Layout, Fabrication, and Installation of SLINKY Ground Heat Exchangers

INTERNATIONAL GROUND SOURCE HEAT PUMP ASSOCIATION
OKLAHOMA STATE UNIVERSITY
Acknowledgements

The following individuals have contributed in the development of the materials and ideas reported in this document:

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I. Introduction

After a number of years of testing multiple-pipe ground heat exchangers, sufficient research and experimental test results exist that will allow significant reductions in trench length. These new pipe configurations reduce heat exchangers trench length to 125 feet per nominal ton of cooling capacity when using the equivalent of 4 foot of pipe per foot of trench and 80 feet of trench length when using the equivalent of 12 foot of pipe per foot of trench. Table 1 summarizes the new designs that have been tested and proved successful.

<table>
<thead>
<tr>
<th>Description</th>
<th>Pipe (feet)</th>
<th>Trench (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLINKY</td>
<td>1,000</td>
<td>80</td>
</tr>
<tr>
<td>Extended SLINKY</td>
<td>500</td>
<td>125</td>
</tr>
<tr>
<td>Four Pipe</td>
<td>500</td>
<td>125</td>
</tr>
</tbody>
</table>

Note: Pipe size is 3/4 inch.

These types of ground heat exchangers have a number of advantages that should lower the installation first cost.

1. These heat exchangers can be fabricated off site.
2. By rolling or folding, the heat exchangers can be transported to the job site thus minimizing field labor.
3. The heat exchanger is a unit type construction which simplifies field placement in the trench without the use of special placement equipment.

A fixture (figure 2) can be constructed to hold the pipe in place while the loops are being tied together. Plastic wire tie wraps with metal catches, nylon rope, duct tape or any other low cost method of fastening the pipe together for transportation and placement is acceptable.

II. Pipe Material Selection

The International Ground Source Heat Pump Association (IGSHPA) recommends the following for polyethylene and polybutylene pipe materials (See Appendix C of the IGSHPA's the Closed-Loop/ Ground-Source Heat Pump Systems: Installation Guide):

**POLYETHYLENE**

The minimum cell classification number acceptable for polyethylene pipe is PE355434C or PE345434C when tested under ASTM 3350.

**POLYBUTYLENE**

Polybutylene shall be manufactured in accordance with ASTM Standard D-2581. The material shall be:

1. Either Class B (general purpose and dielectric, in colors) or Class C (weather resistant, black in color containing not less than 2% carbon black)
2. Type II (density, 0.91 to 0.92 g/cm³)
3. Grade 1 (flow rate 0.25 to 0.75 g/10 min)

The cell classification shall be printed on the pipe for positive identification. If the pipe cannot be identified by cell classification number, then other means of identification must be established. Labels such as PE3408, high density, etc., are not sufficient and cannot be used to satisfy the intent of the IGSHPA recommended minimum standards.
NOTES:
1. Each type of heat exchanger is fabricated from a 3/4 in. HDPE pipe.
2. Trench depths are 5 ft.

FIGURE 1: Multiple pipe ground heat exchangers

FIGURE 2: Fabrication fixture
III. Coil Configuration

Circular coiled heat exchangers can be configured in a number of different ways. The two types fabricated and tested at Oklahoma State University are: 1) a SLINKY (Figure 3) in which the individual circular coils overlap and 2) a Extended SLINKY (Figure 4) where individual coils are separated and do not overlap.

In addition to the two heat exchangers described in Figures 3 and 4, contractors have developed other configurations that are specifically designed to meet their installation needs. Two of these methods are given here.

**Lynn Vick Method**

The Extended SLINKY can be fabricated in a flat configuration (Figure 5) for transportation to the field by tying the return pipe to the base of the coil. Before the coil is placed in the trench, the return pipe is cut free from the bottom of the heat exchanger and is installed at the top of the ground heat exchanger.

**Bill Van Alstine Method**

Coils are 30 to 32 inches in diameter and are spaced 30 to 32 inches apart from the point where they are tied. A 30- to 32-inch circle is used since it is easier to shape while the person fabricating is standing up. The 30- to 32-inch spacing places the loops against each other but not overlapping (see Figure 6). This spacing is an average man's step or arm length hence no special measuring devices are needed. The trench length (approximately 150 feet) will vary depending on how much lead in pipe is needed at the header pit. Seven hundred feet of pipe is required for this configuration.
**IV. Pipe Sizes**

Circular heat exchanger pipe sizes have been formed from 1/2, 3/4, 1, and 1-1/4 inch pipe sizes. Pipe sizing will be selected on system flow rate, fluid type, operating temperatures and pumping energy.

