Project:	**Office**
Effort:	**Vertical Thermal Conductivity Test**
Location:	**CO**
Loop design:	**Terry Proffer, CGD**
	Major Geothermal

Vertical Thermal Conductivity Test:

Purpose: To determine final thermal conductivity performance for confirming final ground heat exchanger (GHX) parameters. The key thermal conductivity parameters required to finalize a closed loop ground heat exchanger design are as follows:

1. Static temperature, usually in °F - directly measured by the test instrumentation from undisturbed conditions
2. Thermal conductivity, expressed in btuh/ft/°F – how much energy per linear foot of heat exchanger is needed to change the surrounding temperature per degree F, directly measured by the test instrumentation
3. Diffusivity, expressed in ft²/day - area linear diffusivity of energy surrounding the linear heat exchanger in a narrow plane over a 24 hour period, usually determined from empirical geologic data (not directly measured)

Thermal conductivity testing, using the line source test method, consists of introducing a known amount of energy into a narrow, straight cylinder, and measuring the amount of energy lost to the host medium over a given amount of time. In the case a formation thermal conductivity test for use in designing a closed loop heat exchanger, the "narrow, straight cylinder" is often a borehole or trench with a HDPE u-bend pipe assembly used to carry fluid that is heated from a test unit, with the water returning to a data logger at a given flow rate, in a continuous path for about 48 hours.

This type of testing provides an average thermal conductivity value for the length of the test heat exchanger. For this reason in a vertical test, the resulting data is only appropriate for the depth tested. If the design calls for shorter or longer boreholes, the test must be rerun to the desired depth. For this reason, vertical thermal conductivity test parameters should never be finalized until the system has been pre-modeled to determine load durations, flow rates from equipment, and integrated with surface conditions.

A vertical test requires that the installed test loop be allowed for at least 5 days to return to representative static conditions (ASHRAE, IGSHPA).

Final thermal conductivity test parameters should never be determined until the closed loop

ground heat exchanger has been pre-modeled by the mechanical engineer or a qualified, experienced loop designer, based upon the energy loads (hourly, 12 month duration), minimum flow rates required, as determined by the loads and/or heat pump equipment schedule, and thermal conductivity and static temperature ranges based upon local geologic conditions and/or adjacent thermal conductivity test data.

Summary Test Parameters:

The TC test hole shall be completed as follows:

1. Test hole depth of **500'**, starting at **5' to 6'** below grade
2. **1,010' x 1.25"** circuit pipe, pressure tested – HDPE, DR11, purpose built pipe for closed loop ground heat exchanger installations (i.e.; Centennial Cen-fuse or equivalent, backed with manufacturer's warranty and technical specifications)
3. Circuit pipe shall have 2' line distance markings on both legs of pipe. Driller shall record footage marks at u-bend and at end of tails, on both legs.
4. Grouted bottom to top with approved grout materials, minimum 30% solids bentonite – thermally enhanced grout **is not** desired for TC testing
5. 48 hour thermal conductivity test, ASHRAE minimum standards

Test bore parameters, detail:

Location	TBD
Depth, nominal	**500'**
Borehole diameter	5" to 6"
Circuit pipe	**1,010' x 1.25"** nominal u-bend assembly
HDPE grade and type	DR11, rated for ground loop heat exchanger use
Acceptable make(s):	Centennial Plastics, Cen-fuse with factory u-bend, or equivalent (to be submitted to engineer for approval
Circuit length	**505'** each leg minimum
Installation	Pipe shall be installed immediately upon hole reaching total depth, and grouted concurrently. NO EXCEPTIONS.
Pressure testing	Circuit shall be pressure tested to 100 psi with water for 1.0 hour without any significant loss of pressure (1.0 psi +/- is acceptable for natural pipe expansion)
Grout	30% high-solids sodium bentonite grout; grout manufacturer and grade submitted by contractor to be approved by engineer or loop designer.
Grout method	To be grouted from bottom to top as per IGSHPA minimum standards, immediately upon completion of the drilling of the test hole to Total Depth. If the tremie pipe is determined not to follow the circuit u-bend to the bottom of the hole, the contractor must demonstrate the tremie line has been installed to TD before commencing grout injection by proving sufficient tremie length has been inserted into the hole. No exceptions!
Capping	Circuit to be fusion capped or heat crimped immediately after circuit is loaded and pressure tested and hole is grouted. Circuit **shall not**

be left uncapped (fusion) overnight without on-site supervision.

Note: Final test bore location to be confirmed in writing by Mechanical Engineer (ME) or ME's designated representative before proceeding.

Pipe handling:

Intent – To verify that the test circuit remains clean internally throughout the installation and confirm that the HDPE assembly is leak-free.

1. Circuit pipe shall be cleaned and blown out with compressed air at the site to verify that the test loop has no internal debris or blockage.
2. Pipe shall be pressure tested to 100 psi with water for 1.0 hour minimum to confirm pipe integrity and documented accordingly by loop installer.
3. Pipe shall be protected at all times from internal contamination of dirt or other debris while preparing to load into the borehole.
4. Upon completion of installing the pipe and grouting by positive displacement from total depth to surface, circuit ends shall be fusion capped or heat crimped prior to leaving the test hole to rest before testing commences.

