

SAMPLE SPECIFICATION:
Vertical Test Bore and Formation Thermal Conductivity Test
for a Vertical Ground-Loop Heat Exchanger
on Closed-Loop Ground Source Heat Pump Systems

PART 1 - VERTICAL TEST BORE

1.1 SCOPE

- A. A vertical bore shall be installed according to these specifications. The completed bore shall be located so that it may be incorporated into the final ground-loop heat exchanger design. A completed vertical test bore shall consist of the vertical bore with an approved polyethylene u-bend assembly installed to the completed bore depth with an approved grouting material installed in the bore annulus.
- B. Vertical bore can be drilled either by a mud-rotary drilling rig or by a compressed-air drilling rig which ever is most feasible based on geological conditions.
- C. Drilling contractor shall provide a detailed test bore report. The report shall include the following information:
 - 1. Each formation type encountered (drill log)
 - 2. Each formation depth (in feet)
 - 3. Depth of any significant cracks, fissures or caverns encountered
 - 4. All water bearing zones and if encountered:
 - a. Zone depths
 - b. Estimated flow rate
 - 5. Type of drilling equipment used (i.e. mud-rotary, air-rotary, air-hammer, etc.), and rig model number
 - 6. Bag quantity of drill mud used if applicable
 - 7. Total time to drill the test bore excluding shut-downs to obtain water or mechanical break-downs.A completed, signed report shall be supplied immediately at the conclusion of the drilling process.
- D. Drilling contractor shall be responsible for all permits and following all applicable codes and regulations. Where any discrepancy exists between local codes and regulations and this specification, the more stringent of the two documents prevail.
- E. Drilling contractor shall take all necessary precautions to protect the site from any damage resulting from the drilling operation.

1.2 BORE DIAMETER

- A. The diameter of the vertical bore shall not be greater than 6 inches (152.4 mm) and shall not be less than 4.5 inches (114.3 mm). The final diameter shall be determined by the drilling contractor's available equipment.

1.3 COMPLETED BORE DEPTH

- A. The completed bore depth shall be within 5% of the final estimated design bore depth for the specific project. The completed depth shall be determined by the placement of the u-bend. The distance from the bottom of the u-bend to the surface shall constitute the completed bore depth. At minimum, an additional 5 feet (1.52 m) of pipe length (on both the supply and return legs) shall be left above the installed u-bend assembly, above ground level/finished grade.

1.4 POLYETHYLENE U-BEND ASSEMBLY

- A. The polyethylene u-bend assembly shall be manufactured from a polyethylene extrusion grade material having a minimum cell classification of PE345434C per ASTM D-3350 and shall fully comply with the ISGHPA standard 1C "Ground Heat Exchanger Materials". The u-bend shall be factory assembled and pressure tested to 100 psi prior to insertion into the vertical bore. The u-bend pipe diameter shall be 3/4 inch (19 mm), 1 inch (25.4 mm) or 1-1/4 inch (31.8 mm) IPS-OD as determined from the table below:

U-Bend Pipe Diameter	Completed Bore Depth
3/4 in. (19 mm) Polyethylene	100 - 200 ft (30.48 – 60.96 m)
1 in. (25.4 mm) Polyethylene	150 - 300 ft (45.72 – 91.44 m)
1-1/4 in. (31.8 mm) Polyethylene	250 - 500 ft (76.20 – 152.4 m)

- B. Any and all connections made below grade shall be done using heat fusion.
- C. Pipe manufacturer and total installed u-bend length shall be reported immediately following bore completion.

1.5 GROUTING MATERIAL

- A. The annular space between the vertical bore wall and the u-bend assembly shall be filled with a bentonite-based grouting material with a minimum solids content of 20%. The grouting material shall be mixed in strict accordance to the manufacturers mixing instructions. Grouting material shall be placed using a pressure pump with a tremie pipe system. The material shall be installed from the bottom to the top of the vertical bore. If any settling occurs during the initial 24-hour period after installation, additional material shall be added to insure that grouting material remains at surface level.
- B. In the event that a geological formation is encountered that prevents the grouting material from forming a solid seal, either a 3/8 inch (9.5 mm) or 3/4 inch (19 mm) granular bentonite material may be use through that specific formation zone. Upon completion of that specific zone, the grout slurry shall continue to be use until reaching the surface of the vertical bore.
- C. Grout manufacturer and percent solids shall be reported immediately following bore completion.

