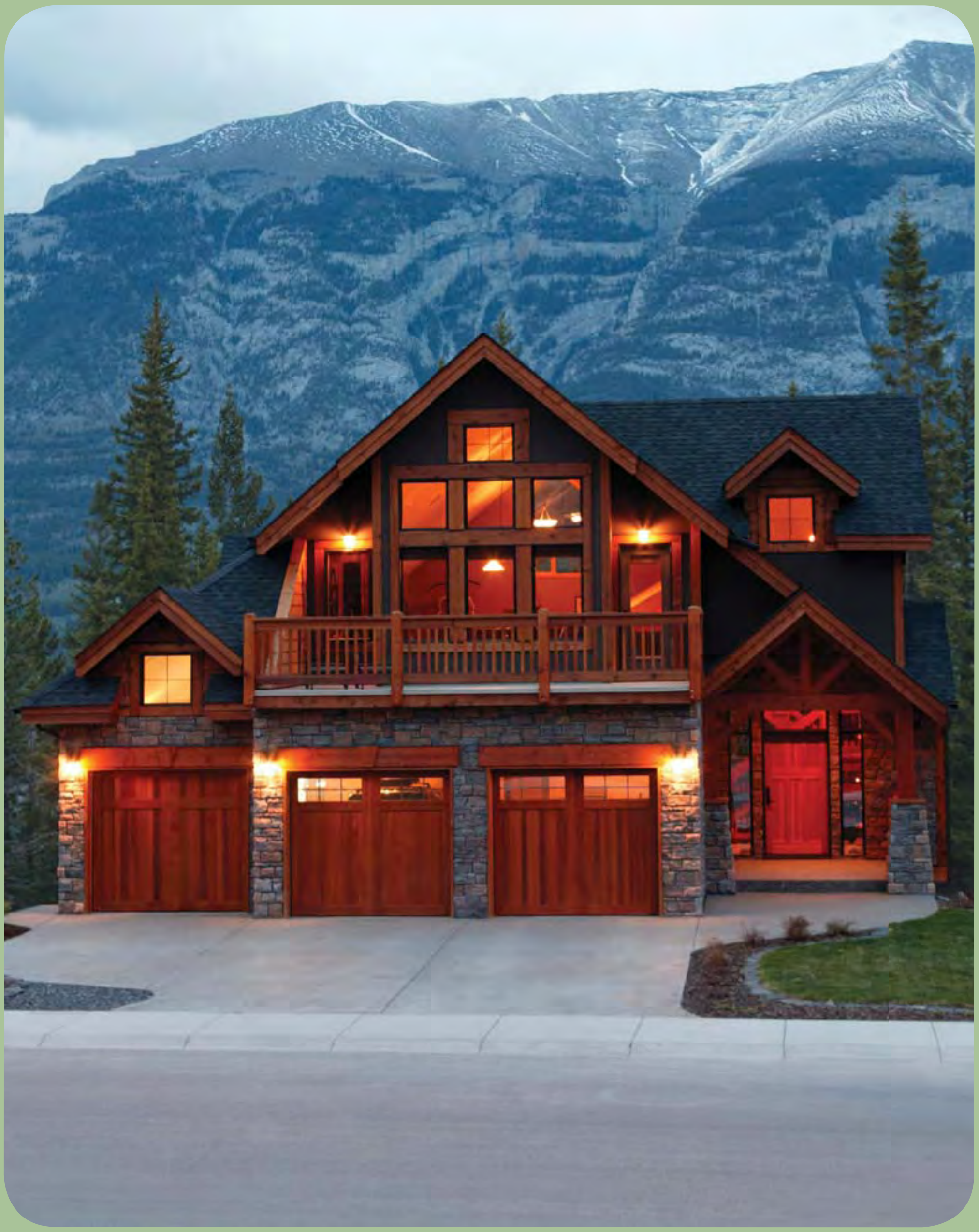
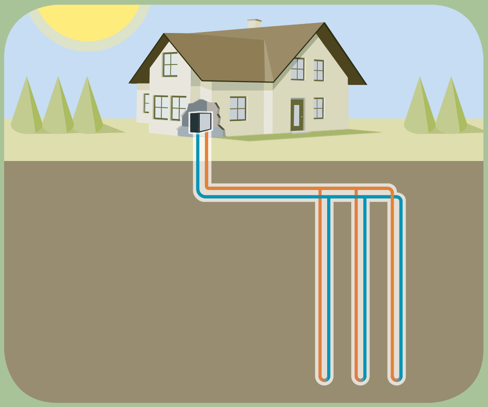
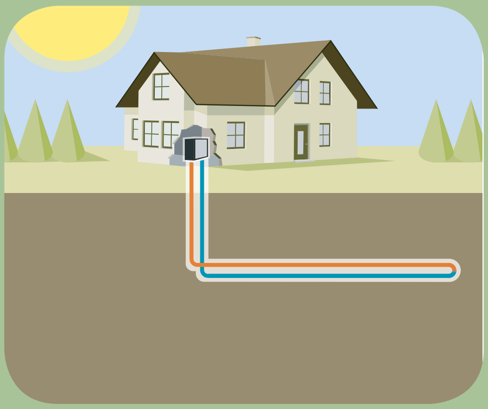





WATER-TO-WATER SYSTEM DESIGN GUIDE

TRANQUILITY WATER-TO-WATER SYSTEMS

CLIMATEMASTER® GEOTHERMAL HEAT PUMP SYSTEMS

SMART | RESPONSIBLE | COMFORTABLE

Table of Contents

Part I: System Overview

WHY HYDRONICS?

According to Webster's Dictionary, hydronic heating is "a system of heating or cooling that involves the transfer of heat by a circulating fluid (as water or vapor) in a closed system of pipes." Because water is the most efficient way to move thermal energy, a hydronic system requires much less transport energy in the process and takes up far less space. For example, a 1" [25mm] diameter pipe can carry as much heat as a 10" x 19" [254 x 483 mm] rectangular duct carrying hot air at 130°F [54°C]. In addition, the mass of the ground loop [geothermal piping] and/or radiant floor piping provides thermal storage, allowing the system to virtually ignore large changes in outdoor temperatures. There is no storage benefit in most HVAC systems.

Figure 1-1: Thermal Energy Comparison

Hydronics systems, especially systems using radiant floor heating, provide lower operating costs than forced air systems. More Watts are used to circulate air through duct work than to circulate water through piping. For example, a typical 80% efficient natural gas residential furnace with an output capacity of 80,000 Btuh [23.4 kW] uses an 850 Watt fan motor. For every Watt used to power the fan, 94 Btuh [28 Watts] of heat is delivered via the forced air duct work. If a boiler or heat pump is used to generate heat, but the heat is delivered through a radiant floor system, the pumping power would typically be around 300-400 Watts, or 40% to 50% of the air delivery system Watts, resulting in around 230 Btuh [67 Watts] of heat per Watt of pump power.

Radiant floor systems provide heat at occupant level. Hot air rises to the ceiling (forced air systems), but heat always moves to cold (radiant system). Therefore, a warm floor will heat objects in the space, not the air directly, resulting in a space that feels warmer at lower thermostat settings. Occupants will feel more comfortable, and when the thermostat setting is lowered, the heat loss decreases, resulting in better comfort at lower operating costs.

Hydronic heating systems can be combined with boilers or heat pumps to generate hot water for radiant floor systems, baseboard convectors, or radiators. Heat pumps are inherently more efficient than fossil fuel (natural gas, oil, or propane) heating systems, and geothermal heat pumps are more efficient than air-source heat pumps, due to the mild heat source of the ground (as compared to outdoor air temperatures). Water-to-air heat pumps heat the air, and require a fan to circulate air through duct work. Water-to-water heat pumps heat water, allowing the design of a hydronic heating system with the benefits of more efficient energy distribution, lower operating costs and better comfort.

Fossil fuel furnaces and boilers are always less than 100% efficient. Even the best systems are 95-96% efficient. Geothermal heat pumps typically deliver 4 to 6 Watts of heat for every Watt of energy consumed to run the compressor and ground loop pump(s). In other words, for each Watt of energy used, 3 to 5 Watts of free energy from the ground is added to provide 4 to 6 Watts of energy to heat the space. The use of a high efficiency water-to-water heat pump and a hydronic heating system is an unbeatable combination.

Water-to-Water Heat Pumps

ClimateMaster water-to-water heat pumps offer high efficiencies, advanced features, extremely quiet operation and application flexibility. As ClimateMaster's most adaptable products, water-to-water heat pumps may be used for radiant floor heating, snow/ice melt, domestic hot water heating, and many other hydronic heating applications.

ClimateMaster's exclusive double isolation compressor mounting system provides the quietest water-to-water units on the market. Compressors are mounted on rubber-grommets or vibration isolation springs to a heavy gauge mounting plate, which is then isolated from the cabinet base with rubber grommets for maximized vibration/sound attenuation. A compressor discharge muffler and additional sound attenuation materials further enhance the quiet operation (THW models).

ClimateMaster water-to-water heat pumps are available as heating only (THW series) or with reversible operation for heating and cooling (TMW series). Figure 1-2 shows the simple refrigerant circuit of the THW series. With only four major components, the refrigerant circuit is easy to understand and troubleshoot if necessary.

The THW series includes a special high temperature scroll compressor coupled with heat exchangers designed specifically for water heating, which provides unmatched efficiencies and performance. The evaporator is a coaxial (tube-in-tube) heat exchanger that is capable of operation over a wide range of temperatures, and is more rugged than other types of evaporators, especially for open loop (well water) systems. The condenser uses a close approach temperature brazed plate heat exchanger that is designed for high temperature operation. This combination of coaxial/brazed plate heat exchangers provides the best combination of durability and efficiency. ClimateMaster always recommends coaxial heat exchangers for evaporators. Brazed plate heat exchangers may be used for condensers when the unit is not reversible.

Part I: System Overview

Figure 1-2: THW Series Refrigerant Circuit

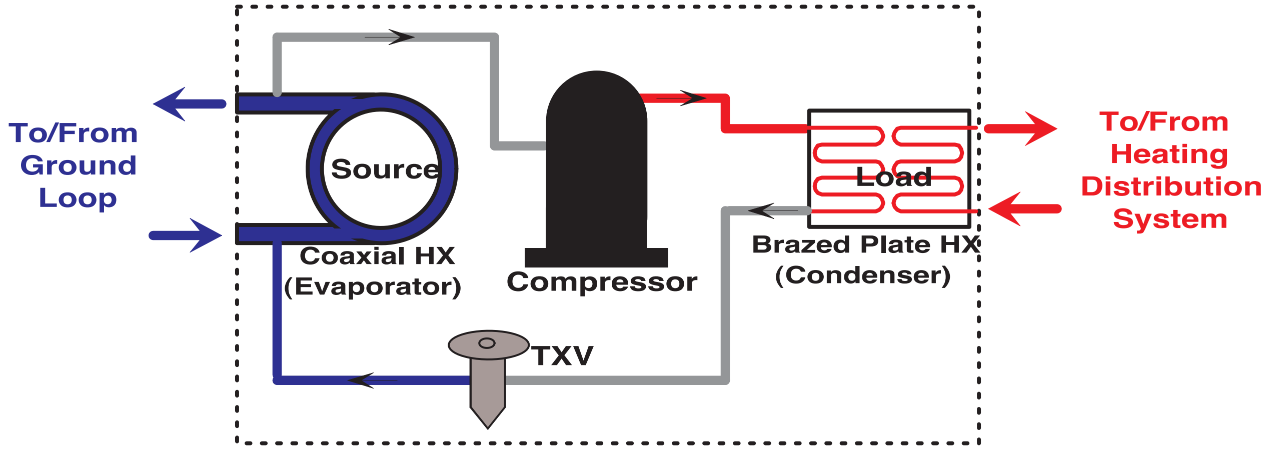


Figure 1-3: THW Series Refrigerant Circuit, Domestic Hot Water Mode

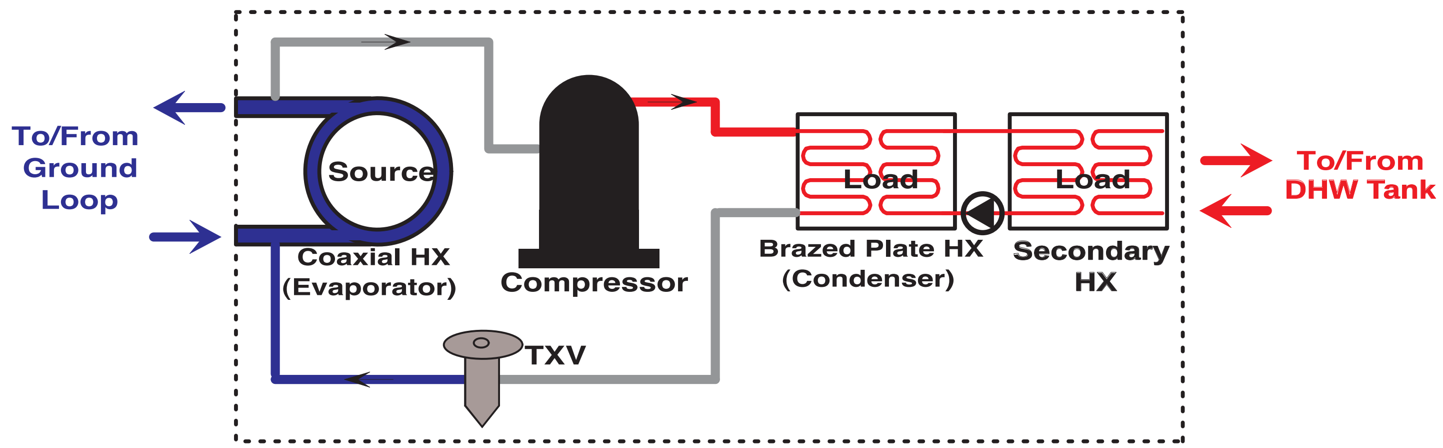


Figure 1-4: Reversible Water-to-Water Heat Pump, Heating Mode

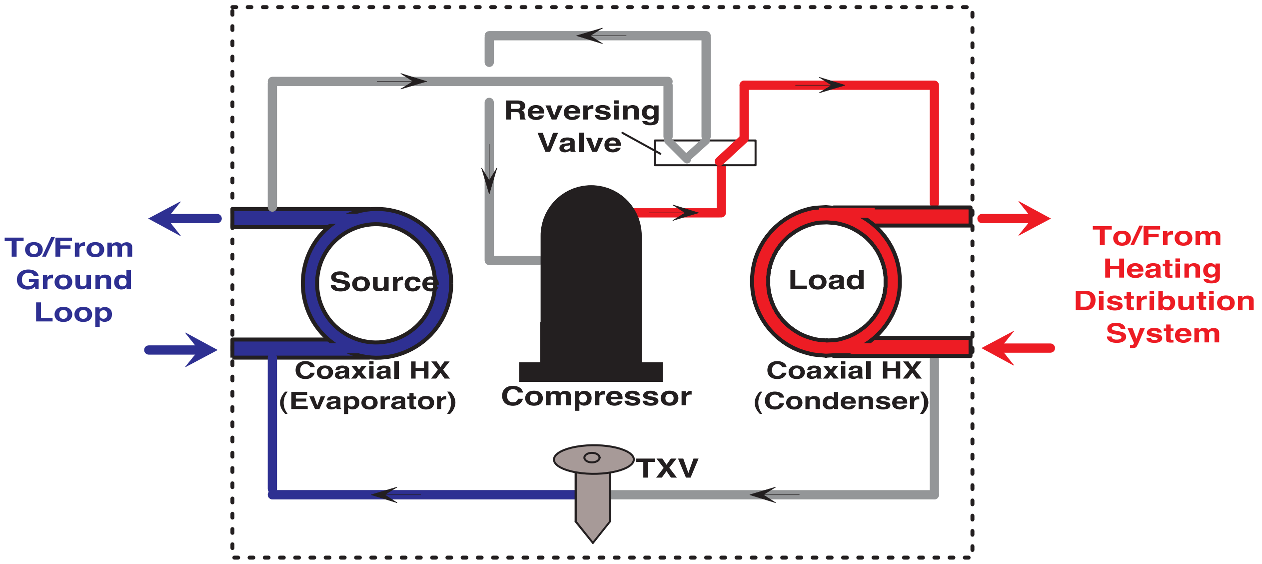
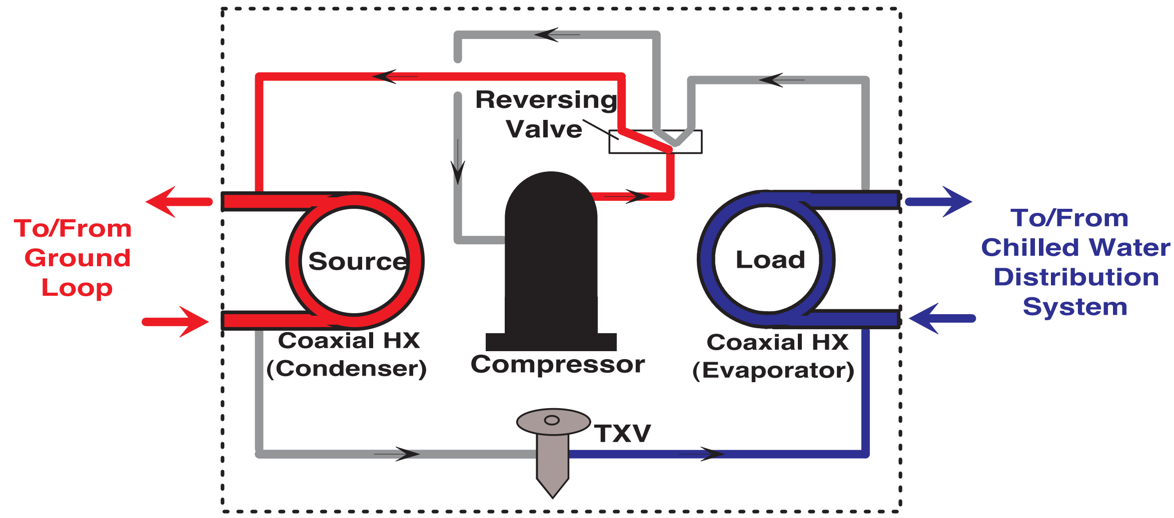


Figure 1-5: Reversible Water-to-Water Heat Pump, Cooling Mode



The THW series compressors have a wide operating map, which allows high temperature operation, up to 145°F [63°C] leaving water temperature, even at 32°F [0°C] ground loop temperatures. The ground loop heat exchanger [evaporator] is called the "Source" heat exchanger in ClimateMaster technical literature, and the heating system heat exchanger is called the "Load" heat exchanger. The terminology is not as important for heating only water-to-water units, since the ground loop heat exchanger is always an evaporator, but for reversible units, the evaporator and condenser change, depending upon operating mode, heating or cooling.

Figure 1-3 shows the THW's DHW circuit. An additional plate heat exchanger provides a secondary level of separation between the refrigerant and the potable water.

Figure 1-4 shows a ClimateMaster reversible water-to-water unit. With the addition of a reversing valve, the Source and Load heat exchangers can change functions, depending upon the desired mode of operation. In the heating mode, the "Load" heat exchanger functions as the condenser, and the "Source" heat exchanger functions as the evaporator.

In figure 1-5, the reversible water-to-water heat pump now provides chilled water on the load side instead of hot water. The load heat exchanger becomes the evaporator, and the source heat exchanger becomes the condenser. Because the evaporator is susceptible to freezing under adverse operating conditions (e.g. failed pump, controls problem, etc.), a coaxial heat exchanger is used on the load side for reversible units.

When selecting equipment for systems that require cooling, all aspects of the system design should be considered. In many cases, a separate water-to-air unit for forced air cooling is more cost effective than using a chilled water / fan coil application due to the complication in controls and seasonal change-over. For ground loop applications, the water-to-water and water-to-air units can share one ground loop system.

WATER-TO-WATER HEAT PUMP DESIGN

Design Temperatures

Various types of hydronic distribution systems have been used successfully with geothermal heat pumps. Radiant floor systems use relatively mild water temperatures, whereas baseboard radiation and other types of heat distribution systems typically use hotter water temperatures. When designing or retrofitting an existing hydronic heating system, it is especially important to consider maximum heat pump water temperatures as well as the effect water temperatures have on system efficiency.

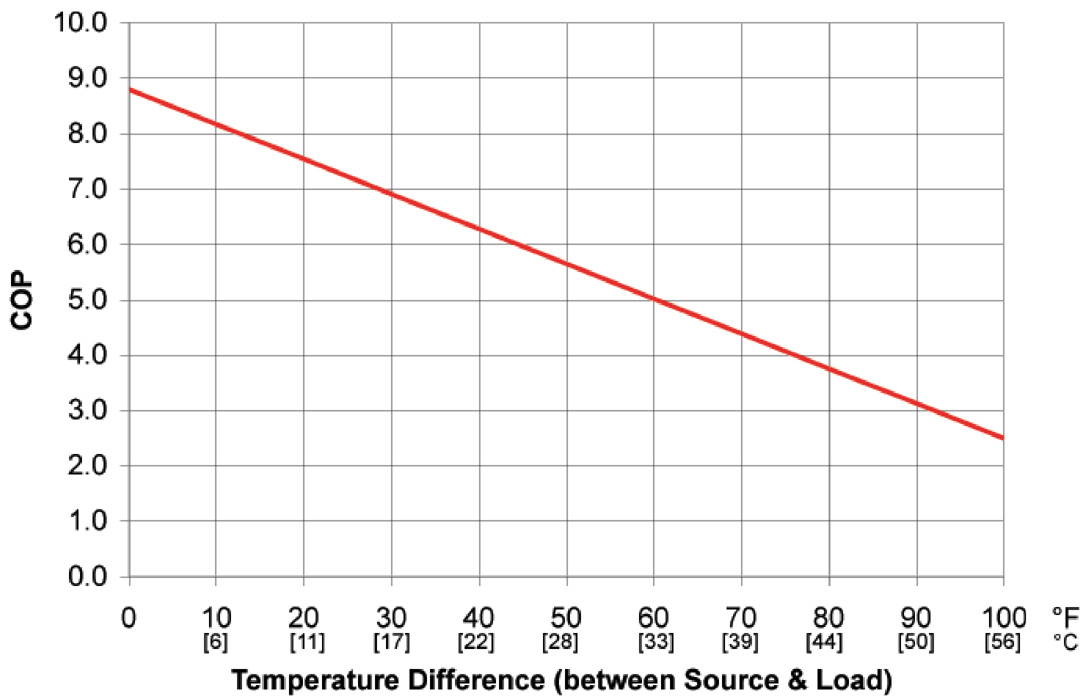
Heat pumps using R-22 refrigerant are not designed to produce water above 130°F [54°C]. Some heat pumps with R-410A and R-407C refrigerant are capable of producing water up to 145°F [63°C]. Regardless of the refrigerant, the efficiency of the heat pump decreases as the temperature difference (TD) between the heat source (generally the earth loop) and the load water (the distribution system) increases. Figure 1-6 illustrates the effect of source and load temperatures on the system. The heating capacity of the heat pump also decreases as the temperature difference increases.

As the temperature difference increases, the Coefficient of Performance (COP) decreases. When the system produces 130°F [54°C] water from a 30° [-1°C] earth loop, the TD is 100°F [55°C], and the COP is approximately 2.5. If the system is producing water at 90° F [32°C], the TD is 60°F [33°C] and the COP rises to about 5.0, doubling the efficiency.

If the water temperature of the earth loop is 90°F [32°C], and the distribution system requires the same temperature, a heat pump would not be needed. The system would operate at infinite efficiency, other than the cost of pumping the water through the distribution system. When using the various types of hydronic heat distribution systems, the temperature limits of the geothermal system must be a major consideration. In new construction, the distribution system can easily be designed with the temperature limits in mind. In retrofits, care must be taken to address the operating temperature limits of the existing distribution system.

Part I: System Overview

Figure 1-6: COP vs TD



System Components

The efficiency, life expectancy and reliability of any hydronic heating system depends upon how well the various components (heat pump, distribution system, controls, etc.) work together. The heat pump must be sized for the building loads; the earth loop must be sized to match the building loads, ground conditions and climate; the circulating pumps must be sized for the equipment, piping and ground loop. The distribution system must be designed to heat and/or cool the building comfortably. The components must then all be controlled effectively.

Building Heat Loss & Heat Gain

The design must begin with an accurate heating and/or cooling load of the building. This is the most important step in the design process. The sizing of the circulation pumps, the distribution system and the earth loop are all derived directly from the sizing of the equipment. Overestimating the heat loss or heat gain means over sizing the system. The extra cost of the oversized system is unnecessary. In fact, it may result in the selection of a different type of system. If an oversized system is installed, it may be inefficient and uncomfortable. If the system is undersized it will not do an adequate job of heating and/or cooling the building.

Loop Design & Installation

Several factors determine the loop design for a specific installation. The energy balance of the building determines how much heat is taken from and rejected to the earth over the course of a year. The climate determines the ambient earth temperatures and is a major factor in the energy needs of the building. The earth itself (the conductivity of the soil or rock and the moisture content) are major factors in calculating the size of the loop. The earth can only take (heat rejected) or give up (heat extracted/absorbed) a fixed amount of Btu/hr [Watts] in a given area. The heat exchanger must have sufficient surface area.

The design of the loop itself (the size and type of pipe, the velocity of the liquid circulating in the pipe and the spacing and layout of the pipe) has a major effect on the heat absorption and rejection capabilities of the loop. The depth (vertical) or trench length (horizontal) of the loop must be calculated using IGSHPA (International Ground Source Heat Pump Association) methods or approved software. In addition, the type and percentage of antifreeze can have a significant effect on loop performance.

The workmanship of the installation also plays a large role in the effectiveness of the loop. All fusion joints must be done properly. Vertical loops must be grouted properly for good contact with the earth. Horizontal loops must be backfilled with material that will not cut the pipe, and the soil should be compacted around the pipe for good contact. All closed loop piping systems should be hydrostatically pressure tested before burial.
Many factors affect loop performance. ClimateMaster offers training in loop design and installation, and also provides residential and commercial loop sizing software.

Controls

The control of a mechanical system determines how it functions. For the building to work efficiently and comfortably, the building owner or manager must understand system functionality and controls.

As Figure 1-6 shows, the efficiency of a heat pump is a factor of the difference in temperature between the source and the load. The heat loss or heat gain of a building varies with the weather and the use of the building. As the outdoor temperature decreases, the heat loss of the building increases. When the ventilation system is operating, the heating or cooling loads increase. As the occupancy increases, or more lighting is used, or the solar gain increases, the cooling load increases. At times the building may require virtually no heating or cooling.

The output of the hydronic heating distribution equipment, whether it is baseboard radiation, fan coil units or radiant floor heating equipment, is directly related to the temperature and velocity of the water flowing through it. Baseboard radiation puts out approximately 50% less heat with 110°F [43°C] water than with 130°F [54°C] water. The same is true with fan coil units and radiant floor heating. For example, if a system is designed to meet the maximum heat loss of a building with 130°F [54°C] water, it follows that if the heat loss is 50% lower (when the outdoor temperature is higher), the load can be met with 110°F [43°C] water. The lower water temperature greatly increases the COP of the heat pump. Outdoor temperature reset, discussed in part IV of this manual, is a very cost-effective method of matching the heating (load side) water temperature with the heat loss of the building.

Other considerations for controls include heating/cooling switchover, pump control, backup heat (if equipped), distribution system or zone controls, and priority assignments (e.g. determining if radiant floor heating or domestic hot water will take priority). The THW series includes internal controls, which makes system installation much easier. Other ClimateMaster water-to-water heat pumps must be controlled via external controls.

SUMMARY

Hydronic geothermal systems can be used very effectively in new installations, as well as in many retrofit applications. Efficient systems can be designed for residential, commercial and industrial applications.

To make a system as efficient as possible, it is important to follow good design criteria. Some of the factors to consider are listed below:

- An accurate heat loss and heat gain must be calculated to properly size the system.
- The system must meet the application requirements. In other words, the design of the system must take into consideration the type of distribution system and the needs of the customer. For example, baseboard radiation designed for 180°F [82°C] water should not be used with 130°F [54°C] water without careful consideration and design analysis.
- The components of the system must be designed to work together. The earth loop must be designed to work with the heat pump; the pumping system must work effectively with the earth loop and the heat distribution system; and the distribution system must be chosen to work properly with the water temperatures available from the heat pump.
- The system must be controlled to operate as efficiently as possible. It is important to operate the system to take variations in the building loads into account. For example, the heat loss of the building is reduced when the outdoor temperature climbs, and the temperature of the water circulated through the distribution system can be lowered, allowing the heat pumps to operate more efficiently. It is possible to integrate the functions of the mechanical systems in a building.

Part II: Load Side Design

HEAT LOSS / HEAT GAIN CALCULATIONS

Heat loss loss/gain calculations for any residential HVAC design should be performed using standard industry practices. ClimateMaster accepted calculations include methods developed by ACCA (Air Conditioning Contractors of America) used in Manual J, HRAI (Heating, Refrigeration and Air Conditioning Institute of Canada) and ASHRAE (American Society of Heating Refrigerating and Air Conditioning Engineers). Light commercial load calculations should be performed using ACCA Manual N or the ASHRAE method. Other methods for load calculations outside of North America are acceptable providing the methodology is recognized by the local HVAC industry.

Heat Loss Calculations for Radiant Floor or Zoned Baseboard Systems

A room-by-room calculation must be performed for all radiant floor or zoned baseboard systems in order to determine the design of the radiation system. Once the heat loss has been calculated and the decision on flooring material has been made for each room, the amount of radiant floor tubing, pipe spacing, water temperature and layout can be determined, based upon the Btuh/square foot [Watts/square meter] requirements. Similarly, the amount of heat loss will allow the designer to determine the length of baseboard convector required based upon the design water temperature.

Outdoor design temperatures should be obtained from the appropriate ACCA, ASHRAE or HRAI manual at the 99.6% condition or local requirements, whichever is most severe. Indoor design temperatures vary, based upon the type of system and customer preference. Following are some minimum design guidelines:

System Type	Indoor Design Range	Minimum Indoor Design
100% Radiant Floor*	65-70°F [18-21°C]	65°F [18°C]
Mixed Radiant/Forced Air	68-72°F [20-22°C]	68°F [20°C]
Baseboard	68-72°F [20-22°C]	68°F [20°C]

*The nature of radiant floor heating tends to allow occupants to feel the same comfort level with radiant floor heating at 65°F [18°C] as with a forced air system at 70°F [21°C].

It is important to remember that a radiant floor system heats objects, not the air. In turn, these objects radiate heat, which heat people and furnishings to a comfortable temperature. Air temperature remains near 65°F [18°C], and is approximately equal from ceiling to floor. Forced air heating, by comparison, heats the air, which heats the people and objects. Therefore, a higher air temperature is required in order to bring people and objects up to the same temperature as in a radiant heating system.

When calculating the heat loss of a structure, the nature of radiant heating should be considered to allow for a more appropriately sized system. As mentioned above, a thermostat setting of 65°F [18°C] for a radiant floor system is comparable to a forced air system with a thermostat setting of 70°F [21°C]. This principle affects the heat loss in two ways:

1. The lower temperature difference [between indoor and outdoor temperatures] causes the heat loss to be lower.
2. The lack of air movement lowers the infiltration rate of the structure.

Following is an example of the differences in load calculations for radiant floor systems and forced air systems:

System A: Forced Air System
ACCA Manual J heat loss calculation
2,000 sq. ft. [186 sq. meter] residential structure
Outside design temperature = 0°F [-18°C]
Indoor design temperature = 70°F [21°C]
Temperature difference = 70°F [39°C]
Air changes per hour = 0.60 AC/H
Heat loss = 50,000 Btu/hr [14,654 Watts]

System B: Radiant Floor System
ACCA Manual J heat loss calculation
2,000 sq. ft. [186 sq. meter] residential structure
Outside design temperature = 0°F [-18°C]
Indoor design temperature = 65°F [18°C]
Temperature difference = 65°F [36°C]
Air changes per hour = 0.50 AC/H
Heat loss = 44,423 Btu/hr [13,020 Watts]

When the characteristics of a radiant floor system are considered, equipment sizing can be significantly impacted. In the example above, the heat loss for the structure decreases by 5,577 Btu/hr [1,635 Watts], or 11%. Industry estimates are as high as 20%. However, ClimateMaster encourages the use of load calculations at actual temperature differences and infiltration rates for equipment sizing, rather than "rules of thumb."

Heat Gain Calculations

Most space cooling is accomplished through the use of forced air. Heat gain calculations must be performed on a room-by-room or zoned basis. Although load calculations for single zone systems may consider the whole house or building as one zone, a room-by-room calculation will facilitate air duct sizing.

Outdoor design temperatures should be obtained from the appropriate ACCA, ASHRAE or HRAI manual at the 0.4% condition or local requirements, whichever is most severe. Indoor design temperatures for cooling typically range from 70-78°F [21-25°C], with most designed at 75°F [24°C].

Part II: Load Side Design / Equipment Sizing

SIZING WATER-TO-WATER EQUIPMENT / BUFFER TANKS

Water-to-Water Equipment Sizing

Water-to-water equipment sizing is dependent upon the type of hydronic system application (load side – indoor) and the type of ground loop system (source side – outdoor). Since the capacity and efficiency of the water-to-water unit is directly related to the entering source temperature, care must be taken to insure that the unit will provide adequate capacity at design conditions. The complexity of the ground loop sizing can be simplified with the use of software, like ClimateMaster's GeoDesigner. GeoDesigner allows the user to enter the heat loss/heat gain, the water-to-water unit size, and the ground loop parameters. An analysis based upon bin weather data allows the user to size the equipment/ground loop and obtain annual operating costs. Below is a typical screen shot.

Figure 2-1: GeoDesigner Heat Pump / Loop Sizing

Part II: Load Side Design / Equipment Sizing

Backup Heat
Just like water-to-air systems, which typically have some type of backup heating capability, water-to-water systems can also benefit from the use of supplemental heating to help lower initial installation costs. Design temperatures are usually chosen for 1%. In other words, 99% of the time, the outdoor temperature is above the design temperature. If the heat pump is designed to handle 100% of the load, it is larger than required 99% of the time. GeoDesigner can determine an economical balance point that will allow the water-to-water unit to be downsized when a backup boiler or water heater is used for supplemental heat.

For example, suppose a home in Chicago has a heat loss the same as the example above [44,423 Btuh, 13,019 Watts]. One THW010 unit has a heating capacity of approximately 10kW [33,000 Btuh] at 32°F [0°C] entering source (ground loop) temperature. According to GeoDesigner, the water-to-water unit could handle the heating load 98% of the time. A backup electric boiler would consume about 326 kWh annually for back up heat [$33 per year at $0.10/kWh]. Two THW010 units could handle the heating load no matter what the outdoor temperature is (100% heating – no backup required). However, this combination would only save about 239 kWh per year [$24 per year at $0.10/kWh], yet the additional installation cost for a second unit and significantly more ground loop would never pay back in operating cost savings. In most cases, sizing for 100% of the heating load is not cost effective.

Cooling
Cooling is not always desired with radiant heating systems. A water-to-water heat pump system can provide chilled water to ducted or non-ducted fan coil units. A reversible water-to-water heat pump can provide chilled water to cool the building, as well as hot water for the heating system. Buildings with fan coil units can generally be retrofitted for cooling quite easily. The difficulty, as mentioned in part I, is using existing fan coils for heating, especially if they were originally sized for high water temperatures.

For optimal cooling and dehumidification, ClimateMaster recommends a separate water-to-air heat pump for cooling. Controls are much simpler when a water-to-water unit is used for space heating and/or domestic water heating, and a water-to-air unit is used for cooling. Since the water-to-water and water-to-air units can share one ground loop, the installation cost of using a water-to-air unit for cooling is simply the incremental cost of the unit. Generally, no additional ground loop is required (in Northern climates), and the cost of the water-to-air unit is usually less than the cost of chilled water/fan coil units, especially if the cost of additional piping/valving/controls and labor is considered. The cost of a water-to-air unit is approximately the same as a ductless mini split, and is much more efficient. The advantages of geothermal heat pumps for cooling (no outdoor unit, no refrigerant line sets, longevity, etc.) should be considered when cooling is required.

