GEOTHERMAL HEAT PUMPS – CONFIGURATIONS/INSTALLATION

There are three main categories when dealing with geothermal heat pumps; open-loop, closed-loop, and direct-exchange. The closed-loop and direct-exchange systems can be arranged in either parallel or series configurations.

OPEN-LOOP SYSTEMS

In an open-loop system, heat transfer is performed with surface or groundwater. The water is taken into heat pump units and then discharged into the environment. There are several types of open-loop configurations that can be used depending on the surrounding conditions and needs of the building.

SINGLE-WELL SYSTEMS

Single-well systems rely on a lone well that serves as a water supply to the open-loop system. The water is pumped into the system and released after it is used into a drainage field or an existing body of water. An example of an open-loop single well is displayed in Figure 6. These systems provide an economical solution to a groundwater heat pump if there is a preexisting well. In residential situations, a domestic water supply well could possibly be too small to meet the water needs of the groundwater heat pump. Residential wells typically produce 300 to 400 gallons of water per day, where a groundwater heat pump for the same residence may require thousands of gallons of water per day. In addition to this, the water discharged from the system may be limited by environmental or local regulations. A slightly modified single-well system which may alleviate some of these concerns is a standing-column well.

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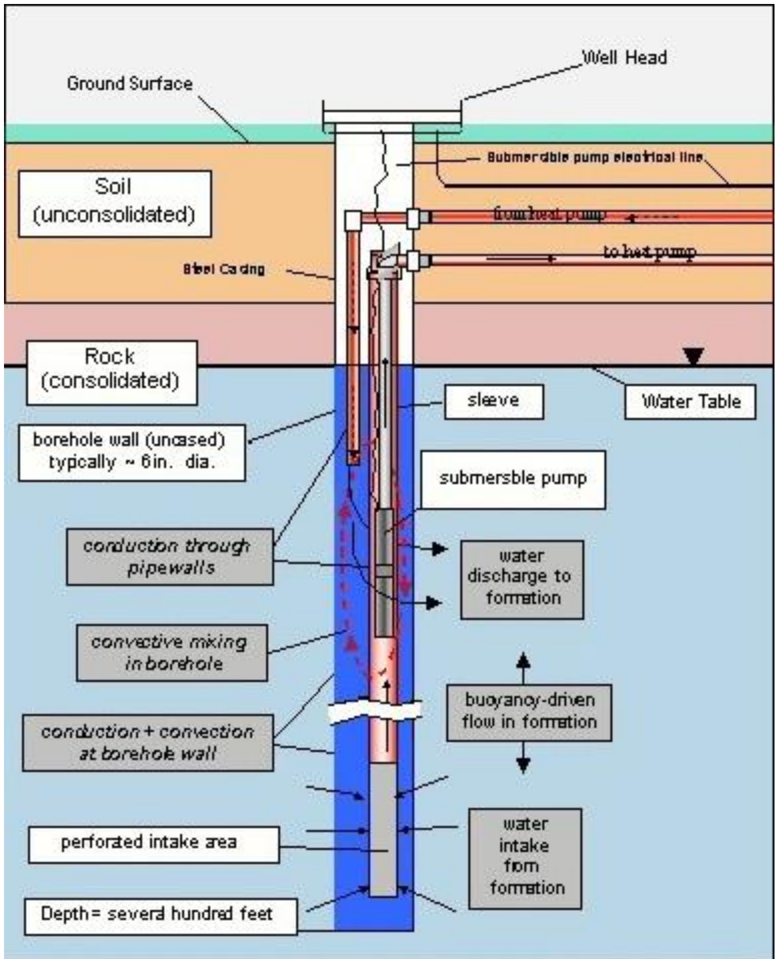
STANDING-COLUMN WELLS

A standing-column well uses the same concepts as a single-well system, except in a standing-column well most to all of the discharged water is dispensed into the original well source. This minimizes the amount of water discharge from the system into the environment. A standing-column well system is feasible when there is accessibility to fractured bedrock aquifers near the ground surface. A standing-column well typically consists of an installation of uncased boreholes 6 inches in diameter and at a depth of 1000 to 1500 feet. The surrounding aquifer is in contact with the borehole, which allows the formation of a standing column of water from the bottom of the well to the top of the groundwater table. An example of a standing-column well can be seen in Figure 7.

