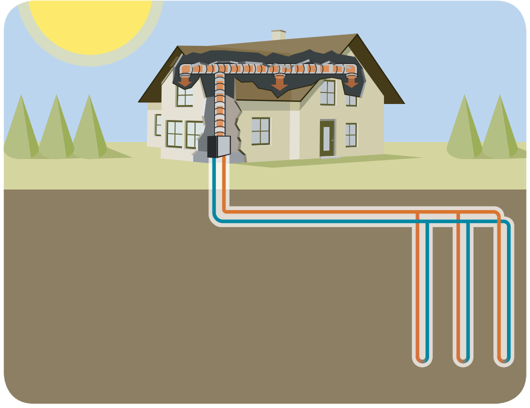


Geothermal Applications

APPLYING GEOTHERMAL COMFORT TO RESIDENTIAL CONSTRUCTION

Table of Contents

ClimateMaster: Smart. Responsible. Comfortable.

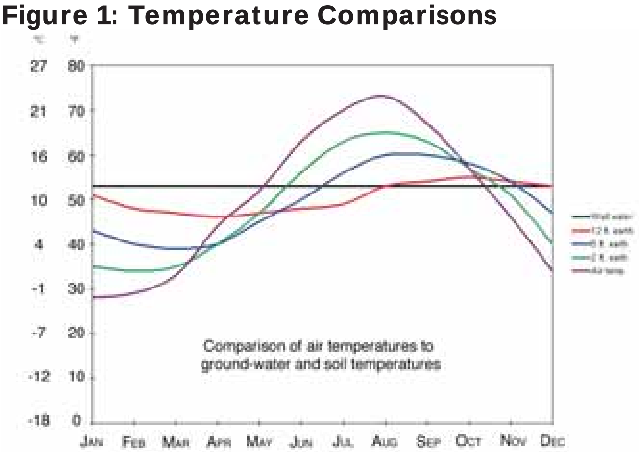
System Components

System Components

Geothermal heat pumps have a number of names such as water-source heat pump, Geoexchange, ground loop heat pump, earth-coupled heat pump, ground source heat pump, etc. Technically, "Geothermal" is defined as, "energy from the internal heat of the earth." This type of geothermal energy is called "high temperature geothermal." Temperatures can exceed 300°F [150°C] in geothermal wells. Unfortunately, these hydrothermal reservoirs are located only in limited areas of North America, primarily in the Western part of the United States. Therefore, the term "Geothermal heat pump" refers to "low temperature geothermal energy," which involves the use of a mechanical device that can transfer heat to and from the ground to heat, cool and produce domestic hot water (DHW) for residential and commercial applications.

Geothermal technology is not new. The first recorded geothermal system was a 1912 Swiss patent. Ground water (open loop) heat pumps have been used successfully since the 1930s. EEI (Edison Electric Institute) sponsored closed loop research in the 1940s and 1950s, although the lack of suitable material for closed loop piping slowed interest. U.S. researchers began investigating geothermal closed loop systems again in the 1970s with the advent of plastic pipe, which was suitable for the application. Oklahoma State University was one of the pioneers of geothermal closed loop technology during this time.

Figure 1: Temperature Comparisons



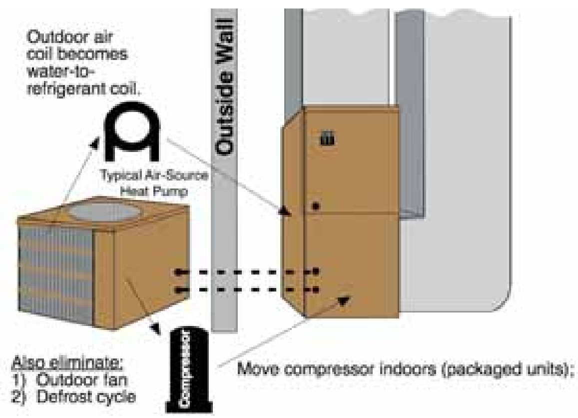
The basic concept of a geothermal heating and cooling system involves the use of a very stable heat sink/heat source. Rather than depending upon widely varying outdoor air temperature as does a "conventional" air source heat pump, geothermal heat pumps take advantage of the nearly constant ground temperature. Figure 1 shows typical average annual ground temperatures and air temperatures. Clearly, the ground temperature is a much more stable source of energy than the air. This allows proven heat pump technology to be applied in an inherently more efficient manner. For example, it is much easier to heat with 50°F [10°C] ground than 15°F [-9.4°C] air.

Geothermal systems consist of three main components, the geothermal (or water source) heat pump, the heat sink/heat source, and the distribution system. Each component will be addressed below.

The Geothermal Heat Pump

The Geothermal Heat Pump uses a compressor, a condenser, an evaporator, a reversing valve, and a thermal expansion valve (the basic heat pump refrigerant circuit) to transfer heat to and from the ground to the home. Most geothermal heat pumps installed in North America are packaged water-to-air heat pumps, whereby the home is heated and cooled via a forced air or ducted distribution system connected to a single indoor unit that contains all of the refrigeration components. Water-to-water heat pumps are also popular, which heat or chill water for radiant floor applications, chilled water/fan coil applications or domestic hot water (DHW) generation. Split systems are also available, which allow the compressor section to be located remotely from the air handling section.

Figure 2: Geothermal Heat Pump Concept



The Geothermal Heat Pump

Packaged Water-to-Air Heat Pumps
ClimateMaster has a number of choices for packaged geothermal heat pumps with airflow configurations for most any installation. Three families of two-stage products are available. Those are the Tranquility® 30 Digital (TE), and Tranquility® 30 (TT), and the Tranquility® 22 Digital (TZ). The Tranquility® Digital series include iGate™ communicating technology and vFlow™ variable flow technology. All three families include a variable speed ECM blower and a two-stage Ultra scroll compressor. TE and TT products are available in sizes 026 to 072 (7.6 to 21.1 kW) in upflow, downflow, or horizontal supply air configurations. TE and TT products are industry leaders with efficiencies among the highest in the industry, unique cabinet features, and unsurpassed quality. TZ products are available in sizes 024 to 060 (7.0 to 17.6 kW) in upflow or horizontal supply air configurations. All Tranquility® series units are designed with Zero Ozone Depletion EarthPure® (HFC-410A) refrigerant.

Tranquility® 20 series, the single stage version of EarthPure packaged units, are available in sizes 018 through 070 [5.3 to 20.5 kW]. The Tranquility® 20 (TS) series is available with upflow, downflow and horizontal supply air options, plus left- or right-hand return air options. The ECM variable speed fan motor is optional for Tranquility® 20 units.

Optional HWG (Hot Water Generator), ClimaDry® II Whole House Dehumidification, and numerous other options and accessories create a broad product offering for customers demanding the most from their heating and cooling systems.

Tranquility® Water-to-Air packaged units

Split Systems Water-to-Air Heat Pumps
Split system heat pumps add even greater flexibility to ClimateMaster's broad product line. Whether the installation involves replacement of an older heating and cooling system or is new construction, the split system allows geothermal installations where a packaged unit may not be practical.

The Tranquility® indoor split units are typically placed in a basement, garage, closet or mechanical room, allowing the air handler to be located where it's most convenient. For example, a narrow closet may not be large enough for a packaged unit, but may accommodate an air handler. Split systems also work well when a top return/bottom discharge arrangement is required.

Replacement geothermal applications with dual fuel heat pumps generally handle 80% to 100% of the heating load, which in many cases may cut heating and cooling costs in half. A dual fuel system allows the customer to keep the existing furnace, and avoid upgrading the electrical service in most situations. Plus, the higher efficiencies in cooling and the optional hot water generator contribute to a quick return on investment.

ClimateMaster Tranquility® Split System Geothermal Heat Pump

iGate™ Communicating Controls

iGate™ Information gateway to monitor, control and diagnose your system
The Tranquility® Digital Series (TE, TZ, TEP, TES) is equipped with industry-first, iGate™ – Information Gateway – a 2-way communicating system that allows users to interact with their geothermal system in plain English AND delivers improved reliability and efficiency by precisely controlling smart variable speed components. iGate™ makes the Tranquility Digital series the easiest geothermal products to install and service.

Monitor/Configure – Installers can configure Tranquility® Digital units from the thermostat, including: Air flow, loop ∆T, water-flow option configuration, unit configuration, accessory configuration, and demand reduction (optional, to limit unit operation during peak times). Users can look up the current system status: temperature sensor readings and operational status of the blower and pump.

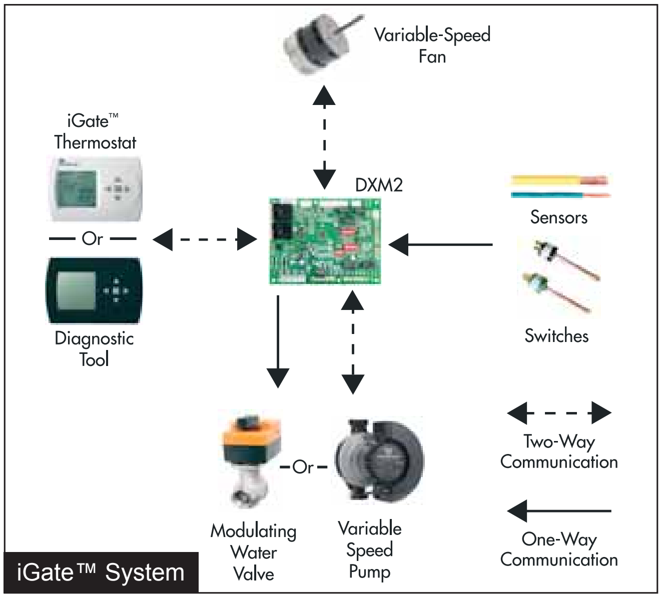
Precise Control - The new DXM2 board enables intelligent, 2-way communication between the DXM2 board and smart components like the communicating thermostat, fan motor, and water pump. The DXM2 control can also directly control the modulating valve and accepts various feedback/input. The Intelligent DXM2 board uses information received from the smart components and sensors to precisely control operation of the variable-speed fan and variable-speed water pump (or modulating valve) to deliver higher efficiency, reliability and increased comfort.

Diagnostics – iGate™ takes diagnosing geothermal units to the next level of simplicity, by providing a dashboard of system and fault information, in plain English, on the iGate thermostat/ service tool.

iGate™ Service Warning warns the homeowner of a fault and displays dealer information (if programmed), fault descriptions, possible causes and current system status (temperature readings, fan RPM and water flow status) to provide to a dealer on the phone.

In iGate™ Service Mode, the service personnel can access fault descriptions, possible causes and most importantly, the conditions (temp, flow, i/o conditions, configuration) at the time of the fault and at the time of the call. Manual Operation mode allows the service personnel to manually command operation for any of the thermostat outputs, blower speed, as well as pump speed or valve position from the thermostat, to help troubleshoot specific components.

With the iGate™ communicating system, consumers and contractors have a gateway to system information never before available.



iGate™ System

AIRFLOW SELECTION

	CFM
HEAT STAGE 1	600
HEAT STAGE 2	750
AUXILIARY HEAT	850
EMERGENCY HEAT	850
COOL STAGE 1	525
COOL STAGE 2	700
COOL DEHUMID 1	425
COOL DEHUMID 2	550
CONTINUOUS FAN	350
HEAT OFF DELAY	60
COOL OFF DELAY	30

◄ PREVIOUS NEXT ►

POSSIBLE FAULT CAUSES
LOW WATER COIL TEMP

LOW WATER TEMP - HTG

LOW WATER FLOW - HTG

LOW REFRIG CHARGE - HTG

INCORRECT LT1 SETTING

BAD LT1 THERMISTOR

◄ PREVIOUS

FAULT TEMPERATURE CONDITIONS
LT1 LOW WATER TEMP
HEAT 1 11:11 AM 11/14

LT1 TEMP	28.1
LT2 TEMP	97.3
HOT WATER EWT	121.5
COMP DISCHARGE	157.7
LEAVING AIR	92.7
LEAVING WATER	34.9
ENTERING WATER	42.1
CONTROL VOLTAGE	26.4

◄ PREVIOUS

vFlow™ Internal Variable Water Flow Control

vFlow™ Internal Variable Water Flow
Industry-first, built-in vFlow™ replaces a traditionally inefficient, external component of the geothermal system (water circulation) with an ultra-high-efficient, variable speed, internal water flow system. This saves homeowners 70-80% on operating water circulator vs traditional single speed pump systems. It saves installers time and labor by avoiding installing bulky external flow centers or flow regulators. Multi-unit installations are also much simpler with vFlow™ systems, as the units automatically adjust water flow across the system.

vFlow™ is enabled by iGate™, which facilitates intelligent communication between the thermostat, DXM2 control, sensors and internal water pump/valve to make true variable water flow a reality.

vFlow™ is available for three applications:

1) Closed loop – individual unit pumping: vFlow™ Internal Flow Controller model would be used. This includes variable speed pump, flushing ports, 3 way flushing valves and expansion tank. Copper water coil is standard with this option.
2) Closed loop – multi unit / central pumping: vFlow™ Internal Low Pressure Drop (high Cv) Motorized Modulating Valve would be used. Copper water coil is standard with this option.
3) Open loop: vFlow™ Internal Motorized Modulating Valve would be used. Cupro-Nickel water coil is standard with this option. Valves in open loop models have higher pressure drop than the valves in the closed loop (modulating valve) models for better flow control when used in systems with higher pressure water supply pumps, and are not recommended for closed loop applications.

vFlow™ delivers three main benefits:

1) Easier and quicker unit installation as the flow control is built in to the unit.
2) Superior reliability by varying the water flow to deliver more stable operation.
3) Higher cost savings by varying the flow (and pump watt consumption) to match the unit's mode of operation.

Internal components
Tranquility® Digital units can be installed more easily and compactly than others because water-flow components are internal to the unit. It also saves installing contractors labor and time by eliminating the need for an external flow regulator or a bulky external pumping module.

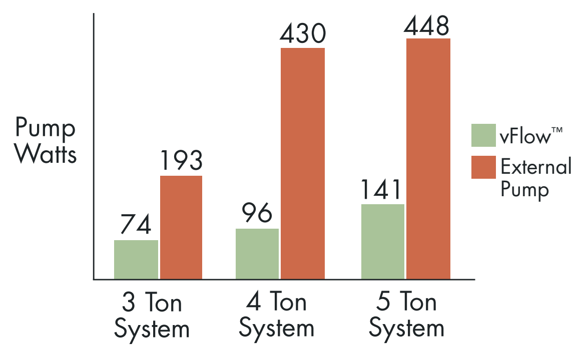
Variable flow
vFlow™ technology enables variable water flow through the unit, with the DXM2 control adjusting the pump speed to maintain an installer-set loop ΔT. By controlling the water flow, the system is able to operate at its optimal capacity and efficiency. vFlow™ provides a lower flow rate for part load where units typically operate 80% of the time and a higher, more normal flow rate for full load operation.

Variable speed pump or motorized modulating valve delivers variable water-flow, controlled by DXM2 control, based on loop water ΔT.

Energy Savings with water circulation control
Units with vFlow™ deliver higher operating cost savings by varying the water flow to match the unit's operation (ex: lower water flow when unit is in part load operation). Lowering the flow results in lower energy consumption by the water pump (=higher cost savings) in vFlow™ units (whether internal or external pump).

In closed loop applications, using vFlow™ with an internal variable-speed (ECM) flow controller, the ECM pump uses fewer watts than a fixed speed (PSC) pump, even at full load (see chart). The ECM pump excels in energy savings in part load, saving 70-80% watts compared to fixed speed pumps (see chart). The ECM pump can operate with independent flow rates for heating and cooling, further saving even more energy.