Drill log:

Drilling contractor to maintain and supply the following immediately upon completion of test:

General stratigraphic description	Depth and thickness of unconsolidated geology and/or rock types, surface to total depth
Geology	General descriptions are acceptable - Example: surface to 10' sandy-gravel surface fill 10' to 30' coarse grey sandstone 30' to 45' fine grey shale, etc.
Drill and pipe load rate	Time to drill, surface to TD Time to load pipe and grout

Note: As the diffusivity value is determined from empirical interpretation of the lithologic log, a reasonably accurate geologic description is encouraged. For loads that are heavily cooling dominant, the diffusivity value becomes more critical. We recommend professional interpretation of drill returns, to Unified Soil Classification standards, for any project that is cooling dominant.

A detailed lithologic description of the borehole log shall be copied to Major Geothermal for independent confirmation of interpreted diffusivity value provided by thermal conductivity testing data processor.

Any unusual or unforeseen conditions are to be reported with the final written drill log, such as artesian aquifers, difficult drilling conditions, etc. A prediction of production rates is requested in the final drilling report (i.e., 2.0 completed holes per day). The ME or ME's representative reserves the right to inspect the drilling and loop installation during the operation.

Test procedure:

Test and data processing shall be completed to ASHRAE minimums for Line Source test procedure. It is imperative that the power supply is clean and free from voltage and amperage fluctuation. Power should be provided by a dedicated diesel generator; line power must not be used due to normal grid fluctuations

Time delay	Test bore shall rest undisturbed for no less then 5 days prior to commencement of non-stop test
Activation of test	As per ASHRAE standards (example: Test procedures as described with operator's manual for data logger supplied by Geothermal Resource Technologies Inc. or equivalent)
Measurement of undisturbed temperature	Data logger shall be activated to flow and sample temperature for a period of no less than 15 minutes prior to activating heating elements to commence TC test
Heat input minimum capability	Minimum 7,5000 watts (500' borehole) Maximum 12,500 watts (500' borehole)
Power	20 kw minimum diesel generator 240 volts @ 20 amps minimum
Test duration	48 hours minimum
Data processing, turnaround	Within 96 hours of completion of test

Note: If testing service is not Major Geothermal, and data processor be unable or unwilling to interpret undisturbed temperature sampling for the prescribed 15 minute sampling period, raw data shall be forwarded to Major Geothermal in either .xl, .xls or .csv format for undisturbed temperature selection.

Testing contractor may be asked to provide an example of a TC test performed previously to validate experience. If the selected contractor has no experience with providing a thermal conductivity test, all procedures, data logger type, and processing method must be approved by the Mechanical Engineer **prior** to the start of the test.

As per ASHRAE, the standard deviation of power must be less than 1.5%. We have found from experience that line source power almost always exceeds this deviation, therefore we recommend that it never be used to run a TC test. Should power deviation exceed 1.5%, contractor shall rerun test at his own expense.

Should power source or data logger equipment fail during test, or power or other attributes be found to be substandard, contractor will be required to rerun test at no charge to client.

Licensing/Permit/Utility Survey

Contractor is responsible for any applicable state or local licensing, permitting, utility surveys, preparation and site cleanup.

Test Program Overview

- A closed loop vertical borehole or trenched horizontal heat exchanger specification is selected to be compatible with minimum and maximum final ground heat exchanger (GHX) designs. The GHX will be modeled using the cumulative monthly heating and cooling loads, anticipated peak loads, and a minimum and maximum estimated thermal performance of the host geologic conditions.
- The vertical test loop shall be grouted with conventional high-solids bentonite grout unless otherwise required. Thermally enhanced grout is not necessary for testing purposes, as the test relies upon the line source method of analysis. After the initial thermal penetration phase (8 to 12 hours), the conductivity values directly reflect the actual thermal performance of the host geology. TE grout may be used but is not necessary.
- The number of circuits, pipe size and grade will be selected based upon the maximum anticipated flow rates as demanded by the type and grade of ground source heat pumps.
- For vertical heat exchangers, the borehole depth and loop parameters are maintained to be compatible with least and worst case models so that the test bore may be later assimilated into the final ground heat exchanger system.
- Depending upon circumstances, the hole and/or trench may be logged to provide a reasonable geologic description of host conditions by depth, with any changes noted.
- The test ground heat exchanger must rest for a minimum of 5 days prior to the beginning of the thermal conductivity (TC) test. Allowing the test circuit to rest for a longer period of time prior to testing is acceptable and encouraged.
- Should the subsurface geologic conditions be anticipated to maintain reasonable continuity between borehole locations at the site, a single test is expected to be valid for future design and installation work.
- Tie-in of the data acquisition unit to the loop, charge the system with water, and select appropriate amount of energy to be induced into the borehole heat exchanger as determined by variables. Energy input to be confirmed with mechanical engineer prior to start of test.
- The DA unit will first sample the static temperature, and then commence measuring the rate of flow in gpm and the ΔT of the induced heat every few minutes.
- Operate the test for 48 hours (absolute minimum of 40 hours). The test must operate continuously for this time period without interruption. Data turnaround is expected to be within 24 to 72 hours of the completed test.

Borehole Circuit - Drill, Loop, Grout

The anticipated total depth for the borehole is expected to be **505'**, using an **1,010' x 1.25"** HDPE circuit pipe, schedule DR11, rated for GHX applications. The final vertical configuration will be adjusted dependent upon flow rates required, pressure drop impacts, etc., to determine final spacing and manifolding schedule.

Coordination

The loop must be allowed to rest for at least 5 days minimum to return to static conditions.

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