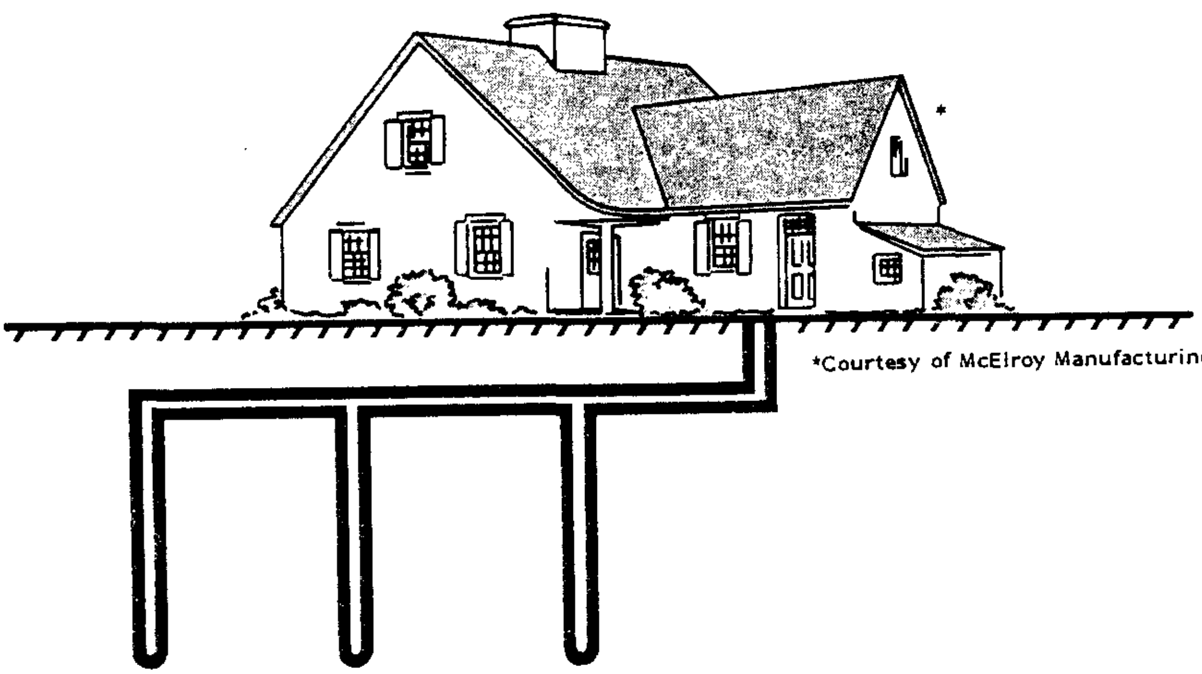
MANUAL 2100-099E

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 not 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

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 deficieicy 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 thermal 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 25°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

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

VERTICAL (SERIES) SYSTEM

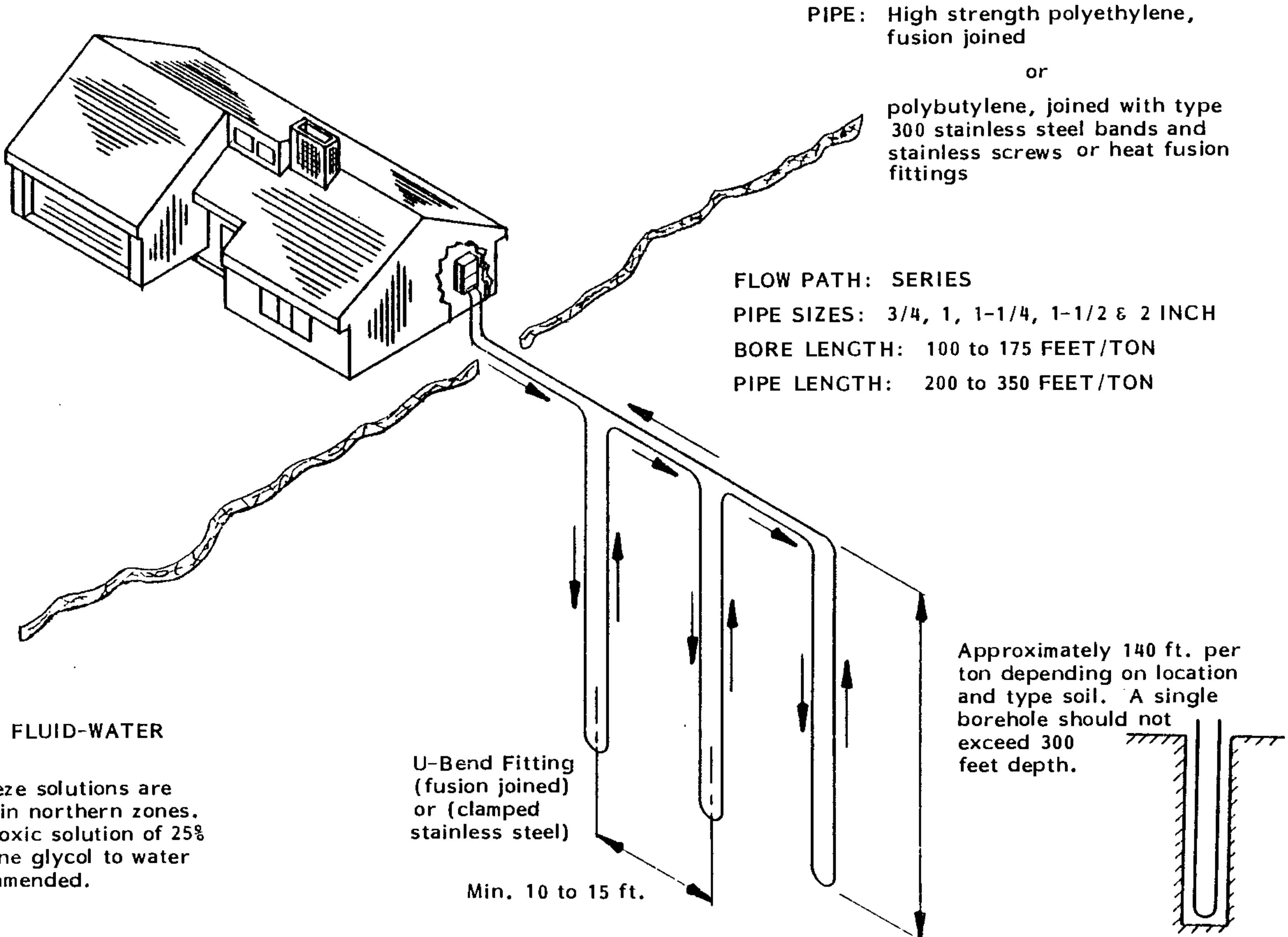
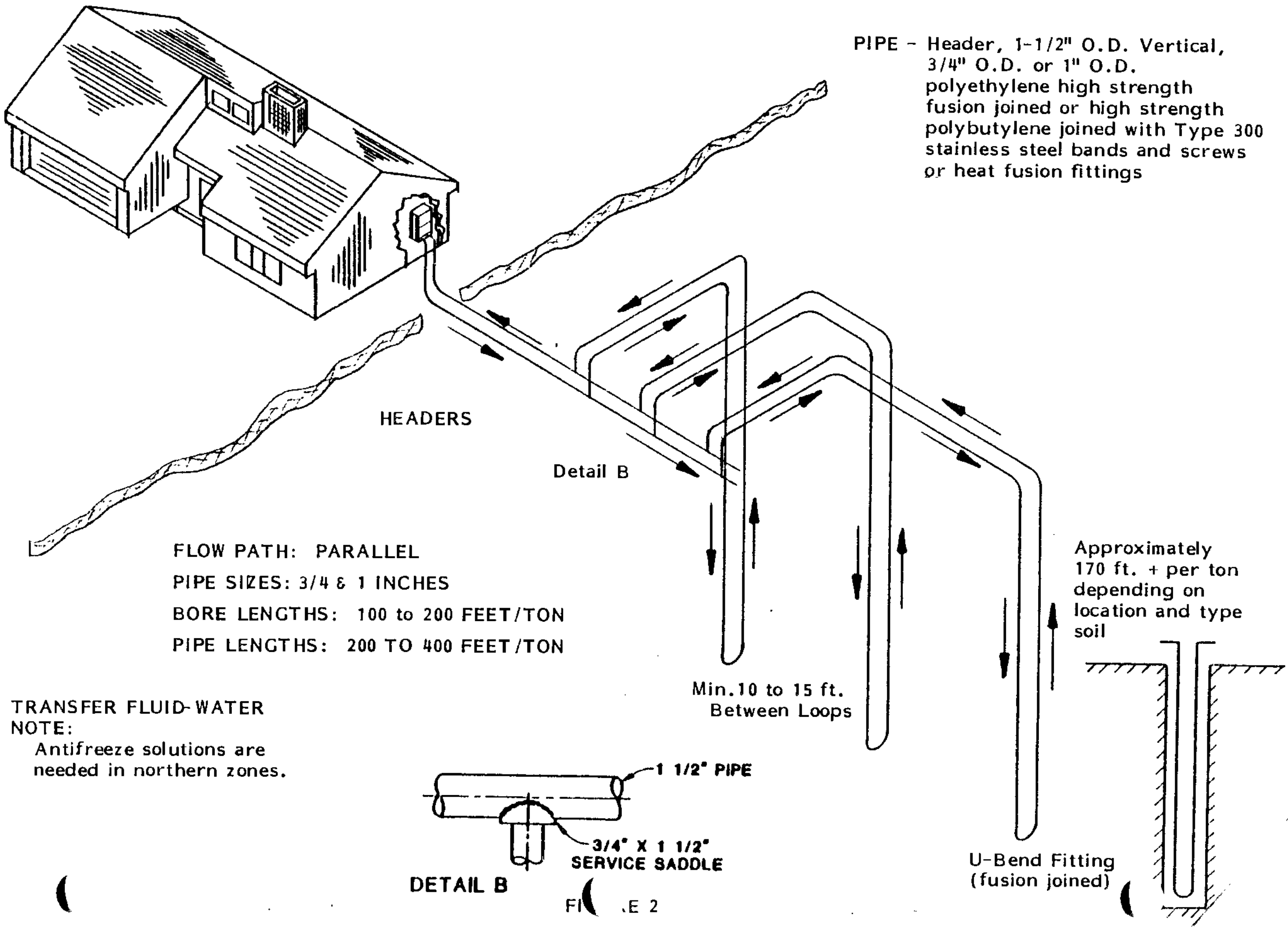