In open loop applications, when the motorized modulating valve slows down the water flow during part load operation, the external pump consumes fewer watts, thus saving energy.



ClimateMaster: Smart. Responsible. Comfortable.

The Geothermal Heat Pump

Water-to-Water Heat Pumps

Water-to-water heat pumps give the customer "the best of both worlds," geothermal heating and cooling, plus the ability to enjoy the benefits of warm radiant floors. The ClimateMaster Tranquility® TMW series water-to-water heat pumps provide hot and/or chilled water. In most applications, the water-to-water unit is connected to a buffer tank, where hot or chilled water is stored, and the hydronic system components (radiant floor or fan coil units) pull hot or chilled water from the tank. This "decouples" the unit water flow rate from the hydronic system flow rates, giving the designer the flexibility of using as many heating/cooling zones as desired. Radiant floor heating is known for its unequaled comfort and energy savings; when coupled with geothermal technology, the system is the ultimate in heating and cooling.

The THW Series is a heating only water-to-water heat pump. It is unlike any other water-to-water heat pump on the market today. The THW can deliver up to 145°F (63°C) leaving load water temperature even at 32°F (0°C) entering source temperature. The THW includes a built-in controller to control the unit and circulating pumps. It even has an outdoor reset function to vary the buffer tank set point depending on the outdoor temperature to heat only as much as needed. The THW also has an optional DHW mode for heating potable water.

In summary, with ClimateMaster's broad equipment line, almost any installation can include a geothermal heat pump. Forced air heating and cooling, radiant floor heating, chilled water cooling, and combinations of various systems provide customers with systems customized to their specific needs. High value, high quality and environmentally responsible products separate ClimateMaster geothermal heat pumps from other heating and cooling systems.

The ClimateMaster Family of Geothermal Heating and Cooling Systems

Heat Source/Heat Sink

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.

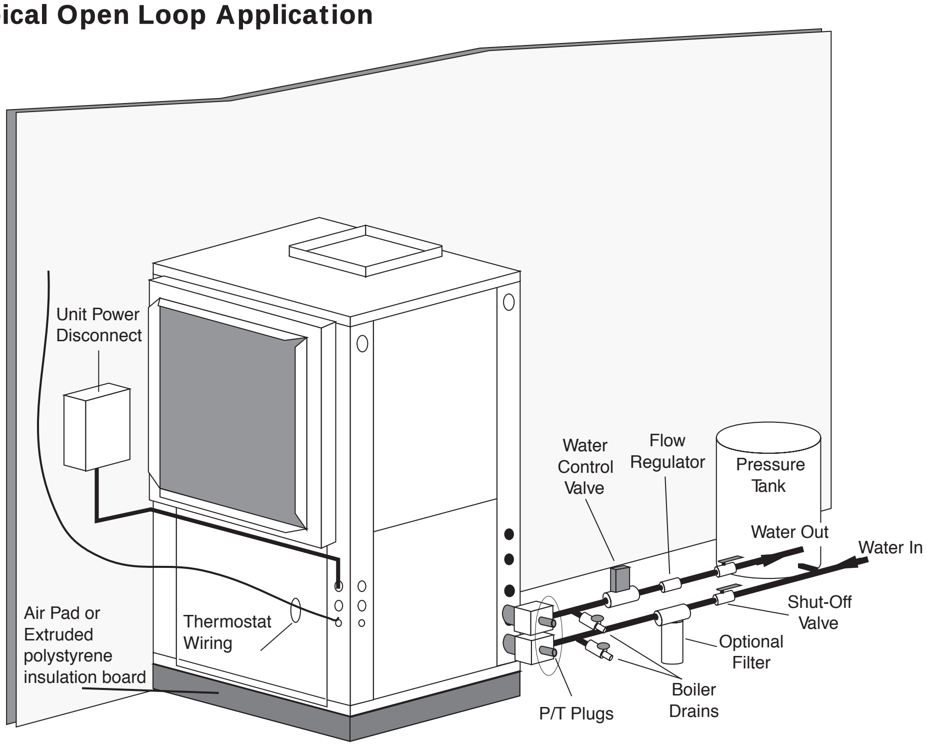
Open Loop Systems (Well Water)

Typical open loop piping is shown in Figure 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 drops and temperatures 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 1 for water quality guidelines. The unit can be ordered with either a copper or cupro-nickel water heat exchanger. Consult Table 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 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 1.

Figure 3: Typical Open Loop Application



Water Quality Standards

Table 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	HX Material	Closed Recirculating	Maximum Allowable at maximum water temperature. 10°C	24°C	38°C
	Copper	-	<20ppm	NR	NR
	Cupronickel	-	<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

Water Quality Parameter	HX Material	Closed Recirculating	Open Loop and Recirculating Well
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.: 3/22/2012

The ClimateMaster Water Quality Table provides water quality requirements for ClimateMaster coaxial heat exchangers. When water properties are outside of those requirements, an external secondary heat exchanger must be used to isolate the heat pump heat exchanger from the unsuitable water. Failure to do so will void the warranty for the coaxial heat exchanger.

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.

Heat Source/Heat Sink

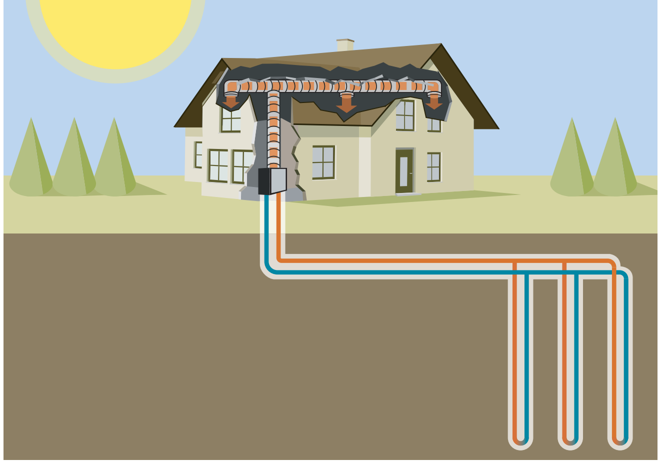
Open Loop Systems (continued)
A closed, bladder-type expansion tank should be used to minimize mineral formation due to air exposure. The expansion tank should be sized to provide at least one minute continuous run time of the pump using its drawdown capacity rating to prevent pump short cycling. Discharge 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 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 [2.0 to 2.6 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 [2.6 l/m per kW] is required.

Closed Loop Systems

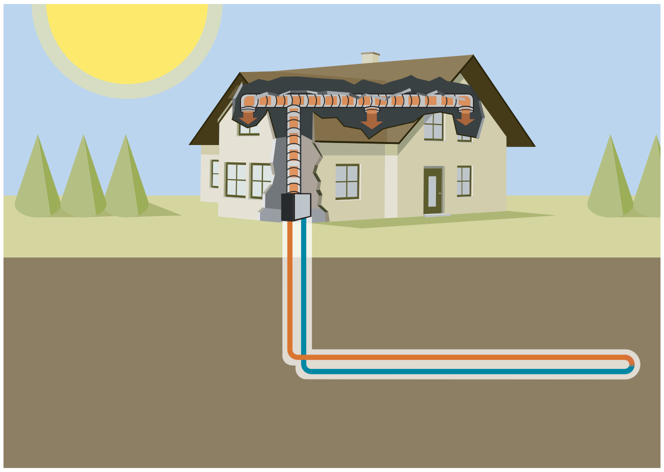
Vertical (Drilled) Closed Loop



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 15 feet [4.6 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.

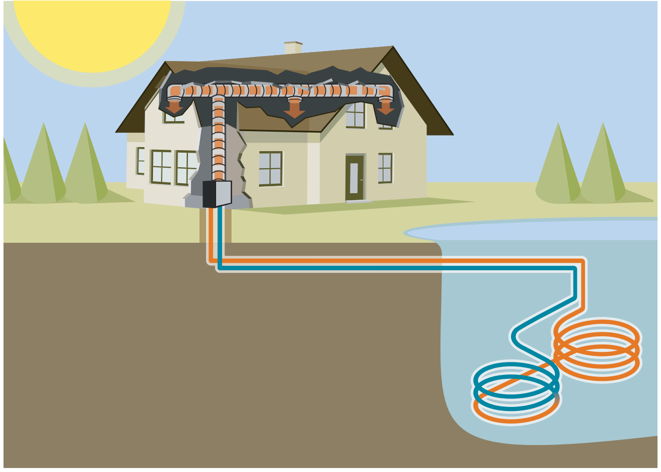
Heat Source/Heat Sink

Horizontal (Trenched or Bored) Loop



Horizontal loops may be installed with a trencher, backhoe or horizontal boring machine. Excavation costs for horizontal loops are usually less than the costs for 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.
- 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 2 illustrates the proper fusion times for Geothermal PE 3408 ASTM Pipe.

Table 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 1-1/4” vertical bores 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.

Closed Loop Design/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. 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 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.

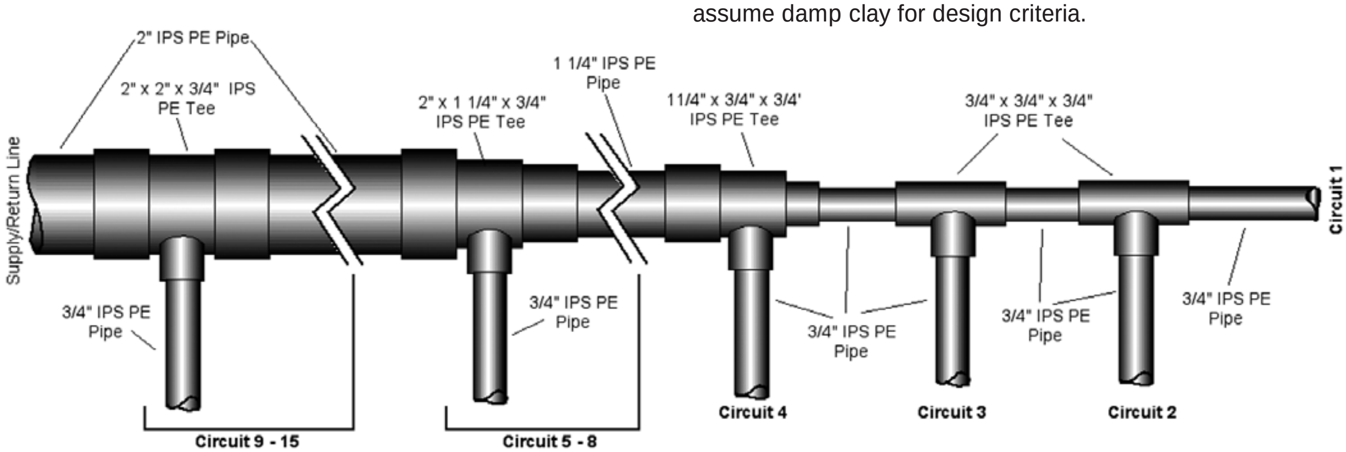
Loop Circuiting - Loops should be designed with a compromise between pressure drop and turbulent flow (Reynold's Number) in the heat exchange pipe for heat transfer. Therefore the following rules should be observed when designing a loop:

- 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 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 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].

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.

Figure 4a: Typical Header Through 15 Tons



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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 5 details a "laydown" header.

Figure 4b: Typical Header Through 5 Tons

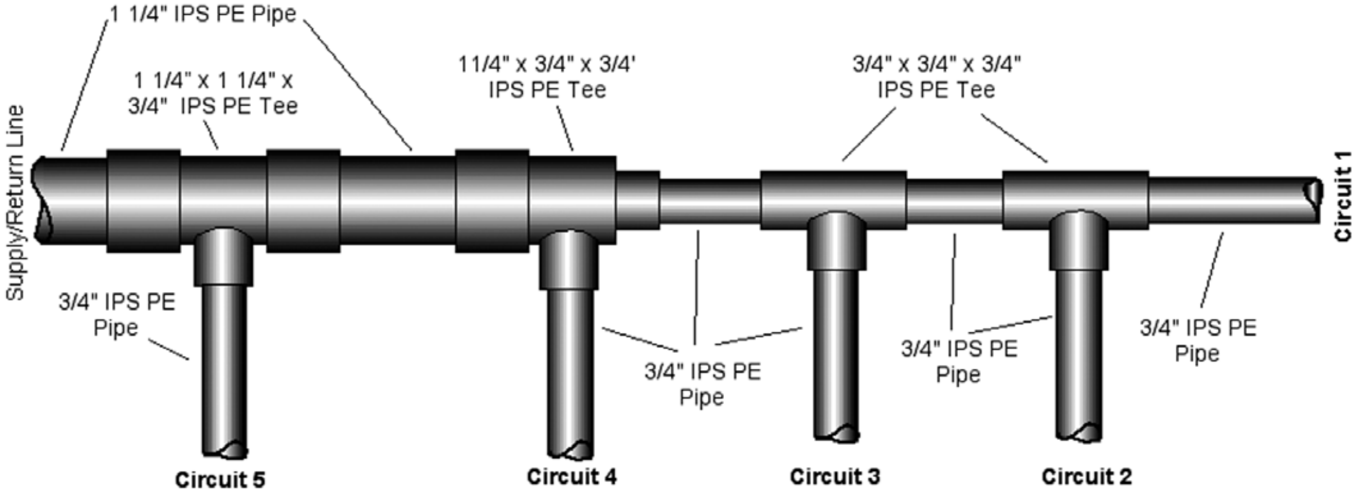
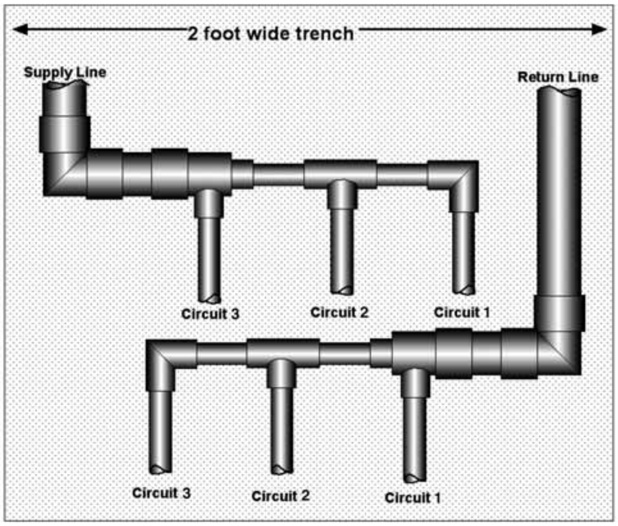


Figure 5: Typical "Laydown" Header



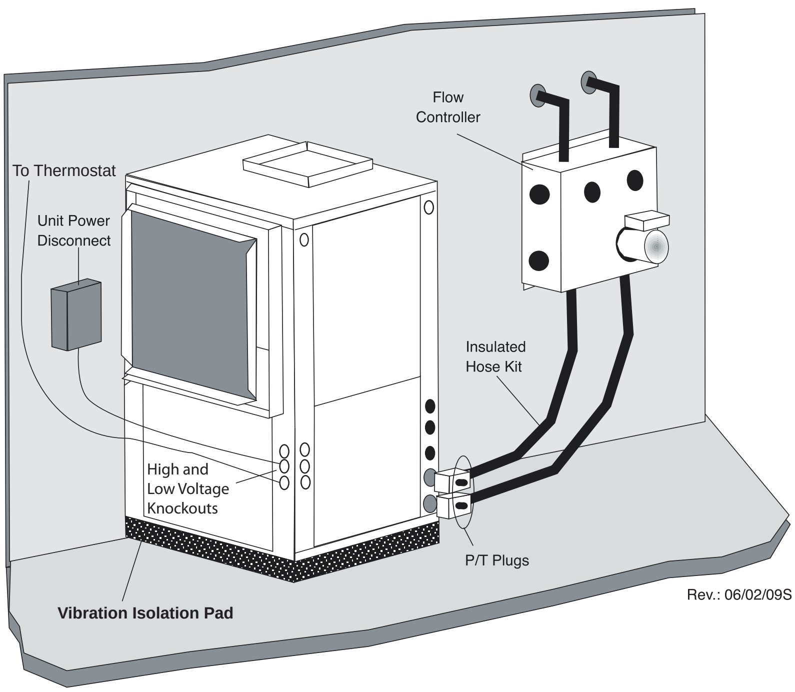
Closed Loop Design/Installation Guidelines

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 calcuations may call for 3 - UP26-99 pumps, try substituting 2 - UP26-116 pumps. This makes the installation much easier and reduces cost. Chart 1 shows the various pump combinations.

