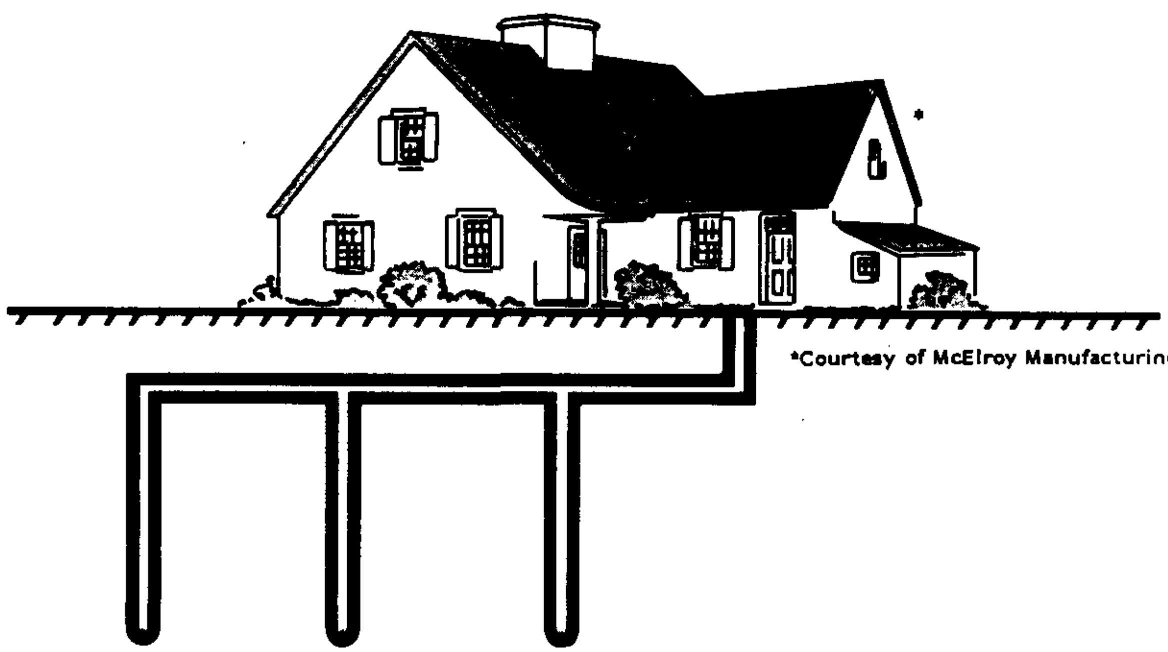
MANUAL 2100-099 G

EARTH COUPLED LOOP SYSTEM DESIGN MANUAL



*Courtesy of McElroy Manufacturing.

BARD MANUFACTURING CO. • BRYAN, OHIO 43506

DEPENDABLE QUALITY EQUIPMENT . SINCE 1914

IMPORTANT

The following Bard Water Source Heat Pumps will <u>not</u> work on earth loop systems.

WPV30 or WPVD30
WPV36 or WPVD36
WPV53 or WPVD53
WPV62 or WPVD62
WQS30 or WQSD30
WQS36 or WQSD36
WQS50 or WQSD50

For EARTH LOOP SYSTEMS use one of the following:

WPV30A or WPVD30A
WPV36A or WPVD36A
WPV53A or WPVD53A
WPV62A or WPVD62A
HWP30 or HWPD30
HWP36 or HWPD36
WPV30B
WPV36B
WPV53B
WPV62B

The design of an earth coupled system is divided up into the following steps.

I. Determine the structure design heating load in Btuh loss and design cooling load in Btuh gain. It is very important that an accurate load calculation of the structure be done, therefore, it is recommended that "Manual J" from ACCA or other national accepted methods be used.

II. Select a water source heat pump. When selecting a water source heat pump for use on an earth coupled system, it may have to operate at entering water temperatures between 30°F to 100°F, therefore it is very important that the minimum and maximum entering water temperatures of the selected water source be within that range. Several models on the market today have a much smaller operating range such as 45° to 85° or 60° to 85° entering water temperature. Some of those will not provide satisfactory operation on an earth coupled installation.

The heating or cooling capacity of the water source heat pump should be determined from the manufacturer's specifications for the local ground water temperatures. The water source heat pump should be sized as follows:

Heat Pumps Sized For Cooling. The sensible output capacity of cooling equipment, should not be less than calculated total sensible load nor should it exceed the calculated sensible load by more than 25 percent. The corresponding latent capacity should not be less than the calculated total latent load. The equipment sensible and latent capacities should be determined from the manufacturers cataloged performance data. Catalog performance should be verified at the local ground water temperature and indoor design conditions expected on a design day. [1]

Heat pumps which are sized for heating only should not be less than 75 percent nor more than 115 percent of the calculated total heating load. (Auxiliary heat should be sized to make up for any deficielcy in output when the heat pump unit is undersized.) Emergency heat may be required in some locations. [2]

Heat pumps which provide heating and cooling shall be sized to the cooling requirements specified above. In this case the thermal balance point will be limited by the design cooling requirement but, if a lower tharmal balance point is desired, heat pumps may be oversized for sensible cooling by up to 25 percent. Auxiliary heat should be sized to make up for the difference between the design heating load and the heat pump output on a design day. Emergency heat may also be required in some locations. [3]

III. Selection of type earth coil and materials to be used.

EARTH COUPLED SYSTEMS--Earth coupling is a method by which water used by the heat pump is circulated through pipes buried in the ground. Heat is transferred to and from the soil through the walls of the pipe. Earth coupled systems are used in areas where insufficient ground water is available, or where it is impractical to drill a well. The piping may be buried in either a vertical or a horizontal configuration.

When designing an earth coupled system, particular attention must be paid to balancing the system between the heat pump unit and the earth coupled loop. In a balanced system, the earth coupled loop will remove all of the heat energy transferred to the water by the heat pump (cooling cycle), and will provide all of the heat energy to the water that the heat pump unit is capable of absorbing (heating cycle). The net result of a perfectly balanced system is that the change in water temperature through the heat pump is offset by an equal and opposite change in temperature through the earth coupled loop. For instance, if the heat pump unit in the cooling cycle causes the water temperature to rise 15°F, then the loop must cause a corresponding drop of 15°F.

A word of caution is required here. Although the earth coupled loop is designed for a balanced rise and fall in water temperature, suggesting that the net average loop water temperature remains constant, because the ground temperature may vary ±15°F from season to season, the loop water temperature may vary ±20°F from the balance point temperature. This is because the ground is able to overcool the loop water in winter, and may undercool in summer. Because of this, the temperature of the water entering the water source heat pump unit may drop below 30°F in winter or rise above 100°F in summer. This range in entering water temperature is extremely important because water source heat pumps are designed to operate within specific operating temperature ranges (see manufacturer's specifications for water source heat pump operating ranges). The temperature ranges are established to protect both the heat pump unit and the water loop piping. Furthermore, these temperature ranges are based on water only passing through the system. The low temperature limit of 40°F in a water source heat pump unit is established to protect the loop water from freezing. Again, this low limit presumes that water only flows through the system. If, however, water is mixed with a non-toxic antifreeze solution, the entering water temperature can be allowed to fall to 30°F.

HEAT PUMP:

Use only a water source heat pump that can be operated on loop temperatures well below 40°F down to 30°F. Information on when to use an antifreeze solution in a ground coupled water source heat pump system is contained in the following discussions on vertical and horizontal configurations.

PIPE:

Use polybutylene (PB) or polyethylene (PE) pipe for horizontal coils, vertical U-bend wells and for service lines to the wells and lake exchangers. IPS PB pipe is used with insert fittings and clamps. CTS PB pipe is fused together with appropriate fittings using a fusion tool. PE pipe is heat butt fused with appropriate fittings using a fusion tool.

CLEANLINESS:

During installation keep trash, soil and small animals out of the pipe. Leave the ends of the earth loop pipe taped until the pipe is ready to be connected to the service lines or the equipment room piping.

PRESSURE TESTING:

Plastic pipe assemblies should be pressure tested at twice the anticipated system operating pressure prior to backfilling. Normal static equipment room pressure is 50 psig.

BACKFILL:

Narrow trenches made with a chain trencher can be backfilled with the tailings provided no sharp rocks are present.

Wider backhoed trenches can be backfilled with the excavated material provided it is in loose granular form. If the material contains clumps of clay or rocks, the plastic pipe must be covered first with sand before filling in with clumps and rocks.

Drilled boreholes of 4-6 inches in diameter are common for vertical geothermal wells. Backfill may be any granular material not containing sharp rocks. This includes the drilling tailings, sand, pea gravel or bentonite mud.

LOCATION MARKERS:

It is desirable that the locations of important points such as well heads be marked for subsequent recovery. The placement of a steel rod just below the surface can identify these features or mark the outline of an entire serpentine earth coil.

[1,2,3] "Manual J by Air Conditioning Contractors of America, 1981 Edition, p. 44.

AS-BUILT PLANS:

Earth coupling features should be drawn on a site plan as installed if possible, to aid in the location of key components. A simple way to locate key features is to make 2 measurements (sides of a triangle) from 2 corners of a building to the feature. Record these measurements in a table on the plans.

Reasons for using an earth coupled system.

1. Unlike a standard solar system the loop operates day or night, rain or shine all year, delivering heat to and from the heat pump.

2. It is cost effective in northern or southern climates.

3. Because the water circulates through a sealed closed-loop of high strength plastic pipe, it eliminates scaling, corrosion, water shortage, pollution, waste and disposal problems possible in some open well water systems.

VERTICAL. A vertical earth coupled system consists of one or more vertical boreholes through which water flows in plastic pipe. A distinct advantage of a vertical system over a horizontal system is that the vertical system requires less surface area (acreage). In areas where the ambient groundwater (average well water) temperature is less than 60°F, the use of an antifreeze solution, such as propylene glycol, to avoid freezing the loop is recommended. (Figures 1, 2 and 3).

Boreholes are drilled 5" to 6" in diameter for 1-1/2" diameter pipe. For 3/4" diameter pipe loop systems, the vertical loops are connected in parallel to a 1-1/2" diameter pipe header. A borehole of 3" to 4" in diameter is used for 3/4" diameter loops, this lowers drilling cost. The 3/4" diameter pipe also costs less per ton of heat pump capacity. The smaller pipe is easier to handle, yet there is no sacrifice in pressure rating. Also two loops in one hole reduces borehole length. Depth for these systems is usually between 80 and 180 feet.

The basic components of a vertical earth coupled system are detailed in Figure 1. Each borehole contains a double length of pipe with a U-bend fitting at the bottom. Multiple boreholes may be joined in series or in parallel. Sand or gravel packing is required around the piping to assure heat transfer. In addition, the bore around the pipes and immediately below the service (connecting) lines must be cemented closed to prevent surface water contamination of an acquifer in accordance with local health department regulations.

SERIES U-BEND

A series U-bend well earth coupling is one in which all the water flows through all of the pipe, progressively traveling down and then up each well bore. Series wells need not be of equal length.

PIPE:

1-1/2" CTS or IPS polybutylene or polyethylene pipe is commonly used in 5 to 6 inch bore holes. IPS PB pipe is used with insert fittings and clamps. Turn the clamps so that they face inward and will not be chaffed by the well bore. Tape the clamped section of the U-bend with duct tape to provide added protection to the clamps while the pipe is being installed into the well.

CTS PB pipe is heat fused together with fittings. PE pipe is heat fused together with butt joints.

STIFFENER:

Tape the last 10 to 15 feet of pipe above the U-bend together to a rigid piece of pipe or conduit. This will make installing the pipe into the well easier.

FILL AND PRESSURE TEST:

Fill with water and pressure test before lowering the U-bend into a well bore. When drilling with air, a bore can be completed that contains no water. If unfilled plastic pipe is lowered into the bore, it will be crushed as the hole slowly fills.

MULTIPLE WELLS:

Multiple 100' wells connected in series are the easiest to drill and install in most areas. It will be difficult to sink water filled plastic U-bends into mud filled holes over 150' deep without weights. Wells are generally spaced 10 feet apart in residential systems.

SERVICE LINES:

Follow the guidelines for the horizontal earth coil when installing the service lines to and from the U-bend well.

PARALLEL U-BEND

A parallel U-bend well earth coupling is one in which the water flows out through one header, is divided equally, and flows simultaneously down two or more U-bends. It then returns to the other header. Headers are reverse return plumbed so that equal length U-bends have equal flow rates. Lengths of individual parallel U-bends must be within 10% of each other to insure equal flow in each well.

PIPE:

1-1/2" CTS polybutylene or polyethylene pipe is used for the headers with 1" or 3/4" pipe used for the U-bends. 4" bore holes are sufficient for placement of 1" U-bends.

Follow "Series U-bend Well" instructions on:

STIFFENER
FILL & PRESSURE TEST
MULTIPLE WELLS
SERVICE LINES

RULE OF THUMB
MINIMUM DIAMETERS FOR BOREHOLES

Nom Pipe Size	Single U-Bend	Double U-Bend
3/4"	3 1/4"	4 1/2"
1	3 1/2"	5 1/2"
1 1/4	4	5 3/4"
1 1/2	4 3/4"	6
2	6	7

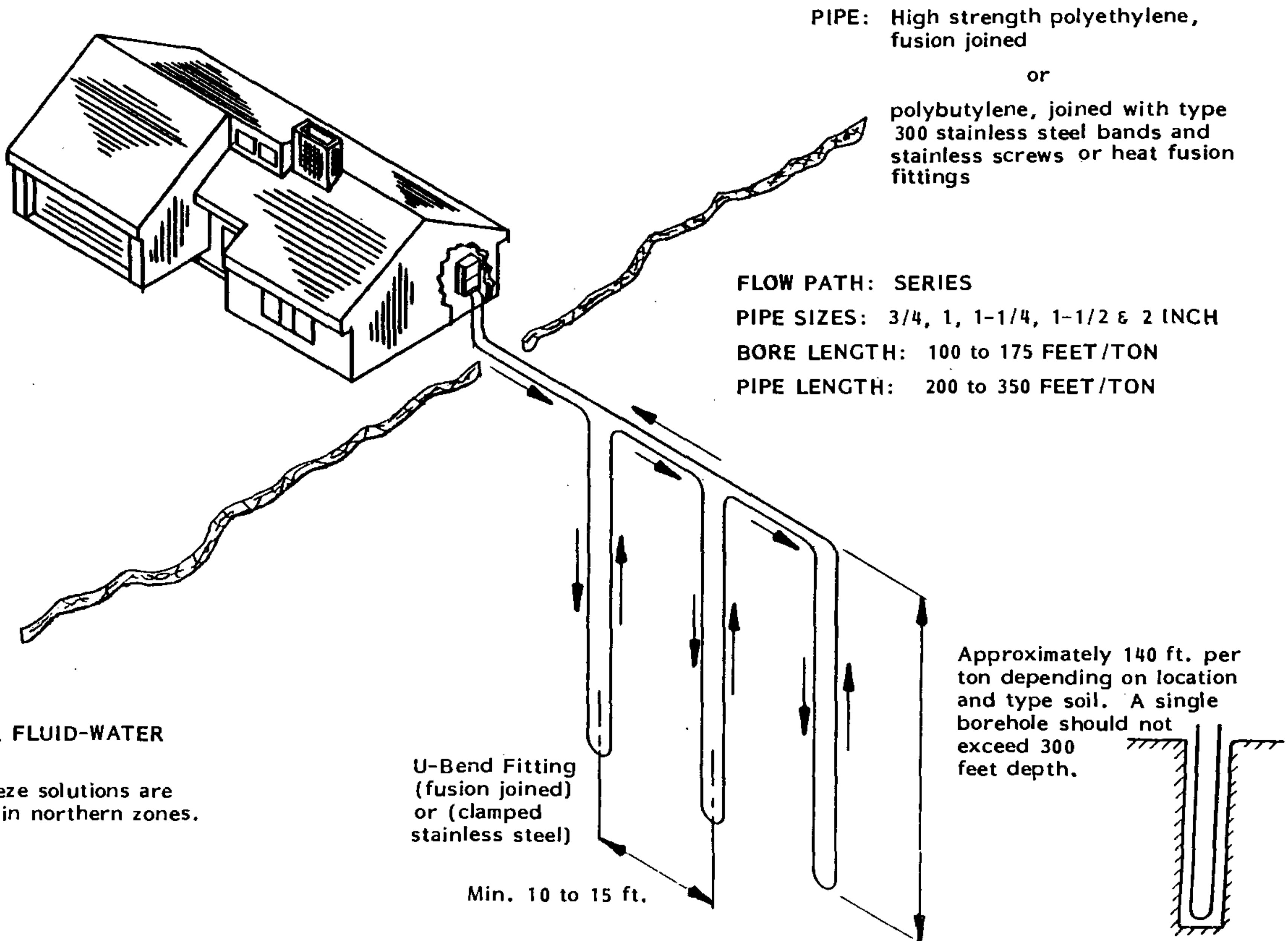
RULE OF THUMB

PVC pipe is not recommended for the buried portion of the earth coupled ground heat exchanger.

RULE OF THUMB

For parallel systems, use one loop for each one ton (12,000 Btuh) of heat pump capacity. For example a three ton heat pump would have three parallel loops. Headers are constructed from 3/4 and 1 inch pipe. For heat pumps with reduced flow requirements (2 GPM/ton and less), the series system should be considered in order to maintain the necessary fluid velocities to promote good heat transfer. See Table 1B.

VERTICAL (SERIES) SYSTEM



TRANSFER FLUID-WATER

NOTE:

Antifreeze solutions are needed in northern zones.

VERTICAL (PARALLEL) SYSTEM

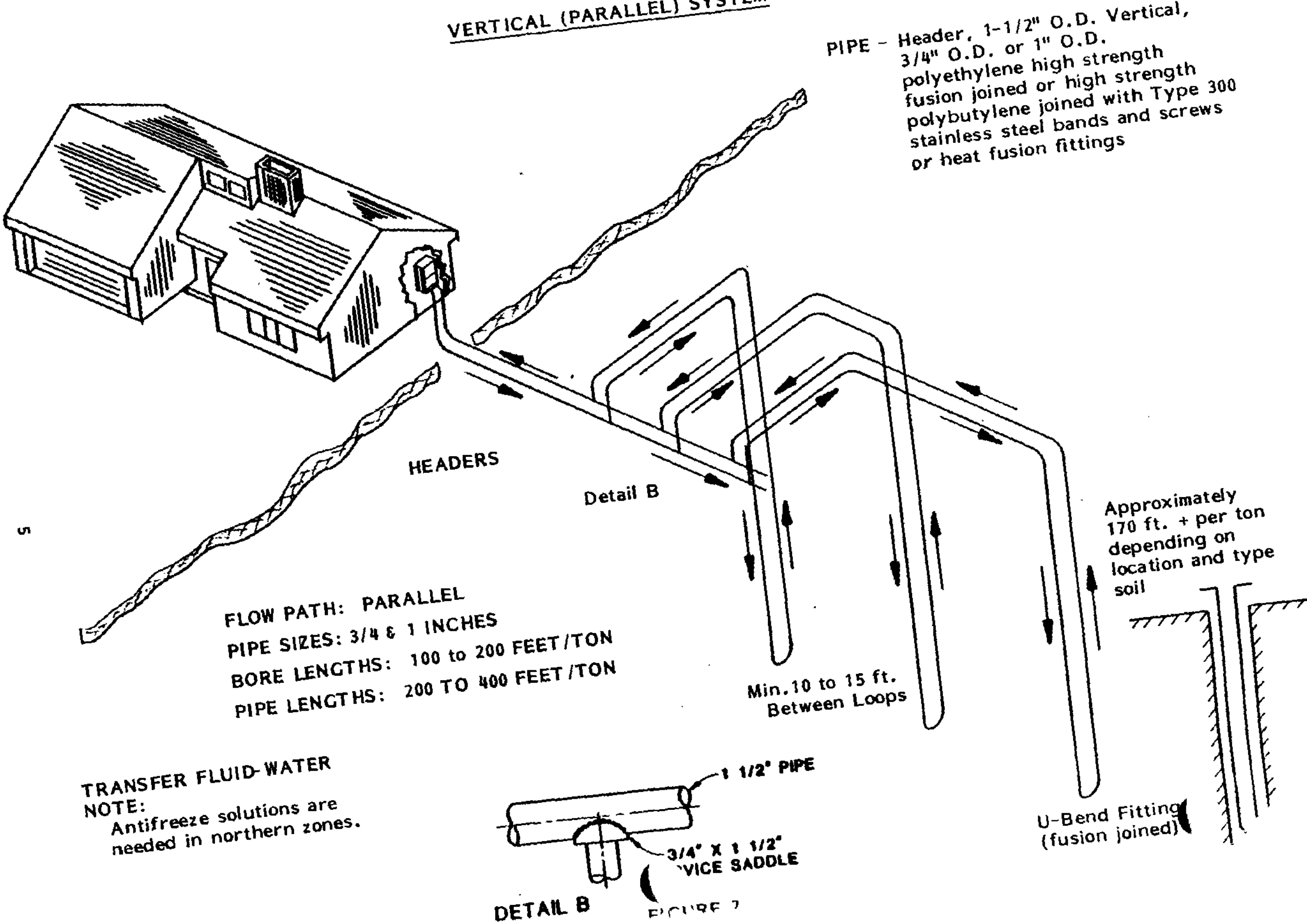
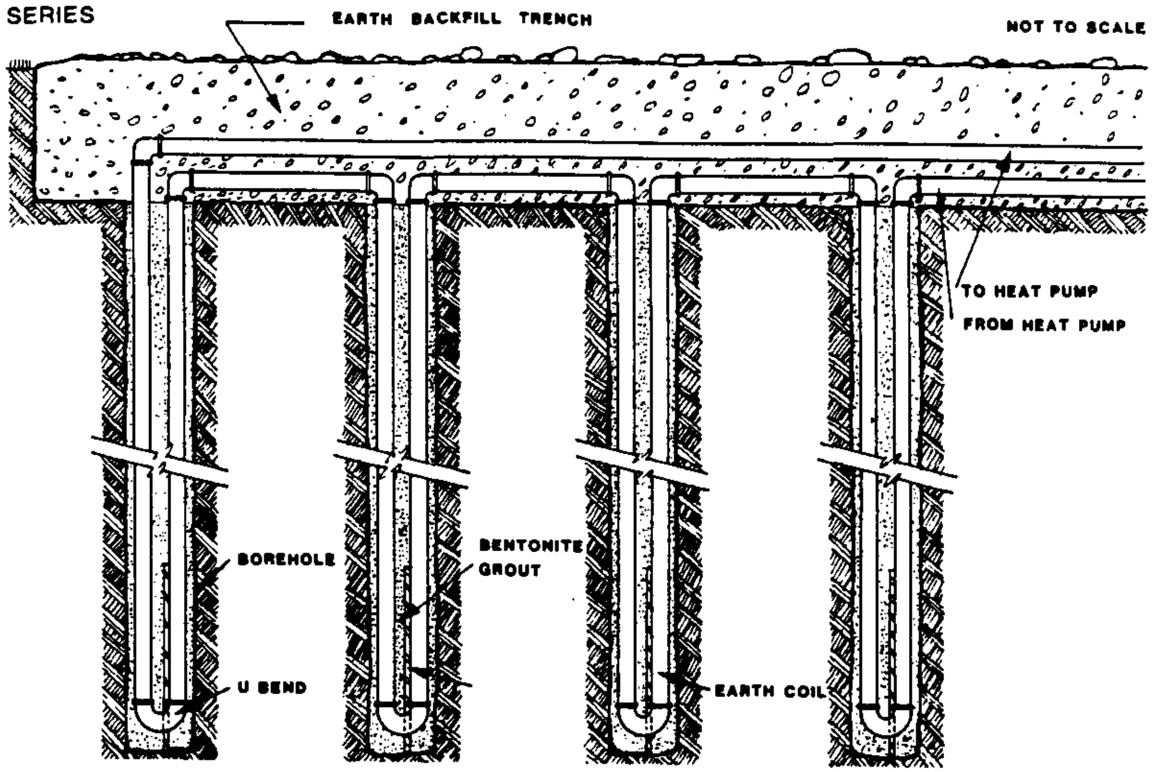