FIGURE 1.

TRANSFER FLUID-WATER
NOTE:

Antifreeze solutions are needed in northern zones. A non-toxic solution of 25% propylene glycol to water is recommended.

VERTICAL (PARALLEL) SYSTEM



FI .E 2

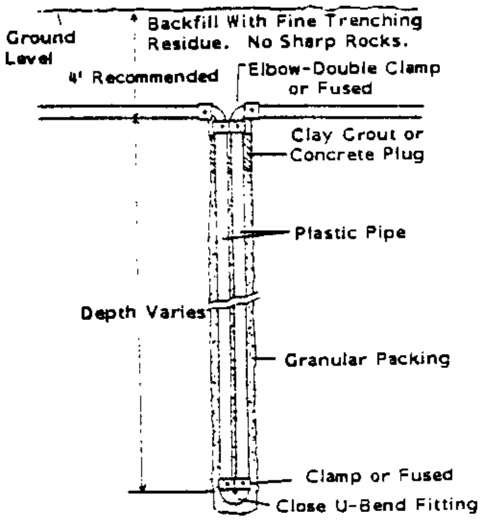
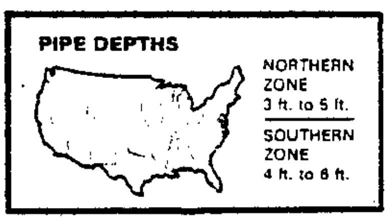


FIGURE 3. Vertical Earth Coupled Borehole & Piping

<u>HORIZONTAL</u>. 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.

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 or 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 (see Figure 6). The steel rod enables the use of a metal detector to find joints in pipe.

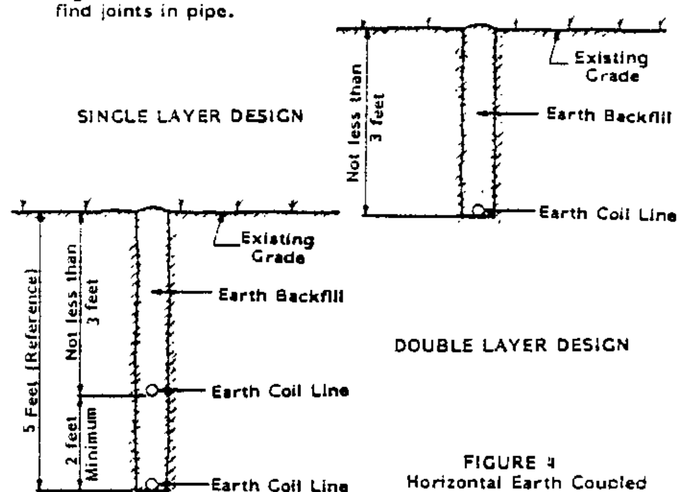


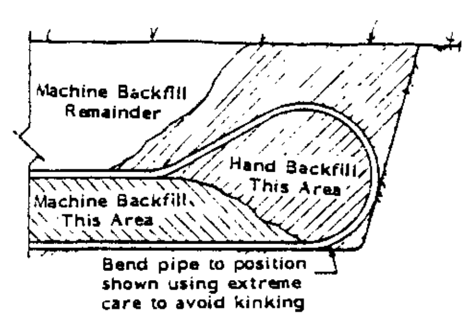
FIGURE 4
Horizontal Earth Coupled Pipe Separation in the Trench

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 5.

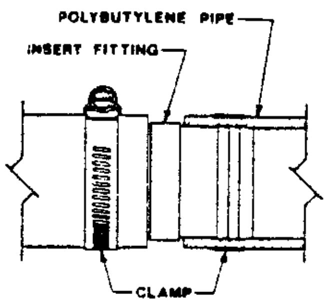
SECTION VIEW

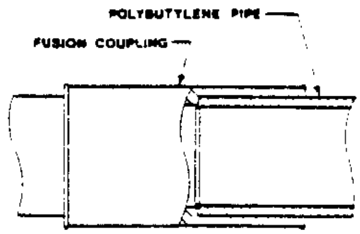


NARROW TRENCH RETURN BEND DETAIL
DOUBLE LAYER HORIZONTAL EARTH COIL

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

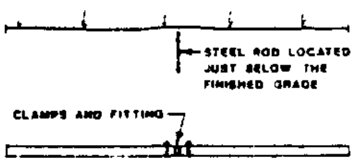
FIGURE 6.





SOCKET FUSED COUPLING

CLAMP INSTALLATION DETAIL



FITTING LOCATION INDICATER DETAIL

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:

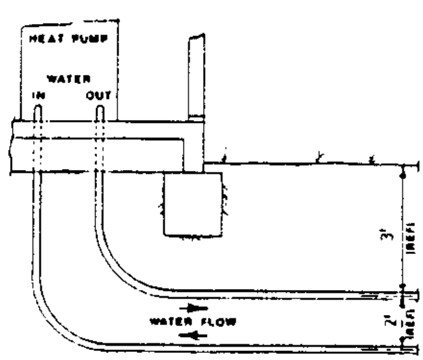
Narrow trenches are installed by trenching machines. The trenches are usually 6" wide. Generally speaking, the trencher will require about 5' between trenches. This is sufficient spacing for horizontal earth coils.

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.