**V. Forming the Circular Heat Exchanger**

Forming the SLINKY coil from a pipe roll consists of allowing the pipe roll to remain in the same circular configuration it was coiled during manufacturing. The trick is to "lay off" individual coils from the pipe coil roll. A common mistake is to uncoil the pipe as if it were to placed in a straight line. Laying off of the pipe should begin with the outside coil of the pipe roll, as shown in Figure 7. This end should be the closest to the fixture when unrolling it. Figure 8 illustrates how the individual pipe coils are pulled from the roll to and through the coil fixture. It works much in the same way as you would unroll a newly purchased garden hose.
VI. Coil Tying

Tie Type

The tie wrap must be sufficiently strong to hold the coil in position during fabrication, transportation and placement in the trench. After placement and backfilling, the ties are of no value and therefore can deteriorate with no consequence.

Plastic wire tie wraps with metal catches are recommended. These type of ties have sufficient strength to allow a SLINKY coil to be rolled into a doughnut shape (see Figure 9). Figure 10 illustrates how the tie is made. Wire ties with sufficient strength to hold the coil in place are expensive.

Duct tape has been successfully used by a number of contractors. If the coil is carefully tied with a sufficient number of tape wraps the coil can be successfully transported and installed in the trench.
It has been reported that “duct tape secures the pipe over a wider area using less pressure and requires no special tools. The pipe is less likely to crimp during handling and the cost is less.” Trial and error will go a long way in determining how much tape is needed for a given installation crew.

**Tie Spacing**

Tie spacing for the SLINKY is 10 inches between each loop. The pipe does overlap. The loops intersect at the top and bottom as shown in Figure 3.

For the extended SLINKY, as shown in Figure 4, the spacing is 20 inches between each loop. These loops do not overlap. They are individually spaced apart from each other and only intersect at the bottom (see Figure 4).

The loops are tied at the top and bottom of the SLINKY where they intersect. The loops for the extended SLINKY are tied at their intersection at the coil base (trench bottom).

**VII. Fixtures**

In order to shape the loops more easily than just rolling it out and measuring it by hand, a fixture can be used to map out the spacing for the loops to be tied. The fixture is constructed from a 3/4 inch 4x8 foot sheet of plywood (see Figure 10). The pipe loops are pulled through the fixture and the loop height is constrained by the frame boundaries of the fixture. Figure 8 illustrates the procedure. Once the pipe is placed in the fixture to the specific measurements, the loops can be tied, as in Figure 11.

**FIGURE 10: Fabrication fixture details**
IX. Pressure Testing

The coils should be pressure tested at the job site to ensure that no shipping or transportation damage has occurred. Testing pressure levels should be a minimum of twice the expected maximum operating pressure. A common practice is to pressurize the loop to 120 psi using water. Normally, the water pressure and/or temperature will expand the pipe and within 30 minutes, the pressure will drop to the 60 to 80 psi range depending upon the size and volume of fluid in the heat exchanger.
IX. Spacing

Minimum spacing is 15 feet for a SLINKY coil and 10 feet for an Extended SLINKY. These design recommendations are based on experience gained from tests at OSU and from field observations.

Spacing can be adjusted based on soil moistures, soil type, heat pump run time and heating/cooling dominated climates.

X. Placement

SLINKY
The SLINKY is placed vertically or edgewise in narrow chain type trenches (see Figure 12). Trench width will be slightly greater than coil width. In certain installations that require the use of backhoe type trenching equipment, the SLINKY may be placed horizontally or flat at the bottom of the trench. In these situations, trench width will be equal to or slightly greater than coil heights.

Extended SLINKY
The trenched portion of the Extended SLINKY is placed at the bottom of the trench. The return line can be spaced approximately 6 to 12 inches above the coil by using a “setting hook.” A person walks in front of the trencher while backfilling with the setting hook holding the return line in its proper position.

![FIGURE 12: Placing the SLINKY in the trench](image)

XI. Backfilling

Silty soils and sands are most easily backfilled using a vibratory machine such as the type used to consolidate concrete. A number of hydraulic driven and electric powered vibrators are available from rental stores and for purchase.

Clay type soils must be carefully prepared before returning the material to the trench. If the clay material has been pulverized by a trencher into a granular type of consistency, then placement and tamping is recommended. If the material is removed in large clumps, then a roto-tiller or similar method of granulating the soil should be used. If the clay is unmanageable, then a prepared backfill or backfill material such as a well-graded sand should be used. Flooding as a means of consolidating a clay type soil is not recommended.
Sharp Rocks

Soils containing sharp rocks should not be used as backfill material. Sharp rocks may be removed by using a piece of expanded metal placed over the trench during backfill. If this method is not acceptable, then a backfill of well graded material should be used.

