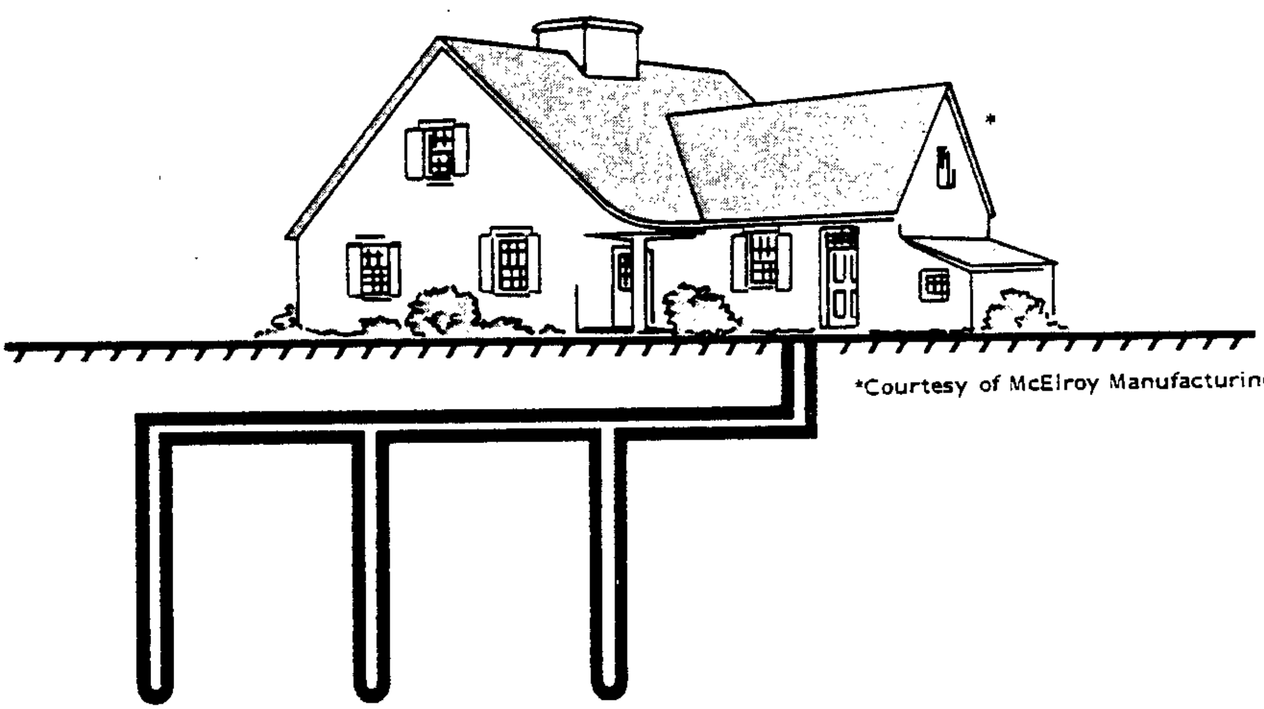
MANUAL 2100-099A

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

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.

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.

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 4-3/4" in diameter for 1-1/2" diameter pipe to a recommended depth of not more than 300 feet, over 300 feet it is too difficult to push the pipe to the bottom of borehole, (100- 200 feet is sufficient), and are set a minimum of 10 feet apart to avoid thermal overlap in the soil. 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. On a parallel system it is very important that all loops are equal in length to insure equal pressure drops.

The basic components of a vertical earth coupled system are detailed in Fig. 1 (next page). 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 aquifer in accordance with local health department regulations.

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

VERTICAL (SERIES) SYSTEM

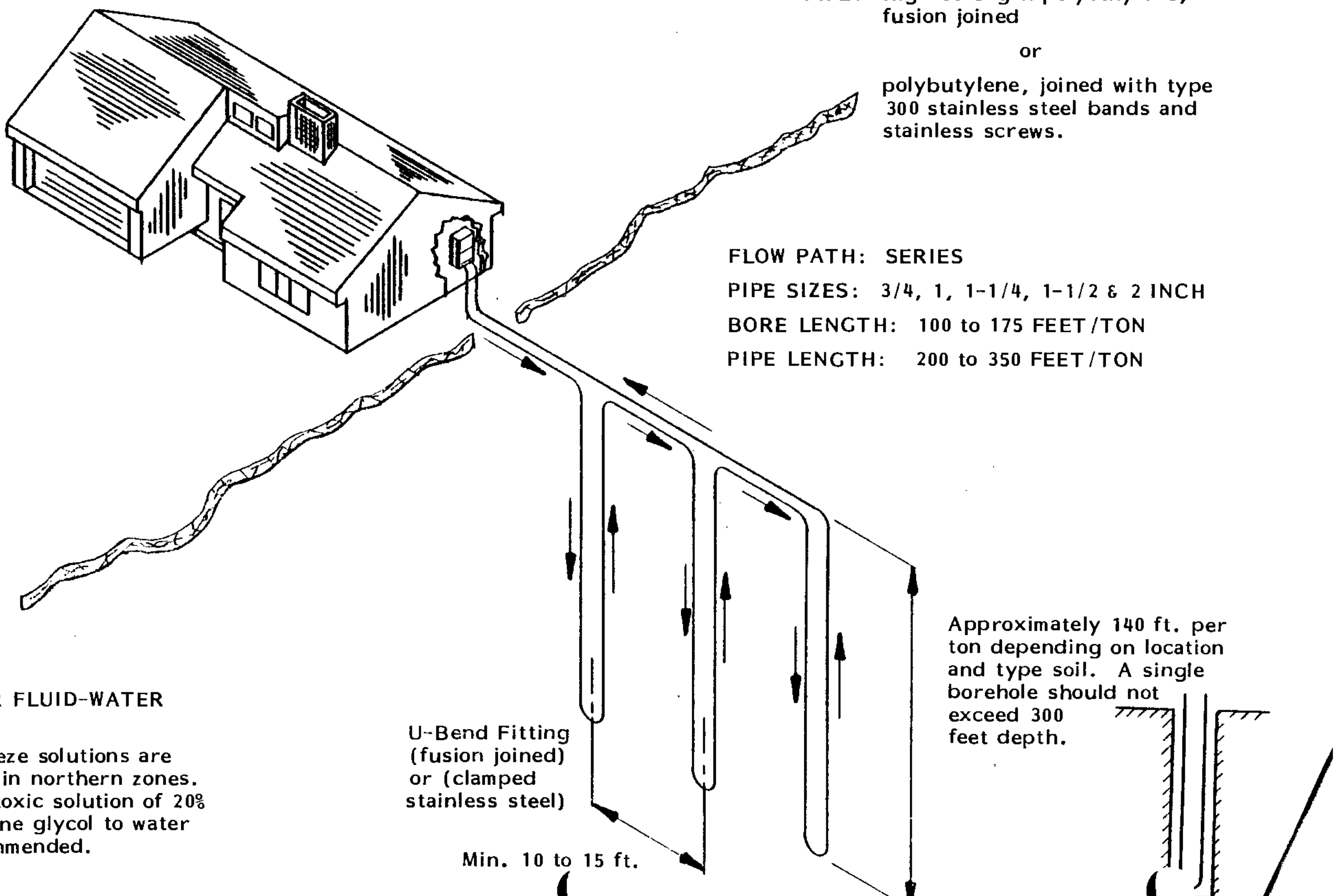


FIGURE 1.

