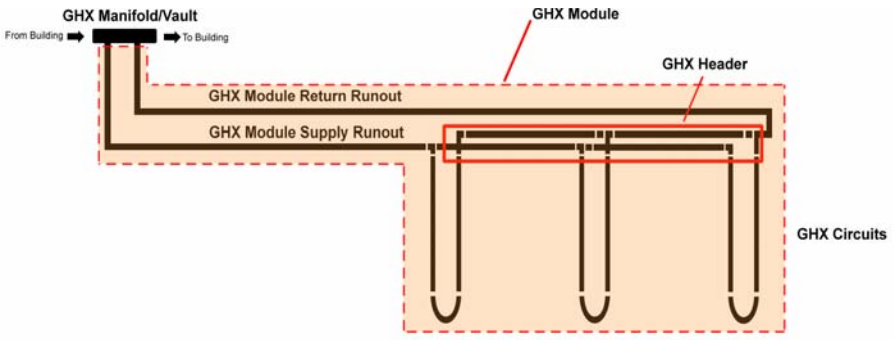


Gaia Geothermal

Ground Loop Design Version 2012

Introduction to Nomenclature

•Standardized Nomenclature is critical to clear communication.



Gaia Geothermal

Ground Loop Design Version 2012

Introduction to Nomenclature

•**U-Tube**: An assembly of two lengths of HDPE pipe connected on one end with a molded, purpose built U-bend.

• **GHX**: Refers to a **g**round **h**eat e**x**changer, and may include vertical, horizontal trenching, horizontal boring, pond or lake heat exchanger buried in the ground or submerged in a body of water.

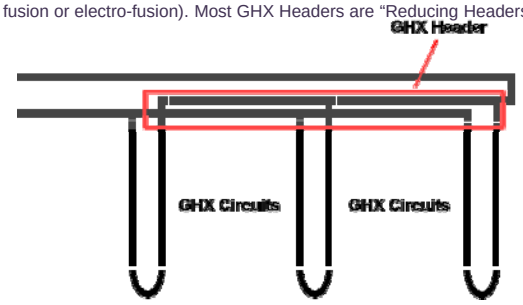
Gaia Geothermal

Ground Loop Design Version 2012

Introduction to Nomenclature

•**GHX Circuits**: HDPE pipe buried in the ground in horizontal or vertical orientation designed to transfer energy to and from the ground. Typically a number of GHX Circuits are fusion welded to a GHX Header that is in turn fusion welded to a Supply-Return Runout. Heat transfer fluid is circulated through the assembly to a building.

•**GHX Header**: Connection points between Supply-Return Runout piping and GHX Circuits. GHX Headers are buried in the ground adjacent to the GHX Field and are comprised of an assembly of fusion welded fittings and pipe. Fittings and pipe are manufactured using HDPE resin and are connected using heat fusion (butt fusion, socket fusion or electro-fusion). Most GHX Headers are "Reducing Headers"

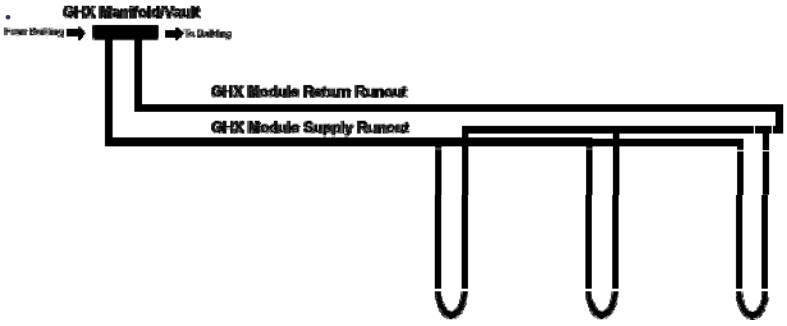


Gaia Geothermal

Ground Loop Design Version 2012

Introduction to Nomenclature

•**GHX Module Supply-Return Runout** : Supply-Return Runout refers to the high-density polyethylene (HDPE) piping installed to connect the GHX Circuit piping to the Pump House header. The Supply-Return Runout has both a supply pipe and a return pipe.