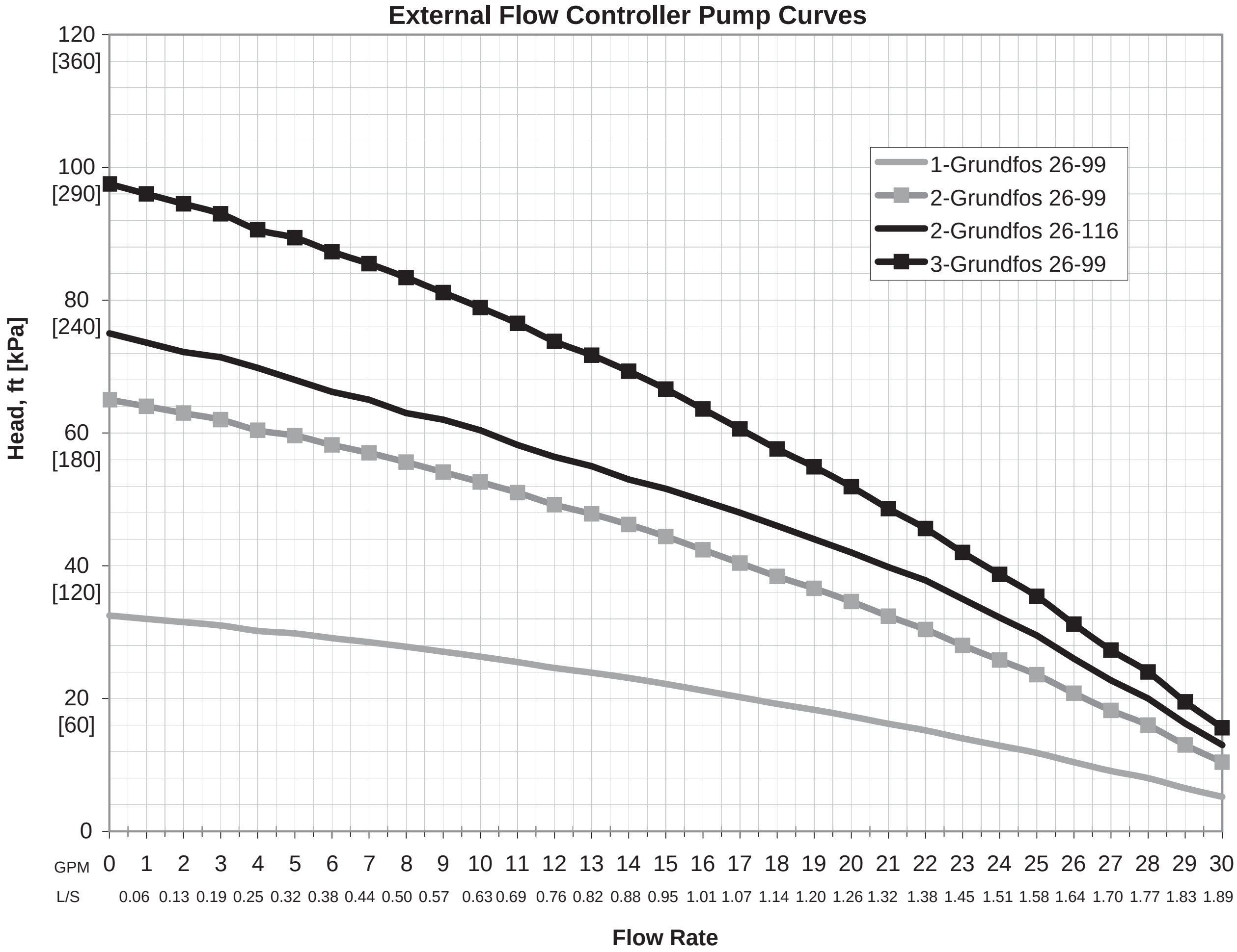
Loop pressure drop calculation should be performed for accurate flow estimation in any system including unit, hose kit, inside piping, supply/return headers, circuit piping, and fittings. Use Tables 3A through 3F for pressure drop calculations using antifreeze and PE/rubber hose piping materials.

Figure 6: Typical Ground-Loop Application

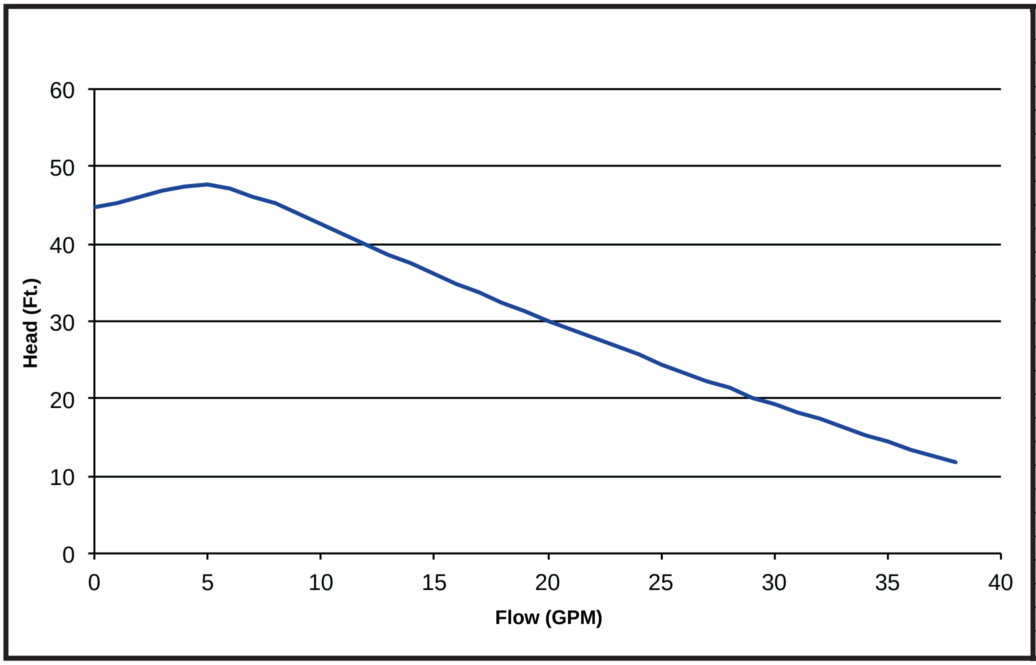


Closed Loop Design/Installation Guidelines

Chart 1: Flow Controller Performance



Internal Flow Controller (Magna Geo 25-140) Pump Performance



GPM	Head (ft)
0.0	44.7
1.0	45.4
2.0	46.1
3.0	46.8
4.0	47.5
5.0	47.7
6.0	47.1
7.0	46.1
8.0	45.3
9.0	43.9
10.0	42.6
11.0	41.2
12.0	39.9
13.0	38.7
14.0	37.4
15.0	36.1
16.0	34.9
17.0	33.7
18.0	32.5
19.0	31.3
20.0	30.1
21.0	28.9
22.0	27.8
23.0	26.7
24.0	25.6
25.0	24.5

Table 3a: Polyethylene Pressure Drop per 100ft of Pipe

Antifreeze (30°F [-1°C] EWT): 17% 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	0.35	0.55	1221	0.14	0.35	975	0.06	0.22	773	0.03	0.17	676	0.01	0.11	541
2	0.89	1.10	2442	0.28	0.70	1950	0.11	0.44	1547	0.07	0.34	1352	0.03	0.22	1081
3	2.49	1.66	3664	0.82	1.06	2925	0.19	0.66	2320	0.10	0.51	2028	0.04	0.32	1622
4	4.05	2.21	4885	1.41	1.41	3901	0.47	0.89	3094	0.22	0.68	2703	0.05	0.43	2162
5	5.92	2.76	6106	2.05	1.76	4876	0.69	1.11	3867	0.37	0.85	3379	0.11	0.54	2703
6	8.09	3.31	7327	2.80	2.11	5851	0.94	1.33	4640	0.50	1.01	4055	0.17	0.65	3243
7	10.54	3.87	8549	3.64	2.47	6826	1.22	1.55	5414	0.65	1.18	4731	0.23	0.76	3784
8	13.27	4.42	9770	4.58	2.82	7801	1.54	1.77	6187	0.81	1.35	5407	0.29	0.87	4324
9	16.27	4.97	10991	5.61	3.17	8776	1.88	1.99	6960	1.00	1.52	6083	0.35	0.97	4865
10	19.53	5.52	12212	6.73	3.52	9752	2.25	2.22	7734	1.19	1.69	6758	0.42	1.08	5405
11	23.05	6.08	13433	7.93	3.87	10727	2.65	2.44	8507	1.40	1.86	7434	0.49	1.19	5946
12	26.82	6.63	14655	9.22	4.23	11702	3.08	2.66	9281	1.63	2.03	8110	0.57	1.30	6486
13	30.84	7.18	15876	10.60	4.58	12677	3.54	2.88	10054	1.87	2.20	8786	0.65	1.41	7027
14				12.06	4.93	13652	4.02	3.10	10827	2.12	2.37	9462	0.74	1.51	7567
15				13.59	5.28	14627	4.53	3.32	11601	2.39	2.54	10138	0.83	1.62	8108
16				15.21	5.63	15603	5.06	3.54	12374	2.67	2.71	10813	0.93	1.73	8649
17				16.91	5.99	16578	5.63	3.77	13148	2.97	2.88	11489	1.03	1.84	9189
18				18.69	6.34	17553	6.21	3.99	13921	3.28	3.04	12165	1.14	1.95	9730
19				20.54	6.69	18528	6.83	4.21	14694	3.60	3.21	12841	1.25	2.06	10270
20				22.47	7.04	19503	7.47	4.43	15468	3.94	3.38	13517	1.37	2.16	10811
21							8.13	4.65	16241	4.29	3.55	14193	1.49	2.27	11351
22							8.82	4.87	17014	4.65	3.72	14868	1.61	2.38	11892
23							9.53	5.09	17788	5.02	3.89	15544	1.74	2.49	12432
24							10.27	5.32	18561	5.41	4.06	16220	1.87	2.60	12973
25							11.03	5.54	19335	5.81	4.23	16896	2.01	2.71	13513
26							11.81	5.76	20108	6.22	4.40	17572	2.15	2.81	14054
28							13.45	6.20	21655	7.08	4.74	18923	2.45	3.03	15135
30							15.18	6.65	23201	7.99	5.07	20275	2.76	3.25	16216
32							17.01	7.09	24748	8.95	5.41	21627	3.09	3.46	17297
34										9.95	5.75	22979	3.44	3.68	18378
36										11.01	6.09	24330	3.80	3.90	19459
38										12.11	6.43	25682	4.18	4.11	20540
40										13.25	6.77	27034	4.57	4.33	21621
42										14.44	7.10	28385	4.98	4.54	22702
44													5.41	4.76	23783
46													5.84	4.98	24864
48													6.30	5.19	25946
50													6.77	5.41	27027

Closed Loop Design/Installation Guidelines

Table 3b: Polyethylene Pressure Drop per 100ft of Pipe

Antifreeze (30°F [-1°C] EWT): 24% 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	0.59	0.55	716	0.24	0.35	572	0.10	0.22	453	0.06	0.17	396	0.02	0.11	317
2	1.18	1.10	1431	0.48	0.70	1143	0.19	0.44	906	0.11	0.34	792	0.05	0.22	634
3	1.80	1.66	2147	0.72	1.06	1715	0.29	0.66	1360	0.17	0.51	1188	0.07	0.32	950
4	4.45	2.21	2863	1.05	1.41	2286	0.38	0.89	1813	0.22	0.68	1584	0.09	0.43	1267
5	6.96	2.76	3579	2.26	1.76	2858	0.51	1.11	2266	0.28	0.85	1980	0.11	0.54	1584
6	9.48	3.31	4294	3.29	2.11	3429	0.97	1.33	2719	0.40	1.01	2376	0.14	0.65	1901
7	12.31	3.87	5010	4.28	2.47	4001	1.43	1.55	3173	0.69	1.18	2773	0.17	0.76	2217
8	15.45	4.42	5726	5.36	2.82	4572	1.81	1.77	3626	0.95	1.35	3169	0.26	0.87	2534
9	18.88	4.97	6441	6.55	3.17	5144	2.21	1.99	4079	1.17	1.52	3565	0.38	0.97	2851
10	22.62	5.52	7157	7.83	3.52	5715	2.64	2.22	4532	1.40	1.69	3961	0.49	1.08	3168
11	26.64	6.08	7873	9.22	3.87	6287	3.10	2.44	4986	1.64	1.86	4357	0.58	1.19	3485
12	30.94	6.63	8588	10.70	4.23	6858	3.59	2.66	5439	1.91	2.03	4753	0.67	1.30	3801
13	35.51	7.18	9304	12.27	4.58	7430	4.11	2.88	5892	2.18	2.20	5149	0.76	1.41	4118
14				13.93	4.93	8001	4.67	3.10	6345	2.48	2.37	5545	0.87	1.51	4435
15				15.69	5.28	8573	5.25	3.32	6799	2.78	2.54	5941	0.97	1.62	4752
16				17.53	5.63	9144	5.87	3.54	7252	3.11	2.71	6337	1.09	1.73	5069
17				19.47	5.99	9716	6.51	3.77	7705	3.45	2.88	6733	1.20	1.84	5385
18				21.49	6.34	10287	7.18	3.99	8158	3.80	3.04	7129	1.33	1.95	5702
19				23.59	6.69	10859	7.88	4.21	8612	4.17	3.21	7526	1.46	2.06	6019
20				25.78	7.04	11430	8.61	4.43	9065	4.55	3.38	7922	1.59	2.16	6336
21							9.36	4.65	9518	4.95	3.55	8318	1.73	2.27	6652
22							10.15	4.87	9971	5.37	3.72	8714	1.87	2.38	6969
23							10.96	5.09	10425	5.79	3.89	9110	2.02	2.49	7286
24							11.79	5.32	10878	6.23	4.06	9506	2.17	2.60	7603
25							12.66	5.54	11331	6.69	4.23	9902	2.33	2.71	7920
26							13.55	5.76	11784	7.16	4.40	10298	2.49	2.81	8236
28							15.41	6.20	12691	8.14	4.74	11090	2.83	3.03	8870
30							17.37	6.65	13597	9.17	5.07	11882	3.19	3.25	9503
32							19.43	7.09	14504	10.25	5.41	12675	3.56	3.46	10137
34										11.39	5.75	13467	3.95	3.68	10771
36										12.58	6.09	14259	4.37	3.90	11404
38										13.83	6.43	15051	4.79	4.11	12038
40										15.12	6.77	15843	5.24	4.33	12671
42										16.46	7.10	16635	5.70	4.54	13305
44													6.18	4.76	13938
46													6.68	4.98	14572
48													7.20	5.19	15206
50													7.73	5.41	15839