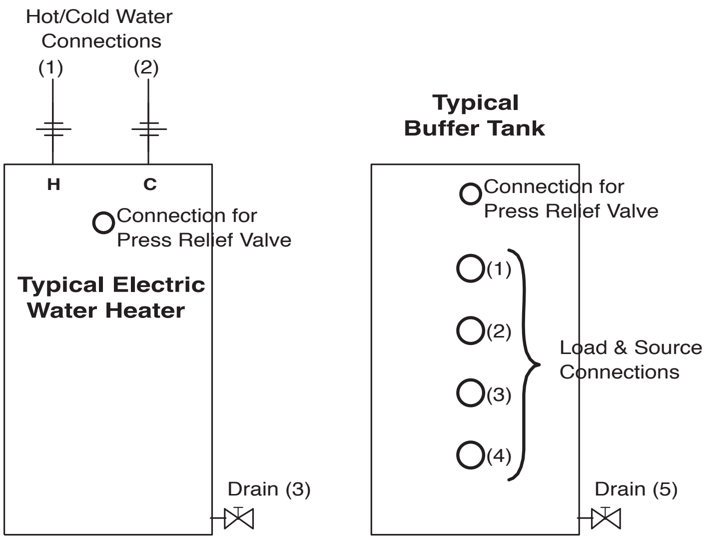
Buffer Tank Sizing / Application
All water-to-water units used in heating applications require a buffer tank to prevent equipment short cycling and to allow different flow rates through the water-to-water unit than through the hydronic heating delivery system. A buffer tank is also required for chilled water cooling applications if the water-to-water unit(s) is more than 20% larger than the cooling load and/or multiple fan coil units will be used. Water-to-water units sized for the cooling load in applications with only ONE fan coil unit may be able to operate without a buffer tank, but this would be an unusual situation, since the cooling load is normally much smaller than the heating load. The best approach is to plan for a buffer tank in every application.

The size of the buffer tank should be determined based upon the predominant use of the water-to-water equipment (heating or cooling). For heating, buffer tanks should be sized at one U.S. gallon per 1,000 Btuh [13 Liters per kW] of heating capacity at the maximum entering source water temperature (EST) and the minimum entering load water temperature (ELT), the point at which the water-to-water unit has the highest heating capacity, usually 50-70°F [10-21°C] EST and 80-90°F [26-32°C] ELT. For cooling, buffer tanks should be sized at one U.S. gallon per 1,000 Btuh [13 Liters per kW] of cooling capacity at the minimum EST and the maximum ELT, the point at which the water-to-water unit has the highest cooling capacity, usually 50-70°F [10-21°C] EST and 50-60°F [10-16°C] ELT. Select the size of the tank based upon the larger of the calculations (heating or cooling). The minimum buffer tank size is 40 U.S. gallons [150 Liters] for any system.

Electric water heaters typically make good buffer tanks because of the availability and relatively low cost. However, the water heater must be A.S.M.E. rated (rated for heating) in order to qualify as a buffer tank. Attention should be paid to insulation values of the tank, especially when a buffer tank is used to store chilled water due to the potential for condensation. A minimum insulation value of R-12 [2.11 K-m2/W] is recommended for storage tanks.

CAUTION:
Maximum leaving water temperature of the THW series equipment is 145°F [63°C]. For domestic hot water tank temperatures or heating buffer tank temperatures above 130°F [54°C], pump and pipe sizing is critical to insure that the flow rate through the heat pump is sufficient to maintain leaving water temperatures below the maximum temperature, and to provide water flow rates within the ranges shown in the performance section of this manual.

Figure 2-2: Connections – Electric Water Heater / Buffer Tank



When using an electric water heat as a buffer tank, there are fewer water connections. Alternate piping arrangements may be required to make up for the lack of water connections. Schematics are shown in the next section. Above is an illustration showing the water connection differences between a buffer tank and an electric water heater.

Part II: Load Side Design / System Design & Selection

SYSTEM DESIGN

As mentioned in part I, hydronics applications offer a wide range of application flexibility, so much in fact, that it is necessary to narrow down the choices in order to start designing the system. As with any heating and cooling design, there is never a perfect solution, but rather a compromise between installation costs, operating costs, desired features and comfort. Once the system is selected, design of the distribution system, pumps, piping and other components can be considered.

SYSTEM SELECTION

Figures 2-3a and 2-3b present system selection in flow chart format for the load side of the water-to-water unit. There are six piping schematics following the flow charts that illustrate each of the possible choices. There are also two additional piping schematics, one for alternate buffer tank piping, and one for using a backup boiler for supplemental heat. To select the correct drawing, begin in figure 2-3a, and finish the selection process in figure 2-3b.

Figure 2-3a: System Selection Flow Chart (Part 1)

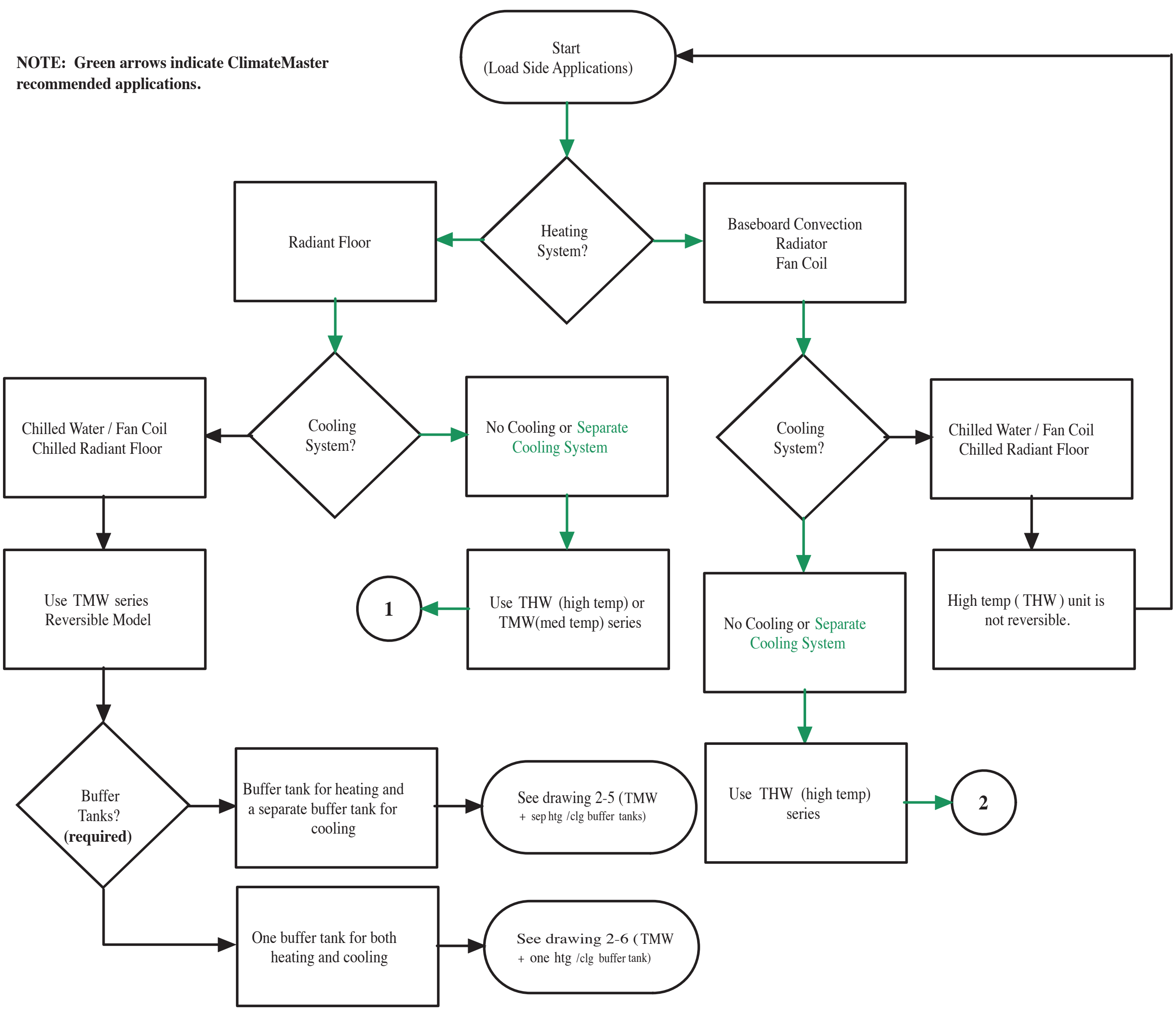
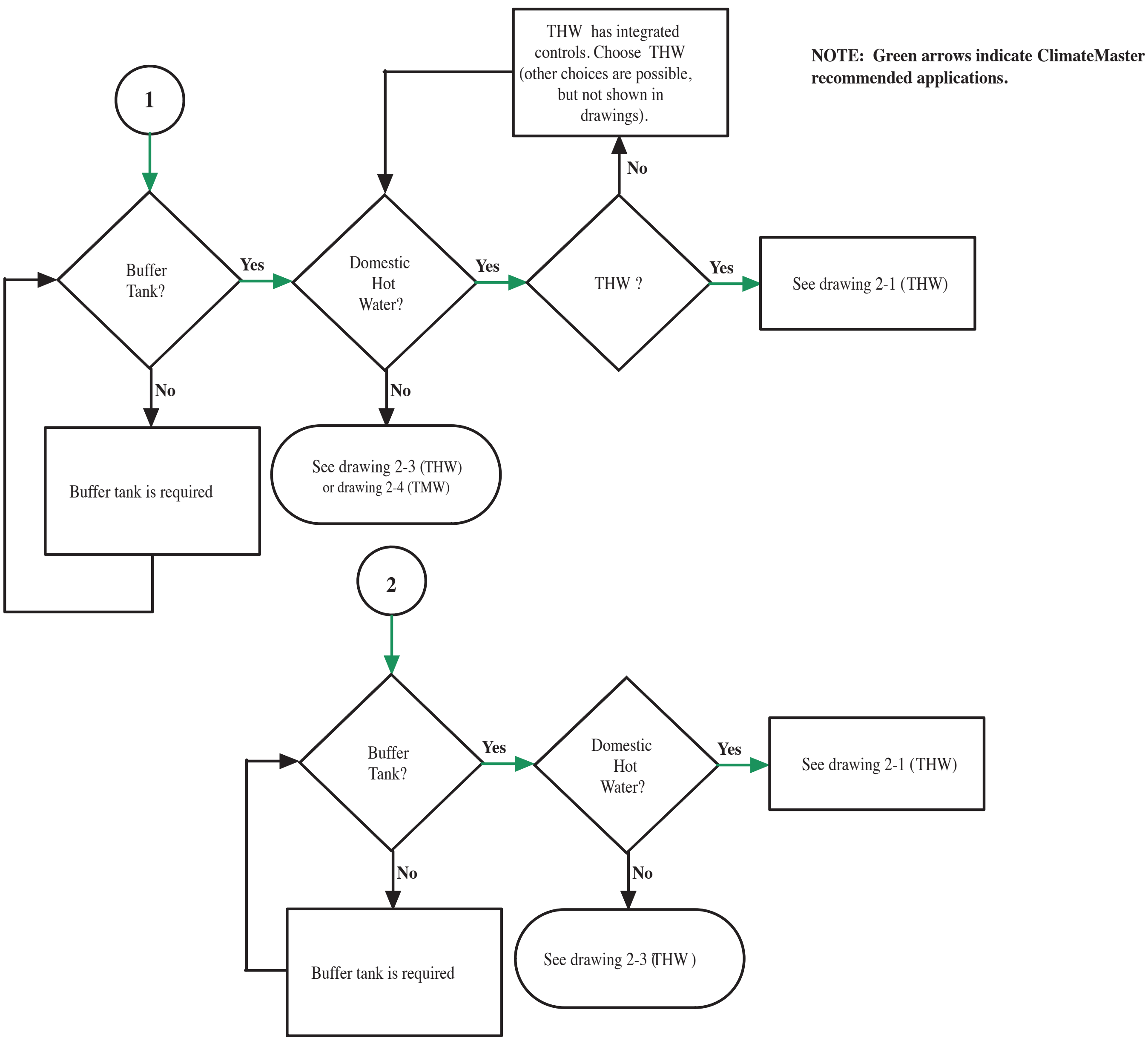


Figure 2-3b: System Selection Flow Chart (Part 2)

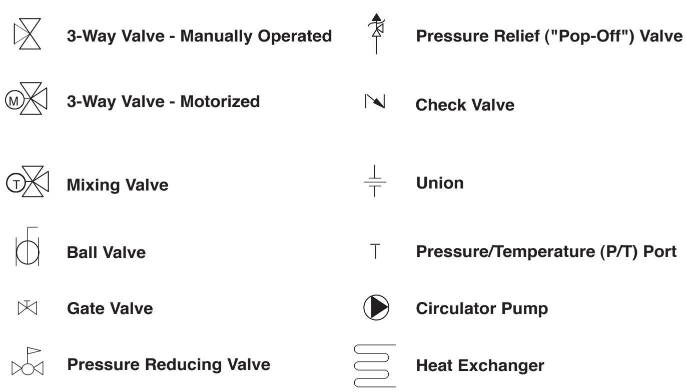


Part II: Load Side Design / System Design & Selection

System Descriptions

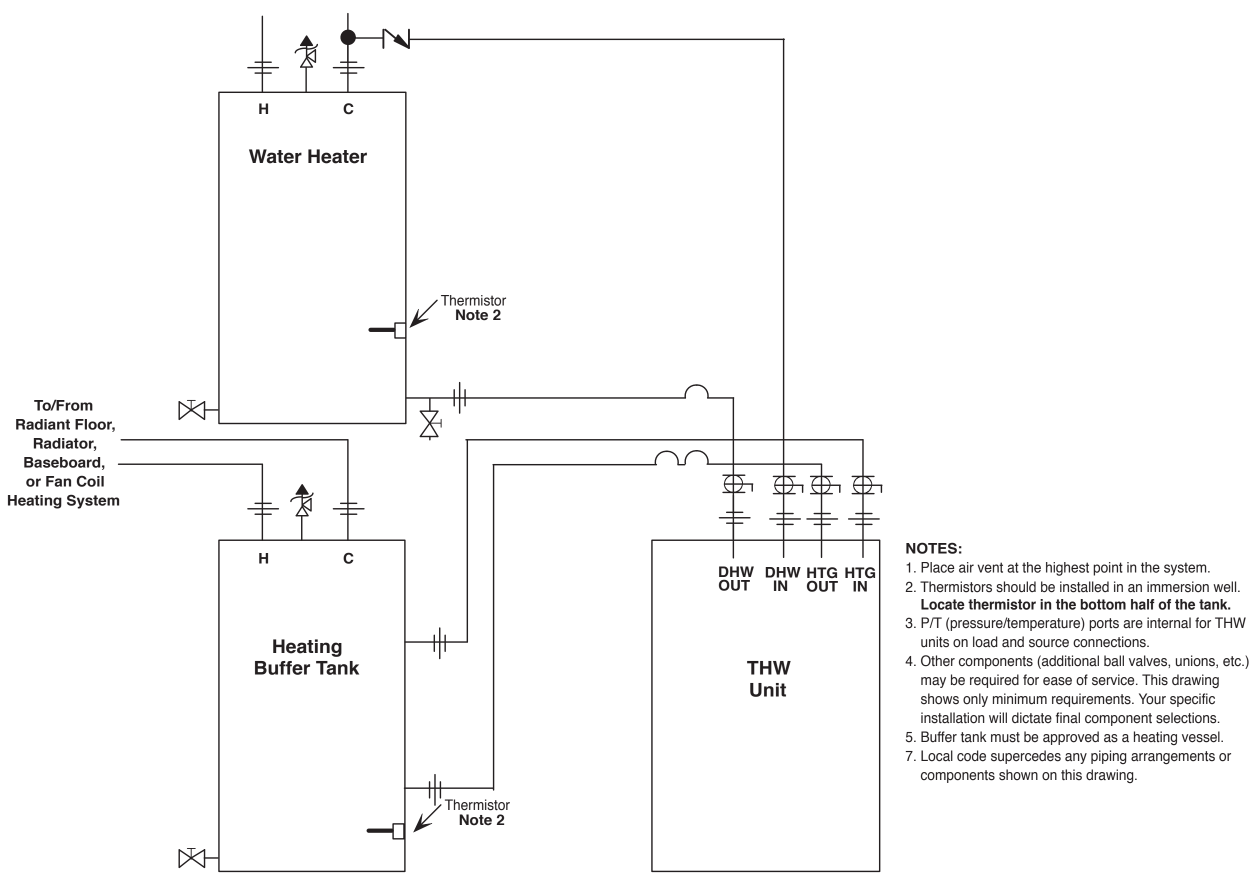
Figure 2-4: Component Legend for Drawings 2-1 to 2-8

Component Legend



Drawing 2-1: THW Typical Load Piping - Indirect Water Heater / No Cooling or Separate Cooling System

Drawing 2-1 – THW Typical Load Piping / No Cooling or Separate Cooling System: System #1 uses one or more water-to-water units and a buffer tank for each unit. Drawing 2-1 shows a typical piping arrangement for this system. A thermistor mounted in an immersion well senses buffer tank temperature, which allows the internal controls (THW units only) to engage the water-to-water unit compressor, load pump and source pump(s) when the tank temperature drops below the set point, typically 120°F [49°C] or less. The radiant floor (or baseboard, radiator, fan coil, etc.) system therefore is completely isolated from the water-to-water unit. The controls for the hydronic distribution system energize pumps and/or zone valves to allow heated water in the buffer tank to flow through the heating distribution system. Potable water is heated via a secondary internal DHW heat exchanger, so that heating system water and potable water do not mix. The THW unit has an internal motorized valve, which allows the load pump to send heated water to the buffer tank or the DHW heat exchanger. A thermistor mounted in an immersion well senses DHW tank temperature, which allows the internal controls (THW units only) to engage the water-to-water unit compressor, load pump and source pump(s) when the DHW tank temperature drops below the set point, typically 130°F [54°C]. If desired, cooling is accomplished with a separate system.

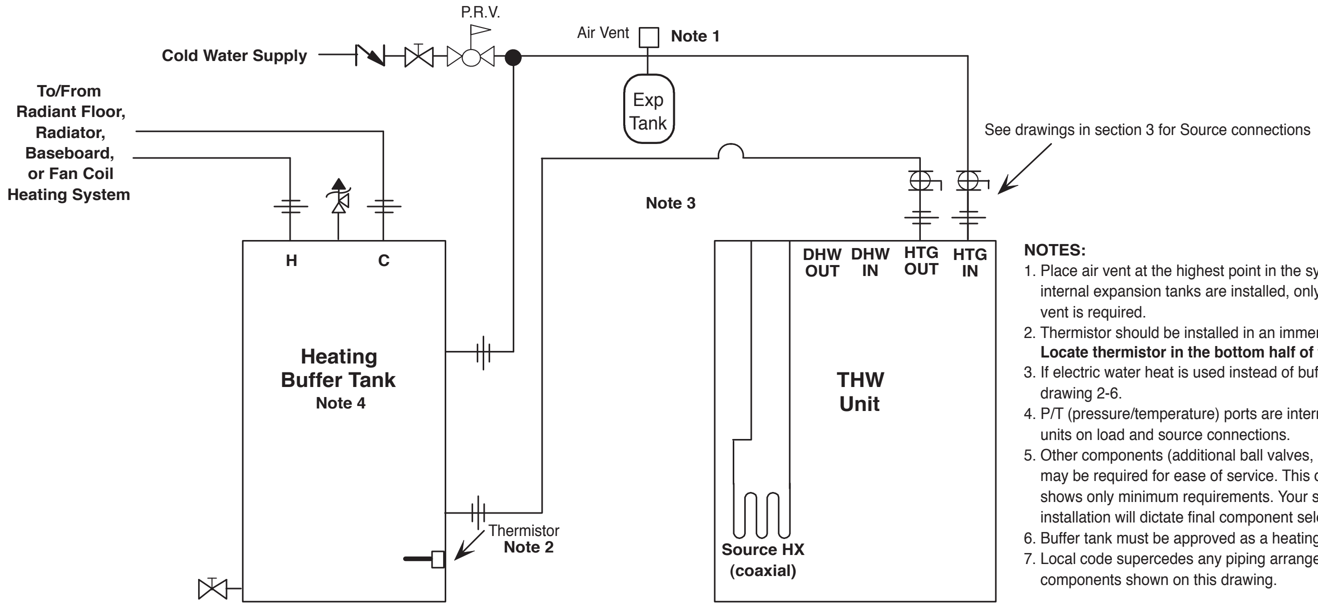


Part II: Load Side Design / System Design & Selection

CAUTION:
Maximum leaving water temperature of the THW series equipment is 145°F [63°C]. For domestic hot water tank temperatures or heating buffer tank temperatures above 130°F [54°C], pump and pipe sizing is critical to insure that the flow rate through the heat pump is sufficient to maintain leaving water temperatures below the maximum temperature, and to provide water flow rates within the ranges shown in the performance section of this manual.

Drawing 2-2 – THW Typical Load Piping / No DHW Heating or Separate DHW System / No Cooling or Separate Cooling System: System #2 uses one or more water-to-water units and a buffer tank for each unit. Drawing 2-2 shows a typical piping arrangement for this system. A thermistor mounted in an immersion well senses tank temperature, which allows the internal controls (THW units only) to engage the water-to-water unit compressor, load pump and source pump(s) when the tank temperature drops below the set point, typically 120°F [49°C] or less. The radiant floor (or baseboard, radiator, fan coil, etc.) system therefore is completely isolated from the water-to-water unit. The controls for the hydronic distribution system energize pumps and/or zone valves to allow heated water in the buffer tank to flow through the heating distribution system. Potable water is heated with a separate system. If desired, cooling is accomplished with a separate system.

Drawing 2-2: THW Typical Load Piping - No DHW Heating or Separate DHW System / No Cooling or Separate Cooling System

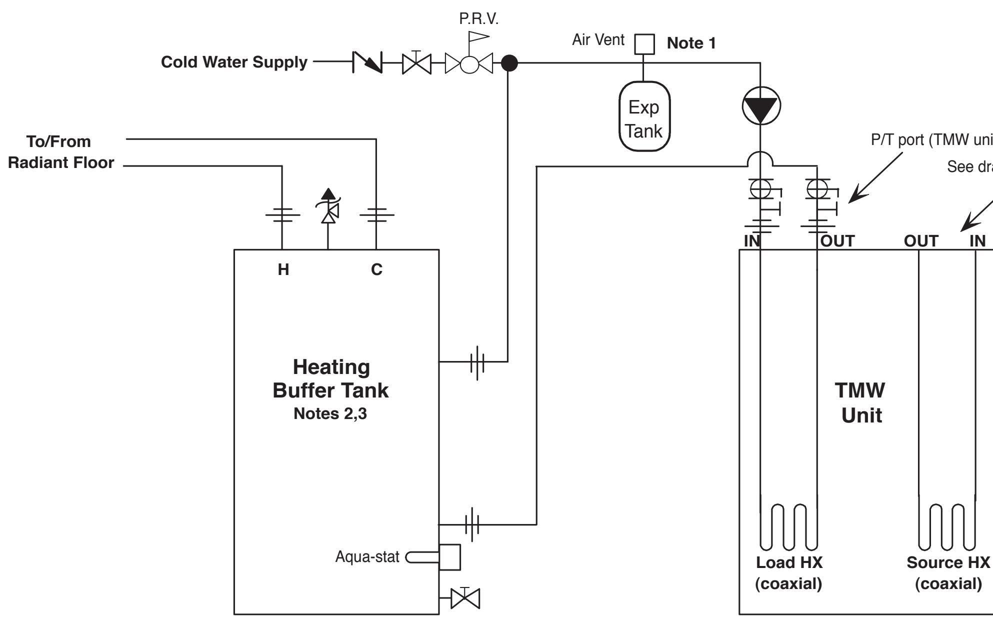


NOTES:
1. Place air vent at the highest point in the system. If internal expansion tanks are installed, only an air vent is required.
2. Thermistor should be installed in an immersion well. **Locate thermistor in the bottom half of the tank.**
3. If electric water heat is used instead of buffer tank, see drawing 2-6.
4. P/T (pressure/temperature) ports are internal for THW units on load and source connections.
5. Other components (additional ball valves, unions, etc.) may be required for ease of service. This drawing shows only minimum requirements. Your specific installation will dictate final component selections.
6. Buffer tank must be approved as a heating vessel.
7. Local code supercedes any piping arrangements or components shown on this drawing.

Part II: Load Side Design / System Design & Selection

Drawing 2-3 – TMW Typical Load Piping / No DHW Heating or Separate DHW System / No Cooling or Separate Cooling System: System #3 uses one or more water-to-water units and a buffer tank for each unit. Drawing 2-4 shows a typical piping arrangement for this system. A thermistor mounted in an immersion well senses tank temperature, which allows the water-to-water unit to engage the compressor, load pump and source pump(s) when the tank temperature drops below the set point, typically 120°F [49°C] or less. The radiant floor (or baseboard, radiator, fan coil, etc.) system therefore is completely isolated from the water-to-water unit. The controls for the hydronic distribution system energize pumps and/or zone valves to allow heated water in the buffer tank to flow through the heating distribution system. Potable water is heated with a separate system. If desired, cooling is accomplished with a separate system.

Drawing 2-3: THW Typical Load Piping - No DHW Heating or Separate DHW System / No Cooling or Separate Cooling System



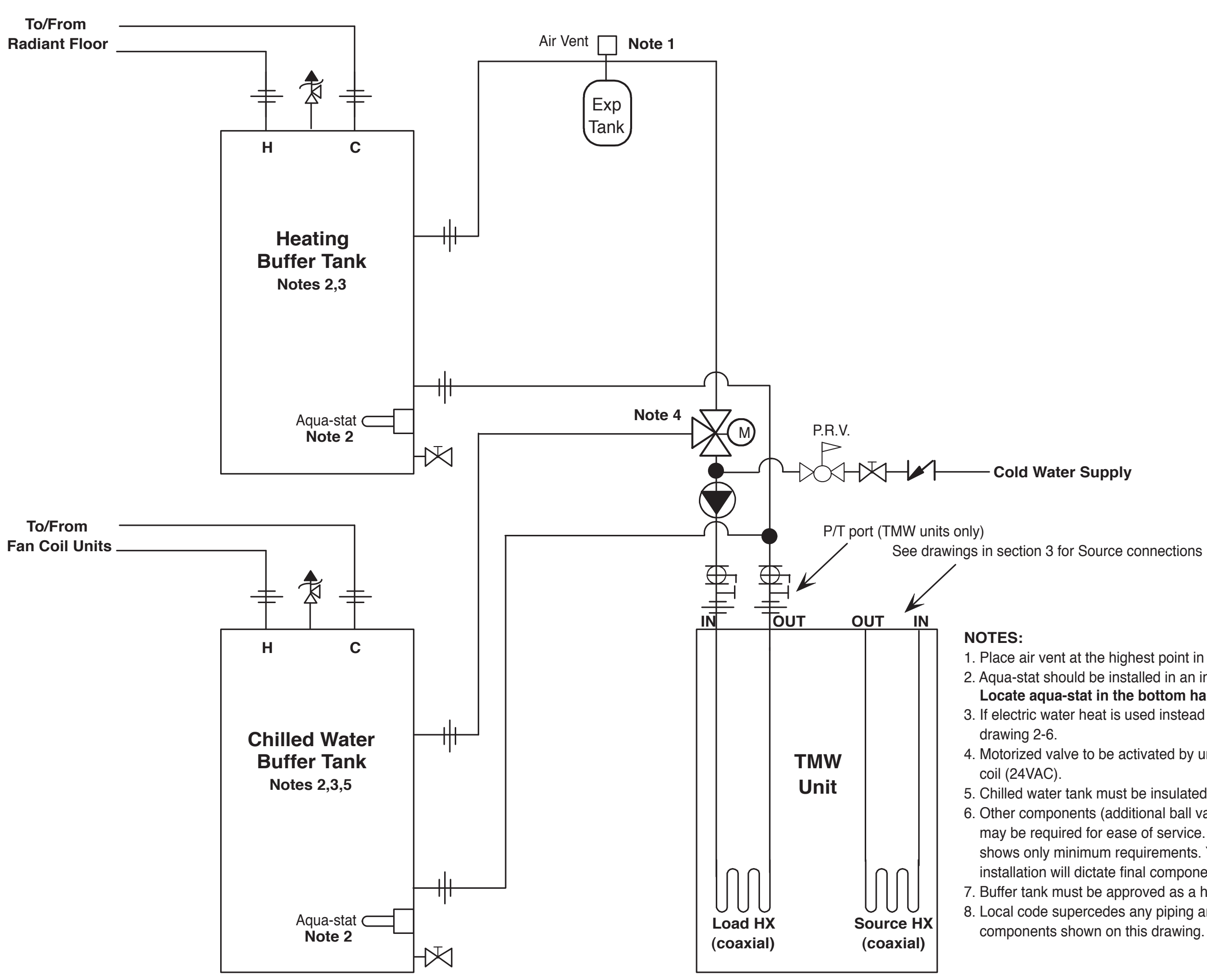
NOTES:

1. Place air vent at the highest point in the system.
2. Aqua-stat should be installed in an immersion well. **Locate aqua-stat in the bottom half of the tank.**
3. If electric water heat is used instead of buffer tank, see drawing 2-6.
4. Other components (additional ball valves, unions, etc.) may be required for ease of service. This drawing shows only minimum requirements. Your specific installation will dictate final component selections.
5. Buffer tank must be approved as a heating vessel.
6. Local code supercedes any piping arrangements or components shown on this drawing.

Part II: Load Side Design / System Design & Selection

Drawing 2-4 – TMW Typical Load Piping - Chilled Water Cooling System / Separate Heating & Cooling Buffer Tanks / No DHW Heating or Separate DHW System: System #4 uses one or more water-to-water units and two buffer tanks, one for heated water, and one for chilled water. Drawing 2-4 shows a typical piping arrangement for this system. An aqua-stat (well-mounted if possible) in each tank senses tank temperature, which allows the water-to-water unit to engage the compressor, load pump and source pump(s) when the heating tank temperature drops below the set point [typically 120°F [49°C] or less], or when the chilled water tank temperature rises above the set point (typically 45-50°F [7-10°C]). The radiant floor (or baseboard, radiator, fan coil, etc.) heating system and the chilled water cooling system (typically fan coil units) therefore are completely isolated from the water-to-water unit. The controls for the hydronic distribution system energize pumps and/or zone valves to allow heated/chilled water in the buffer tanks to flow through the heating/cooling distribution systems. The motorized valve is used to switch between the two tanks based upon heating or cooling season. Due to the complexity of the controls, a manual seasonal changeover switch is the best way to determine heated or chilled water operation. The switch (typically a light switch) switches the unit reversing valve and motorized valve. A reversible unit is required for this application (THW is heating only – TMW units are reversible). Potable water is heated with a separate system.

Drawing 2-4: THW Typical Load Piping - Chilled Water Cooling System / Separate Heating and Cooling Buffer Tanks - No DHW Heating or Separate DHW System

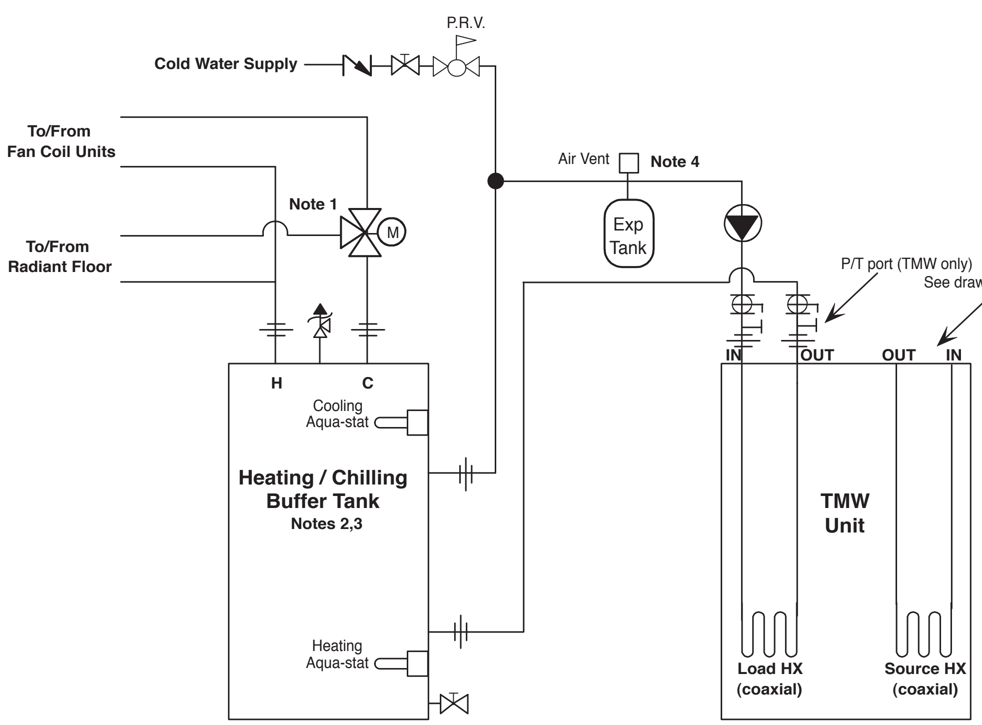


NOTES:
1. Place air vent at the highest point in the system.
2. Aqua-stat should be installed in an immersion well. **Locate aqua-stat in the bottom half of the tank.**
3. If electric water heat is used instead of buffer tank, see drawing 2-6.
4. Motorized valve to be activated by unit RV solenoid coil (24VAC).
5. Chilled water tank must be insulated to avoid condensation.
6. Other components (additional ball valves, unions, etc.) may be required for ease of service. This drawing shows only minimum requirements. Your specific installation will dictate final component selections.
7. Buffer tank must be approved as a heating vessel.
8. Local code supercedes any piping arrangements or components shown on this drawing.

Part II: Load Side Design / System Design & Selection

Drawing 2-5 – TMW Typical Load Piping - Chilled Water Cooling / Single Buffer Tank / No DHW Heating or Separate DHW System: System #5 uses one or more water-to-water units and a buffer tank for each unit. Drawing 2-5 shows a typical piping arrangement for this system. Two aqua-stats (well-mounted if possible) sense tank temperature, one for heating and one for cooling, which allows the water-to-water unit to engage the compressor, load pump and source pump(s) when the tank temperature drops below the set point (typically 120°F [49°C] or less] in the heating mode, or when the tank temperature rises above the set point [typically 45-50°F [7-10°C]) in the cooling mode. The radiant floor (or baseboard, radiator, fan coil, etc.) heating system and the chilled water cooling system (typically fan coil units) therefore are completely isolated from the water-to-water unit. The controls for the hydronic distribution system energize pumps and/or zone valves to allow heated/chilled water in the buffer tank to flow through the heating/cooling distribution systems. The motorized valves are used to switch between the two distribution systems (and aqua-stats) based upon heating or cooling season. Due to the complexity of the controls, a manual seasonal changeover switch is the best way to determine heated or chilled water operation. The switch (typically a light switch) switches the unit reversing valve, motorized valves, and aqua-stats (additional relays are required for determining heating/cooling logic). A reversible unit is required for this application (THW is heating only – TMW units are reversible). When using one tank for both heated and chilled water, a buffer tank (not an electric water heater) is recommended, since water heaters do not have enough connections to facilitate all of the water connections and the two well-mounted aqua-stats. Potable water is heated with a separate system.