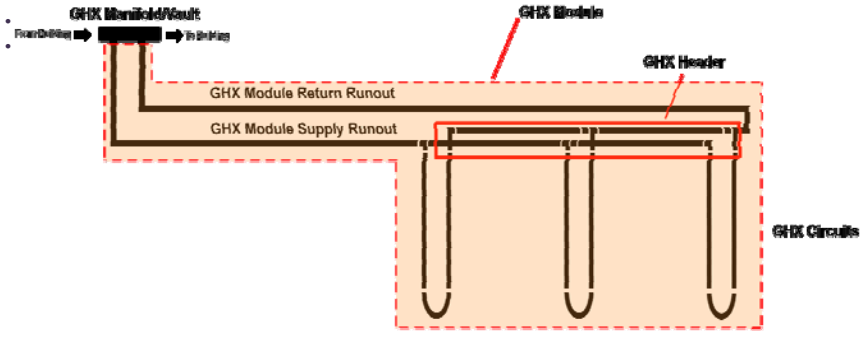
Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Introduction to Nomenclature

•**GHX Module**: Completed assembly of GHX components, including GHX Supply and Return Runouts, GHX header and GHX Circuits.



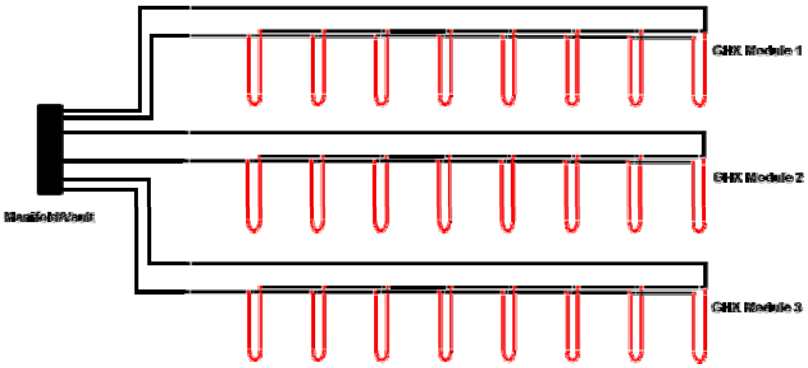
Geothermal Training Institute

Gaia Geothermal

Ground Loop Design
Version 2012

Introduction to Nomenclature

•**GHX Field**: Assembly of all GHX Modules connected to a single building or group of buildings via GHX Manifold(s)/Vault(s).



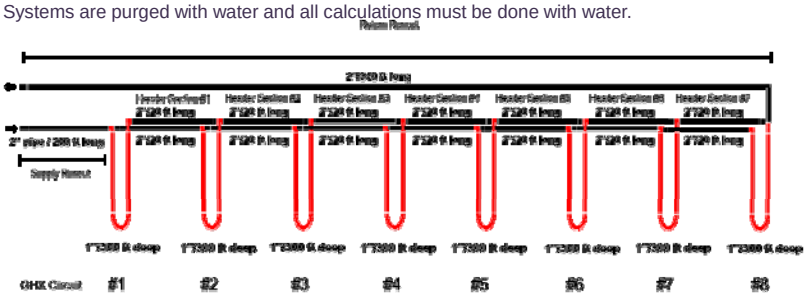
Geothermal Training Institute

Gaia Geothermal

Ground Loop Design
Version 2012

Purging Design: RR Systems

- You want to have a piping system that you can purge with available purge pumps.
- A 2 ft/sec fluid velocity throughout entire system is required to purge air effectively.
- Systems are purged with water and all calculations must be done with water.