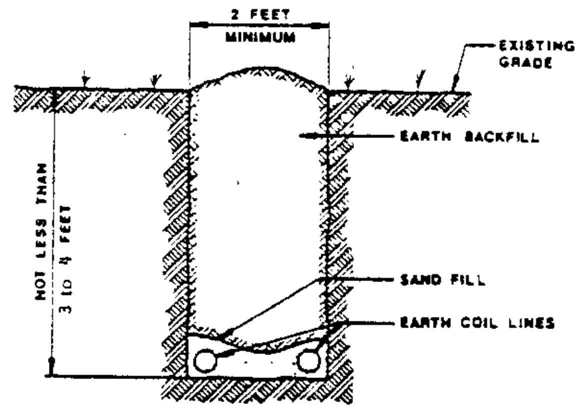


WATER FLOW/CONNECTION SCHEMATIC
DOUBLE LAYER HORIZONTAL EARTH COIL

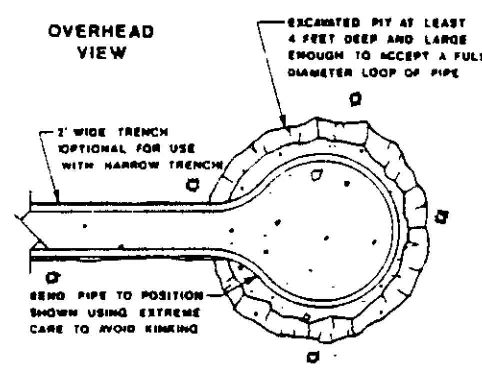
BACKHOE TRENCHES:

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.



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.

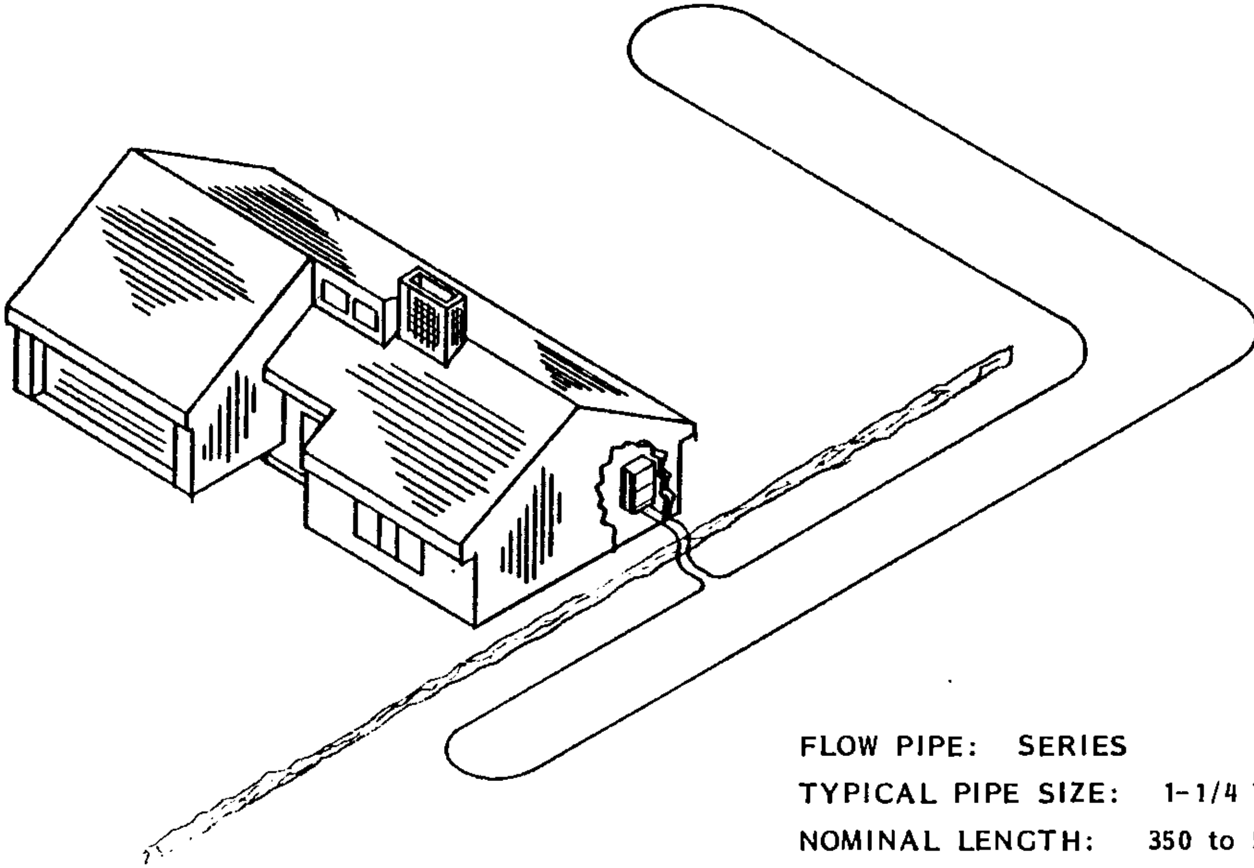
If two pipes are buried in the same trench, keep them 2' apart.

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.

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. A 25% by volume propylene glycol to water solution.

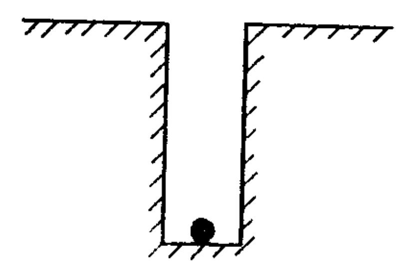


FIGURE 7.