Drawing 2-5: THW Typical Load Piping - Chilled Water Cooling System / Single Buffer Tank - No DHW Heating or Separate DHW System

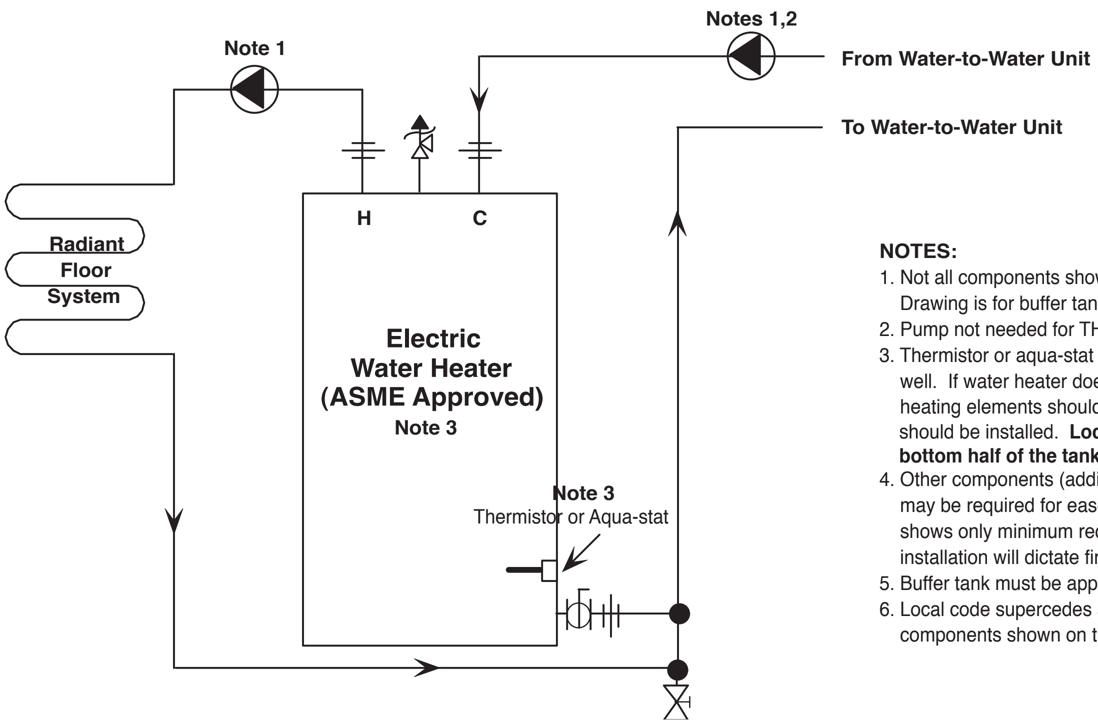


NOTES:
1. Motorized valves to be activated by unit RV solenoid coil (24VAC).
2. Aqua-stat should be installed in an immersion well. **Locate heating aqua-stat in the bottom half of the tank. Locate cooling aqua-stat in the top half of the tank.**
3. Chilled water tank must be insulated to avoid condensation.
4. Place air vent at the highest point in the system.
5. Other components (additional ball valves, unions, etc.) may be required for ease of service. This drawing shows only minimum requirements. Your specific installation will dictate final component selections.
6. Buffer tank must be approved as a heating vessel.
7. Local code supercedes any piping arrangements or components shown on this drawing.

Part II: Load Side Design / System Design & Selection

Drawing 2-6 – Alternate Buffer Tank (Electric Water Heater) Typical Piping: A "true" buffer tank is the best approach for control of a hydronic system using a heat pump. Tanks are usually well insulated, and there are typically a number of water connections (6 or more in many cases), so that plumbing is easier and water flows are not restricted. However, due to the cost of buffer tanks, some installers use an electric water heater for the buffer tank. An electric water heater is much less expensive, but may not have enough water connections, and may require external installation. Drawing 2-6 may be used as an alternate piping schematic for drawings 2-1 through 2-4 when an electric water heater is used. Drawing 2-5 requires a buffer tank due to the need for two aqua-stats. If a water heater is used, it must be approved as a heating vessel (A.S.M.E. approval in the U.S.).

Drawing 2-6: Alternate Buffer Tank (Electric Water Heater) Typical Piping



NOTES:
1. Not all components shown (expansion tank, air vent, etc.). Drawing is for buffer tank connections only.
2. Pump not needed for THW unit with internal load pump option.
3. Thermistor or aqua-stat should be installed in an immersion well. If water heater does not have well, one of the heating elements should be removed, and a well adapter should be installed. **Locate thermistor/aqua-stat in the bottom half of the tank.**
4. Other components (additional ball valves, unions, etc.) may be required for ease of service. This drawing shows only minimum requirements. Your specific installation will dictate final component selections.
5. Buffer tank must be approved as a heating vessel.
6. Local code supercedes any piping arrangements or components shown on this drawing.

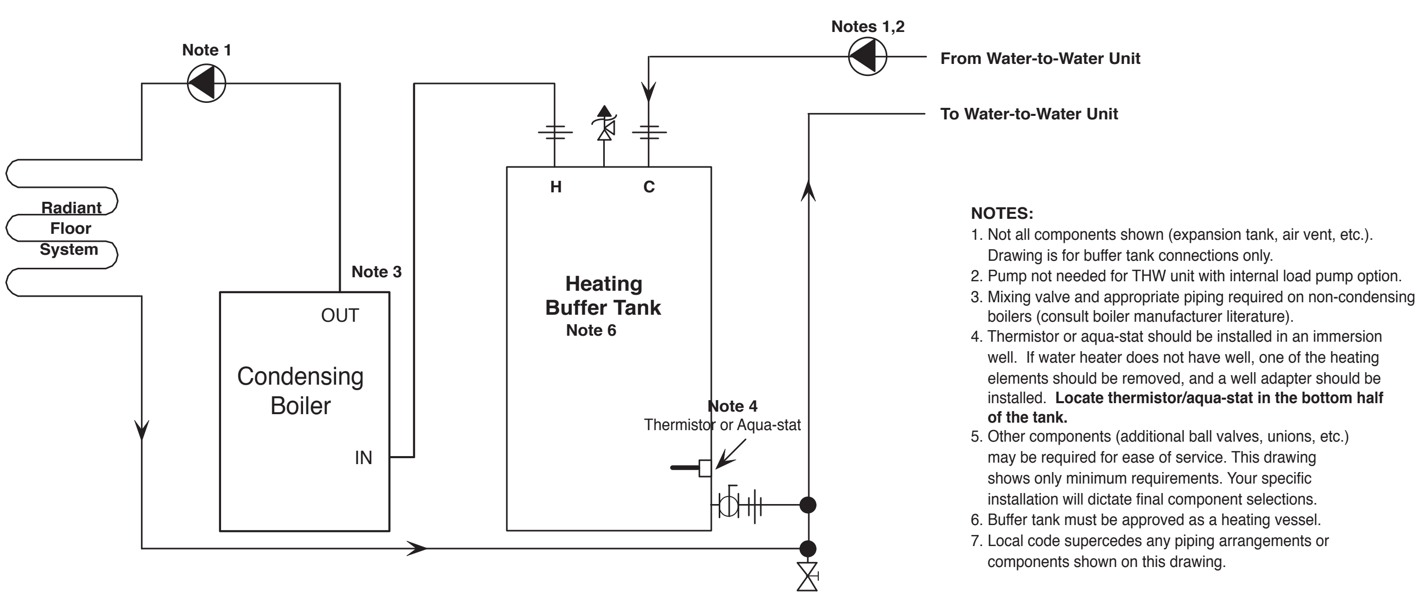
Part II: Load Side Design / System Design & Selection

Drawing 2-7 – Piping for Backup Boiler (2nd Stage Heating): Drawing 2-7 may be used for two different types of applications. A boiler backup may be required because the water-to-water unit lacks sufficient capacity at design conditions, or because the hydronic heating distribution system requires hotter water than the water-to-water unit can produce.

• Water-to-Water Unit Lacks Capacity: This type of system would be used when the water-to-water unit has been sized to handle less than 100% of the heating load. It is common practice to size geothermal heat pump systems to handle 80-90% of the load in order to lower equipment and ground loop requirements, especially when the cooling load is less than the heating load. In this case, the boiler control should be set at the same temperature as the buffer tank (or the boiler can be controlled by outdoor temperature). When the buffer tank begins to drop in temperature (i.e. the heat pump can no longer maintain tank temperature), the boiler comes on to make up the difference. This type of system is excellent for retrofit installations, where an existing boiler is in good operating condition.

• Distribution System Requires Hotter Water: This type of system would be used when baseboard convectors, cast iron radiators or fan coil units are already installed in a retrofit application. Since the TMW water-to-water units are only capable of producing up to 130°F [54°C] leaving water temperature (THW water-to-water units can produce up to 145°F [63°C] leaving water temperature), and the existing distribution system may require up to 180°F [82°C] at design conditions, the water-to-water system should be sized to handle the heating load up to the point where hotter water is required (i.e. at the outdoor temperature balance point). Typically, a properly sized water-to-water unit can handle the load until the outdoor temperature drops to 20 to 30°F [-7 to -1°C]. At that point, the water-to-water unit compressor must be disengaged (through the use of an outdoor thermostat or other control means), and the boiler should be started. The water delivered to the hydronic system now increases in temperature to help satisfy the increased load.

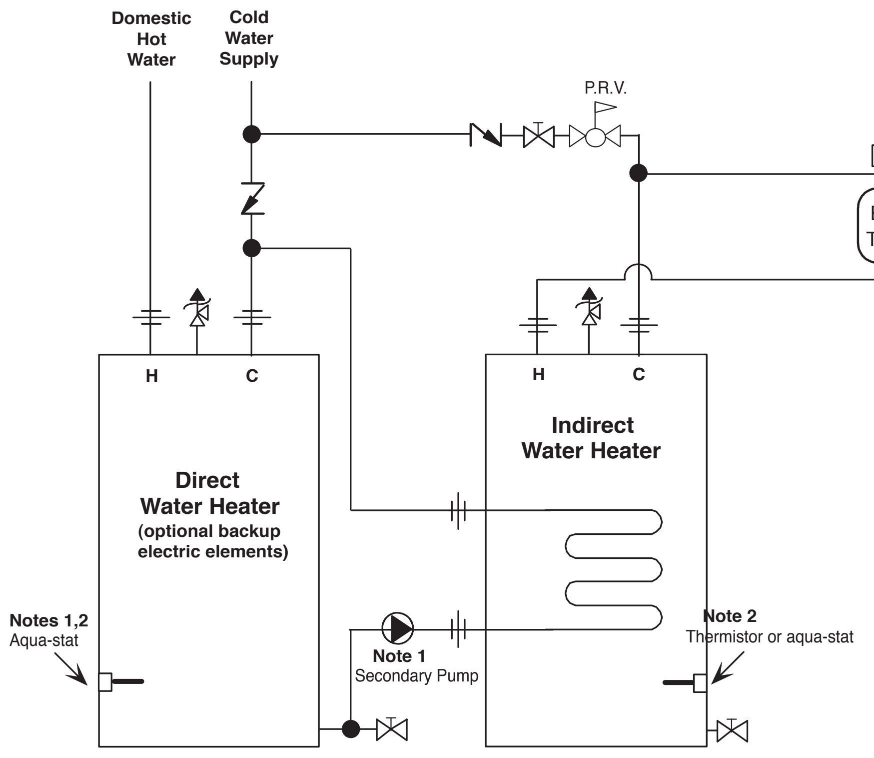
Drawing 2-7: Piping for Backup Condensing Boiler (2nd Stage Heating)



Part II: Load Side Design / System Design & Selection

Drawing 2-8 – Piping for Indirect Water Heaters with Insufficient Heat Exchanger Mass: Drawing 2-8 may be used for indirect water heaters that lack a heat exchanger of sufficient mass (see figure 2-8 later in this section). Most indirect water heaters are designed for 180°F [82°C] or hotter water. Using lower water temperatures could cause the heat pump to short cycle and the tank temperatures to remain below set point. When the piping is arranged as shown in drawing 2-8, the mass is increased. The disadvantages of this arrangement are higher installation costs, more mechanical room space, and an additional pump (plus the additional Watts associated with the pump). It is always best to use an indirect water heater with more heat exchanger mass that is designed for operation with lower water temperatures.

Drawing 2-8: Alternate DHW Piping - Indirect Water Heater with Low Mass Heat Exchanger



NOTES:

1. Aqua-stat controls secondary pump.
2. Thermistor/aqua-stat should be installed in an immersion well. **Locate thermistor/aqua-stat in the bottom half of the tank.**
3. Place air vent at the highest point in the system. If internal expansion tanks are installed, only an air vent is required.
4. If optional THW pump is used, this pump is not necessary.
5. Other components (additional ball valves, unions, etc.) may be required for ease of service. This drawing shows only minimum requirements. Your specific installation will dictate final component selections.
6. Local code supercedes any piping arrangements or components shown on this drawing.

Part II: Load Side Design / Piping Design

PIPING SYSTEM DESIGN

As with any heating and cooling application, proper design of the delivery system is crucial to system performance, reliability and life expectancy. Table 2-1 gives specifications for 3/4" [19 mm] and 1" [25 mm] copper piping. ClimateMaster recommends only type "L" straight length copper tubing for connection between the water-to-water unit and the buffer tank. In addition, all piping must be rated for 760 psi at 200°F [5.24 Pa at 93.3°C]. All piping must be insulated. The smaller 3/4" [19 mm] tubing requires 1" [25 mm] diameter insulation with a minimum 1/2" [13 mm] wall thickness. The larger 1" [25 mm] tubing requires 1-3/8" [35 mm] diameter insulation with a minimum 1/2" [13 mm] wall thickness. The smaller 3/4" [19 mm] tubing may be used on water-to-water units up to the THW008 /TMW008 with a maximum of 25 ft. [7.6 m] one-way and 8 elbows. The larger 1" [25 mm] tubing may be used on water-to-water units up to the THW012 / TMW060 with a maximum of 25 ft. [7.6 m] one-way and 8 elbows. Refer to ASTM 388 for detailed information. Local codes supersede any recommendations in this manual.

melting point of approximately 361-421°F [183-216°C], and is typically applied using a propane torch. Proper flux is required. An acetylene torch may be used, but care must be taken not to overheat the piping, which can cause the material to become brittle. Solder type 95/5 1/8" [3.2 mm] diameter solder has melting point of approximately 452-464°F [233-240°C], and is typically applied using a map gas torch (propane will work). Proper flux is required. An acetylene torch may be used, but care must be taken not to overheat the piping, which can cause the material to become brittle.

When preparing copper joints for soldering, tubing should be cut square, and all burrs must be removed. Do not use dented or pitted copper. Clean the inside of the tubing with a brush; clean the outside with emery cloth approximately 1/2" [13 mm] from the end of the fitting. Debris in the system could cause pump failure or corrosion. Do not put the fitting in a bind before soldering. Flux should be applied as a thin film. Excess flux will end up in the circulating fluid. Rotate fitting while soldering to spread flux over the entire fitting.

Table 2-1: Copper Type "L" Piping Specifications

Pipe size*	Flow rate**	Pressure Drop***	Volume****	Pipe size*	Flow rate**	Pressure Drop***	Volume****
3/4" [19.1 mm]	2 [7.6]	1.5 [0.5]	2.7 [10.1]	1" [25.4 mm]	10 [37.9]	7.0 [2.1]	4.1 [15.3]
	4 [15.1]	5.0 [1.5]			12 [45.4]	9.0 [2.7]	
	6 [22.7]	10.0 [3.0]			14 [53.0]	13.0 [3.9]	
	8 [30.3]	17.0 [5.1]			16 [60.6]	16.0 [4.8]	
	10 [37.9]	25.0 [7.5]					

*Nominal inside diameter water pipe -- e.g. 3/4" type L has an inside diameter of 0.811" [206 mm] & an outside diameter of 0.875" [222 mm]
**U.S. gallons per minute [liters per minute]
***Foot of head per 100 ft. of pipe [meters of head per 30m of pipe]
****U.S. gallons per 100 ft. of pipe [liters per 30m of pipe]

PIPING SYSTEM INSTALLATION

Once the piping system has been designed, proper installation techniques must be used to insure a problem-free system. When piping is hung, 1-1/4" [32 mm] and smaller tubing must be supported every 6 ft. [1.8 m]; 1-1/2" [38 mm] and larger tubing must be supported every 10 ft. [3 m]. Always support the pipe where a transition from horizontal to vertical is made. Plastic coated or copper hangers should be used, allowing enough space for the pipe insulation. Standoff type supports are good for rigid support, wall runs or short runs less than 10 ft. [3 m]. Clevis hangers (held by threaded rod) are good for piping at different heights. Finally, rail type hangers are good for different types of pipe (e.g. water, conduit, etc.). Polyethylene clips are best for small pipes. Always run piping at 90 or 45 degree angles. Local codes supersede any recommendations in this manual.

Two types of soldering material may be used for hydronic installations, 50/50 [50% tin, 50% lead] and 95/5 (95% tin, 5% antimony). However, 50/50 may not be used for domestic water piping. Solder type 50/50 1/8" [3.2 mm] diameter solder has a

Once the fitting has been prepared, take care not to use too much solder. Look for a silver ring to appear on the fitting. When solder drips, the joint has excess solder. Excess solder can get into the system circulating fluid. Note that approximately 0.9" [23 mm] of 1/8" [3.2 mm] diameter solder is all that is needed for 3/4" [19 mm] copper; 1.3" [33 mm] is needed for 1" [25 mm] copper; and 1.7" [43 mm] is needed for 1-1/4" [32 mm] copper.

Let the joint cool naturally. Cooling with water can cause high stress at the joint area, and potentially premature failure (this is especially important when heavy objects are soldered in place, such as pumps). Once the joint is cool, wipe any excess flux to lessen potential surface oxidation. Keep the piping open to the atmosphere. Pressure can cause blowout of material when heated, causing pin hole leaks. When a thread by sweat (soldered) transition fitting is used, always make the soldered connection first, and then make the threaded fitting [with proper sealants]. Adequate ventilation must be present when soldering. Flux fumes can be dangerous.

Part II: Load Side Design Components

When soldering valves and unions, take care not to overheat the non-metallic components. Remove synthetic gasket material from dielectric unions before soldering. Likewise, use small strips of damp, clean rags to keep the valve body when soldering.

Safety
ClimateMaster is always concerned about the safety of installation technicians. Exercise caution when soldering around combustible materials, wood, plastic or paper. Cleaning fluids, pressurized containers and other hazardous materials should be removed before beginning any solder joints.

Always wear eye protection, long sleeve shirts and gloves when installing ClimateMaster equipment and related systems/ components. Use shields on safety glasses. Always have the proper fire extinguisher and/or water near the work area.

Local codes supersede any recommendations in this manual.

System Components
Below are some general guidelines for component selection and design/installation criteria for the piping system. Local codes supersede any recommendations in this manual.

Shut off/flow regulation valves: Use full port ball valves or gate valves for component isolation. If valves will be used frequently, ball valves are recommended. Globe valves are designed for flow regulation. Always install globe valves in the correct direction (fluid should enter through the lower body chamber).

Check valves: Swing check valves must be installed in the horizontal position with the bonnet of the valve upright. Spring check valves can be mounted in any position. A flow check valve is required to prevent thermo siphoning (or gravity flow) when the circulator pump is off or when there are two circulators on the same system.

Mixing valves: Three and four port thermostatic mixing valves are common in hydronics applications, especially when boilers are used. Most oil and gas-fired boilers cannot accept cool return water without flue gas condensation problems. Three-way mixing valves are limited to systems where the coolest return water from the distribution system is always above the dew point temperature of the exhaust gases. When this is not possible, a four-port mixing valve should be used.

Buffer tanks: A buffer tank is required for all hydronic heating systems using water-to-water heat pumps and chilled water systems. Buffer tank sizing is address earlier in this section. The buffer tank must be A.S.M.E. rated (approved for use as a heating vessel). See note below regarding pressure relief valves.

Pressure relief valves: Most codes require the use of a pressure relief valve if a closed loop heat source can be isolated by valves. Even if local code does not require this device, ClimateMaster recommends its installation. If the pressure relief valve in the buffer tank is rated above 30 psi [207 kPa] maximum pressure, remove the existing valve and replace with the lower rated model. The pressure relief valve should be tested at start up for operation. This valve can also be used during initial filling of the system to purge air. Note that the waste pipe must be at least the same diameter as the valve outlet (never reduce), and that valves may not be added to this pipe. The bottom of the pipe must be at least 6" [15 cm] from the floor. If the piping is connected to a drain, there must be an air gap.

Backflow prevention check valves: Most codes require backflow prevention check/fill valves on the supply water line. Note that a single check valve is not equal to a backflow prevention check valve. Even if local code does not require this device, ClimateMaster recommends its installation. This is particularly important if the system will use antifreeze.

Pressure-reducing valves or feed water valves: This valve lowers the pressure from the make-up water line to the system. Most are adjustable and directional. A "fast fill" valve is a must for initially filling the system. Some have screens, which must be cleaned after the initial filling. If there is a restriction in the screen, the system could go to zero pressure, potentially causing pump(s) failure or pressure relief valves to open. A valve on each side of the pressure-reducing valve should be installed for servicing. Both valves should have tags reading, "Do not shut this valve under normal operation – Service valve only".

Expansion tanks: Expansion tanks are required on hydronics systems to help absorb the pressure swings as the temperature in the system fluctuates. If the piping system will be used for chilled water, the tank must be insulated. A non-metallic (plastic, fiberglass) tank is recommended for chilled water systems to lengthen the life expectancy of the expansion tank.

Elbows/T's: Calculate added pressure drop of elbows and T's in the system when considering pump sizing and pipe diameter selection.

Anti-freeze: Antifreeze is required if any of the piping system is located in areas subject to freezing. In addition, antifreeze should be used for snow melt systems and fan coil unit installations where design water temperatures drop below 40°F [4°C]. Consult the antifreeze manufacturer's specifications catalog for concentration amounts and recommendations.

Well-type thermistors & aqua-stats: All thermistors and aqua-stats should be installed in a thermal well for more accurate sensing of the water in the tank. The well should be threaded into an opening in the tank, and the thermistor or aqua-stat probe should be coated with conductive paste to make sure that the sensor is in contact with the walls of the well. Figure 2-5 shows a typical well-type installation. Attaching a thermistor or aqua-stat to piping outside of the tank only senses temperature accurately when the pumps are running, and may create false readings, which could short cycle the heat pump or cause overheating of the tank.

Part II: Load Side Design / Distribution Design

Figure 2-5: Well-Type Thermistors & Aqua-Stats

> **NOTICE:**
> Well should be located in the bottom half of the tank. If well is near the top of the tank, thermistor/aqua-stat will react too slowly, and a demand for heating may not be made until the tank is drawn down to the thermistor level (especially important with DHW heating).

SOURCE & LOAD PUMP SIZING

THW series units are available with optional internal source and load pumps. See Part III for pump curves. The ground loop and load piping (heating system) must be designed to provide proper water flow through the unit heat exchangers using the internal pumps. For all other units, review the ClimateMaster Flow Controller I.O.M. manual for source side (loop) pump sizing. This section provides a guideline for load pump sizing with maximum piping lengths and typical valving configurations. Consult the ASHRAE Fundamentals Handbook for pressure drop calculations not meeting the guidelines in this section.

For units up through the THW012 / TMW060, one 1/6 hp (245 W power consumption) circulator pump (Grundfos UP26-99 or equivalent) will be sufficient for the load side piping, providing the following guidelines are not exceeded:

- Maximum one-way distance from the water-to-water unit to the buffer tank of 25 ft. [7.6 meters]
- Minimum copper tubing size for units up through the THW008 / TMW008 of 3/4" [19 mm] I.D.; minimum size for units up through the THW012 / TMW060 of 1" [25 mm] I.D.
- Maximum of 8 elbows.
- Maximum components limited to those shown in Drawings 2-1 through 2-8.
- Only one water-to-water unit is piped to each buffer tank.

IMPORTANT DESIGN NOTE: Depending upon the temperature difference between the entering and leaving load temperatures, the buffer tank and/or domestic hot water tank may require lower settings. For example, if the load pump selection for a THW010 provides a temperature difference of 5°F [3°C] when the total pressure drop of the system is considered [piping, valves, heat exchanger pressure drop, etc.], the tank could be set as high as 140°F [60°C], since the maximum leaving water temperature for the THW series is 145°F [63°C]. However, if the design temperature difference is 10°F [6°C], the tank temperature must be lowered to a maximum of 135°F [57°C] to avoid a leaving water temperature above the maximum allowed, potentially causing nuisance lockouts. It is always a good idea to provide a few degrees "buffer" for operating conditions where the temperature difference could be lower.

HYDRONIC HEATING / COOLING DISTRIBUTION DESIGN

This section looks at the design parameters associated with each of the delivery systems, particularly when retrofitting an existing hydronic heating system. Domestic water heating, baseboard radiation, cast iron radiators, radiant floor heating and fan coil units will be addressed in this section.

Domestic Water Heating

A water-to-water heat pump is a very efficient means for generating domestic hot water (DHW). Typically, a water-to-water unit is 4 to 6 times more efficient than an electric water heater, providing much lower annual operating costs. Recovery rate is much better than an electric water heater and similar to fossil fuel water heaters. For example, a typical electric water heater has a capacity of 4.5 or 5.5 kW. ClimateMaster's smallest water-to-water unit is 8 kW. Most fossil fuel water heaters have output capacities of 28,000 Btuh to 32,000 Btuh [8.2 to 9.4 kW], depending upon efficiency.

ClimateMaster's THW series heat pumps are already designed for water heating. A 3-way valve is optional, which allows the unit to switch between space heating and domestic water heating. Leaving water temperatures up to 145°F [63°C] are possible with the THW series. The THW is equipped with an internal secondary DHW heat exchanger that keeps the heating water loop separate from the potable water. ClimateMaster TMW series water-to-water heat pumps also have the capability to heat domestic hot water, but the maximum leaving water temperatures are in the 130°F [54°C] range, and the units do not have the controls in place for switching between space heating and domestic water heating.

> **CAUTION:**
> Maximum leaving water temperature of the THW series equipment is 145°F [63°C]. For domestic hot water tank temperatures or heating buffer tank temperatures above 130°F [54°C], pump and pipe sizing is critical to insure that the flow rate through the heat pump is sufficient to maintain leaving water temperatures below the maximum temperature, and to provide water flow rates within the ranges shown in the performance section of this manual.

Part II: Load Side Design / Distribution Design

When generating DHW with a heat pump (other than the THW) or boiler, potable water must never come in contact with heating water. Therefore, an indirect water heater or secondary heat exchanger is required. As shown in figure 2-7, an indirect water heater has a coil inside the tank to isolate the two liquids (potable water and heating water). Figure 2-8 shows a brazed plate heat exchanger that can be used in between the heat pump and direct water heater (electric, oil, natural gas, propane). Only one pump is needed for an indirect water heater (the water-to-water unit's load pump circulates water between the heat pump heat exchanger and the water heater heat exchanger), but two pumps are required when a secondary or brazed plate heat exchanger is used (one pump between the water-to-water unit and the brazed plate and one pump between the brazed plate and the water heater).

Figure 2-6: Example Secondary Heat Exchanger Sizing

SWEP INTERNATIONAL

v.1.5.6

SWEP North America, Inc.
3483 Satellite Blvd., Suite 210
Duluth, GA 30096

SWEP SSP CBE

HEAT EXCHANGER: B10Tx30H/1P (1" fittings)

SINGLE PHASE - Rating

Heat Pump

Customer: Example
Reference: THW010 (60Hz) secondary HX for DHW

Date: 14SEP2007

DHW tank

DUTY REQUIREMENTS		SIDE 1	SIDE 2
Fluid Side 1	Propylene Glycol - Water (20.0 %)		
Fluid Side 2	Water		
Inlet temperature	°F [°C]	143.00 [61.67]	125.00 [51.67]
Outlet temperature	°F [°C]	135.00 [57.22]	132.87 [56.04]
Flow rate	US gpm [l/m]	12.00 [45.43]	12.00 [45.43]
Max. pressure drop			
Thermal length	NTU	0.795	0.782

Sized to deliver 130°F [54°C] at the DHW tank.

PHYSICAL PROPERTIES			
Reference temperature	°F [°C]	139.00 [59.44]	128.94 [53.86]
Dynamic viscosity	cP	0.774	0.514
Dynamic viscosity - wall	cP	0.817	0.496
Density	lb/cuft	62.47	61.57
Specific heat capacity	Btu/lb,°F	0.9699	0.9991
Thermal conductivity	Btu/ft,h,°F	0.3056	0.3744

PLATE HEAT EXCHANGER			
Heat load	Btu/h [W]	46650 [13672]	
Total heat transfer area	sqrft [m^2]	9.34 [0.868]	
Heat flux	Btu/h/sqrft	4995	
Log mean temperature difference	°F [°C]	10.06 [5.59]	
Overall H.T.C. (available/required)	Btu/sqrft,h,°F	950/496	
Pressure drops - total	psi [kPa]	1.62 [11.17]	1.68 [11.58]
- in ports	psi [kPa]	0.194 [1.34]	0.191 [1.32]
Port diameter	in	0.945	0.945
Number of channels		15	14
Number of plates		30	
Oversurfacing	%	91	
Fouling factor	sqrft,h,°F/Btu	0.001	

Note:

DATE 14SEP07 PAGE 1 OF 1

SWEP A DOVER COMPANY

Part II: Load Side Design / Distribution Design

Figure 2-7: Indirect Water Heater

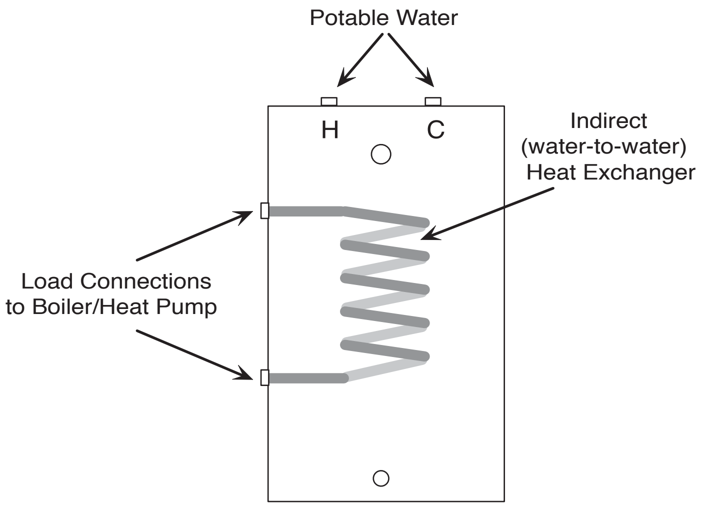
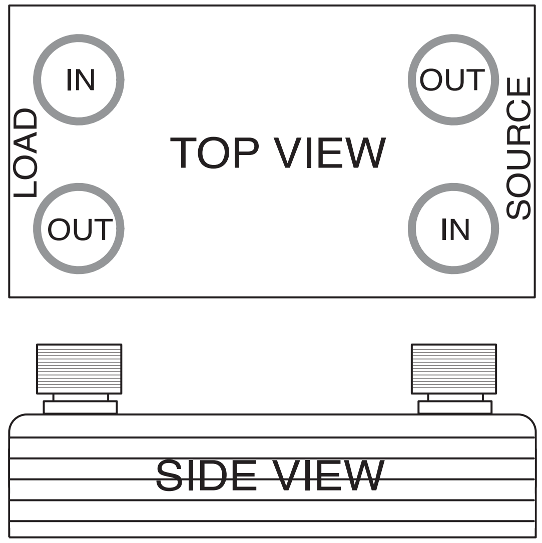


Figure 2-8: Brazed Plate Heat Exchanger



Some indirect water heaters have electric elements for use as backup. The THW series equipment has an emergency DHW function that will send a 24VAC signal to a field-installed contactor to energize the backup electric elements if the unit is locked out. A direct electric water heater could also be used for backup when a brazed plate heat exchanger is installed.

IMPORTANT DESIGN NOTE: Most indirect water heaters are designed for 180°F [82°C] water circulating through the heat exchanger. At lower water temperatures capacities are significantly reduced. Make sure that the heat exchange capacity is adequate at the lower water temperatures used by water-to-water heat pumps. Some indirect solar water heater manufacturers publish data at lower water temperatures, and some European manufacturers of indirect water heaters have significantly more heat exchange surface (i.e. more coils), which will allow the use of cooler water. Brazed plate heat exchanger sizing is also critical for the same reason. Larger heat exchangers will be required for lower DHW temperatures.

Figure 2-9: Indirect Water Heaters

"Typical" indirect water heater rated for 180°F (82°C) or hotter water.

Indirect water heater with more surface area (photo courtesy of TURBOMAX). Consult manufacturer's data for operating at lower water temperatures.

Part II: Load Side Design / Distribution Design

RADIANT FLOOR HEATING

Radiant floor heating has been used for centuries. The Romans channeled hot air under the floors of their villas. In the 1930s, architect Frank Lloyd Wright piped hot water through the floors of many of his buildings. Home builders' surveys have shown that, if given a choice, most new home owners prefer radiant floor heat over other types of systems. A simple 1" [25mm] diameter pipe can carry as much heat as a 10" x 19" [254 x 483 mm] rectangular duct carrying hot air at 130°F [54°C].

Comfort is improved with radiant floor systems. A room with radiant floor heating will have an average floor temperature of 80-85°F [27-29°C] with an overall room temperature at occupant level of 68-70°F [20-21°C]. In forced air systems temperatures near the ceiling often reach 90-100°F [32-38°C], which can be 20-30°F [11-17°C] higher than the temperature at the floor. (see figures 2-10a and 2-10b). Therefore, radiant floor heating is more comfortable because heat is directed to occupant level. Radiant floor heating systems may also lower operating costs, since a lower thermostat setting is typically used for this type of system as compared to forced air. The lower heat loss at the ceiling lowers the temperature difference between the ceiling and the outside, resulting in a smaller heat loss, which lowers the heat pump capacity required to heat the structure.

Figure 2-10a: Fahrenheit

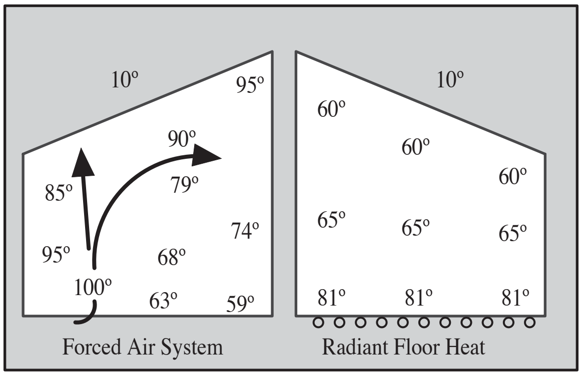
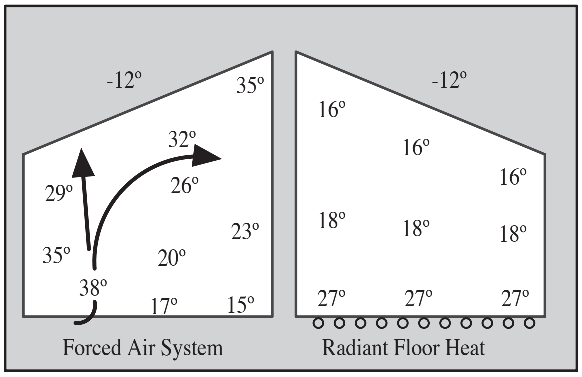


Figure 2-10b: Celsius



Conventional cast iron radiators or fin-tube baseboard units often present obstacles to the effective use of floor and wall space within a room. They severely restrict the placement of furniture, as well as the placement of paintings, wall hangings, and other decor. With radiant floor technology, these obstacles are eliminated giving homeowners more freedom to arrange their rooms as they choose.

Advantages of Geothermal Radiant Floor Heating:

- Independent zoning
- Ductless
- Quiet
- Reliable, fewer moving parts
- Easily controlled
- Space savings - Fewer limitations of furniture or room arrangements
- Can be matched to another system for air conditioning, if needed
- Equipment requires smaller installation footprint than a standard boiler installation.
- Does not require complex ventilation to vent away potentially harmful combustion gases
- No combustion chamber to maintain and clean
- No risk of carbon monoxide (CO) poisoning
- Simple controls - One thermostat or zoned thermostats

Most people who own radiant floor heating systems feel that the most important advantages are comfort and quiet operation. Radiant floor systems allow even heating throughout the whole floor, not just in localized spots as with other types of heating systems. The room heats from the bottom up, warming the feet and body first.

Radiant floor heating also allows for lower water temperatures, which uses less energy and lowers utility bills. Radiant floors operate between 85-140°F [29-60°C], compared to other hydronic heating systems' range of 130-180°F [54-82°C].

To some, the greatest advantage of radiant floor heating is aesthetic. The system is "invisible." There are no heat registers or radiators to obstruct furniture arrangements and interior design plans. Radiant floor systems also eliminate the fan noise of forced hot air systems.

Combining the advantages of radiant floor heating with the advantages of geothermal technology provides unmatched comfort and savings. Plus, ClimateMaster water-to-water units can share the same ground loop with the water-to-air cooling system, or can be used for chilled water for fan coil units. Most systems, however, use a separate forced air geothermal system for the ultimate in comfort, energy cost savings and ease of control. Radiant floor heating and geothermal systems provide home owners with state-of-the art heating and cooling.

Homes are not the only benefactors of radiant floor heating systems. Industrial buildings, especially those with high ceilings and large overhead doors, have an advantage with a radiant floor heating system. Heat energy is stored in the concrete floor.