VERTICAL (PARALLEL) SYSTEM

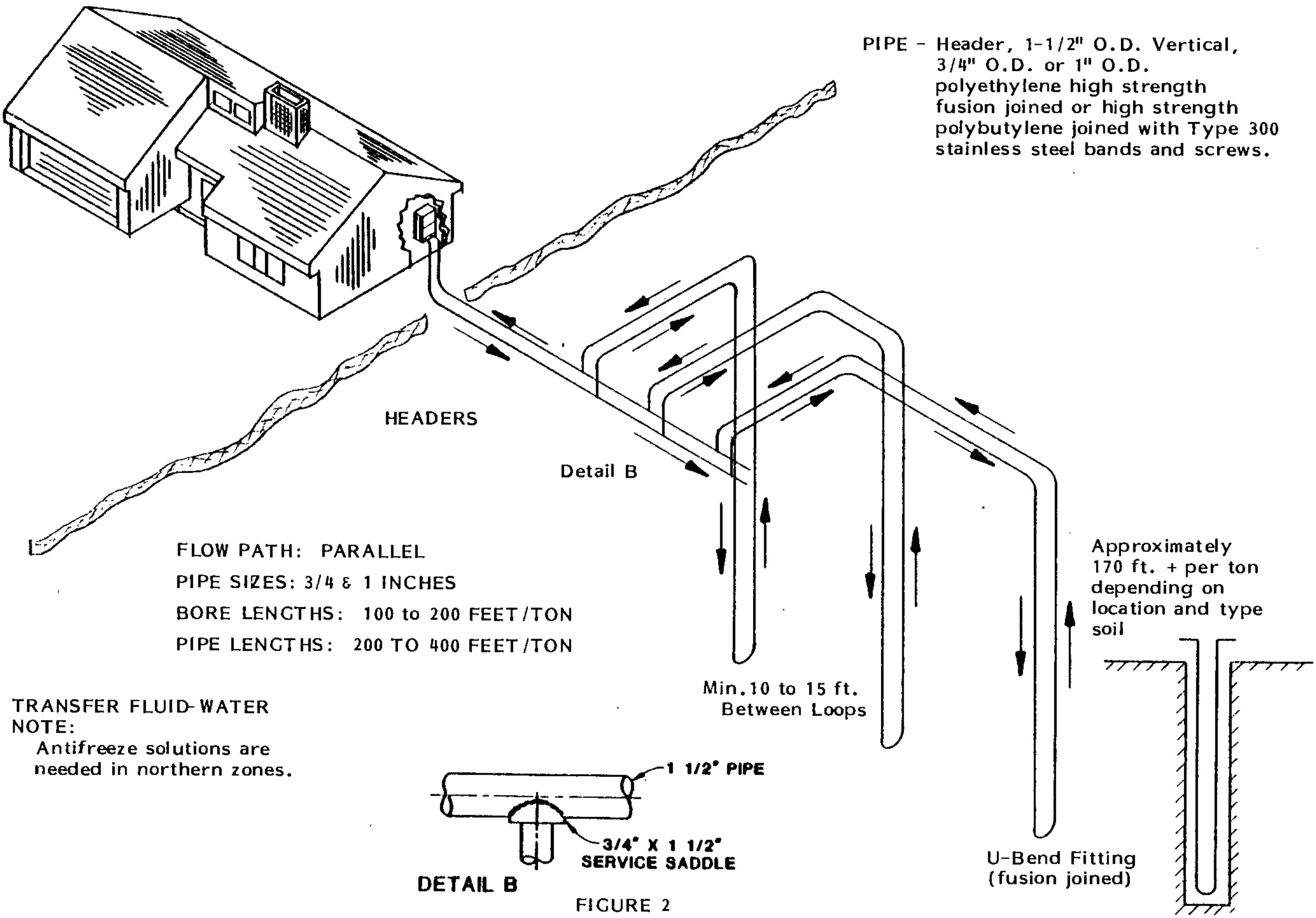


FIGURE 2

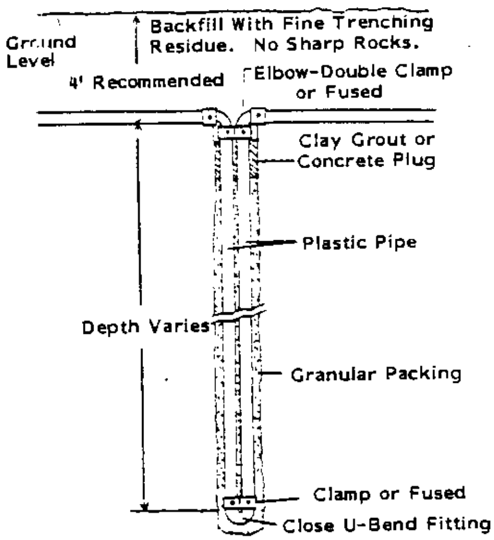
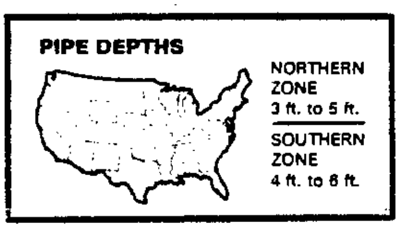


FIGURE 3. Vertical Earth Coupled Borehole & Piping

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 (20% by volume) Propylene Glycol.

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 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.

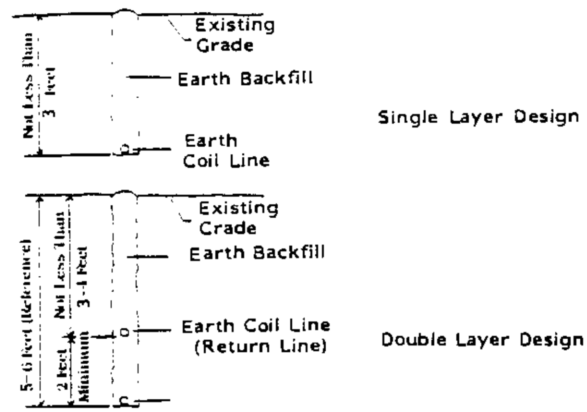
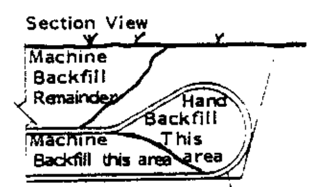


FIGURE 4. Horizontal Earth Coupled Pipe Separation in the Trench

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.