HORIZONTAL (SERIES) SYSTEM

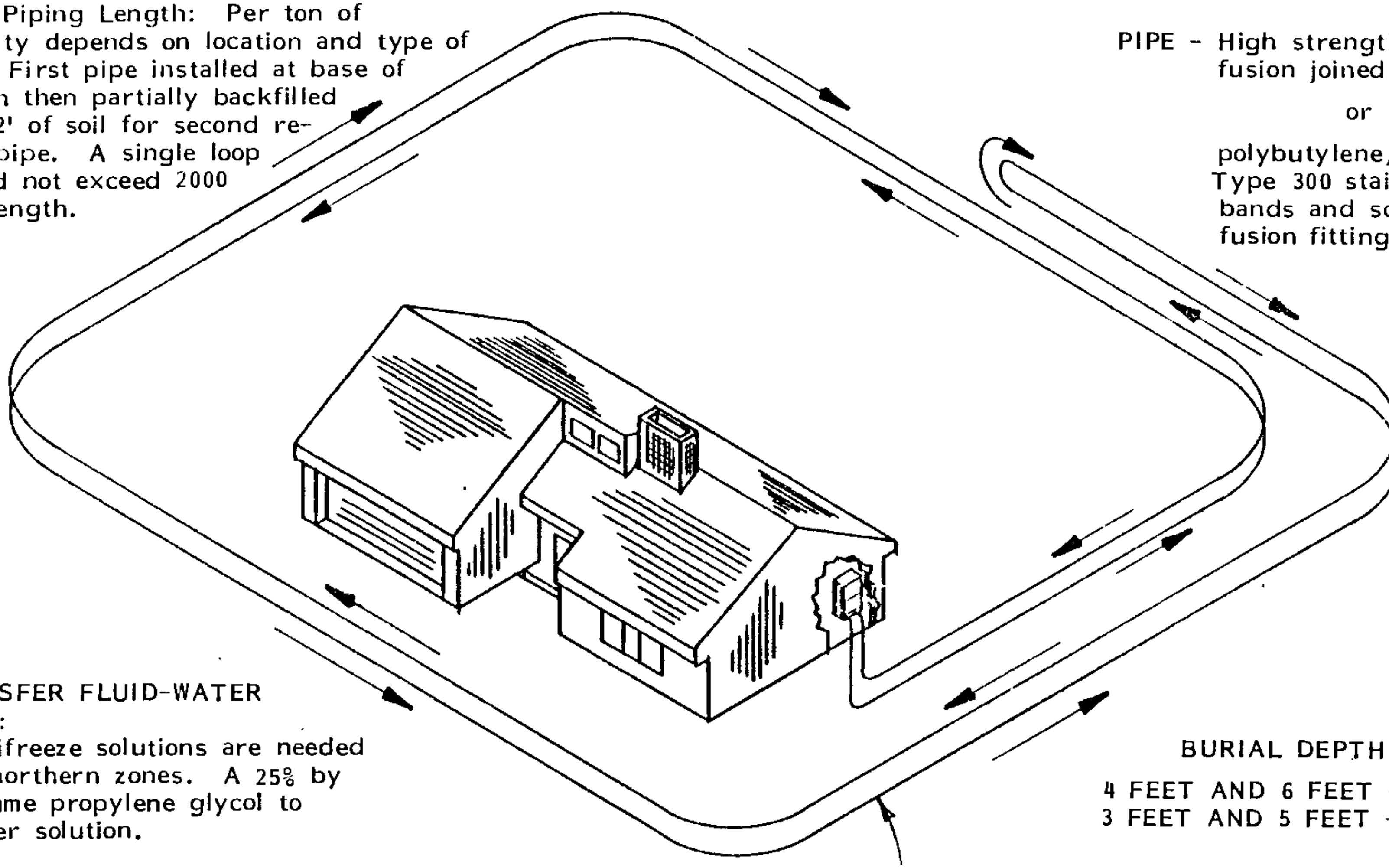
TWO PIPES IN SAME TRENCH

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

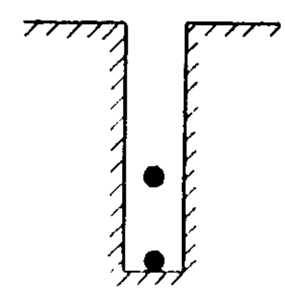
polybutylene, joined with Type 300 stainless steel bands and screws or heat fusion fittings



TRANSFER FLUID-WATER
NOTE:
Antifreeze solutions are needed in northern zones. A 25% by volume propylene glycol to water solution.

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

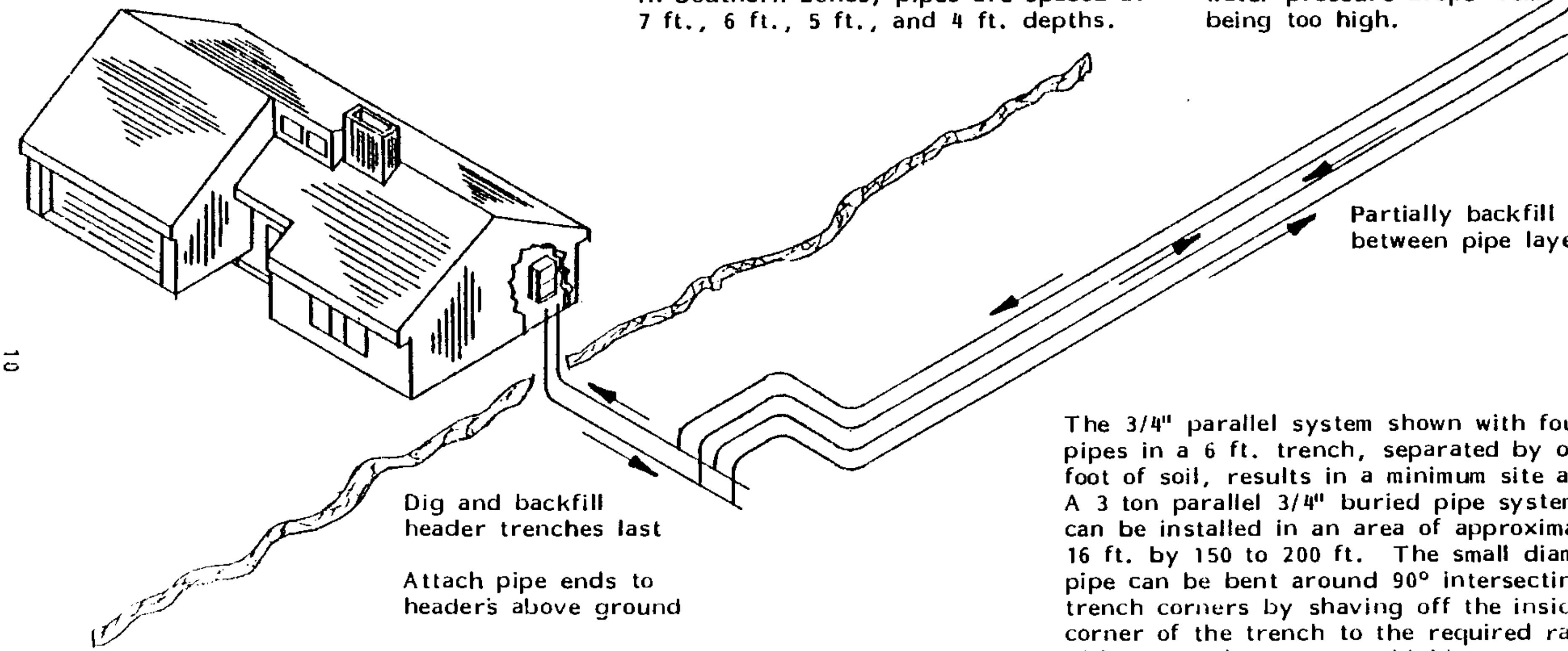
FIGUR 3.

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)

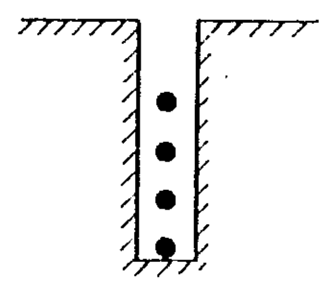


FIGURE 9.

TABLE 1. EARTH COUPLING CONSIDERATIONS

AREA OF CONCERN	VERTICAL SYSTEM	HORIZONTAL SYSTEM
1. LIMITATIONS	Boreholes should not exceed 300 feet depth	Single earth coil should not exceed 2000 feet length
2. PIPING MATERIAL	Polybutylene or polyethylene piping	Polybutylene or polyethylene piping
3. PIPE LENGTH	As required to fill and connect boreholes with total linear borehole depth as determined in earth coil design section of this manual	Sized for each application in linear feet per heat pump unit capacity—contact Bard Manufacturing for additional information
4. PIPING CONNECTIONS	If system requires more than one borehole, then connection can be either series or parallel— if parallel, all boreholes must be equal depth	If system requires more than 2000 feet of coil, divide into equal lengths and connect in parallel
5. SERVICE LINES	Service lines between boreholes and from house to field should be polybutylene or polyethylene buried below the frost line or to minimum 4 feet deep	If earth coil line(s) cannot connect directly to heat pump, use polybutylene or polyethylene service pipe buried below the frost line or to minimum 4 feet deep
6. PIPE FITTINGS	IPS 304 stainless steel, brass or bronze	Same as vertical
7. PIPE FITTING LUBRICANT	Use vegetable base lubricant only—petroleum base lubricant will damage piping	Same as vertical
8. CLAMPS	300 series stainless steel worm gear clamps only -check carefully: some "all-stainless" clamps contain 400 series screws which corrode when exposed to some acids in the soil	Same as vertical
9. CLOGGING	When installing, keep soil, sand, trash, etc. out of pipes until connection is made	Same as vertical
10. FLUSHING THE SYSTEM	Before connecting to heat pump, flush piping with high capacity water pump to remove debris	Same as vertical
11. SYSTEM TESTING	Before connecting to heat pump, pipe system should be tested under 50 PSI water pressure	Same as vertical

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 because of low energy costs.