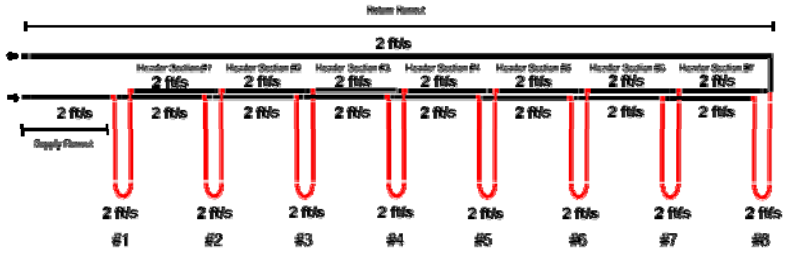
Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Purging Design: RR Systems

- You want to have a piping system that you can purge with available purge pumps.
- A 2 ft/sec fluid velocity throughout entire system is required to purge air effectively.
- Systems are purged with water and all calculations must be done with water.



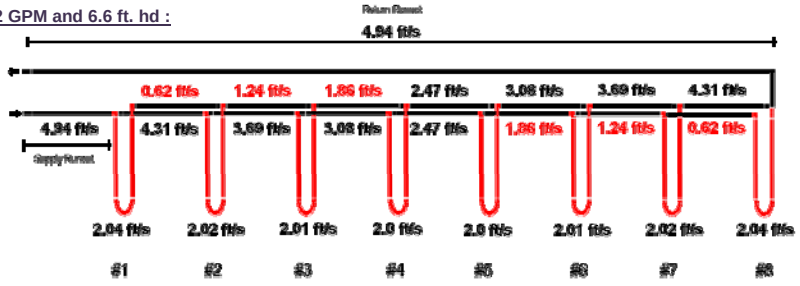
Gaia Geothermal

Ground Loop Design Version 2012

Purging Design: RR Systems

- You want to have a piping system that you can purge with available purge pumps.
- A 2 ft/sec fluid velocity throughout entire system is required to purge air effectively.
- Systems are purged with water and all calculations must be done with water.

45.32 GPM and 6.6 ft. hd :



- The GHX circuits are being purged but the headering is not.

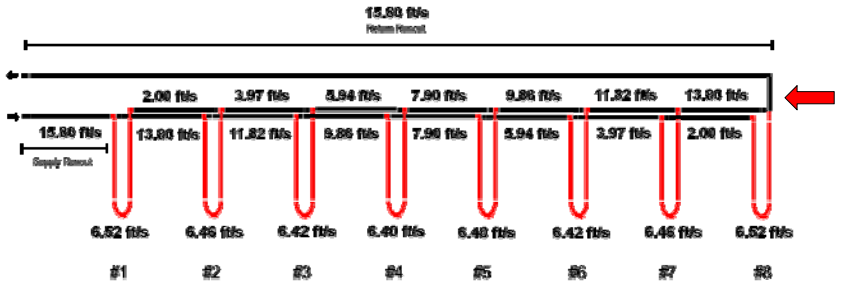
Gaia Geothermal

Ground Loop Design Version 2012

Purging Design: RR Systems

• Based on this configuration, to achieve 2 ft/s flow rates across the headering system requires:

146 GPM and 345 ft. hd.



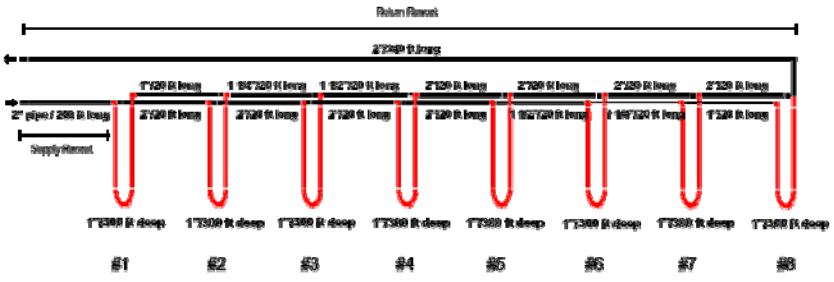
• This clearly is unreasonable and justifies the use of a reducing headering system.