Flooding

Flooding can be successful in silt type soils with low clay contents. Two methods used are given here.

Method A
Flooding should begin with water after a 10 to 12 inch mound of dirt is formed over the trench. A plastic standpipe or metal T-bar connected to a water hose can be used to inject water under the soil at the top of the SLINKY. Backfilling is resumed when water begins to surface in the trench and the mounded soil above the trench begins to sink. Backfilling the trench to the surface before water flooding solves two problems. It contains the water in the trench and it supports the walls of the trench to slow caving of the sidewalls of the trench as backfilling takes place.

Method B
The coils are self supporting in the trench which is important during backfilling. The same guidelines and procedures for backfilling around these coils should be used as with other ground heat exchanger designs. The soil prior to filling should be in a granular state so that there are no air voids present. Water flooding of the trench is recommended to ensure good contact between the soil and pipe. The flooding should be done before the trench is fully backfilled to allow the water to be contained within the trench.

XII. Headers

Any header system used successfully for other types of parallel ground heat exchangers are appropriate. The header system should be designed to allow easy removal of air by standard methods. The “mini-header or reduced header” designed to remove entrapped air is recommended. Header procedures for above ground and bell hole fabrication have proved successful.

Above Ground

In the above ground header system, pig-tails are added to the heat exchanger so that loop connections can be made at the ground surface. After connecting, the headers and loops are placed into the header trench. The advantage here is that minimal excavation is required.

Bell hole

In the bell hole procedure, a pit is dug large enough for a person to make the loop connections below grade. This type of method is generally required for multiple parallel loops when the number of loops exceeds four or five.

Reverse Bend

A reverse bend can be used when the spacing between the loops and the header is small. This procedure requires that the pipe is looped before connection to the header pipe. This additional loop on the heat exchanger allows the pipe to be moved freely in the horizontal direction. Care should be taken not to force this loop into a smaller bend radius than recommended by the pipe manufacturer.
XIII. Additional Information

Questions relating to the Oklahoma State University research project on how the pipe was placed in the trench, backfilling procedures and water flooding methods should be directed to either Fred Jones or Randy Perry who may be reached at (405) 744-5711. These two OSU employees installed these type of heat exchangers at the OSU Heat Pump Laboratory and at the Fred Jones residence located in Stillwater, Oklahoma. Questions of a technical nature should be directed to either Dr. Jim Bose (405) 744-6270 or Dr. Marvin D. Smith (405) 744-5711.

Additional information about circular heat exchangers and ground source heat pumps can be obtained from:

1. International Ground Source Heat Pump Association
   482 Cordell South
   Stillwater, Okla. 74078
   (405) 744-5175

2. Electric Power Research Institute
   Attention: Dr. Powell Joyner
   3412 Hillview Ave.
   P.O. Box 10412
   Palo Alto, Calif. 94303
   (415) 855-2560

3. National Rural Electric Cooperative Association
   Attention: Mr. Peyton Collie
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   Washington, D.C. 20036
   (202) 857-9795

4. University of Kentucky
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   Agricultural Engineering
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5. University of Alabama
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6. South Dakota State University
   Attention: Dr. Charles Rasmund
   Mechanical Engineering
   Brookings, S.D. 57007
   (605) 688-4288

7. Oklahoma State University
   Attention: Dr. James E. Bose
   Division of Engineering Technology
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   (405) 744-6270

8. McElroy Manufacturing
   Attention: Mr. Larry Eitelman
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   Tulsa, Okla. 74158-0550
   (918) 838-8611
II. Glossary

Circular Coil: the family of multiple pipe ground heat exchangers fabricated from coiled plastic pipe patterned in a circle form.

Coil Base: the edge of the coil in contact with the trench bottom

Coil Height: the fabricated major vertical distance of a multiple pipe circular heat exchanger

Coil Width: the horizontal distance or trench measurement

Duct Tape: fiber tape used in the HVAC industry for sealing air distribution systems

Extended SLINKY: a circular coil in which the individual circular loops do not cross.

Loop: a continuous length of pipe with a single flow path.

Pitch: the space between circular coils.

Pipe Bend Radius: the pipe manufacturers recommended minimum allowable radius for an installed pipe

SLINKY: scientific name; a curtate cycloid (Palme Mogensen, Sweden)

Well-Graded: a material with a full range of particle sizes