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

GUIDELINES PRDCEDURE

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 25 degrees on the low end and 105 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 25 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 than .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

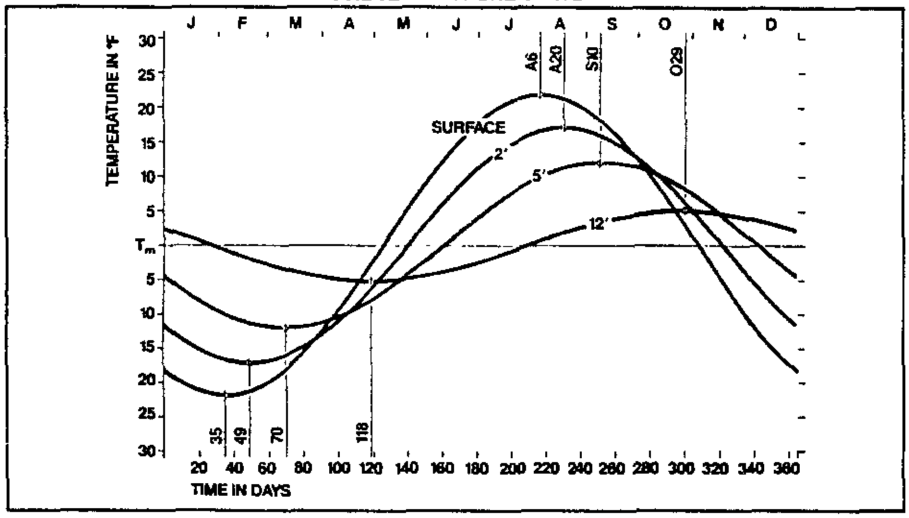


FIGURE B
COMPARISON OF T_M AT VARYING DEPTHS
FOR DIFFERENT SOILS

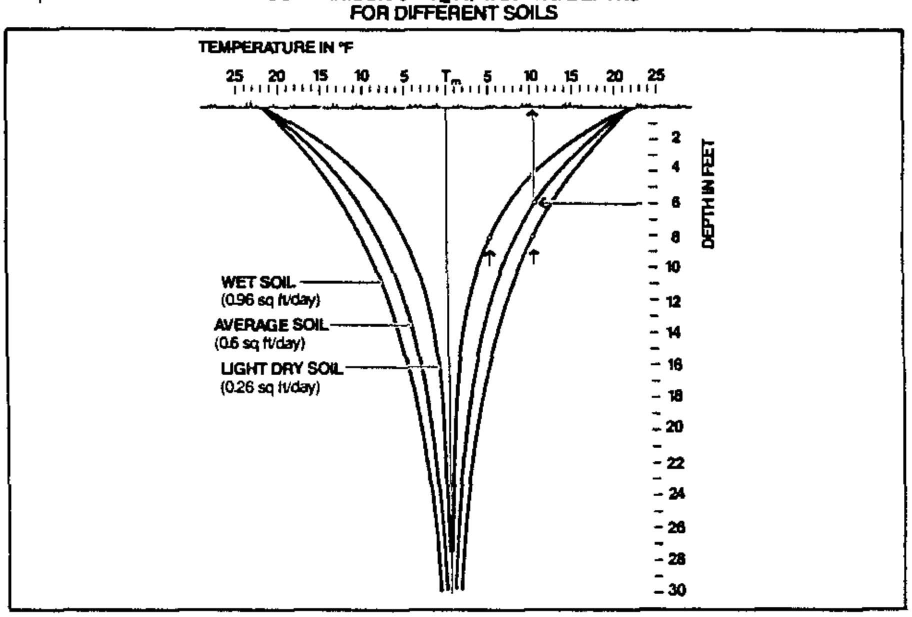
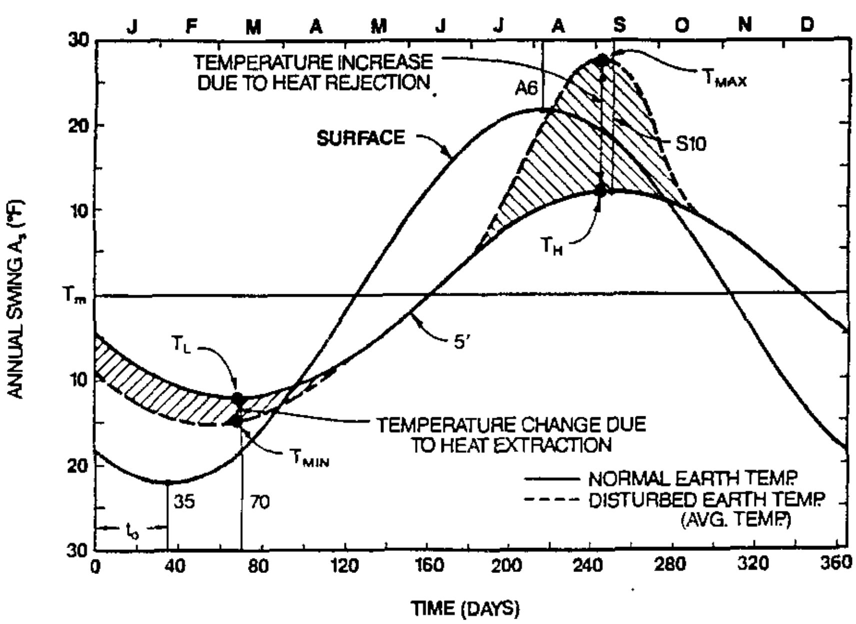


FIGURE C
HORIZONTAL EARTH COIL TEMPERATURE VARIATIONS



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.

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

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 (Ft^2/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.

CALCULATE LENGTH OF EARTH COIL--The accompanying Table 2 shows typical earth coil lengths. To optimize the length use the design service from Bard Manufacturing.

The earth coil must be designed to provide a balance between unit capacity, soil resistance and pipe resistance. Table 2 shows typical trench, (pipe lengths) and hole depths per ton of unit capacity at local earth temperature.

Notice as the number of pipes in the trench or borehole increases the total length of the pipe increases by 20 percent for each time an additional pipe is added. Example: 400 ft. of pipe in a horizontal system will require 480 ft. of pipe in a horizontal system when installed in two layers in same trench.

The values in the table are given for two sizes of polyethylene pipe. There will be a small difference in lengths if polybutylene pipe is used (add 5%).

To use the table for an approximate length for cost estimation, divide the capacity of the selected heat pump unit, at local ground water temperature, for both heating and cooling modes by 12,000. Then multiply this number times the length of pipe, trench or borehole depth from the table for the type of system you plan to install.

EXAMPLE: HWP36 at 60°F entering ground water has a capacity of 36,800 Btuh cooling and 38,900 Btuh heating.

$\frac{36,800 \text{ Btuh}}{12,000}$ = 3.01 x 400 ft - 1226 feet of 1¼" Sch 40 polyethylene pipe required for cooling.

$\frac{38,900 \text{ Btuh}}{12,000}$ = 3.24 x 400 ft - 1297 feet of 1¼" Sch 40 polyethylene pipe required for heating.

Therefore, approximately 1297 feet of 1-1/2" Sch 40 polyethylene pipe is required for a horizontal earth coupled system with one at 5 foot depth in northern climate.

This also assumes that the heating and cooling loads of the structure are equal to the capacity of the heat pump in either mode.

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.

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.