Table 3c: Polyethylene Pressure Drop per 100ft of Pipe

Antifreeze (30°F [-1°C] EWT): 20% 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	0.56	0.55	757	0.23	0.35	604	0.09	0.22	479	0.05	0.17	419	0.02	0.11	335
2	1.12	1.10	1514	0.45	0.70	1209	0.18	0.44	959	0.10	0.34	838	0.04	0.22	670
3	1.81	1.66	2271	0.68	1.06	1813	0.27	0.66	1438	0.16	0.51	1257	0.06	0.32	1005
4	4.56	2.21	3027	1.14	1.41	2417	0.36	0.89	1917	0.21	0.68	1675	0.09	0.43	1340
5	6.84	2.76	3784	2.31	1.76	3022	0.55	1.11	2397	0.26	0.85	2094	0.11	0.54	1675
6	9.32	3.31	4541	3.24	2.11	3626	1.02	1.33	2876	0.44	1.01	2513	0.13	0.65	2010
7	12.10	3.87	5298	4.21	2.47	4230	1.41	1.55	3355	0.72	1.18	2932	0.17	0.76	2345
8	15.19	4.42	6055	5.27	2.82	4835	1.78	1.77	3834	0.94	1.35	3351	0.28	0.87	2680
9	18.58	4.97	6812	6.44	3.17	5439	2.17	1.99	4314	1.15	1.52	3770	0.39	0.97	3015
10	22.26	5.52	7569	7.71	3.52	6044	2.59	2.22	4793	1.38	1.69	4188	0.48	1.08	3350
11	26.22	6.08	8325	9.07	3.87	6648	3.05	2.44	5272	1.62	1.86	4607	0.57	1.19	3685
12	30.46	6.63	9082	10.53	4.23	7252	3.53	2.66	5752	1.87	2.03	5026	0.66	1.30	4020
13	34.97	7.18	9839	12.08	4.58	7857	4.05	2.88	6231	2.15	2.20	5445	0.75	1.41	4355
14				13.72	4.93	8461	4.59	3.10	6710	2.43	2.37	5864	0.85	1.51	4690
15				15.45	5.28	9065	5.17	3.32	7190	2.74	2.54	6283	0.96	1.62	5025
16				17.26	5.63	9670	5.77	3.54	7669	3.06	2.71	6702	1.07	1.73	5360
17				19.17	5.99	10274	6.41	3.77	8148	3.39	2.88	7120	1.18	1.84	5695
18				21.16	6.34	10878	7.07	3.99	8627	3.74	3.04	7539	1.31	1.95	6030
19				23.24	6.69	11483	7.76	4.21	9107	4.11	3.21	7958	1.43	2.06	6365
20				25.40	7.04	12087	8.48	4.43	9586	4.48	3.38	8377	1.56	2.16	6700
21							9.22	4.65	10065	4.88	3.55	8796	1.70	2.27	7035
22							9.99	4.87	10545	5.28	3.72	9215	1.84	2.38	7370
23							10.79	5.09	11024	5.70	3.89	9634	1.99	2.49	7705
24							11.62	5.32	11503	6.14	4.06	10052	2.14	2.60	8040
25							12.47	5.54	11983	6.59	4.23	10471	2.29	2.71	8375
26							13.35	5.76	12462	7.05	4.40	10890	2.45	2.81	8710
28							15.18	6.20	13420	8.01	4.74	11728	2.79	3.03	9380
30							17.12	6.65	14379	9.03	5.07	12565	3.14	3.25	10050
32							19.16	7.09	15338	10.10	5.41	13403	3.51	3.46	10720
34										11.23	5.75	14241	3.90	3.68	11390
36										12.40	6.09	15079	4.30	3.90	12060
38										13.63	6.43	15916	4.72	4.11	12730
40										14.90	6.77	16754	5.16	4.33	13400
42										16.23	7.10	17592	5.62	4.54	14070
44													6.09	4.76	14740
46													6.59	4.98	15410
48													7.09	5.19	16080
50													7.62	5.41	16750

Closed Loop Design/Installation Guidelines

Table 3d: Polyethylene Pressure Drop per 100ft of Pipe
Antifreeze (30°F [-1°C] EWT): 25% Ethylene 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	0.40	0.55	1048	0.16	0.35	837	0.06	0.22	664	0.04	0.17	580	0.02	0.11	464
2	0.81	1.10	2096	0.33	0.70	1674	0.13	0.44	1328	0.08	0.34	1160	0.03	0.22	928
3	2.57	1.66	3144	0.68	1.06	2511	0.20	0.66	1991	0.11	0.51	1740	0.05	0.32	1392
4	4.24	2.21	4192	1.47	1.41	3348	0.42	0.89	2655	0.17	0.68	2320	0.06	0.43	1856
5	6.19	2.76	5241	2.15	1.76	4185	0.72	1.11	3319	0.36	0.85	2900	0.09	0.54	2320
6	8.45	3.31	6289	2.93	2.11	5022	0.99	1.33	3983	0.52	1.01	3480	0.17	0.65	2783
7	11.00	3.87	7337	3.81	2.47	5859	1.28	1.55	4646	0.68	1.18	4060	0.24	0.76	3247
8	13.84	4.42	8385	4.79	2.82	6695	1.61	1.77	5310	0.85	1.35	4640	0.30	0.87	3711
9	16.96	4.97	9433	5.86	3.17	7532	1.96	1.99	5974	1.04	1.52	5220	0.36	0.97	4175
10	20.34	5.52	10481	7.02	3.52	8369	2.35	2.22	6638	1.25	1.69	5800	0.44	1.08	4639
11	23.99	6.08	11529	8.27	3.87	9206	2.77	2.44	7301	1.47	1.86	6380	0.51	1.19	5103
12	27.90	6.63	12577	9.61	4.23	10043	3.21	2.66	7965	1.70	2.03	6960	0.59	1.30	5567
13	32.07	7.18	13625	11.04	4.58	10880	3.69	2.88	8629	1.95	2.20	7540	0.68	1.41	6031
14				12.55	4.93	11717	4.19	3.10	9293	2.22	2.37	8120	0.77	1.51	6495
15				14.15	5.28	12554	4.72	3.32	9956	2.50	2.54	8701	0.87	1.62	6959
16				15.83	5.63	13391	5.28	3.54	10620	2.79	2.71	9281	0.97	1.73	7423
17				17.59	5.99	14228	5.86	3.77	11284	3.10	2.88	9861	1.08	1.84	7886
18				19.43	6.34	15065	6.47	3.99	11948	3.42	3.04	10441	1.19	1.95	8350
19				21.35	6.69	15902	7.11	4.21	12611	3.75	3.21	11021	1.30	2.06	8814
20				23.35	7.04	16739	7.77	4.43	13275	4.10	3.38	11601	1.43	2.16	9278
21							8.46	4.65	13939	4.46	3.55	12181	1.55	2.27	9742
22							9.17	4.87	14603	4.84	3.72	12761	1.68	2.38	10206
23							9.91	5.09	15266	5.23	3.89	13341	1.81	2.49	10670
24							10.67	5.32	15930	5.63	4.06	13921	1.95	2.60	11134
25							11.46	5.54	16594	6.04	4.23	14501	2.10	2.71	11598
26							12.27	5.76	17258	6.47	4.40	15081	2.24	2.81	12062
28							13.97	6.20	18585	7.36	4.74	16241	2.55	3.03	12989
30							15.76	6.65	19913	8.30	5.07	17401	2.88	3.25	13917
32							17.65	7.09	21240	9.30	5.41	18561	3.22	3.46	14845
34										10.34	5.75	19721	3.58	3.68	15773
36										11.43	6.09	20881	3.95	3.90	16701
38										12.56	6.43	22041	4.34	4.11	17629
40										13.75	6.77	23201	4.75	4.33	18556
42										14.98	7.10	24361	5.17	4.54	19484
44													5.61	4.76	20412
46													6.07	4.98	21340
48													6.54	5.19	22268
50													7.02	5.41	23195

Table 3e: 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

Closed Loop Design/Installation Guidelines

Table 3f: 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] low temperature protection.
3. All fluids with antifreeze are shown at 30°F [-1°C]; water is at 50°F [10°C].

Closed Loop Design/Installation Guidelines

⚠ CAUTION! ⚠

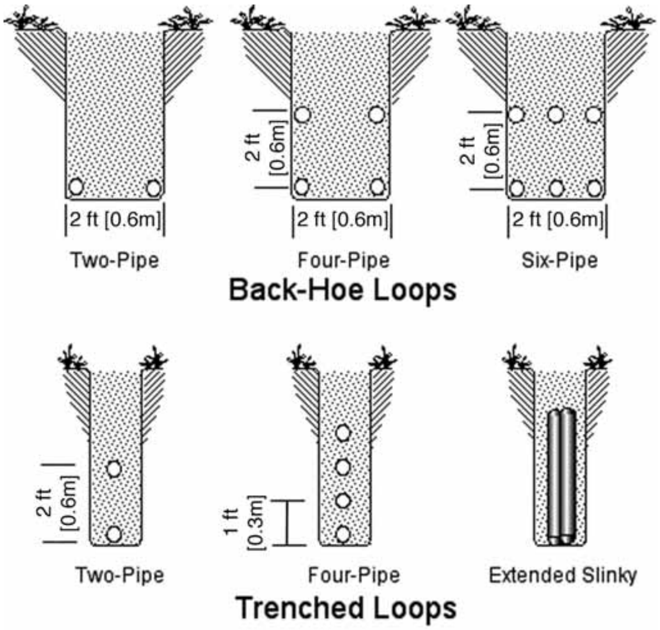
CAUTION! This manual is not intended for commercial loop design.

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 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 7: Typical Horizontal Loop Configurations



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 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.

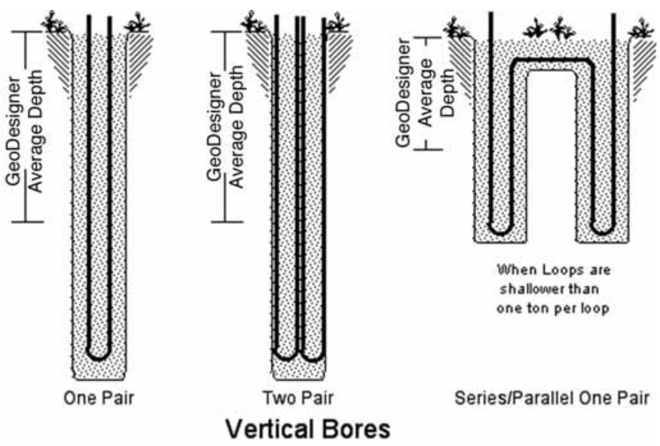
Vertical Applications

For vertical earth loops, drill boreholes using any size drilling equipment. Regulations which govern water well installations also apply to vertical ground loop installations. Vertical applications typically require multiple boreholes. Space boreholes a minimum of 10 feet [3 meters] apart. In southern or cooling dominated climates 15 feet 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 boreholes may be drilled if convenient. Assemble each U-bend assembly, fill with water and perform a hydrostatic pressure test prior to insertion into the borehole.

To add weight and prevent the pipe from curving and digging into the borehole 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 borehole filled with water or drilling mud solutions, since water filled pipe is buoyant under these circumstances.

Figure 8: Typical Vertical Loop Configurations



Closed Loop Design/Installation Guidelines

Carefully backfill the boreholes with an IGSHPA approved Bentonite grout (typically 20% silica sand soilds by weight) from the bottom of the borehole 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 boreholes 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 8 illustrates common vertical bore heat exchangers.

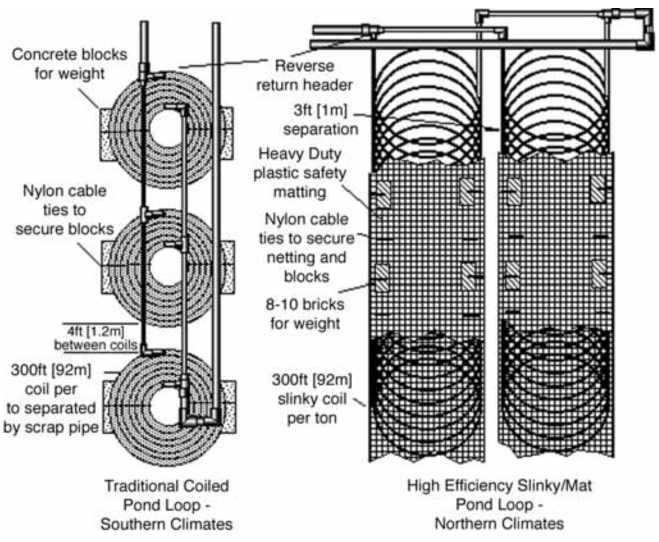
Use an IGSHPA design based software such as GeoDesigner for determining loop sizing and configurations.

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 ton [26 meters per kW -- one 92 meter coil per 3.5 kW of 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. Actual area can be 1500-3000 sq. ft. per ton [39.6 to 79.2 sq. meters per kW] of cooling. 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 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.

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

Figure 9: Typical Pond/Lake Loop Configurations



the pipe expands and contracts protect the pipe as shown in Figure 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 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 12 to protect it from damage.

Below Grade Entry
New and Retrofit Construction: Bring the pipe through the wall as shown in Figure 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.