The water for the system is drawn from the bottom of the well and discharged into the top of the well. This allows for no net withdrawal from the groundwater itself. At times of higher demand for heating or cooling, this type of system can “bleed,” which means it returns only a portion of the water back to the well and the other portion is discharged into the surrounding environment. When this “bleeding” occurs a net groundwater inflow happens within the column. “This chills the standing column during periods of peak heat rejection (when building demand for cooling is the greatest) and/or warms it during peak heat extraction (when heating demand is greatest), thus reducing the required bore depth.,” [Virginia Tech Website]. In comparison to closed-loop geothermal heat pump systems, a standing-column well can save the owner significantly if it is well designed and accurately sited. The ground area required to install a standing-column well is the least of any geothermal heat pump system, making this type of system ideal for areas with limited space and the proper geological conditions.



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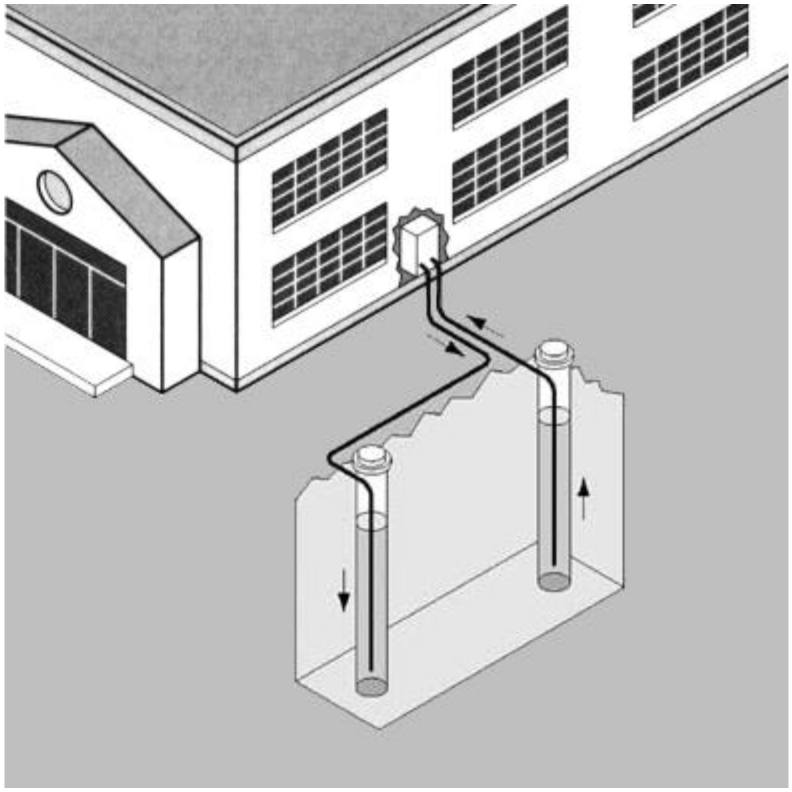
DOUBLE-WELL SYSTEMS

Double-well systems consist of both a supply and discharge well. Similarly to standing-column wells, a double-well system may be used in instances where there are water discharge regulations or limits. An important design aspect of this type of open-loop system is the distance between the supply and discharge wells. A main consideration when determining the distance between the wells is the flow rate from the injection well to the production well. There may be a flow between wells, but it must be low enough so that the discharged water arriving at the production well is approximately the same temperature as the natural aquifer. Typical well spacing in a double-well system is in range of 200 to 600 feet. This is largely dependent upon the maximum system heat/cooling loads, time span of these maximum load conditions, and the natural flow rate and thickness of the aquifer. An example of a double-well system is shown in Figure 8.



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SURFACE WATER SYSTEMS

A surface water system uses a larger body of water like a lake or an ocean for both the water supply and discharge points. If the water body is deep enough to have a thermocline in a source containing thermal stratification, a source of cold water that remains undisturbed is available year round. Sometimes, this colder water provided by the water supply may be enough to provide direct space cooling using water/air heat exchangers. This eliminates the need for heat pumps or refrigerant to cool the building interior. When using this direct space cooling method, the temperature of the building loop water must remain below 55 °F to provide effective dehumidification. "Data from lakes in Alabama suggest that significant thermal stratification occurs in lakes deeper than 30 feet, with bottom water temperatures between 45 and 55 °F throughout the year, even when summer surface water temperatures reach 80 to 90 °F."[9]