V. 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.

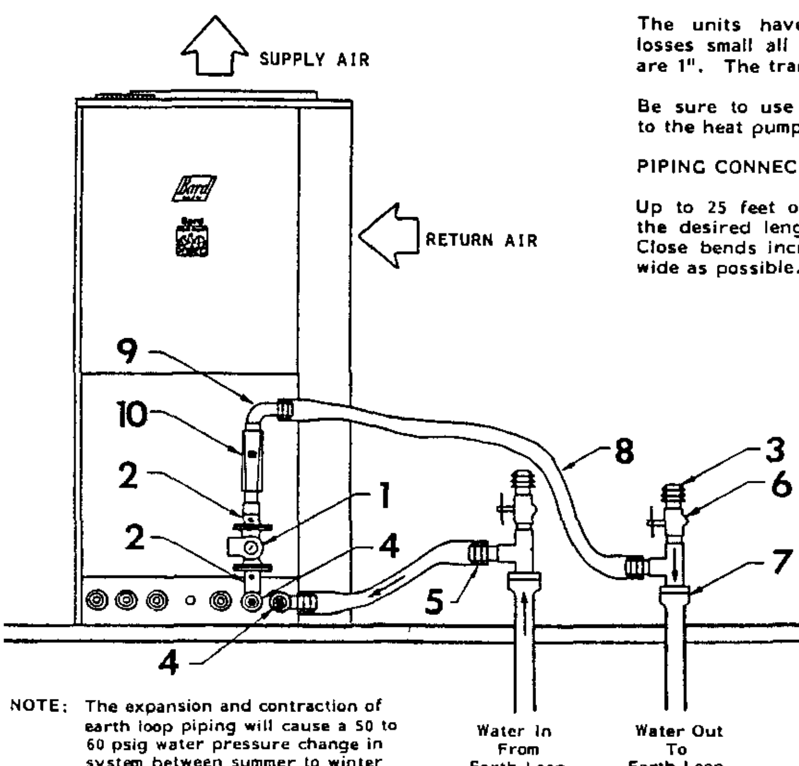
The small circulator keeps the operating cost of the system to a minimum. However, the performance of the circulator MUST be closely matched with the pressure or head loss of the entire system in order to provide the required flow through the heat pump. Insufficient flow through the heat exchanger is 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 10)

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 10A)

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.

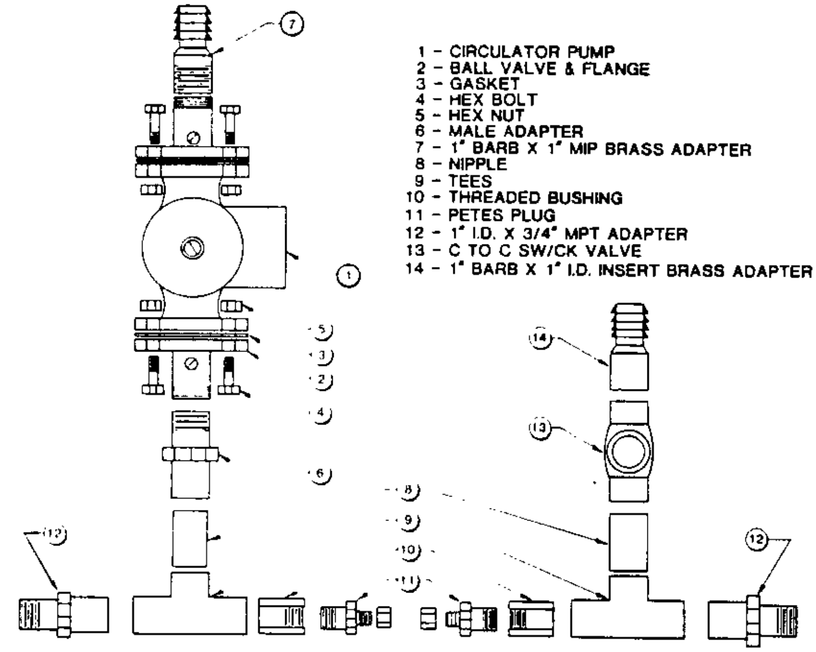
PIPING CONNECTIONS:

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.

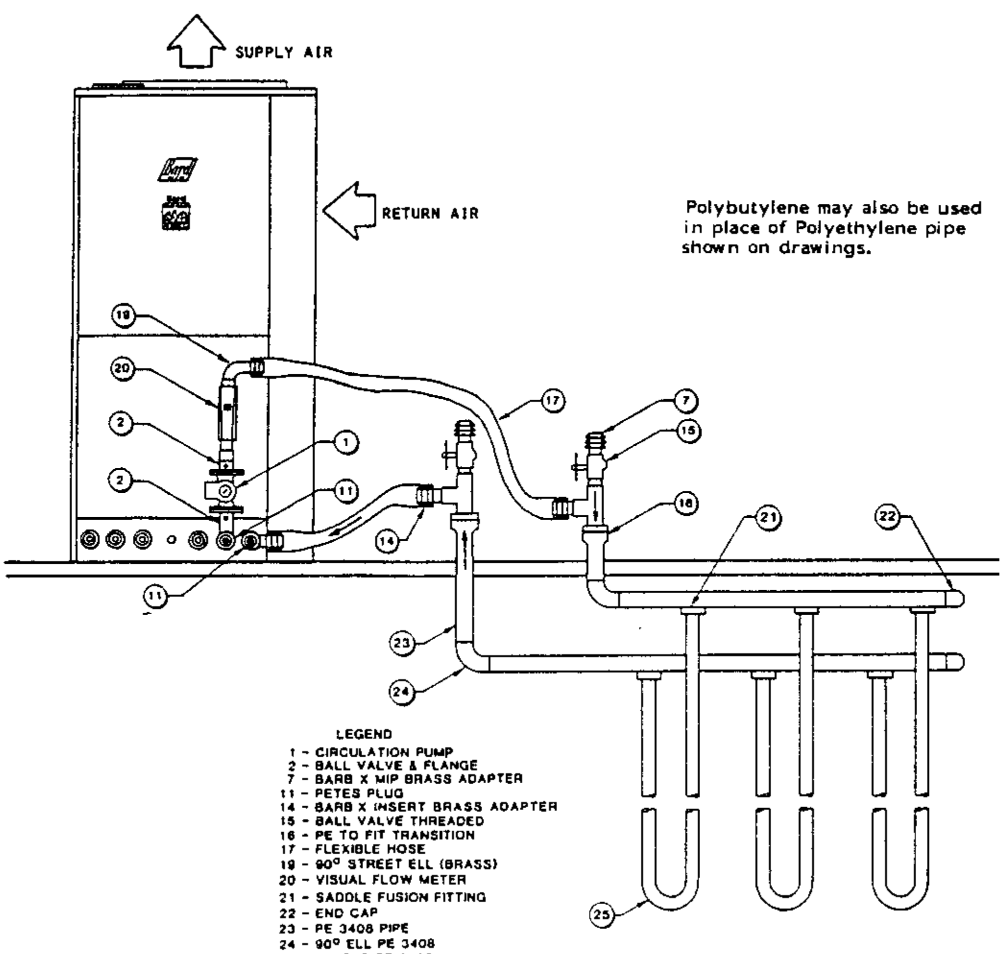
FIGURE 10A. Closed Loop Equipment Room Piping

Drawing compliments of Oklahoma State University

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



DETAIL A



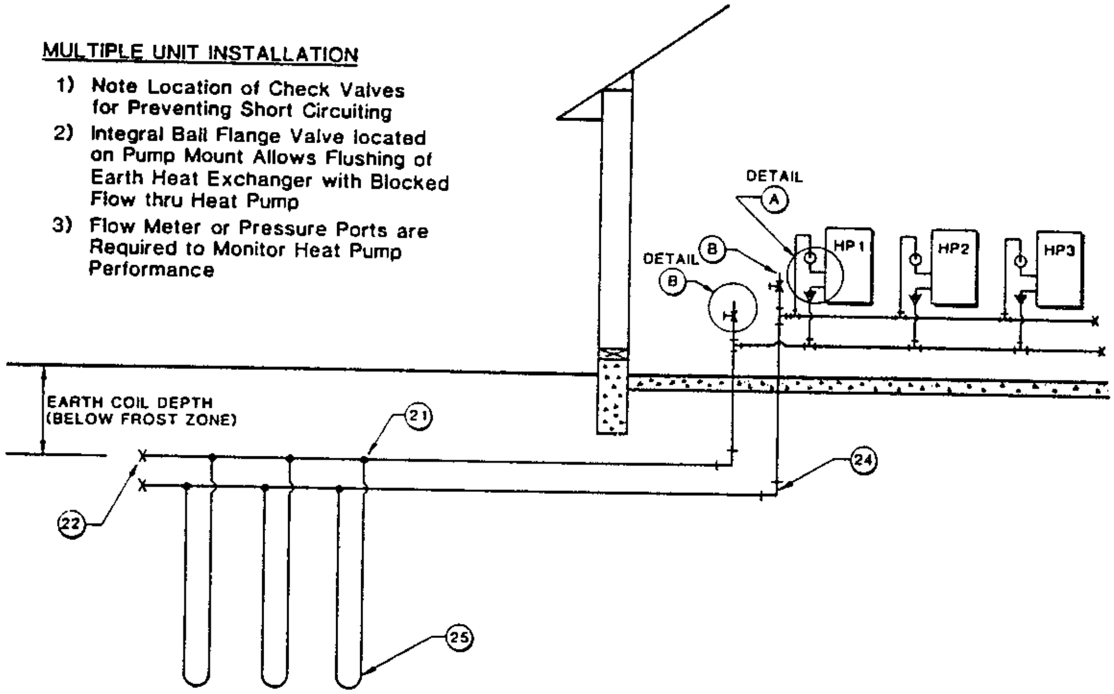
Polybutylene may also be used in place of Polyethylene pipe shown on drawings.

