GROUND LOOP DESIGN REPORT

Commercial Example

Date:	January 1, 2008	
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From:	GeoPro, Inc.	
Subject:	Commercial Ground-Loop Design Example	

BUILDING DESIGN LOADS:

According to information provided to GeoPro, Inc, the peak heating and cooling loads for the building were given to be as follows:

Design Cooling Load (MBH) 1200 (100.0 Tons)
Design Heating Load (MBH) 900 (75.0 Tons)

A summary of the zone loads used in the loopfield design program is provided in Table 1. The load distribution listed in Table 1 was not provided, but was estimated based on the building's operating schedule and anticipated future conditions.

Table 1. Zone loads used for the geothermal loopfield design.

	Cooling Loads (MBH)		**Heating Loads (MBH)**	
Time	Zone 1	% of Peak	Zone 1	% of Peak
8-12	900	75.0	900	100.0
12-4	1200	100.0	900	100.0
4-8	1200	100.0	900	100.0
8-8	600	50.0	900	100.0

Occupancy = 5 days/wk

Important in the design calculation for large loopfields (usually greater than approximately 50 Tons) is a measure of the relative heating energy extracted from the ground loop to the cooling energy rejected to the ground loop. For small loopfields, the ratio of boreholes completely surrounded by other boreholes is small, but for large loopfields severely unbalanced annual ground heat absorption or rejection loads can result in long-term ground temperature reduction or rise (10 year) in and near the center of the loopfield. Generally, a measure of the ground load is expressed in terms of full load operating hours in both heating and cooling mode, which can be determined if an energy calculation is made on the facility. If this has not been done, Kavanaugh provides equivalent full-load heating and cooling run hours for various building types and geographical locations in the U.S. from ASHRAE sponsored research.

Table 2. Equivalent full-load heating and cooling run hours.

Cooling	700*	Heating	800*

*-Heating and cooling FLRH's were calculated based on system load profile provided by Doe Engineering

LOOPFIELD DESIGN PARAMTERS:

The design parameters important to the proper design of the loopfield are described below. The length of heat exchanger that is required depends primarily on the thermal properties of the ground, the ground temperature, the thermal conductivity of the grout in the borehole, and the desired minimum and maximum temperatures in the return flow from the loopfield during peak heating and cooling load periods. Parameters that have a minor effect include the borehole diameter and the nominal pipe diameter. The grid is chosen to result in enough boreholes for desired flowrate conditions in each u-bend. A brief discussion of each parameter follows.

Table 3. Loopfield Design Parameters.

EWT_{min}	=	30 °F	**k_{grout}**	=	0.40/0.88 Btu/hr ft °F
EWT_{max}	=	90 °F	**D_{bore}**	=	5.0 in.
Flow Rate	=	3.0 gpm/Ton	**D_{pipe}**	=	1.00 in. (nominal)
T_{soil*}	=	55 °F	**Flow Regime**	=	Turbulent
k_{soil*}	=	1.00 Btu/hr ft °F	**Bore Layout**	=	Varies with $k_{grout,}$ see recommendations
α_{soil*}	=	0.75 ft^2 / day			
Heat Pump	=	Waterfurnace Premier 034 (COP=3.92 @ EWT=30 °F / EER=15.70 @ EWT=90°F)			

** - Deep earth temperature, formation thermal conductivity and diffusivity were estimated due to the fact that no FTC test was performed. Estimates were made based on past experience and knowledge of the area. Please contact Galen Streich, GRTI at 605-692-9069 for details about FTC testing.*

Minimum and Maximum Entering Water Temperatures ($EWT_{min,}$ EWT_{max}) The loopfield is designed to provide a minimum and a maximum entering water temperature to the geothermal heat pumps in the building during periods when the design heating and cooling loads, respectively, occur. A maximum entering water temperature between 85 to 95 °F is common in the cooling mode, resulting in heat pump operation that is still very efficient at peak cooling conditions. Minimum entering water temperatures for peak heating conditions are generally in the range from 30 to 45 °F, depending on the equipment that are selected and many other factors. Some equipment will operate with sufficient capacity and efficiency down to 25 °F. Operating at minimum entering water temperatures below 45 °F will require that the water in the loop be treated with an anti-freeze to prevent freezing in the water-to-refrigerant heat exchanger. It is recommended that the loop fluid be freeze-protected to 18 °F for a 30 °F minimum entering water temperature.

Undisturbed Soil Formation Temperature (T_{soil}) The deep soil temperature at the loopfield site should be determined by direct measurement, as would be the case when doing a soil formation thermal conductivity test. If that has not been done, soil temperature data should be obtained from geologic survey maps of the area or from direct measurement of temperature of water in a nearby well.