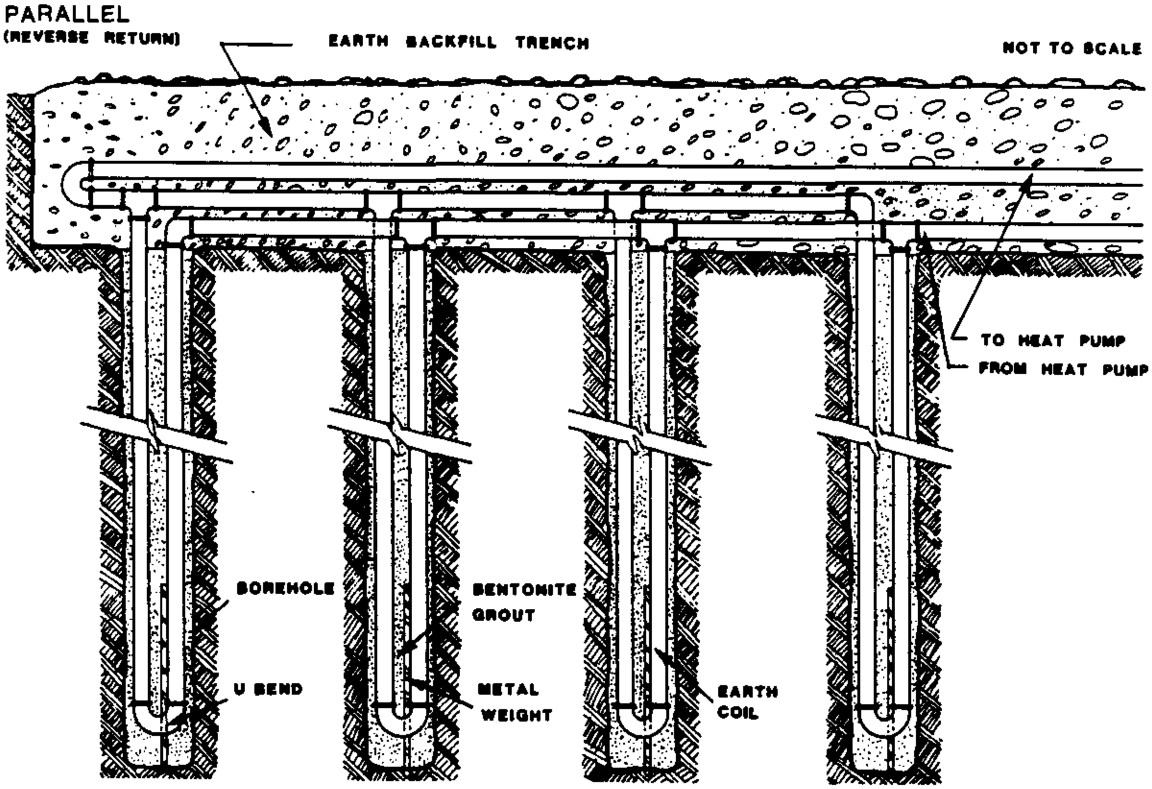
FIGURE 7

FIGURE 3. Series and Parallel Vertical Loops

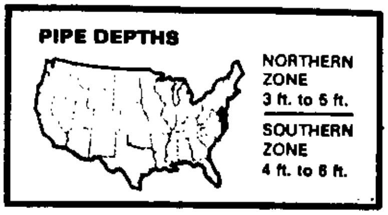
SERIES



PARALLEL
(REVERSE RETURN)



HORIZONTAL. A horizontal earth coupled system is similar to a vertical system in that water circulates through underground piping. However, the piping in this system is buried in a trench. (Figures 7, 8 and 9).



Pipe depths in the Northern Zone should be 3 to 5 feet. Excessive depth will reduce the ability of the sun to recharge the heat used in winter.

Pipe depths in the Southern Zone should be 4 to 6 feet, so that the high temperature of the soil in late summer time will not seriously affect system performance.

Antifreeze will be necessary in the Northern Zone to prevent freezing of the circulated water and to allow the system to gain capacity and efficiency, by using the large amount of heat released when the water contained in the soil is frozen.

Antifreeze solutions used is a non-toxic Propylene Glycol or Calcium Chloride.

The use of multiple pipes in a trench reduces total trench length substantially. If a double layer of pipe is laid in the trench (Figure 4), then the two layers should be set two feet apart to minimize thermal interference. Example: A 1-1/2" series horizontal system with pipes at 5 feet and 3 feet. After installing first pipe at 5 feet depth, partially backfill to 3 feet depth using a depth gauge stick before installing second pipe. With the return line running closest to the surface and the supply line running below it. This arrangement will maximize the overall system efficiency by providing warmer water in heating mode and colder water for cooling mode. Connect pipe ends to heat pump after the pipe temperature has stabilized, so that shrinkage will not pull pipe loose.

FIGURE 4A. Single and Stacked Horizontal Earth Coils

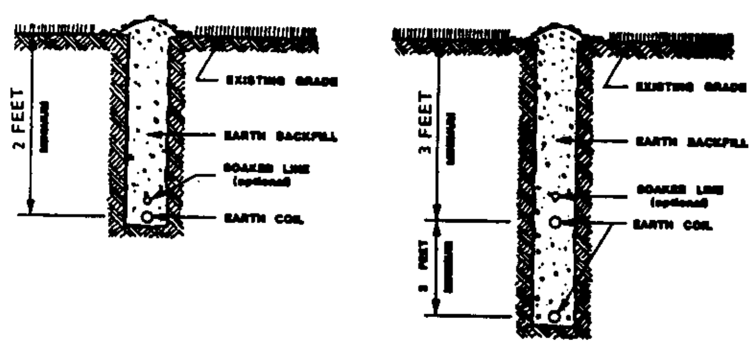
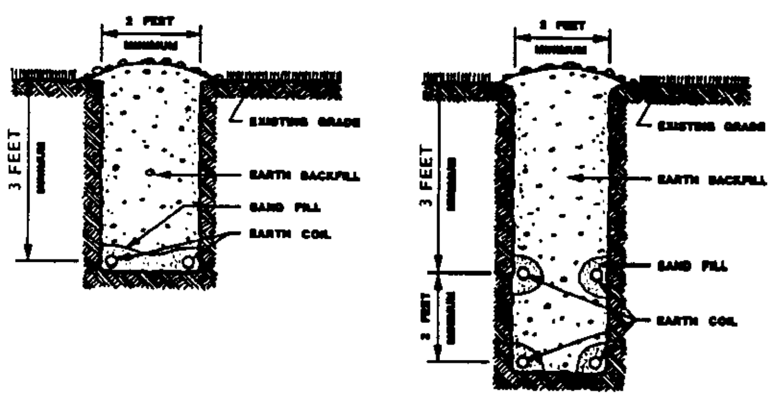


FIGURE 4B. Two Pipe and Four Pipe Earth Coil in a Wide Trench



Two pipes in the same trench, one above the other, separated by two feet of earth require a trench 60 percent as long as a single pipe. The total length of pipe would be 120 percent as long as a single pipe due to the heat transfer effect between the pipes.

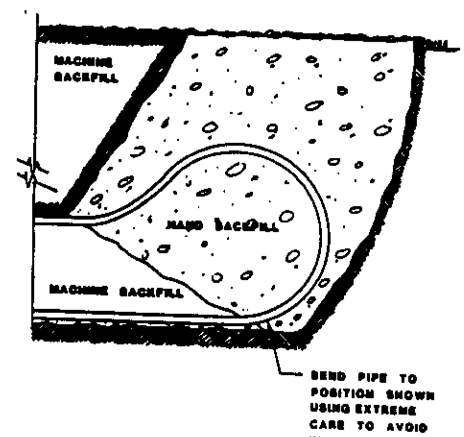
In addition, when laying a double layer of pipe, be careful to avoid kinks when making the return bend (see Figure 5). Backfill the trench by hand when changing direction. If it is necessary to join two pipes together in the trench, use the fusion technique for IPS304 stainless steel or brass fittings for greater strength and durability, then mark fitting locations for future reference by inserting a steel rod just below grade. The steel rod enables the use of a metal detector to find joints in pipe.

Trenches can be located closer together if pipe in the previous trench can be tested and covered before the next trench is started. This also makes backfilling easier. Four to five feet spacing is good.

In those areas with dry climates and heavy clay soil, heat dissipated into the soil may reduce the thermal conductivity of the soil significantly. In such cases, the designer may specify additional feet of pipe per ton of capacity. A few inches of sand may also be put in with the pipe, or a drip irrigation pipe buried with the top pipe to add occasional small amounts of water.

FIGURE 5A. Horizontal Earth Coil Turnarounds

Section View



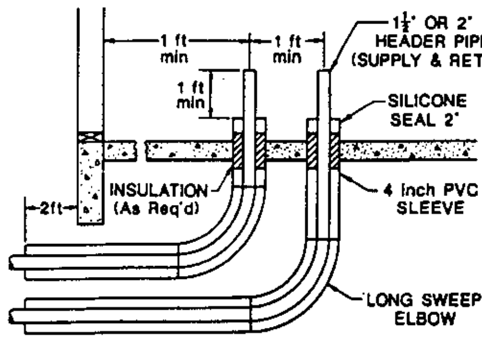
NARROW TRENCH RETURN BEND DETAIL
DOUBLE LAYER HORIZONTAL EARTH COIL

When making the return bend be careful not to kink the pipe. 2" pipe requires a 4' diameter bend.

RULE OF THUMB
Maximum length for series systems is:
a) 1500 feet for 1-1/2 inch pipe or nominal three ton heat pump system and
b) 2500 feet for 2 inch pipe or nominal five ton heat pump system.
NOTE: Fluid pressure drop dictates the length of pipe run in any ground heat exchanger design.

FIGURE 6.

GROUND HEAT EXCHANGER BUILDING STUB OUT



Note:
(1) Ground Heat Exchanger Stub Outs should be spaced a minimum of 1 ft. from any wall or obstruction.
(2) Long Sweep Elbows are required for 1½" or 2" Header Pipes.

Series horizontal earth couplings are ones in which all the water flows through all of the pipe. These may be made of 1", 1½" and 2" pipe either insert coupled or fused.

NARROW TRENCHES:

Narrow trenches are installed by trenching machines. The trenches are usually 6" wide. Generally speaking, the trencher will require about 5' between trenches. This is sufficient spacing for horizontal earth coils.

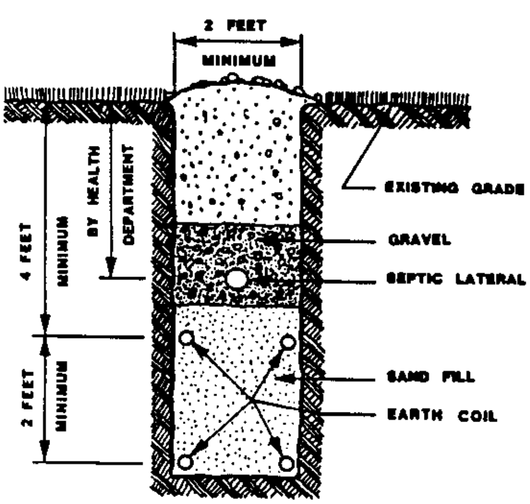
The pipe can be coiled into an adjoining trench. Since the trencher spaces the trenches about 5' apart, looping the coil from one trench to another will give a large enough diameter return. The end trench should be backhoed to give enough room for the large diameter bend.

If the pipe is brought back in the same trench, bend the pipe over carefully to avoid kinking the pipe and hand backfill the area around the return bend (Figure 5).

To reduce the bend radius, elbows may be used. However, keeping the number of fittings underground to a minimum may be preferable since the potential for leaks is reduced.

If a double layer of pipe is used, the incoming water to the heat pump should be from the deepest pipe. This provides the heat pump with the coolest water in summer and the warmest in winter.

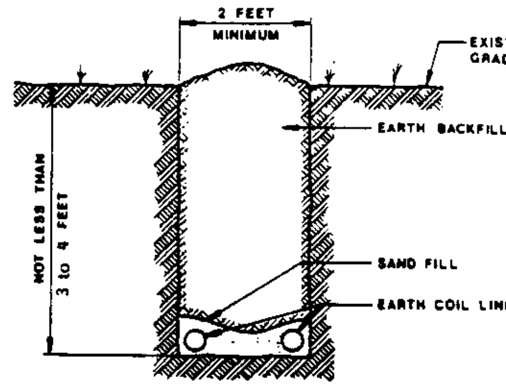
FIGURE 4C. A Wetting System for Horizontal Earth Coils



BACKHOE TRENCHES:

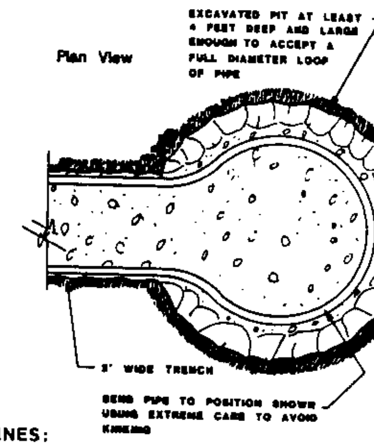
If a backhoe is used, the trench will probably be about 2' wide. In a wide backhoed trench, two pipes may be placed side by side, one on each side of the trench. The pipes in the trench must be at least 2' apart.

Backfill carefully around the pipe with fine soil or sand. Do not drop clumps of clay or rock onto the pipe.



A pit may be excavated at the end of the trench to accommodate a 4' diameter return bend.

FIGURE 5B. WIDE TRENCH RETURN BEND DETAIL SINGLE OR DOUBLE LAYER HORIZONTAL EARTH COIL



SERVICE LINES:

The recommendations for the horizontal earth coils also apply for the installation of the service lines to and from the U-bend wells and pond or lake exchanger.

Bury the service lines a minimum of 3' for single layer pipe, 3' and 5' deep for double layer pipes.

If two pipes are buried in the same trench, keep them 2' apart.

A parallel horizontal earth coupling is one in which the water flows out through a supply header, is divided equally, and flows simultaneously into two or more earth coils. It then returns to the other header. Headers are reverse return plumbed so that equal length earth coils have equal flow rates. Lengths of individual parallel earth coils must be within 10% of each other to insure equal flow in each coil.

Follow "Series Horizontal Earth Coupling" instructions on NARROW TRENCHES and BACKHOE TRENCHES.

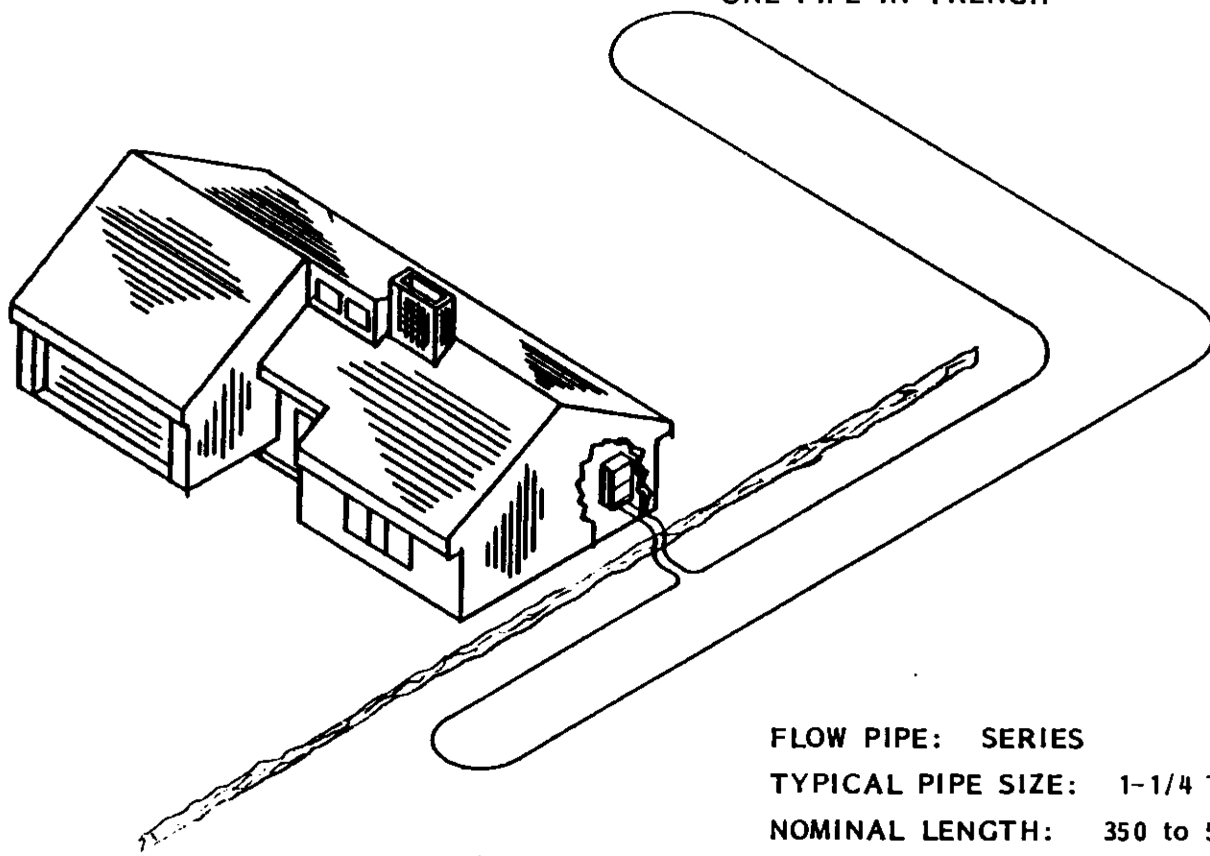
RULE OF THUMB

TRENCH LENGTH IS REDUCED IN THE FOLLOWING PROPORTION WHEN MULTIPLE PIPES ARE INSTALLED IN A SINGLE TRENCH.

Number of Pipes	Trench/Pipe (Feet)	Depths (Ft)
1	500 / 500	5
2	300 / 600	4,6
4	200 / 800	3,4,5,6

HORIZONTAL (SERIES) SYSTEM

ONE PIPE IN TRENCH



PIPE: High strength polyethylene, fusion joined

or

polybutylene, joined with Type 300 stainless steel bands and screws or heat fusion fittings

FLOW PIPE: SERIES

TYPICAL PIPE SIZE: 1-1/4 TO 2 INCHES

NOMINAL LENGTH: 350 to 500 FEET/TON

BURIAL DEPTH: 3.5 to 6 FEET

MAXIMUM HEAT PUMP SIZE: 5 TONS

TRANSFER FLUID-WATER

NOTE:

Antifreeze solution needed in northern zones.