Closed Loop Design/Installation Guidelines

Figure 10: Slab on Grade Entry Detail

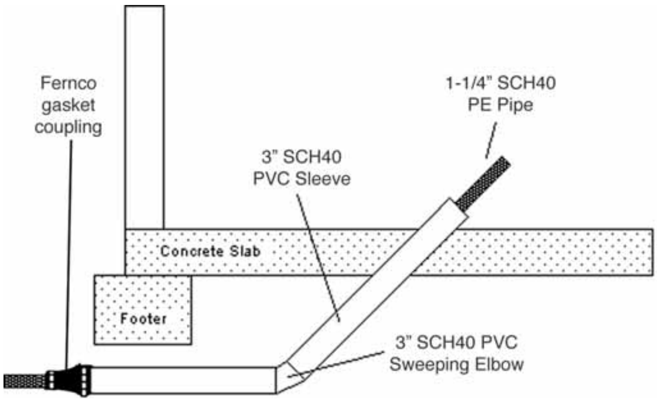


Figure 12: Pier and Beam (Craw Space) Detail

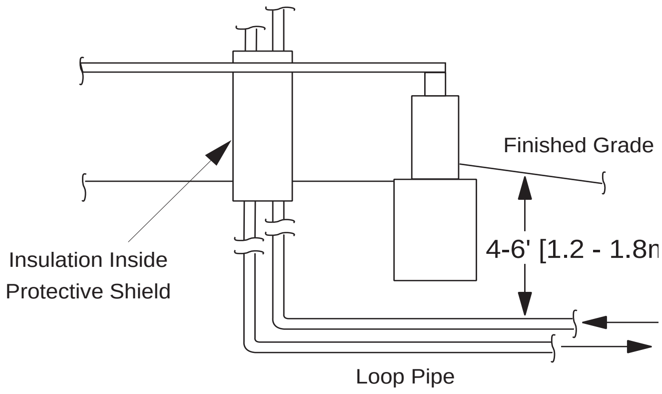


Figure 11: Retrofit Construction Detail

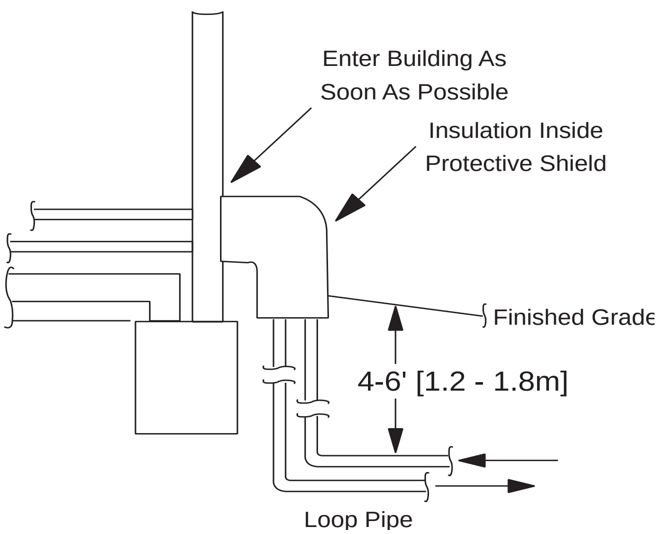
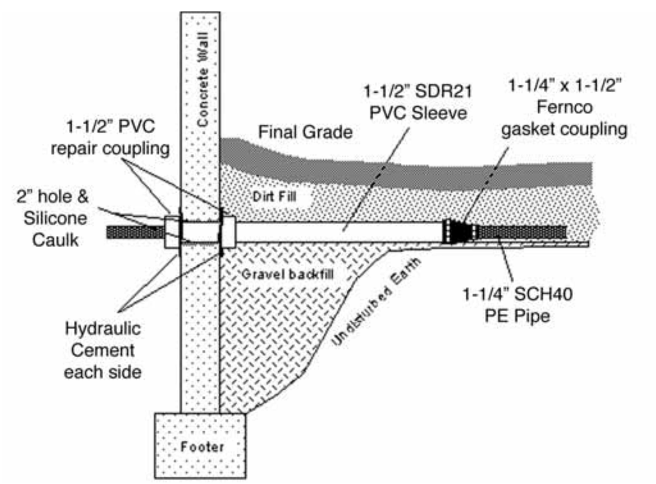


Figure 13: Below Grade Entry Detail



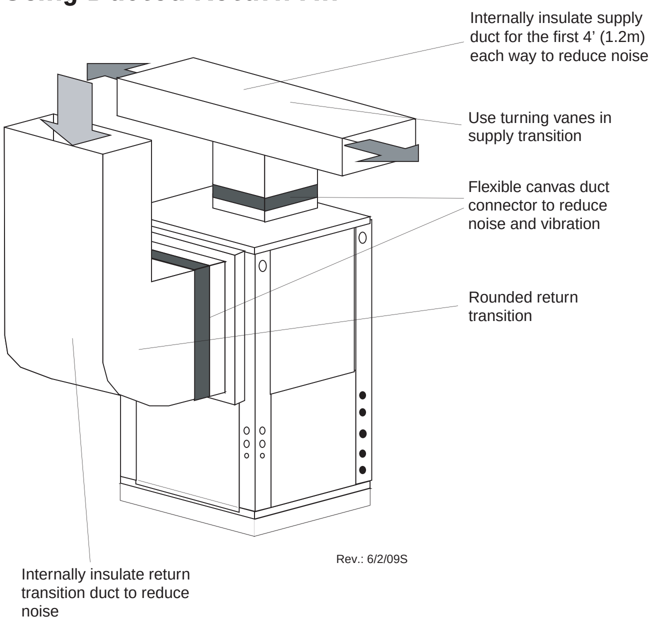
The Heating/Cooling Distribution System

Ducted Forced Air System

The most common type of heating and cooling distribution system is the ducted forced air system, which delivers warm or cool air to the living space. Water-to-air packaged units or split system heat pumps are typically connected to a central duct layout, which distributes conditioned air to the various zones. As in all forced air systems, properly designed and sealed ductwork is crucial to occupant comfort.

A flexible connector is recommended for both discharge and return air duct connections on metal duct systems to eliminate the transfer of vibration to the duct system. To maximize sound attenuation of the unit blower, the supply and return plenums should include internal fiberglass duct liner or be constructed from ductboard for the first few feet. Application of the unit to uninsulated ductwork in an unconditioned space is not recommended, as the unit's performance will be adversely affected.

Figure 14: Typical Vertical Unit Installation Using Ducted Return Air



At least one 90° elbow should be included in the supply duct to reduce air noise. For airflow charts, consult catalog data for the series and model of the specific unit.

All ductwork should be designed in accordance with recommended practices as outlined in one of the following industry guidelines:

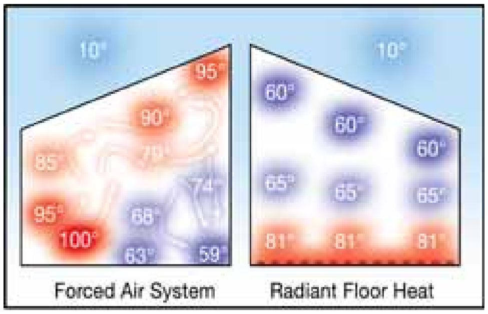
- Air Conditioning Contractors of American (ACCA) Manual G "Selection of Distribution System," Manual T "Basic Air Distribution" and Manual D "Residential Duct Systems"
- Sheet Metal and Air Conditioning Contractors National Association (SMACNA) "HVAC Duct System Design"
- American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) handbooks.

Ductwork should be designed so that air velocities do not exceed the following:

	Supply	Return
Main Ducts	900 fpm (274 mpm)	600 fpm (183 mpm)
Branch Ducts	700 fpm (213 mpm)	600 fpm (183 mpm0
Registers, Diffusers, and Grills (Face Velocity)	750 fpm (229 mpm)	600 fpm (183 mpm)

Hydronics (In-Floor, Fan Coils)

Figure 15: Forced Air vs. Radiant Heat



Hydronic installations (radiant floor heating, fan coil heating/cooling) allow geothermal technology to be applied to distribution systems other than forced air ducted systems. The most popular geothermal hydronic application is radiant floor heating using ClimateMaster water-to-water heat pumps (Tranquility® TMW or THW Series). The distribution of heat at occupant level as shown in figure 15, not only provides better comfort, but also reduces heat loss, since hot air is not rising above occupant level, and therefore lowers the temperature difference at the ceiling. Radiant floor heating systems typically operate for 10% to 20% less than forced air systems. Since geothermal systems operate for 30% to 50% less than conventional heating and cooling systems, the combination can be lead to substantial energy cost savings.

Homes with radiant floor heating may or may not require cooling. If cooling is desired, ClimateMaster recommends a separate water-to-air unit with ductwork dedicated to cooling. If space is not available for a separate unit, chilled water may be used with fan coil units, although controls difficulty and system switch-over lag time may be obstacles to using one water-to-water unit for both heating and cooling.

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 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.

The Heating/Cooling Distribution System and Equipment Sizing

Figure 16: Typical Radiant Floor Header System

The size of the buffer tank should be determined based upon the predominant use of the 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 (loop) water temperature (EST) and the minimum entering load (floor) 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. The minimum buffer tank size is 40 U.S. gallons [36 liters] for any system.

Electric water heaters typically make good buffer tanks because of the availability and relatively low cost. However, all local codes and regulations must be followed. Insulation values of the tank should be considered, 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-m^2/W] is recommended for storage tanks. Care must be taken when using the fittings where the elements are threaded into the water heater for piping connections. Typically, these fittings have very few threads, and use a flange to seal against the water heater.

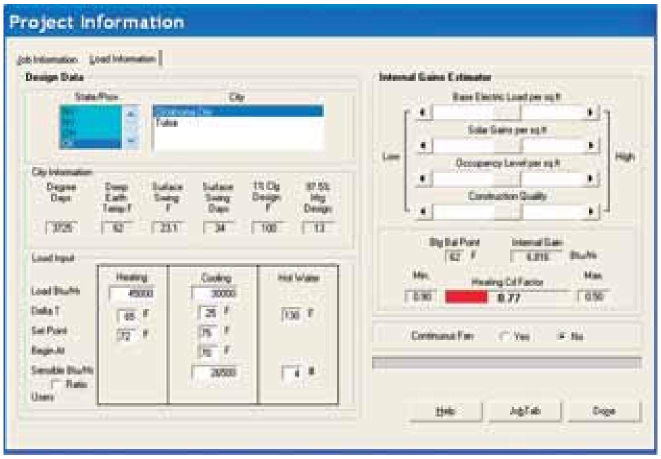
Equipment Sizing

Geothermal equipment sizing is particularly important not only for comfort and IAQ (Indoor Air Quality) considerations, but also for impact on installation costs. Since most geothermal installations are closed loop, oversized equipment increases installation costs. Undersized equipment may compromise occupant comfort and even contribute to equipment operation issues. For example, an undersized heat pump will run longer, which can potentially drive the loop temperature too high or too low, causing even more run time, and may eventually lead to operation at the extreme limits of the heat pump.

Fortunately, equipment sizing procedures are well documented and easily calculated using readily available computer software. Heat loss loss/gain calculations for any residential HVAC design should be performed using standard industry practices. Accepted calculations include ACCA (Air Conditioning Contractors of America) Manual J, HRAI (Heating, Refrigeration and Air Conditioning Institute of Canada) and ASHRAE (American Society of Heating Refrigeration and Air Conditioning Engineers) manuals. Software versions of Manual J and other methods save considerable design time. Either a whole house or room by room calculation may be used for equipment sizing, but a room by room calculation should be used for duct sizing.

Once the heat loss/gain has been determined, equipment should be selected using the ClimateMaster GeoDesigner software. Since the equipment capacity is directly related to the EWT (Entering Water Temperature), the type of heat source/sink must be considered when sizing equipment. For example, an open loop system in the Northern U.S. will operate at approximately 50°F [10°C] water year around, but a closed loop system in Georgia may see temperatures ranging from 40°F [4°C] to 95°F [35°C], which will affect the capacity of the heat pump in both heating and cooling. GeoDesigner uses the heat loss/gain calculations along with the loop type to determine heat pump capacity at design conditions in both heating and cooling modes.

Figure 17: GeoDesigner Entry Screen For Heat Loss/Gain



Because a heat pump operates in both heating and cooling, it's rare that a particular model will exactly match both the heating and cooling loads. Sizing a heat pump for cooling is the best approach in Southern locations, since the heating capacity is of little concern. However, in a Northern location, equipment sized only for the cooling load could cause excessive use of backup heat, increasing operating costs. On the other hand, if a heat pump is sized for the full heating load in a Northern climate, it will most likely be severely oversized for cooling. In climates where relatively humidity is high in the summer, oversized equipment can cause comfort and even IAQ problems. A heat pump that is not running very often may not provide sufficient dehumidification.

Newer technology has helped alleviate some of the sizing issues mentioned above. Two-stage compressors, ECM fan motors and whole house dehumidifiers (see ClimaDry® II section) help provide the appropriate capacities at design conditions and at part-load conditions, and help keep relative humidity lower than single speed systems or systems without dehumidification mode. Proper

Equipment Sizing

equipment sizing is still important, but some flexibility may be gained by including some of the latest technology.

Regardless of location, local codes and/or electric utility program requirements always supersede any recommendations in this manual. In general, the following guidelines may be used when sizing geothermal water-to-air heat pumps:

- Heat pump sensible cooling capacity (shown as SC in the equipment catalog data) should be within 5-10% of the design cooling sensible load at the maximum loop EWT.
- In most areas of North America the heat pump total cooling capacity at design conditions should not exceed 25% of the total cooling load. In Northern climates where heat loss may be more than twice the heat gain, this may not always be possible, and consideration should be given to two-stage equipment and/or additional dehumidification methods.
- Depending upon climate, the heat pump may need some amount of auxiliary heat to satisfy the heating load at design conditions. In Southern climates, the heat pump may provide 100% of the heating, but for most installations, auxiliary heat will allow the use of a smaller heat pump and avoid over sizing the equipment for cooling. Due to the higher heating capacities of geothermal heat pumps as compared to air source heat pumps, very little auxiliary heat is normally required.
- As a general rule of thumb, an economical balance point (outdoor temperature below which auxiliary heat or less is required) may be achieved by sizing the equipment such that approximately 10% of the kilo Watt hours per year are used by auxiliary heat (an example GeoDesigner report is shown below). Since electric auxiliary heat is only about 25% as efficient as the heat pump, excessive amounts of auxiliary heat may contribute to high energy costs. In the example below, the balance point was 20°F [-7°C], which means that the heat pump can handle the entire heating load when the outdoor temperature is above this temperature. Below the balance point, the heat pump will still provide most of the heating, but will require some auxiliary heat to meet the full load requirement. For the location where this example was calculated, only 510 hours per year on average fall below 20°F [-7°C], which is a relatively small portion of the total annual heating hours. This rule of thumb only applies if the sensible cooling load is satisfied by the heat pump selection. If the cooling load requires a larger heat pump than what the rule of thumb would indicate for heating, the cooling load should determine the heat pump size.