ISOLATION HEAT EXCHANGER

"Indirect open-loop systems employ an isolation heat exchanger between the building loop and the water supply. This eliminates exposure of building water loop or heat pump components to poor-quality supply water, making more sites potentially attractive for open-loop systems. The isolation heat exchanger also allows the building loop and supply water loops to be operated at different flow rates and pressures for optimal thermal and hydraulic performance.”[10]

EVALUATING OPEN-LOOP FEASIBILITY

WATER QUALITY

- Heat exchanger is exposed to dissolved ions, suspended solids, and microorganisms from the supply well.
- The heat exchanger is prone to scaling and buildup of corrosion films and fouling.
- The thermal and hydraulic resistance to heat transfer is increased, which decreases overall efficiency.
- Water treatment is not economical.

WATER AVAILABILTY

- Required groundwater flow rate typically is between 2-3 gallons per minute per system ton.

DISCHARGE WATER PERMITTING

- Groundwater must be re-injected into the ground or drainage system.
- Must follow local water discharge regulations.
- Water is discharged at higher elevation than the intake point which represents a static pressure head. This requires more power to overcome by the circulating pump.

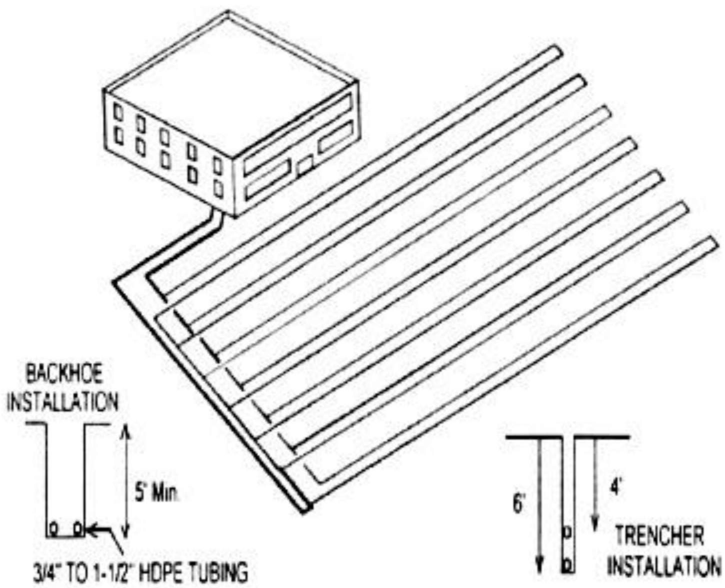
CLOSED-LOOP SYSTEMS

Closed-loop systems are the most common geothermal heat pumps. They circulate the working fluid through the pipes and do not use a water source. They work by only transfering heat through the piping networks meaning that there is no direct interaction between the working fluid and the earth. The length of required piping depends on ground thermal conductivity, ground temperature, and heating and cooling power needed, as mentioned in Geothermal Basics above.

The most common closed-loop systems are: vertical, horizontal, slinky, and pond.

HORIZONTAL CLOSED-LOOPS

Horizontal closed-loop systems are composed of pipes that run horizontally through the ground. A long horizontal trench, deeper than the frost line, is dug and U-shaped coils are placed horizontally to connect the pipes. A trench for a horizontal loop field will be similar to one seen under the slinky loop field. The width of the field is dependent on the number of pipes. Horizontal loop fields are very common and economical if there is adequate land available.



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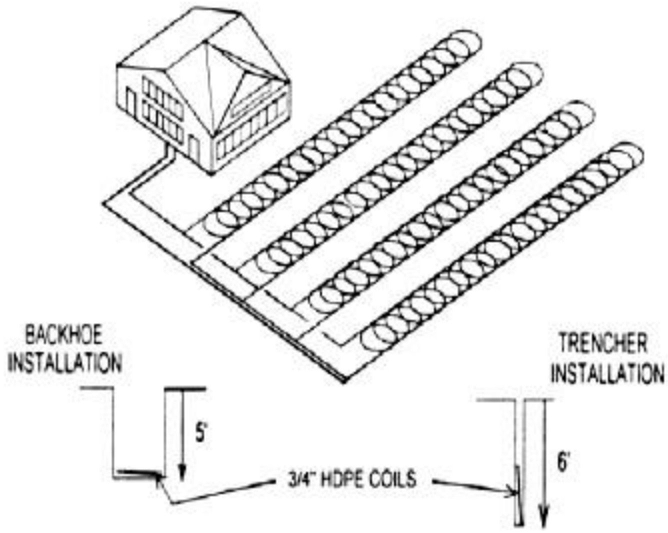
SLINKY CLOSED-LOOPS

A slinky closed-loop field is installed in the horizontal orientation with an overlaying piping network. Slinky loop fields are used when there is not adequate space for a horizontal closed-loop system. Slinky closed-loop systems have easy installation.