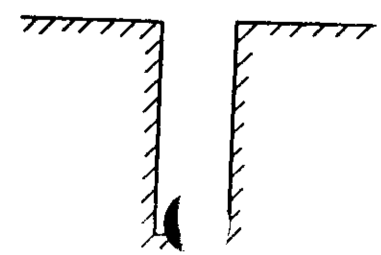


FIGURE 7

HORIZONTAL (SERIES) SYSTEM

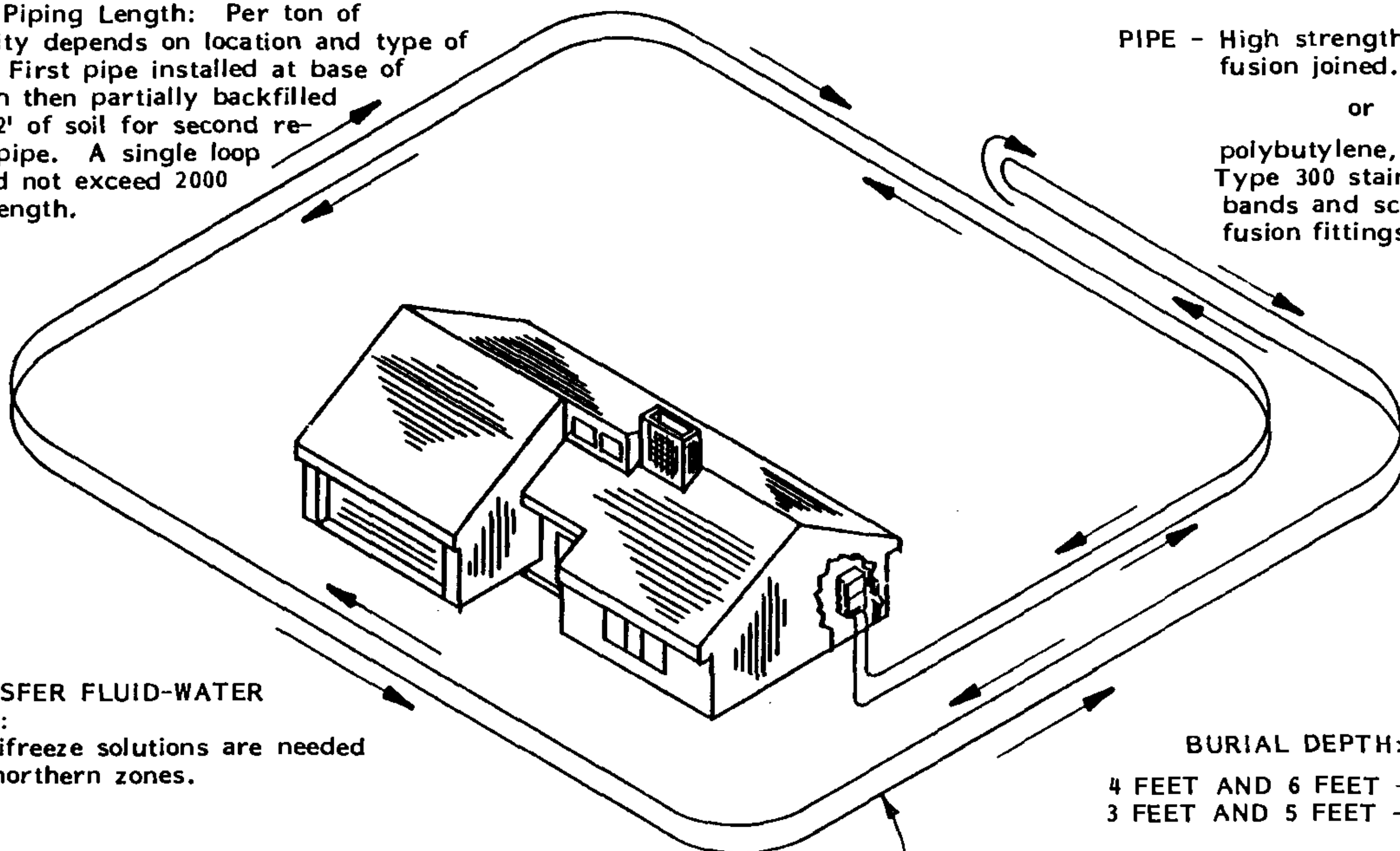
TWO PIPES IN SAME TRENCH

Total Piping Length: Per ton of capacity depends on location and type of soil. First pipe installed at base of trench then partially backfilled with 2' of soil for second return pipe. A single loop should not exceed 2000 feet length.

PIPE - High strength polyethylene, fusion joined.

or

polybutylene, joined with Type 300 stainless steel bands and screws or heat fusion fittings



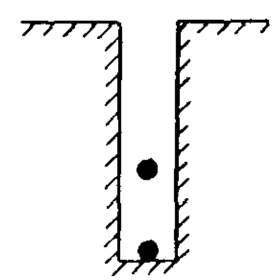
TRANSFER FLUID-WATER

NOTE:

Antifreeze solutions are needed in northern zones.

BURIAL DEPTH:

4 FEET AND 6 FEET - SOUTHERN
3 FEET AND 5 FEET - NORTHERN



FLOW PATH: SERIES

TYPICAL PIPE SIZE: 1-1/4 TO 2 INCHES

PRACTICAL LENGTH: 210 TO 300 FEET OF TRENCH/TON
420 TO 600 FEET OF PIPE/TON

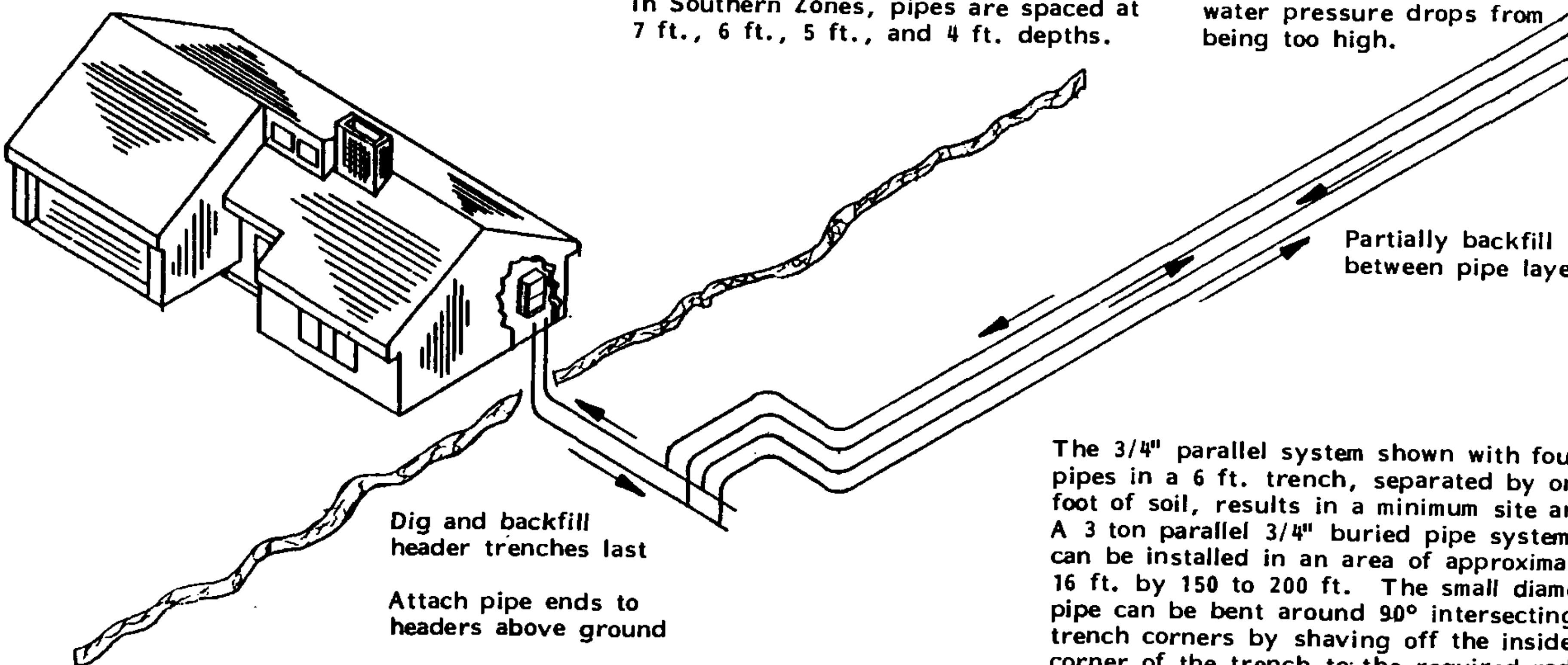
FIGURE 8.

HORIZONTAL MULTI-LEVEL (PARALLEL) SYSTEM

Be sure the buried pipe system is properly designed for the heat pump load, soil type, climate, the pipe used, and the operating cycle pattern.

System uses 3/4" or 1" pipe, installed four ft. deep, spaced one foot apart vertically. Return bends as shown. Trenches spaced four feet apart. In Northern Zone, pipes are installed at 6 ft., 5 ft., 4 ft., and 3 ft. depths. In Southern Zones, pipes are spaced at 7 ft., 6 ft., 5 ft., and 4 ft. depths.

The use of smaller diameter pipes results in a thinner pipe wall and thus better heat transfer without sacrificing the pipe pressure rating. Parallel hookups are usually required in order to keep water pressure drops from being too high.



The 3/4" parallel system shown with four pipes in a 6 ft. trench, separated by one foot of soil, results in a minimum site area. A 3 ton parallel 3/4" buried pipe system can be installed in an area of approximately 16 ft. by 150 to 200 ft. The small diameter pipe can be bent around 90° intersecting trench corners by shaving off the inside corner of the trench to the required radius with a shovel to prevent kinking.

FLOW PATH: PARALLEL

TYPICAL PIPE SIZE: PARALLEL PATHS 3/4 TO 1 INCHES
HEADERS 1-1/2 TO 2 INCHES

PARALLEL PIPE LENGTH: 500 FT. MAX. PIPE LENGTH (3/4 INCH)
750 FT. MAX. PIPE LENGTH (1 INCH)

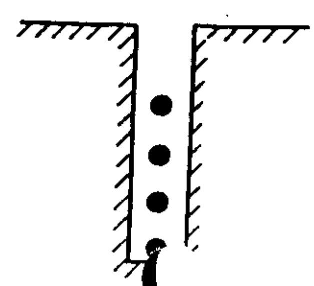


FIG 9.

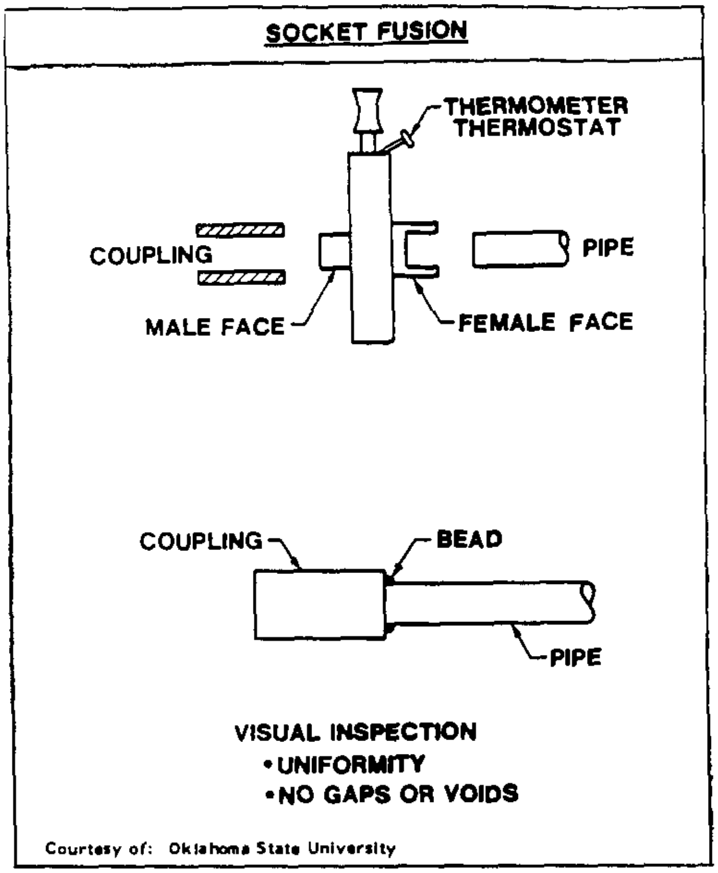


FIGURE 10A.

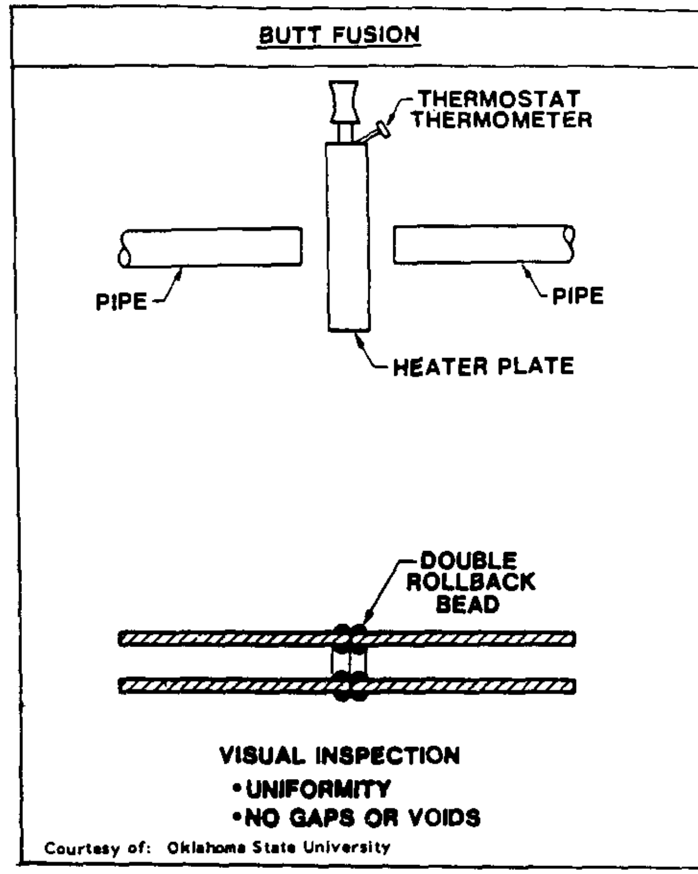


FIGURE 10B.

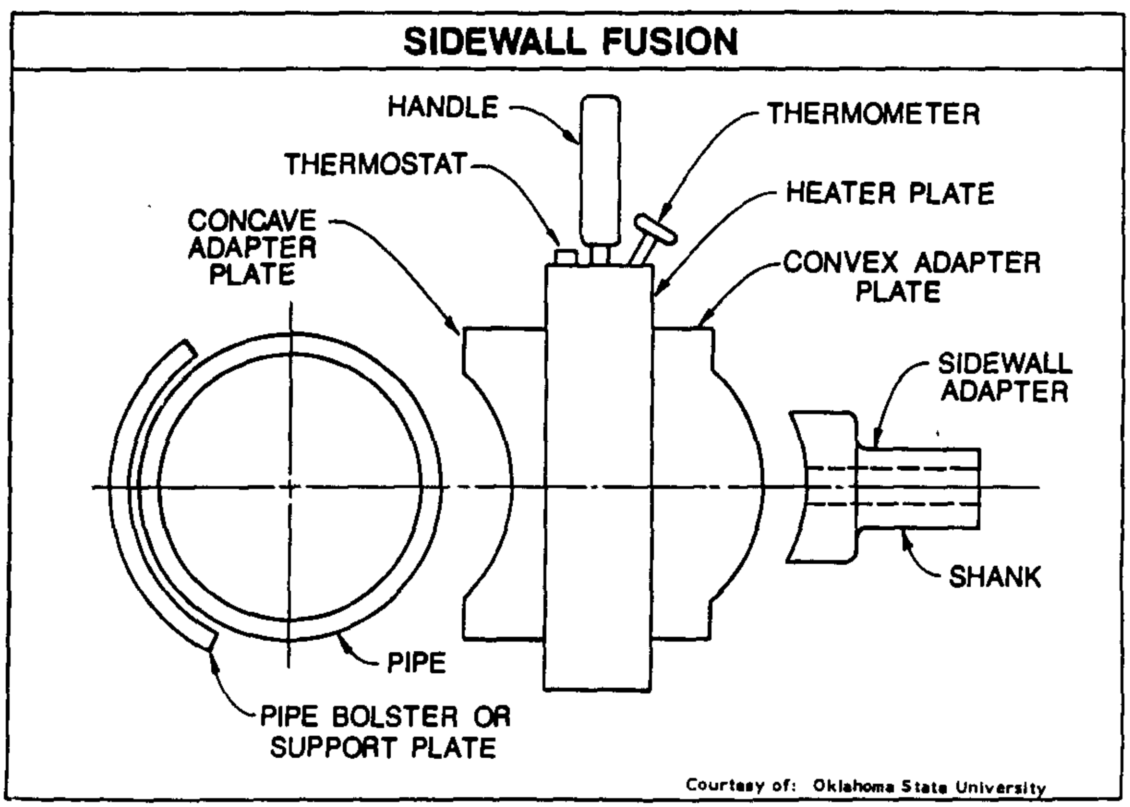


FIGURE 10C.

PIPE JOINING METHODS

HEAT FUSION: Heat fusion is the process where plastic pipe materials are aligned, cleaned or trimmed, heated to their melting point, brought together, allowed to cool to form a homogeneous material. The appropriate ASTM standards are:

1. D 2610 "Specifications for Butt Fusion Polyethylene (PE) Plastic Pipe Fittings, Schedule 40"

   Scope.

2. D 2683 "Specification for Socket-Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe"

   Scope:

3. D 2657 "Practice for Heat Joining of Polyolefin Thermoplastic Pipe and Fittings"

   Scope: This practice describes general procedures for making joints with polyolefin pipe and fittings by means of heat-joining techniques in either a shop or field environment.

For reliability, all underground piping joints should be thermally fused rather than mechanically coupled. The arguments for this are:

1. Heat fusion joining results in a joint which is stronger than the pipe itself. The pipe wall at this point has a larger cross section which gives the joint the added strength.
2. The connection or joint is all plastic eliminating corrosion problems.
3. There are industry standards (ASTM, PPI,--) which have written guidelines for proper joining methods.
4. Training programs are available from the manufacturer's of the pipe and fusion machines.

HEAT FUSION METHODS: The industry has accepted two heat fusion techniques, butt and socket. The fusion method chosen will depend on the pipe manufacturer's requirements an recommendations, and the ease in which field personnel can trained to reliably fabricate ground heat exchangers.

SOCKET FUSION JOINING: In the socket fusion method, the two pipe ends are joined by fusing each pipe end to a socket fitting (see Figure 10A). This requires two heat fusion procedures for each joint.

BUTT FUSION: The second type of heat fusing joining is the butt fusion procedure where the two pipe ends are simultaneously heated to a plastic state and brought together to form the heat fused joint (see Figure 10B). A single heat fusion process is required to form the joint between the two plastic pipe ends. The butt fusion process is performed by using specially designed machines (available from several manufacturers) which provide for securely holding the two pieces to be fused, aligning the pieces, trimming and squaring their ends, heating the surfaces to be joined, and butting them together while they remain in a plastic state.

SIDEWALL BUTT FUSION JOINING: In addition to joining the flat ends of pipe or fittings, the butt fusion process can also be used when joining the concave surface of a service saddle to the convex surface on the sidewall of a pipe (see Figure 10C). This is done by heating these surfaces with appropriate convex and concave shaped heaters and then butting these surfaces together. This is known as sidewall fusion joining. Typical butt fusion fittings are illustrated in Figure 10B.

SELECTION OF HEAT FUSION METHOD: Polyethylene is heat fused and joined using both butt and socket procedures. Material grade, density, etc. will determine if the particular grade can be fused with either method. Some high density polyethylene materials cannot be socket fused.

Polybutylene in the sizes used in ground heat exchangers is normally socket fused.

Both fusion procedures when properly done yield highly reliable joints that are stronger than the pipe itself.

IV. Design of Earth Coil

Earth coupling is a method by which water used by the heat pump is circulated through pipes buried in the ground. Heat is transferred to and from the soil through the walls of the pipe. Earth coupled systems are used in areas where insufficient ground water is available, or disposal of well water is impractical, or regulations prohibit the use of well water, or the environment corrodes outdoorcondensing units. The piping may be buried in either a vertical or a horizontal configuration.

The first recorded experience of earth coupling a heat pump was a 1912 Swiss patent. The next period of earth coupling activity occurred after World War II in both the United States and Europe. In the period from 1946 to 1953 twelve major earth coil research projects were undertaken by the Edison Electric Institute. This research developed many of the basic theories and designs that are used in earth coupling today. Work on earth coupling was terminated bacause of low energy costs.

The majority of the research work in the United States since 1978 has been conducted at Oklahome State University (OSU). Currently many universities and utilities are conducting continuing studies of earth coils.

GUIDELINES PROCEDURE

1. Calculate the cooling and heating loads
2. Determine duct capacity
3. Select heat pump
4. Determine type of earth coil
5. Select pipe for earth coil
6. Calculate length of earth coil
7. Choose fluid in earth coil
8. Layout pipes and fittings
9. Calculate pressure drop in feet of head
10. Select circulating pump or pumps

CALCULATE THE COOLING AND HEATING LOADS--Use ACCA Manual J, Ashrae, or equivalent method of calculating heat gains and losses for the building.

DETERMINE DUCT CAPACITY--Use ACCA Manual D, Ashrae, or equivalent to determine the CFM capacity of the duct system. If it is a new building design ductwork to meet the needs of the heat pump selected.

SELECT HEAT PUMP--In an earth coupled system the heat pump should supply the entire cooling load at design maximum entering water temperature. There is no problem if the heat pump is oversized for the heating load. However, if the heating load of the building exceeds the cooling load, the heating capacity of the heat pump shall be equal to or greater than 70% of the design heating problem if the heat pump is oversized for the cooling load. Once the heating and cooling loads are known, the heat pump can be selected. In earth coupling applications, heat pump selection involves several important considerations.

Unlike in well water applications where water temperature is constant, earth coupled systems must be designed for entering water temperatures that may vary between 30 degrees on the low end and 110 degrees on the high end. Consequently, when selecting a heat pump for earth coupling one must determine capacity and efficiency at both high and low design entering water temperatures.

DETERMINE TYPE OF EARTH COIL--There are three basic earth coil designs listed below in order of difficulty.