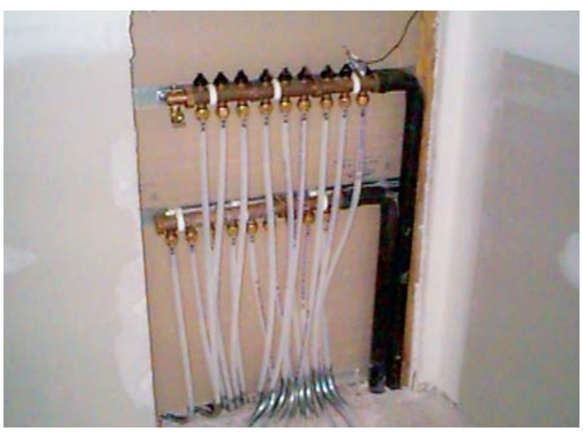
Part II: Load Side Design / Distribution Design

When a door is opened, the stored heat is released to the space immediately. The larger the temperature difference between the air in the space and the floor, the quicker the floor releases its heat to the space.

Maintenance garages benefit from radiant floor heating systems. Cold vehicles brought into the garage are warmed from underneath. The snow melts off the vehicle and dries much more quickly than when heated from above. In addition, mechanics who work on the vehicles will be more productive, especially when their work requires them to lie on the floor.

Health care centers and child care centers can benefit greatly from radiant heating. Since children play on the floor frequently, the benefits of a warm floor will keep children from getting chilled while playing.

Figure 2-11: Radiant Floor Zone Manifold



In residential applications occupants in a space feel comfortable with lower air temperatures if their feet are warm. Typically the space will feel comfortable with air temperatures as low as 65°F [18°C]. Since the heat loss of a building is directly related to the temperature difference between inside and outside, a lower temperature difference also means the heat loss is lower.

Some of the factors affecting the heating capacity of a floor heating system are:

- Spacing of the pipe – tighter spacing increases heating capacity.
- Water flow through the pipe – more water flow increases capacity (high flow rates, however, increase pressure drop and may result in larger pumps).
- Temperature of the supply water – higher temperature increases heating capacity of the floor.
- Sub-floor material (wood, concrete or light-weight poured concrete) – concrete is best.
- Floor covering (ceramic tile, carpet, wood, etc.) – be careful with carpeting, which is an insulator, and may require hotter water and/or tighter pipe spacing depending upon pad type, carpet type, and thickness.
- Insulation value under the floor – make sure that the system is not heating the ground underneath instead of the conditioned space.
- Piping layout – always consult the piping manufacturer's literature for the best layout.

The spacing of the pipe in residential applications can vary from 4" to 12" [10 to 30 cm]. If the spacing is too great, the temperature of the floor can vary noticeably. The design of the radiant floor piping system is beyond the scope of this manual. Most distributors of radiant floor piping and accessories offer some design assistance to heating and cooling contractors.

Once the load calculations have been finished, the water-to-water equipment [and loop if applicable] has been sized, and the buffer tank has been designed, the radiant floor piping system can be designed based upon the water temperature in the buffer tank (i.e. aqua-stat set point or maximum water temperature at design conditions if using outdoor reset).

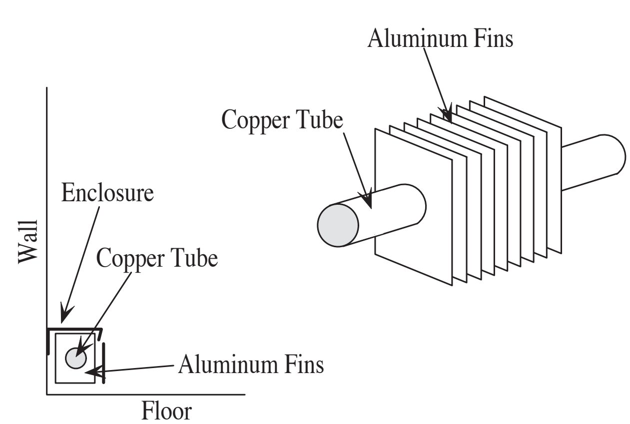
BASEBOARD RADIATION

In existing systems, baseboard radiation is typically designed to operate with 160-200°F [71-93°C] water or steam. Baseboard radiators are usually constructed of copper tube with closely spaced aluminum fins attached to provide more surface area to dissipate heat, as shown in figure 2-12. Some of the factors affecting the amount of heat given off by fin tube radiators are the water temperature, water flow, air temperature, pipe size and fin size/spacing. A decorative cover is normally fitted over the fin tube.

In some cases, water-to-water heat pumps can replace a boiler that was used to generate hot water for baseboard radiation. For example, if an existing home has had weatherization and insulation upgrades, it is possible that the heat loss of the home has decreased enough to allow lower water temperatures. Manufacturer's data on the baseboard convector should be consulted to determine the Btuh/ft. of radiation [W/m] at lower water temperatures. The THW series can provide up to 145°F [63°C] for baseboard radiation. Higher water temperatures, however, lower the C.O.P. of the heat pump, so lower water temperatures are better if possible.

Another alternative for baseboard radiation is double-stack convection, where there are two rows of fin/tubes within the enclosure. This denser design allows for the use of cooler water temperatures.

Figure 2-12: Baseboard Radiation



Part II: Load Side Design / Distribution Design

The heating capacity of a baseboard system is a factor of the area of copper tube and fins exposed to the air, and the temperature difference between the air and the fin tube. The velocity and volume of water flowing through the baseboard affects the temperature of the copper and fins. Baseboard units are normally rated in heat output per length of baseboard at a standard water temperature and flow rate. Manufacturers provide charts, which will give the capacities at temperatures and flow rates below the standard. Table 2-2 shows approximate heating capacities for fin tube radiation using water from 100-200°F [43-93°C].

Table 2-2: Heating Capacity in Btuh/Foot [Watts/meter] of Baseboard Radiators

Average Water Temperature	Entering Air Temperature		
	55°F [13°C]*	65°F [18°C]*	70°F [21°C]*
110°F [43°C]	190-380 [184-364]	160-320 [154-308]	150-300 [144-289]
120°F [49°C]	240-480 [230-463]	205-410 [197-394]	195-390 [187-374]
130°F [54°C]	295-590 [282-568]	265-532 [255-512]	245-490 [236-472]
140°F [60°C]	350-700 [338-673]	315-630 [302-607]	295-590 [282-568]
200°F [93°C]		700-1400 [673-1345]	

*Table values are in Btuh/ft. [W/m]

The heating capacity in Btuh/foot [Watts/meter] of baseboard radiators drops as the water temperature is reduced. The heating capacity of most copper fin tube baseboard radiators is rated using 200°F [93°C] water and 65°F [18°C] air temperature. Listed above is the range of heating capacities of baseboard radiators at the standard temperatures and the capacities when the temperatures are reduced to the operating range of a heat pump system. Some of the factors that affect the capacity of a radiator are as follows:

- Size of the fins - range from 2.75" x 3" [7 x 7.6 cm] to 4" x 4"[10.2 x 10.2 cm]
- Fin spacing - 24 to 48 per foot [79 to 157 per meter]
- Size of copper tube - range from 3/4"[19 mm] to 2" [50 mm]
- Fin material - aluminum or steel
- Configuration and height of the enclosure
- Height unit is mounted from the floor
- Water flow through the tubing

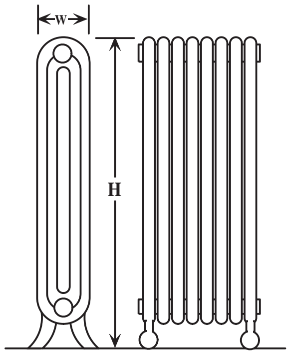
Generally, the smaller fins with less fins per foot [meter] will have lower heating capacity. Larger copper tube diameter and/or more aluminum fins will have higher capacity. Higher water flow will increase capacity. Adding a second fin tube to the same enclosure will increase the capacity by 50 to 60%. Adding two fin tubes with enclosures will increase the capacity by 75 to 80%. Baseboards are available, using two or three fin tubes tiered above one another in the same cabinet. The air can be heated enough with the additional surface area to set up a convection current with water temperatures as low as 110-130°F [43-54°C].

The operation of a baseboard radiation system depends on the ability to set up convection current in the room (i.e. air is warmed by the fin tube, rises and is displaced by cool air). It is important to ensure that the heat output of the system is adequate to meet the heat loss of the room or building at the temperatures the geothermal system is capable of producing. Baseboard radiation is limited to space heating. Cooling is typically provided by a separate, forced air distribution system.

CAST IRON RADIATION

Retrofit applications for hydronic / geothermal heat pump systems are often required to work with existing cast iron radiators. Typically, cast iron radiator systems, as shown in figure 2-13, operate with water temperatures of 125-200°F [52-93°C]. As with baseboard systems, if an existing home has had weatherization and insulation upgrades, it is possible that the heat loss of the home has decreased enough to allow lower water temperatures. Cast iron radiators can operate well with design water temperature as low as 110°F [43°C]. Careful consideration must be made, however, when operating at lower temperatures, as the heat emission rate is substantially less when operating below 140°F [60°C]. To determine heat emission for cast iron radiators, calculate the surface area of the radiator, and refer to table 2-3 for output capacity. Note: Table 2-3 is for general reference only. The various cast iron radiator styles and sizes will change the output. Many resources are available for determining heating capacities. Also consult the radiator manufacturer's data when possible.

Figure 2-13: Cast Iron Radiator



Part II: Load Side Design / Distribution Design

Table 2-3: Typical Cast Iron Radiator Capacities

Design Water Temperature, °F [°C]	Btuh per sq ft	Watts per sq m
110 [43]	30	95
120 [49]	50	158
130 [54]	70	221
140 [60]	90	284
180 [82]	170	536
200 [93]	210	663

FAN COIL UNITS

Fan coil units (or air handlers) consist of a hot water coil and/or chilled water coil (usually copper tubing with aluminum fins) and a fan or blower to move the air over the coil. The term "fan coil unit" typically applies to smaller units, which are installed in the zone or area where the heating or cooling is needed. The term "air handler" normally refers to larger units. Fan coils are available in many different configurations, sizes and capacities from a number of manufacturers. Some are designed to be connected to a duct work system and can be used to replace a forced air furnace. Others are designed for use without duct work, and are mounted in a suspended ceiling space with only a grill showing in place of a ceiling tile. There are also console type fan coils that can be mounted on a wall under a window or flush with the wall surface. A typical horizontal fan coil illustration is shown in figure 2-14.

Figure 2-14: Typical Horizontal Fan Coil

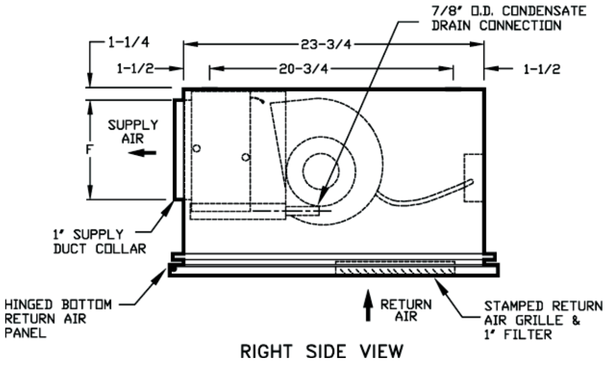


Table 2-4: International Environmental Corp. – Fan Coil Heating Water Temperature Capacity Correction Factor Table

EAT °F [°C]	EWT °F [°C]							
	100 [38]	110 [43]	120 [49]	130 [54]	140 [60]	145 [63]	150 [66]	180 [82]
65 [18]	0.318	0.409	0.500	0.591	0.682	0.728	0.773	1.045
68 [20]	0.295	0.386	0.478	0.568	0.659	0.705	0.750	1.023
70 [21]	0.272	0.363	0.455	0.545	0.636	0.682	0.727	1.000

Fan coils and air handlers typically have one or two coils and a blower. Air is heated by hot water circulated through a hot water coil. Chilled water is circulated through the coil if cooling is needed. Depending upon the application, the unit will include one coil for both heating and cooling (hot water/chilled water) or a coil dedicated to heating (hot water) and another coil specifically for cooling (chilled water). Blowers can be provided to fit various applications, with or without duct work. Unit heaters (small, wall-mounted fan coils) typically use axial fans in applications where duct work is not needed.

Fan coil units have been used to heat buildings using water temperatures as low as 90-100°F [32-38°C]. As with radiators/baseboard convectors, heating capacities fall dramatically when operated below design temperatures. Table 2-4 shows the heating correction factors for lower water temperatures. For example, a fan coil designed for 180°F [82°C] entering water temperature and 70°F [21°C] entering air temperature would have only 36% of its original heating capacity when operated at 110°F [43°C] entering water temperature. For this reason, two coils are recommended if the fan coil will be used for forced air space heating, one for heating, one for cooling. Careful consideration should be given to fan coil selection, since the heating and cooling coils could be significantly different in physical size. Proper fan coil selection may involve selecting a larger model with multiple fan speeds in order to satisfy the capacity requirements without providing too much airflow. Manufacturers' literature will be necessary for proper selection.

In a retrofit situation when replacing a conventional boiler, care must be taken to ensure that any air handlers or fan coil units in the building will heat the building with cooler water temperatures, and will be able to handle the increased flow rates if necessary. If the insulation levels of the building are being upgraded, the existing coils may meet the lower heat loss of an upgraded building with lower water temperatures.

Part II: Load Side Design / Distribution Design

SNOW MELTING APPLICATIONS

Although snow melting is now considered somewhat controversial due to the energy use, geothermal systems are quite capable of heating sidewalks and driveways for melting snow. As with any hydronic heating system, the load calculation is the first and most important step in designing a reliable and cost-effective snow melt system. Consult the ASHRAE HVAC Applications Handbook for slab piping design and temperature requirements.This will determine the Btu/hr [kW] requirement of the water-to-water equipment. Follow procedures above for sizing the equipment and buffer tank.

The hot water in the piping system will heat the slab, melting the snow. Snow melt controls are available that actually "sense" when conditions are right for snowfall. Snow/ice melt detection is used to automatically start and stop a snow melt system. When there is snow on the sensor, the sensor melts the snow/ice, detects the moisture and allows the control to start the melting process. This prevents accumulation of snow on the slab and provides a faster response. Automatic snow/ice detection is safer, more convenient and consumes less energy than manual (ON/OFF) type systems.

In systems where snow and ice removal is critical, such as hospital ramps, the pick up time for a snow melting slab can be reduced by maintaining the slab at an idling temperature. The idling temperature may be just below the freezing point. When snow melting is required, the slab temperature is increased. When the slab and outdoor temperatures are warm enough, the snow melting system should automatically turn off.

Another important aspect of choosing a good controller is slab protection. Snow melt systems deal with extreme temperature differences. Limiting the rate of heat transfer into the slab provides slab protection. This is done by slowly ramping up the temperature difference across the slab and limiting the maximum temperature difference. This function prevents cracking of the slab due to thermal expansion caused by high heat output.

Piping design and component selection for a snow melt system are identical to systems used for hydronic heating (see drawings 2-2 and 2-3). The difference is simply the load on the system. In other words, the size of the water-to-water unit and the related components is calculated based upon the amount of heat needed for a sidewalk [for snow melting] instead of the amount of heat needed to condition a structure.

COOLING SYSTEMS

Cooling an existing building with a radiant heating system can be a challenge. If radiant heating emitters (radiators, baseboard convectors, radiant floor piping) are cooled lower than the dew point, condensation will form on the floor or drip off the emitters. A limited amount of cooling can be accomplished by circulating chilled water through the piping in the floor or through radiant ceiling panels. This can be effective in buildings with high solar loads or lighting loads, where much of the heat gain is radiant heat. Cooling and dehumidifying fresh air used for ventilation as it is brought into the building (using a dedicated outside air system) can sometimes provide the additional cooling needed. Care must be taken to avoid cooling the radiant surface below the dew point.

A water-to-water heat pump system can provide chilled water to ducted or non-ducted fan coil units. A reversible water-to-water heat pump can provide chilled water to cool the building, as well as hot water for the heating system. Buildings with fan coil units can generally be retrofitted for cooling quite easily. The difficulty, as mentioned above, is using existing fan coils for heating, especially if they were originally sized for higher water temperatures.

For optimal cooling and dehumidification, ClimateMaster recommends a separate water-to-air heat pump for cooling. Controls are much simpler when a water-to-water unit is used for space heating and/or domestic water heating, and a water-to-air unit is used for cooling. Since the water-to-water and water-to-air units can share one ground loop, the installation cost of using a water-to-air unit for cooling is simply the incremental cost of the unit. Generally, no additional ground loop is required, and the cost of the water-to-air unit is usually less than the cost of chilled water/ fan coil units, especially if the cost of additional piping/valving/ controls and labor is considered. The cost of a water-to-air unit is approximately the same as a ductless mini split, and is much more efficient. The advantages of geothermal heat pumps for cooling (no outdoor unit, no refrigerant line sets, longevity, etc.) should be considered when cooling is required.

Part III: Source Side Design / System Selection

SYSTEM DESIGN

System Selection

Figures 3-1a and 3-1b present system selection in flow chart format for the source side of the water-to-water unit. There are five piping schematics following the flow charts that illustrate each of the possible choices. To select the correct drawing, begin in figure 3-1a, and finish the selection process in figure 3-1b if necessary.

Figure 3-1a: System Selection Flow Chart (Part 1)

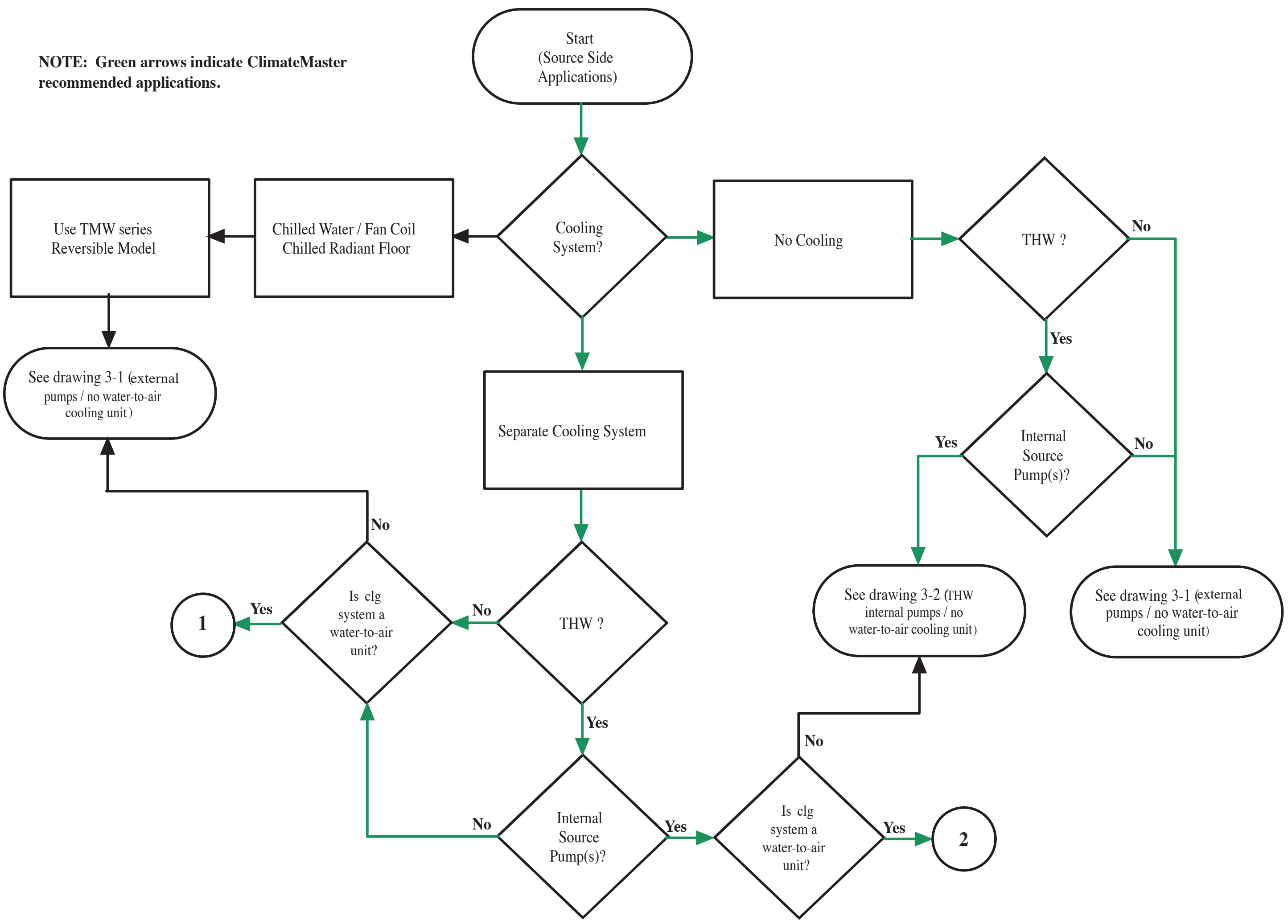
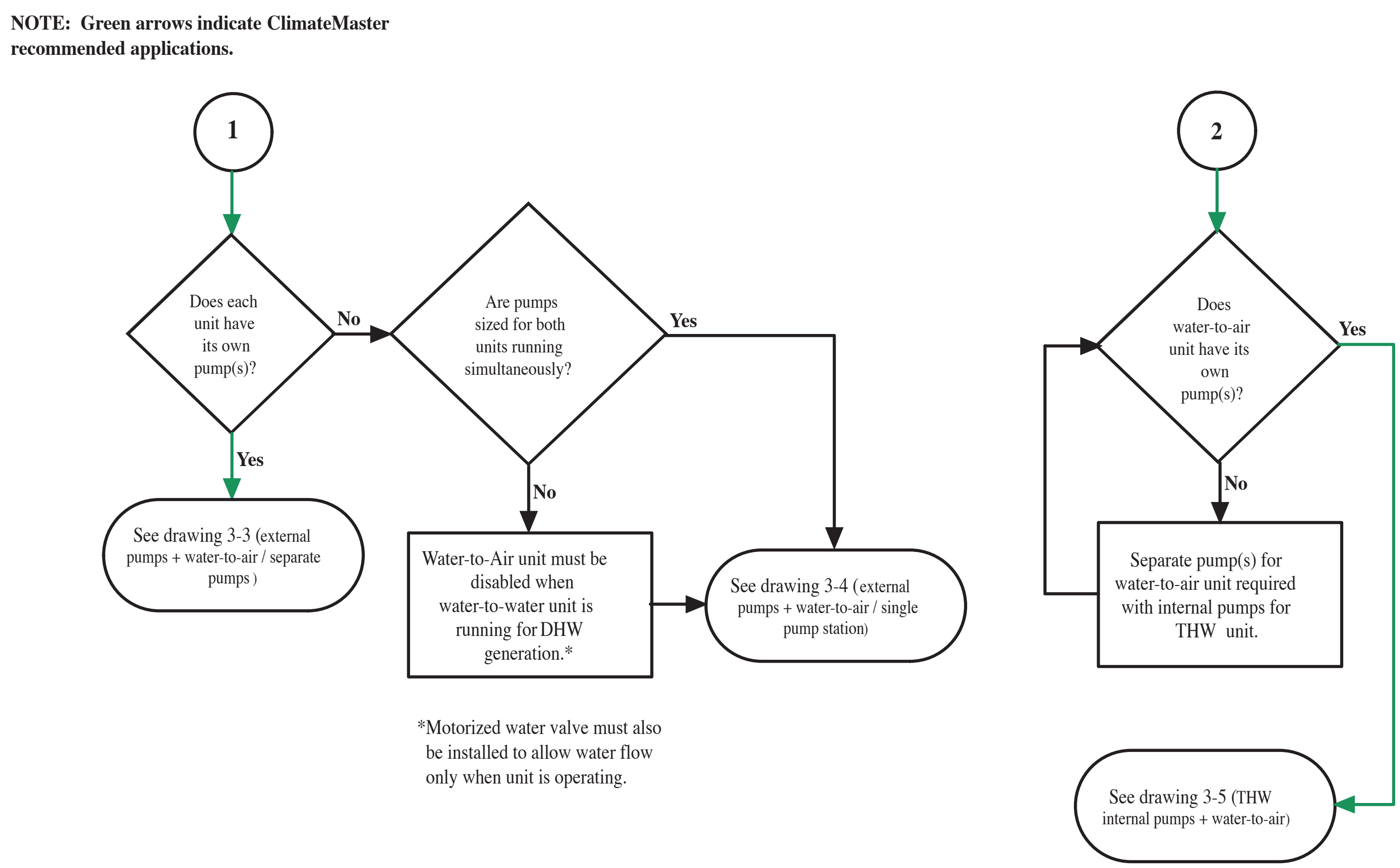


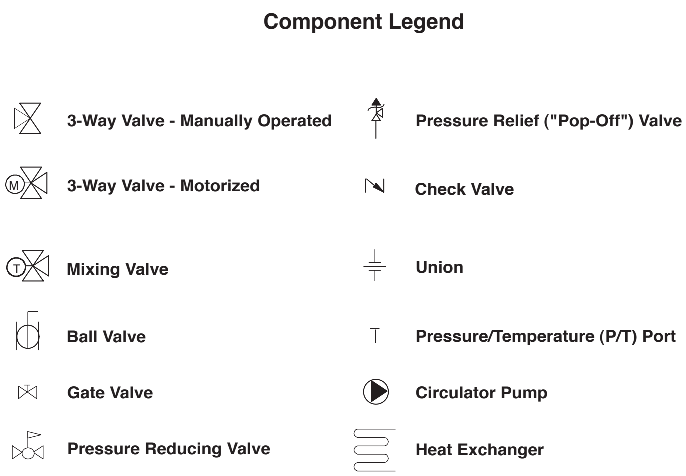
Figure 3-1b: System Selection Flow Chart (Part 2)



Part III: Source Side Design / System Selection

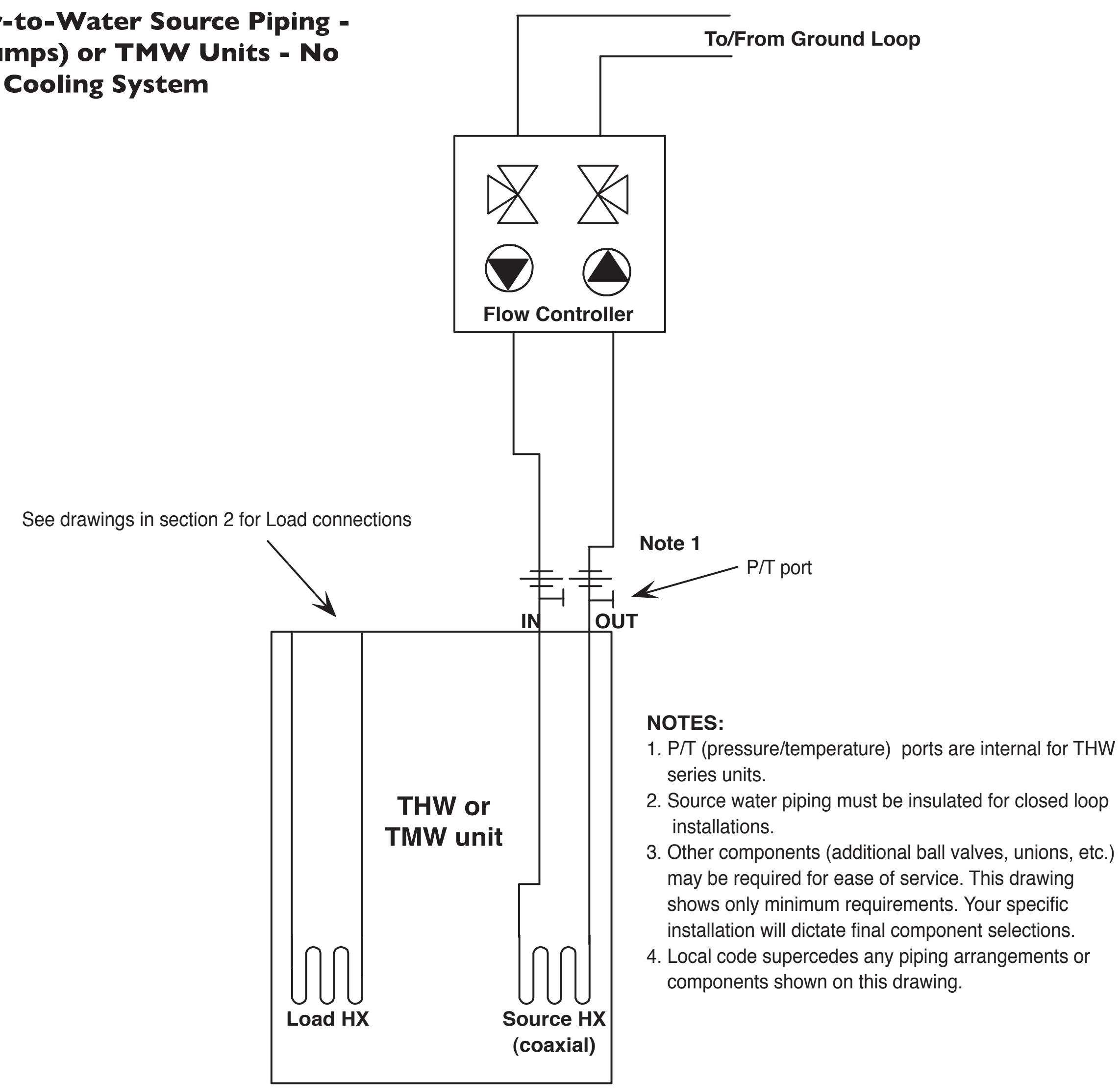
System Descriptions

Figure 3-2: Component Legend for Drawings 3-1 to 3-5



Drawing 3-1 – Heating only application with external Flow Controller: Drawing 3-1 is used for water-to-water units without internal source pumps. The ClimateMaster Flow Controller includes one or two circulator pumps, plus 3-way valves for purging air from the system. It is important to note that when headering the ground loop outside of the mechanical room the header must be a reducing type in order to be able to purge air from the system at the Flow Controller 3-way valves. Reducing headers are addressed later in this section.

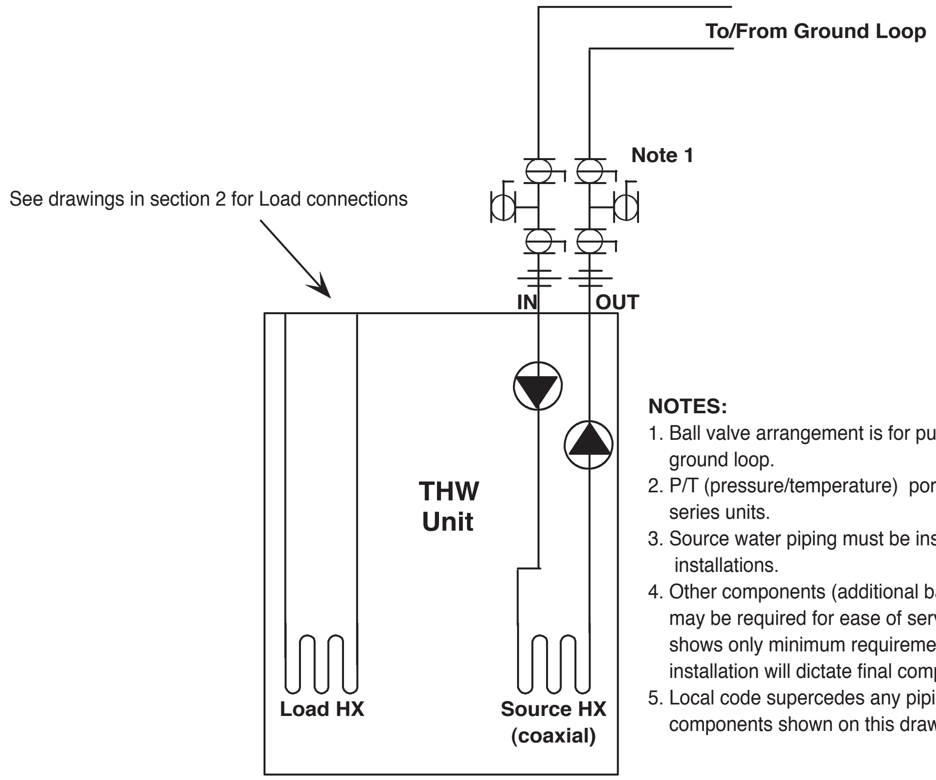
Drawing 3-1: Water-to-Water Source Piping - THW (No Source Pumps) or TMW Units - No Cooling or Separate Cooling System



Part III: Source Side Design / System Selection

Drawing 3-2 – Heating only application with internal source pump(s) – THW only: Drawing 3-2 is used for THW series units with optional internal source pump(s). Three-way valves are required for purging air from the system. It is important to note that when headering the ground loop outside of the mechanical room the header must be a reducing type in order to be able to purge air from the system at the Flow Controller 3-way valves. Reducing headers are addressed later in this section.

Drawing 3-2: THW Source Piping (Internal Source Pumps) - No Cooling or Separate Cooling System



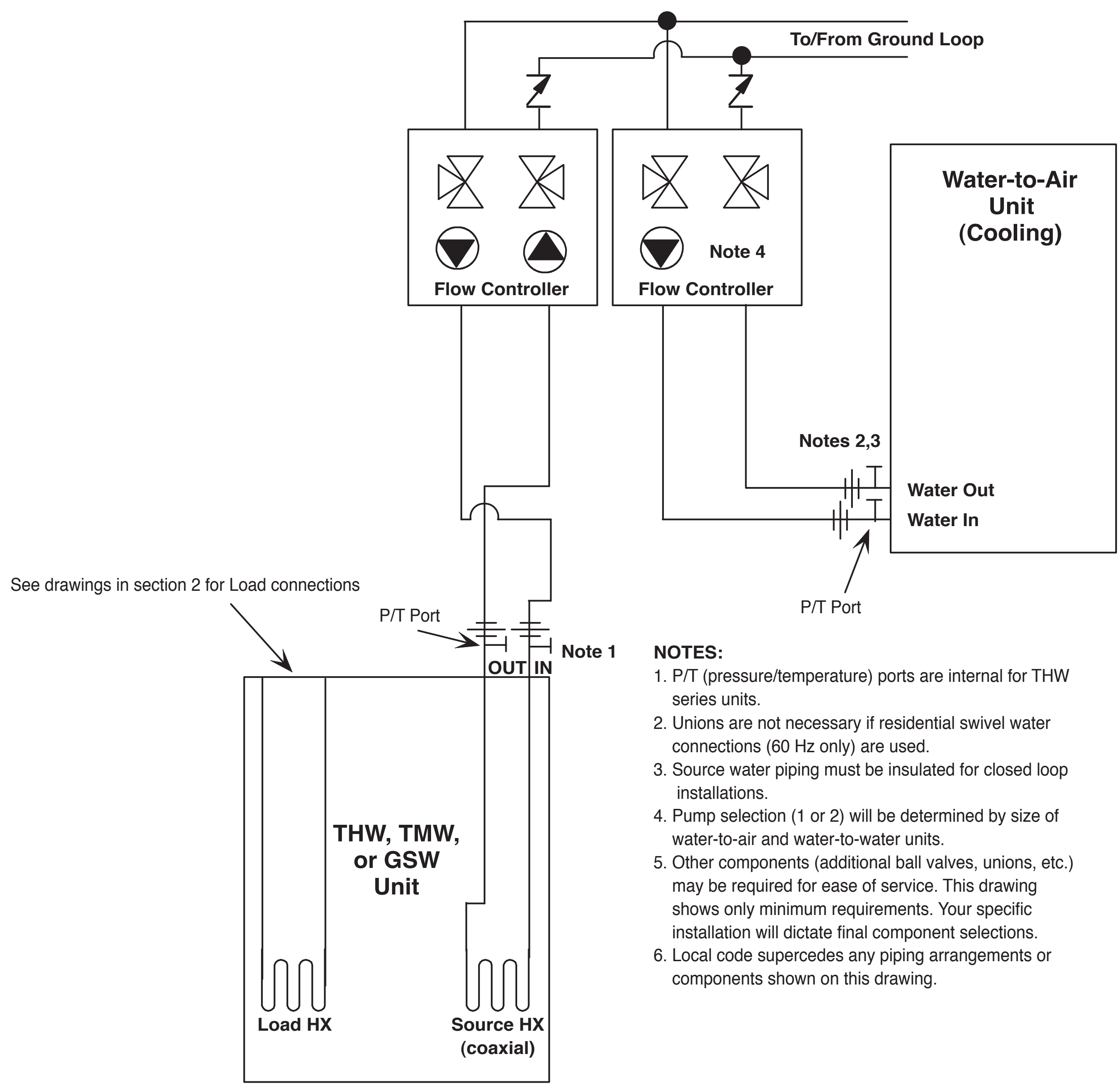
NOTES:

1. Ball valve arrangement is for purging air from the ground loop.
2. P/T (pressure/temperature) ports are internal for THW series units.
3. Source water piping must be insulated for closed loop installations.
4. Other components (additional ball valves, unions, etc.) may be required for ease of service. This drawing shows only minimum requirements. Your specific installation will dictate final component selections.
5. Local code supercedes any piping arrangements or components shown on this drawing.