Gaia Geothermal

Ground Loop Design Version 2012

Purging Design: RR Systems

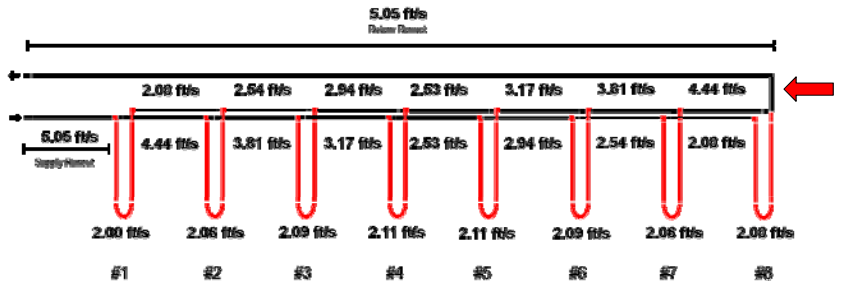
• Reducing headering systems enable purging velocities throughout a system while maintaining reasonable flow rates and pressure drops.



Purging Design: RR Systems

• Reducing headering systems enable purging velocities throughout a system while maintaining reasonable flow rates and pressure drops.

46.7 GPM and 46.2 ft. hd.



Purging Design: RR Systems

• Other Reducing Header Options:

Header Section	Example	Velocity (ft/s)	Design Option 1	Velocity (ft/s)	Design Option 2	Velocity (ft/s)
Runout	2”/2”	5.05 /5.05	2”/2”	2.34/2.34	2”/2”	2.69/2.69
1	2”/1”	4.44/2.00	2”/1”	2.06/2.00	2”/1”	2.37/2.29
2	2”/1 ¼”	3.81/2.54	2”/1 ½”	3.84/2.56	2”/2”	2.03/2.93
3	2”/1 ½”	3.17/2.94	2”/2	3.20/2.96	2”/2”	3.67/2.18
4	2”/2”	2.53/2.53	2”/2”	2.55/2.55	2”/2”	2.92/2.92
5	1 ½”/2”	2.94/3.17	2”/2”	2.96/3.20	2”/2”	2.18/3.67
6	1 ¼”/2”	2.54/3.81	1 ½”/2”	2.56/3.84	2”/2”	2.93/2.03
7	1”/2”	2.00/4.44	1”/2”	2.00/2.06	1”/2”	2.29/2.37
Flow Rate		46.7 gpm		49.5 gpm		71.9 gpm
PD		37.6 ft. hd.		42.5 ft. hd		84 ft. hd.

Gaia Geothermal

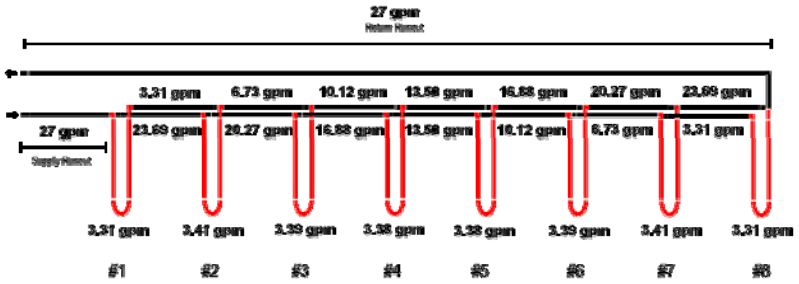
Ground Loop Design Version 2012

Design and Performance: RR Systems

Flow Balance and Reynolds Numbers

• Flow balance is important to ensure that all of the GHX circuits exchange an equal # of BTUS with the ground. Unbalanced systems perform poorly.

• This RR system has GHX circuit flow rates that range from 3.31 gpm to 3.41 gpm, a less than 5% imbalance across the entire GHX Module. Note: Propylene Glycol with freeze protection down to 20F, 27 gpm, 20.2 ft hd.