1. Single layer horizontal
2. Double layer horizontal
3. Single U-bend vertical

The trenches should be spaced a minimum of five feet apart. Single layer horizontal systems are usually trenched a minimum of four feet deep as far north as Indianapolis. But in northern locations such as Chicago the trenches are usually five feet deep. Double layer horizontal systems are trenched at six feet with the pipes installed at four feet and six feet. The boreholes for vertical systems are spaced a minimum of 15 feet apart. The depth of the borehole is detemined by drilling conditions.

Earth coil systems may be designed for series or parallel flow. Series flow is easier to install and test but usually requires larger diameter pipe. Vertical systems with series flow do not need to have the boreholes the same depth. Parallel flow requires more care in installation but usually reduces pipe diameter and pressure drop.

SELECT PIPE FOR EARTH COIL--After years of testing and experience the plastic pipes listed below have been found to be the most cost effective for earth coils.

Polybutylene 2110 SDR 13.5	Polyethylene 3408 SDR 11
Polybutylene 2110 SDR 17	Polyethylene 3408 Schedule 40

Use either butt or socket fusion to join the pastic pipe as recommended by the pipe manufacturer.

CALCULATING LENGTH OF EARTH COIL--Table 2 shows typical earth coil lengths which will provide adequate system performance in those areas of the country depicted in the Table. However, precise calculations which consider the unique characteristics of each locale can reduce the length of coil needed and enhance the performance of the system.

$$L_h = \frac{12{,}000 \text{ Btuh/Ton } [COP-1/COP] [R_p + (R_s)(F_h)]}{T_1 - T_{min}}$$

$$L_c = \frac{12{,}000 \text{ Btuh/Ton } [EER/3.41 + 1) \div (EER/3.41)][R_p + (R_s)(F_c)]}{T_{max} - T_h}$$

where:

L_h = Heating length in feet per ton of heat pump capacity
L_c = Cooling length in feet per ton of heat pump capacity
COP = COP of the heat pump at the design entering fluid temperature
R_p = Pipe resistance
R_s = Soil resistance
F_h = Heating run fraction
T_1 = Low soil temperature at day To
T_{min} = Design minimum entering fluid temperature
EER = EER of the heat pump at the design entering fluid temperature
F_c = Cooling run fraction
T_{max} = Design Maximum entering fluid temperature
T_h = High soil temperature at day $T_0 + 180$

IMPORTANT: Generally, in southern locales the cooling length will be longer, while in northern areas the heating length will be longer. Always select the longest earth coil length for each installation.

The first element to consider is heat pump COP. Remember this is not the COP at well water temperature but the COP at the loop entering water temperature. This loop temperature will range between 30 and 50 degrees depending upon location and loop design. Typically the average January COP is between 2.8 and 3.1. Note that earth coil systems are designed for the peak demand months of January and August. As a result, a system may have a January COP of 2.9 and a March COP of 3.1. Some southern applications might have a COP greater than 3.1 but in those locations the cooling load is dominant.

Just as the COP must be for the January entering water temperature, so the EER must be for the August entering water temperature. Typically the entering water temperature ranges between 70 and 100 degrees. Typical EER values fall between 10 and 11.

Pipe resistance is the next element to consider. It is calculated using Fourier's equation.

$$R_p = \frac{1}{2\pi K_p}\left[LN \frac{D_o}{D_i}\right]$$

R_p = Pipe Resistance
K_p = Thermal Conductivity of Pipe (Btuh/Lft – °F)
LN = The Natural Logarithm
D_o = Pipe Outside Diameter (Ft)
D_i = Pipe Inside Diameter (Ft)

The calculation of soil resistance is based upon the Kelvin line source theory. This theory is set out in the following equation.

$$R_s = \frac{I(X)}{2\pi K_s}$$

R_s = Soil Resistance
I(X) = Integral
K_s = Thermal Conductivity of Soil (Btuh)Lft – °F)

The above discussion assumes unfrozen soil. Frozen soil has less resistance to heat transfer. In addition freezing soil releases 144 Btu/Lb of latent heat.

The heating run fraction is the percent of time the heat pump is assumed to run during the peak month of January. The cooling run fraction is the same except it represents the operation in August. Both numbers have been developed from a department of energy study and assume that the heat pump has a capacity equal to the design load of the building.

Caution: the run fraction will increase if the heat pump is undersized. For example, in Chicago, Illinois, the heating run fraction for a 2400 square foot medium insulated house is .44. If the heat pump supplies only 75% of the design heating load, then the run fraction will increase to more then .65. At some point undersizing will lead to 100% run time or a run fraction of 1.0.

There are two benefits for sizing the heat pump as close to design load as possible. One it lessens any future residential demand charges for electricity and two it lowers the run fraction which increases capacity and efficiency.

FIGURE A
SOIL TEMPERATURE SWING

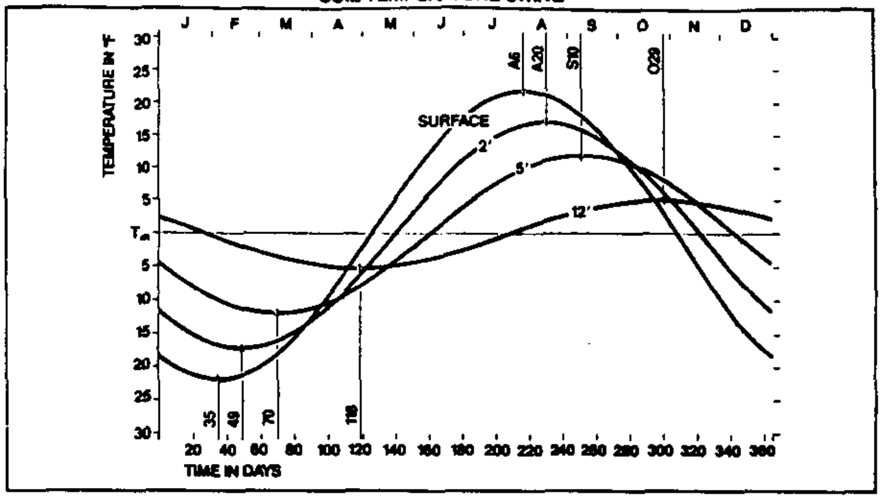


FIGURE B
COMPARISON OF T_M AT VARYING DEPTHS
FOR DIFFERENT SOILS

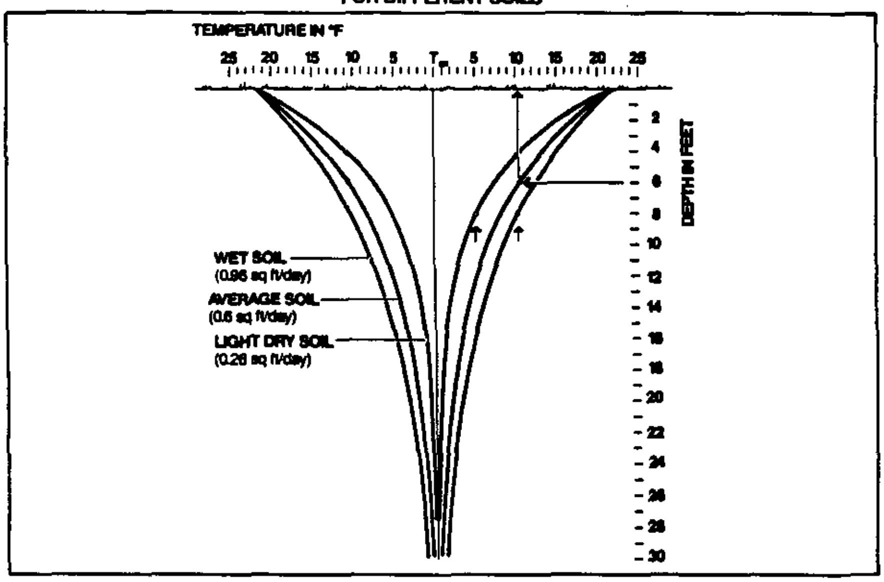
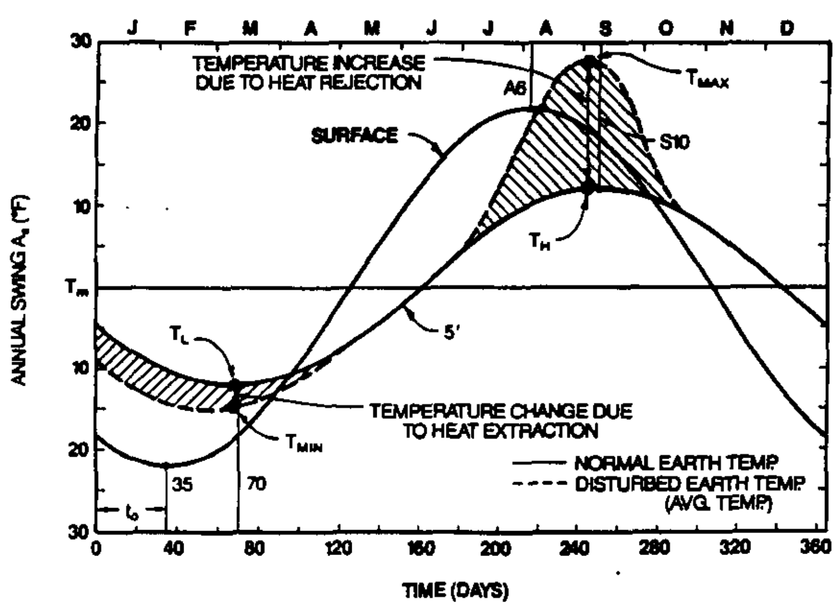


FIGURE C
HORIZONTAL EARTH COIL
TEMPERATURE VARIATIONS



The last element to be considered is the allowable temperature differential of the earth coil. This number is the amount of temperature swing from the peak soil temperature which the system is designed for and the heat pump can use. It can be expressed by the following equations.

$T_{hd} = T_l - T_{min}$

$T_{cd} = T_{max} - T_h$

T_l = Low Soil Temperature

T_h = High Soil Temperature

T_{min} = Design Minimum Entering Fluid Temperature

T_{max} = Design Maximum Entering Fluid Temperature

Note: Although Bard heat pumps can operate between 25 and 105 degrees all designs should allow some margin for error.

T_l and T_h represent the peaks of the annual temperature wave. This wave is represented by figure A. The formula for calculating the temperature of the undisturbed soil at a depth for a given day is set out below.

$$T_d = T_m - A_s\left[e^{-x(\pi/365\alpha)^{1/2}}\right]\cos\left[\frac{2\pi}{365}(t-t_0) - \frac{x}{2}\left(\frac{365}{\pi\alpha}\right)^{1/2}\right]$$

T_d = Soil Temperature on that Day

T_m = Mean Annual Soil Temperature

A_s = Annual Soil Temperature Swing

e = Exponential Logarithm

x = Depth in Feet

T = Day of the Year

T_o = Phase constant, Day of Minimum Surface Temperature

α = Thermal Diffusivity of Soil (Ft²/Day)

T_m can be assumed to equal well water temperature from a well of 50 to 100 feet deep. It can be approximated by adding about 2°F to the mean annual air temperature. Typically the minimum surface temperature (T_o) falls within one week of February 4. The maximum surface temperature will occur within about one week of August 5. There is a phase lag with increasing depth. This lag averages about one week per foot of depth.

For complete design data refer to "Design/Data Manual for Closed Loop Ground-Coupled Heat Pump Systems" by J.E. Bose, published by American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, Ga. 30329 or attend a Factory School on Water Source Heat Pumps at Bard Manufacturing Company.

Bard Manufacturing will design the earth loop for you if you desire. Just complete the enclosed worksheet, Form No. F1115 and send to:

Earth Coupled Loop System Design
Bard Manufacturing Company
Box 607
Bryan, Ohio 43506

The information will be inputted into a computer and a printout with various earth loop designs will be sent to you.

RULE OF THUMB

When using 20% propylene glycol antifreeze solution, the minimum water flow rate for the selected heat pump will need to be increased 40% to have same heat transfer.

Example: A 4 GPM flow would need to be increased to 5.6 GPM for approximately the same heat transfer properties.

RULE OF THUMB

To adjust the total earth loop piping head loss for other antifreezes and water solutions at 25°F, multiply pressure loss on line 6 for water by:

Fluid	Multiplier
20% Propylene Glycol	1.36
20% Calcium Chloride	1.23
20% Methanol Alcohol	1.25

TABLE 2. TYPICAL TRENCH, (PIPE LENGTHS) AND HOLE DEPTHS PER TON* FOR VARIOUS DESIGNS AND CLIMATES.

The actual trench lengths and hole depths per ton of WSHP capacity may differ significantly in your area due to soil and climate variations or other conditions.

	Number of pipes in trench and vertical spacing (4-6' Horizontal)					
	Northern Climate			Southern Climate		
	1 at 5'	2 at 3', 5'	4 at 2', 3', 4', 5'	1 at 6'	2 at 4', 6'	4 at 3', 4', 5', 6'
1¼"SCH. 40 3408 Polyethylene	400' (400')	240' (480')	168' (672')	400' (400')	240' (480')	168' (672')
3/4"SDR-11 3408 Polyethylene	460' (460')	275' (550')	192' (768')	460' (460')	275' (550')	192' (768')
	Number of loops in wet hole. (10-15' Horizontal spacing)					
	Northern Climate or Southern Climate					
	1			2		
1¼"SCH. 40 3408 Polyethylene	140' (280')			110' (220')		
3/4"SDR-11 3408 Polyethylene	170' (340')			135' (270')		

*Capacity of unit at local ground water temperature. (Table practical for 50°F to 70°F ground water temperature in heavy soil (clay).
Contact Bard Manufacturing Company, Telephone: 419-636-1194 for additional information.

Table courtesy of Ditch Witch, The Charles Machine Works, Inc.; Perry, Oklahoma.