DETAIL B

Drawings courtesy of Oklahoma State University.

MULTIPLE UNIT INSTALLATION

1) Note Location of Check Valves for Preventing Short Circuiting
2) Integral Ball Flange Valve located on Pump Mount Allows Flushing of Earth Heat Exchanger with Blocked Flow thru Heat Pump
3) Flow Meter or Pressure Ports are Required to Monitor Heat Pump Performance



Drawings courtesy of Oklahoma State University.

The components for a circulation system are: (See Fig. 10B)

1. Flow Meter (Bard part number 8603-012) - on water-in side to monitor water flow.

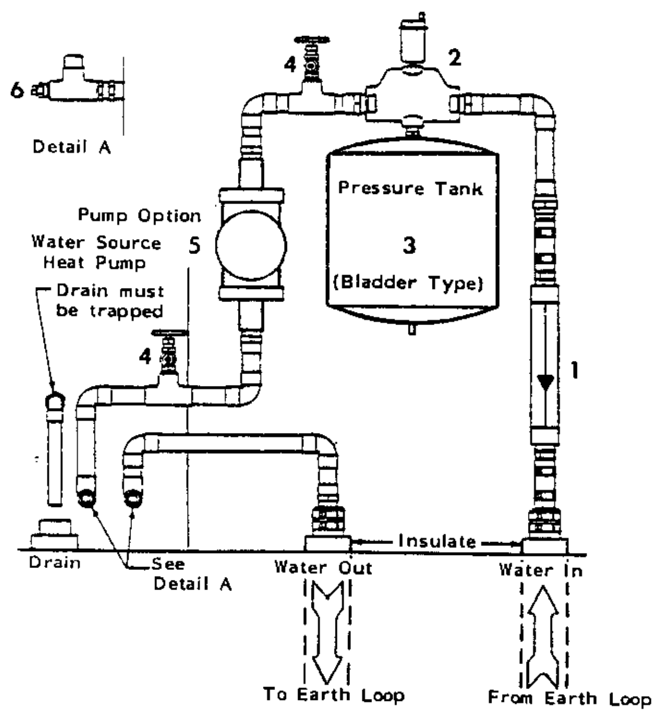
2. Air Vent/Air Purger - will help bleed off any air trapped in the system.

3. Pressure Tank (Ex Trol Model No. 60) - to allow for seasonal expansion and contraction and maintain system under pressure.

4. 2 Boiler Drains - to allow filling of system and antifreeze addition.

5. 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. Use stainless steel for calcium chloride antifreeze.

6. Brass Test Plugs - on both "water-in" and "water-out" lines to monitor water temperatures. Use one thermometer to monitor these temperatures. Using two different thermometers to measure the temperature differential can introduce large measurement errors.



NOTE: Always use 1" piping in equipment room regardless of size fittings on water source heat pump water coil. Also use PVC plastic pipe in equipment room when using calcium chloride antifreeze.

Drawing compliments of CEO Systems Inc.	FIGURE 10B. Alternate Closed Loop Equipment Room Piping

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
________	____________	X3	________	+	________	________
________	____________	X3	________	+	________	________
________	____________	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)		
________	(________	÷ 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 1.36 to obtain TOTAL HEAD LOSS FOR SYSTEM using propylene glycol 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.

TABLE 1A. Water Coil Pressure Drop					
Model	HWP30-HWPD30 WPV30A-WPVD30A	HWP36-HWPD36 WPV36A-WPVD36A	Model	WPV53A-WPVD53A	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	20% Calcium Chloride at 25°F	20% Propylene Glycol at 25°F
3/4" (0.86)	1.1	2.2	3.3
1" (1.077)	1.4	2.8	4.1
1-1/4" (1.380)	1.7	3.5	5.3
1-1/2" (1.676)	2.1	4.3	6.4
2" (2.095)	2.6	5.3	8.0

*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 propylene glycol antifreeze and water solution at 25°F, multiply the total earth loop head loss for water by 1.36.

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.

F1125-286

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).

26 - 96 (Circulating Pump Model) — 2 (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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VI. Freeze Protection

Antifreeze solutions 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.

When the local well water temperature is below 60°F, the water in the earth loop should be protected from freezing down to 18°F. The recommended antifreeze material is propylene glycol. 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

Where the ground water at 100 ft. depth is less than or equal to 66°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

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 mildly 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.

VII. 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 a flushing rig (Figure 13) 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.

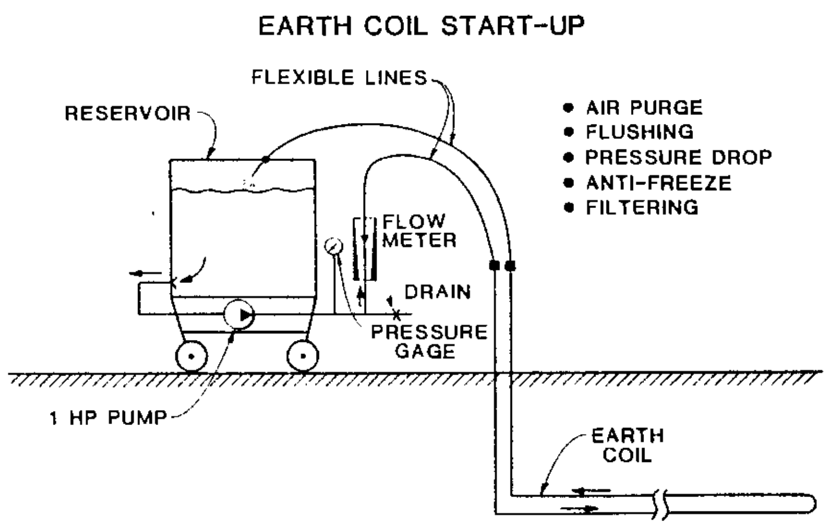
The flow rate should be the desired operating flow of the model of water source heat pump being used (see manufacturer's specifications). Water flow should not be less than that of the minimum flow rate required for the model of water source being used. If water flow is less than system calculations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

VIII. 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 13. PORTABLE RIG FOR FLUSHING EARTH COUPLED SYSTEMS



ACKNOWLEDGMENTS

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

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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

IX. 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:

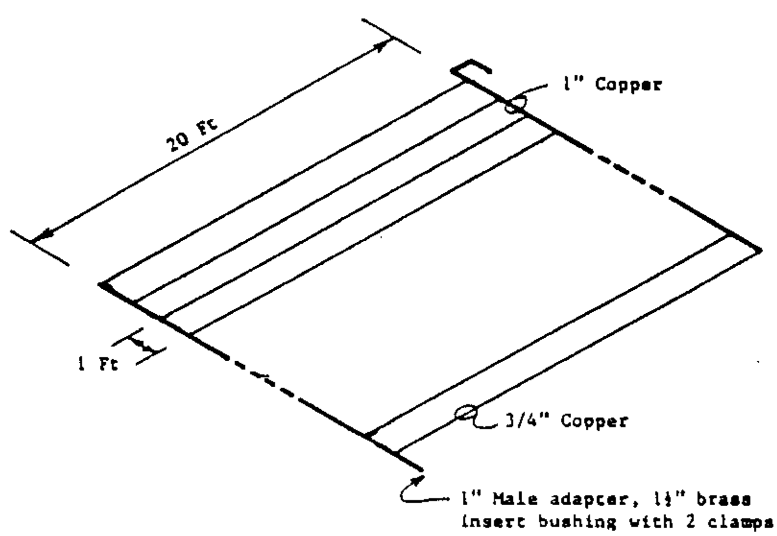
Bury the service lines a minimum of 4' deep or below the frost line, whichever is deeper, across the shore and keep them separated about 2' in the trench.