Gaia Geothermal

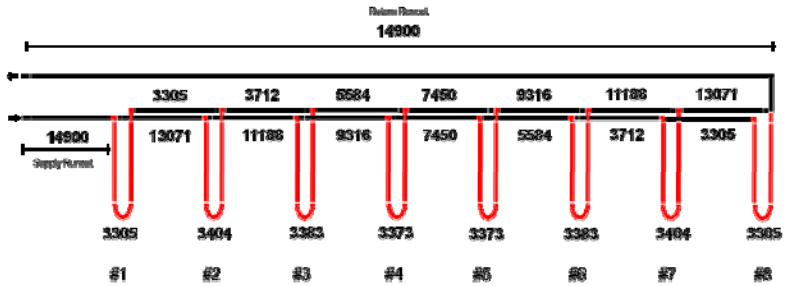
Ground Loop Design Version 2012

Design and Performance: RR Systems

Balanced Flow and Reynolds Numbers

• Reynolds indicate flow type (turbulent, laminar, etc). Turbulent flow is optimal for efficient heat transfer.

• This RR system has GHX circuit flow Reynolds Numbers drop from 3,404 to 3,305, a 5% drop.



Gaia Geothermal

Ground Loop Design Version 2012

The Finance/Lifecycle Costing Module

Lifecycle costing is a standard investment analysis methodology that counts present and future costs and savings in today's dollar terms (known as net present value, or NPV, analysis.

Future costs and savings are converted into today's dollar terms using the discount rate, which is typically the inflation rate.

Typically, the commercial real estate sector likes to see NPV analysis that has a investment payback of approximately < =8 years.

To do a full NPV analysis on a geothermal system requires the designer to take into account "hard" and "soft" costs for a geothermal system and one or more conventional systems.

Gaia Geothermal

Ground Loop Design Version 2012

The Finance/Lifecycle Costing Module

Gaia Geothermal

Ground Loop Design Version 2012

The Finance/Lifecycle Costing Module

Hard Costs

Installation Costs - installation costs per square foot.

Energy Consumption (kWh) costs

Soft Costs

CO_2 emissions costs
Opportunity costs related to mechanical room size
Maintenance costs
Water consumption costs

Incentives

Federal/National
State/Provincial

Gaia Geothermal

Ground Loop Design Version 2012

The Finance/Lifecycle Costing Module

Hard Costs: Installation

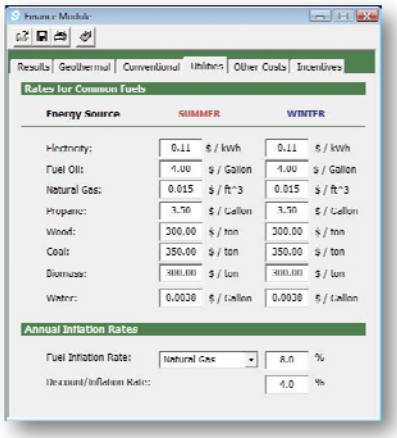
System Type	Cost per Square Ft Installed
Geothermal Vertical	$16 to $21
Geothermal Horizontal	$13 to $17
Geothermal Surface Water	$13 to $16
Geothermal Vertical/Hybrid	$14 to $18
VAV- Water Cooled w/boiler	$16 to $19
VAV- Air Cooled w/boiler	$14 to $18
Fan Coil WCC w/ boiler	$12 to $16
Rooftop Gas/Electric	$10 to $16