Part III: Source Side Design / System Selection

Drawing 3-3 – Heating with water-to-water unit and cooling with water-to-air unit application – units without internal source pump(s) / separate Flow Controllers for each unit: Drawing 3-3 is used for water-to-water units without internal source pumps. The ClimateMaster Flow Controller includes one or two circulator pumps, plus 3-way valves for purging air from the system. The use of a separate water-to-air unit for cooling is the ClimateMaster preferred application when cooling is required (drawings 3-3, 3-4, and 3-5). This application provides better and simpler control of the heating and cooling system. Plus, pumps can be sized specifically for each unit's flow rate (except drawing 3-4). Check valves are required on the loop side of the Flow Controller piping to prevent short cycling (i.e. bypassing the ground loop). In cases where the water-to-water unit will be generating domestic hot water in the summer when the water-to-air unit is operating, a mixing valve may be required to ensure that the entering source water temperature to the water-to-water unit is not warmer than the maximum temperature shown in the performance catalog (TMW units only). It is important to note that when headering the ground loop outside of the mechanical room the header must be a reducing type in order to be able to purge air from the system at the Flow Controller 3-way valves. Reducing headers are addressed later in this section.

Drawing 3-3: Water-to-Water Source Piping - THW (No Source Pumps) or TMW Units - Water-to-Air Cooling with Separate Loop Pumps (ClimateMaster Preferred System When Cooling is Desired)



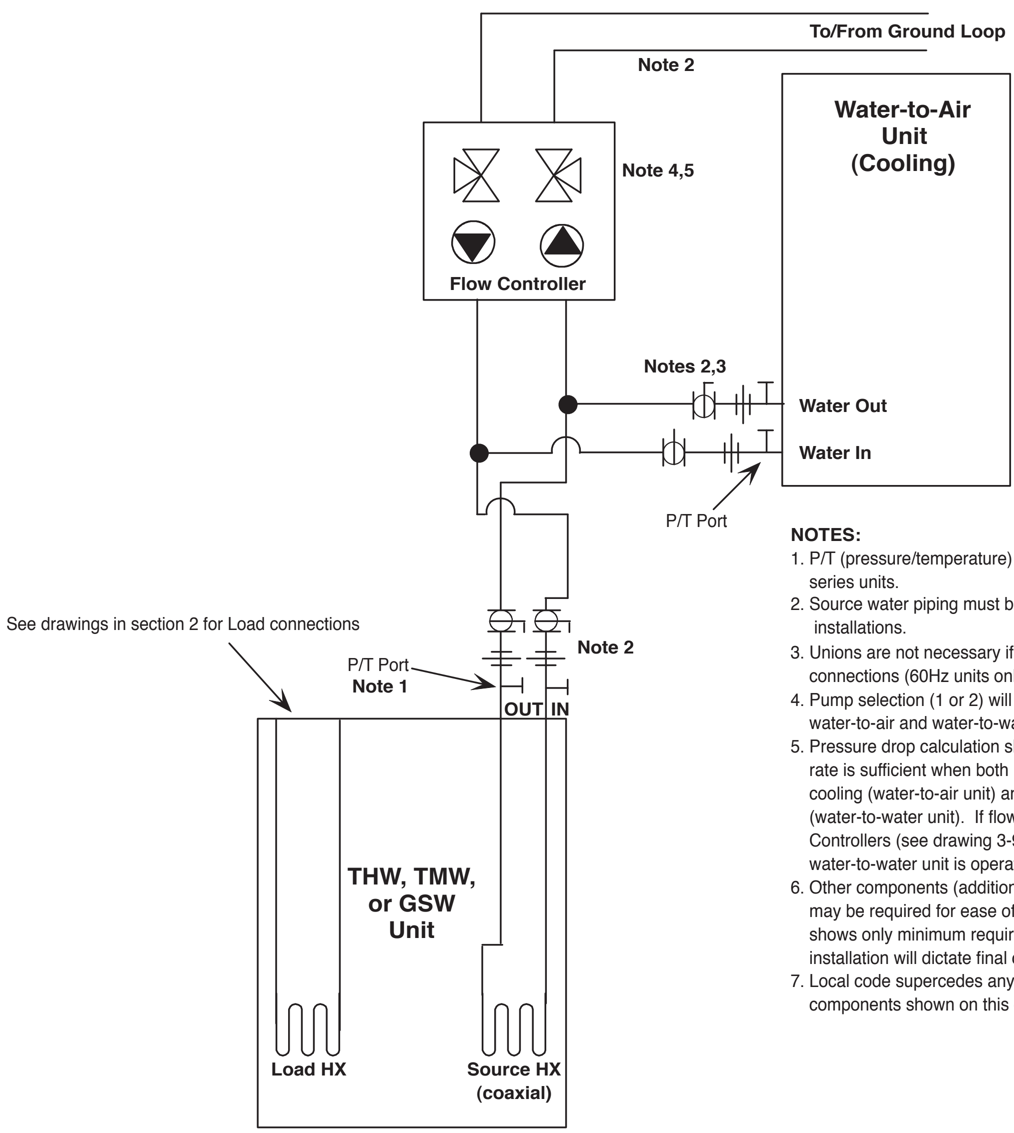
NOTES:

1. P/T (pressure/temperature) ports are internal for THW series units.
2. Unions are not necessary if residential swivel water connections (60 Hz only) are used.
3. Source water piping must be insulated for closed loop installations.
4. Pump selection (1 or 2) will be determined by size of water-to-air and water-to-water units.
5. Other components (additional ball valves, unions, etc.) may be required for ease of service. This drawing shows only minimum requirements. Your specific installation will dictate final component selections.
6. Local code supercedes any piping arrangements or components shown on this drawing.

Part III: Source Side Design / System Selection

Drawing 3-4 – Heating with water-to-water unit and cooling with water-to-air unit application – units without internal source pump(s) / single Flow Controller for both units: Drawing 3-4 is used for water-to-water units without internal source pumps. The ClimateMaster Flow Controller includes one or two circulator pumps, plus 3-way valves for purging air from the system. The use of a separate water-to-air unit for cooling is the ClimateMaster preferred application when cooling is required (drawings 3-3, 3-4, and 3-5). This application provides better and simpler control of the heating and cooling system. Plus, pumps can be sized specifically for each unit's flow rate (except drawing 3-4). When using only one set of source pumps, as shown in drawing 3-4, care must be taken to ensure that all combinations of unit operation are considered. In other words, if both units are running (e.g. water-to-water unit is making domestic hot water and the water-to-air unit is cooling), the pumps must be sized so that both units have sufficient water flow. If it is not possible for both units to run with this type of arrangement (i.e. there is not enough flow), the water-to-air unit compressor should be locked out when the water-to-water unit is running via a field-installed relay (water flow must also be stopped through the water-to-air unit via a water solenoid valve). Since the domestic hot water tank should be quickly satisfied, a momentary disruption of cooling will be less noticeable than an interruption in domestic hot water generation (domestic hot water priority). In cases where the water-to-water unit will be generating domestic hot water in the summer when the water-to-air unit is operating, a mixing valve may be required to ensure that the entering source water temperature to the water-to-water unit is not warmer than the maximum temperature shown in the performance catalog (TMW units only). It is important to note that when headering the ground loop outside of the mechanical room the header must be a reducing type in order to be able to purge air from the system at the Flow Controller 3-way valves. Reducing headers are addressed later in this section.

Drawing 3-4: Water-to-Water Source Piping - THW (No Source Pumps) or TMW Units - Water-to-Air Cooling (Shared Pumping with Water-to-Water)

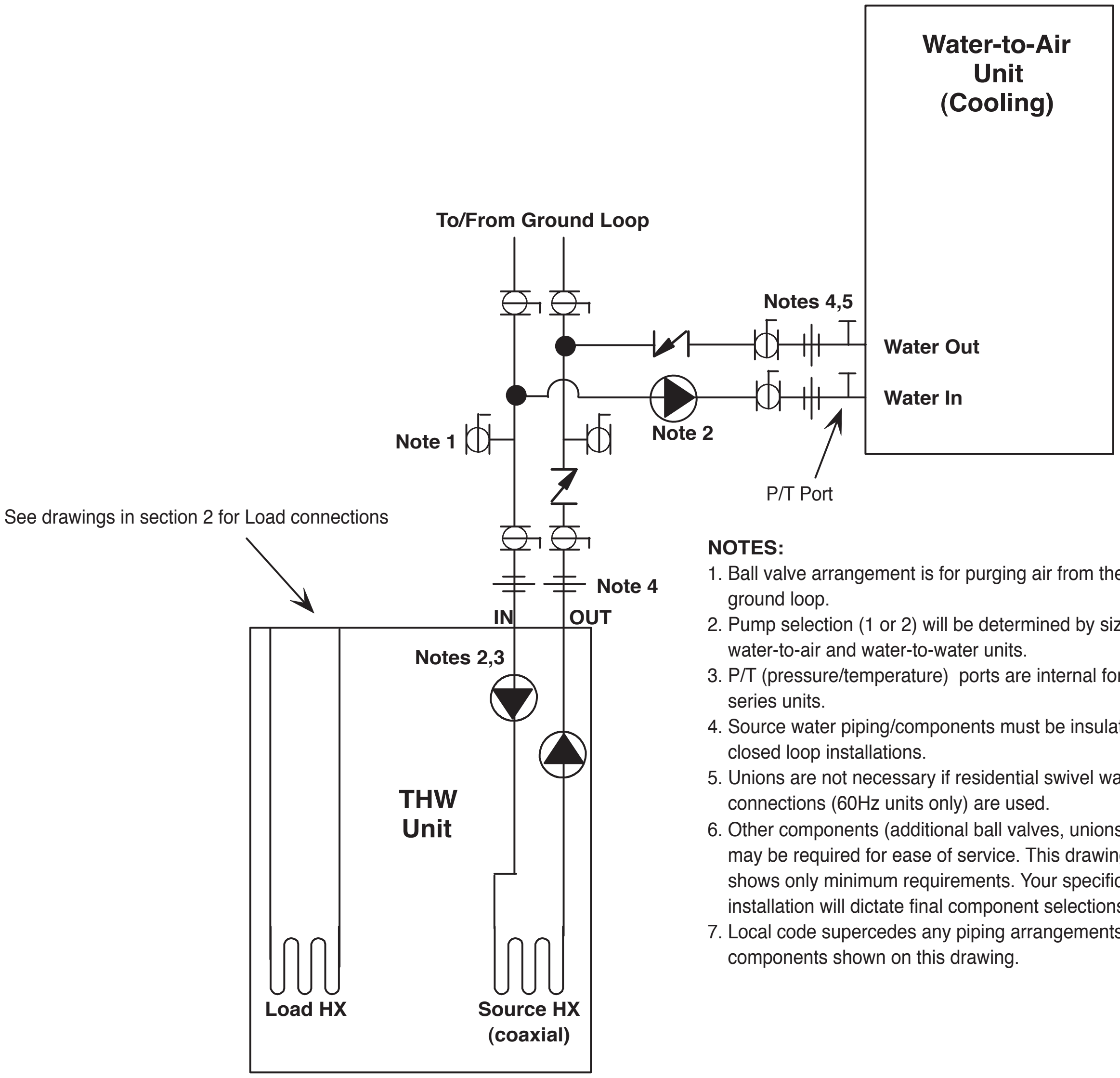


NOTES:
1. P/T (pressure/temperature) ports are internal for THW series units.
2. Source water piping must be insulated for closed loop installations.
3. Unions are not necessary if residential swivel water connections (60Hz units only) are used.
4. Pump selection (1 or 2) will be determined by size of water-to-air and water-to-water units.
5. Pressure drop calculation should be made to determine if flow rate is sufficient when both units are operating (e.g. forced air cooling (water-to-air unit) and domestic hot water generation (water-to-water unit). If flow is not sufficient, use two Flow Controllers (see drawing 3-9) or lock out cooling unit when water-to-water unit is operating to generate DHW.
6. Other components (additional ball valves, unions, etc.) may be required for ease of service. This drawing shows only minimum requirements. Your specific installation will dictate final component selections.
7. Local code supercedes any piping arrangements or components shown on this drawing.

Part III: Source Side Design / Open Loop Design

Drawing 3-5 – Heating with water-to-water unit and cooling with water-to-air unit application – water-to-water units with optional internal source pump(s) / separate pump(s) for each unit: Drawing 3-5 is used for water-to-water units with optional internal source pumps. A combination of ball valves as shown in the drawing is required for purging air from the system. The use of a separate water-to-air unit for cooling is the ClimateMaster preferred application when cooling is required (drawings 3-3, 3-4, and 3-5). This application provides better and simpler control of the heating and cooling system. Plus, pumps can be sized specifically for each unit's flow rate (except drawing 3-4). Check valves are required at each unit to prevent short cycling (i.e. bypassing the ground loop). In cases where the water-to-water unit will be generating domestic hot water in the summer when the water-to-air unit is operating, a mixing valve may be required to ensure that the entering source water temperature to the water-to-water unit is not warmer than the maximum temperature shown in the performance catalog (TMW units only). It is important to note that when headering the ground loop outside of the mechanical room the header must be a reducing type in order to be able to purge air from the system at the Flow Controller 3-way valves. Reducing headers are addressed later in this section.

Drawing 3-5: THW Source Piping (Internal Source Pumps) - Separate Water-to-Air Cooling System



NOTES:
1. Ball valve arrangement is for purging air from the ground loop.
2. Pump selection (1 or 2) will be determined by size of water-to-air and water-to-water units.
3. P/T (pressure/temperature) ports are internal for THW series units.
4. Source water piping/components must be insulated for closed loop installations.
5. Unions are not necessary if residential swivel water connections (60Hz units only) are used.
6. Other components (additional ball valves, unions, etc.) may be required for ease of service. This drawing shows only minimum requirements. Your specific installation will dictate final component selections.
7. Local code supercedes any piping arrangements or components shown on this drawing.

Part III: Source Side Design / System Selection

HEAT SOURCE/HEAT SINK

The heat source/heat sink for geothermal systems is determined based upon the specific application. Where water quality is good and a sufficient quantity of water is available, an open loop (well water) source/sink is a very cost effective solution. Otherwise, one of the three types of closed loop applications may be a better choice. In any case, operating costs are very similar, since the source/sink and heat pump are sized according to the heat loss/heat gain of the home. All residential applications (open or closed loop) require extended range equipment. ClimateMaster residential series equipment is standard with insulated water and refrigerant circuit insulation, designed for low temperature operation.

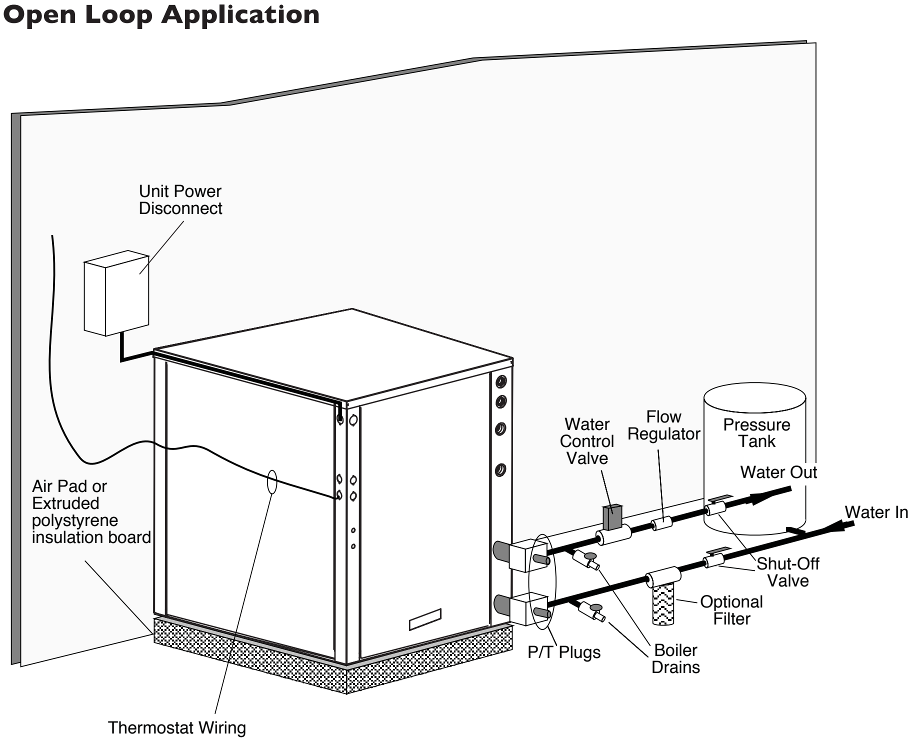
Open Loop (Well Water)

Typical open loop piping is shown in Figure 3-3. Shut off valves should be included for ease of servicing. Boiler drains or other valves should be "tee'd" into the lines to allow acid flushing of the heat exchanger. Shut off valves should be positioned to allow flow through the coaxial heat exchanger via the boiler drains without allowing flow into the piping system. P/T plugs should be used so that pressure drop and temperature can be measured. Piping materials should be limited to copper or PVC SCH80. *Note: Due to the pressure and temperature extremes, PVC SCH40 is not recommended.*

Water quantity must be plentiful and of good quality. Consult table 3-1 for water quality guidelines. The unit can be ordered with either a copper or cupro-nickel water heat exchanger. Consult Table 3-1 for recommendations. Copper is recommended for open loop ground water systems that are not high in mineral content or corrosiveness. In conditions anticipating heavy scale formation or in brackish water, a cupro-nickel heat exchanger is recommended. In ground water situations where scaling could be heavy or where biological growth such as iron bacteria will be present, an open loop system is not recommended. Heat exchanger coils may over time lose heat exchange capabilities due to build up of mineral deposits. Heat exchangers must only be serviced by a qualified technician, as acid and special pumping equipment is required. Desuperheater (HWG) coils can likewise become scaled and possibly plugged. In areas with extremely hard water, the owner should be informed that the heat exchanger may require occasional acid flushing. In some cases, the desuperheater option should not be recommended due to hard water conditions and additional maintenance required.

Table 3-1 should be consulted for water quality requirements. Scaling potential should be assessed using the pH/Calcium hardness method. If the pH <7.5 and the calcium hardness is less than 100 ppm, scaling potential is low. If this method yields numbers out of range of those listed, the Ryznar Stability and Langelier Saturation indices should be calculated. Use the appropriate scaling surface temperature for the application, 150°F [66°C] for direct use (well water/open loop) and DHW (desuperheater); 90°F [32°F] for indirect use. A monitoring plan should be implemented in these probable scaling situations. Other water quality issues such as iron fouling, corrosion prevention and erosion and clogging should be referenced in Table 3-1.

Figure 3-2: Typical Open Loop Application



Part III: Source Side Design / Open Loop Design

Table 3-1: Water Quality Standards

Water Quality Parameter	HX Material	Closed Recirculating	Open Loop and Recirculating Well		
Scaling Potential - Primary Measurement					
Above the given limits, scaling is likely to occur. Scaling indexes should be calculated using the limits below					
pH/Calcium Hardness Method	All	-	**pH < 7.5 and Ca Hardness <100ppm**		
Index Limits for Probable Scaling Situations - (Operation outside these limits is not recommended)					
Scaling indexes should be calculated at 66°C for direct use and HWG applications, and at 32°C for indirect HX use. A monitoring plan should be implemented.					
Ryznar Stability Index	All	-	**6.0 - 7.5** If >7.5 minimize steel pipe use.		
Langelier Saturation Index	All	-	**-0.5 to +0.5** If <-0.5 minimize steel pipe use. Based upon 66°C HWG and Direct well, 29°C Indirect Well HX		
Iron Fouling					
Iron Fe^{2+} (Ferrous) (Bacterial Iron potential)	All	-	**<0.2 ppm (Ferrous)** If Fe^{2+} (ferrous)>0.2 ppm with pH 6 - 8, O2<5 ppm check for iron bacteria.		
Iron Fouling	All	-	**<0.5 ppm of Oxygen** Above this level deposition will occur.		
Corrosion Prevention					
pH	All	**6 - 8.5** Monitor/treat as needed	**6 - 8.5** Minimize steel pipe below 7 and no open tanks with pH <8		
Hydrogen Sulfide (H_2S)	All	-	**<0.5 ppm** At H_2S>0.2 ppm, avoid use of copper and copper nickel piping or HX's. Rotten egg smell appears at 0.5 ppm level. Copper alloy (bronze or brass) cast components are OK to <0.5 ppm.		
Ammonia ion as hydroxide, chloride, nitrate and sulfate compounds	All	-	**<0.5 ppm**		
Maximum Chloride Levels			Maximum Allowable at maximum water temperature.		
			10°C	24°C	38°C
	Copper	-	<20ppm	NR	NR
		-	<150 ppm	NR	NR
	304 SS	-	<400 ppm	<250 ppm	<150 ppm
	316 SS	-	<1000 ppm	<550 ppm	< 375 ppm
	Titanium	-	>1000 ppm	>550 ppm	>375 ppm
Erosion and Clogging					
Particulate Size and Erosion	All	<10 ppm of particles and a maximum velocity of 1.8 m/s Filtered for maximum 841 micron [0.84 mm, 20 mesh] size.	<10 ppm (<1 ppm "sandfree" for reinjection) of particles and a maximum velocity of 1.8 m/s. Filtered for maximum 841 micron 0.84 mm, 20 mesh] size. Any particulate that is not removed can potentially clog components.		

Rev.: 8/3/2010

Notes:
- Closed Recirculating system is identified by a closed pressurized piping system.
- Recirculating open wells should observe the open recirculating design considerations.
- NR - Application not recommended.
- "-" No design Maximum.

Part III: Source Side Design / Open Loop Design - Closed Loop Design

Open Loop (continued)
A closed, bladder-type expansion tank should be used to minimize mineral formation due to air exposure. The expansion tank should be sized to provide at least one minute continuous run time of the pump using its drawdown capacity rating to prevent pump short cycling. Discharge water from the unit is not contaminated in any manner and can be disposed of in various ways, depending on local building codes (e.g. recharge well, storm sewer, drain field, adjacent stream or pond, etc.). Most local codes forbid the use of sanitary sewer for disposal. Consult your local building and zoning department to assure compliance in your area.

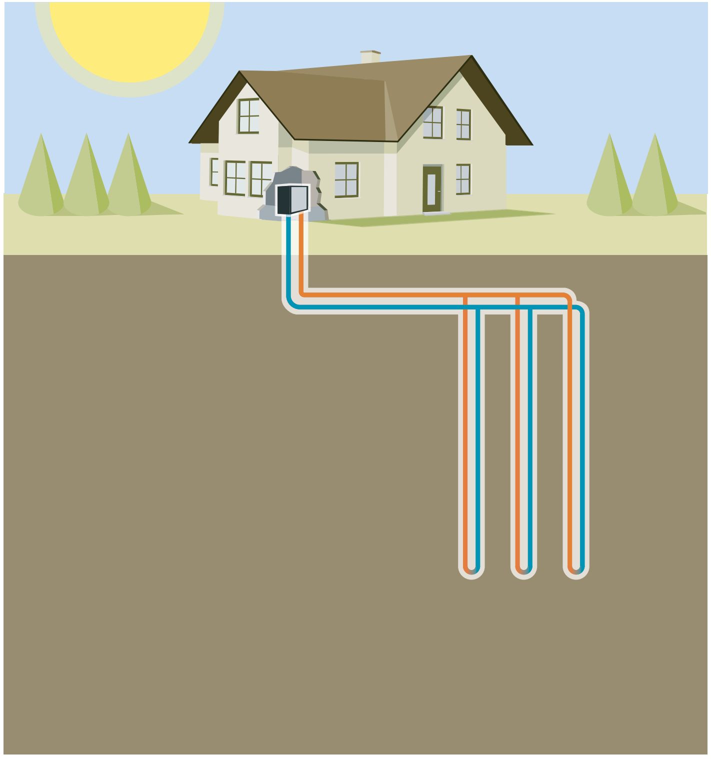
The placement of the water control valve is important for proper operation. Figure 3-3 shows proper placement of the valve. Always maintain water pressure in the heat exchanger by placing the water control valve(s) on the discharge line to prevent mineral precipitation during the off-cycle. Pilot operated slow closing valves are recommended to reduce water hammer. Insure that the total 'VA' draw of the valve can be supplied by the unit transformer. For instance, a slow closing valve can draw up to 35VA. This can overload smaller 40 or 50 VA transformers depending on the other controls in the circuit. A typical pilot operated solenoid valve draws approximately 15VA.

Flow regulation for open loop systems can be accomplished by two methods. One method of flow regulation involves simply adjusting the ball valve or water control valve on the discharge line. Measure the pressure drop through the unit heat exchanger, and determine flow rate from tables in the installation manual of the specific unit. Since the pressure is constantly varying, two pressure gauges may be needed. Adjust the valve until the desired flow of 1.5 to 2 gpm per ton [1.6 to 2.2 l/m per kW]* is achieved. A second method of flow control requires a flow control device mounted on the outlet of the water control valve. The device is typically a brass fitting with an orifice of rubber or plastic material that is designed to allow a specified flow rate. On occasion, flow control devices may produce velocity noise that can be reduced by applying some back pressure from the ball valve located on the discharge line. Slightly closing the valve will spread the pressure drop over both devices, lessening the velocity noise. NOTE: When EWT is below 50°F [10°C], 2 gpm per ton [2.2 l/m per kW] is required.*

*** This note is for water-to-air units, which are rated for cooling capacities. THW/TMW series residential water-to-water units are rated for heating capacities at 32°F [0°C] entering source temperature. Consult unit performance data for open loop minimum flow rates.**

Closed Loop Systems

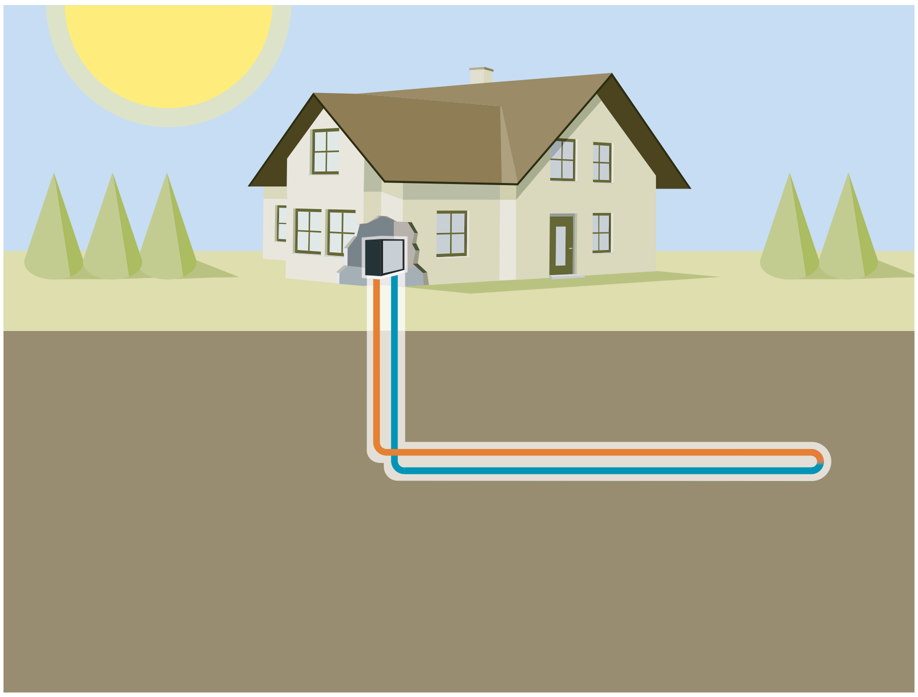
Vertical (Drilled) Closed Loop



Vertical or drilled closed loop systems take up the least amount of land or yard space. Since the heat exchange takes place along the vertical drilled (bore) hole walls, only a small diameter hole (typically 4" [10 cm]) is required for each ton [3.5 kW] of heat pump capacity. Minimal spacing is required between bore holes, typically 10 feet [3 meters] for residential applications. Depending upon drilling costs, vertical loops may be more expensive than horizontal or pond/lake loops, but their compact layout makes a geothermal closed loop application possible for almost any home that has a small yard, driveway or sidewalk. Loops can even be installed underneath the foundation. Closed loop design and installation guidelines (later in this section) provide details on vertical loop designs.

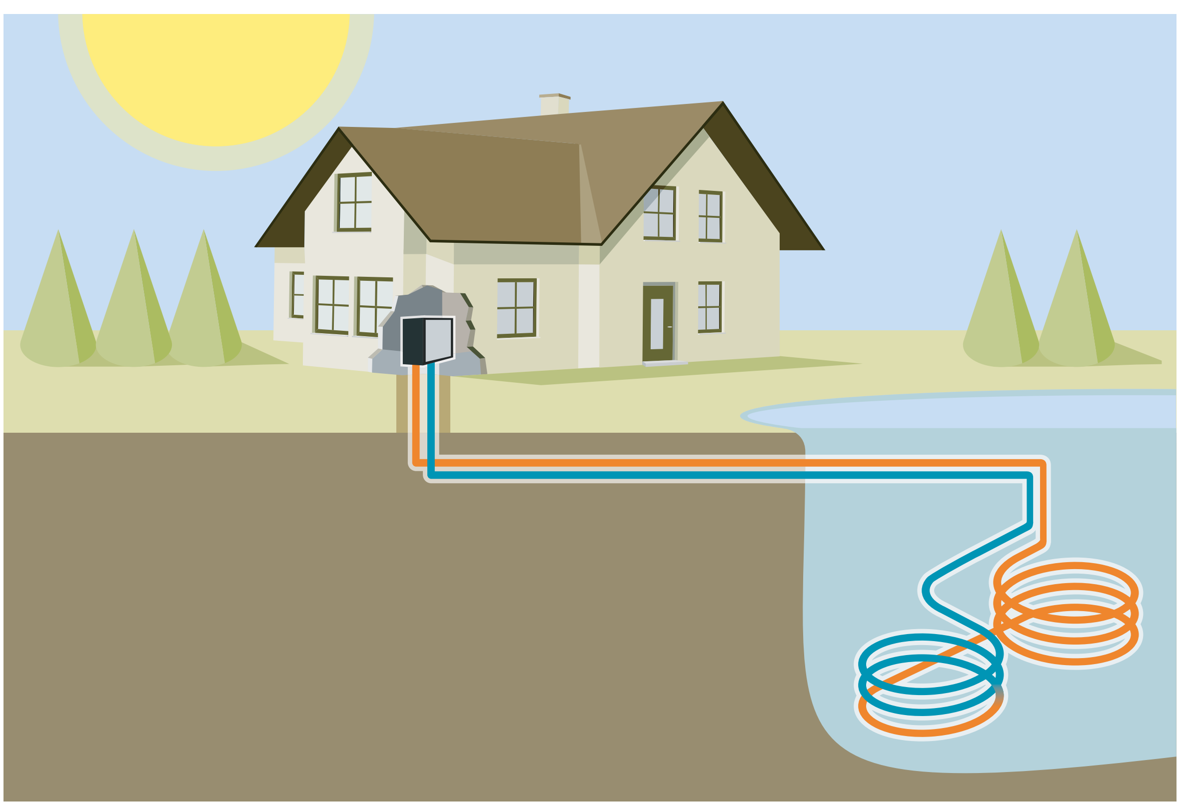
Part III: Source Side Design / Closed Loop Design

Horizontal (Trenched or Bored) Loop



Horizontal loops may be installed with a trencher, backhoe or horizontal boring machine. Excavation costs are usually less than comparable vertical loops, but significantly more land space is required. For rural installations, horizontal loops can be very cost effective. Pipe is typically buried around five feet [1.5 meters] deep, and may be configured in a variety of layouts, depending upon available space and the cost of pipe versus the cost of excavation. Between one and six pipes per trench are buried and connected to a header system. Closed loop design and installation guidelines (later in this section) provide details on horizontal loop designs.

Pond/Lake Loop



Pond or lake loops are one of the most cost-effective closed loop installations because of the limited excavation required (supply and return line trenches to the pond). Pond loops require a minimum of about 1/2 acres [0.2 Hectares] of land and a minimum depth of 8 to 10 feet [2.5 to 3 meters]. Like other closed loop installations, pond loops utilize polyethylene pipe, but are typically laid out in a coil or "slinky" arrangement. Closed loop design and installation guidelines (later in this section) provide details on pond loop designs.

CLOSED LOOP DESIGN/INSTALLATION GUIDELINES

Closed Loop Basics*

Closed Loop Earth Coupled Heat Pump systems are commonly installed in one of three configurations: horizontal, vertical and pond loop. Each configuration provides the benefit of using the moderate temperatures of the earth as a heat source/heat sink. Piping configurations can be either series or parallel.

Series piping configurations typically use 1-1/4 inch, 1-1/2 inch or 2 inch pipe. Parallel piping configurations typically use 3/4 inch or 1 inch pipe for loops and 1-1/4 inch, 1-1/2 inch or 2 inch pipe for headers and service lines. Parallel configurations require headers to be either "closed-coupled" short headers or reverse return design.

Select the installation configuration which provides you and your customer the most cost effective method of installation after considering all application constraints.

Loop design takes into account two basic factors. The first is an accurately engineered system to function properly with low pumping requirements (low Watts) and adequate heat transfer to handle the load of the structure. The second is to design a loop with the lowest installed cost while still maintaining a high level of quality. These factors have been taken into account in all of the loop designs presented in this manual.

In general terms, all loop lengths have been sized by the GeoDesigner loop sizing software so that every loop has approximately the same operating costs. In other words, at the end of the year the homeowner would have paid approximately the same amount of money for heating, cooling, and hot water no matter which loop type was installed. This leaves the installed cost of the loop as the main factor for determining the system payback. Therefore, the "best" loop is the most economical system possible given the installation requirements.

Pipe Fusion Methods

Two basic types of pipe joining methods are available for earth coupled applications. Polyethylene pipe can be socket fused or butt fused. In both processes the pipe is actually melted together to form a joint that is even stronger than the original pipe. Although when either procedure is performed properly the joint will be stronger than the pipe wall, socket fusion in the joining of 2" pipe or less is preferred because of the following:

- Allowable tolerance of mating the pipe is much greater in socket fusion. According to general fusion guidelines, a 3/4" SDR11 butt fusion joint alignment can be off no more than 10% of the wall thickness (0.01 in. [2.54mm]). One hundredth of an inch [2-1/2 mm] accuracy while fusing in a difficult position can be almost impossible to attain in the field.
- The actual socket fusion joint is 3 to 4 times the cross sectional area of its butt fusion counterpart in sizes under 2" and therefore tends to be more forgiving of operator skill.

* All Polyethylene pipe discussed in this manual is IPS (Iron Pipe Size) in inches.

- Joints are frequently required in difficult trench connections and the smaller socket fusion iron is more mobile. Operators will have less of a tendency to cut corners during the fusion procedure, which may happen during the facing and alignment procedure of butt fusion.

In general socket fusion loses these advantages in fusion joints larger than 2" and of course socket fittings become very expensive and time consuming in these larger sizes. Therefore, butt fusion is generally used in sizes larger than 2". In either joining method proper technique is essential for long lasting joints. All pipe and fittings in the residential price list are IGSHPA (International Ground Source Heat Pump Association) approved. All fusion joints must be performed by certified fusion technicians. Table 3-2 illustrates the proper fusion times for Geothermal PE 3408 ASTM Pipe.