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

ANTIFREEZE:

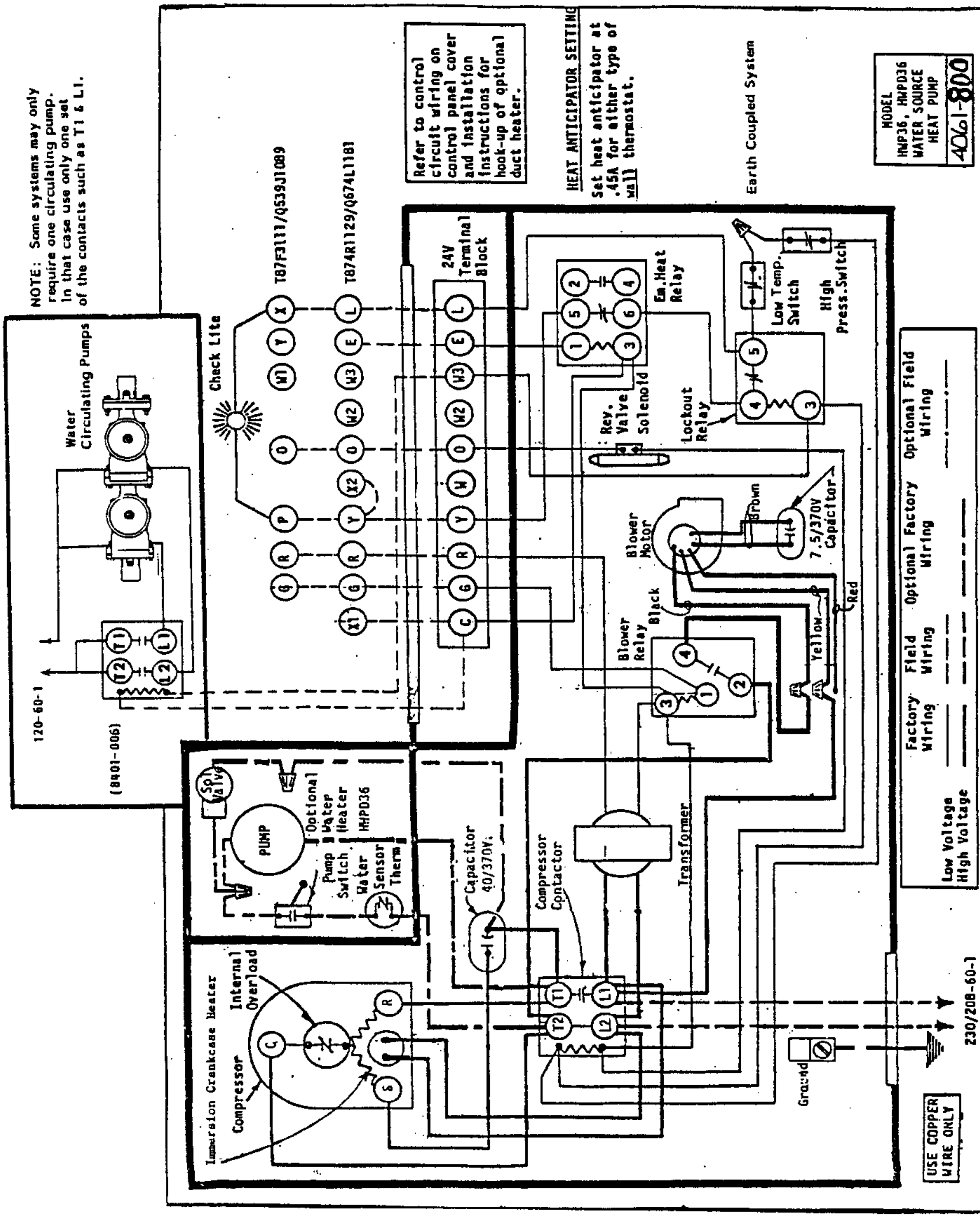
The equivalent of 25% propylene glycol is required.

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

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



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

BE 101685
****

BARD EARTH LOOP DESIGN

SEND TO: JOHN SMITH HEATING & COOLING DATE:10/16/85
WILLOW ST.
BRYAN, OHIO
CONTRACTOR OR JOB NAME OR NO.: BRYAN PROFFESSONAL 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 AVERAGE ROCK
SUMMER WET SOIL (SATURATED OR AVERAGE ROCK

****

BARD HEAT PUMP MODELS: WPV62A OR WPVD62A
WITH 2 KW OF RESISTANCE ELECTRIC HEAT
FOR 100% BACK UP RESISTANCE HEAT 15 KW IS REQUIRED

WSHP PERFORMANCE
UNIT COOLING CAP. @ 52 EARTH TEMPERATURE 61340 BTUH 12.33 EER
UNIT HEATING CAP. @ 52 EARTH TEMPERATURE 56360 BTUH 2.73 COP

APPROXIMATE WATER TEMP. (WARMEST) 89 F TO (COLDEST) 36
F ANTICIPATED IN THE SYSTEM DURING NORMAL ANNUAL OPERATION
UNIT COOLING CAP. @ 89 ENTERING WATER TEMP. 56070 BTUH
UNIT HEATING CAP. @ 36 ENTERING WATER TEMP. 47120 BTUH
UNIT OPERATING WATER TEMP. RANGE 25 TO 105 @ 8 GPM

****

DESIGN FOR VERTICAL EARTH LOOP

****

600 LENGTH OF BORE HOLE FOR UNIT ABOVE
1380 LENGTH OF PIPE FOR UNIT

ONE LOOP IN BORE HOLE
PE SCH 40 1-1/2 IN. PIPE 1.61 I.D.
TOTAL BORE LENGTH TO BE DRILLED IN MULTIPLE HOLES AT DEPTHS OF APPROXIMATELY 100 FT. HAVE BEEN ASSUMED.

APPROXIMATE 147 GAL OF WATER IN THE LOOP WITH 2 GALLONS ADDED FOR EQUIPMENT

****

TO DETERMINE CIRCULATION PUMP SIZE SEE SECTION V MANUAL 2100-099

TO DETERMINE NEED OF ANTI-FREEZE SEE SECTION VI MANUAL 2100-099
FOR 18F. FREEZE PROTECTION 32 GALLONS OF PROPLYENE GLYCOL OR 245 LBS OF CALCIUM CHORIDE IS REQURIED.

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.

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) __________ (Zip)

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

   __________ (City), __________ (State) __________ (Zip)

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. Type of System: Vertical Loop [ ] Horizontal Loop [ ] Type of Antifreeze to be used. None [ ] Calcium Chloride [ ] Propylene Glycol [ ]

7. Water Flow Thru Loop System: Series [ ] Parallel [ ]

8. Type of pipe to be used: __________ Pipe Nominal Size ______________ In.

   (See Table 1 back of the sheet)

9. Number of layers of pipe in trench or loops in bore hole: ______________

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- 1085

TABLE 1. Recommended Earthloop Pipes

Note: PE are polyethylene pipes
PB are polybuthylene pipes

	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 2. Geographical Locations of Input Data.

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