EXAMPLE: Computer Printout

```
BARDLOOP REVISED 07/13/87
*******************************************************************************
                    BARD EARTH LOOP DESIGN

SEND TO:     JOHN SMITH HEATING & COOLING        DATE:8/3/87
             WILLOW ST.
             BRYAN, OHIO 43506
CONTRACTOR OR JOB NAME OR NO.: BRYAN PROFFESSIONAL BUILDING
JOB GEOGRAPHIC LOCATION: BRYAN, OHIO
*******************************************************************************
BUILDING LOAD & LOCAL EARTH DATA
NOTES:
BUILDING COOLING GAIN  63452  BTUH
BUILDING HEATING LOSS  53719  BTUH

LOCAL GROUND WATER TEMPERATURE  52  F
APPROX. EARTH TEMP. AUG. 20TH  52  AND FEB 20TH  52  @ 100  FT/ DEPTH
ANNUAL ANTICIPATED SOIL TEMP. SWING DEG. F  0
LOCAL SOIL CONDITIONS: WINTER WET SOIL (SATURATED) OR AVE ROCK
                       SUMMER WET SOIL (SATURATED) OR AVE ROCK
*******************************************************************************
BARD HEAT PUMP MODELS: WPV62A OR WPVD62A
          WITH  1  KW OF RESISTANCE ELECTRIC HEAT
          FOR 100% BACK UP RESISTANCE HEAT  15  KW IS REQUIRED

WSHP PERFORMANCE
AT AVERAGE EARTH TEMP OF  52  F. HEATING  56360  BTUH  2.73  COP, COOLING
 61340  BTUH  12.33  EER
-------------------------------------------------------------------------------
MAXIMUN ANTICIPATED SYSTEM WATER TEMPERATURES DURING NORMAL ANNUAL OPERATION
UNIT COOLING CAP. @  91  ENTERING WATER TEMP.  55730  BTUH
UNIT HEATING CAP. @  38  ENTERING WATER TEMP.  48160  BTUH
UNIT OPERATING WATER TEMP. RANGE  25  TO  105  @  10.5 GPM
*******************************************************************************
        DESIGN FOR VERTICAL EARTH LOOP
*******************************************************************************
 SERIES LOOP FLOW
LENGTH OF BORE HOLE FOR UNIT ABOVE 600  FT.
ONE LOOP IN THE BORE HOLE TOTAL BORE LENGTH TO BE DRILLED IN  6
 HOLES AT A DEPTH OF  100  FT. HAVE BEEN ASSUMED
LENGTH OF PIPE FOR UNIT  1380  FT.
PE SCH 40 1-1/2 IN. PIPE  1.61  I.D.
*******************************************************************************
TO DETERMINE CIRCULATION PUMP SIZE SEE SECTION V MANUAL 2100-099
PRESSURE LOSS FOR: WSHP COIL= 23.12  FT. HD. + 25FT. OF 1 IN. CONNECTION HOSE=
 2.429821  FT. HD. + PIPE HEADER= 0  FT. HD. + EARTH PIPE LOOP= 17.78506
TOTAL SYSTEM PRESSURE LOSS (AS DESIGNED ABOVE) IS  43.33488  FT. HD. AT A  10.5
 GPM FLOW RATE
DENSITY:  63.6 #/FT CU,  VISCOSITY : 12.58  #/FT CU-HR,  FLUID VELOCITY =
 1.654739  REYNOLDS NO.= 4040.669

TO DETERMINE NEED OF ANTI-FREEZE SEE SECTION VI MANUAL 2100-099
GALLONS OF FLUID IN TOTAL SYSTEM ABOVE:  149  GALS.
FOR 18F. FREEZE PROTECTION  32 GALLONS OF PROPYLENE GLYCOL ANTI-FREEZE

DESIGN ON THIS PAGE IS APPLICABLE ONLY TO BARD HEAT PUMPS.
THIS INFORMATION IS BASED ON THE LATEST THEORIES AND PERFORMANCE DATA AVAILABLE
AND IS SUBJECT TO CHANGE WITHOUT NOTICE AS ADVANCES IN TECHNOLOGY ARE MADE.
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V. Installation of the Earth Coupled Ground Heat Exchanger

IN THIS SECTION: Site Plan; Installation Equipment; Pipe Installation Considerations.

Installation of the ground heat exchanger will be for most persons involve a new skill or trade. As the industry develops, it appears that a new trade is being formed, that is, the notion of a loop installer whose primary purpose is to install, pressure test, and connect it to the residence. In this way, the HVAC person sees two water lines or taps that can be connected to the heat pump as specified by the manufacturer, distributor, or dealer. The loop contractor in many cases is responsible for final grading and restoration. In any case, the person responsible for the overall project must be identified to the customer.

SITE PLAN

The site plan is a location description of the buried underground utilities that serve a given area. Two things are for certain:

1. Memories fail and utilities lines seem to move underground with time and
2. Installation costs go up dramatically as the number of services are cut or severed.

Figure 11 has some of the types of services that need to be identified by locator services that are available in most areas. The location description and sketch should include:

1. The location of all buried utilities. Locator services for electrical, telephone, and gas service are available and can usually be found in the local telephone book. These services are generally at no cost to the homeowner or contractor.
2. The location of the ground heat exchanger should be established from two permanent points in case of future excavations.

The owner should be consulted to determine if:

1. Special areas are to be avoided. Trees, shrubs, and gardens that are not to be disturbed should be identified.
2. Acceptable locations for entry and exit of heavy equipment. Be cautious, they may not know the limits of their driveway. The contractor is generally liable! A lightweight machine with large flotation tires can reduce pavement and yard loads. Machines with four-wheel steer can maneuver in crowded locations.
3. Services like underground water sprinklers may not be known or easily identified by the contractor. Ask the owner to uncover these buried systems or agree in writing in advance that the contractor is not liable.

INSTALLATION EQUIPMENT

Chain trenchers, bulldozers, backhoes, and vibratory plows are used to bury horizontal ground heat exchangers. The economic choice of which machine to use depends on local site conditions and the competition situation. Generally speaking, the machine which moves the least amount of soil will be the most cost productive. Figure 12 describes the various machines that have been used to bury horizontal ground heat exchangers.

CHAIN TRENCHERS: In many cases, trenchers are the most economic choice since the amount of soil or dirt removed is minimal when compared to other methods, and trenching productivity is usually much higher than that of a backhoe. Systems are now being developed which allow the automatic placement and backfilling of multiple pipes in a single trench simultaneously. A trailing vibrator and the addition of water to form a slurry has increased productivity significantly for the multiple pipe system. Trench widths are about 6 inches with depths to seven feet for 65 horsepower trenchers. The most common size chain trencher is in the depth range of three to five feet. A six foot boom costs about 5% of the cost of a trencher. Multiple pipes in the trench greatly reduce trench length and the area required for a horizontal buried pipe system.

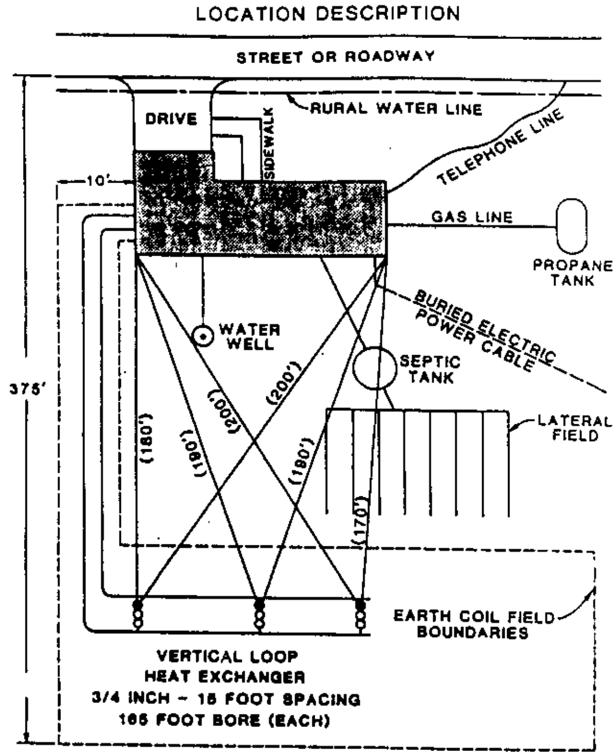
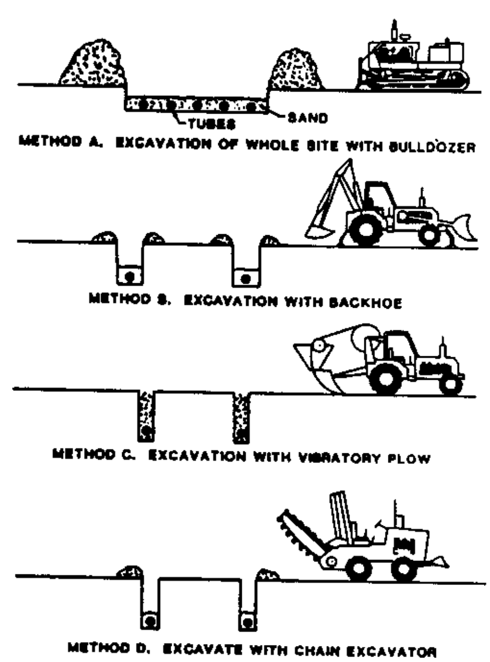


FIGURE 11. Location Description of Underground Utilities Courtesy of Oklahoma State University.

BULLDOZERS: Method A using a bulldozer would only be appropriate if the soil had been removed for some other purpose or if excavation for a large header system were required.

In larger installations in Europe, track type machines have been used to plow in horizontal ground heat exchangers and backfill around the pipe in a continuous operation. The backfill process consists of a hopper and chute arrangement which places the material in the immediate pipe area.



FOUR BASIC INSTALLATION TECHNIQUES

FIGURE 12.

Courtesy of Oklahoma State University.

BACKHOES: Backhoes (Method B) have been used where there is a presence of rocks, cobbles, or boulders which are too large or too hard to be removed by a chain trencher. Backhoes have also been used where more than one pipe is placed in a single trench either stacked vertically (such as 1x2) or multiple pipes placed horizontally in several layers (such as 2x3). NOTE: The nomenclature 1x2 defines a pipe system of 1 level or layer, and 2 pipes. A system of three pipes at two levels or layers would be denoted as 2x3. The backhoe may also be used to open the site from the foundation to the ground heat exchanger. The soil removed by a backhoe tends to be lumpy and can leave air pockets around the pipes greatly reducing the heat transfer.

VIBRATORY PLOWS: Vibratory plows are commonly used at depths not greater than three feet. To facilitate rapid burial, a vibrator or vibratory plow is used to improve the speed of placement and reduce the size of machine. Loose or unstable soils are also amenable to this type of pipe placement and they work better than a chain trencher in glacial till. The shallow depth results in larger seasonal soil temperature swings and longer lengths of pipe.

DRILLING MACHINES: Drilling is required to install vertical loops. Two applicable techniques for boring holes are (a) mud and air rotary drilling, and (b) standard auger or hollow-stem auger drilling. Boring holes for earth loop insertion and boring holes in order to find and produce water wells are two completely different tasks. The ground heat exchanger application is much simpler. Since the objective is to install a specified length of heat exchanger in a vertical configuration, it is not important to reach a given depth at a particular site. If 600feet of bore hole is required, two 300 foot vertical bore holes are acceptable and may be more cost effective. Soil and rock conditions will determine drill rates and consequently determine an economic bore hole depth. Since ground temperatures fluctuate near the surface, hole depths greater than 50 feet are normally recommended. However, the 50 foot depth is not a minimum value. Some general guidelines are as follows:

1. Soil moisture and temperature stability generally increase with depth which favors the deeper holes.

2. Fewer holes mean less connections at the surface which can be a time saver, also less surface area required.

3. If "many" holes are drilled, several bore holes may need to be connected in series before tieing back to the main header. Too many parallel flow paths can result in low flow and reduced performance of the ground heat exchanger.

4. If hard rock layers are encountered, it may be more profitable to move and repeat the process.

5. Extensive hard rock in a drilling service area can easily justify a down-hole hammer or the use of a rock quarry drilling contractor with a top-hole hammer.

6. Vertical loops using 3/4" or 1" pipe and a close U-bend require only a 3-4" hole. This smaller drilling system needs less mud flow, a smaller and less expensive bit, smaller mud pans, a smaller mud pump, and results in less wear and tear on the mud pump. In many cases, this will result in lower drilling costs.

The bore hole does not need to be cased for performance reason. It may need to be cased if the soil is unstable or a formation presents a problem due to lost circulation during drilling. The bore hole must only remain open long enough to insert the ground heat exchanger. Most of these problems can be controlled by proper mud formulation and use. Drilling rates are faster than water well drilling which generally requires sampling, and casing. Well completion procedures are not required which greatly reduces time and cost.

In mud or air rotary drilling, the drill rig rotates the drill pipe and sends either high pressure fluid (air, water, or mud) down the inside of the drill pipe to lubricate and cool the bit and to bring the cuttings back to the surface along the outside of the drill string. In rotary mud drilling removed soil or earth is collected in a mud pan to be replaced in the hole or removed from the job site if necessary. Drilling mud (bentonite or fluid additives) are added to the mud to control its viscosity and to prevent a number of drilling problems. If the drill cuttings are of a high density, the drilling fluid viscosity must be increased to carry the cuttings to the surface. The mud must also be dense enough to support the bore hole wall if the surrounding soil is unstable or be mixed to form a clay deposit on the wall of the hole if the mud tries to leak through the wall of the hole into a porus formation. The proper mud mix can also prevent swelling. A less dense mud may be required to keep mud from migrating through surrounding porus formations.

In extreme cases of unstable soils, drill pipe with large inside diameters are used which allow loops with U-bends to be inserted inside the drill string before its removal. The drill bit in this case has a knockout point which allows the U-bend and loop to remain in the bore hole while the drill string is removed.

In hollow-stem auger drilling, the drill rig rotates a hollow auger with cutting teeth and a temporary point at the bottom. The drilling operation may be completely dry and hence clean at the surface. Most of the cuttings are brought to the surface but some of them are simply pushed into the walls and compacted in place. The hollow auger essentially serves as a casing in the hole as it is drilled. When a hole is completed, the point at the bottom of the auger is pulled, the ground heat exchanger is inserted, and then the hollow auger is pulled or screwed out. In some designs, a disposable bit point is used which allows a weight on a rope to be used to "knock out" the disposable point. Auger drilling is applicable in a limited number of different soils and can present some serious problems in clay or adhesive soils, or rock. In moist soils auger drilling is slower than rotary mud or air drilling.

PIPE INSTALLATION CONSIDERATIONS

Consistently successful plastic pipe installations for ground heat exchanger applications are the result of good planning, the use of suitable materials and equipment, and close attention to the correct procedures.

Time spent in careful planning will substantially reduce the time and cost of the installation.

The following factors should be considered during planning:

1. Depth of trench, as influenced by climate, soil type, size of trencher available.

2. Length of trench as influenced by the area available, the heating and cooling load, the number of pipes in the trench, type of soil, moisture content of soil.

3. Depth and number of vertical holes if used, as influenced by the area available, obstructions, the heating and cooling load, soil and rock types.

4. Trench pattern, as influenced by above and below ground obstructions, ground slope, trenching turn radius limitations, backfilling and restoration requirements. (Be sure all buried conductors are located and marked).

5. Type and size of trenching chain, as influenced by type of soil and rock, depth of trench, and size of trencher.

6. Type of plastic pipe. Use of high quality polyethylene or polybutylene. PVC is not acceptable in either heat transfer characteristics or strength.

Several factors to be considered regarding the trenching phase in order to minimize problems, time and cost:

1. A combination of narrow chain, correct teeth, 4-wheel steering for maneuverability, 4-wheel drive for good traction, good backfilling capability with a 6-way blade, and high enough horsepower to finish most jobs in one day, will minimize expensive interruptions and complications due to weather and variations in soil conditions.

2. Remove rocks left in the bottom of the trench to eliminate damage to the pipe. Use long-handled tongs.

3. A backhoe attachment with a 12" bucket may be needed to dig out large rocks and dig access hole at the building.

4. Where mucky or sandy conditions cause caving, use a pipe guide mounted on the trenching boom to guide the pipe down to the bottom of the trench as it is dug.

5. Two by six (2x6) boards inserted in previously dug trenches and wedged will prevent dirt from an intersecting trench from having to be removed from the previous trench. Place a piece of plywood over the near length of the previously dug trench.

The pipe installation phase can be accomplished as the trenching proceeds. Be sure that the following procedures are followed:

1. Inspect the trench to insure that rocks are removed. Also remove rocks from the edge of the trench and from the top of the spoils pile so they will not fall in with the 4-6" of fines or sand that are first put in the trench to support and cover the pipe for protection.

2. Inspect the pipe as it is laid out beside the trench for cuts, kinks, or other damage.