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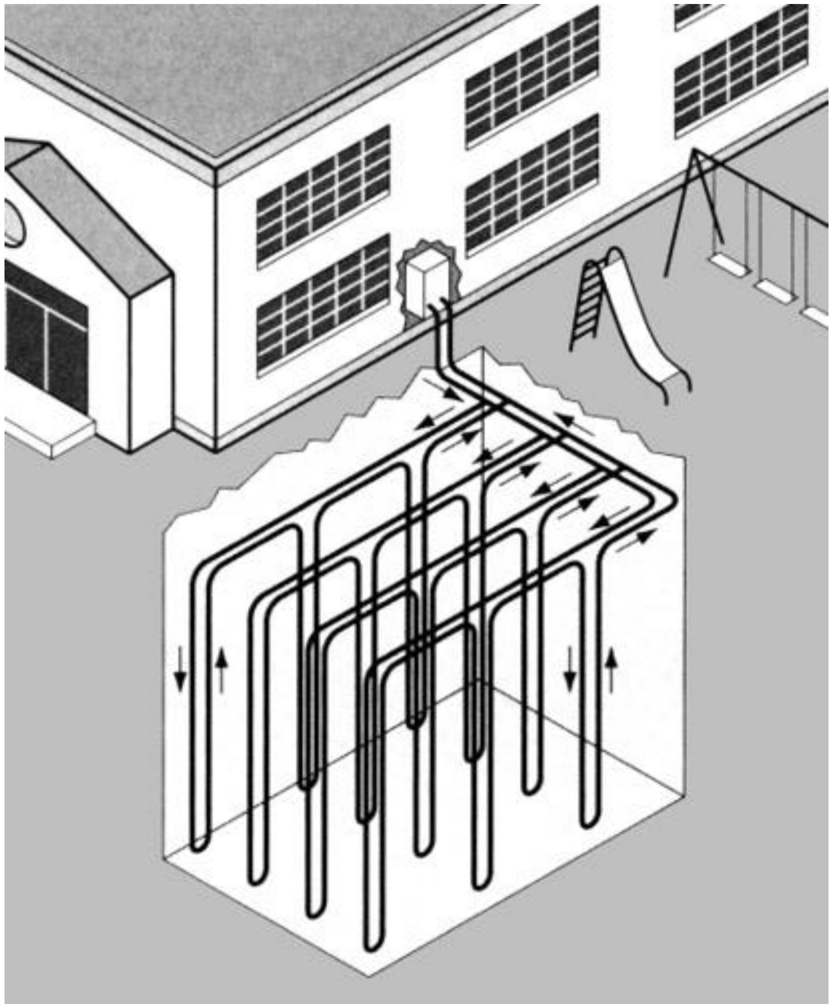
VERTICAL CLOSED-LOOPS

Vertical closed-loop fields are oriented with a piping network running vertically into the ground. Holes are bored into the ground about 150-250 feet deep. There are U shaped connectors at the bottom of the hole connecting pipes. The borehole is commonly filled with a bentonite grout surrounding the pipe to provide a good thermal connection to the surrounding soil or rock to maximize the heat transfer. Vertical closed-loop fields are ideal for limited areas. During the cooling season, the local temperature rise in the bore field is influenced most by the moisture travel in the soil.