PART 2 - FORMATION THERMAL CONDUCTIVITY TEST

2.1 SCOPE

- A. The formation thermal conductivity test is designed to determine the average thermal conductivity of the formation for the completed bore depth.
- B. Testing agency responsible for data collection oversight and data analysis must have a minimum of ten years company experience in thermal conductivity testing of vertical bore heat exchangers. Experience must include not less than 100 successfully completed tests. A list of previous tests shall be made available upon request, including references and contact information.

2.2 ELAPSED TIME AFTER BORE INSTALLATION BEFORE TESTING

- A. When the test bore is drilled with a mud rotary drilling device, the test shall be scheduled to start no sooner than 48 hours (2 days) after final bore completion.
- B. In the event that compressed air drilling is employed, the test shall be scheduled to start no sooner than 120 hour (5 days) after final bore completion.

2.3 EQUIPMENT

- A. The testing device shall be designed so that a constant rate of heated water is supplied in an uninterrupted fashion to the u-bend assembly.
- B. The minimum combined accuracy of the temperature sensor and datalogger shall be ± 0.5 °F. Loop fluid temperature readings shall be taken with temperature sensors mounted in the fluid stream. The temperature sensor and datalogger accuracy shall be verified on an annual basis with an instrument traceable to the National Institute of Standards and Technology (NIST).
- C. Power transducers shall have a minimum accuracy of ± 2.0 % of reading. The datalogger and power transducers shall be calibrated at least every two years by the manufacturer using recognized national or international measurement standards such as those maintained by NIST.
- D. The testing device shall have the capability to automatically collect data at predetermined intervals. Collected data shall be available to the design engineer in an electronic format compatible with Microsoft Excel®.
- E. The entire testing device shall be designed to prevent as much heat loss to the environment as possible. The testing device shall have an equivalent insulation 1.0" fiberglass. Each end of the u-bend assembly shall be insulated with a 0.5" closed-cell insulation to prevent heat loss or heat gain.

2.4 DATA ACQUISITION FREQUENCY

- A. Data collection device shall have the ability to accurately determine the undisturbed formation temperature by measuring the temperature of the fluid exiting the loop prior to the start of the test for a period of 20 minutes. Data shall be recorded at a maximum interval of 15 seconds during this period.
- B. Data shall be taken at a frequency of no more than every 5 minutes throughout the duration of the thermal conductivity test. Data collected shall consist of the following as a minimum; temperature into the loop, temperature out of the loop, ambient air temperature within the test unit compartment, ambient outdoor air temperature and input heat rate.

2.5 INPUT HEAT RATE

- A. The average heat input shall be within the range of 51.2 Btu/ft (15 watts) and 85.4 Btu/ft (25 watts).
- B. The average input heat rate shall be reported in the final analysis.

2.6 TEST DURATION

- A. The duration of the formation thermal conductivity test shall be a minimum of 40 hours from the initial starting time.
- B. Power interruptions are unacceptable for this type of testing. In the event an interruption occurs which lasts longer than 5 minutes, power should be restored as soon as possible and the test continued to conclusion. Provisions shall be made to run the test again based on the analysis of the collect data. In such event, the vertical bore shall be allowed to thermally rest for a period of at least 14 days prior to re-starting the test.

2.7 TEST DATA ANALYSIS PROCEDURE AND REPORT

- A. Data analysis shall follow current IGSHPA (International Ground Source Heat Pump Association) standards. Data analysis personnel shall have an engineering degree from an accredited university with a background in heat transfer and experience with Line Source theory. Documentation regarding qualifications shall be supplied upon request. .
- B. The test report shall include calibration/accuracy documentation of the test equipment including:
 - 1. Calibration dates of the power transducers and datalogger
 - 2. Verification of temperature sensor accuracy as described in 2.3.B.