3. Make all joints while the pipe is laying beside the trench and test with 40 PSI air pressure and soap.

4. Joints must be mechanically strong enough to force the pipe to absorb the stress and strain of the length expansion and contraction caused by the temperature changes in the circulated water. Pipe ends should be extra long and not cut for attaching the end fittings until the rest of the pipe has reached soil temperature in the trench.

5. Carefully lower the pipe into the trench after the bottom has been again checked for rocks and the fines smoothed.

6. If the soil is a heavy clay in very dry climates, it may shrink away from the pipe as it dries when heated during the summer cooling cycle operation of the heat pump. Use a sand fill around the pipe or a subsoil drip irrigation line buried a few inches above the pipe. The sand will crumble to maintain contact with the pipe. Add water with a drip line when in-out water temperature indicates reduced heat transfer through the pipe to the soil.

The backfilling is critical and its successful completion depends on the following good procedures:

1. If the rocks have been removed from the edge of the trench and the top of the spoils pile, and the dirt has not formed clods due to rain, an experienced trencher operator can angle-blade the top of the spoils pile into the trench on the first pass. A worker should follow closely and tamp the fines by hand and make sure no rocks fall in.

2. Several more passes with the angle blade should be used to make the backfilling as uniform as possible and to prevent bridging.

3. Several stages of tamping, and rolling over with the trencher wheels may be necessary to complete the job.

Additional considerations are required when closed vertical loops are used in limited site areas:

1. Soil conditions - These will determine whether the auger, recirculating mud, or down-hole hammer method is used. It will also determine the type of drill bit and whether a mud additive is required.

2. The depth and number of holes for vertical loops depends on the heating and cooling load, the drilling rate, the site area, soil and rock types, and moisture level.

3. Each loop should be assembled, laid out straight, taped to reduce springback friction, and carefully tested for leaks and flow before the hole is drilled so that it can be lowered into the hole before it can cave in or the mud can settle to the bottom of the hole. The hole should be 5-10 feet deeper than the length of the loop to accommodate expansion of the loop. Fill the loop with water prior to insertion. If the hole is to be grouted in place, it should be filled with water and pressured to a level that will prevent the pipe from being crushed by the denser backfill material.

   Taping short lengths of scrap steel rebar on the end of the pipe loop will hold the loop end straight and offset buoyancy of the plastic, to make insertion easier and faster.

4. Test the loops after they are connected with 40 PSI air or water.

5. If the water table is low, pea gravel and a broad grade sand should be filled in around the pipes above the water table so that good thermal contact can be maintained at all times.

6. The hole can be filled with grout, if required, using a small plastic discharge pipe inserted with the loop.

INSTALLATION CHECKLIST

BURIED PIPE SYSTEM DESIGN

__Heat Pump Sized.
__Water pump pressure, GPM, specified.
__Type, diameter, length of pipe.
__Type of joint specified.
__Climate, zone location.
__Designed heating & cooling load specified.
__Soil moisture and type specified.
__Heat pump COP* specified (*Coefficient of Performance).
__Pipe depth specified.
__Need for sand or drip system specified.
__Backfilling specified.
__(Other)______________________________

PLANNING

__Buried pipe system design completed.
__Pipe and fittings as specified on layout are on hand.
__Flagging of existing buried conduit and WSHP pipe route is scheduled.
__Soil and rock characteristics have been determined.
__Size and type machine is scheduled. Larger trencher can complete job faster if weather is limiting factor.
__Alligator chain with Tungsten carbide mining teeth scheduled for installation, if needed.
__Backhoe scheduled for installation, if needed.
__Pipe, fitting, clamps, fusion machine scheduled.
__Testing pump, reservoir, valve gauge assembly scheduled with correct size fittings for pipe.
__Sand scheduled, if needed.
__Buried drip irrigation pipe scheduled if seasonal soil moisture control desired.
__(Other)______________________________

TRENCHING

__Is jobsite flagged for buried conduits and WSHP pipe route?
__Alligator chain with Tungsten carbide mining teeth for frozen soil and rock.
__Feed chute for unstable soils.
__Backhoe for access holes, large rocks.
__Tongs, narrow hoes for removing loose rocks. Shovels, including long handle and narrow.
__Fuel, oil, grease gun, tools, fuel filter cartridge, tire gauge, trailer spare.
__Water hose.
__Extension cord, trouble light, flood light, flashlight.
__Boards, plywood strips for intersecting trenches, claw hammer, nails.
__(Other)______________________________

PIPE INSTALLATION AND TESTING

__Correct size, length, and type of pipe, DO NOT USE PVC PIPE.
__Fittings, fusion machine, heavy extension cord.
__Pipe cutter.
__Type 300 stainless steel clamps. Make sure screws are not plated steel.
__Torque wrench for clamps.
__High pressure water pump with reservoir, valves, gauges, correct fittings for pipe.
__Anti-freeze.
__Sand, if needed.
__Buried drip irrigation pipe, if needed.
__(Other)______________________________

Compliments of Ditch Witch

VI. The Circulation System Design

Equipment room piping design is based on years of experience with earth coupled heat pump systems. The design eliminates most causes of system failure.

Surprisingly, the heat pump itself is rarely the cause. Most problems occur because designers and installers forget that a closed loop earth coupled heat pump system is NOT like a household plumbing system.

Most household water systems have more than enough water pressure either from the well pump or the municipal water system to overcome the pressure or head loss in 1/2" or 3/4" household plumbing. A closed loop earth coupled heat pump system, however, is separated from the pressure of the household supply and relies on a small, low wattage pump to circulate the water and antifreeze solution through the earth coupling, heat pump and equipment room components.

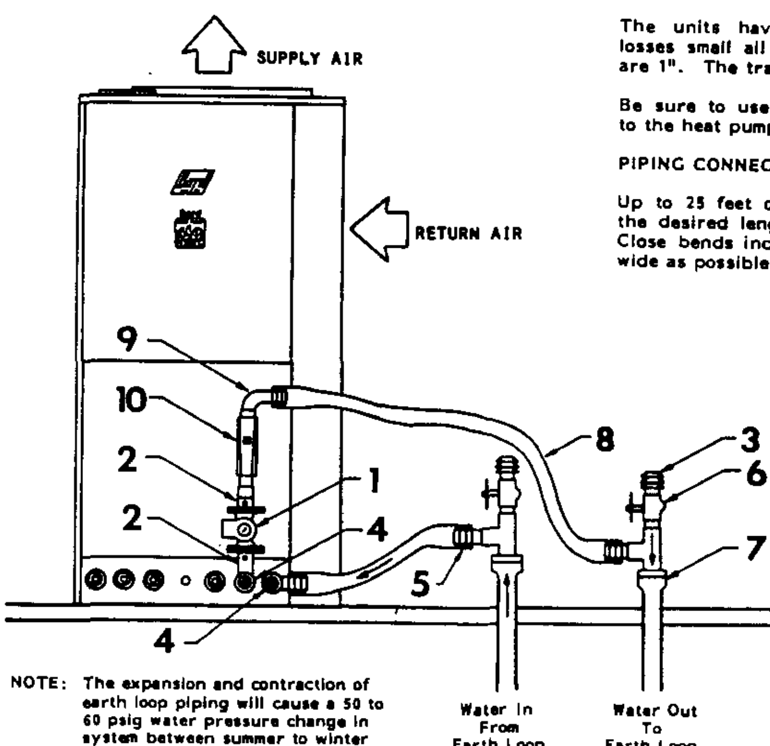
The small circulator keeps the operating cost of the system to a minimum. However, the performance of the circulator MUST be closely matched with the pressure or head loss of the entire system in order to provide the required flow through the heat pump. Insufficient flow through the heat exchanger is one of the most common causes of system failure. Proper system piping design and circulator selection will eliminate this problem.

Bard supplies a worksheet to simplify head loss calculations and circulator selection. Refer to "Circulating Pump Worksheet" section.

Two general methods are used to pipe the water circuit in the equipment room. The first and easiest to use is to install a pump module. This module comes complete with connecting hose and heat pump adapters available from module manufacturers. A second method is to "site build" the piping at the installation.

To move the transfer fluid (water or propylene glycol and water solution) through the earth loop system and the water source heat pump, some type of circulation system is required. Design of circulation system must include provisions for the following: (See Figure 13)

1. Selection of a circulation pump or pumps for total system.
2. Providing air bleed off before start-up and running.
3. Providing for flow monitoring.
4. Positive pressure control and limiting.
5. Antifreeze charging capability.



NOTE: The expansion and contraction of earth loop piping will cause a 50 to 60 psig water pressure change in system between summer to winter operation.

The components for a circulation system are: (See Figure 13)

1. Circulating Pumps - are engineered for each individual system to provide the correct water flow and overcome the friction loss of the system piping. Isolation flanges or ball valves to insulate pump from system are required on pump. You need to be able to remove the pump from piping without losing the transfer fluid for repairs if ever required. Stainless steel pump body required for use with calcium chloride antifreeze.*

   *Determining pressure drop and selecting a circulation pump or pumps. It is very important in selecting the circulating pump that a very accurate pressure drop calculation be made because final pressure drop the selected pump must pump against will determine the actual flow rate (GPM) that is delivered to the water source heat pump, the pumping cost and efficiency of the entire system.

2. Ball Valve and Flange
3. Barb X MIP Brass Adapter
4. Brass Test Plugs - In order to start up and troubleshoot a closed loop system properly, water in and water out temperatures at the heat pump must be monitored. A test plug is installed on one leg of each connection line. A probe thermometer can be temporarily inserted, the temperature monitored and the thermometer removed. Use one thermometer to monitor these temperatures. Using two different thermometers to measure the temperature differential can introduce large measurement errors.
5. Barb X insert brass adapter
6. Two Boiler Drains - Are located on both sides of the circulator for final filling, air purging and antifreeze addition.

   The top drain should be the highest point in the equipment room piping. This will help purge air out of the system during final filling at start up.
7. PE or PB pipe to fit transition.
8. 1" reinforced flexible hose.
9. 90° street ell (brass).
10. Flow Meter (Bard part number 8603-012) - on water-in side to monitor water flow.

HEAT PUMP CONNECTIONS:

The units have various female connections. To keep head losses small all piping and components in the circulating pump are 1". The transision from 1" will be made at the heat pump.

Be sure to use a back-up wrench when installing the adapters to the heat pump.

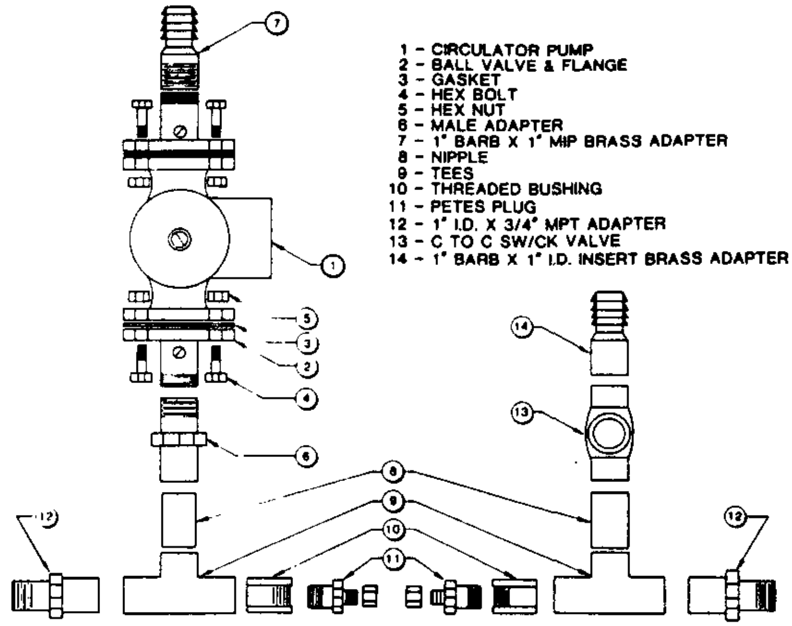
PIPING CONNECTIONS:

Up to 25 feet of reinforced flexible hose is used. Cut hoses to the desired lengths and install with as few bends as possible. Close bends increase pipe head loss so any bends should be as wide as possible. Use the clamps to secure hoses in position.

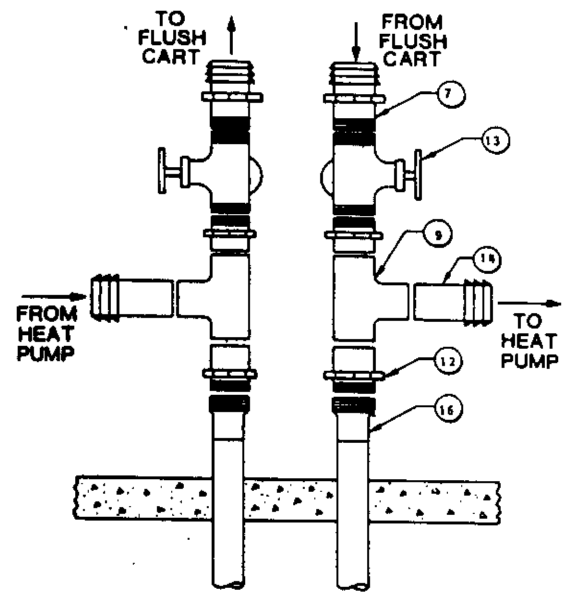
FIGURE 13. Closed Loop Equipment Room Piping

Drawing compliments of Oklahoma State University

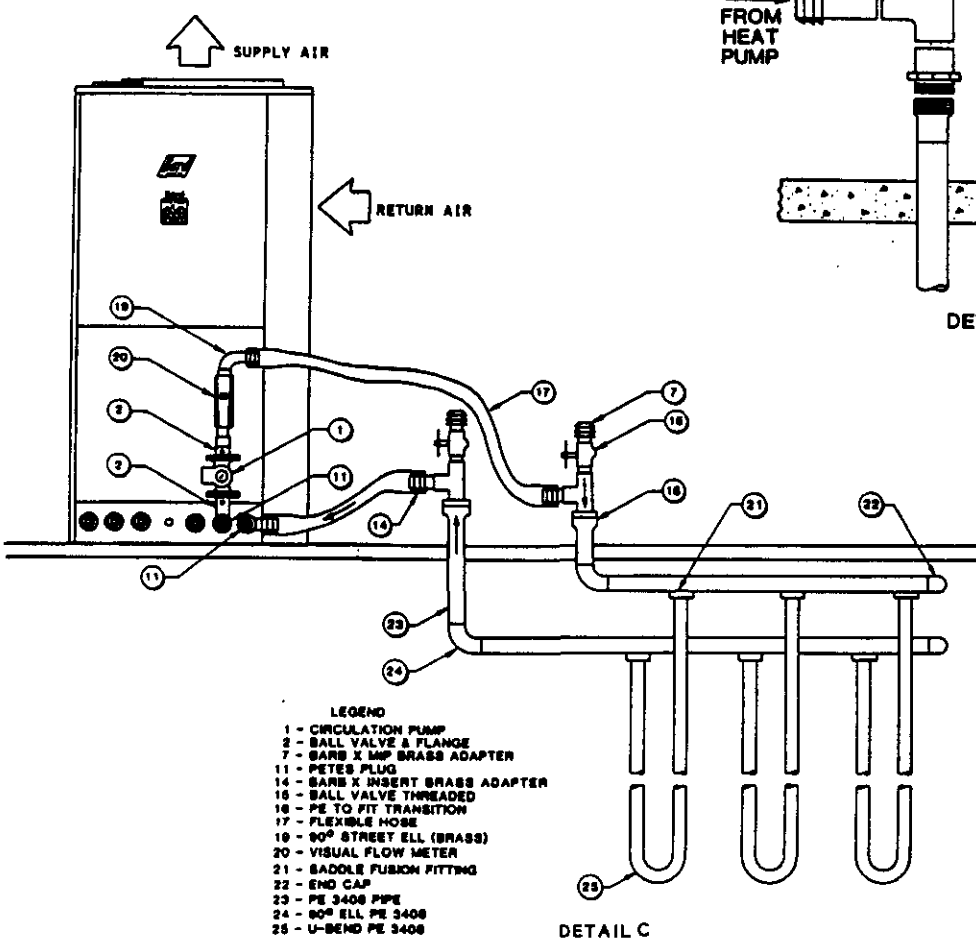
NOTE: All indoor piping must be plastic if calcium chloride antifreeze is used.



DETAIL A



DETAIL B



Polybutylene may also be used in place of Polyethylene pipe shown on drawings.

DETAIL C

Drawings courtesy of Oklahoma State University.

CIRCULATING PUMP WORKSHEET

1. Find the Bard heat pump model used in Table 1. MODEL________________

2. Enter water coil head loss: (Table 1) ________________ ft. hd.

3. Continue across Table 1 to find GPM flow required for this heat pump. ________ GPM

4. Count each elbow, tee, reducer, air scoop, flowmeter, etc., as 3 FEET OF PIPE EQUIVALENT. Add the EQUIVALENT FEET OF PIPE to the actual feet of PIPE USED. The TOTAL LENGTH is used to determine the PIPING HEAD LOSS below.

   NOTE: For a parallel earth loop system figure for only one loop at this time.

Pipe Type & Size	No. Elbows, Tees Devices, Etc. *		Equiv. Ft. of Pipe		Actual Pipe Used	Total Pipe Length
________	____________	X 3	________	+	________	________
________	____________	X 3	________	+	________	________
________	____________	X 3	________	+	________	________
________	____________	X 3	________	+	________	________
________	____________	X 3	________	+	________	________

*IF THE PIPE IS BENT AT A 2 FT. RADIUS OR LARGER, DO NOT FIGURE THE CURVE AS AN ELBOW.

5. PIPING HEAD LOSS for different types of pipe at GPM flow rate of water source heat pump. NOTE: For parallel earth loop system figure for only one loop.

Pipe Type and Size	Total Pipe Length			Piping** Head Loss (Table 2)		
________	(________	÷ 100)	X	__________	=	________________ ft. hd.
________	(________	÷ 100)	X	__________	=	________________ ft. hd.
________	(________	÷ 100)	X	__________	=	________________ ft. hd.
________	(________	÷ 100)	X	__________	=	________________ ft. hd.
________	(________	÷ 100)	X	__________	=	________________ ft. hd.

**For parallel earth loops divide the heat pump GPM (line 3) by number of loops to determine flow rate through each individual loop to select piping head loss.

SUBTOTAL ________________ ft. hd.

6. Multiply SUBTOTAL by multiplier (see Table 2) to obtain TOTAL HEAD LOSS FOR SYSTEM using antifreeze solution.

TOTAL HEAD LOSS ________________ ft. hd.

7. PUMP SELECTION: Use Table 3 and flow rate, (line 3). Select the pump output which is LARGER or equal to the TOTAL HEAD LOSS FOR SYSTEM. (line 5 or 6).

________________________ Circulating Pump Model   ________ No. Pumps

If the TOTAL HEAD LOSS calculated in line 6 is greater than the pump outputs listed in Table 3, go to the pump manufacturer's performance curves and find the required GPM flow for the heat pump. Pump performances are listed for each pump model at different flow rates.

Series pump performance is simply a TOTAL OF THE INDIVIDUAL PUMP PERFORMANCES: if one pump can overcome 10 feet of head loss, two can overcome 20 feet of head loss, three can overcome 30 feet of head loss, etc.

REMEMBER: UNDER NO CIRCUMSTANCES MIX DIFFERENT PUMP SIZES WHEN USING PUMPS IN SERIES.

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TABLE 1A. Water Coil Pressure Drop					
Model	HWP30-HWPD30 WPV30A-WPVD30A WPV30B	HWP36-HWPD36 WPV36A-WPVD36A WPV36B	Model	WPV53B WPV53A-WPVD53A	WPV62B WPV62A-WPVD62A
GPM	Ft. Hd.	Ft. Hd.	GPM	Ft. Hd.	Ft. Hd.
4	4.6	4.4	6	5.8	5.8
5	6.9	4.6	7	7.4	8.1
6	10.0	5.5	8	9.2	10.4
7	13.1	6.9	9	12.0	12.9
8	17.3	9.0	10	15.0	15.5
9	21.9	12.7	11	17.8	18.5
10	27.7	17.5	12	20.8	21.5
11	34.1	24.0	13	24.2	24.7
12	40.6	35.3	14	27.7	28.4
13	46.8	47.5			

When selecting pipe size for parallel flow, it is necessary to maintain turbulent flow in the earth coil for heat transfer. The table below lists the minimum flows for turbulence.

TABLE 1B. Minimum Flow For Turbulence (GPM)*				
Nominal Pipe Size (Pipe ID)	Water at 40°F	Calcium Chloride 20% at 25°F	Propylene Glycol 20% at 25°F	Methanol 20% at 25°F
3/4" (0.86)	1.1	2.2	3.3	2.4
1" (1.077)	1.4	2.8	4.1	3.1
1-1/4" (1.380)	1.7	3.5	5.3	3.9
1-1/2" (1.676)	2.1	4.3	6.4	4.8
2" (2.095)	2.6	5.3	8.0	5.9

*For each separate loop.

TABLE 3. Selection of Circulation Pump or Pumps									
	Grundfos* Pump Models	No. of Pumps	Water Flow Rate Required in G.P.M.						
			4	5	6	8	10	12	14
PUMP OUTPUT (FEET of HEAD) @ GPM @ TOP OF COLUMN	20-42	1	11.5	11	--	--	--	--	--
	26-64	1	18.8	18	17.5	16	14.5	13.5	12
	26-64	2	37.6	36	35.0	32	29	27	24
	40-75	1	23.8	23.5	23	22.5	21.5	21	19.5
	40-75	2	47.6	47	46	43	43	42	49
	26-96	1	27.5	27	26	23.5	21.5	19	16
	26-96	2	55.0	54	52	47	43	38	32

*Other models of circulation pumps may be used. Consult the manufacturer's specifications.

TABLE 2. Piping Feet of Head Loss at Different Flow Rates Per 100 Feet											
PIPE SIZE AND MATERIAL		DI	G.P.M. FLOW RATE								
			1	2	3	4	5	6	8	10	12	14
Connection Hose 1"		1.050	*	*	*	1.33	1.95	2.68	4.43	6.53	8.99	11.77
PVC 3/4" - 200 PSI			*	*	*	3.7	5.7	*	*	*	*	*
PVC 1" - 200 PSI			*	*	*	1.0	1.9	2.7	4.2	6.3	8.9	11.8
Copper 3/4"			*	*	*	4.3	6.3	*	*	*	*	*
Copper 1"			*	*	*	1.5	1.9	2.7	4.5	6.9	9.6	12.8
PE3408 (Polyethylene)		DI									
1. SDR-11	3/4	0.860	0.31	1.03	2.07	3.41	5.03	*	*	*	*	*
2. SDR-11	1	1.077	0.11	0.36	0.71	1.18	1.73	2.38	3.92	*	*	*
3. SDR-11	1-1/4	1.358	*	0.12	0.24	0.39	0.58	0.79	1.31	1.93	2.65	3.47
4. SDR-11	1-1/2	1.554	*	*	0.13	0.21	0.31	0.42	0.69	1.02	1.40	1.83
5. SDR-11	2	1.943	*	*	*	0.07	0.11	0.15	0.24	0.35	0.48	0.63
6. SCH 40	3/4	0.824	0.38	1.26	2.54	4.18	6.16	8.46	*	*	*	*
7. SCH 40	1	1.049	0.12	0.40	0.81	1.33	1.96	2.69	4.45	*	*	*