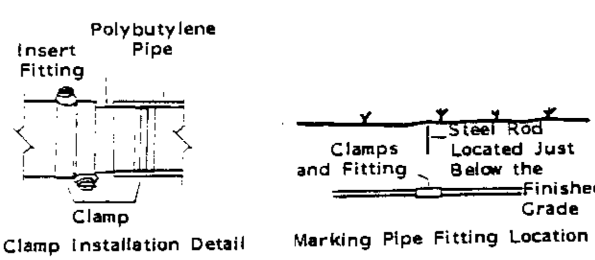
In those areas with dry climates and heavy clay soil, heat dissipated into the soil may reduce the thermal conductivity of the soil significantly. In such cases, the designer may specify additional feet of pipe per ton of capacity. A few inches of sand may also be put in with the pipe, or a drip irrigation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

FIGURE 5.



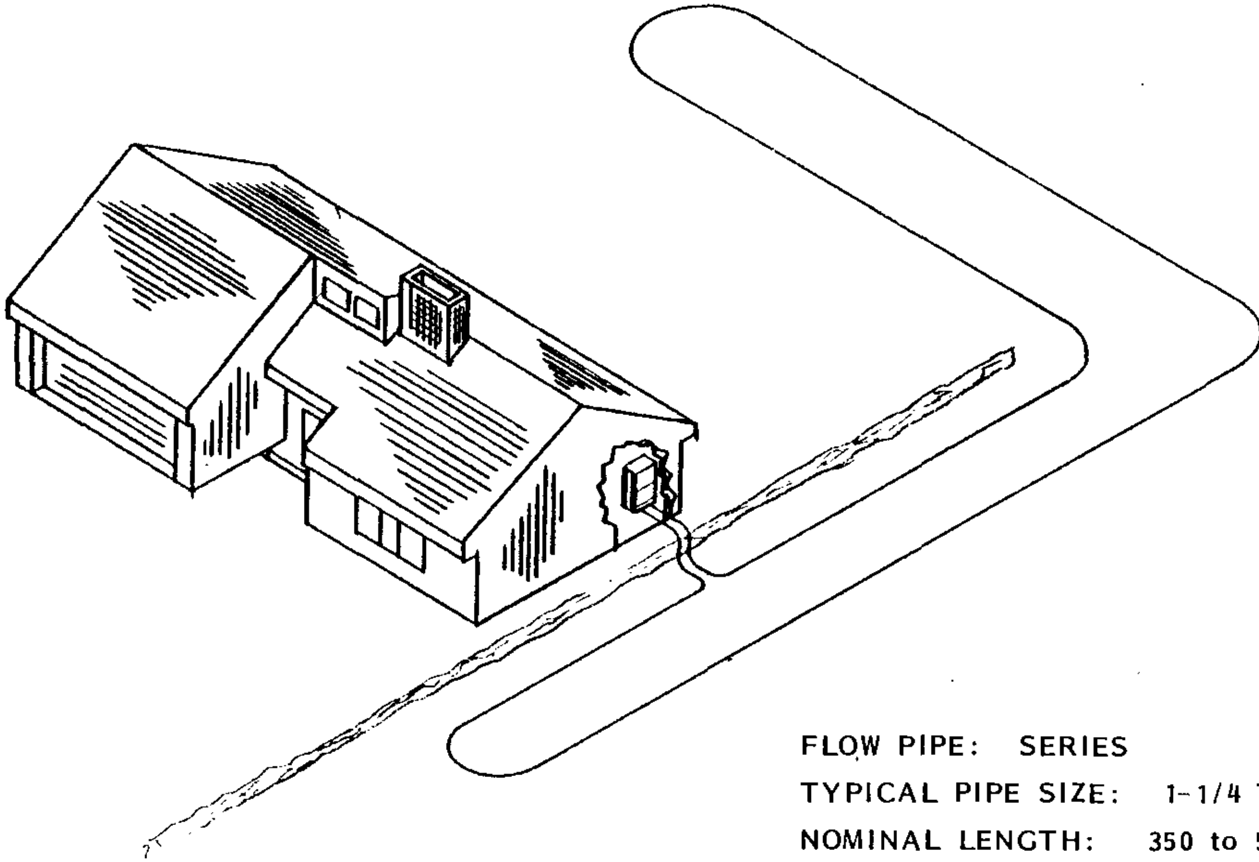
Bend pipe to position shown using extreme care to avoid kinking.

FIGURE 6.



HORIZONTAL ERIES) SYSTEM

ONE PIPE IN TRENCH



PIPE: High strength polyethylene, fusion joined

or

polybutylene, joined with Type 300 stainless steel bands and screws.

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 20% by volume propylene glycol to water solution.

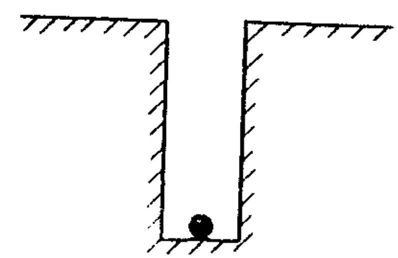


FIGURE 7.