Gaia Geothermal

Ground Loop Design Version 2012

The Finance/Lifecycle Costing Module

Hard Costs: Energy



Gaia Geothermal

Ground Loop Design Version 2012

The Finance/Lifecycle Costing Module

Soft Costs: CO_2

Region/State	CO_2 Emission Factors			CH_4	N_2O
	lbs/kWh	short tons/MWh	metric tons/MWh	lbs/MWh	lbs/MWh
New England	0.98	0.491	0.440	0.0207	0.0140
Connecticut	0.84	0.471	0.427	0.0174	0.0120
Maine	0.85	0.426	0.388	0.0585	0.0270
Massachusetts	1.28	0.639	0.579	0.0174	0.0159
New Hampshire	0.68	0.341	0.310	0.0172	0.0111
Rhode Island	1.06	0.526	0.477	0.0068	0.0047
Vermont	0.03	0.014	0.013	0.0090	0.0039
Mid Atlantic	1.04	0.520	0.471	0.0093	0.0145
New Jersey	0.71	0.363	0.329	0.0077	0.0078
New York	0.86	0.429	0.389	0.0081	0.0089
Pennsylvania	1.20	0.602	0.574	0.0107	0.0203
East North Central	1.63	0.816	0.740	0.0123	0.0267
Illinois	1.16	0.582	0.528	0.0082	0.0180
Indiana	2.08	1.038	0.942	0.0143	0.0321
Michigan	1.58	0.790	0.717	0.0140	0.0250
Ohio	1.80	0.900	0.817	0.0130	0.0288
Wisconsin	1.61	0.821	0.746	0.0138	0.0260

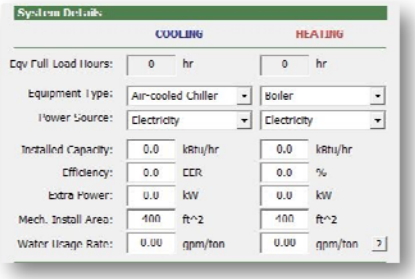
Gaia Geothermal

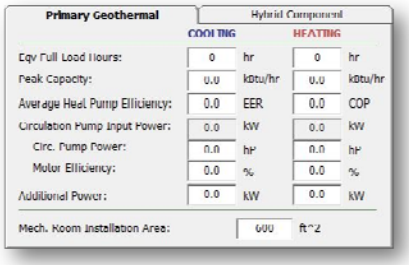
Ground Loop Design Version 2012

The Finance/Lifecycle Costing Module

Soft Costs: Mechanical Room Size

- **In some cases, the geothermal system will have a smaller footprint than a conventional system.**
- **For new construction, this means construction costs savings**
- **For retrofits, this means space available for other uses = savings**





Gaia Geothermal

Ground Loop Design Version 2012

The Finance/Lifecycle Costing Module

Soft Costs: Maintenance Costs

System Type	Cost per Square Ft per year
Geothermal Vertical	$0.09 to $0.11
VAV- Air Cooled Chiller w/ gas boiler	$0.10 to $0.14
VAV- Water Cooled Chiller w/boiler	$0.18 to $0.20
Cooling tower systems	$0.50 or more

Gaia Geothermal

Ground Loop Design Version 2012

The Finance/Lifecycle Costing Module

Soft Costs: Water Consumption Costs

- **Cooling towers consume 2 gpm/ton.**
- **A 300 ton system will use 600 gpm**
- **Water can cost $2.50/hour of cooling**

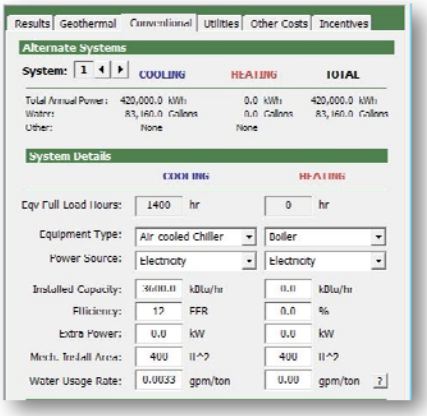
Gaia Geothermal

Ground Loop Design Version 2012

The Finance/Lifecycle Costing Module

Soft Costs: Water Consumption Costs

- **Cooling towers consume 2 gpm/ton.**
- **A 300 ton system will use 600 gpm**
- **Water can cost $2.50/hour of cooling**



Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

The Finance/Lifecycle Costing Module

Incentives

- **Commercial Incentives**
- **Residential Incentives**

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Challenges of Using Design Software

- Garbage In/Garbage Out
- Need to know the site-specific information
- Need to Understand Relationships Between Design Parameters
  - GLD is an excellent training tool!