8. SCH 40	1-1/4	1.380	*	0.11	0.22	0.36	0.54	0.74	1.21	1.79	2.46	3.21
9. SCH 40	1-1/2	1.610	*	*	0.11	0.18	0.26	0.35	0.58	0.86	1.18	1.55
10. SCH 40	2	2.067	*	*	*	*	0.08	0.11	0.18	0.26	0.36	0.47
PB2110 (Polybutylene)		DI									
11. SDR-17, IPS	1-1/2	1.676	*	*	0.09	0.15	0.21	0.29	0.48	0.71	0.98	1.28
12. SDR-17, IPS	2	2.095	*	*	*	0.05	0.07	0.10	0.17	0.25	0.34	0.44
13. SDR-13.5, Cts	1	0.957	0.19	0.62	1.25	2.06	3.03	4.16	*	*	*	*
14. SDR-13.5, Cts	1-1/4	1.171	*	0.24	0.48	0.79	1.17	1.60	2.64	*	*	*
15. SDR-13.5, Cts	1-1/2	1.385	*	0.11	0.22	0.36	0.53	0.72	1.19	1.76	2.41	3.2
16. SDR-13.5, Cts	2	1.811	*	*	0.06	0.10	0.15	0.20	0.33	0.49	0.68	0.88

Notes:
1. These head losses are for water at 40°F temperature.
2. Count each elbow, tee, reducer, air scoop, flow meter, etc., as 3 feet of equivalent pipe length and add to actual measured pipe length for total length.
3. To adjust the total earth loop piping head loss for other antifreezes and water solutions at 25°F, multiply pressure loss on line 6 for water by:

Propylene Glycol - 1.36, Calcium Chloride - 1.23, Menthanol Alcohol - 1.25

PRESSURE DROP CALCULATIONS TO SELECT CIRCULATION PUMP

Transfer fluid requirements for closed-loop, earth-coupled heat pump systems varies with fluid temperature and heat pump size. To determine the circulation pump size requirement, the system flow rate requirements (GPM for heat pump used) and total system pressure drop in feet of head loss. From these two pieces of information a circulation pump can be selected from the pump manufacturer performance curves.

The fluid (water) flow rate and water coil pressure drop are found in the manufacturer's heat pump specifications or Table 1 of this section for Bard water source heat pumps. The head loss for different pipe materials and sizes per 100 feet are found in Table 2 of this section and a quick pump selection table for flow rates that match Bard water source heat pumps are in Table 3 of this section.

Following are two examples of how to determine the head loss of earth loops. First example will be a series horizontal system and the second example will be a parallel vertical system.

EXAMPLE 1

Given:

A. Series horizontal system.

B. Bard HWP36 water source heat pump to be used.

C. Heat pump water flow requirement is 5 GPM with a 4.6 ft. hd. loss (see Table 1).

D. Earth loop 1200 ft. 1-1/2" SDR17 polybutylene pipe.

E. 20 ft. 1" copper pipe connecting earth loop to water source heat pump.

F. The circulation pumping system lay out to be similar to Figure 10B.

CIRCULATING PUMP WORKSHEET

1. Find the Bard heat pump model used in Table 1. MODEL HWP36

2. Enter water coil head loss: (Table 1) — 4.6 ft. hd.

3. Continue across Table 1 to find GPM flow required for this heat pump. 5 GPM

4. Count each elbow, tee, reducer, air scoop, flowmeter, etc., as 3 FEET OF PIPE EQUIVALENT. Add the EQUIVALENT FEET OF PIPE to the actual feet of PIPE USED. The TOTAL LENGTH is used to determine the PIPING HEAD LOSS below.

   NOTE: For a parallel earth loop system figure for only one loop at this time.

Pipe Type & Size	No. Elbows, Tees Devices, Etc. *		Equiv. Ft. of Pipe		Actual Pipe Used	Total Pipe Length
1" Copper	20	x3	60	+	20	80
1½" PB SDR17	None	x3	None	+	1200	1200
		x3		+		
		x3		+		
		x3		+		

*IF THE PIPE IS BENT AT A 2 FT. RADIUS OR LARGER, DO NOT FIGURE THE CURVE AS AN ELBOW.

5. PIPING HEAD LOSS for different types of pipe at GPM flow rate of water source heat pump. NOTE: For parallel earth loop system figure for only one loop.

Pipe Type and Size	Total Pipe Length		Piping** Head Loss (Table 2)		
1" Copper	(80	÷ 100) x	1.9	=	1.52 ft. hd.
1½" PB SDR17	(1200	÷ 100) x	0.21	=	2.52 ft. hd.
	(	÷ 100) x		=	ft. hd.
	(	÷ 100) x		=	ft. hd.
	(	÷ 100) x		=	ft. hd.

**For parallel earth loops divide the heat pump GPM (line 3) by number of loops to determine flow rate through each individual loop to select piping head loss.

SUBTOTAL 8.64 ft. hd.

6. Multiply SUBTOTAL by 1.36 to obtain TOTAL HEAD LOSS FOR SYSTEM using propylene glycol antifreeze solution.

TOTAL HEAD LOSS 11.75 ft. hd.

7. PUMP SELECTION: Use Table 3 and flow rate, (line 3). Select the pump output which is LARGER or equal to the TOTAL HEAD LOSS FOR SYSTEM. (line 5 or 6).

Circulating Pump Model	No. Pumps
24 - 64	1

If the TOTAL HEAD LOSS calculated in line 6 is greater than the pump outputs listed in Table 3, go to the pump manufacturer's performance curves and find the required GPM flow for the heat pump. Pump performances are listed for each pump model at different flow rates.

Series pump performance is simply a TOTAL OF THE INDIVIDUAL PUMP PERFORMANCES: If one pump can overcome 10 feet of head loss, two can overcome 20 feet of head loss, three can overcome 30 feet of head loss, etc.

REMEMBER: UNDER NO CIRCUMSTANCES MIX DIFFERENT PUMP SIZES WHEN USING PUMPS IN SERIES.

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EXAMPLE 2

Given:

A. Vertical system.

B. Bard WPV53A water source heat pump.

C. Heat pump water flow requirements are 10 GPM with a 15 ft.hd. loss (see Tables 1A and 1B).

D. Heat pump connected to circulation pump module and earth coil with 25 ft. of 1" I.D. connection hose.

E. Pressure drop through flow meter and connections to coil of water source heat pump 1" copper.

F. Three loops (U-bends) with 373 ft. pipe each.

G. Loops are 3/4" SDR-11 polyethylene pipe.

H. Flow rate through each loop will be 1/3 of total flow through total earth loop system because there are three loops and each one will have an equal share of the total flow rate.

10 GPM ÷ 3 = 3.3 GPM Per Loop

I. 240 ft. of 1-1/2" SDR-11 polyethylene pipe headers.

CIRCULATING PUMP WORKSHEET

1. Find the Bard heat pump model used in Table 1. MODEL WPV53A

2. Enter water coil head loss: (Table 1) — 15 ft. hd.

3. Continue across Table 1 to find GPM flow required for this heat pump. 10 GPM

4. Count each elbow, tee, reducer, air scoop, flowmeter, etc., as 3 FEET OF PIPE EQUIVALENT. Add the EQUIVALENT FEET OF PIPE to the actual feet of PIPE USED. The TOTAL LENGTH is used to determine the PIPING HEAD LOSS below.

   NOTE: For a parallel earth loop system figure for only one loop at this time.

Pipe Type & Size	No. Elbows, Tees Devices, Etc. *		Equiv. Ft. of Pipe		Actual Pipe Used	Total Pipe Length
1" Hose	NA	x3	NA	+	25	25
1" Copper	14	x3	42	+	10	52
PE SDR-11 3/4"	4	x3	12	+	373	385
PE SDR-11 1½"	8	x3	24	+	240	264
		x3		+		

*IF THE PIPE IS BENT AT A 2 FT. RADIUS OR LARGER, DO NOT FIGURE THE CURVE AS AN ELBOW.

5. PIPING HEAD LOSS for different types of pipe at GPM flow rate of water source heat pump. NOTE: For parallel earth loop system figure for only one loop.

Pipe Type and Size	Total Pipe Length		Piping** Head Loss (Table 2)		
1" Hose	(25	÷ 100) x	6.53	=	1.63 ft. hd.
1" Copper	(52	÷ 100) x	6.9	=	3.59 ft. hd.
PE SDR-11 3/4"	(385	÷ 100) x	2.07	=	7.97 ft. hd.
PE SDR-11 1½"	(264	÷ 100) x	1.02	=	2.69 ft. hd.
	(	÷ 100) x		=	ft. hd.

**For parallel earth loops divide the heat pump GPM (line 3) by number of loops to determine flow rate through each individual loop to select piping head loss.

SUBTOTAL 30.88 ft. hd.

6. Multiply SUBTOTAL by 1.36 to obtain TOTAL HEAD LOSS FOR SYSTEM using propylene glycol antifreeze solution.

TOTAL HEAD LOSS 42.0 ft. hd.

7. PUMP SELECTION: Use Table 3 and flow rate, (line 3). Select the pump output which is LARGER or equal to the TOTAL HEAD LOSS FOR SYSTEM. (line 5 or 6).

Circulating Pump Model	No. Pumps
26 - 96	2

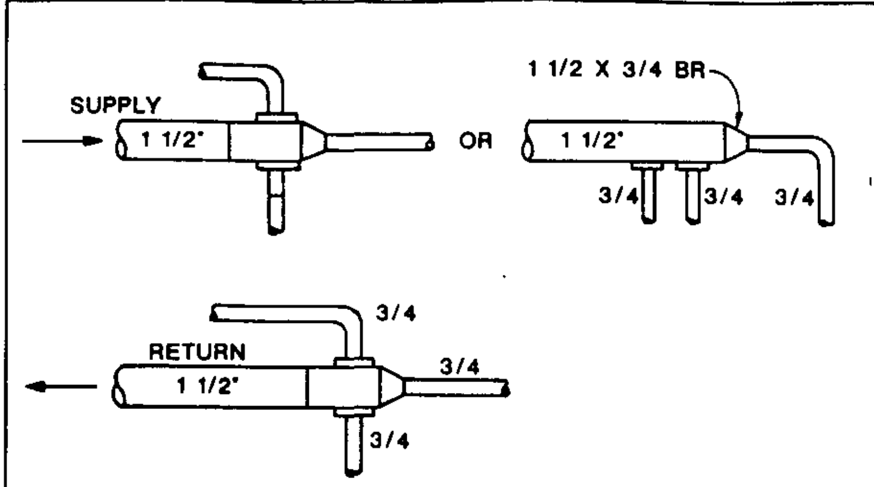
If the TOTAL HEAD LOSS calculated in line 6 is greater than the pump outputs listed in Table 3, go to the pump manufacturer's performance curves and find the required GPM flow for the heat pump. Pump performances are listed for each pump model at different flow rates.

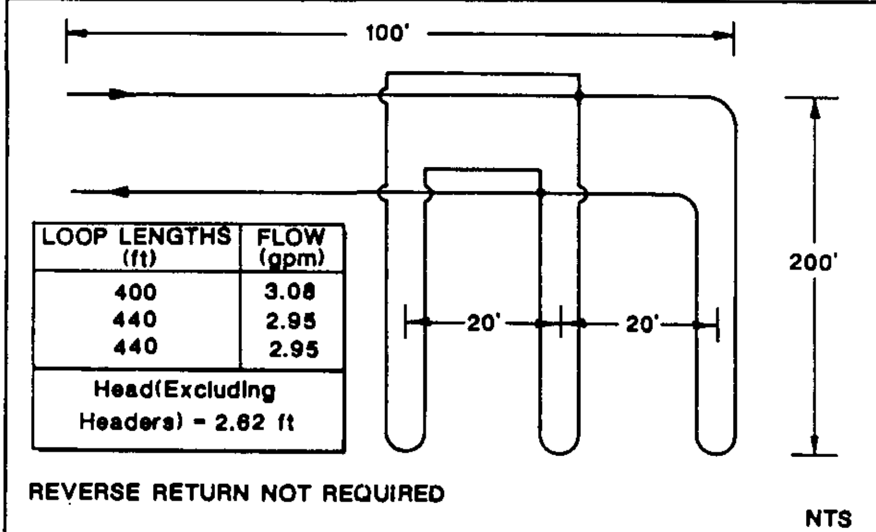
Series pump performance is simply a TOTAL OF THE INDIVIDUAL PUMP PERFORMANCES: If one pump can overcome 10 feet of head loss, two can overcome 20 feet of head loss, three can overcome 30 feet of head loss, etc.

REMEMBER: UNDER NO CIRCUMSTANCES MIX DIFFERENT PUMP SIZES WHEN USING PUMPS IN SERIES.

F1125-284

CLOSE HEADER SYSTEM

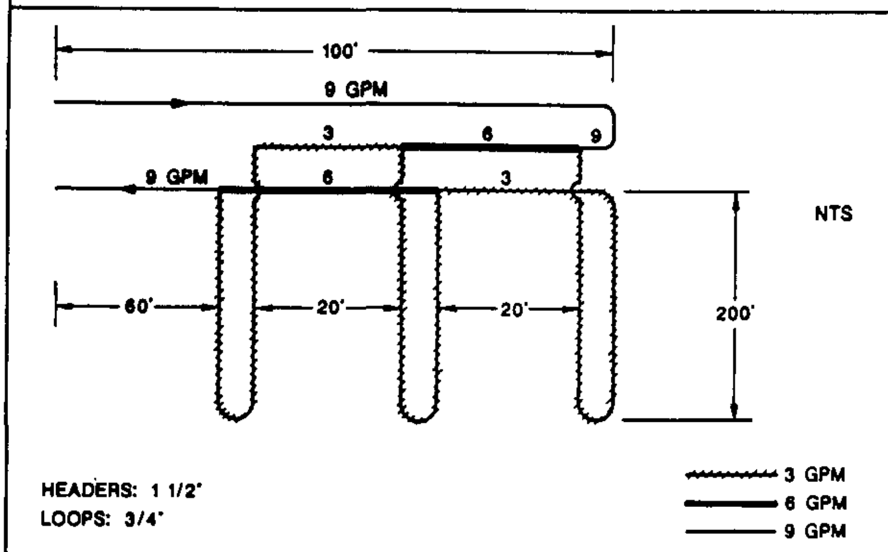




LOOP LENGTHS (ft)	FLOW (gpm)
400	3.08
440	2.95
440	2.95
Head(Excluding Headers) = 2.62 ft	

REVERSE RETURN NOT REQUIRED

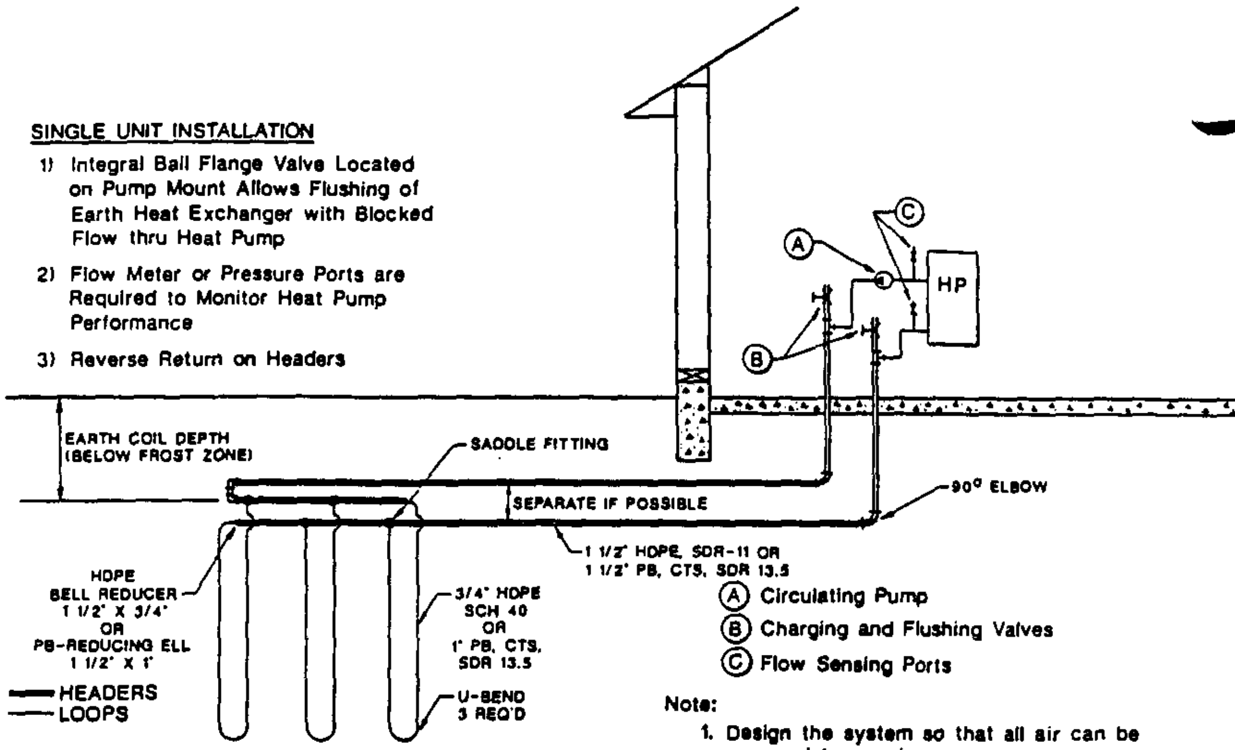
SPACED HEADER WITH REVERSE RETURN



Drawings courtesy of Oklahoma State University.

SINGLE UNIT INSTALLATION

1) Integral Ball Flange Valve Located on Pump Mount Allows Flushing of Earth Heat Exchanger with Blocked Flow thru Heat Pump
2) Flow Meter or Pressure Ports are Required to Monitor Heat Pump Performance
3) Reverse Return on Headers

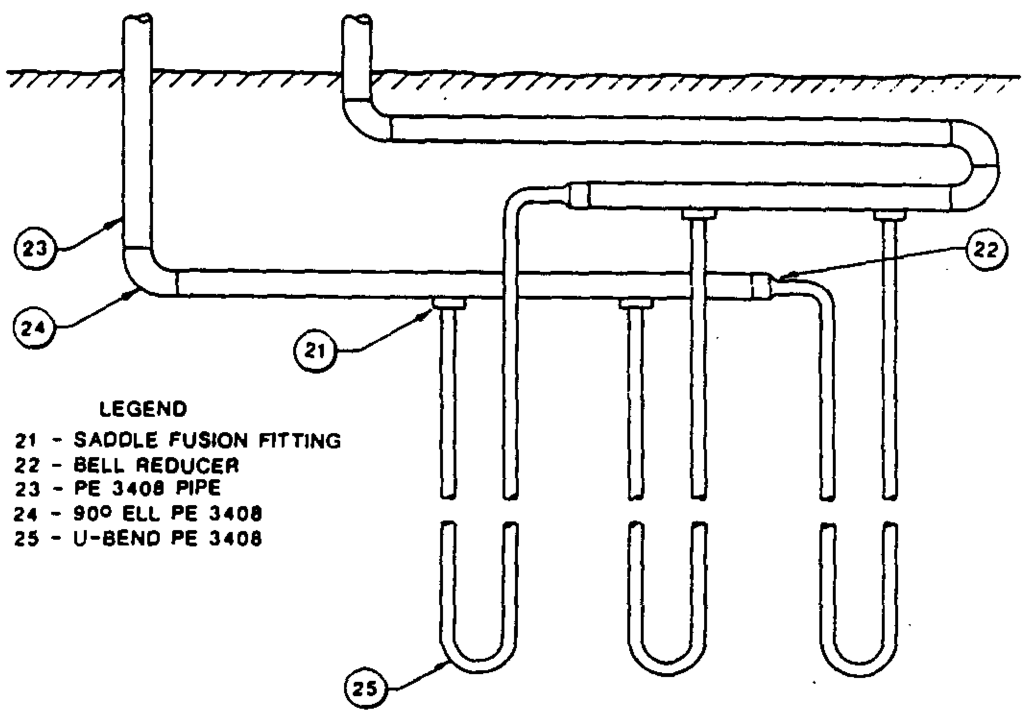


Ⓐ Circulating Pump
Ⓑ Charging and Flushing Valves
Ⓒ Flow Sensing Ports

Note:

1. Design the system so that all air can be removed by purging.
2. Expansion tank may be required on large or multiple unit systems.

(REVERSE RETURN)



LEGEND
21 - SADDLE FUSION FITTING
22 - BELL REDUCER
23 - PE 3408 PIPE
24 - 90° ELL PE 3408
25 - U-BEND PE 3408

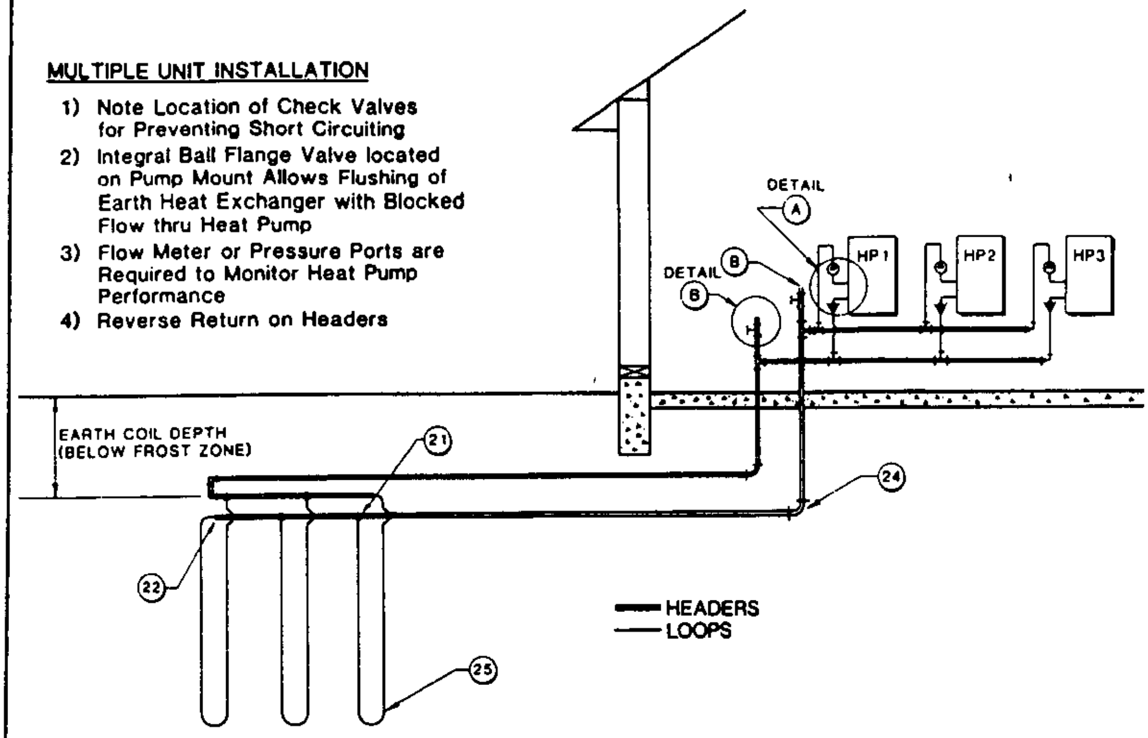
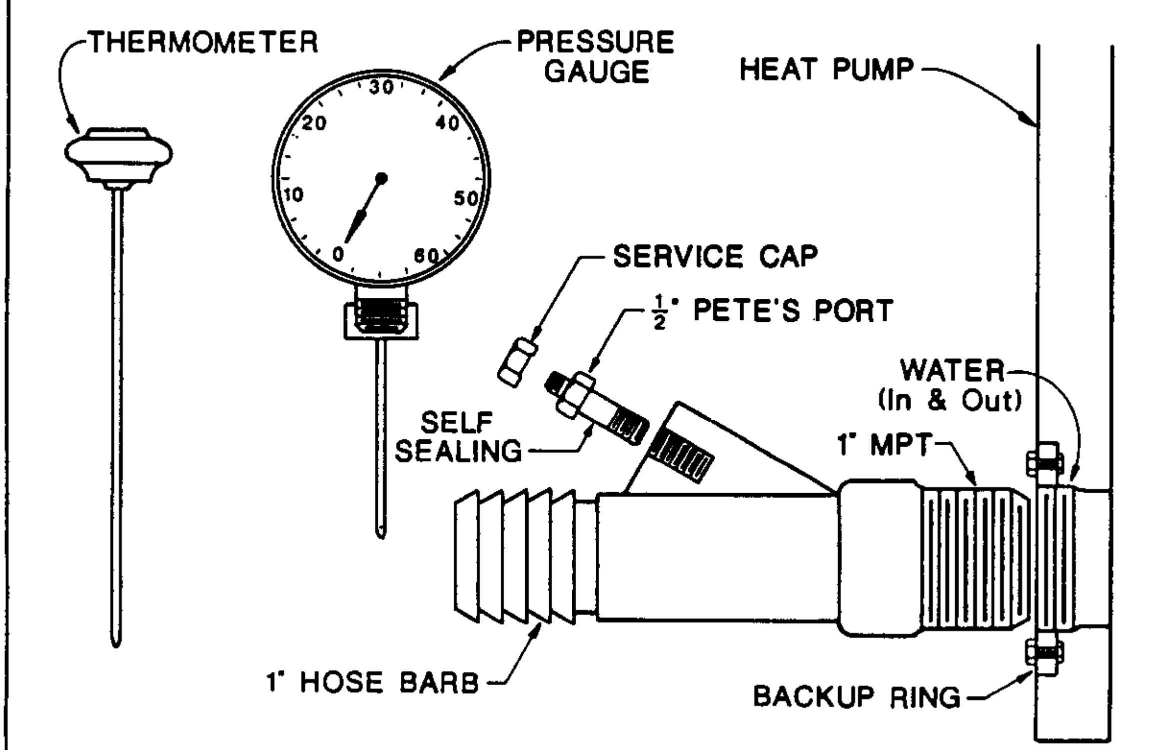


FIGURE 14. Multiple Unit Installation

PRESSURE AND TEMPERATURE SENSING ADAPTER AND COMPONENTS



Drawings courtesy of Oklahoma State University.

VII. Freeze Protection

Antifreeze Solutions: Except in the very most southern climates, an antifreeze solution will be required to prevent freezing in the heat pump heat exchanger. The choices are as follows:

1. Salts ---- Calcium Chloride and Sodium Chloride
2. Glycols -- Ethylene and Propylene
3. Alcohols - Methyl, Isopropyl, and Ethyl

The selection of an earth coil circulation fluid is based upon the following:

1. Safety (toxicity and flammability)
2. Freezing point
3. Heat transfer characteristics (primarily thermal conductivity and viscosity)
4. Frictional pressure drop and pumping requirements (primarily viscosity)
5. Cost (initial charge, makeup and inhibitor costs)
6. Corrosiveness
7. Physical and chemical compatibility with all system components
8. Availability of product in local market area
9. Ease of transporting and storing
10. Long life

The earth coil circulation fluid freezing point is particularly important and determines the solute concentration in the circulation fluid that is required for freeze protection of the evaporator of the heat pump. The coldest expected evaporator exit temperature of the earth coil circulation fluid during heating operation determines the required freezing point of the circulation fluid. The refrigerant temperature in the evaporator runs approximately 10 degrees F lower than the exit water temperature, therefore it is necessary to provide freeze protection for the minimum operating evaporator refrigerant temperature.

Generally speaking, the salts are safe, are non toxic, have good heat transfer characteristics, are low cost, have long life, but are corrosive in the presence of air and most metals. The major drawback of the salts is their corrosive nature and their cleanup problems when spilled. One very strong point is that they are considered non toxic and environmentally safe. With proper metal component selection and air purging of the system, they can and have been used successfully. In northern climates where heat pump loop operating temperatures go as low as 30°F calcium chloride and methanol has been used.

Glycols are safe, are considered toxic, are generally non corrosive, have fair heat transfer characteristic, are medium cost, with a finite life. For low temperature operation, the glycols can become viscous requiring greater pumping power and therefore reduce the heat pump system efficiency.

Improperly handled, alcohols are not safe (burn and explode when mixed with air), are toxic, are relatively non corrosive, with fair heat transfer characteristics, are medium cost, and have long life. Their major drawbacks are their explosive and toxic behavior. Diluting the alcohol solution before taking them on site reduces the explosive risk somewhat. Alcohols are non corrosive which makes their use very popular. Their application has been in both the northern and southern climates.

CAUTION: Many anti corrosion inhibitors are toxic and care must be taken to prevent a non toxic antifreeze solution from becoming toxic after the solution is inhibited.

Metal Components: The metal components in the system must be compatible with the cl/gc circulating fluid. The components that must be carefully selected are:

1. Circulation pump and pump flanges
2. All metal piping
3. Sensing ports
4. Any metal component in contact with the circulating fluid

Depending on the antifreeze selected, the metals chosen for the system must be carefully selected. The dealer's recommendation must be carefully followed.

Antifreeze solution used in earth loop system must be non toxic and non corrosive. Non toxic in case there is a leak in the loop system so the ground water will not be contaminated and non corrosive to protect the metal components used in the circulation pumps and other system components.

To determine the amount of antifreeze to be added to the water in the earth loop, calculate the approximate volume of water in the system by using the following table which gives the gallons of water per 100 feet of pipe.

TABLE 4

PIPE MATERIAL	NOMINAL PIPE SIZE	GALLONS PER 100' OF PIPE
Polyethylene		
SDR-11	3/4	3.02
SDR-11	1	4.73
SDR-11	1-1/4	7.52
SDR-11	1-1/2	9.85
SDR-11	2	15.40
SCH 40	3/4	2.77
SCH 40	1	4.49
SCH 40	1-1/4	7.77
SCH 40	1-1/2	10.58
SCH 40	2	17.43
Polybutylene		
SDR-17 IPS	1-1/2	11.46
SDR-17 IPS	2	17.91
SDR-13.5 CTS	1	3.74
SDR-13.5 CTS	1-1/4	5.59
SDR-13.5 CTS	1-1/2	7.83
SDR-13.5 CTS	2	13.38
Copper	1	4.3

Add two gallons for the equipment room devices and heat pump.

PROPYLENE GLYCOL

Propylene glycol solution is lower in toxicity, can offer low corrosivity, low volatility, and low flammability hazard. However, propylene glycol is more costly and yields more viscous solutions. Propylene glycol solutions may be considered for use down to about 15 degrees F. Use of propylene glycol solutions below 15 degrees F offers excess viscosity which, in turn, yields excessively high frictional pressure drops and excessively low heat transfer coefficients.

The 15 degrees F temperature is definitely the maximum lower limit for closed loop systems. A more reasonable lower limit threshold would be a maximum 25% mixture by volume and operating above 30 degrees F. Lower operating temperatures and/or higher concentrations of propylene glycol are not economical when you consider the energy required to pump the fluid and maintain turbulent flow under those conditions.

In order to obtain good heat transfer within the buried pipe system the calculated reynolds number should not fall below 2500 for the coldest exit fluid temperature from the heat pump.

The quality of the water used to prepare glycol solutions is important. The water should be "soft" and have a low concentration of chloride and sulfate ions. Glycol inhibitor is commonly added by the manufacturer. Glycol solutions normally have a pH of 8.8 to 9.2. Glycol solutions having pH that falls below 7.5 should be replaced. Addition of inhibitor cannot restore the solution. Indiscriminate mixing of differently inhibited solutions should be avoided unless the solutions are known to be compatible.

Never use chromite treatment because it will result in rapid buildup of sludge. Glycol solutions, even though inhibited, do not have an indefinite service life and should be checked yearly. Spent glycol solution should be removed from the system and replaced with fresh glycol solution.

Where the ground water at 100 ft. depth is less than or equal to 60°F, a 20% by volume solution of propylene glycol is required. The percentage of antifreeze depends on geographical location. A 20% by volume solution of propylene glycol is required for 18°F freeze protection.

Example: For 100 gallons of water in system, 20 gallons of propylene glycol is required.

Two short pieces of hose, a bucket and a small submersible pump are needed to add the antifreeze.

Block the system by closing a ball valve. Blocking flow prevents the antifreeze from being pumped into one boiler drain and out the other.