HORIZONTAL (SERIES) SYSTEM

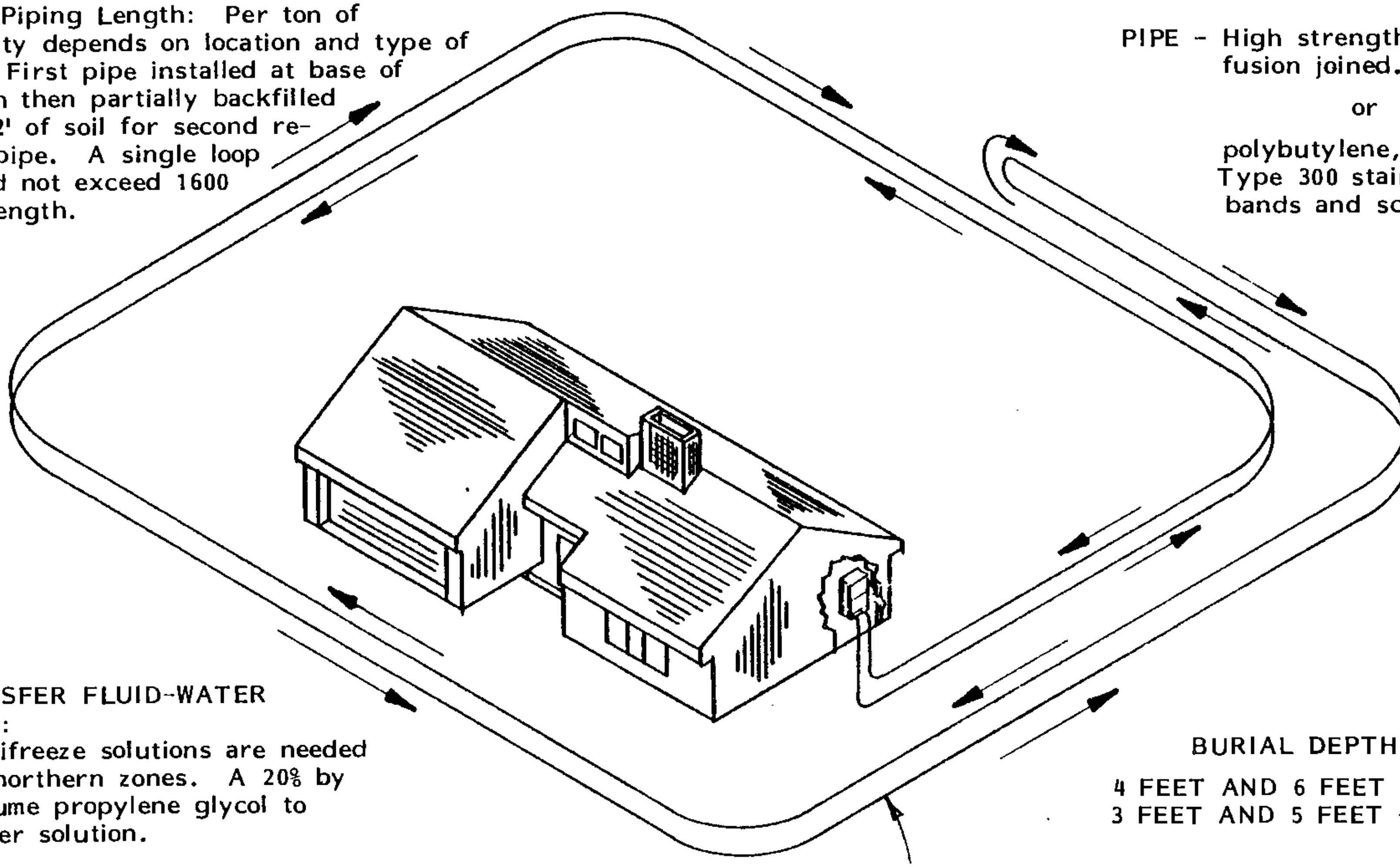
TWO PIPES IN SAME TRENCH

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 1600 feet length.

PIPE - High strength polyethylene, fusion joined.

or

polybutylene, joined with Type 300 stainless steel bands and screws.



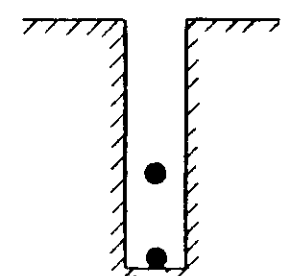
TRANSFER FLUID-WATER

NOTE:

Antifreeze solutions are needed in northern zones. A 20% 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

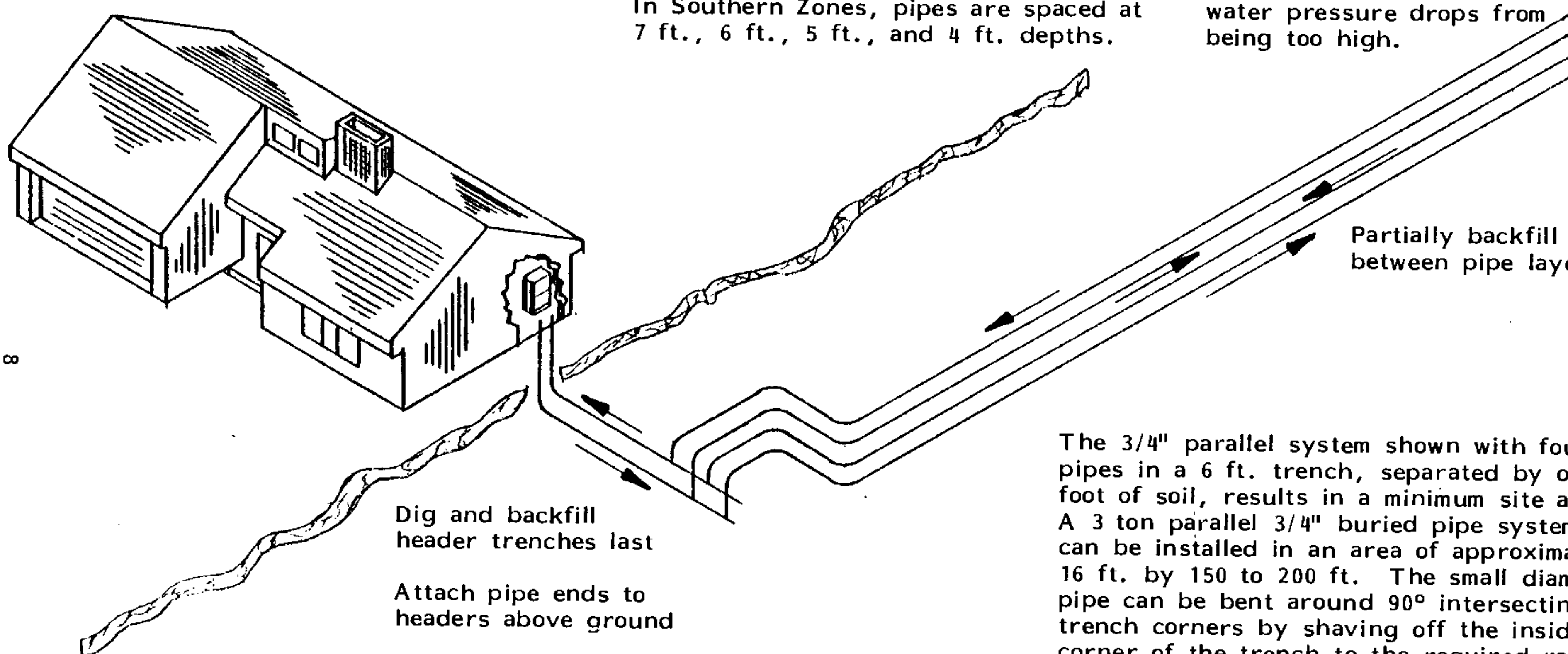
FIGURE

HORIZONTAL MULTI-LEVEL (PARALLEL) SYSTEM

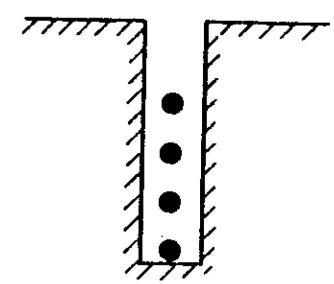
Be sure the buried pipe system is properly designed for the heat pump load, soil type, climate, the pipe used, and the operating cycle pattern.