Table 3-2: Fusion Times for Polyethylene 3408 ASTM Pipe

Pipe Size	Socket Fusion Time (Sec)	Butt Fusion		Holding Time	Curing Time
		Time (sec.)	Bead, in [mm]		
3/4" IPS	8 - 10	8	1/16 [1.6]	60 Sec	20 min
1" IPS	10 - 14	12	1/16 [1.6]	60 Sec	20 min
1-1/4" IPS	12 - 15	15	1/16 - 1/8 [1.6 - 3.2]	60 Sec	20 min
1-1/2" IPS	15 - 18	15	1/16 - 1/8 [1.6 - 3.2]	60 Sec	20 min
2" IPS	18 - 22	18	1/8 [3.2]	60 Sec	20 min

Always use a timing device

Parallel vs Series Configurations

Initially, loops were all designed using series style flow due to the lack of fusion fittings needed in parallel systems. This resulted in large diameter pipe (>1-1/4") being used to reduce pumping requirements due to the increased pressure drop of the pipe. Since fusion fittings have become available, parallel flow using (3/4" IPS) for loops 2 ton [7 kW] and above has become the standard for a number of reasons.

- Cost of Pipe - The larger diameter (>1-1/4") pipe is twice the cost of the smaller (3/4" IPS) pipe. However, the heat transfer capability due to the reduced surface area of the smaller pipe is only decreased by approximately 10-20%. In loop designs using the smaller pipe, the pipe length is simply increased to compensate for the small heat transfer reduction, although it still results in around 50% savings in pipe costs over the larger pipe in series. In some areas vertical bores using 1-1/4" pipe can be more cost effective, where drilling costs are high.
- Pumping power - Parallel systems generally can have much lower pressure drop and thus smaller pumps due to the multiple flow paths of smaller pipes in parallel.
- Installation ease - The smaller pipe is easier to handle during installation than the larger diameter pipe. The 'memory' of the pipe can be especially cumbersome when installing in cold conditions. Smaller pipe takes less time to fuse and is easier to cut, bend, etc.

Part III: Source Side Design / Closed Loop Installation Guidelines

In smaller loops of two tons [7 kW] or less, the reasons for using parallel loops as listed above may be less obvious. In these cases, series loops can have some additional advantages:
- No header - fittings tend to be more expensive and require extra labor and skill to install.
- Simple design - no confusing piping arrangement for easier installation by less experienced installers.

Parallel Loop Design
Loop Configuration - Determining the style of loop primarily depends on lot (yard) size and excavation costs. For instance, a horizontal 1 pipe loop will have significantly (400%) more trench than a horizontal 6 pipe loop. However, the 6 pipe will have about 75% more feet of pipe. Therefore, if trenching costs are higher than the extra pipe costs, the 6 pipe loop is the best choice. Remember that labor is also a factor in loop costs. The 6 pipe loop could also be chosen because of the small available space. Generally a contractor will know after a few installations which configuration is the most cost effective for a given area. This information can be applied to later installations for a more overall cost effective installation for the particular area. Depth of the loop in horizontal systems generally does not exceed 5 feet [1.5 meters] because of trench safety issues and the sheer amount of soil required to move. In vertical systems economic depth due to escalating drilling costs in rock can sometimes require what is referred to as a parallel-series loop. That is, a circuit will loop down and up through two or more consecutive bores (series) to total the required circuit length. Moisture content and soil types also effect the earth loop heat exchanger design. Damp or saturated soil types will result in shorter loop circuits than dry soil or sand.

Loop Circuiting - Loops should be designed with a compromise between pressure drop and turbulent flow (Reynold's Number) in the heat exchange pipe for heat transfer. Therefore the following rules should be observed when designing a loop:

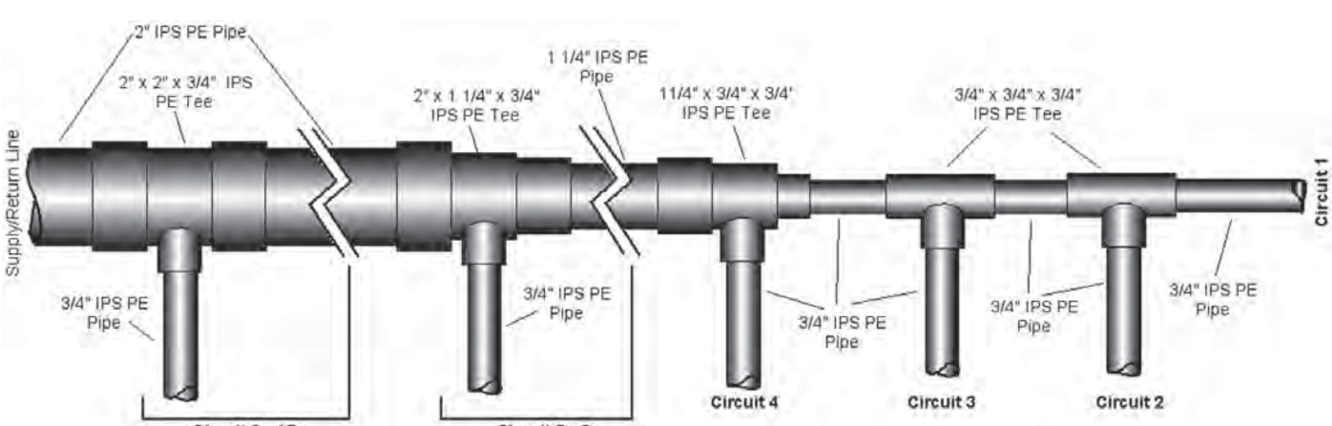
NOTICE: Whenever designing an earth loop heat exchanger, always assume the worst case, soil and moisture conditions at the job site in the final design. In other words, if part of the loop field is saturated clay, and the remainder is damp clay, assume damp clay for design criteria.

- 3 gpm per ton [3.23 l/m per kW] flow rate (2.25 gpm per ton [2.41 l/m per kW] minimum). In larger systems 2.5 to 2.7 gpm per ton [2.41 to 2.90 l/m per kW] is adequate in most cases. Selecting pumps to attain exactly 3 gpm per ton [3.23 l/m per kW] is generally not cost effective from an operating cost standpoint. *
- One circuit per nominal equipment ton [3.5 kW] with 3/4" IPS and 1" IPS circuit per ton [3.5 kW]. This rule can be deviated by one circuit or so for different loop configurations.

Header Design - Headers for parallel loops should be designed with two factors in mind, the first is pressure drop, and the second is ability to purge all of the air from the system ("flushability"). The header shown in Figure 3-4A is a standard header design through 15 tons [52.8 kW] for polyethylene pipe with 2" supply and return runouts. The header shown in Figure 3-4B is a standard header design through 5 tons [17.6 kW] for polyethylene pipe using 1-1/4" supply and return runouts. Notice the reduction of pipe from 2" IPS supply/return circuits 15 to 8 to 1-1/4" IPS pipe for circuits 7 to 4 to 3/4" IPS to supply circuits 3, 2, and 1. This allows minimum pressure drop while still maintaining 2 fps [0.6 m/s] velocity throughout the header under normal flow conditions (3 gpm/ton [3.23 l/m per kW]), thus the header as shown is self-flushing under normal flow conditions. This leaves the circuits themselves (3/4" IPS) as the only section of the loop not attaining 2 fps [0.6 m/s] flush velocity under normal flow conditions (3 gpm per ton* [3.23 l/m per kW], normally 3 gpm [11.4 l/m] per circuit). Pipe diameter 3/4" IPS requires 3.8 gpm [14.4 l/m] to attain 2 fps [0.6 m/s] velocity. Therefore, to calculate flushing requirements for any PE loop using the header styles shown, simply multiply the number of circuits by the flushing flow rate of each circuit (3.8 gpm for 2 fps velocity [14.4 l/m for 0.6 m/s]). For instance, on a 5 circuit loop, the flush flow rate is 5 circuits x 3.8 gpm/circuit = 19 gpm [5 circuits x 14.4 l/m per circuit = 72 l/m or 1.2 l/s].

*** This note is for water-to-air units, which are rated for cooling capacities. THW/TMW series residential water-to-water units are rated for heating capacities at 32°F [0°C] entering source temperature. Consult unit performance data for open loop minimum flow rates.**

Figure 3-4a: Typical Header Through 15 Tons



Part III: Source Side Design / Closed Loop Installation Guidelines

Headers that utilize large diameter pipe feeding the last circuits should not be used. PE 1-1/4" IPS pipe requires 9.5 gpm [36 l/m] to attain 2 fps [0.6 m/s] and since increasing the flow through the last circuit would also require increasing the flow through the other circuits at an equal rate as well, we can estimate the flush flow requirements by multiplying the number of circuits by 9.5 gpm [36 l/m] for 1-1/4" IPS. For instance, a 5 circuit loop would require 5 circuits x 9.5 gpm/circuit = 47.5 gpm [5 circuits x 36 l/m per circuit = 180 l/m or 3.0 l/s] to attain flush flow rate. This is clearly is a difficult flow to achieve with a pump of any size.

Header Layout - Generally header layouts are more cost effective with short headers. This requires centrally locating the header to all circuits and then bringing the circuits to the header. One of the easiest implementations is to angle all trenches into a common pit similar to a starburst. This layout can utilize the laydown or 'L' header and achieves reverse return flow by simply laying the headers down in a mirror image and thus no extra piping or labor. Figure 3-5 details a "laydown" header.

Figure 3-4b: Typical Header Through 5 Tons

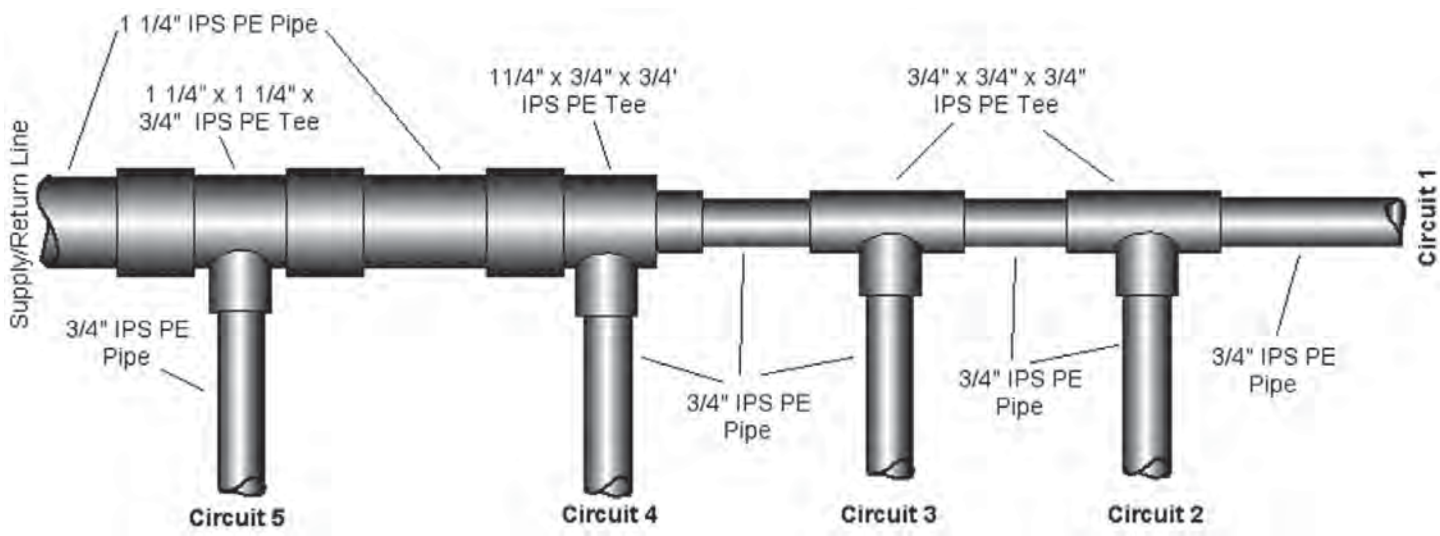
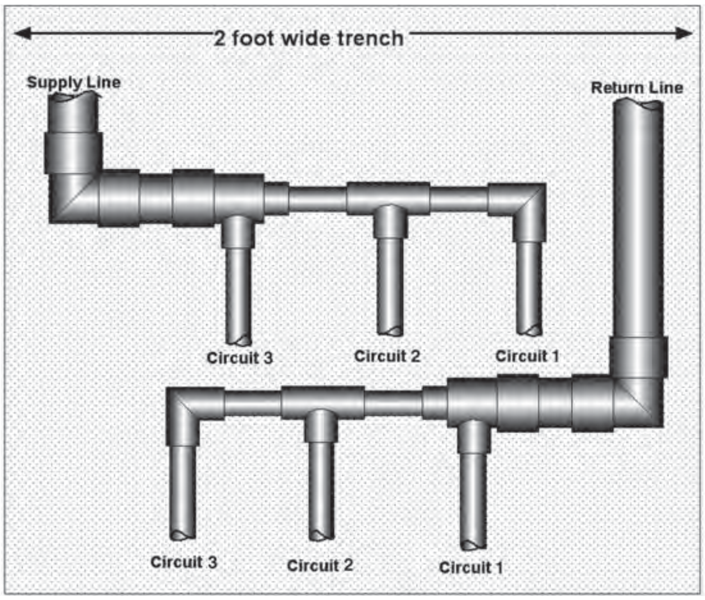


Figure 3-5: Typical "Laydown" Header



Part III: Source Side Design / Closed Loop Installation Guidelines

Inside Piping - Polyethylene pipe provides an excellent no leak piping material inside the building. Inside piping fittings and elbows should be limited to prevent excessive pressure drop. Hose kits employing 1" rubber hose should be limited in length to 10-15 feet [3 to 4.5 meters] per run to reduce pressure drop problems. In general 2 feet of head [6 kPa] pressure drop is allowed for all earth loop fittings which would include 10-12 elbows for inside piping to the Flow Controller. This allows a generous amount of maneuvering to the Flow Controller with the inside piping. Closed cell insulation (3/8" to 1/2" [9.5 to 12.7 mm] wall thickness) should be used on all inside piping where loop temperatures below 50°F [10°C] are anticipated. All barbed connections should be double clamped.

Flow Controller Selection - The pressure drop of the entire ground loop should be calculated for the selection of the Flow Controller (a pressure drop spreadsheet is downloadable from the web site). In general, if basic loop design rules are followed, units of 3 tons [10.6 kW] or less will require only 1 circulating pump (UP26-99). Units from 3.5 to 6 tons [12.3 to 21.1 kW] will require a two pump system (2 - UP26-99)*. Larger capacity units with propylene glycol as antifreeze may require 2 - UP26-116 pumps. However, the UP26-116 should be avoided where possible, as power consumption of the 26-116 is significantly higher than the 26-99, which will affect heating and cooling operating costs. In many cases, where pressure drop calculations may call for 3 - UP26-99 pumps, try substituting 2 - UP26-116 pumps. This makes the installation much easier and reduces cost. Chart 3-1 shows the various pump combinations. Pumps for 50Hz units will have similar characteristics, but different model numbers.

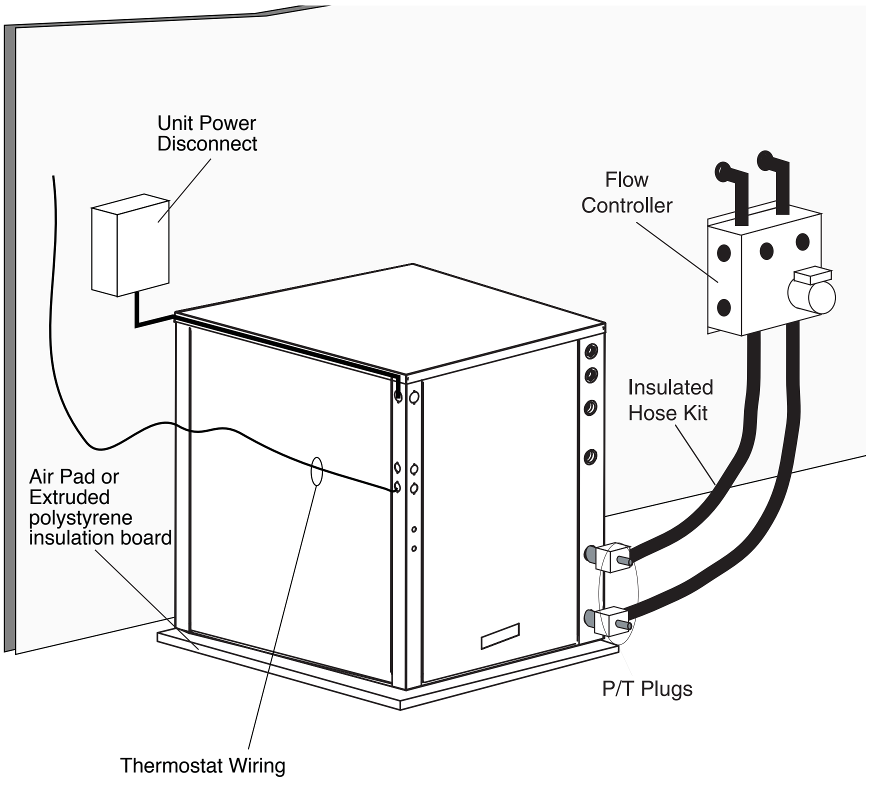
Loop pressure drop calculation should be performed for accurate flow estimation in any system including unit, hose kit, inside piping, supply/return headers, circuit piping, and fittings. Use Tables 3-3A through 3-3E for pressure drop calculations using antifreeze and PE/rubber hose piping materials.

Prior to installation, locate and mark all existing underground utilities, piping, etc. Install loops for new construction before sidewalks, patios, driveways and other construction has begun. During construction, accurately mark all ground loop piping on the plot plan as an aid in avoiding potential future damage to the installation (see Site Survey Sheet). This should be done before and after loop installation. Final installation should be plotted from two fixed points to triangulate the header/manifold location.

Loop Piping Installation

The typical closed loop ground source system is shown in Figure 3-6. All earth loop piping materials should be limited to only polyethylene fusion in below ground (buried) sections of the loop. Galvanized or steel fittings should not be used at any time due to the tendency to corrode by galvanic action. All plastic to metal threaded fittings should be avoided as well due to the potential to leak in earth coupled applications; a flanged fitting should be substituted. P/T plugs should be used so that flow can be measured using the pressure drop of the unit heat exchanger in lieu of other flow measurement means (e.g. flow meter, which adds additional fittings and potential leaks). Earth loop temperatures can range between 25-110°F [-4 to 43°C]. Flow rates of 2.25 to 3 gpm per ton [2.41 to 3.23 l/m per kW] of cooling capacity are recommended for all earth loop applications. **

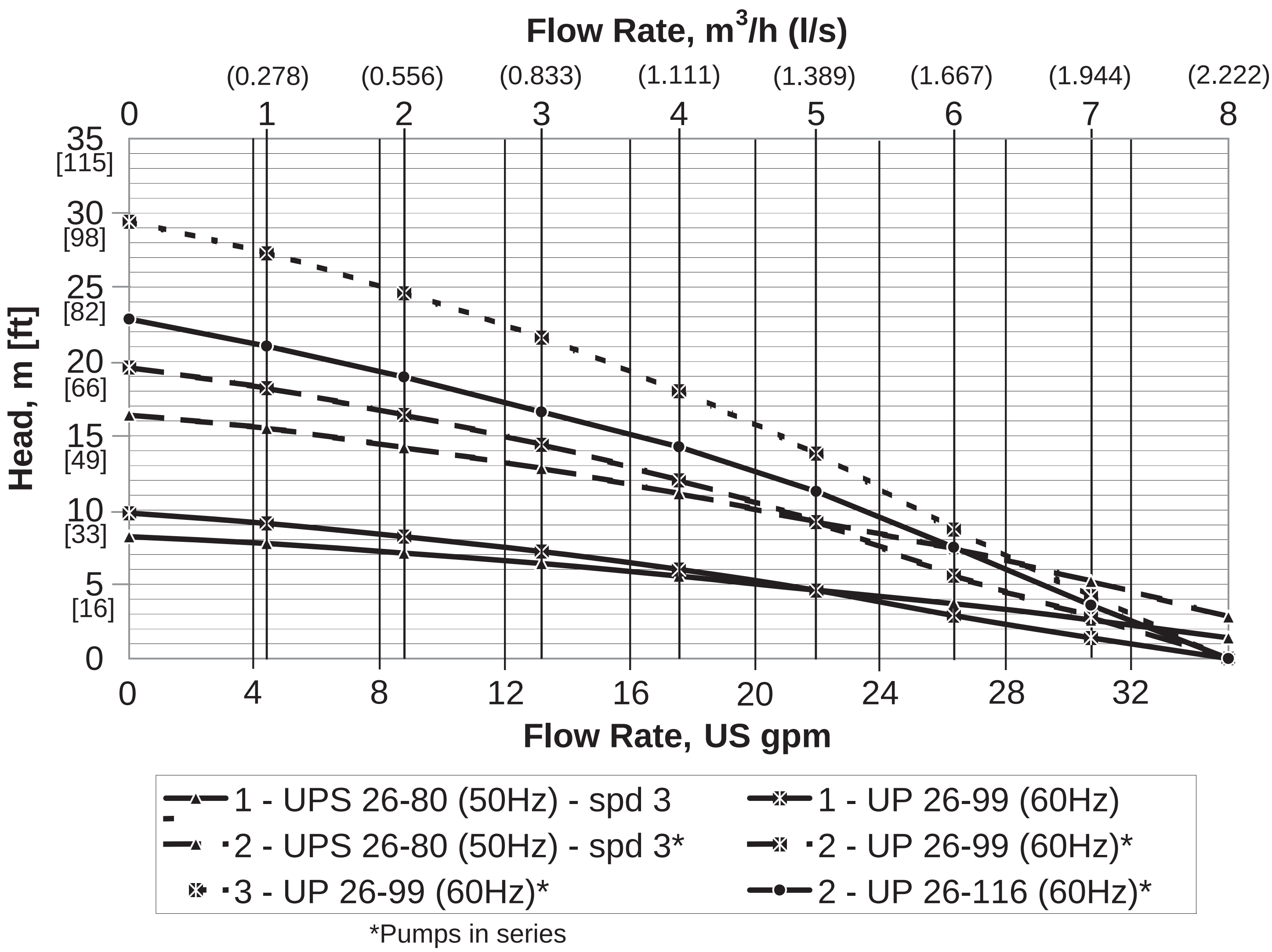
Figure 3-6: Typical Ground-Loop Application



* For water-to-air units. Typically, THW008 & TMW008 water-to-water units only need one pump. Sizes 010 & 012 need two pumps.

** This note is for water-to-air units, which are rated for cooling capacities. THW/TMW series residential water-to-water units are rated for heating capacities at 32°F [0°C] entering source temperature. Consult unit performance data for open loop minimum flow rates.
Closed Loop Systems

Chart 3-1: Flow Controller Pump (Source) Performance & Internal (Load) Pump(s) Performance for THW Units



THW (Optional) Internal Pumps		
Model	Source	Load
008 (50Hz)	1 - UPS26-80	1 - UPS26-80
010 (50Hz)	2 - UPS26-80	1 - UPS26-80
010 (60Hz)	2 - UP26-99	1 - UP26-99
012 (50Hz)	2 - UPS26-80	1 - UPS26-80

Part III: Source Side Design / Closed Loop Installation Guidelines

Table 3-3a: Polyethylene Pressure Drop per 100ft of Pipe
Antifreeze (30°F [-1°C] EWT): 20% Methanol by volume solution - freeze protected to 15°F [-9.4°F]

Flow Rate	3/4" IPS SDR11			1" IPS SDR11			1-1/4" IPS SCH40			1-1/2" IPS SCH40			2" IPS SCH40		
	PD (ft)	Vel (ft/s)	Re	(ft)	Vel (ft/s)	Re	PD (ft)	Vel (ft/s)	Re	PD	Vel (ft/s)	Re	PD	Vel (ft/s)	Re
1	0.36	0.55	1123	0.12	0.35	895	0.04	0.21	688	0.02	0.16	611	0.01	0.10	491
2	1.22	1.10	2245	0.42	0.70	1789	0.13	0.43	1408	0.06	0.32	1223	0.02	0.19	932
3	2.48	1.66	3388	0.85	1.06	2709	0.26	0.64	2096	0.13	0.47	1796	0.04	0.29	1423
4	4.11	2.21	4511	1.41	1.41	3604	0.43	0.86	2817	0.21	0.63	2407	0.06	0.38	1864
5	6.08	2.76	5633	2.09	1.76	4499	0.64	1.07	3504	0.31	0.79	3019	0.09	0.48	2355
6	8.36	3.31	6756	2.87	2.11	5393	0.88	1.29	4225	0.42	0.95	3630	0.13	0.57	2796
7	10.95	3.87	7899	3.76	2.47	6314	1.16	1.50	4913	0.56	1.10	4203	0.17	0.67	3287
8	13.83	4.42	9022	4.75	2.82	7208	1.46	1.72	5633	0.70	1.26	4815	0.22	0.76	3728
9	17.00	4.97	10144	5.84	3.17	8103	1.80	1.93	6321	0.86	1.42	5426	0.26	0.86	4219
10	20.44	5.52	11267	7.02	3.52	8997	2.16	2.15	7042	1.04	1.58	6037	0.32	0.96	4709
11	24.14	6.08	12410	8.29	3.87	9892	2.55	2.36	7729	1.23	1.73	6610	0.37	1.05	5151
12	28.12	6.63	13532	9.65	4.23	10812	2.98	2.57	8417	1.43	1.89	7222	0.44	1.15	5642
13	32.35	7.18	14655	11.11	4.58	11707	3.42	2.79	9138	1.65	2.05	7833	0.50	1.24	6083
14				12.65	4.93	12602	3.90	3.00	9826	1.87	2.21	8445	0.57	1.34	6574
15				14.27	5.28	13496	4.39	3.22	10546	2.11	2.36	9018	0.65	1.43	7015
16				15.97	5.64	14416	4.92	3.43	11234	2.37	2.52	9629	0.72	1.53	7506
17				17.76	5.99	15311	5.47	3.65	11955	2.63	2.68	10240	0.80	1.63	7996
18				19.63	6.34	16206	6.05	3.86	12642	2.91	2.84	10852	0.89	1.72	8438
19				21.58	6.69	17100	6.65	4.08	13363	3.20	2.99	11425	0.98	1.82	8928
20				23.61	7.04	17995	7.27	4.29	14051	3.50	3.15	12036	1.07	1.91	9370
21				25.71	7.40	18915	7.92	4.50	14738	3.81	3.31	12648	1.16	2.01	9860
22				27.89	7.75	19810	8.59	4.72	15459	4.13	3.47	13259	1.26	2.10	10302
23				30.15	8.10	20704	9.29	4.93	16147	4.47	3.62	13832	1.36	2.20	10793
24							10.00	5.15	16867	4.81	3.78	14444	1.47	2.29	11234
25							10.75	5.36	17555	5.17	3.94	15055	1.58	2.39	11725
26							11.51	5.58	18276	5.53	4.10	15666	1.69	2.49	12215
28							13.10	6.01	19684	6.30	4.41	16851	1.92	2.68	13147
30							14.78	6.44	21092	7.11	4.73	18074	2.17	2.87	14079
32							16.56	6.86	22468	7.96	5.04	19258	2.43	3.06	15011
34							18.41	7.29	23876	8.85	5.36	20481	2.70	3.25	15944
36							20.34	7.72	25285	9.78	5.67	21666	2.99	3.44	16876
38							22.36	8.15	26693	10.75	5.99	22888	3.28	3.63	17808
40							24.46	8.58	28101	11.76	6.30	24073	3.59	3.82	18740
42							26.64	9.01	29510	12.81	6.62	25296	3.91	4.02	19721
44							28.90	9.44	30918	13.90	6.93	26480	4.24	4.21	20653
46							31.24	9.87	32326	15.02	7.25	27703	4.58	4.40	21585
48										16.18	7.57	28926	4.94	4.59	22517
50										17.38	7.88	30110	5.30	4.78	23449

Part III: Source Side Design / Closed Loop Installation Guidelines

Table 3-3b: Polyethylene Pressure Drop per 100ft of Pipe
Antifreeze (30°F [-1°C] EWT): 25% Propylene Glycol by volume solution - freeze protected to 15°F [-9.4°F]

Flow Rate	3/4" IPS SDR11			1" IPS SDR11			1-1/4" IPS SCH40			1-1/2" IPS SCH40			2" IPS SCH40		
	PD (ft)	Vel (ft/s)	Re	(ft)	Vel (ft/s)	Re	PD (ft)	Vel (ft/s)	Re	PD	Vel (ft/s)	Re	PD	Vel (ft/s)	Re
1	0.42	0.55	636	0.14	0.35	507	0.04	0.21	389	0.02	0.16	346	0.01	0.10	278
2	1.41	1.10	1271	0.48	0.70	1013	0.15	0.43	798	0.07	0.32	692	0.02	0.19	528
3	2.86	1.66	1919	0.98	1.06	1534	0.30	0.64	1187	0.15	0.47	1017	0.04	0.29	806
4	4.74	2.21	2554	1.63	1.41	2041	0.50	0.86	1595	0.24	0.63	1363	0.07	0.38	1056
5	7.01	2.76	3190	2.41	1.76	2548	0.74	1.07	1985	0.36	0.79	1709	0.11	0.48	1333
6	9.64	3.31	3826	3.31	2.11	3054	1.02	1.29	2393	0.49	0.95	2056	0.15	0.57	1583
7	12.62	3.87	4473	4.33	2.47	3575	1.34	1.50	2782	0.64	1.10	2380	0.20	0.67	1861
8	15.94	4.42	5109	5.47	2.82	4082	1.69	1.72	3190	0.81	1.26	2726	0.25	0.76	2111
9	19.59	4.97	5745	6.73	3.17	4589	2.07	1.93	3580	1.00	1.42	3073	0.30	0.86	2389
10	23.56	5.52	6380	8.09	3.52	5095	2.49	2.15	3988	1.20	1.58	3419	0.37	0.96	2667
11	27.83	6.08	7028	9.56	3.87	5602	2.94	2.36	4377	1.42	1.73	3743	0.43	1.05	2917
12	32.41	6.63	7663	11.13	4.23	6123	3.43	2.57	4767	1.65	1.89	4090	0.50	1.15	3195
13				12.80	4.58	6630	3.94	2.79	5175	1.90	2.05	4436	0.58	1.24	3445
14				14.58	4.93	7136	4.49	3.00	5564	2.16	2.21	4782	0.66	1.34	3723
15				16.45	5.28	7643	5.07	3.22	5972	2.44	2.36	5107	0.74	1.43	3973
16				18.41	5.64	8164	5.67	3.43	6362	2.73	2.52	5453	0.83	1.53	4250
17				20.48	5.99	8670	6.31	3.65	6770	3.03	2.68	5799	0.92	1.63	4528
18				22.63	6.34	9177	6.97	3.86	7159	3.35	2.84	6145	1.02	1.72	4778
19				24.88	6.69	9684	7.66	4.08	7567	3.69	2.99	6470	1.12	1.82	5056
20				27.22	7.04	10190	8.38	4.29	7957	4.03	3.15	6816	1.23	1.91	5306
21				29.64	7.40	10711	9.13	4.50	8346	4.39	3.31	7162	1.34	2.01	5584
22				32.15	7.75	11218	9.90	4.72	8754	4.76	3.47	7509	1.45	2.10	5834
23							10.71	4.93	9144	5.15	3.62	7833	1.57	2.20	6112
24							11.53	5.15	9552	5.55	3.78	8179	1.69	2.29	6362
25							12.39	5.36	9941	5.96	3.94	8526	1.82	2.39	6640
26							13.27	5.58	10349	6.38	4.10	8872	1.95	2.49	6917
28							15.10	6.01	11147	7.26	4.41	9543	2.22	2.68	7445
30							17.04	6.44	11944	8.19	4.73	10235	2.50	2.87	7973
32							19.08	6.86	12723	9.18	5.04	10906	2.80	3.06	8501
34							21.22	7.29	13521	10.20	5.36	11598	3.11	3.25	9029
36							23.45	7.72	14318	11.28	5.67	12269	3.44	3.44	9557
38							25.78	8.15	15116	12.39	5.99	12961	3.78	3.63	10084
40							28.20	8.58	15914	13.56	6.30	13632	4.14	3.82	10612
42							30.71	9.01	16711	14.77	6.62	14325	4.51	4.02	11168
44										16.02	6.93	14995	4.89	4.21	11696
46										17.31	7.25	15688	5.28	4.40	12223
48										18.65	7.57	16380	5.69	4.59	12751
50										20.04	7.88	17051	6.11	4.78	13279

Part III: Source Side Design / Closed Loop Installation Guidelines

Table 3-3c: Polyethylene Pressure Drop per 100ft of Pipe
Antifreeze (30°F [-1°C] EWT): 25% Ethanol by volume solution - freeze protected to 15°F [-9.4°F]

Flow Rate	3/4" IPS SDR11			1" IPS SDR11			1-1/4" IPS SCH40			1-1/2" IPS SCH40			2" IPS SCH40		
	PD (ft)	Vel (ft/s)	Re	(ft)	Vel (ft/s)	Re	PD (ft)	Vel (ft/s)	Re	PD	Vel (ft/s)	Re	PD	Vel (ft/s)	Re
1	0.37	0.55	1013	0.13	0.35	807	0.04	0.21	620	0.02	0.16	551	0.01	0.10	442
2	1.26	1.10	2025	0.43	0.70	1614	0.13	0.43	1270	0.06	0.32	1103	0.02	0.19	841
3	2.55	1.66	3056	0.88	1.06	2444	0.27	0.64	1891	0.13	0.47	1620	0.04	0.29	1283
4	4.22	2.21	4068	1.45	1.41	3251	0.45	0.86	2540	0.21	0.63	2171	0.07	0.38	1681
5	6.24	2.76	5081	2.14	1.76	4058	0.66	1.07	3161	0.32	0.79	2723	0.10	0.48	2124
6	8.58	3.31	6093	2.95	2.11	4864	0.91	1.29	3811	0.44	0.95	3274	0.13	0.57	2522
7	11.23	3.87	7124	3.86	2.47	5694	1.19	1.50	4431	0.57	1.10	3791	0.17	0.67	2964
8	14.19	4.42	8137	4.87	2.82	6501	1.50	1.72	5081	0.72	1.26	4342	0.22	0.76	3363
9	17.44	4.97	9149	5.99	3.17	7308	1.85	1.93	5701	0.89	1.42	4894	0.27	0.86	3805
10	20.97	5.52	10162	7.20	3.52	8115	2.22	2.15	6351	1.07	1.58	5445	0.33	0.96	4248
11	24.77	6.08	11193	8.51	3.87	8922	2.62	2.36	6972	1.26	1.73	5962	0.38	1.05	4646
12	28.85	6.63	12205	9.91	4.23	9752	3.05	2.57	7592	1.47	1.89	6514	0.45	1.15	5088
13				11.40	4.58	10559	3.51	2.79	8242	1.69	2.05	7065	0.52	1.24	5487
14				12.98	4.93	11366	4.00	3.00	8862	1.92	2.21	7616	0.59	1.34	5929
15				14.64	5.28	12173	4.51	3.22	9512	2.17	2.36	8133	0.66	1.43	6327
16				16.39	5.64	13003	5.05	3.43	10132	2.43	2.52	8685	0.74	1.53	6770
17				18.23	5.99	13810	5.61	3.65	10782	2.70	2.68	9236	0.82	1.63	7212
18				20.15	6.34	14616	6.21	3.86	11403	2.98	2.84	9788	0.91	1.72	7610
19				22.15	6.69	15423	6.82	4.08	12052	3.28	2.99	10305	1.00	1.82	8053
20				24.23	7.04	16230	7.46	4.29	12673	3.59	3.15	10856	1.10	1.91	8451
21				26.38	7.40	17060	8.13	4.50	13293	3.91	3.31	11407	1.19	2.01	8893
22				28.62	7.75	17867	8.82	4.72	13943	4.24	3.47	11959	1.29	2.10	9292
23				30.94	8.10	18674	9.53	4.93	14563	4.58	3.62	12476	1.40	2.20	9734
24							10.27	5.15	15213	4.94	3.78	13027	1.51	2.29	10132
25							11.03	5.36	15834	5.30	3.94	13579	1.62	2.39	10575
26							11.81	5.58	16483	5.68	4.10	14130	1.73	2.49	11017
28							13.44	6.01	17754	6.47	4.41	15198	1.97	2.68	11858
30							15.17	6.44	19024	7.29	4.73	16301	2.23	2.87	12699
32							16.99	6.86	20265	8.17	5.04	17370	2.49	3.06	13539
34							18.89	7.29	21535	9.08	5.36	18473	2.77	3.25	14380
36							20.87	7.72	22805	10.04	5.67	19541	3.06	3.44	15221
38							22.95	8.15	24075	11.03	5.99	20644	3.37	3.63	16061
40							25.10	8.58	25346	12.07	6.30	21712	3.68	3.82	16902
42							27.34	9.01	26616	13.14	6.62	22815	4.01	4.02	17787
44							29.65	9.44	27886	14.26	6.93	23883	4.35	4.21	18628
46										15.41	7.25	24986	4.70	4.40	19468
48										16.60	7.57	26089	5.07	4.59	20309
50										17.83	7.88	27157	5.44	4.78	21150