Figure 18: Geo A Summary Report From GeoDesigner Software

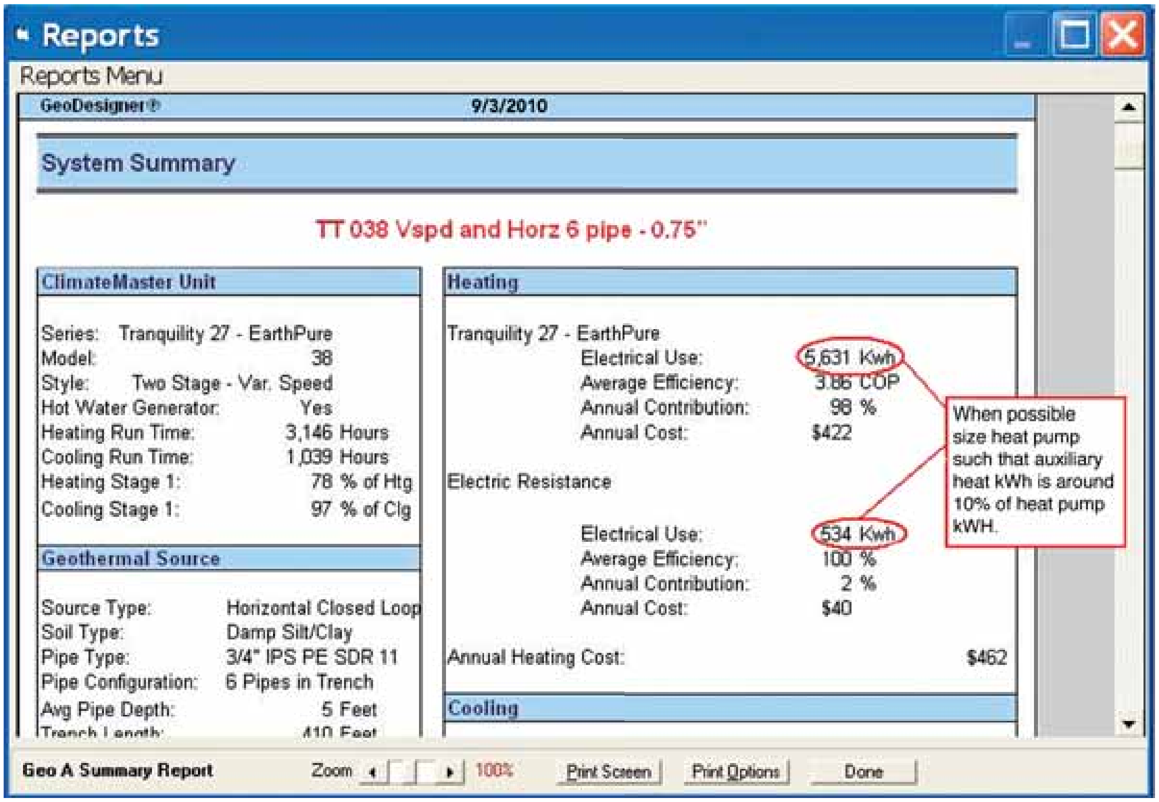
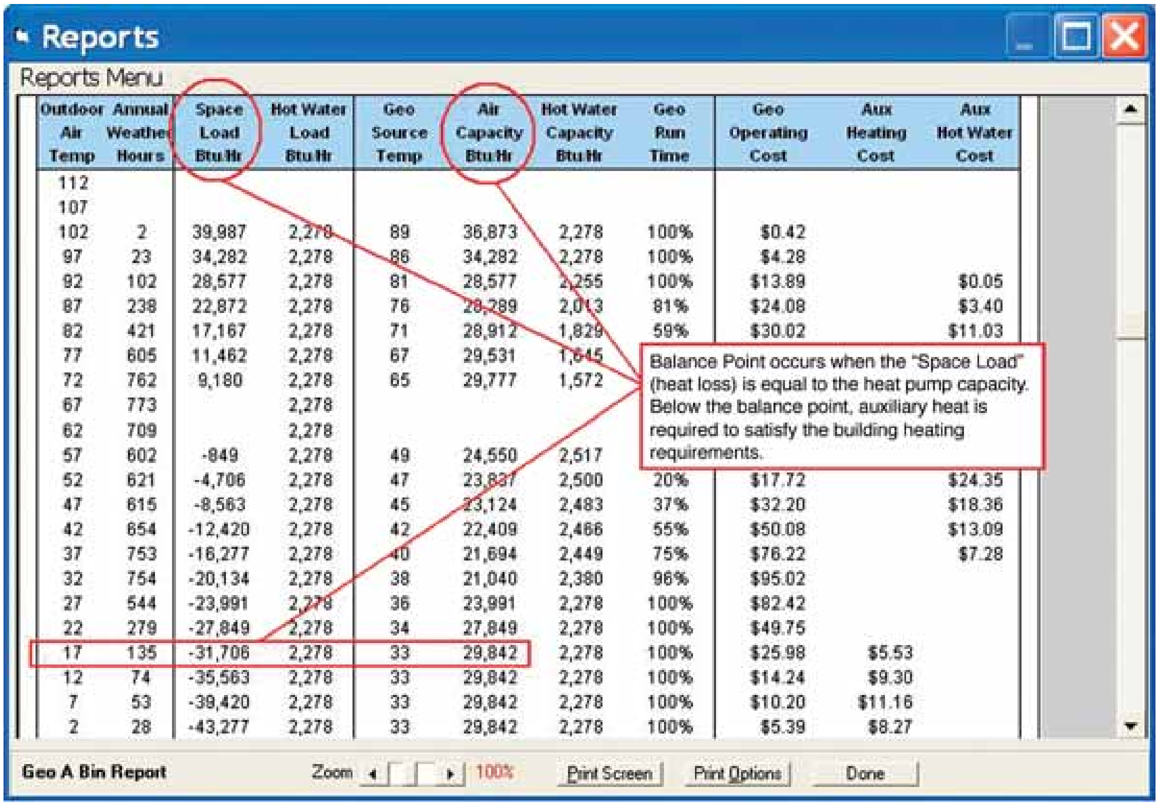


Figure 19: Geo A Bin Report From GeoDesigner Software



Reports

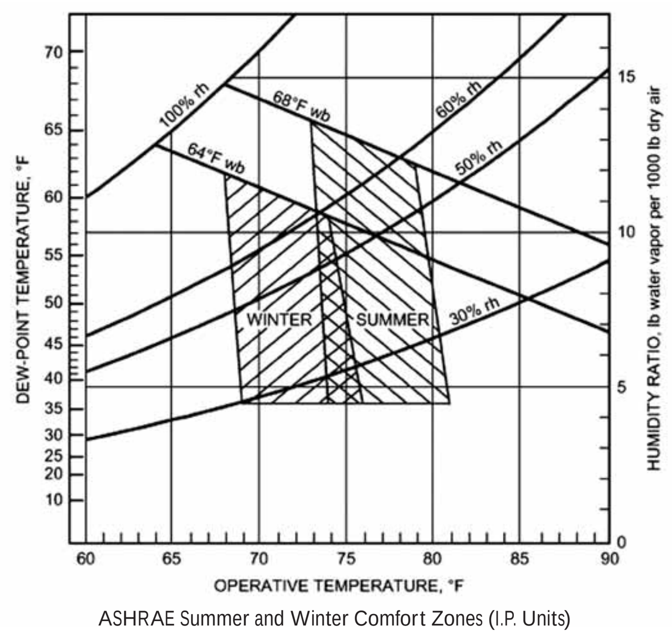
Reports Menu

Outdoor Air Temp	Annual Weather Hours	Space Load Btu/Hr	Hot Water Load Btu/Hr	Geo Source Temp	Air Capacity Btu/Hr	Hot Water Capacity Btu/Hr	Geo Run Time	Geo Operating Cost	Aux Heating Cost	Aux Hot Water Cost
112										
107										
102	2	39,987	2,278	89	36,873	2,278	100%	$0.42		
97	23	34,282	2,278	86	34,282	2,278	100%	$4.28		
92	102	28,577	2,278	81	28,577	2,255	100%	$13.89		$0.05
87	238	22,872	2,278	76	28,289	2,013	81%	$24.08		$3.40
82	421	17,167	2,278	71	28,912	1,829	59%	$30.02		$11.03
77	605	11,462	2,278	67	29,531	1,645				
72	762	9,180	2,278	65	29,777	1,572				
67	773		2,278							
62	709		2,278							
57	602	-849	2,278	49	24,550	2,517				
52	621	-4,706	2,278	47	23,837	2,500	20%	$17.72		$24.35
47	615	-8,563	2,278	45	23,124	2,483	37%	$32.20		$18.36
42	654	-12,420	2,278	42	22,409	2,466	55%	$50.08		$13.09
37	753	-16,277	2,278	40	21,694	2,449	75%	$76.22		$7.28
32	754	-20,134	2,278	38	21,040	2,380	96%	$95.02		
27	544	-23,991	2,278	36	23,991	2,278	100%	$82.42		
22	279	-27,849	2,278	34	27,849	2,278	100%	$49.75		
17	135	-31,706	2,278	33	29,842	2,278	100%	$25.98	$5.53	
12	74	-35,563	2,278	33	29,842	2,278	100%	$14.24	$9.30	
7	53	-39,420	2,278	33	29,842	2,278	100%	$10.20	$11.16	
2	28	-43,277	2,278	33	29,842	2,278	100%	$5.39	$8.27	

Balance Point occurs when the "Space Load" (heat loss) is equal to the heat pump capacity. Below the balance point, auxiliary heat is required to satisfy the building heating requirements.

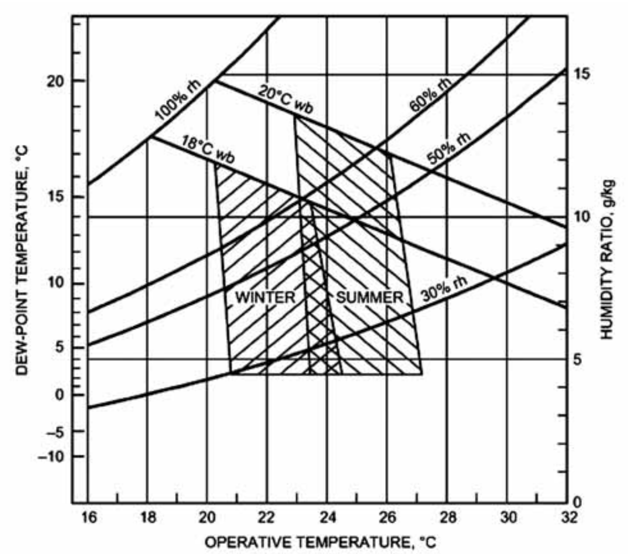
Geo A Bin Report Zoom 100% Print Screen Print Options Done

- Once the equipment is selected for sensible cooling and the proper size for heating has been determined, the latent cooling requirements should be considered. In the product catalog data, TC (Total Cooling capacity) and SC (Sensible Cooling capacity) are shown. Latent capacity equals TC minus SC. The heat gain calculation should also show TC and SC, which can be compared to the product catalog data. In most residential applications, properly selected equipment for heating and cooling will provide adequate latent capacity to maintain 50% to 55% RH (Relative Humidity). However, especially in humid climates, the latent capacity may not be sufficient to satisfy the latent load (this is true of any residential air conditioning system). In those cases, equipment selection should include two-stage operation, ECM fan and in some cases additional dehumidification equipment. Two-stage operation increases equipment run time, thereby increasing the amount of moisture removal over time. The ECM fan option provides a dehumidification mode that operates the fan at about 25% less than the normal airflow in the cooling mode (the heating mode is unaffected). Finally, ClimaDry® II Whole House Dehumidification can be applied to further assist in removing moisture in extreme climates.



ASHRAE Summer and Winter Comfort Zones (I.P. Units)
Acceptable ranges of operative temperature and humidity for people in typical summer and winter clothing during primarily sedentary activity.

Loop Sizing



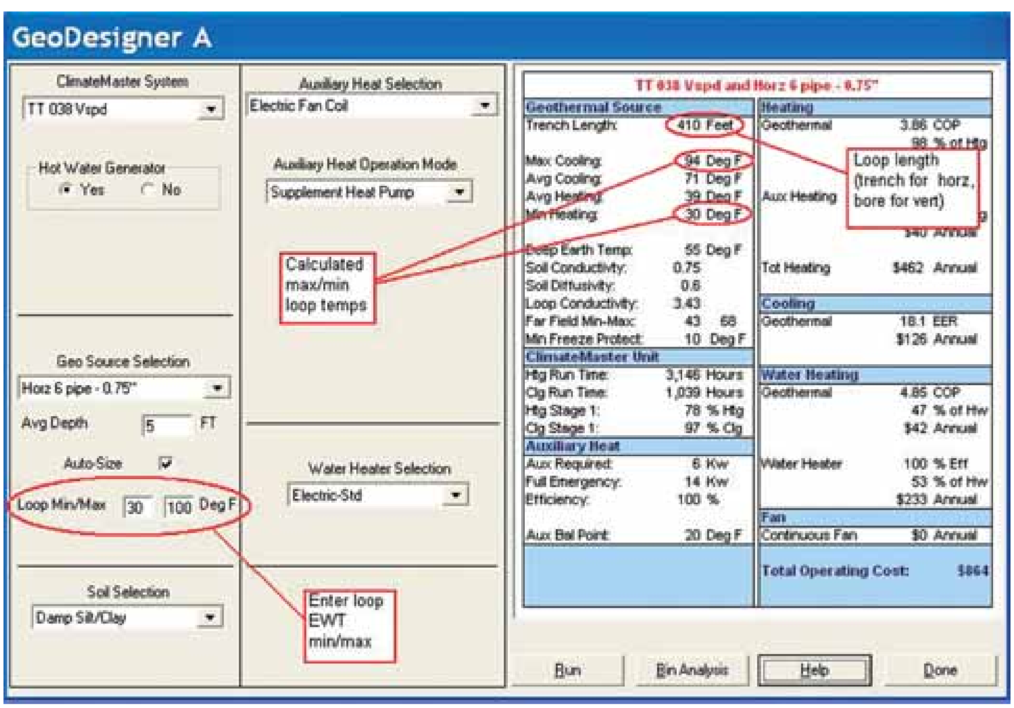
ASHRAE Summer and Winter Comfort Zones (S.I. Units)
Acceptable ranges of operative temperature and humidity for people in typical summer and winter clothing during primarily sedentary activity.

Loop Sizing
Like equipment sizing, properly designed residential geothermal loops require the use of GeoDesigner software. Loop type and configuration are addressed earlier in this manual. Therefore, the loop type will depend upon the available space and economic considerations (excavation costs, etc.). Loop sizing involves the calculation of the amount of loop piping required. A load calculation is required in order to use the GeoDesigner software, since equipment and loop are determined based upon heat loss/heat gain.

ClimateMaster heat pumps are designed for EWTs of 20°F [-7°C] to 120°F [49°C]. However, economical minimum and maximum loop temperatures should not be outside the range of 25°F [-4°C] and 105°F [41°C]. A good starting point for minimum EWT is 30 to 40°F [17 to 22°C] above the winter outdoor design temperature. For maximum EWT, a good starting point is 90 to 100°F [32 to 38°C]. For example, for a location with a 0°F [-18°C] design temperature, a good starting minimum EWT would be 30°F [-1°C]. Generally speaking, climates where heating is the dominant factor, maximum EWT should be closer to 100°F [38°C], since cooling costs will be less of a factor than heating costs. In Southern climates, maximum EWT should be lower (closer to 90°F [32°C]), since lower cooling EWT will provide higher efficiencies and thus keep cooling cost low.

Once starting minimum/maximum EWTs have been determined, enter the values into GeoDesigner (see illustration below). Adjusting the loop EWTs will change the amount of loop required. As long as the minimum and maximum EWT remains in the 25°F [-4°C] to 105°F [41°C] range, loop sizing is primarily an economic decision. More loop yields milder operating temperatures, which lowers operating costs, but increases installed costs. In some cases, it may even be more cost effective to increase the loop length to allow the use of the next size smaller heat pump, since milder loop temperatures increase heat pump capacity.

Figure 20: GeoDesigner Loop Sizing



Options

Options

ClimateMaster residential geothermal heat pumps have a number of options to customize the installation to the customer's individual needs.

ECM Fan

The ECM (Electrically-Commutated Motor) or variable speed fan motor is standard on Tranquility® 30 and 22 series units. For Tranquility® 20 series water-to-air units, a PSC (Permanent Split Capacitor) fan motor is standard, and the ECM motor is available as an option. The ECM motor has a number of features such as soft start, constant CFM [l/s], dehumidification mode and numerous airflow settings (4 heating airflow choices, 4 cooling airflow choices, 3 dehumidification mode airflow choices, 4 auxiliary heat airflow choices, and 1 constant fan airflow).

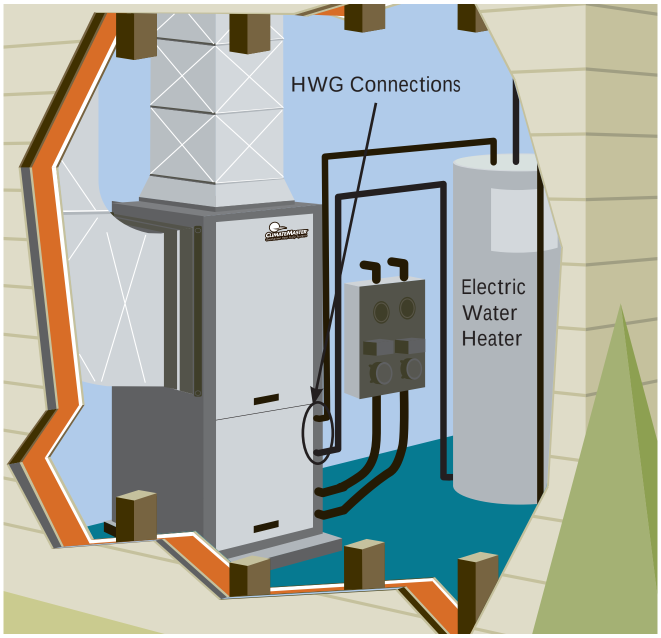
Hot Water Generator

The HWG (Hot Water Generator) or desuperheater option provides considerable operating cost savings by utilizing excess heat energy from the heat pump to help satisfy domestic hot water requirements. The HWG is active throughout the year (any time the heat pump is operating), providing virtually free hot water when the heat pump operates in the cooling mode, or hot water at the COP of the heat pump during operation in the heating mode. Actual HWG water heating capacities are provided in the appropriate heat pump performance data. All ClimateMaster heat pumps equipped with the HWG option include a built-in water to refrigerant heat exchanger that eliminates the need to tie into the heat pump refrigerant circuit in the field. The control circuit and pump are also built in for residential equipment.
Figure 21 shows a typical example of HWG water piping connections on a unit with built-in pump. Electric water heaters are recommended. If a gas, propane, or oil water heater is used, a second preheat tank must be installed. If the electric water heater has only a single center element, the dual tank system is recommended to insure a usable entering water temperature for the HWG.