Soil Thermal Properties (k_{soil} , α_{soil}) The soil thermal conductivity (k_{soil}) should be directly measured with a formation thermal conductivity test. The report should include the deep soil temperature, the soil thermal conductivity and the soil thermal diffusivity (α_{soil}). If that test has not been performed, as is usually the case of small jobs, estimated soil thermal conductivity, diffusivity and temperature should be obtained based on knowledge of the general soil type at the site down to the depth that the boreholes will be drilled.

Grout Thermal Conductivity (k_{grout}) The grout thermal conductivity is the one parameter in the loopfield design that the designer has control over. Commonly-used grouts range in thermal conductivity from 0.38 to 1.20 Btu/hr ft °F. Research has shown that borehole lengths can be reduced by 15 to 30 percent when a product with a thermal conductivity of 0.85 Btu/hr ft °F is used as compared to a conventional bentonite grout thermal conductivity of about 0.40 Btu/hr ft °F. Increasing the grout thermal conductivity to values above 0.85 results in diminishing borehole length reductions while adding additional material and labor costs to the job.

Borehole Diameter$_{bore}$ (D) The borehole diameter has a minor influence on the required borehole length, and is generally selected by the drilling contractor based on their equipment availability. The borehole must be large enough to allow for insertion of the pipe u-bend into the ground along with the grout tremie pipe. The borehole diameter has some effect on the design length of the loopfield, with smaller bores having less effect. Low grout thermal conductivity increases the effect of borehole diameter.

Pipe Diameter (D_{pipe}) The diameter of the pipe in the borehole is generally selected based on the required flow rate in the pipe. Turbulence of the flowing fluid and pressure drop considerations dictate the pipe diameter selection. The effect of pipe diameter on borehole design length is minor, with design lengths usually decreasing by 3-4% for each increase in nominal pipe diameter. Each nominal pipe diameter requires a minimum flow rate for turbulence, with that flow rate dependent on the level of antifreeze and the loop temperature. Turbulent flow in the u-bend is mandatory for proper loopfield performance, and is most critical when loop temperatures are at the minimum design values when fluid viscosity is maximized.

Heat Pump Brand The brand and size of heat pump equipment to be used must be selected to properly relate the building heating and cooling loads, through the capacities and efficiencies of the equipment, to ground heating and cooling loads. Within a specific heat pump brand and series, changing the assumed equipment size will have a minor effect of the borehole length calculations, with larger capacity equipment usually having lower heating and cooling efficiencies.

LOOPFIELD DESIGN:

The design borehole lengths were calculated using GchpCalc version 4.1 (Kavanaugh, University of Alabama). The required borehole length depends on all of the design parameters listed above.

The results of the calculations are as follows:

EWT_{min}	EWT_{max}	Grid	k_{grout}	Spacing	L_c	L_h	$L_{10\text{-}dg}$
30.0°F	90.0°F	7 x 12	0.40 Btu/hr ft °F	20' c-c	288' / bore	197' / bore	304' / bore
30.0°F	90.0°F	7 x 10	0.88 Btu/hr ft °F	20' c-c	278' / bore	192' / bore	297' / bore

RECOMMENDATIONS (FOR USE WITH STANDARD, 20%-SOLIDS GROUT) :

Borefield Layout	84 bores [7 x 12 grid] - 20' min. c-c spacing
Depth (Below Header Trench)	295 feet [300' below surface]
Grout Thermal Conductivity	0.40 Btu/hr ft °F (20% Solids Grout)
U-bend Pipe Diameter	1.00 in (nominal)

RECOMMENDATIONS (FOR USE WITH T.E. GROUT (TC=0.88 BTU/HR FT F) :

Borefield Layout	70 bores [7 x 12 grid] - 20' min. c-c spacing
Depth (Below Header Trench)	295 feet [300' below surface]
Grout Thermal Conductivity	0.88 Btu/hr ft °F (200-lb sand mix)
U-bend Pipe Diameter	1.00 in (nominal)

The above recommendations will adequately serve the building **according to the provided loads and system load profile**. The minimum effective borehole spacing for the proposed layout is 20'. Ensure that the heat pumps are adequately sized to handle 90°F maximum entering water temperatures in cooling mode and 30°F minimum entering water temperatures in heating mode to fully comply with this design. Freeze protection to 18°F using 20% propylene glycol by volume (or equivalent) as a circulating fluid is recommended.

If you have questions regarding this analysis please call GeoPro Technical Support at (605) 542-5291 (email: RCarda@GeoProInc.com).