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 1600 feet length
2. PIPING MATERIAL	SDR-15 IPS polybutylene or high density schedule 40 polyethylene	SDR-15 IPS polybutylene or high density schedule 40 polyethylene
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 1600 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 IPS polybutylene or high density polyethylene buried below the frost line or to minimum 4 feet deep	If earth coil line(s) cannot connect directly to heat pump, use IPS polybutylene or high density polyethylene service pipe buried below the frost line or to minimum 4 feet deep
6. PIPE FITTINGS	IPS 304 stainless steel, brass or nylon— double clamp all nylon fittings	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

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 will require 480 ft. of pipe 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 polybuthlene pipe is used.

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 1½" Sch 40 polyethylene pipe required for cooling.

$\frac{38,900 \text{ Btuh}}{12,000}$ = 3.24 x 400 ft = 1297 feet of 1½" 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. F1115-284 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')			120' (240')		
3/4"SDR-11 3408 Polyethylene	170' (340')			145' (290')		

*Capacity of unit at local ground water temperature. (Table practical for 50°F to 70°F ground water temperature)

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

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. The circulation system should consist of the following items to insure proper fluid flow through system (GPM) while the water source heat pump is operating.

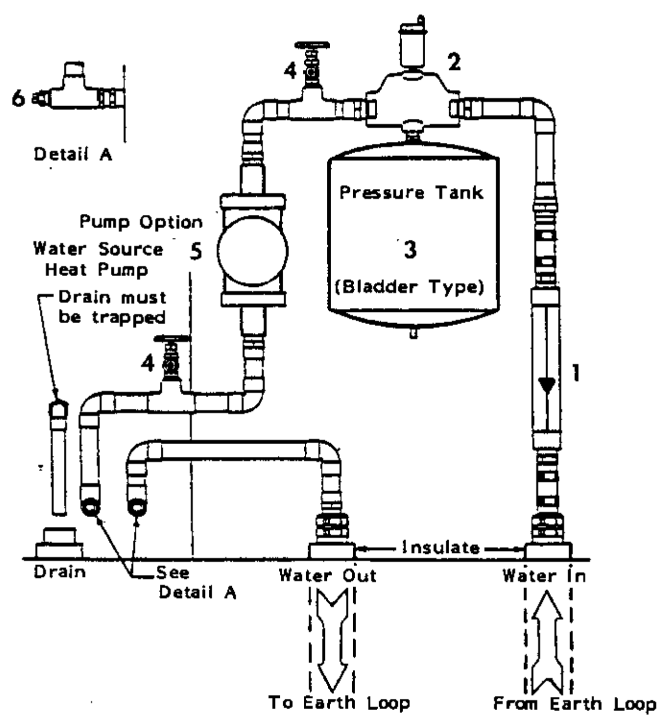
The components for a circulation system are: (See Fig. 10)

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.
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.

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 vents for start-up and running.
3. Providing for flow monitoring.
4. Positive pressure control and limiting.
5. Antifreeze charging capability.

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.



NOTE: Always use 1" piping in equipment room regardless of size fittings on water source heat pump water coil. Also never use PVC plastic pipe in any earth coupled system!

Drawing compliments of GEO Systems Inc.	FIGURE 10. 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 1.3 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 1. Water Coil Head Loss In Feet of Head and G.P.M. Required		
Heat Pump Model	Feet of Head	G.P.M. Flow Rate
HWP30 or HWPD30	4.6	4
HWP36 or HWPD36	4.6	5
WPV30A or WPVD30A	4.6	4
WPV36A or WPVD36A	4.6	5
WPV53A or WPVD53A	5.8	6
WPV62A or WPVD62A	5.8	8

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
PUMP OUTPUT (FEET OF HEAD) @ G.P.M. @ TOP OF COLUMN	20-42	1	11.5	11	--	--
	26-64	1	18.8	18	17.5	16
	26-64	2	37.6	36	35.0	32
	40-75	1	23.8	23.5	23	22.5
	40-75	2	47.6	47	46	43
	26-96	1	27.5	27	26	23.5
	26-96	2	55.0	54	52	47

*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	G.P.M. Flow Rate									
	1	1½	2	2½	3	3½	4	5	6	8
Connection Hose 1"	*	*	*	*	.67	.89	1.14	1.73	2.42	1.43
Copper 1"	*	*	*	*	.86	*	1.5	1.9	2.7	4.5
Polybutylene 1" SDR 13.5					1.05	*	1.79	2.71	3:80	6.48
" 1½" SDR 15	*	*	*	*	.074	*	.126	.191	.267	.356
" 1½" SDR 17	*	*	*	*	.065	*	.110	.166	.233	.397
" 2" SDR 15 & 19	*	*	*	*	.022	*	.037	.057	.079	.135
" 2" SDR 17	*	*	*	*	.021	*	.037	.55	.078	.133
Polyethylene 3/4" SDR -11	.23	.62	1.02	1.5	2.08	2.7	3.37	5.04	6.93	11.4
" 1" SDR -11	.21	.35	.51	.72	.92	1.18	1.73	1.78	2.38	3.93
" 1½" SCH. 40	*	*	*	*	*	*	.162	.254	.347	.578
" 2" SCH. 40	*	*	*	*	*	*	.046	.069	.092	.162

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 35°F, multiply the total earth loop head loss for water by 1.3

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" SDR15 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 10.

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" PE	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" PE	(1200	÷ 100) x	.191	=	2.29 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 8.412 ft. hd.

6. Multiply SUBTOTAL by 1.3 to obtain TOTAL HEAD LOSS FOR SYSTEM using propylene glycol antifreeze solution.

   TOTAL HEAD LOSS 10.9 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: GRUNDFOS 20-42   No. Pumps: 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 WPV53 water source heat pump.

C. Heat pump water flow requirements are 6 GPM with a 5.8 ft.hd. loss (see Table 1).

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 air vent system and connections to coil of water source heat pump 1" copper.

F. Three loops (4 tubes) 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.

$$6 \text{ GPM} \div 3 = 2 \text{ GPM Per Loop}$$

I. 240 ft. of 1-1/2" SCH 40 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) — 5.8 ft. hd.

3. Continue across Table 1 to find GPM flow required for this heat pump. 6 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
3/4" PE	4	x3	12	+	373	385
1½" PE	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	÷ 100)	x	Piping** Head Loss (Table 2)	=		
1" HOSE	(25	÷ 100)	x	2.42	=	.605	ft. hd.
1" COPPER	(52	÷ 100)	x	2.7	=	1.40	ft. hd.
3/4" PE	(385	÷ 100)	x	1.02	=	3.93	ft. hd.
1½" PE	(264	÷ 100)	x	.347	=	.92	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 12.66 ft. hd.