Typically a single tank of at least 52 gallons [235 liters] is used to limit installation costs and space. However, a dual tank, is the most efficient system, providing the maximum storage and temperate source water to the HWG.

It is always advisable to use water softening equipment on domestic water systems to reduce the scaling potential and lengthen equipment life. In extreme water conditions, it may be necessary to avoid the use of the HWG option since the potential cost of frequent maintenance may offset or exceed any savings.

Figure 21: Typical HWG Installation



ClimaDry® II Whole House Dehumidification Overview

Indoor Air Quality (IAQ) and Relative Humidity (RH) are increasingly becoming design issues that must be addressed by selecting heating and cooling equipment with advanced capabilities. The patented ClimateMaster ClimaDry® II reheat option offers unique features unlike anything currently available today.

ClimateMaster's ClimaDry® II reheat option is an innovative means of providing modulating reheat without the complication of refrigeration controls. ClimaDry® II is Hot Gas Generated Reheat, which utilizes one of the biggest advantages of a water source heat pump (WSHP), the transfer of energy through the loop piping system. ClimaDry® II simply diverts condenser water through a water-to-air coil that is placed after the evaporator coil. If condenser water is not warm enough, the internal "run-around" loop increases the water temperature with each pass through the condenser coil.

ClimaDry® II Benefits

ClimaDry® II is like no other reheat option on the market. Proportional reheat is controlled to the desired leaving air temperature set point (factory set point of 72°F, [22°C}), no matter what the loop temperature is. Since dehumidification operation will occur under less than full load cooling conditions a good percentage of the time, it is important to have a reheat function that provides 100% reheat in the spring and fall when the loop is cool. Supply air temperature is field adjustable to +/- 3°F [+/- 1.7°C] for even greater flexibility with an optional potentiometer.

Competitors without ClimaDry® II typically use an on/off (non-modulating) refrigeration based reheat circuit, typically referred to as "Hot gas reheat" (HGR). HGR needs higher condensing temperatures to work well, typically 85°F [29°C] entering water temperature (EWT). With HGR, cooler water temperatures produce cooler supply air temperatures, which could overcool the space, requiring additional space heating from another source or a special auto-change-over relay to allow the unit to switch back and forth between reheat and heating. Rarely does HGR provide 100% reheat, like ClimaDry® II.

ClimaDry® II

ClimaDry® II is a simple and easy to troubleshoot refrigerant circuit. No switching valves or hard to diagnose leaky check valves are utilized. No unusual refrigerant pressures occur during the reheat mode. The ClimaDry® II refrigerant circuit is like every other ClimateMaster unit (without reheat), so everything the technician already knows applies to troubleshooting the ClimaDry® II refrigeration circuit. Plus, the water loop portion of the ClimaDry® II option is easy to understand and diagnose.

Features Include:

- Modulating reheat for precise control of supply air temperatures
- 100% reheat (operates as a dehumidifier)
- "Neutral" supply air temperature even at part load (non-design) conditions
- Supply air temperature adjustment, +/- 3°F [+/-1.7°C] from 72°F [22°C] factory setpoint with optional potentiometer
- Integrated reheat controls – simply attach a humidistat or dehumidistat
- Microprocessor (DXM) controls standard
- Ultra simple refrigeration circuit
- All water system eliminates refrigeration circuit modifications (same refrigeration circuit as units without ClimaDry® II)
- Stable refrigeration pressures, even at low EWTs
- All components located inside the cabinet
- Moves heat of rejection from ground loop to supply air stream

Availability

ClimaDry® II is currently available on ClimateMaster vertical and horizontal residential Tranquility® 30 (TT) and Tranquility® 20 (TS) series units.

ClimaDry® II Applications

With the ClimaDry® II option, return air from the space is conditioned by the air-to-refrigerant (evaporator) coil, then reheated by the water-to-air (reheat) coil to dehumidify the air, but maintain the same space temperature (thus operating as a dehumidifier). The moisture removal capability of the heat pump is determined by the unit's latent capacity rating. Latent Capacity (LC) equals Total Capacity (TC) minus Sensible Capacity (SC). For example, at 85°F [29°C] EWT, the moisture removal capability (latent capacity) of a ClimateMaster size 036 heat pump is 9.6 MBtuh [2.8kW] as shown in Table 4.

Dividing the latent capacity by 1,069 BTU/LB of water vapor at 80°F DB and 67°F WB [26.7°C DB and 19.4°C WB] moist air enthalpy, converts the amount of moisture removal to pounds per hour (multiply pounds per hour by 0.4536 to obtain kg/hr). Calculations are shown in figure 22. Most ClimateMaster heat pumps have a sensible-to-total (S/T) ratio of 0.72 to 0.76. Therefore, approximately, 25% of the cooling capacity is dedicated to latent cooling capacity (moisture removal). When selecting a unit with ClimaDry® II, the space sensible and latent loads should be calculated. If the unit will be used for space cooling, a unit with at least enough capacity to satisfy the building sensible load should be selected. If the latent cooling load is not satisfied by the selection, a larger unit with enough latent capacity will be required. The ClimaDry® II option can be used for the additional moisture load. If the unit will be used for dehumidification purposes only, the latent capacity is the only consideration necessary. In this case, sensible load is immaterial. Example latent capacities for a typical ClimateMaster heat pump are shown in table 4.

ClimaDry® II is especially useful in Northern Climates, where the heat pump may be oversized in cooling to provide enough heating. Units with ClimaDry® II will compensate for these applications by operating as a whole house dehumidifier when necessary to maintain space RH.

Since the ClimaDry® II option is internal to the unit, installation is much easier than a separate whole house dehumidifier. Plus, an additional compressor and controls can be eliminated, simplifying the system and lowering operating and installation costs.

Table 4: Typical Unit Latent capacity

Latent Capacity at 85°F [29.4°C] EWT				
Size	MBtuh	lbs/hr	kW	kg/hr
18	4.7	4.4	1.4	2.0
24	6.1	5.7	1.8	2.6
30	6.8	6.4	2.0	2.9
36	9.6	9.0	2.8	4.1
42	11.0	10.3	3.2	4.7
48	12.7	11.9	3.7	5.4
60	15.2	14.2	4.5	6.4
70	16.9	15.8	5.0	7.2

Figure 22: Example Size 030 Performance

Performance Data
Model 030

LC = TC - SC = 30.4 - 21.5 = 8.9 MBtuh
8900 Btuh ÷ 1069 = 8.3 lbs/hr (3.8 kg/hr)

1000 CFM Nominal Airflow

Performance capacities shown in thousands of Btuh

70	4.0	1.1	2.5	730	30.3	18.9	1.69	36.0	17.9	2.9	820	33.8	2.23	26.1	108	4.43	4.0
	4.0	1.1	2.5	1000	31.5	22.0	1.79	37.6	17.6	3.0	1100	34.8	2.06	27.8	99	4.94	4.1
	6.0	2.3	5.3	730	31.3	19.3	1.59	36.7	19.7	2.6	820	35.2	2.26	27.5	110	4.57	4.2
	6.0	2.3	5.3	1000	32.6	22.4	1.68	38.3	19.4	2.7	1100	36.3	2.09	29.2	101	5.10	4.3
	8.0	3.8	8.8	730	31.8	19.5	1.54	37.0	20.7	2.3	820	36.0	2.28	28.2	111	4.64	4.4
	8.0	3.8	8.8	1000	33.1	22.6	1.63	38.6	20.3	2.4	1100	37.1	2.10	30.0	101	5.18	4.5
80	4.0	1.0	2.3	730	28.4	18.1	1.87	34.8	15.2	3.5	820	36.8	2.29	28.9	112	4.71	4.4
	4.0	1.0	2.3	1000	29.6	21.1	1.98	36.3	15.0	3.6	1100	37.9	2.12	30.7	102	5.25	4.5
	6.0	2.2	5.1	730	29.6	18.6	1.76	35.6	16.9	3.2	820	38.4	2.32	30.4	113	4.85	4.6
	6.0	2.2	5.1	1000	30.8	21.7	1.86	37.1	16.6	3.4	1100	39.6	2.14	32.3	103	5.41	4.7
	8.0	3.5	8.1	730	30.2	18.8	1.70	36.0	17.7	3.0	820	39.3	2.34	31.2	114	4.93	4.8
	8.0	3.5	8.1	1000	31.4	21.9	1.80	37.5	17.4	3.1	1100	40.5	2.16	33.1	104	5.50	4.9
85	4.0	1.0	2.3	730	27.5	17.8	1.97	34.2	13.9	3.9	820	38.3	2.32	30.3	113	4.84	4.6
	4.0	1.0	2.3	1000	28.6	20.7	2.08	35.7	13.7	4.1	1100	39.5	2.14	32.1	103	5.40	4.7
	6.0	2.2	5.0	730	28.6	18.2	1.85	34.9	15.4	3.6	820	40.1	2.35	31.9	115	5.00	4.8
	6.0	2.2	5.0	1000	29.8	21.2	1.96	36.4	15.2	3.8	1100	41.3	2.17	33.9	105	5.58	4.9
	8.0	3.5	8.0	730	29.2	18.5	1.80	35.3	16.3	3.3	820	41.0	2.37	32.7	116	5.08	5.0
	8.0	3.5	8.0	1000	30.4	21.5	1.90	36.8	16.0	3.5	1100	42.3	2.19	34.8	106	5.67	5.1
90	4.0	1.0	2.3	730	26.5	17.4	2.07	33.6	12.8	4.5	820	39.8	2.35	31.6	115	4.98	4.8
	4.0	1.0	2.3	1000	27.5	20.2	2.19	35.0	12.6	4.6	1100	41.1	2.17	33.6	105	5.55	4.9
	6.0	2.1	4.9	730	27.6	17.8	1.95	34.3	14.2	4.1	820	41.7	2.38	33.4	117	5.14	5.0
	6.0	2.1	4.9	1000	28.7	20.7	2.06	35.8	13.9	4.3	1100	43.0	2.20	35.5	106	5.73	5.1
	8.0	3.4	7.9	730	28.2	18.1	1.89	34.7	14.9	3.8	820	42.7	2.40	34.3	118	5.23	5.2
	8.0	3.4	7.9	1000	29.4	21.0	2.00	36.2	14.7	4.0	1100	44.1	2.21	36.5	107	5.83	5.3

Dividing the latent capacity by 1,069 BTU/LB of water vapor at 80°F DB and 67°F WB [26.7°C DB and 19.4°C WB] moist air enthalpy, converts the amount of moisture removal to pounds per hour (multiply pounds per hour by 0.4536 to obtain kg/hr). Calculations are shown in figure 22.

ClimaDry® II Sequence of Operation

A heat pump equipped with ClimaDry® II can operate in three modes; cooling, cooling with reheat, and heating. The cooling/heating modes are like any other ClimateMaster WSHP. The reversing valve ("O" signal) is energized in cooling, along with the compressor contactor(s) and blower relay. In the heating mode the reversing valve is de-energized. Almost any thermostat will activate the heat pump in heating or cooling modes. The DXM microprocessor board, which is standard with the ClimaDry® II option, will accept either heat pump (Y,O) thermostats or non-heat pump (Y,W) thermostats (see DXM AOM for detailed DXM information).

The reheat mode requires either a separate humidistat/dehumidistat or a thermostat that has an integrated dehumidification function for activation. The DXM board is configured to work with either a humidistat or dehumidistat input to terminal "H" (DIP switch settings for the DXM board are shown below in table 5). Upon receiving an "H" input, the DXM board will activate the cooling mode and engage reheat. Table 6 shows the relationship between thermostat input signals and unit operation.

There are five operational inputs for single stage units and seven operational inputs for two stage units:
-Fan Only
-1st Stage Cooling
-2nd Stage Cooling
-1st Stage Heating
-2nd Stage Heating
-3rd Stage Heating (If applicable)
-Reheat Mode

- Fan Only: A (G) call from the thermostat to the (G) terminal of the DXM control board will bring the unit on in fan only mode.
- 1st Stage Cooling: A simultaneous call from (G), (Y1), and (O) to the (G), (Y1), (O/W2) terminals of the DXM control board will bring the unit on in 1st Stage Cooling.
- 2nd Stage Cooling: A simultaneous call from (G), (Y1), (Y2), and (O) to the (G), (Y1), (Y2), and (O/W2) terminals of the DXM control board will bring the unit on in 2nd Stage Cooling. When the call is satisfied at the thermostat the unit will continue to run in 1st Stage Cooling until the 1st Stage Cooling call is removed or satisfied, shutting down the unit. ***NOTE: Not all units have two-stage cooling functionality.***
- 1st Stage Heating: A simultaneous call from (G) and (Y1) to the (G) and (Y1) terminals of the DXM control board will bring the unit on in 1st Stage Heating.

Table 5: Humidistat/Dehumidistat Logic and DXM (2.1, 2.2., 2.3) DIP settings

Sensor	2.1	2.2	2.3	Logic	Reheat (ON) - H	Reheat (OFF) - H
Humidistat	OFF	OFF	OFF	Reverse	0 VAC	24 VAC
Dehumidistat	OFF	ON	OFF	Standard	24 VAC	0 VAC

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Table 6: ClimaDry® II Operating Modes

Mode	Input						Output					
	O	G	Y1	Y2[3]	W	H	O	G	Y1	Y2[3]	Backup Elec Heat	Reheat
No Demand	ON/OFF[5]	OFF	OFF	OFF	OFF	OFF	ON/OFF[5]	OFF	OFF	OFF	OFF	OFF
Fan Only	ON/OFF[5]	ON	OFF	OFF	OFF	OFF	ON/OFF[5]	ON	OFF	OFF	OFF	OFF
Cooling 1st Stage	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF
Cooling 2nd Stage	ON	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	OFF	OFF
Cooling & Dehumidistat[1]	ON	ON	ON	ON/OFF[5]	OFF	ON	ON	ON	ON	ON/OFF[5]	OFF	OFF
Dehumidistat Only	ON/OFF[5]	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	OFF	ON
Heating 1st Stage	OFF	ON	ON	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF
Heating 2nd Stage	OFF	ON	ON	ON	ON/OFF[5]	OFF	OFF	ON	ON	ON	ON/OFF[5]	OFF
Heating 3rd Stage[4]	OFF	ON	ON	ON	ON[4]	OFF	OFF	ON	ON	ON	ON[4]	OFF
Heating & Dehumidistat[2]	OFF	ON	ON	ON/OFF[5]	ON/OFF[5]	ON	OFF	ON	ON	ON/OFF[5]	ON/OFF[5]	OFF

[1]Cooling input takes priority over dehumidify input.
[2]DXM is programmed to ignore the H demand when the unit is in heating mode.
[3]N/A for single stage units; Full load operation for dual capacity units.
[4]Single stage unit: W = 2nd Stage backup elec. heat; Two-Stage units: W = 3rd stage backup elec. heat.
[5]ON/OFF = Either ON or OFF.