Attach hoses to the boiler drains. Run the uppermost hose to drain. Connect the other hose to the submersible pump in the bucket. Put full strength propylene glycol into the bucket and pump in the amount needed to give the required percentage by volume. When the required amount has been pumped in, turn off the pump, close the boiler drains, disconnect the hoses and open the isolation flange or gate valve.

CALCIUM CHLORIDE

Calcium chloride brines are the second lowest cost brines, next to sodium chloride brines. Calcium chloride brines have been used to as low as -30 degrees F; however, thermal and flow characteristics deteriorate rapidly below -5 degrees F.

Calcium chloride is marketed in flake, solid, and solution forms. The flake form is used most extensively and is available as Type 1 which is 77 minimum weight percent calcium chloride and Type 2 which is 94 minimum weight percent calcium chloride.

Both of the salt brines previously discussed can cause considerable corrosion problems. Regular monitoring and maintenance are necessary. Seclusion of the brines from oxygen and carbon dioxide helps prevent corrosion; however, closed systems such as the earth coil still tend to have some corrosion. Strangely enough, diluted solutions tend to be more corrosive than concentrated solutions. Corrosion is best controlled by minimizing contact with air and maintaining pH between 7.5 and 8.0. Acidic, neutral, or strongly alkaline brines tend to be most corrosive.

Sodium dichromate inhibitor is generally considered to be the most economical and most effective means of combatting corrosion with salt brines. Sodium dichromate comes as orange crystals that are readily dissolved in warm water. Sodium dichromate dissolves very slowly in cold water and should never be put into a brine tank in crystal form. Dissolve dichromate crystals in warm water and add resulting solution to the brine.

If you elect to use the salt brine solutions, the following points have been observed in systems that have successfully operated in this environment for long periods of time with little or no difficulty.

During system startup, all air must be purged or removed. Fluid velocities greater than 2 feet per second must be achieved during the charging, purging and startup operation in order to accomplish this objective.

Air traps at the end of headers and manifolds must be eliminated.

Metal components with high zinc content must be eliminated. This includes circulation pumps, fittings and valves. This can partially be accomplished in the design process by reducing the number of metal components in the system.

Alloys that are high in zinc content should be avoided and substituted with 300 and 400 series stainless steel, copper-nickel or other more noble (cathodic) materials.

Copper-nickel heat exchangers are more likely to survive the salt brine environment than standard copper heat exchangers.

The materials are listed in order of most desirable to least desirable from a corrosion resistance standpoint:

1. 300 SERIES STAINLESS STEEL
2. 400 SERIES STAINLESS STEEL
3. COPPER NICKEL ALLOYS
4. BRONZES
5. COPPER
6. BRASSES
7. ACTIVE STAINLESS STEEL
8. CAST IRON
9. STEEL
10. ALUMINUM

A 20% by weight solution calcium chloride and water may also be used as an antifreeze in the earth coupled system. It is also non toxic, a better heat conductor and less expensive than propylene glycol. However, it is very corrosive. Multiply the gallons of water in the earth loop system by 1.4841 to find the pounds of 94-97% pure calcium chloride required for 18°F freeze protection.

METHYL ALCOHOL (METHANOL)

Methyl alcohol, sometimes referred to as methanol, wood alcohol and carbinol has been widely used as an antifreeze. Methanol water offers low cost, low corrosivity, low viscosity, and good thermal conductivity. Methanol water offers relatively low frictional pressure drops and relatively high heat transfer coefficients. Methanol, however, offers the disadvantages of high volatility, high flammability, and high toxicity. Pure methanol has a flash point of 54 degrees F to 60 degrees F, while a 30 percent methanol in water solution has a flash point of 75 degrees F. These flash points are poor. A 19.41% by volume solution will have a freezing point of 15 degrees F.

VIII. System Start Up

Once the ground water source heat pump system is completely installed, the final step is to start the system and check for proper operation. The proper sequence on startup is to begin with the water side of the system, then proceed to the air side.

FLUSH THE SYSTEM PIPING--DO NOT connect the water lines from the earth coupled loop to the unit before the water lines have been flushed. Flushing will remove any debris and air that may be trapped in the piping. If water is circulated through the unit without first flushing the water loop piping, the heat pump unit may be damaged. Therefore, follow this procedure carefully before connecting to the unit.

When an earth coupled system, connect the piping to flushing rig (Figure 15) that can be easily constructed from a 55 gallon drum, 1 hp water pump, and some relatively inexpensive piping. Fill the earth coupling as much as possible then hook one side of the earth coupling to the pump and return the other side of the earth coupling to the top of the barrel. Fill the barrel and turn on the pump. The barrel must be kept at least half full of water to avoid sucking air into the system.

When the proper flushing connections have been made, check to be sure all accessible fittings are secure and tight, and any valves in the line are open. Start the pump and let the water circulate for at least 20-30 minutes. This will allow enough time for any entrained air or debris to be purged from the system. With an earth coupled system, check for possible leaks in the loop by establishing 50 PSIG water pressure in the line and checking the gauge after 15 minutes. If there are no leaks in the line, the pressure will not drop. If the pressure in the line falls by more than 5 PSIG, it may be necessary to dig holes at the coupling locations to check for loose or failed couplings. With all ground water systems, check carefully for any visible signs of water leakage before digging or boring down to any coupling locations. If visible leakage is found, correct the problem and retest the system. If no visible signs of leakage exist, and the piping system is losing more than 5 PSIG in 15 minutes, then proceed to locate the source of the leakage. Remember, for proper system operation, there can be no leakage in the water loop.

Pipe Size	1"	1½"	2"
Flow, GPM to start purging	3	7	11
Flow, GPM for rapid purging	5	13	21

BOILER DRAINS -- Boiler drains are located on both sides of the circulator for final filling, air purging and antifreeze addition.

The top drain should be the highest point in the equipment room piping. This will help purge air out of the system during final filling at start up.

FLOW RATE ADJUSTMENT -- When the earth loop has been completely flushed and leak tested, remove the flexible connection from the pipe ends and hook up the supply and return lines to the appropriate connections on the water source heat pump, turn on the circulator pump and let the water circulate through the system for five minutes. DO NOT allow the heat pump to operate yet. The proper sequence is to allow water to circulate, then adjust the flow rate, then operate the heat pump.

If the circulator does not operate immediately, turn off the electrical power to the heat pump, close the isolation flanges, remove the indicator plug, insert a small blade screwdriver into the motor shaft and turn gently until the shaft moves freely. Replace the indicator plug, open the isolation flanges, wait a few minutes then restart the pump.

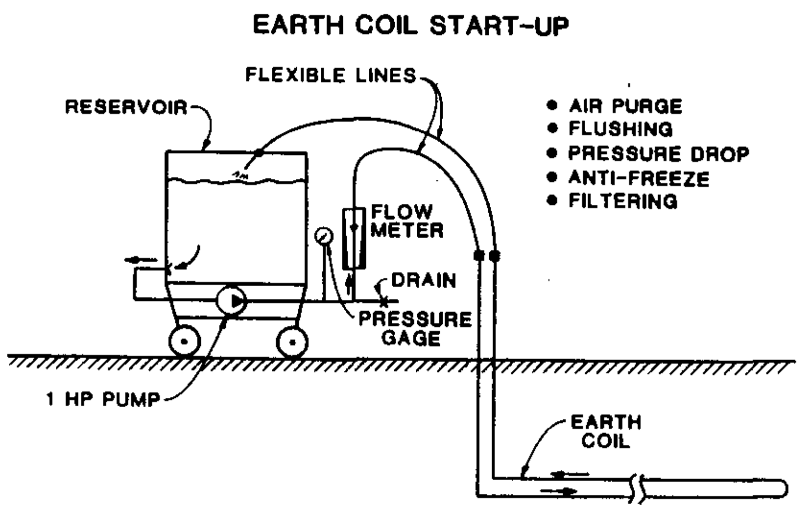
The flow rate should be the desired operating flow of the model of water source heat pump being used (see manufacturer's specifications). Water flow should not be less than that of the minimum flow rate required for the model of water source being used. If water flow is less than system calculations indicate, check your calculations. If the calculations are correct, there is some trapped air or restriction in the water circuit.

IX. Other Items to be Followed

A. Follow the Installation Instructions for the water source heat pump model being used to check the operation of the refrigeration cycle and specifics in installation in structure. The equipment manual will also show the electrical hookup and air flow requirements.

B. Follow the Air Conditioning Contractors of America, "Manual D" for proper duct design for the air side of the system.

FIGURE 15. PORTABLE RIG FOR FLUSHING EARTH COUPLED SYSTEMS



ACKNOWLEDGMENTS

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2. Bose, James E. et al. 1984, "Closed-Loop Ground-Coupled Heat Pump Design Manual," Oklahoma State University, Stillwater, OK.

3. Braud, H. J. Klimkowski, H. and Oliver J. 1983, "Earth-Source Heat Exchanger for Heat Pumps", Louisiana State University, Baton Rouge, LA.

4. Braud, H. J., Baker, F.E. and Smilie, J. L. 1984, "Earth-Coupled Heat Pump Systems", Louisiana Cooperative Extension Service, Baton Rouge, LA.

5. Eitelman, L. 1983, Letter "Pipe Pressure Loss Tables for Polyethylene Pipe," McElroy Manufacturing, Inc., Tulsa, OK.

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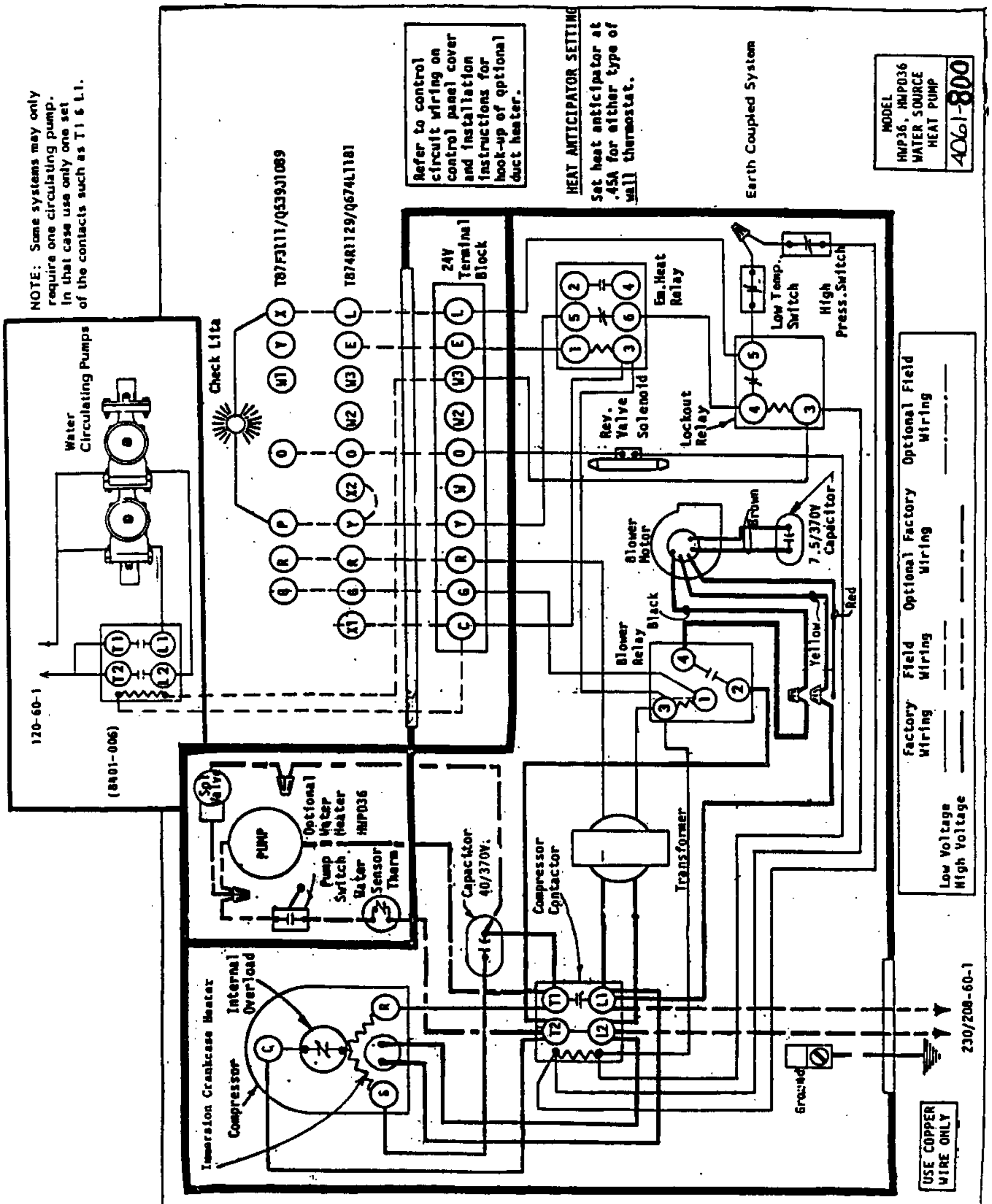
7. Hawkinson, G. 1984, Letter "Pipe Head Loss Tables for Polybutylene Pipe", Vanguard Plastics, Inc. McPherson, KA.

8. Partin, James R. 1981, "Drilled and Trenched Earth-Coupled Heat Pump Exchangers," Stillwater, OK.

9. Bose, J. E., 1985, "Design/Data Manual For Closed Loop Ground-Coupled Heat Pump Systems", American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Atlanta, GA

10. NRECA, 1987, Closed Loop/Cround Coupled Heat Pump Systems Installation Guide, National Rural Electric Cooperative Association, Washington, D.C. 20036

TYPICAL WIRING OF
CIRCULATION PUMP OR PUMPS AND
WATER SOURCE HEAT PUMP



X. Closed Loop Systems Suspended in Ponds and Lakes

The pond or lake should be approximately two acres in size with a volume of water equal to twice the size of the house being heated. A larger pond will be required in colder climates. The zone where the exchanger is placed should remain above 40°F in winter.

CAUTION: The performance of this type of system sometimes is hard to predict due to water stratification and other factors. Be very cautious about using this type of system. Again, make sure the ground water heat pump is designed to operate at lower water temperatures.

LAKE EXCHANGER CONSTRUCTION:

Lengths of 3/4" copper tubing 20 ft. long should be soldered or brazed to 1" copper headers on 1 ft. centers. The headers should be reverse return plumbed for balanced flow in the legs. Refer to the drawing.

Connect the lake exchanger to the polybutylene service lines by using a brass bushing and a copper male adapter. DO NOT thread plastic into metal fittings to make the connection. 1½' IPS PB service lines are appropriate for systems up to 5 tons.

CALCULATING HEAD LOSS:

Locate the exchanger size in the table. Multiply the length of service lines in 100s of feet by the service line head loss in ft/100 ft. and add that number to the exchanger head loss to get the total loss of the exchanger and service lines.

PLACEMENT:

Place the exchanger near the bottom of the lake at least 10-12 ft. below the lake's lowest operating water level. Popular methods of placement include suspending the exchanger under a dock or pier, or tied to a set of old automobile tires which provide spacing of the exchanger above the lake bottom. Do not allow the exchanger to be placed in the silt on the lake bottom. Best performance is obtained where the exchanger is in open water.

SERVICE LINES:

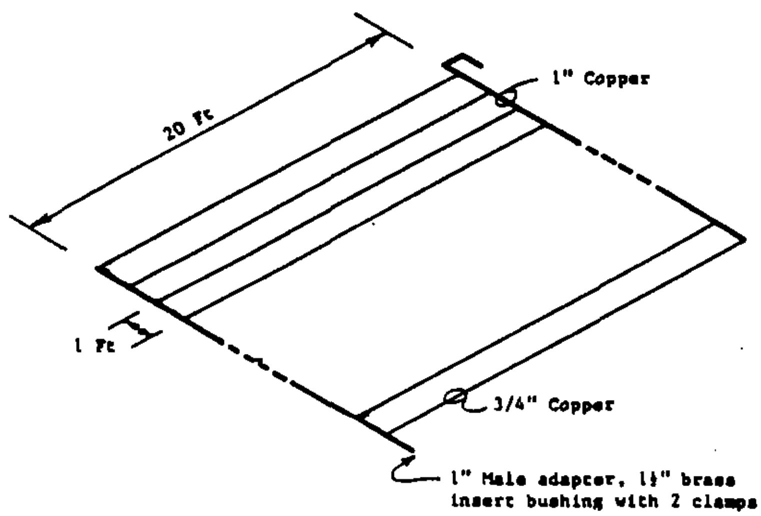
Bury the service lines a minimum of 4' deep or below the frost line, whichever is deeper, across the shore and keep them separated about 2' in the trench.

Follow the "Horizontal Earth Coil Installation" instructions for the service lines to the lake exchanger.

ANTIFREEZE:

The equivalent of 25% propylene glycol is required.

CLOSED LOOP LAKE EXCHANGER



HEAT EXCHANGER SIZE, TONS	NO. of LEGS 20 FT LONG	HEADER LENGTH, FT	FLOW GPM	EXCHANGER HEAD LOSS IN FT	SERVICE LINE HEAD LOSS, FT/100 FT
1	3	4	3	0.20	0.11
2	6	7	6	0.55	0.24
3	9	10	9	1.4	0.72
4	12	13	12	2.8	1.23
5	15	16	15	5.0	1.90

EARTH COUPLED LOOP SYSTEM DESIGN

1. Return Design to: ______________________________ Attn: ____________

   Address ______________________________ Telephone ____________

   City and State ______________________________ Zip ____________

   Job or Contractor (Name or Number): ______________________________

   Location of Job ______________ (City), ______________ (State)

2. Geographical location of installation (near): (See Table 2 back of this sheet)

   ______________ (City), ______________ (State)

3. Building or zone design: Cooling load: ______________________ Btu/Hour

   Heating load: ______________________ Btu/Hour

   Note: For buildings too large for one heat pump, complete work sheet for each zone)

4. Local ground well water temperature: ______________ F°

5. Model of Bard Water Source Heat Pump to be used: ______________

6. System Type: Series [ ], Parallel [ ] Pipe Installed: Horiz [ ] Vert [ ]

7. Antifreeze: None [ ] Calcium Chloride [ ] Propylene Glycol [ ] Methanol Alcohol [ ]

8. Type of pipe to be used: ______________ Pipe Nominal Size ______________ In.
   (See Table 1 back of this page)

9. Number of layers of pipe in trench or loops in bore hole: ______________
   (See back of this page)

10. For horizontal loop systems describe and type of local soil at depth 1 to 6 foot depth during the late summer.

    [ ] a. DRY-LIGHT SOIL (SAND OR GRAVEL) - grass and weeds turn brown in summer

    [ ] b. DAMP-LIGHT SOIL (SAND OR GRAVEL) - grass turns brown, weeds stay green

    [ ] c. DRY-HEAVY SOIL (CLAY) grass turns brown, weeds stay green

    [ ] d. DAMP-HEAVY SOIL (CLAY) - Grass and weeds stay green all summer

    [ ] e. WET-SOIL - swamp, marsh bottoms, etc.

Send to:

Earth Coupled Loop System Design
Bard Manufacturing Company
P.O. Box 607
Bryan, Ohio 43506

F1115-787

	Pipe Material Description	Nominal Size
	PE	
1	SDR-11	3/4
2	SDR-11	1
3	SDR-11	1-1/4
4	SDR-11	1-1/2
5	SDR-11	2
6	SCH 40	3/4
7	SCH 40	1
8	SCH 40	1-1/4
9	SCH 40	1-1/2
10	SCH 40	2
	PB	
11	SDR-17, IPS	1-1/2
12	SDR-17, IPS	2
13	SDR-13.5, Cts	1
14	SDR-13.5, Cts	1-1/4
15	SDR-13.5, Cts	1-1/2
16	SDR-13.5, Cts	2

TABLE 1. Recommended Earthloop Pipes

Note: PE are polyethylene pipes
PB are polybuthylene pipes

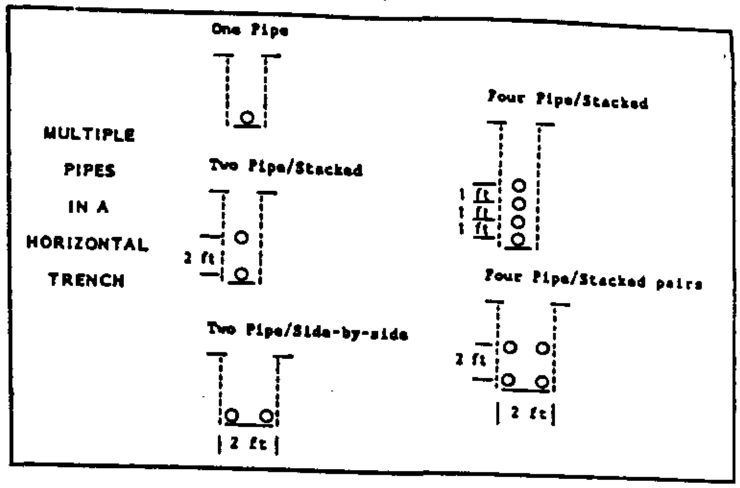


TABLE 2. Geographical Locations of Input Data.

State	Locations
AL	Birmingham, Montgomery
AZ	Phoenix, Tucson
AR	Little Rock
CA	Los Angeles, Merced, San Diego
CO	Colo. Springs, Denver, Grand Junc.
DC	Washington
FL	Appalachicola, Jacksonville
GA	Atlanta, Augusta, Macon
ID	Boise, Idaho Falls
IL	Chicago, E. St. Louis, Urbana
IN	Fort Wayne, Indianapolis, South Bend
IA	Des Moines, Sioux
KS	Dodge City, Topeka
KY	Louisville
LA	Lake Charles, New Orleans, Shreveport
MA	Portland
MS	Plymouth
MI	Battle Creek, Detroit, Sau St Marie
MN	Duluth, Int. Falls, Minneapolis
MS	Biloxi, Columbus, Jackson
MO	Columbia, Kansas City, Springfield
MT	Billings, Great Falls, Missoula
NB	Grand Island, Lincoln, North Platte
NV	Ely, Las Vegas, Winnemucca
NJ	Trenton
NM	Albuquerque, Roswell
NY	Albany, Binghamton, Niagara Falls, Syracuse
NC	New Bern, Greensboro
ND	Bismarck, Grand Forks, Williston
OH	Akron, Columbus, Dayton, Toledo
OK	Altus, Oklahoma City, Tulsa
OR	Astoria, Meford, Portland
PA	Middletown, Philadelphia, Pittsburg, Wilkes-Barre
SC	Charleston, Greenville, Sumpter
SD	Huron, Rapid City
TN	Bristol, Knoxville, Memphis, Nashville
TX	El Paso, Ft. Worth, Houston, San Antonio
UT	Salt Lake City
VT	Burlington
VA	Norfolk, Richmond, Ronoke
WA	Moses Lake, Seattle, Spokane
WV	Charleston, Elkins
WI	Green Bay, Madison
WY	Casper, Cheyene, Lander, Sheridan