6. Multiply SUBTOTAL by 1.3 to obtain TOTAL HEAD LOSS FOR SYSTEM using propylene glycol antifreeze solution.

TOTAL HEAD LOSS 16.46 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
26-64	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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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 10°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

Nominal Pipe Size	Pipe Material		
	Copper	Polybutylene	Polyethylene
3/4"	--	2.77	2.77
1"	4.3	4.5	4.5
1½"	--	10.6	10.6
2"	--	17.4	17.4
1¼"	--	7.7	7.7

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

PROPYLENE GLYCOL

A 25 percent by volume solution of propylene glycol is required for 10°F freeze protection. The percentage of antifreeze depends on geographic location.

Example: For 100 gallons of water in system, 25 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 an isolation 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 percent 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 percent pure calcium chloride required for 10°F freeze protection.

VII. System Start Up

Once the ground watersource 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. 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 ten 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 fifteen 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 fifteen minutes, then proceed to locate the source of the leakage. Remember for proper system operation, there can be no leakage in the water loop.

AIR VENTING -- Air vent is installed in front of the circulator at the highest point in the system. Unscrew the cap on top of the air vent two or three turns to allow air to vent.

REMEMBER: The air vent does not eliminate the need for thorough power flushing of the earth coupling before start up.

EXPANSION TANK -- The easiest way to accommodate the seasonal expansion and contraction of the earth coil is to install an expansion tank into the pipe system. The expansion tank allows for expansion of transfer fluid in the cooling mode when it heats up.

Systems with an expansion tank are completely separated from the household water supply.

In systems with expansion tanks, the system should be pressurized to about 30-50 PSI initially. Connect a hose from a household tap to the boiler drain closest to the expansion tank. The pressure can be checked at the air vent with a tire pressure gauge. Systems with a make-up water connection will automatically be pressurized by the regulator/relief valve.

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.

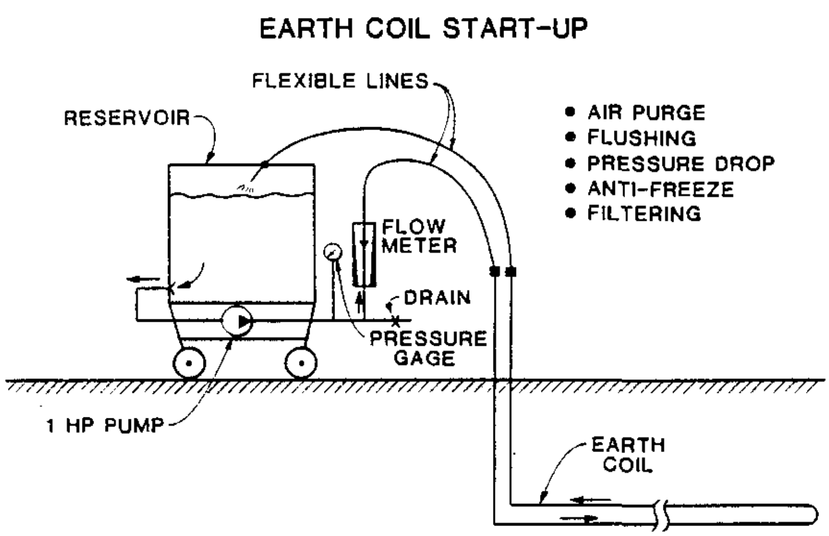
The flow rate should be adjusted to the desired operating flow of the model of water source heat pump being used (see manufacturer's specifications) by using one of the isolation flanges. Water flow should not be less than that of the minimum flow rate required for the model of water source being used. 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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5. Eitelman, L. 1983, Letter "Pipe Pressure Loss Tables for Polyethylene Pipe," McElroy Manufacturing, Inc., Tulsa, OK.

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IX. Closed Loop Systems Suspended in Ponds and Lakes

There have been a number of successful loop installations by suspending 1 inch or larger diameter copper pipe coils in lakes or ponds. There is some disagreement as to the footage and size of copper pipe as well as pond size.

The pond should be approximately 2 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 copper loop should be at least 150 feet of length per ton of ground water heat pump, a minimum of 1 inch diameter. The coil should be installed vertically off of the lake or pond bottom and should be under several feet of water. CAUTION: If the coil should become silted over, performance will suffer considerably and will operate as a conventional closed loop buried in soil. NOTE: The copper tubing should be designed for outdoor use.

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.

PIPE - LAKE EXCHANGER:

Use 1" TYPE L copper for the lake exchanger. 150 ft. plus of length per ton of ground water heat pump capacity.

CONNECTIONS:

Connect the lake exchanger to the 2" or 1-1/2" polybutylene or polyethylene service lines by using a 2" or 1-1/2" brass bushing and a copper male adapter. DO NOT thread plastic into metal fittings to make the connection.

PLACEMENT:

Place the coil on the bottom of the lake so that a minimum of it is in contact with the lake bottom. If possible, stand the coil vertically off the lake bottom. The coil must be under several feet of water. A greater depth may be required in colder climates.