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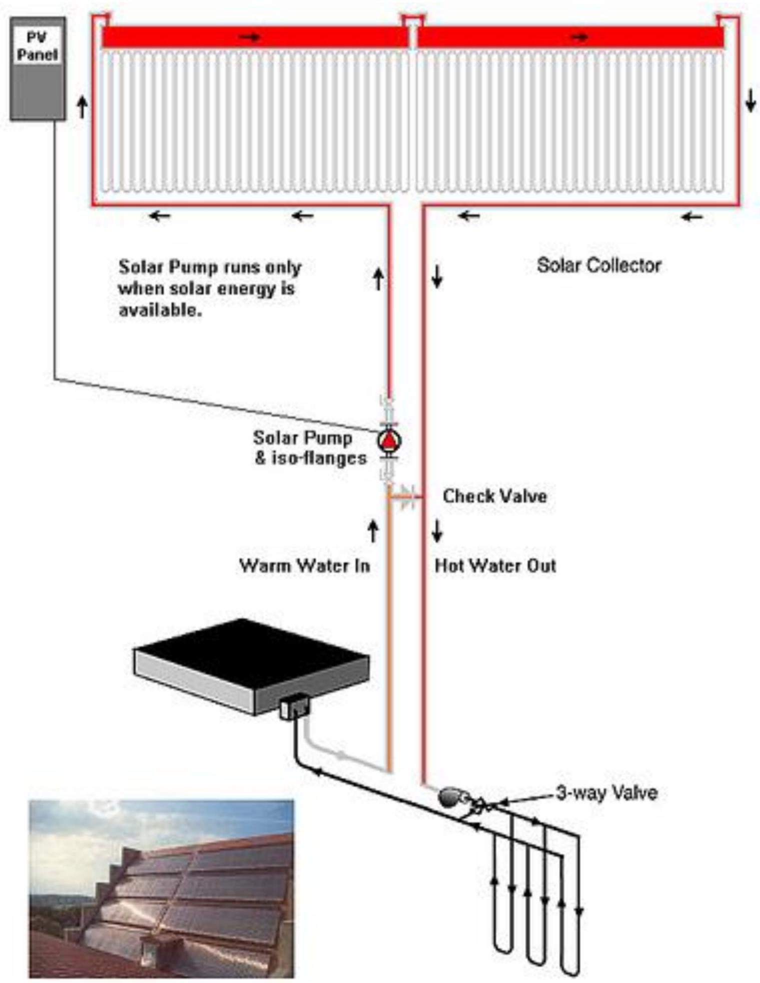
OTHER TYPES OF CLOSED-LOOP SYSTEMS

- Submerged closed-loops
- Hybrid loop with cooling pond
- Hybrid loop with cooling tower
- Hybrid loop with solar collector



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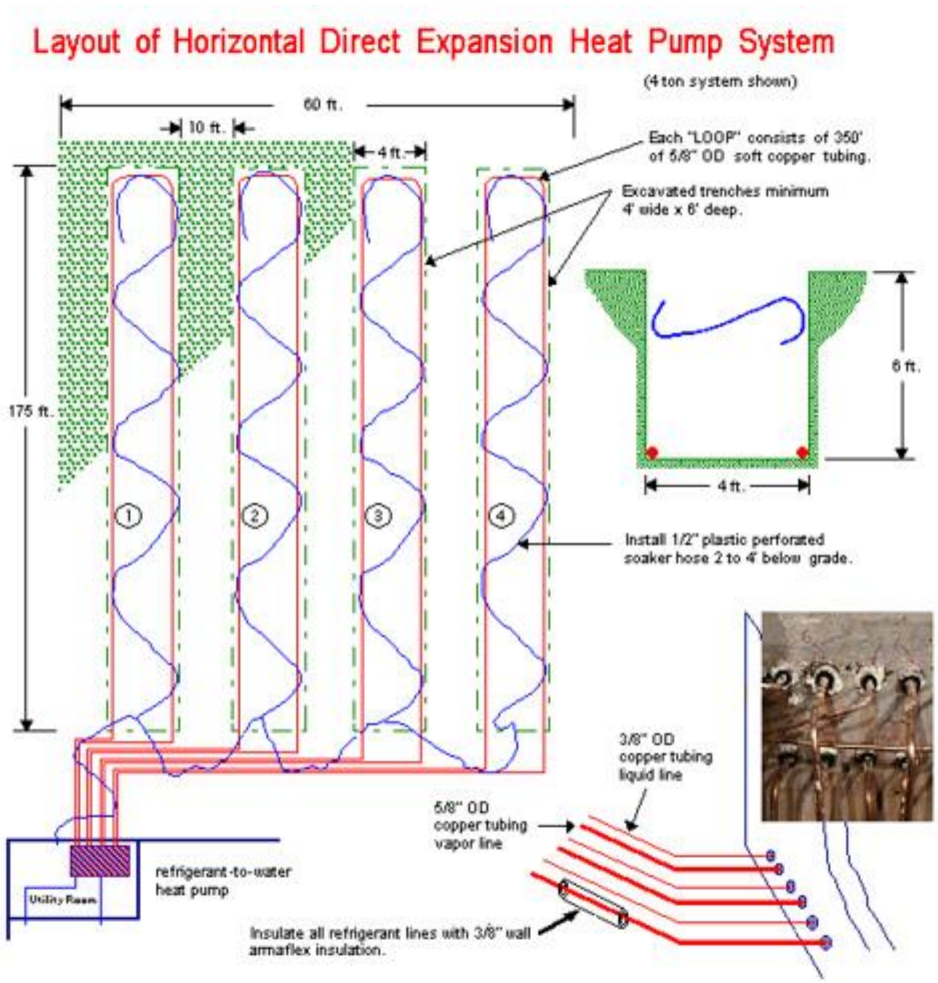
DIRECT EXCHANGE (DX) LOOPS