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design
Version 2012

Course Overview

- How can GLD Software help you?
- Brief introduction to GLD
- Why Use GLD Software?
- System Design Inputs and Their Impact
- How to use GLD
- **What to Look For in a Good Design**
- Practice!

Gaia Geothermal

Ground Loop Design
Version 2012

What to Look For in a Good Design

- Reasonable Loads
- Appropriately selected heat pump(s)
- Appropriate flow rates/EWTs
- Accurate soil temperatures/TC values
- Appropriate Borehole Spacing for land area
- Stable soil temperatures over many years (vertical systems)
- Appropriate pipe selection to minimize PD

Gaia Geothermal

Ground Loop Design
Version 2012

Course Overview

- How can GLD Software help you?
- Brief introduction to GLD
- Why Use GLD Software?
- System Design Inputs and Their Impact
- How to use GLD
- What to Look For in a Good Design
- **Practice!**

Gaia Geothermal

Ground Loop Design
Version 2012

Designing with GLD

- Vertical Systems
- Horizontal Systems
- Surface Water Systems

Gaia Geothermal

Ground Loop Design Version 2012

Vertical Design Project

Known design variables:

- Thermal Conductivity – 1.75 Btu/(hr * ft * ^{o}F) for a 275' boring
- Thermal Diffusivity – 1.25 ft^2 / day
- Ground Temperature – 49.5 ^{o}F
- Loads File – Heavycooling.GT1

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Designing Horizontal Systems

Geothermal Training Institute

Gaia Geothermal

Ground Loop Design Version 2012

Horizontal Design Project

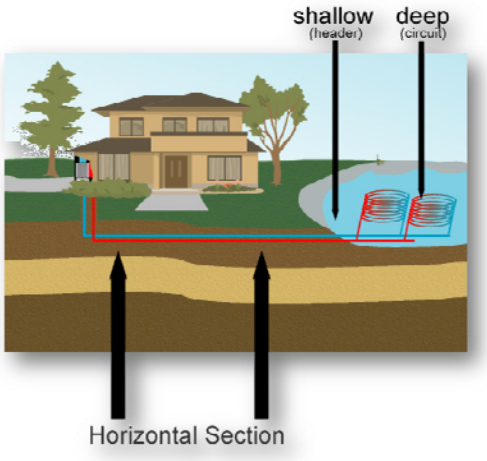
Known design variables:

- Site selected for directional drilling for minimal site impact
- Thermal Conductivity – 1.00 Btu/(hr * ft * ^{o}F) for a 400’ boring
- Thermal Diffusivity – 0.95 ft^2 / day
- Ground Temperature – 51.0 ^{o}F
- Loads File – Heavycooling.GT1
  (Same as Vertical)

Gaia Geothermal

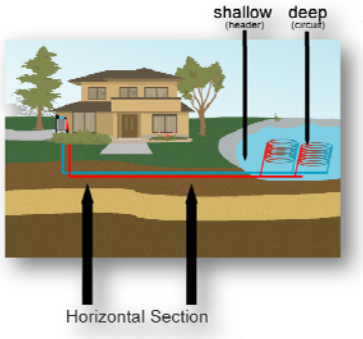
Ground Loop Design Version 2012

Ponds



Ponds

- Building Loads
- Capacity of body of water
- Pond Temperatures
- Soil Properties
- Pipe Size
- Pressure Drop Calculations
  - Turbulent flow essential
- Note: No Annual/Duration loads with ponds!



Pond Module Method

- Step 1: Enter Loads/Pond Temps
- Step 2: Choose pipe style and size
- Step 3: Check the minimum allowable flow rate for turbulent flow
- Step 4: Choose a layout
- Step 5: Enter head loss for pipe and header
- Step 6: Calculate
- Step 7: Modify the parallel loops to balance turbulent flow and reduce pump power.

Gaia Geothermal

Ground Loop Design
Version 2012

GLD Software

David Henrich
David@GroundLoopDesign.com
www.groundloopdesign.com
www.geotrainers.com

Geothermal Training Institute