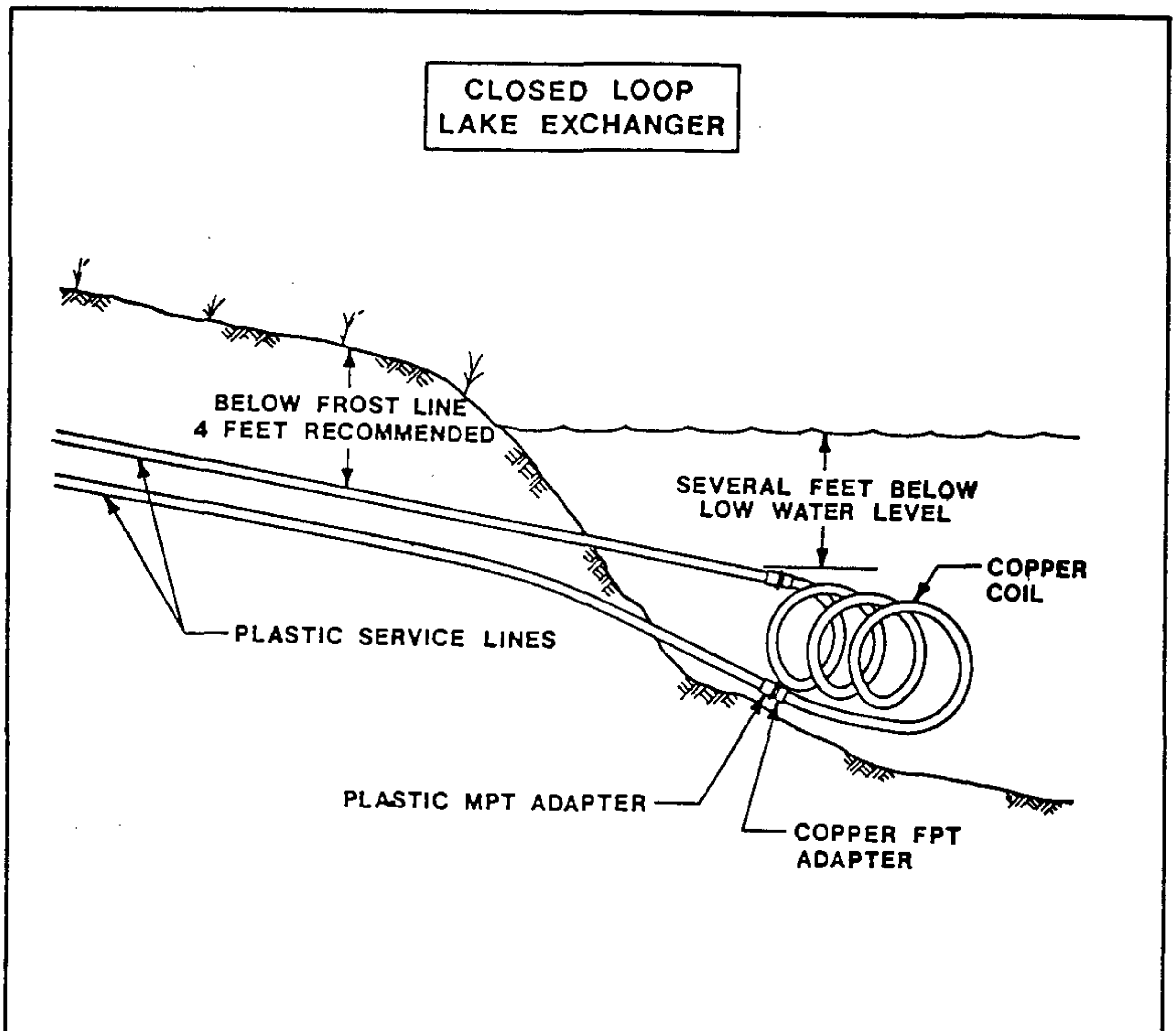
SERVICE LINES:

Bury the service lines a minimum of 4' deep across the shore and keep them separated a minimum of 2' in the trench.

Follow the horizontal coil installation instructions for the service lines to the lake exchanger.

PARALLEL LAKE EXCHANGERS:

Larger systems will require lake coils run in parallel.



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

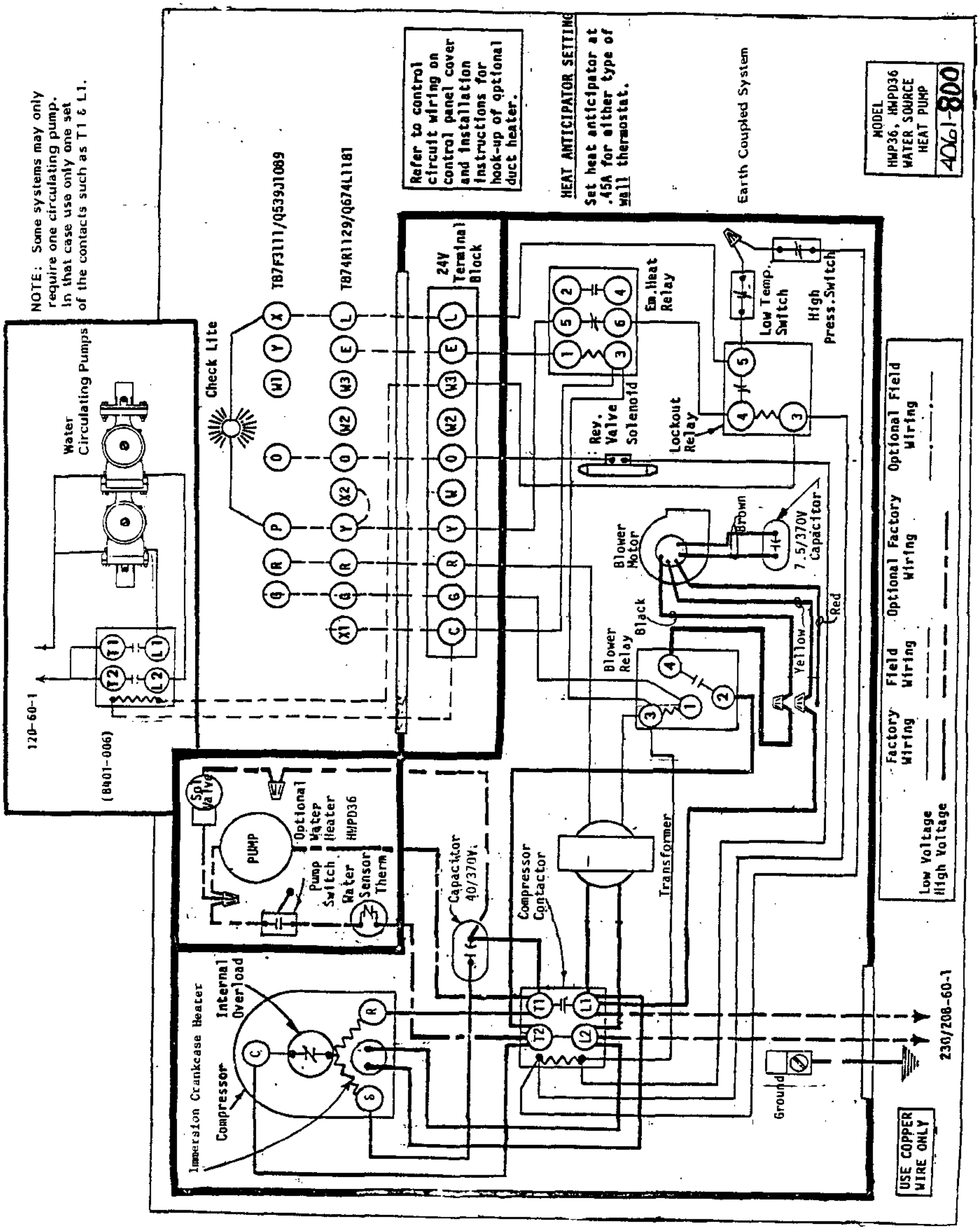
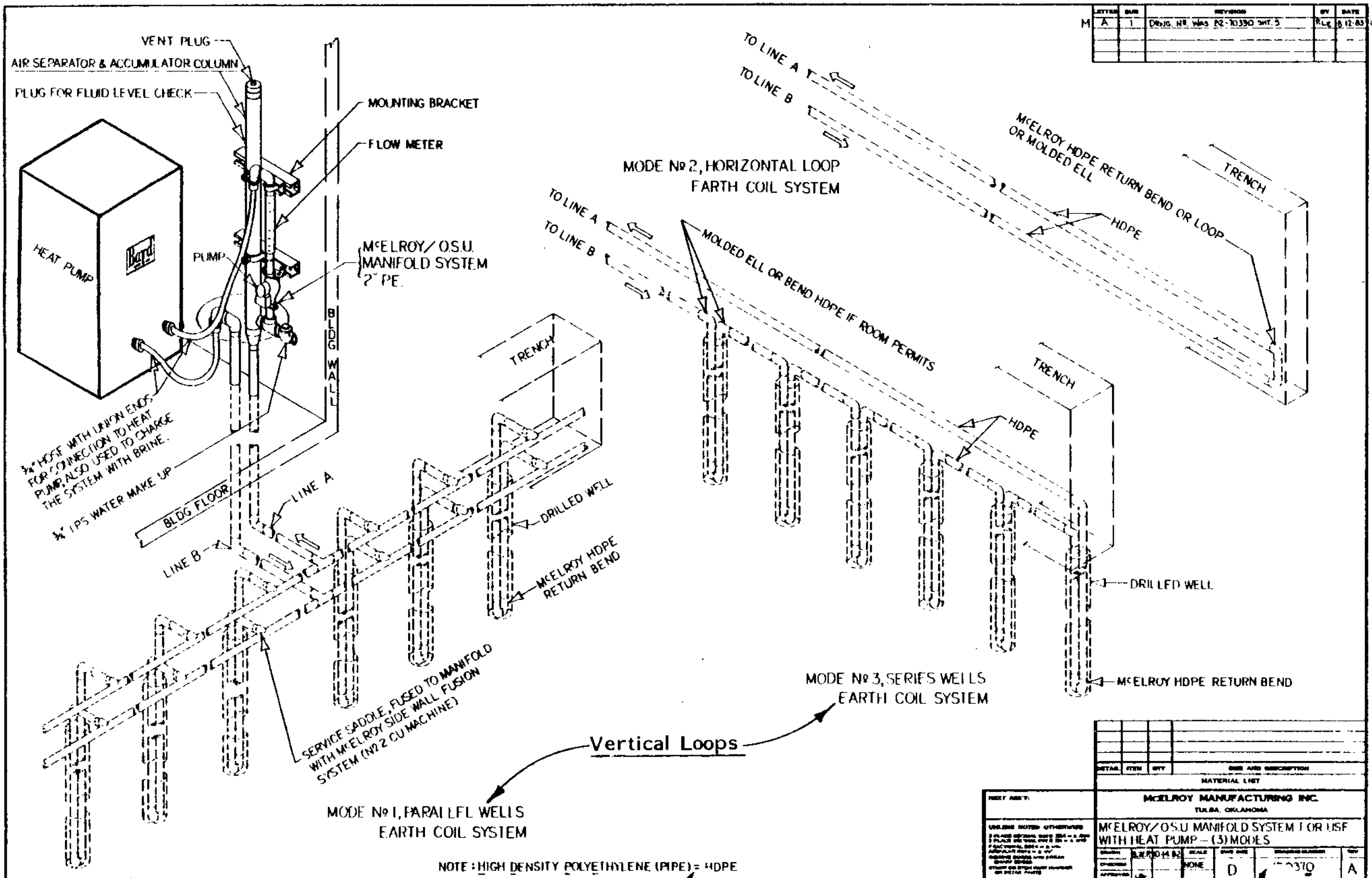