Part III: Source Side Design / Closed Loop Installation Guidelines

Table 3-3d: Polyethylene Pressure Drop per 100ft of Pipe
No Antifreeze (50°F [10°C] EWT): Water

Flow Rate	3/4" IPS SDR11			1" IPS SDR11			1-1/4" IPS SCH40			1-1/2" IPS SCH40			2" IPS SCH40		
	PD (ft)	Vel (ft/s)	Re	PD (ft)	Vel (ft/s)	Re	PD (ft)	Vel (ft/s)	Re	PD (ft)	Vel (ft/s)	Re	PD (ft)	Vel (ft/s)	Re
1	0.23	0.55	2,806	0.08	0.35	2,241	0.02	0.21	1,724	0.01	0.16	1,508	0.00	0.10	1,160
2	0.78	1.10	5,612	0.27	0.70	4,481	0.08	0.43	3,447	0.04	0.32	3,016	0.01	0.19	2,320
3	1.59	1.66	8,418	0.54	1.06	6,722	0.17	0.64	5,171	0.08	0.47	4,525	0.02	0.29	3,481
4	2.62	2.21	11,224	0.90	1.41	8,963	0.28	0.86	6,895	0.13	0.63	6,033	0.04	0.38	4,641
5	3.88	2.76	14,030	1.33	1.76	11,203	0.41	1.07	8,618	0.20	0.79	7,541	0.06	0.48	5,801
6	5.34	3.31	16,836	1.83	2.11	13,444	0.56	1.29	10,342	0.27	0.95	9,049	0.08	0.57	6,961
7	6.99	3.87	19,642	2.40	2.47	15,684	0.74	1.50	12,066	0.36	1.10	10,558	0.11	0.67	8,121
8	8.83	4.42	22,448	3.03	2.82	17,925	0.93	1.72	13,789	0.45	1.26	12,066	0.14	0.76	9,281
9	10.85	4.97	25,254	3.73	3.17	20,166	1.15	1.93	15,513	0.55	1.42	13,574	0.17	0.86	10,442
10	13.05	5.52	28,060	4.48	3.52	22,406	1.38	2.15	17,237	0.66	1.58	15,082	0.20	0.96	11,602
11	15.41	6.08	30,866	5.30	3.87	24,647	1.63	2.36	18,960	0.78	1.73	16,590	0.24	1.05	12,762
12	17.95	6.63	33,672	6.16	4.23	26,888	1.90	2.57	20,684	0.91	1.89	18,099	0.28	1.15	13,922
13				7.09	4.58	29,128	2.18	2.79	22,408	1.05	2.05	19,607	0.32	1.24	15,082
14				8.07	4.93	31,369	2.49	3.00	24,132	1.20	2.21	2,115	0.36	1.34	16,242
15				9.11	5.28	33,609	2.81	3.22	25,855	1.35	2.36	22,623	0.41	1.43	17,403
16				10.20	5.64	35,850	3.14	3.43	27,579	1.51	2.52	24,132	0.46	1.53	18,563
17				11.34	5.99	38,091	3.49	3.65	29,303	1.68	2.68	25,640	0.51	1.63	19,723
18				12.53	6.34	40,331	3.86	3.86	31,026	1.86	2.84	27,148	0.57	1.72	20,883
19				13.78	6.69	42,572	4.24	4.08	32,750	2.04	2.99	28,656	0.62	1.82	22,043
20				15.07	7.04	44,813	4.64	4.29	34,474	2.23	3.15	30,164	0.68	1.91	23,203
21				16.41	7.40	47,053	5.06	4.50	36,197	2.43	3.31	31,673	0.74	2.01	24,364
22				17.80	7.75	49,294	5.48	4.72	37,921	2.64	3.47	33,181	0.81	2.10	25,524
23				19.25	8.10	51,534	5.93	4.93	39,645	2.85	3.62	34,689	0.87	2.20	26,684
24							6.39	5.15	41,368	3.07	3.78	36,197	0.94	2.29	27,844
25							6.86	5.36	43,092	3.30	3.94	37,706	1.01	2.39	29,004
26							7.35	5.58	44,816	3.53	4.10	39,214	1.08	2.49	30,164
28							8.36	6.01	48,263	4.02	4.41	42,230	1.23	2.68	32,485
30							9.44	6.44	51,710	4.54	4.73	45,247	1.38	2.87	34,805
32							10.57	6.86	55,158	5.08	5.04	48,263	1.55	3.06	37,125
34							11.75	7.29	58,605	5.65	5.36	51,280	1.72	3.25	39,446
36							12.99	7.72	62,053	6.24	5.67	54,296	1.91	3.44	41,766
38							14.27	8.15	66,500	6.86	5.99	57,312	2.10	3.63	44,086
40							15.61	5.58	68,947	7.51	6.30	60,329	2.29	3.82	46,407
42							17.01	9.01	72,395	8.18	6.62	63,345	2.49	4.02	48,727
44							18.45	9.44	75,842	8.87	6.93	66,362	2.71	4.21	51,047
46							19.94	9.87	79,289	9.59	7.25	69,378	2.93	4.40	53,368
48										10.33	7.57	72,395	3.15	4.59	55,688
50										11.09	7.88	75,411	3.39	4.78	58,009

Part III: Source Side Design / Closed Loop Installation Guidelines

Table 3-3e: 1" Rubber Hose Pressure Drop per 100ft of Hose

Flow Rate	Methanol*			Propylene Glycol*			Ethanol*			Water*		
	PD (ft)	Vel (ft/s)	Re	PD (ft)	Vel (ft/s)	Re	PD (ft)	Vel (ft/s)	Re	PD (ft)	Vel (ft/s)	Re
1	0.12	0.35	895	0.14	0.35	507	0.13	0.35	807	0.12	0.35	923
2	0.42	0.70	1789	0.48	0.70	1013	0.43	0.70	1614	0.42	0.70	1847
3	0.85	1.06	2709	0.98	1.06	1534	0.88	1.06	2444	0.85	1.06	2796
4	1.41	1.41	3604	1.63	1.41	2041	1.45	1.41	3251	1.40	1.41	3720
5	2.09	1.76	4499	2.41	1.76	2548	2.14	1.76	4058	2.07	1.76	4643
6	2.87	2.11	5393	3.31	2.11	3054	2.95	2.11	4864	2.85	2.11	5567
7	3.76	2.47	6314	4.33	2.47	3575	3.86	2.47	5694	3.73	2.47	6516
8	4.75	2.82	7208	5.47	2.82	4082	4.87	2.82	6501	4.71	2.82	7440
9	5.84	3.17	8103	6.73	3.17	4589	5.99	3.17	7308	5.79	3.17	8363
10	7.02	3.52	8997	8.09	3.52	5095	7.20	3.52	8115	6.96	3.52	9286
11	8.29	3.87	9892	9.56	3.87	5602	8.51	3.87	8922	8.23	3.87	10210
12	9.65	4.23	10812	11.13	4.23	6123	9.91	4.23	9752	9.58	4.23	11160
13	11.11	4.58	11707	12.80	4.58	6630	11.40	4.58	10559	11.02	4.58	12083
14	12.65	4.93	12602	14.58	4.93	7136	12.98	4.93	11366	12.55	4.93	13006
15	14.27	5.28	13496	16.45	5.28	7643	14.64	5.28	12173	14.16	5.28	13930
16	15.97	5.64	14416	18.41	5.64	8164	16.39	5.64	13003	15.85	5.64	14879
17	17.76	5.99	15311	20.48	5.99	8670	18.23	5.99	13810	17.62	5.99	15803
18	19.63	6.34	16206	22.63	6.34	9177	20.15	6.34	14616	19.48	6.34	16726
19	21.58	6.69	17100	24.88	6.69	9684	22.15	6.69	15423	21.41	6.69	17650
20	23.61	7.04	17995	27.22	7.04	10190	24.23	7.04	16230	23.42	7.04	18573

*Notes:
1. Methanol is at 20% by volume; propylene glycol is at 25% by volume; ethanol is at 25% by volume.
2. Percentage by volume, shown above is 15°F [-9.4°C] freeze protection.
3. All fluids with antifreeze are shown at 30°F [-1°C]; water is at 50°F [10°C].

Part III: Source Side Design / Closed Loop Installation Guidelines

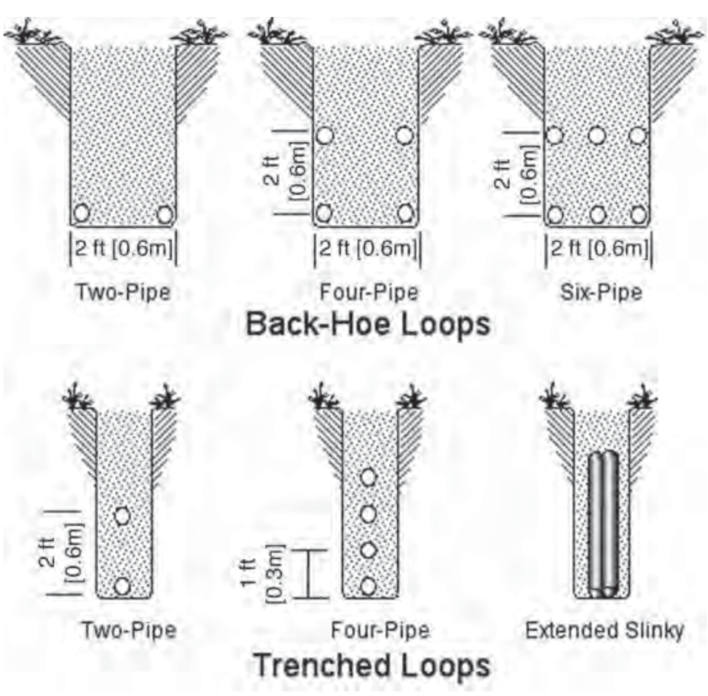
⚠ CAUTION! ⚠

CAUTION! This manual is not intended for commercial loop design.

Horizontal Applications

For horizontal earth loops, dig trenches using either a chain-type trenching machine or a backhoe. Dig trenches approximately 8-10 feet [2.5 to 3 meters] apart (edge to edge of next trench). Trenches must be at least 10 feet [3 meters] from existing utility lines, foundations and property lines and at least 50 feet [15.2 meters] minimum from privies and wells. Local codes and ordinances supersede any recommendations in this manual. Trenches may be curved to avoid obstructions and may be turned around corners. When multiple pipes are laid in a trench, space pipes properly and backfill carefully to avoid disturbing the spacing between the pipes in the trench. Figure 3-7 details common loop cross-sections used in horizontal loops. Actual number of circuits used in each trench will vary depending upon property size. Use GeoDesigner software to determine the best layout.

Figure 3-7: Typical Horizontal Loop Configurations



Vertical Applications

For vertical earth loops, drill bore holes using any size drilling equipment. Regulations which govern water well installations also apply to vertical ground loop installations. Vertical applications typically require multiple bore holes. Space bore holes a minimum of 10 feet [3 meters] apart. In southern or cooling dominated climates 15 feet [4.6 meters] is required. Commercial installations may require more distance between bores. This manual is not intended for commercial loop design.

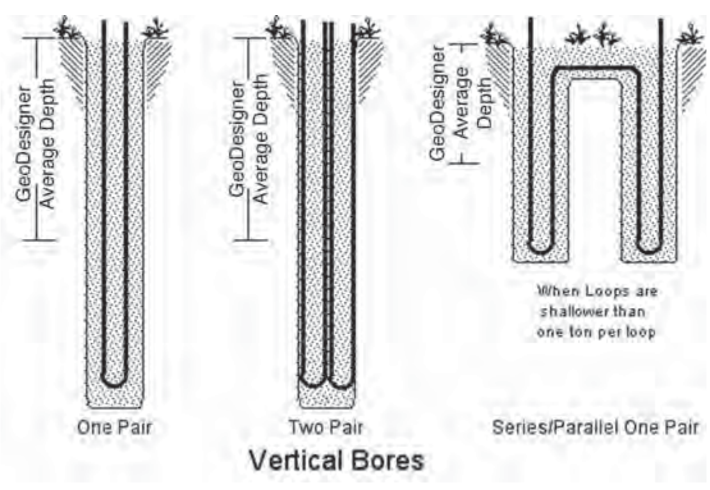
The minimum diameter bore hole for 3/4 inch or 1 inch U-bend well bores is 4 inches [102 mm]. Larger diameter bore holes may be drilled if necessary. Assemble each U-bend assembly, fill with water and perform a hydrostatic pressure test prior to insertion into the bore hole.

To add weight and prevent the pipe from curving and digging into the bore hole wall during insertion, tape a length of conduit, pipe or reinforcing bar to the U-bend end of the assembly. This technique is particularly useful when inserting the assembly into a bore hole filled with water or drilling mud solutions, since water filled pipe is buoyant under these circumstances.

Carefully backfill the bore holes with an IGSHPA approved Bentonite grout (typically 20% silica sand soilds by weight) from the bottom of the bore hole to the surface. Follow IGSPHA specifications for backfilling unless local codes mandate otherwise. When all U-bends are installed, dig the header trench 4 to 6 feet [1.2 to 1.8 meters] deep and as close to the bore holes as possible. Use a spade to break through from ground level to the bottom of the trench. At the top of the hole, dig a relief to allow the pipe to bend for proper access to the header. The "laydown" header mentioned earlier is a cost effective method for connecting the bores. Figure 3-8 illustrates common vertical bore heat exchangers.

Use an IGSHPA design based software such as GeoDesigner for determining loop sizing and configurations.

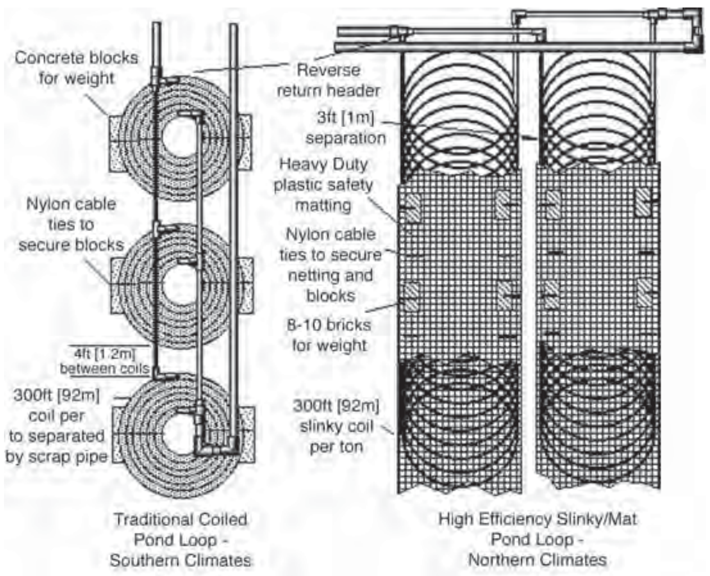
Figure 3-8: Typical Vertical Loop Configurations



Part III: Source Side Design / Closed Loop Installation Guidelines

Pond/Lake Applications
Pond loops are one of the most cost effective applications of geothermal systems. Typically 1 coil of 300 ft of PE pipe per cooling ton [26 meters per kW -- one 92 meter coil per 3.5 kW of cooling capacity] is sunk in a pond and headered back to the structure. Minimum pond sizing is 1/2 acre [0.2 hectares] and minimum 8 to 10 feet [2.4 to 3 meters] deep for an average residential home. In the north, an ice cover is required during the heating season to allow the pond to reach an average 39°F [3.9°C] just below the ice cap. Winter aeration or excessive wave action can lower the pond temperature preventing ice caps from forming and freezing, adversely affecting operation of the geothermal loop. Direct use of pond, lake, or river water is discouraged because of the potential problems of heat exchanger fouling and pump suction lift. Heat exchanger may be constructed of either multiple 300 ft. [92 meter] coils of pipe or slinky style loops as shown in Figure 3-9. In northern applications the slinky or matt style is recommended due to its superior performance in heating. Due to pipe and antifreeze buoyancy, pond heat exchangers will need weight added to the piping to prevent floating. 300 foot [92 meter] coils require two 4" x 8" x 16" [102 x 203 x 406 mm] blocks (19 lbs. [8.6 kg] each) or 8-10 bricks (4.5 lbs [2.1 kg] each) and every 20 ft [6 meters] of 1-1/4" supply/return piping requires 1 three-hole block. Pond Coils should be supported off of the bottom by the concrete blocks. The supply/return trenching should begin at the structure and work toward the pond. Near the pond the trench should be halted and back filled most of the way. A new trench should be started from the pond back toward the partially backfilled first trench to prevent pond from flooding back to the structure.

Figure 3-8: Typical Pond/Lake Loop Configurations



BUILDING ENTRY

Seal and protect the entry point of all earth coupling entry points into the building using conduit sleeves hydraulic cement.

Slab on Grade Construction
New Construction: When possible, position the pipe in the proper location prior to pouring the slab. To prevent wear as the pipe expands and contracts protect the pipe as shown in Figure 3-10. When the slab is poured prior to installation, create a chase through the slab for the service lines with 4 inch [102 mm] PVC street elbows and sleeves.

Retrofit Construction: Trench as close as possible to the footing. Bring the loop pipe up along the outside wall of the footing until it is higher than the slab. Enter the building as close to the slab as the construction allows. Shield and insulate the pipe to protect it from damage and the elements as shown in Figure 3-11.

Pier and Beam (Crawl Space)
New and Retrofit Construction: Bury the pipe beneath the footing and between piers to the point that it is directly below the point of entry into the building. Bring the pipe up into the building. Shield and insulate piping as shown in Figure 3-12 to protect it from damage.

Below Grade Entry
New and Retrofit Construction: Bring the pipe through the wall as shown in Figure 3-13 For applications in which loop temperature may fall below freezing, insulate pipes at least 4 feet [1.2 meters] into the trench to prevent ice forming near the wall.

Pressure Testing
Upon completion of the ground loop piping, hydrostatic pressure test the loop to assure a leak free system.

Horizontal Systems: Test individual loops as installed. Test entire system when all loops are assembled before backfilling and pipe burial.

Vertical U-Bends and Pond Loop Systems: Test Vertical U-bends and pond loop assemblies prior to installation with a test pressure of at least 100 psi [689 kPa]. Perform a hydrostatic pressure test on the entire system when all loops are assembled before backfilling and pipe burial.

Part III: Closed Loop Design / Installation Guidelines

Figure 3-10: Slab on Grade Entry Detail

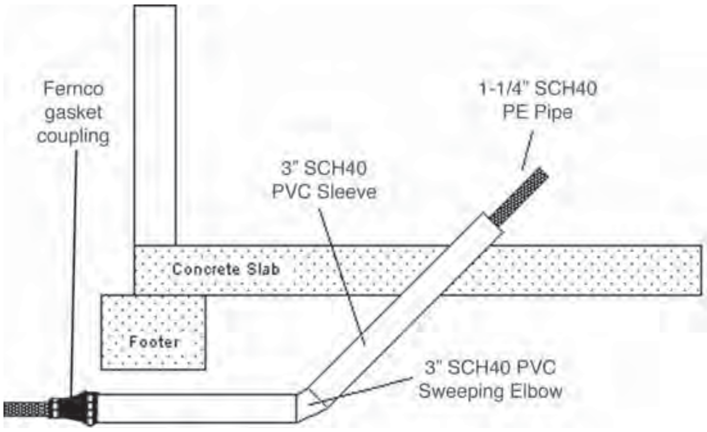


Figure 3-12: Pier and Beam (Craw Space) Detail

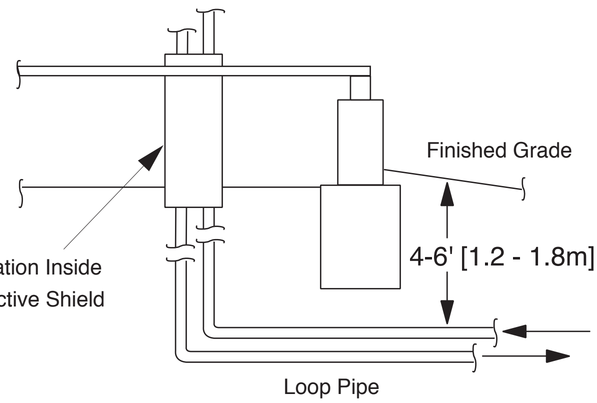


Figure 3-11: Retrofit Construction Detail

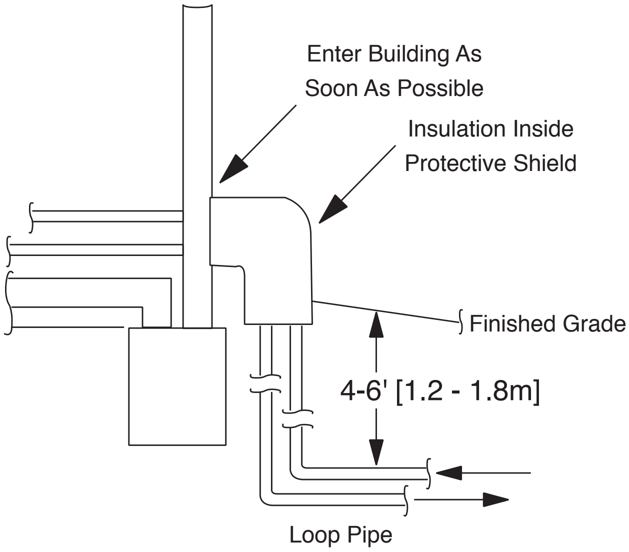
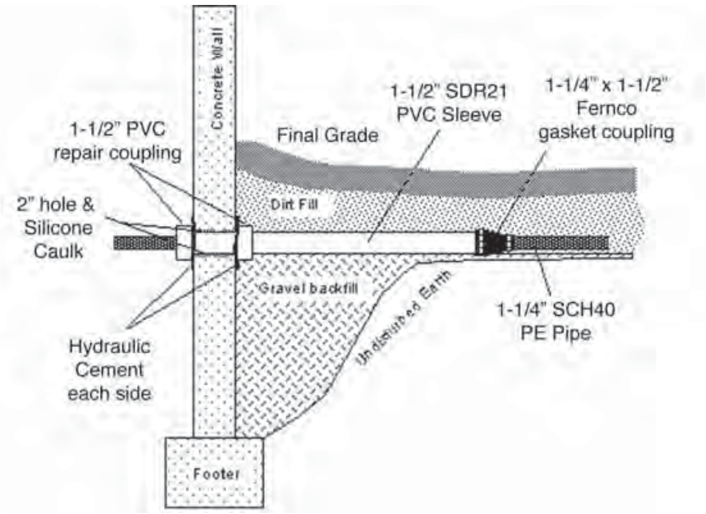


Figure 3-13: Below Grade Entry Detail



Part IV: Controls

CONTROL STRATEGIES

Overview

Controls for hydronics applications can be very simple or very complicated, depending upon the features desired, and the type of system chosen. Water-to-water units are the most flexible of all heat pumps, since there are so many applications that are possible. Below is an overview of the steps necessary for deciding the best control strategy for a particular application.

The first step in deciding which control strategy is appropriate for the application is to decide the type of equipment that will be used. ClimateMaster offers heating only water-to-water units (THW series) and reversible, or heating/cooling water-to-water units (TMW series). ClimateMaster's recommended approach includes a dedicated water-to-water unit for heating / hot water generation, and a dedicated water-to-air unit for cooling. The approach provides the simplest controls interface, and has the advantage of redundancy (i.e. the water-to-air unit may be used for heating in the shoulder seasons if the water-to-water unit is not operating). Plus, the wide variety of water-to-air units allows the designer to address retrofit installations with greater flexibility. For example, duct free (console-type) units may be used when duct work for cooling is not possible.

Once the type of equipment is determined, the type of water-to-water unit can be selected. The THW series includes internal controls specifically designed for hydronic heating systems (see section on THW series controls, below), whereas the TMW series require external controls. The THW series is especially suited to radiant floor heating systems and the production of domestic hot water. However, since the THW series is heating only, the TMW series should be selected when chilled water is required.

The next decision regarding controls involves buffer tank temperatures. A fixed temperature, controlled by an aqua-stat is the simplest and least expensive type of control strategy to install. However, outdoor temperature reset (changing the setpoint temperature of the water in the buffer tank based upon outside temperature) is the most cost-effective strategy when controlled by a microprocessor-based controller. This decision can affect annual operating costs significantly, since the COP of the water-to-water unit improves as the source and load water temperatures are closer together.

The next several pages show the various control drawings, as well as specific information on the internal controls available in the THW series heat pumps. No one strategy is best for all hydronics applications. Individual customer preferences and budgets will help determine which system is best for each application.

THW Series Controls

The ClimateMaster THW series water-to-water heat pump is unlike any other heat pump on the market. The large operating map of the scroll compressor allows high temperature operation, up to 145°F (63°C) leaving load water temperature (even at 32°F [0°C] entering source water temperature). The combination of a coaxial (tube in tube) heat exchanger for the source (ground loop) side and a brazed plate heat exchanger for the load (heating/hot water) side provides very high efficiencies. Integral controls for hydronic heating and domestic water heating avoid the need for external microprocessor-based controls for outdoor temperature reset, warm weather shutdown and staging. Below is a summary of the key components of the THW series internal controls, followed by a list of control features.

<u>"Smart" module (MPC)</u>: Every THW unit includes the ClimateMaster MPC controller. The MPC is a programmable controller that takes inputs such as buffer tank temperature, domestic hot water (DHW) tank temperature, outdoor air temperature, and other inputs to "decide" when to operate the compressor, pumps and hot water valve. The MPC is factory-wired to the CXM compressor control module and user interface.

MPC Programmable Controller

Part IV: Controls

User interface: Figure 4-1 shows the factory installed and wired panel-mounted user interface for customizing the MPC programming. A large dot-matrix style 2" x 2" [5 x 5 cm] back-lit display is controlled by four arrow keys and a select key. The main screen, as shown in figure 4-2, displays current outdoor and water temperatures, and allows the user to change settings by selecting one of the menus from the bottom of the screen. A special installer set up mode allows the technician to change some of the default MPC parameters. The user interface includes a time schedule for DHW generation, Fahrenheit/Celsius selection, vacation mode for DHW, and other user preference options.

Figure 4-1: THW User Interface

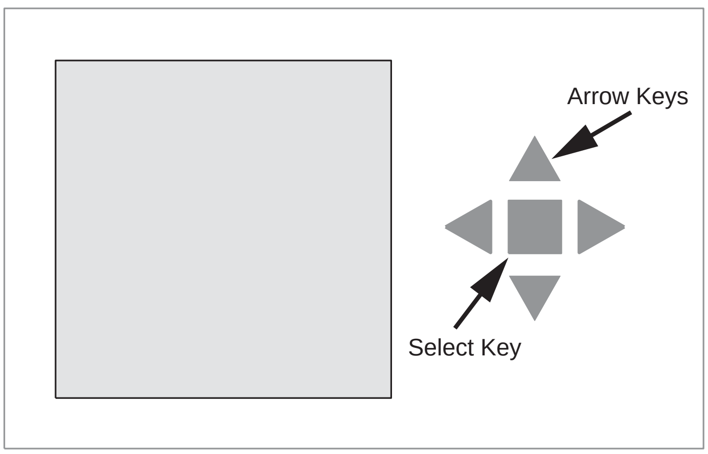
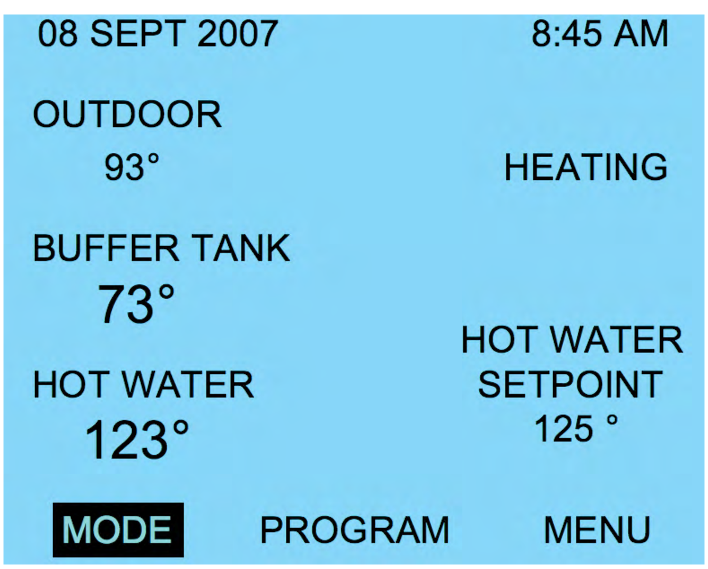


Figure 4-2: THW User Interface Main Screen



12-point terminal block: Thermistors and external wiring are connected to a 12-point terminal block for ease of installation. The MPC, user interface, CXM board and other relays/components are factory-wired to the terminal block. A blue/gray pattern is used for ease of identification.

DHW valve (optional): An internal three-way valve is available, which allows the THW unit to switch between heating and DHW generation.

Internal source and load pumps / internal expansion tanks (optional): Source pump(s), load pump, and expansion tank(s) are available to help lower installation costs and labor. When installed at the factory, pumps are wired and controlled by the MPC.

THW Series Control Features

The advantage of a programmable controller, as outlined above, is the ability to integrate complex decision-making tasks with the standard heat pump (CXM) controls and communicate with a user interface. Below is a list of standard features that are included in the THW series controls.

> **CAUTION:**
> Maximum leaving water temperature of the THW series equipment is 145°F [63°C]. For domestic hot water tank temperatures or heating buffer tank temperatures above 130°F [54°C], pump and pipe sizing is critical to insure that the flow rate through the heat pump is sufficient to maintain leaving water temperatures below the maximum temperature, and to provide water flow rates within the ranges shown in the performance section of this manual.

Outdoor temperature reset: The heat pump capacity and water temperature delivery to the heating system must be designed for local weather conditions, usually at the 99.6% outdoor temperature. Therefore, 99.6% of the heating season, the heating load is less than it is at design conditions. As the outdoor temperature decreases, the heat loss of the structure increases, which requires more capacity from the heating system. If the water temperature is reduced as the outdoor air temperature increases (and vise-versa), the heat pump operates at higher COP most of the year. The MPC has a built in algorithm that adjusts the buffer tank temperature based upon outdoor air temperature to maximize efficiency and comfort. Temperature settings may be adjusted at the user interface if factory defaults are not sufficient.

The base setpoint for energizing the compressor in the heating mode is determined by subtracting one-half the heating differential value (HTD) from the buffer tank heating temperature setpoint. The HTD is the differential used for controlling setpoint. For example, if the buffer tank setpoint is 100°F [38°C], and the HTD is 6°F [3°C], the compressor will be energized at 97°F [36°C] and will be turned off at 103°F [39°C]. The HTD is the difference between the compressor "call" (97°F [36°C]) and the "satisfied" (103°F [39°C]) temperature. The buffer tank temperature may

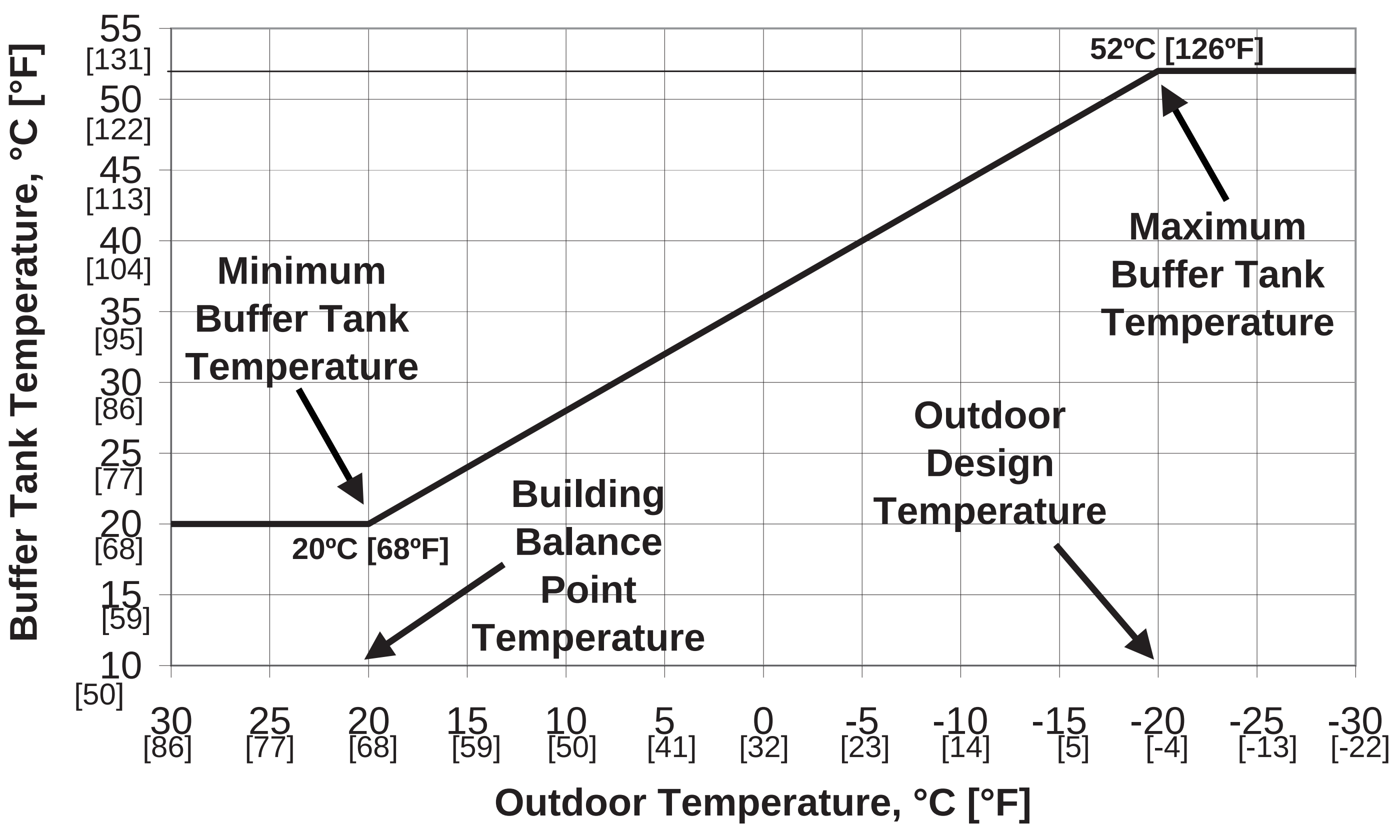
Part IV: Controls

then be reduced by the outdoor temperature reset function, depending on the current outdoor air temperature (OAT) value. The valid range for the buffer tank heating setpoint is 70-140°F [21-60°C], with a default value of 100°F [38°C]. The valid range for the heating differential value (HTD) is 4-20°F [2-11°C], adjustable in 2°F [1°C] increments, with a default value of 6°F [3°C].

There are four outdoor reset variables used for reducing the buffer tank setpoint. The outdoor design temperature (ODT) is the OAT above which setpoint reduction begins. The valid range for ODT is –40°F to 50°F [-40°C to 10°C], with a default value of 0°F [-18°C]. The maximum design buffer tank temperature (MaxBT) is the maximum desired buffer tank setpoint at the outdoor design temperature. The valid range for MaxBT is 80-140°F [27-60°C], with a default value of 130°F [54°F]. The building balance point temperature (the temperature at which heating is no longer needed) is the OAT at which maximum setpoint (MaxBT) reduction will occur. The valid range for building balance point is 50-70°F [10-21°C], with a default value of 60°F [16°F]. The minimum design water temperature is the minimum desired buffer tank setpoint at the building balance point temperature. The valid range for minimum buffer tank temperature is 70°F-120°F [21-49°C], with a default value of 70°F [21°c]. If an OAT sensor is not detected (or if a thermistor error has occurred), the buffer tank setpoint will not be reduced based on the OAT value (i.e. the controller will use the buffer tank setpoint as described in the previous paragraph).

