Construction of a “Slinky”® Style Ground-Coupled Heat Exchanger

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ABSTRACT

Ground-coupled heat exchangers for geothermal heating/cooling systems unite thermal needs of a building and thermal capacity of available ground, using excavation or drilling equipment to place High Density Polyethylene Pipe (HDPE) into soil in the most efficient manner. Each underground system is customized to site and circumstances. Design parameters vary among configuration options but comparable thermal exchange can be achieved. For structures to 50,000 square feet or 150 tons of cooling capacity, a horizontal, “Slinky”-style ground-coupled heat exchanger may be most expedient or cost effective to install. “Slinkies” concentrate partially-uncoiled pipe in trenches or pits that are shorter or more compact than those used for straight loops. Documentation of heat exchanger location, configuration and components benefit future building operators and occupants not familiar with a site’s history or underground features. Subsurface conditions can only be visually documented while exposed during construction. Photo series, slide shows or PowerPoint® presentations can provide such a record.

Introduction

Mission Community College in Santa Clara, California installed a large geothermal heating system in a new campus center. Geothermal benefits were also desired in a new, smaller facilities’ maintenance building. This structure was 7,000 square feet in size and area for a ground-coupled heat exchanger (aka “ground loop”) was limited to 100 x 200 feet, beneath a parking lot. The site’s distinguishing features included near-surface ground water and swelling clay soils. Artesian ground water precluded vertical drilling. The logical choice was a modular, two-layer, “Slinky”® system with thermal capacity between 33 and 45 tons, subject to ground water level, run fraction and load duration.1

Slinky® Design Principles

Ground-coupled heat exchanger construction costs are one-fourth to one-half of total geothermal system costs. Use of readily available equipment, expedited construction schedules and coordination of ground loop installation with other site work minimizes expense. Simplification of work staging, soil treatment and site rehabilitation is similarly beneficial, as increased contractor productivity makes geothermal more attractive to both contractors and customers. Modified field practices do not affect heating and cooling functions or interior design.

Bid-winning excavation contractors know their machines and how to move and manage dirt. What they may not know as well are geothermal design concepts, materials, plumbing practices, tools and completion methods. One experienced and qualified advisor can direct crews and adapt practices to this unique construction mode. This same advisor also provides quality control and assurance to the project.2

Simplicity and modularity enhance construction and operation, even as they reduce cost. Each facilitates crew training, parts inventory and quality control. This Slinky® system consists of four equal quadrants of identical design. The effect is building one small system four times, with common manifolding inside the building. Eliminating cost and complexity of a vault (i.e., “junction box” for circuit piping) saves 25% to 35% of total cost and an additional week of work.3

1 Buildings have definable loads, as determined by physical and climatic conditions, but ground loops do not. Thermal exchange capacity and efficiency of ground loops vary with load duration, soil moisture content and groundwater behavior.

2 Contractor and crew education about geothermal facilities and functions are essential to total quality assurance.

3 Construction was in December, with wet winter weather pending. Total construction time was 3 weeks.
of air or “purging” with small equipment and ability to isolate one section of loop field in emergencies enhances future operation and management. All can be done quickly and “in-house”, using hand tools and easily explained procedures.

Each quadrant consists of ten (10) 600-foot loops of 0.75" HDPE Pipe. Total pipe length is 24,000 feet; total water content is 785 gallons. Five loops are on each of two levels, at -5 and -8 feet, one above the other. All 10 loops from each quadrant connect underground, with supply and return lines to the mechanical room each flowing as one.

Consideration of climate and relative balance of heating and cooling needs determined that no antifreeze is required. Heat extraction from soil surrounding loops will not depress temperature in any part of the system to near freezing. Potable water with minor anti-corrosion conditioner is all that will be used, indoors or out. This is a full-flow system without isolation of the ground loop by a mechanical heat exchanger from building flow.

Concern for swelling clays was resolved by alternating layers of native material with 12" of graded sand around both pipe levels. Full compaction of each layer precludes expansion or settling during use. Ground surface over two northern quadrants will be paved for parking and the southern half will be rocked as a lay-down area for materials and heavy equipment. Rainfall will percolate freely, as no subsurface drainage other than sand layers favoring lateral migration exist.

Elevated ground water will saturate soil around -8 feet loops during most of the year. Construction occurred in December, the driest month of an unusually dry year (2013) and ground water wicked upward to flood lower loops as soon as fill was in place. Upper loops are adjacent to manually-operated “soaker lines” capable of adding municipal water to sand bedding at the -5 foot level. Administrative concerns exist for adding water to compacted fill but optional use of this system will be guided by entering water temperature from the loop field. Perforated soaker lines represent “insurance” that may be seldom used. This ground loop’s capacity is robust.

**Conclusion**

The essence of any ground-coupled, water-source heat pump system (aka: “geothermal heat pump system”) is heat transfer between a buried heat exchanger and surrounding soil, sufficient to put or take enough heat to assure comfort in the host building. Design starts with assessment of available land, construction equipment and contractor skill. “How much pipe” is a more critical variable than the pipe’s configuration. Up, down or sideways can all work the same, providing skill and experience of the designer properly account for interactive variables.

This building, as do most others, occupies enough land to install a ground loop for decades of flexible, reliable service. However, optimization of site size, construction schedule, budget, and low bidder’s unfamiliarity with geothermal require understanding of all options. Heat load calculations for the building cannot foresee future additions or changed uses … but these can be expected over 50 or more years. Operating simplicity is needed so generations of maintenance staff can have understanding and confidence in the “unusual” system. Such flexibility results from construction costs low enough to over-build (slightly) within budget and from assured soil moisture to maximize heat transfer. Such common sense provisions were achieved on-time and on-budget with a modular Slinky® system that can be expanded in the future, if necessary.

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4 45 to 50 gpm rather than 160 to 175 gpm

5 High Density Polyethylene (“HDPE”) pipe is made of 4710 resin and manufactured to Standard Dimension Ratio (“SDR”) 11. Pressure rating at 73.5°F is 200 psi; burst point is 750 to 800 psi for >30 seconds. Operating pressures are <100 psi at <100°F.

6 No rules of thumb describe how much land this may be but a Slinky® footprint (in surface area) may be twice that of vertical bores and one-third that of horizontal loops serving the same load.