FIGURE 14. TYPICAL EARTH COILS

Courtesy of McElroy Manufacturing



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

SAMPLE OF COMPUTER PRINTOUT

```
CUT HERE---------------------------------------

****************************************************
            BARD EARTH LOOP DESIGN

FOR       FRED PAEPKE        DATE:4/23/84
          BOX 472
          BRYAN,OHIO
JOB GEOGRAPHIC LOCATION:BRYAN,OHIO
****************************************************
            BUILDING LOAD
BUILDING COOLING GAIN  20000  BTUH
BUILDING HEATING LOSS  36000  BTUH
LOCAL GROUND WATER TEMPERATURE  52  F
EARTH TEMP. SEPT 1ST  63  @ 5  FT. DEPTH
EARTH TEMP. MAR  1ST  41  @ 5  FT. DEPTH
LOCAL SOIL CONDITIONS: DAMP-HEAVY SOIL(CLAY)
                 --------------------------
            BARD HEAT PUMP MODEL
HWP36, HWPD36, WPV36A, OR WPVD36A
HP PERFORMANCE:
UNIT COOLING CAP. @  52  GROUND WATER 37740  BTUH  14.13  EER
UNIT HEATING CAP. @  52  GROUND WATER 35400  BTUH  3.43  COP
UNIT OPERATING WATER TEMP. RANGE  25  TO  105  @  5 GPM
                 --------------------------
APPROXIMATE  WARMEST ENTERING WATER TEMP. 65
UNIT COOLING CAP. @  65  WATER TEMP.  36050  BTUH
APPROXIMATE  COLDEST ENTERING WATER TEMP. 31
UNIT HEATING CAP. @  31  WATER TEMP.  25950  BTUH
****************************************************

      DESIGN FOR HORIZONTAL EARTH LOOP
****************************************************
 1142 LENGTH OF PIPE FOR SYSTEM
 1142 LENGTH OF TRENCH FOR SYSTEM
1 PIPE IN TRENCH @ AVE 5  FT. DEPTH
1 1/2 POLYETHYLENE PIPE IN DAMP-HEAVY SO
IL(CLAY)

****************************************************

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

TO DETERMINE NEED OF ANTI-FREEZE SEE SECTION VI MANUAL 2100-099

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 THE TECHNOLOGY ARE MADE.


CUT HERE---------------------------------------
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EARTH COUPLED LOOP SYSTEM DESIGN

1. For: (Contractor) ______________________________

   (Address) ______________________________

   (City & State) ______________________ (Zip) __________

   (Telephone ______________________________

2. Geographical location of installation: ______________ , ______________
   (City) (State)

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

   Heating load: ______________________ Btu/Hour

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 ______________

7. Type of pipe to be used: ______________ Pipe Dia: ______________ In.I.D.

8. Proposed length of pipe: ______________________________

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

   ____

10. Description and type of local soil at depth 1 to 6 foot depth. ______________

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

   b. DAMP-LIGHT SOIL (SAND OR GRAVEL) or DRY-HEAVY SOIL (CLAY) - grass turns brown, weeds stay green

   c. DAMP-HEAVY SOIL (CLAY) - grass & weeds stay green all summer

   d. WET-SOIL - swamp, marsh bottoms, etc.

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

F1115-284