Figure 4-3 shows an example outdoor temperature reset curve for a climate that has an outdoor design temperature of -4°F [-20°C]. At design temperature, the radiant floor system needs 126°F [52°C] water. However, when the outdoor temperature is 68°F [20°C], the home needs no heating (building balance point). In between -4°F and 68°F [-20°C and 20°C], the water temperature in the buffer tank is adjusted accordingly. For homes that are well insulated and tightly sealed, the building balance point may be 55°F [13°C] or lower, so the slope of the line changes based upon settings at the user interface. The radiant floor design temperature will also change the slope of the line. If tighter pipe spacing is used, for example, the water temperature at the outdoor design temperature may only be 100°F [38°C]. Again, as the settings are changed at the user interface, the slope of the line will change. As mentioned earlier, the lower the heating water temperature at design conditions, the higher the efficiency (COP) of the heat pump. The combination of a lower design temperature and outdoor temperature reset can result in a significant impact on operating costs.

Figure 4-3: Example Outdoor Temperature Reset



Part IV: Controls

Warm weather shutdown (WWSD): Radiant floor systems are the most comfortable type of heating available today. However, they do have one disadvantage – quickly switching from heating to cooling is not possible due to the mass heat storage in the slab. For example, in the spring or fall, there could be times where heating is required at night, but cooling is required during the day. With a warm floor, the cooling system has to work much harder to cool the space. WWSD shuts down the water-to-water heat pump at a pre-determined outdoor air temperature (adjustable at the user interface). When a water-to-air heat pump is used for space cooling, this unit can be enabled when WWSD is activate, allowing the water-to-air heat pump to heat via forced air during the shoulder seasons, avoiding the warm slab/cooling dilemma (see cooling enable, below). A normally closed contact is provided in the THW unit to de-energize the heating system controls (e.g. radiant floor control panel) during WWSD. WWSD does not affect DHW heating. In other words, the water-to-water unit can still operate for generating DHW, even if the heating distribution (e.g. radiant floor) system is disabled.

The WWSD activation (i.e. when the WWSD feature is enabled) outdoor air temperature range is 40-100°F [4-38°C] with a default value of 70°F [21°C]. The WWSD deactivation (i.e. when the radiant heating returns to operating mode) temperature range is 35-95°F [2-35°C] with a default value of 65°F [18°C] and a minimum difference between activation and deactivation temperatures of 5°F [3°C]. If the outdoor air temperature (OAT) rises above the activation temperature, the cooling enable signal (see below) is enabled, and the control no longer controls the buffer tank temperature. If the OAT falls below the deactivation temperature, the control resumes monitoring the buffer tank temperature.

Cooling enable: Cooling enable is tied to the WWSD feature. If desired, the water-to-air unit controls can be wired to the THW unit controls, which will allow the water-to-air unit to operate during WWSD, but will disable the water-to-air unit when the THW unit is not in WWSD mode. When a heat pump thermostat is connected to the water-to-air unit, forced air heating may be used for the shoulder seasons, allowing quick heating to cooling changeover. If this feature is used, the consumer will easily be able to tell when WWSD is enabled because the water-to-air unit thermostat will only be active during WWSD. Otherwise, the water-to-air unit thermostat will be disabled, indicating that the consumer should utilize the hydronic heating (e.g. radiant floor) thermostat.

Heat pump staging: For large capacity installations, multiple THW units may be controlled by the first heat pump via the backup boiler function. The second unit simply needs a 24VAC relay that is energized by the output of the first unit. The third, fourth, etc. units would be wired in the same manner.

Second stage heating (backup boiler): As discussed in part II of this manual, optimal heat pump sizing may not include a water-to-water heat pump that can handle 100% of the heating load. When a backup boiler is used to supplement the heating capacity, a 24VAC output from the THW unit can energize the boiler. The boiler control box simply needs a relay that can be used to interface with the THW unit.

DHW priority: By default, DHW heating always takes priority over space heating. Normally, the hot water load will be satisfied quickly, and the unit can then switch back to space heating.

Time schedule: DHW temperatures may be adjusted during occupied/unoccupied times via the user interface to save energy costs.

Vacation mode: DHW generation may be disabled when the user interface is placed in vacation mode. A return date and time may be set to restore normal DHW temperatures.

Emergency DHW generation: If the THW unit is locked out, a 24VAC signal can be sent to a contactor at the water heater to allow the operation of the electric elements and associated thermostat.

Enhanced heat pump lockouts: Like any ClimateMaster unit, the CXM board locks out the compressor any time a lockout condition occurs. The MPC reads the lockouts from the CXM, and reports the condition to the user interface. The user interface changes from a blue backlight to a red backlight, indicating a lockout. The actual lockout is reported (e.g. High Pressure) at the interface. In addition to the standard CXM faults, the MPC checks for bad thermistors and high compressor discharge temperature, which are also reported at the user interface.

Pump control: If the optional load and source pump(s) are selected, the control energizes the pumps any time the compressor is operating.

Variable speed floor pump (VSFP) output: Some radiant floor systems utilize a variable speed pump on the floor system, which changes flow based upon the number of zones open or closed. Since the pump has built-in controls, only a power supply is needed. An optional power terminal is available for VSFP applications.

Part IV: Controls / Wiring Diagrams

Wiring Diagrams

Table 4-1 shows the various combinations of water-to-water units and typical applications. Following the table are THW wiring diagrams and TMW wiring diagrams.

Table 4-1: Wiring Diagram Matrix

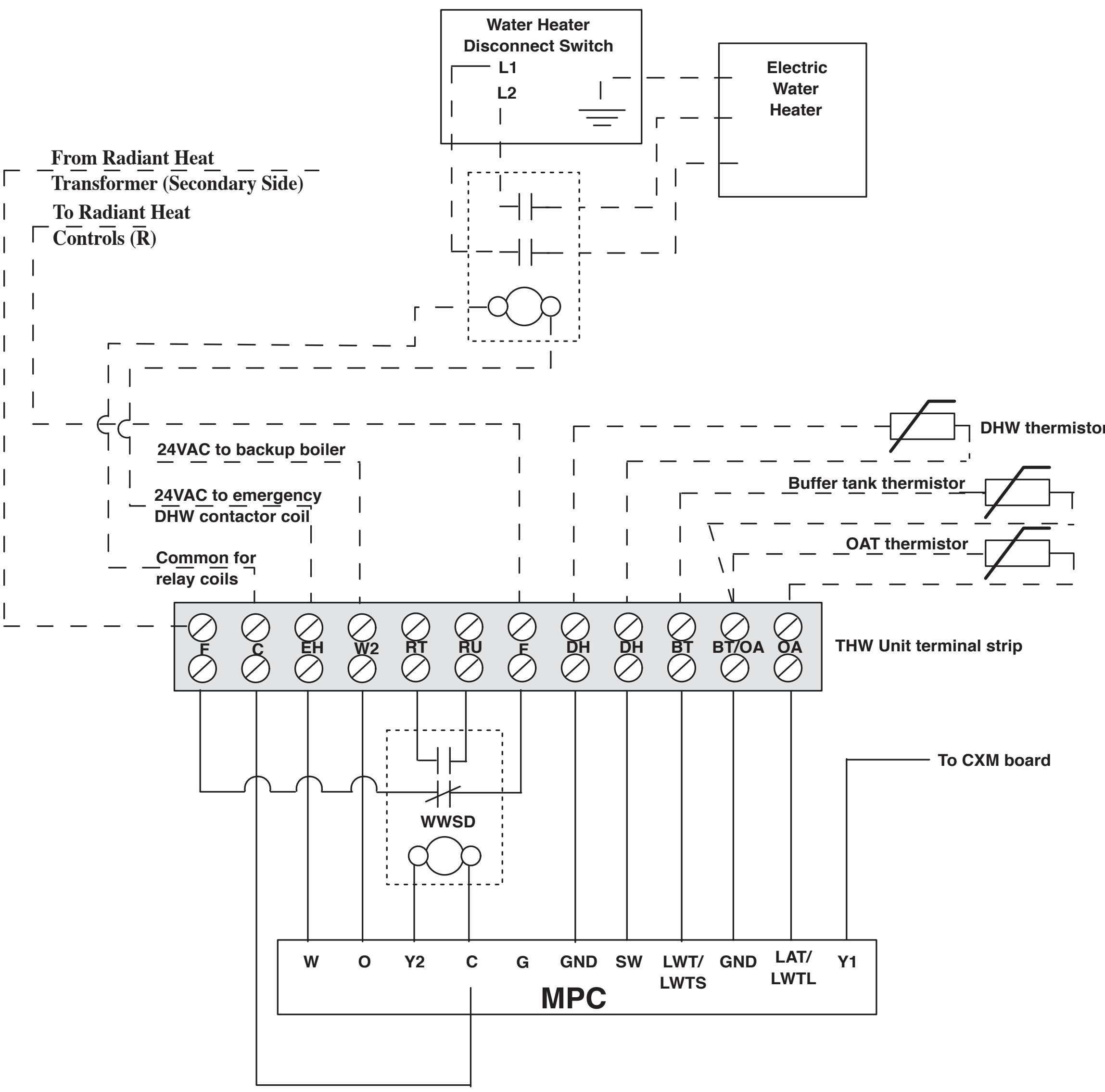
Heat Pump	Chilled Water Cooling	Sep W-A Unit for Cooling	W-W Unit Source Pumps	W-W Unit Load Pumps	W-A Unit Source Pumps	Wiring Diagram
THW	N/A	No	Internal	Internal	N/A	4-1
THW	N/A	No	External	External	N/A	4-2
THW	N/A	Yes	Internal	Internal	External	4-3
THW	N/A	Yes	External	External	External	4-4
TMW	No	No	External	External	N/A	4-5
TMW	No	Yes	External	External	External	4-6
TMW	No	Yes	External	External	N/A	4-7
TMW	Yes	No	External	External	N/A	4-8

THW Series
Wiring diagrams for the THW series are shown below. A 12-point terminal strip (shaded in gray) provides connections for thermistors and other external devices used for controlling the hydronic heating system and separate forced air cooling unit.

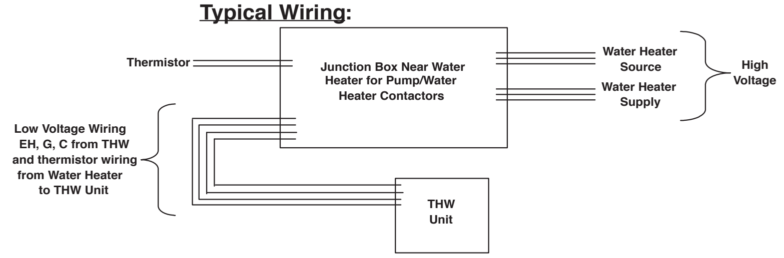
TMW Series
The TMW series water-to-water heat pumps require external controls for hydronic heating. If outdoor temperature reset is not required, a simple aqua-stat can control the heat pump. If more complex control strategies are required, however, ClimateMaster recommends the THW series or an external microprocessor-based controller like those manufactured by Tekmar. ***Due to the many possible applications for water-to-water heat pumps, the drawings below show only simple, aqua-stat type control wiring, and cannot be considered all-encompassing.***

Part IV: Controls / Wiring Diagrams

Drawing 4-1: THW Unit - Internal Pumps / No Cooling / DHW Tank



Typical Wiring:



Legend:	
F	Radiant Floor 24VAC interrupt*
C	Common
EH	Electric Heat (DHW)**
W2	2nd Stage Heat***
RT	24VAC to cooling thermostat
RU	24VAC from water-to-air unit
DH	DHW Tank Thermistor
BT	Buffer Tank Thermistor
OA	Outdoor Air Temperature
BT/OA	Gnd connection for Thermistors
WWSD	Warm Weather Shut-Down
———	Factory Wiring
— — -	Field Wiring

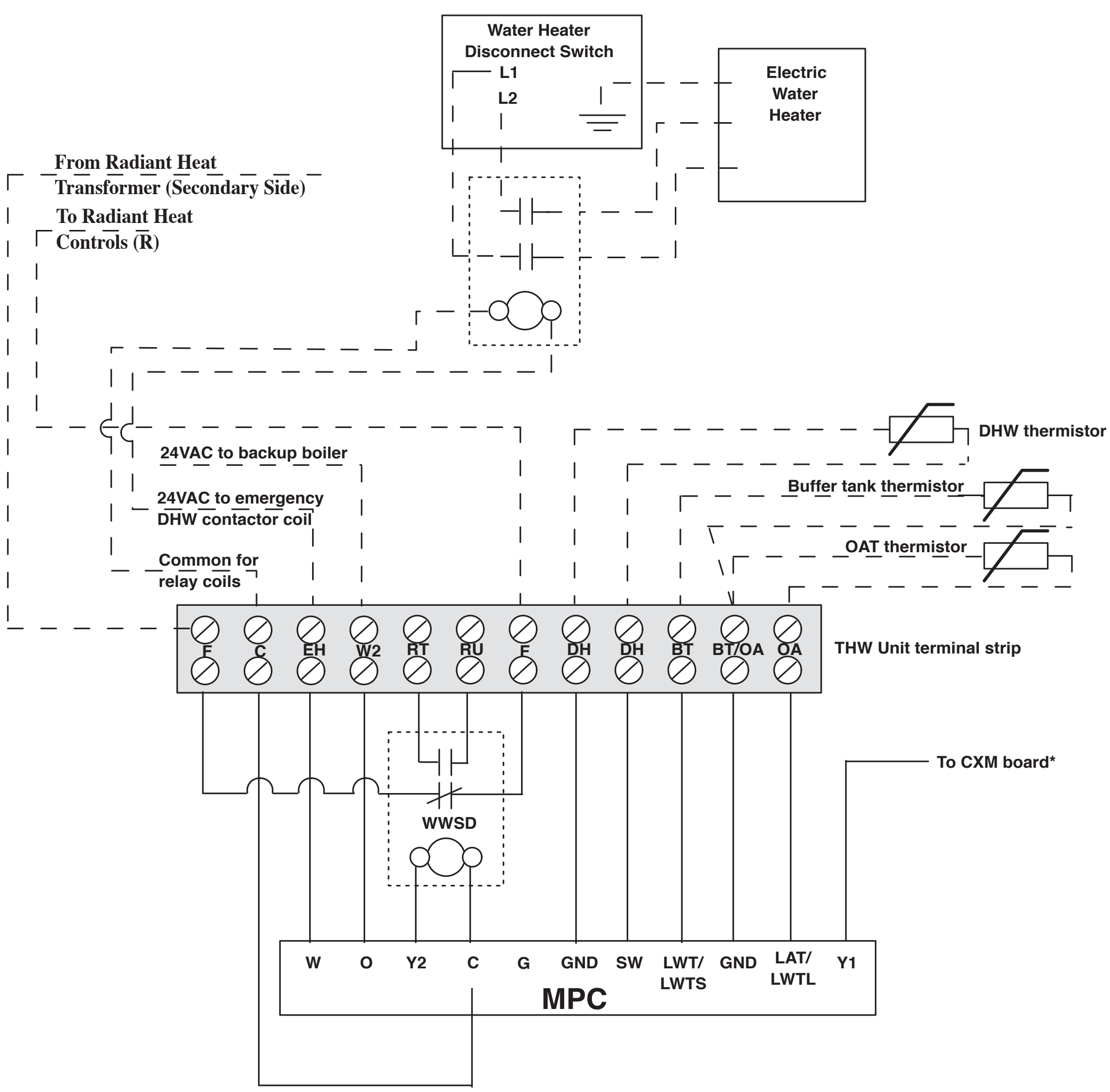
*These connections allow the THW unit to manage seasonal change-over by enabling or disabling the radiant floor or other hydronic heating system with the use of the warm weather shut down feature, which is part of the THW series controls.

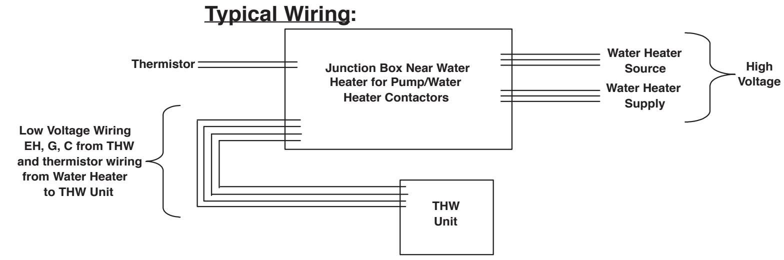
**Optional backup electric elements in DHW tank. Connect this 24VAC output to a contactor to allow the elements to operate.Note that this signal is only energized during a heat pump lock-out.

***Optional 2nd stage heating, provided by a backup boiler or electric elements in a buffer tank. Connect 24VAC output to a contactor (elements) or relay (boiler) to control the 2nd stage device.

Part IV: Controls / Wiring Diagrams

Drawing 4-2: THW Unit - External Pumps* / No Cooling / DHW Tank





Legend:	
F	Radiant Floor 24VAC interrupt**
C	Common
EH	Electric Heat (DHW)***
W2	2nd Stage Heat****
RT	24VAC to cooling thermostat
RU	24VAC from water-to-air unit
DH	DHW Tank Thermistor
BT	Buffer Tank Thermistor
OA	Outdoor Air Temperature
BT/OA	Gnd connection for Thermistors
WWSD	Warm Weather Shut-Down
———	Factory Wiring
– – –	Field Wiring

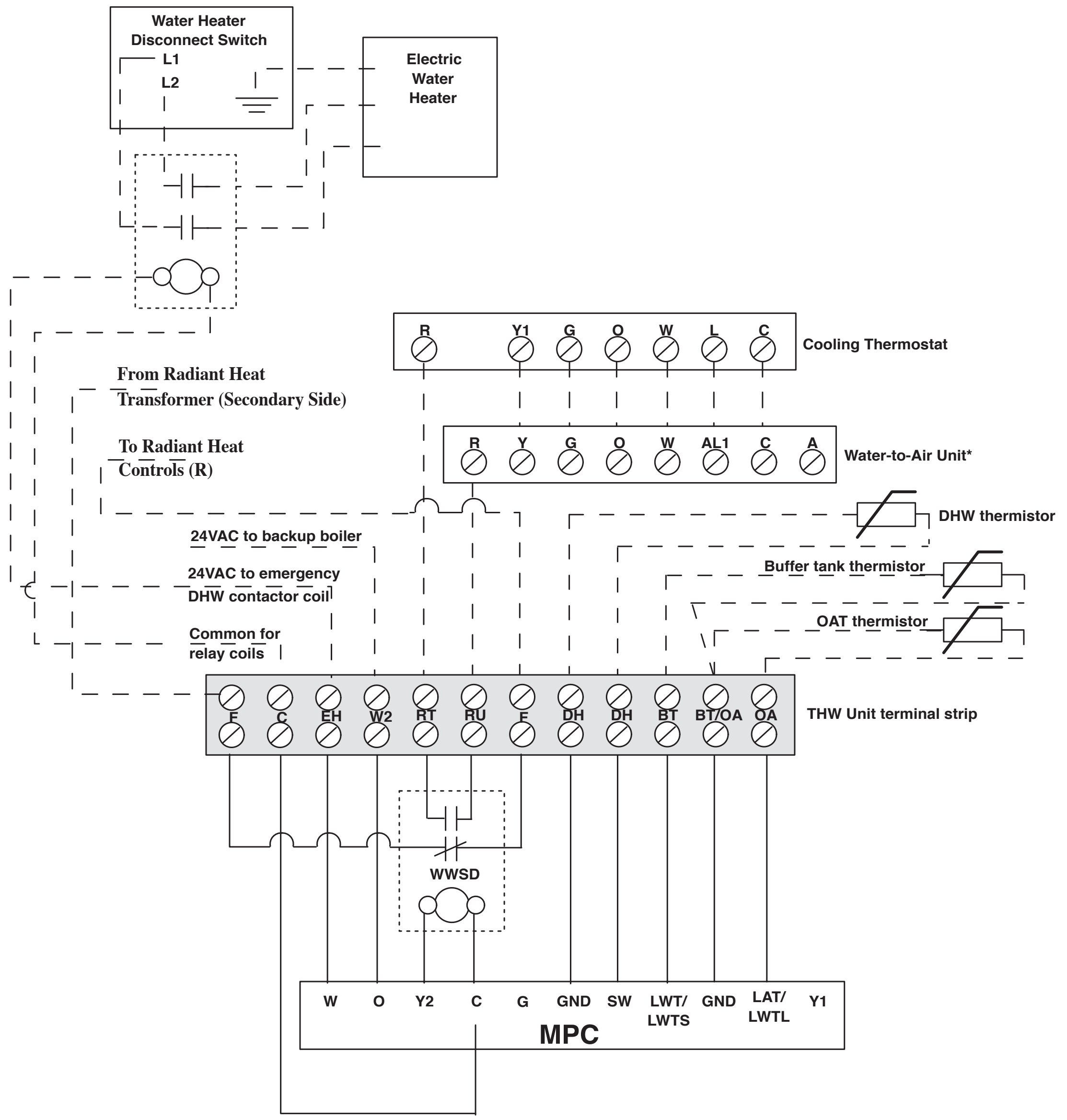
*External pump wiring should be accomplished at the CXM board via a field-installed relay. The coil should be wired between terminals “A” and “C.” Pumps must fuse-protected.

**These connections allow the THW unit to manage seasonal change-over by enabling or disabling the radiant floor or other hydronic heating system with the use of the warm weather shut down feature, which is part of the THW series controls.

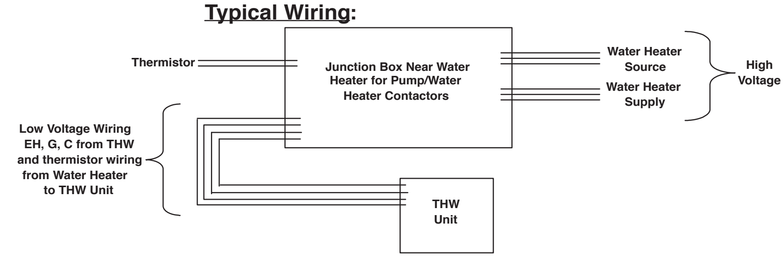
***Optional backup electric elements in DHW tank. Connect this 24VAC output to a contactor to allow the elements to operate. Note that this signal is only energized during a heat pump lock-out.

****Optional 2nd stage heating, provided by a backup boiler or electric elements in a buffer tank. Connect 24VAC output to a contactor (elements) or relay (boiler) to control the 2nd stage device.

Drawing 4-3: THW Unit - Internal Pumps* / Water-to-Air Unit for Cooling



Typical Wiring:



Legend :

F	Radiant Floor 24VAC interrupt
C	Common
EH	Electric Heat (DHW)**
W2	2nd Stage Heat***
RT	24VAC to cooling thermostat****
RU	24VAC from water-to-air unit****
DH	DHW Tank Thermistor
BT	Buffer Tank Thermistor
OA	Outdoor Air Temperature
BT/OA	Gnd connection for Thermistors
WWSD	Warm Weather Shut-Down
———	Factory Wiring
– – –	Field Wiring

* THW unit pumps are controlled by unit controls. External pump(s) for water-to-air unit controlled by its unit controls.

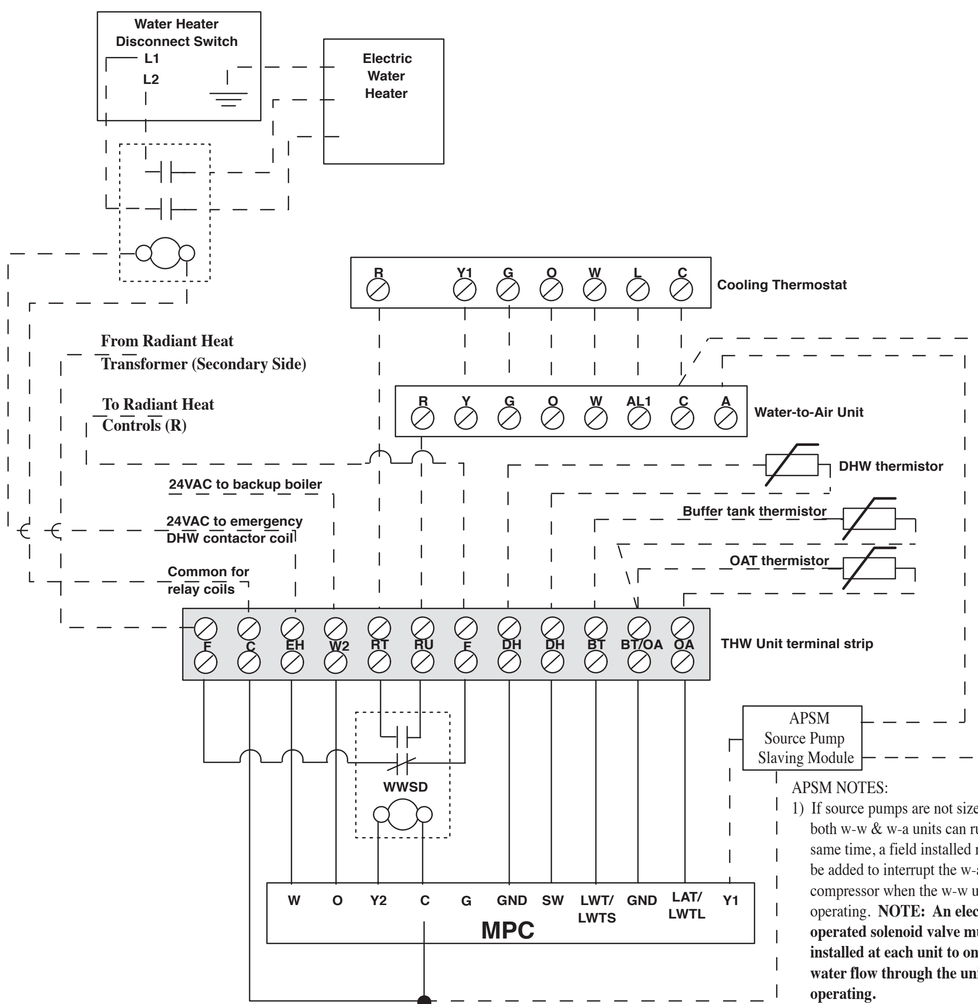
** Optional backup electric elements in DHW tank. Connect this 24VAC output to a contactor to allow the elements to operate. Note that this signal is only energized during a heat pump lock-out.

*** Optional 2nd stage heating, provided by a backup boiler or electric elements in a buffer tank. Connect 24VAC output to a contactor (elements) or relay (boiler) to control the 2nd stage device.

**** These connections (RT/RU) allow the THW unit to manage seasonal change-over by enabling or disabling the cooling t-stat. If a water-to-air heat pump is used for cooling, this unit can also provide forced air heating during mild conditions to avoid keeping a warm slab when cooling may be needed during the day and heating at night. The WWSD (Warm Weather Shut Down) feature provides this function. <u>NOTE: If the water-to-air unit also provides forced air heating to zones where there is no radiant floor heating, this feature should not be used (N.O. contacts of the relay). However, the N.C. contacts should still be used to disable the radiant floor system during warm weather conditions.</u>

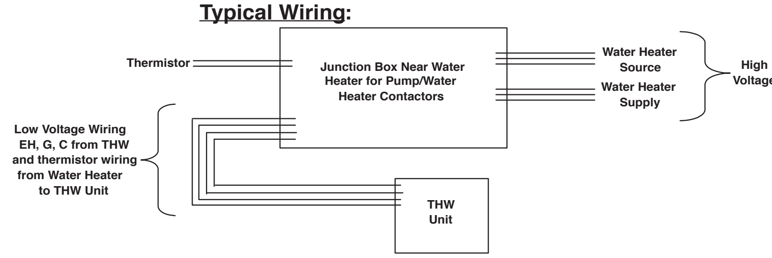
Part IV: Controls / Wiring Diagrams

Drawing 4-4: THW Unit - External Pumps* / Water-to-Air Unit for Cooling / DHW Tank



APSM NOTES:
1) If source pumps are not sized so that both w-w & w-a units can run at the same time, a field installed relay must be added to interrupt the w-a unit compressor when the w-w unit is operating. **NOTE: An electrically operated solenoid valve must be installed at each unit to only allow water flow through the unit that is operating.**
2) If load pump is external, Y1 should also control this pump.

Typical Wiring:



Legend:

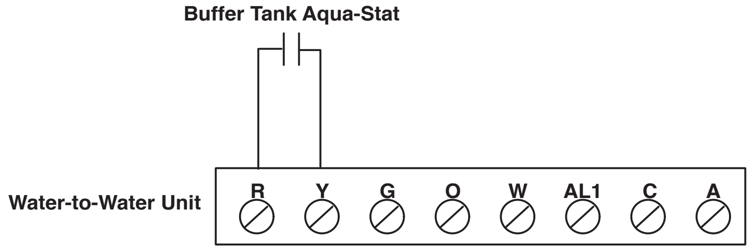
F	Radiant Floor 24VAC interrupt
C	Common
EH	Electric Heat (DHW)*
W2	2nd Stage Heat**
RT	24VAC to cooling thermostat***
RU	24VAC from water-to-air unit***
DH	DHW Tank Thermistor
BT	Buffer Tank Thermistor
OA	Outdoor Air Temperature
BT/OA	Gnd connection for Thermistors
WWSD	Warm Weather Shut-Down
———	Factory Wiring
– – –	Field Wiring

* Optional backup electric elements in DHW tank. Connect this 24VAC output to a contactor to allow elements to operate. Note: This signal is only energized during a heat pump lock-out.

** Optional 2nd stage heating, provided by a backup boiler or electric elements in a buffer tank. Connect 24VAC output to a contactor (elements) or relay (boiler) to control the 2nd stage device.

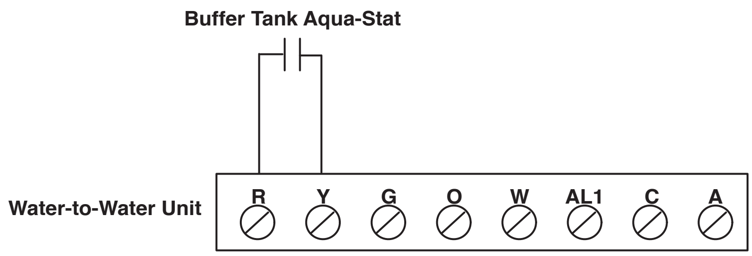
*** These connections (RT/RU) allow the THW unit to manage seasonal change-over by enabling or disabling the cooling t-stat. If a water-to-air heat pump is used for cooling, this unit can also provide forced air heating during mild conditions to avoid keeping a warm slab when cooling may be needed during the day and heating at night. The WWSD (Warm Weather Shut Down) feature provides this function. NOTE: If the water-to-air unit also provides forced air heating to zones where there is no radiant floor heating, this feature should not be used (N.O. contacts of the relay). However, the N.C. contacts should still be used to disable the radiant floor system during warm weather conditions.

**Drawing 4-5: TMW Unit - External Pumps* /
No Cooling**

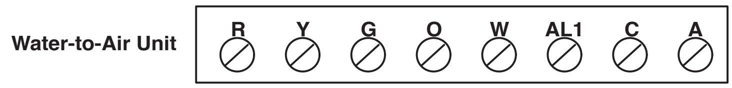


*Wiring assumes that source pumps and load pumps will be energized when compressor is energized.

**Drawing 4-6: TMW Unit - External Pumps* /
Cooling with Separate Water-to-Air Unit**



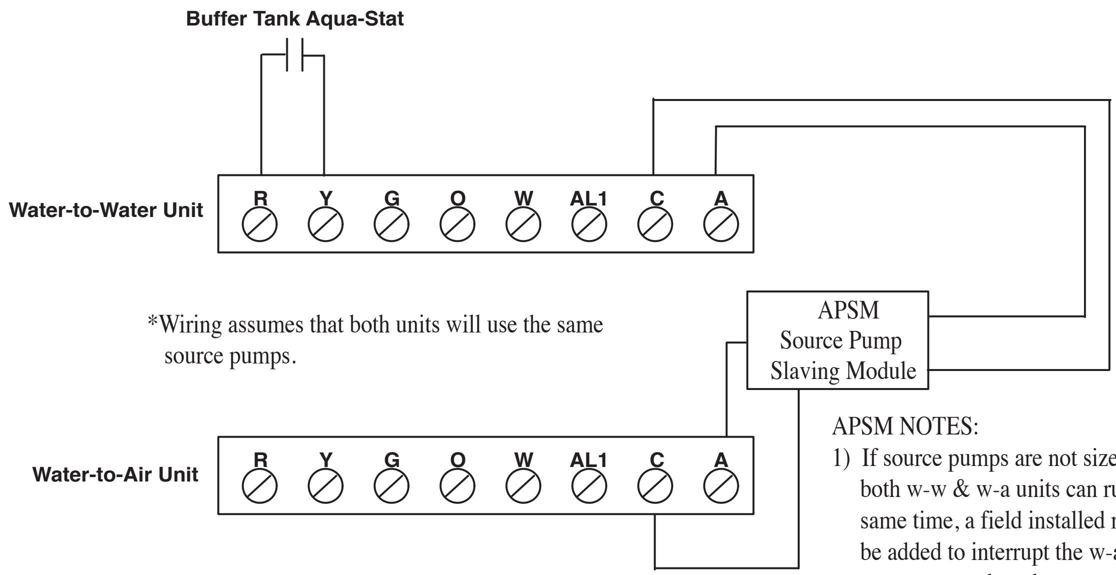
*Wiring assumes that each unit will control its own source pumps. Water-to-water load pump should be energized when its source pump is energized.



Water-to-air unit wired to separate thermostat for space cooling.

Part IV: Controls / Wiring Diagrams

Drawing 4-7: TMW Unit - External Pumps* / Cooling with Separate Water-to-Air Unit

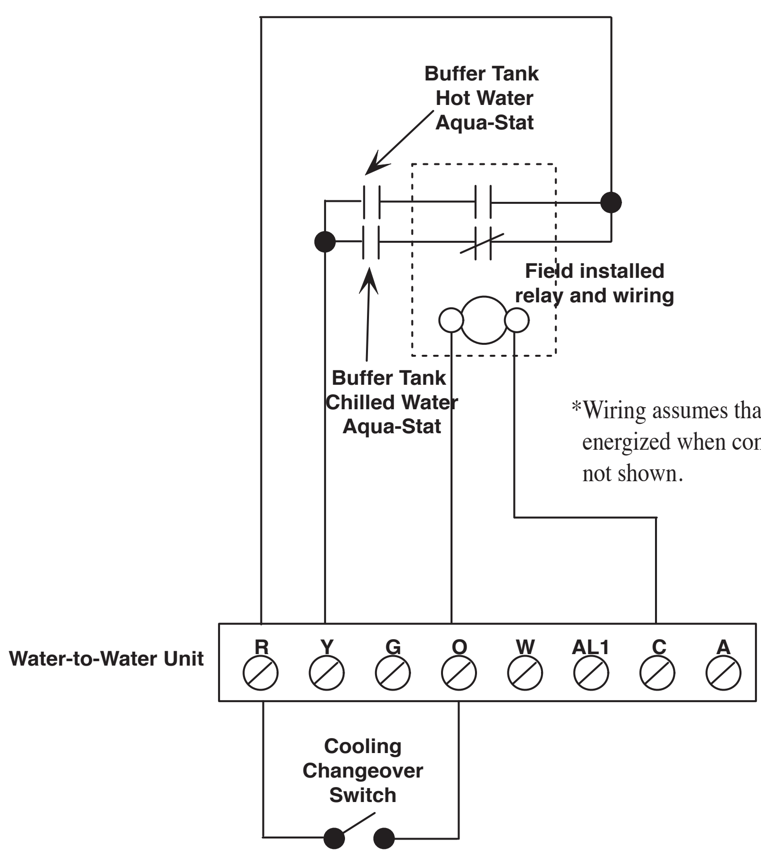


Water-to-air unit wired to separate thermostat for space cooling.

APSM NOTES:

1) If source pumps are not sized so that both w-w & w-a units can run at the same time, a field installed relay must be added to interrupt the w-a unit compressor when the w-w unit is operating. **NOTE: An electrically operated solenoid valve must be installed at each unit to only allow water flow through the unit that is operating.**
2) Load pump should be energized when source pump is energized.

Drawing 4-8: TMW Unit - External Pumps* / Cooling with Chilled Water (Fan Coils)



*Wiring assumes that source pumps and load pumps will be energized when compressor is energized. Fan coil wiring not shown.

Revision Log

Date	Page #	Description
25 Jan., 2011	All	Contents Updated
21 May, 2009	50	Information in Pressure Drop Table (Table 3d) Replaced
12 Nov, 2008B	70, 72	Edited Paint Options
07 July, 2008	127	Edited CSA Information
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