Direct exchange systems have a refrigerant circulating through copper pipes which are drilled directly into the ground, eliminating the need for a heat exchanger between the refrigerant loop and the water loop and the water pump.

The DX loop systems have many benefits, including:

- Simple installation
- Higher efficiencies
- Shorter and smaller piping
- Lower installation costs

- Can also be used for home water heating
- Very long lifetimes



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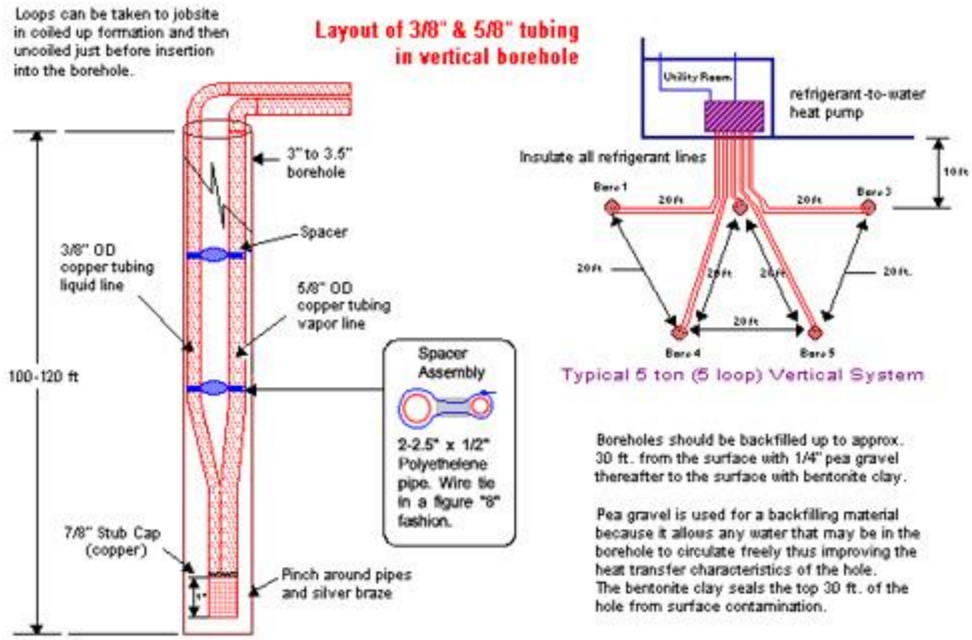
Horizontal DX Arrangement:

- Horizontal-loop DX systems require about 350 feet of copper tubing per system ton, as opposed to 450 to 500 feet per ton for polyethylene ground loops.
- Because of their shorter length, horizontal DX ground loops need only about 500 square feet of land area per system ton, considerably less than the 1,500 to 3,000 square feet needed for conventional horizontal closed-loops.[16]



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Vertical DX Arrangement:

- Vertical DX systems require only a 3-inch diameter bores to a depth of 120 feet per ton, as opposed to 4- to 6-inch diameter bores to a depth of 200 to 300 feet per ton for polyethylene U-tubes in conventional vertical closed loops.
- Vertical DX loops need at least the same land area as their conventional counterparts, or even somewhat more.
- Vertical DX boreholes should be spaced at least 20 feet apart to minimize the possiblity of ground freezing and buckling in the heating mode or excessive warming and drying of the soil in the cooling mode.[18]

Source : http://me1065.wikidot.com/geothermal-home-heating-and-cooling