- 2nd Stage Heating: A simultaneous call from (G), (Y1), and (Y2) to the (G), (Y1), and (Y2) terminals of the DXM control board will bring the unit on in 2nd Stage Heating. When the call is satisfied at the thermostat the unit will continue to run in 1st Stage Heating until the call is removed or satisfied, shutting down the unit. NOTE: Not all units have two-stage heating functionality. 2nd stage heating for units with PSC fan and single stage compressor is auxiliary electric heat (Y, W1, G).
- 3rd Stage Heating (ECM fan models only): A simultaneous call from (G), (Y1), (Y2), and (W) terminals to the (G), (Y1), (Y2), and (W1) terminals of the DXM board will bring the unit on in 3rd Stage Heating (compressor plus auxiliary electric heat).
- Reheat Mode: A call from the Humidistat/Dehumidistat to the (H) terminal of the DXM control board will bring the unit on in Reheat Mode if there is no call for cooling at the thermostat. When the Humidistat/Dehumidification call is removed or satisfied the unit will shut down. NOTE: Cooling always overrides Reheat Mode. In the Cooling mode, the unit cools and dehumidifies. If the cooling thermostat is satisfied but there is still a call for dehumidification, the unit will continue to operate in Reheat Mode.

ClimaDry® II Component Functions

The ClimaDry® II option consists of the following componets:

- Proportional Controller
- Supply Air Sensor
- Motorized Valve
- Internal Loop Pump
- Hydronic Coil

The Proportional Controller operates on a 24 VAC power supply and automatically adjusts the water valve based upon the Supply Air Sensor. The Supply Air Sensor senses supply air temperature at the blower inlet providing the input signal necessary for the proportional control to drive the motorized valve during the reheat mode of operation. The Motorized Valve is a proportional actuator/three-way valve combination used to divert the condenser water from the coax to the hydronic reheat coil during the reheat mode of operation. The proportional controller sends a signal to the motorized valve based on the supply air temperature.

The internal loop pump circulates condenser water through the hydronic reheat coil during the reheat mode of operation. In this application, the internal loop pump is only energized during the reheat mode. The Hydronic Coil is utilized to reheat the air to the setpoint of the proportional controller. Condenser water is diverted by the motorized valve and pumped through the hydronic coil by the internal loop pump in proportion to the control setpoint. The amount of reheating is dependent on the setpoint and how far from setpoint the supply air temperature is. The factory setpoint is 72°F [22°C], generally considered “neutral” air.

ClimaDry® II Application Considerations

The reheat coil adds a small amount of resistance to the air stream. Consult the correction tables in this manual for details.

Unlike most hot gas reheat options, the ClimaDry® II option will operate over a wide range of EWTs. Special flow regulation (water regulating valve) is not required for low EWT conditions.

Water-Source Heat Pumps with ClimaDry® II should not be used as make-up air units. These applications require equipment specifically designed for make-up air.

Consult ClimaDry® II AOM for more details and unit availability.

Modulating reheat valve automatically adjusts reheat capacity based upon leaving air temperature and loop entering water temperature to provide 100% reheat and "neutral" supply air

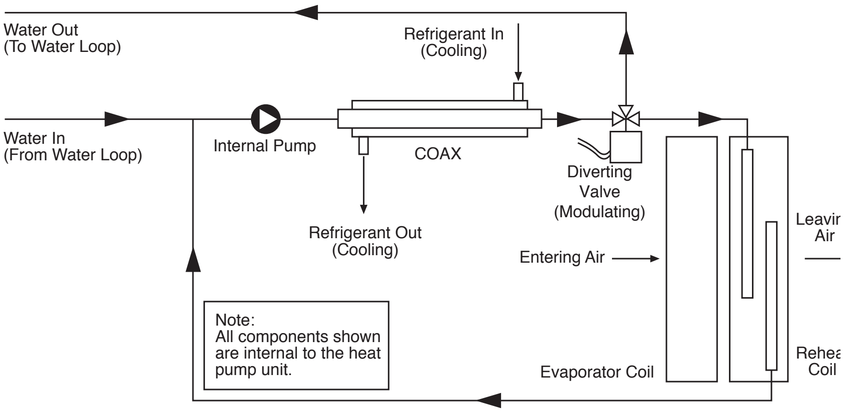
Standard DXM control takes input from either a humidistat or dehumidistat and controls the reheat function by interfacing with the modulating reheat valve

Reheat coil reheats the cool dehumidified air to "neutral" supply temperature

Separation between evaporator coil and reheat coil to allow maximum moisture removal

Standard evaporator coil

Figure 23: ClimaDry® II Schematic



ClimaDry® II

Table 7: Tranquility® 30 Blower Performance Data

Airflow in CFM with wet coil and clean air filter

Model	Max ESP (in. wg)	Fan Motor (hp)	Tap Setting	Cooling Mode			Dehumid Mode			Heating Mode			AUX CFM	Residential Units Only: Aux/ Emerg Mode
				Stg 1	Stg 2	Fan	Stg 1	Stg 2	Fan	Stg 1	Stg 2	Fan		
026	0.50	1/2	4	810	950	475	630	740	475	920	1060	475	4	1060
	0.50	1/2	3	725	850	425	560	660	425	825	950	425	3	950
	0.50	1/2	2	620	730	370	490	570	370	710	820	370	2	820
	0.50	1/2	1	520	610	300				600	690	300	1	690
038	0.50	1/2	4	1120	1400	700	870	1090	700	1120	1400	700	4	1400
	0.50	1/2	3	1000	1250	630	780	980	630	1000	1250	630	3	1350
	0.50	1/2	2	860	1080	540	670	840	540	860	1080	540	2	1350
	0.50	1/2	1	730	900	450				730	900	450	1	1350
049	0.75	1	4	1460	1730	870	1140	1350	870	1560	1850	870	4	1850
	0.75	1	3	1300	1550	780	1020	1210	780	1400	1650	780	3	1660
	0.75	1	2	1120	1330	670	870	1040	670	1200	1430	670	2	1430
	0.75	1	1	940	1120	560				1010	1200	560	1	1350
064	0.75	1	4	1670	2050	1020	1300	1600	1020	1860	2280	1020	4	2280
	0.75	1	3	1500	1825	920	1160	1430	920	1650	2050	920	3	2040
	0.75	1	2	1280	1580	790	1000	1230	790	1430	1750	790	2	1750
	0.75	1	1	1080	1320	660				1200	1470	660	1	1470
072	0.75	1	4	1620	2190	1050	1270	1650	1050	1690	2230	1050	4	2230
	0.75	1	3	1500	1950	980	1170	1520	980	1600	2100	980	3	2100
	0.75	1	2	1400	1830	910	1100	1420	910	1400	1850	910	2	1870
	0.75	1	1	1320	1700	850				1240	1620	850	1	1670

Factory shipped on Tap Setting 2
During Auxiliary operation (residential units only) the CFM will run at the higher if the heating (delay jumper) or AUX settings
Airflow is controlled within +/- 5% up to Max ESP shown with wet coil and standard 1" fiberglass filter
Do not select Dehumidification mode if HP CFM is on setting 1
All units AHRI/ISO/ASHRAE 13256-1 rated HP (Cooling) Delay (Heating) CFM Setting 3

Tranquility® 30 (TT) Series with ClimaDry® II Reheat Option

All Tranquility® 30 (TT) units have an ECM fan motor as a standard feature. The small additional pressure drop of the reheat coil causes the ECM motor to slightly increase RPM to overcome the added pressure drop, and maintain selected CFM up to the maximum ESP.

Table 8: Tranquility® 20 ECM Blower Performance Data

Airflow in CFM with wet coil and clean air filter

Model	Max ESP (in. wg)	Fan Motor (hp)	Tap Setting	Cooling Mode			Dehumid Mode			Heating Mode			Residential Units Only	
				Stg 1	Stg 2	Fan	Stg 1	Stg 2	Fan	Stg 1	Stg 2	Fan	AUX CFM	Aux/ Emerg Mode
018	0.50	1/2	4	640	800	400	500	620	400	640	800	400	4	800
			3	600	750	375	470	590	375	600	750	375	3	750
			2	525	650	330	400	500	330	525	650	330	2	650
			1	450	550	280				450	550	280	1	650
024	0.50	1/2	4	780	950	470	610	740	470	870	1060	470	4	1060
			3	700	850	420	540	660	420	780	950	420	3	950
			2	630	770	360	490	600	360	670	820	390	2	820
			1	550	670	300				570	690	340	1	690
030	0.50	1/2	4	920	1130	560	720	880	560	1000	1230	560	4	1230
			3	820	1000	500	640	780	500	900	1100	500	3	1100
			2	740	900	450	580	700	450	800	980	450	2	980
			1	660	800	400				700	850	400	1	850
036	0.50	1/2	4	1150	1400	700	900	1090	700	1150	1400	700	4	1400
			3	1020	1250	630	800	980	630	1020	1250	630	3	1350
			2	890	1080	540	690	840	540	890	1080	540	2	1350
			1	740	900	450				750	920	450	1	1350
042	0.50	1/2	4	1290	1580	790	1010	1230	790	1290	1580	790	4	1580
			3	1150	1400	700	900	1090	700	1150	1400	700	3	1400
			2	1050	1280	640	820	1000	640	1020	1240	640	2	1350
			1	920	1120	560				900	1080	560	1	1350
048	0.75	1	4	1420	1730	870	1110	1350	870	1520	1850	865	4	1850
			3	1270	1550	780	990	1210	780	1350	1650	775	3	1650
			2	1180	1440	720	920	1120	720	1190	1450	720	2	1450
			1	1050	1280	640				1020	1250	640	1	1350
060	0.75	1	4	1680	2050	1030	1310	1600	1030	1870	2280	1030	4	2280
			3	1500	1830	910	1170	1420	910	1680	2050	910	3	2050
			2	1400	1700	850	1090	1330	850	1480	1800	850	2	1800
			1	1300	1580	790				1270	1550	790	1	1550
070	0.75	1	4	1830	2230	1100	1420	1740	1100	1830	2230	1100	4	2230
			3	1600	1950	980	1250	1520	980	1720	2100	980	3	2100
			2	1440	1750	880	1120	1360	880	1670	1950	880	2	1950
			1	1200	1580	790				1460	1780	790	1	1780

See ECM control section for details on setting taps.
Bold numbers indicate factory settings.
During Auxiliary operation the CFM will run at the higher of the Heating (Delay jumper) or AUX settings.
Airflow is controlled within 5% up to the Max ESP shown with wet coil.
Do not select Dehumidification mode if HP CFM is on setting 1.
All units AHRI/ISO/ASHRAE 13256-1 rated HP CFM Setting 3.

Tranquility® 20 (TS) Series with ClimaDry® II Reheat Option (ECM Motor)

All Tranquility® 20 (TS) units with optional ECM fan motor automatically adjust for the reheat coil. The small additional pressure drop of the reheat coil causes the ECM motor to slightly increase RPM to overcome the added pressure drop, and maintain selected CFM up to the maximum ESP.

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Table 9: Tranquility® 20 (TS) Series PSC Blower Performance Data (Without ClimaDry® II)

Model	Fan Speed	Rated Airflow	Min CFM	Airflow (cfm) at External Static Pressure (in. wg)															
				0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.60	0.70	0.80	0.90	1.00
018	HI	600	450	704	708	711	702	693	692	690	683	675	658	640	598	515			
	MED	600	450	602	601	599	590	581	583	585	579	573	560	547	492				
	LOW	600	450	531	529	527	522	517	512	506	501	495	479	462					
024	HI	850	600	965	960	954	943	931	923	914	898	882	862	842	794	725	635		
	MED	850	600	841	833	825	817	809	800	790	777	763	747	731	686	623			
	LOW	850	600	723	715	707	703	698	689	680	668	656	642	627					
030	HI	950	750	1271	1250	1229	1207	1185	1164	1143	1118	1093	1061	1029	953	875	753		
	MED	950	750	1048	1037	1025	1016	1007	994	981	962	943	915	886	822				
	LOW	950	750	890	887	884	879	874	865	855	842	829	809	789					
036	HI	1250	900	1411	1407	1402	1390	1378	1370	1361	1326	1290	1248	1205	1083	942			
	MED	1250	900	1171	1164	1156	1145	1133	1113	1092	1064	1035	997	958					
	LOW	1250	900	983	967	950	943	936	936										
042	HI	1400	1050	1634	1626	1618	1606	1594	1583	1571	1539	1507	1464	1420	1265	1078			
	MED	1400	1050	1332	1323	1314	1298	1282	1263	1243	1206	1169	1115	1060					
	LOW	1400	1050	1130	1109	1088	1086	1084	1066	1048	1052	1055							
048	HI	1600	1200	1798	1781	1764	1738	1711	1688	1665	1630	1595	1555	1514	1420	1239			
	MED	1600	1200	1384	1382	1379	1375	1371	1356	1341	1318	1294	1261	1227					
	LOW	1600	1200																
060	HI	1950	1500	2311	2306	2300	2290	2279	2268	2257	2233	2209	2175	2140	2088	1990	1901	1856	1752
	MED	1950	1500	2058	2049	2039	2028	2016	2000	1983	1966	1949	1935	1920	1874	1807	1750	1670	1582
	LOW	1950	1500	1868	1863	1858	1858	1858	1848	1838	1822	1806	1799	1792	1749	1699	1636	1570	

Black areas denote ESP where operation is not recommended.
Units factory shipped on medium speed. Other speeds require field selection.
All airflow is rated and shown above at the lower voltage if unit is dual voltage rated, e.g. 208V for 208-230V units.

Table 10: Blower Performance Data - TS Units With ClimaDry® II (PSC Motor)

Coil Face Velocity FPM	TSH/V/D with Reheat ESP Loss				
	TSH/V/D 018 In. of Water	TSH/V/D 024, 030 In. of Water	TSH/V/D 036 In. of Water	TSH/V/D 042, 048 In. of Water	TSH/V/D 060, 070 In. of Water
200	0.037	0.033	0.031	0.028	0.026
250	0.052	0.046	0.042	0.038	0.034
300	0.077	0.066	0.059	0.051	0.044
350	0.113	0.096	0.085	0.073	0.061
400	0.181	0.160	0.145	0.131	0.117
450	0.242	0.226	0.215	0.205	0.194
500	0.360	0.345	0.335	0.326	0.316

For TS units with ClimaDry® II Reheat coil applications, calculate face velocity of the entering air.
From the table above, find ESP for Reheat application.
The loss includes wet coil loss.

Example:
Reheat coil loss can be determined from the above table. Coil velocity (FPM) = Airflow (CFM)/Face Area (sq. ft.)

1) TSH036 has a face area of 4.86 sq. ft. (see physical data table in I.O.M.).
2) At 1,100 cfm, coil velocity (FPM) = 1,100/4.86 = 226 FPM
3) From above table, it will be necessary to subtract 0.037 from the blower performance ESP.
4) On medium speed, the TSH036 (without reheat - see blower table) can deliver 1,100 CFM at 0.28 in. wg. with the standard PSC motor; with the reheat coil, it now delivers 1,085 CFM at 0.28 in. wg. or 1,100 CFM at 0.24 in. wg.
5) If the decrease in airflow is acceptable, no changes are necessary. Otherwise, high speed fan should be used to overcome the pressure drop of the reheat coil.

Revision History

Date	Page #	Description
1 Feb. 13	All	Added TE/TZ info., updated TT 27 to TT 30, various minor updates
10 June, 09	All	Updated photos, tables, formatting, etc.
03 June, 09	30	Updated Figure 22: Example Size 030 Performance
03 June, 09	18	Updated Table 3d: Polyethylene Pressure Drop
05 June, 08	All	Reformatted Document Size
30 April 08	All	Minor Format Changes
01 Oct, 06	All	First Published