Bosch Geothermal Heat Pumps

For Residential Applications

BOSCH

Applications Manual

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1 Explanation of symbols

Warnings

Warnings are indicated in the text by a warning triangle and a gray background.

Signal words at the beginning of a warning are used to indicate the type and seriousness of the ensuing risk if measures for minimizing damage are not taken.

- **NOTE** indicates that damage to property may occur.
- **CAUTION** indicates that personal injury may occur.
- **WARNING** indicates that possible severe personal injury may occur.
- **DANGER** indicates that severe personal injury or death may occur.

Important information

Important information that presents no risk to people or property is indicated with this symbol. It is separated by horizontal lines above and below the text.

WARNING:
Follow each appliances' instructions precisely. For assistance or further information, contact a trained and certified installer, service provider, or the gas licensed plumber or gas fitter.

Application drawings in this manual are conceptual only and do not purport to address all design, installation, code, or safety considerations.

The diagrams in this manual are for reference use by code officials, designers and licensed installers. It is expected that installers have adequate knowledge of national and local codes, as well as accepted industry practices, and are trained on equipment, procedures, and applications involved. Drawings are not to scale.

2 Introduction

This Applications Manual is intended to present some of the most common applications of Bosch geothermal heat pumps for residential applications. Application drawings are shown with system application schematics where applicable. Auxiliary equipment depicted represents Bosch equipment where applicable. There are a wide variety of techniques, practices and strategies possible when installing geothermal heat pumps. It is the responsibility of the installing contractor to determine the best solution for the particular geothermal heat pump system application.

Bosch geothermal heat pumps, if properly designed and installed, are one of the most efficient forms of space heating, as well as space cooling and water heating available today. In this applications manual, we will provide a complete review of geothermal heat pump technology, components and operation, as well as guidance on the design and installation of ground heat exchangers and Bosch geothermal heat pump systems for domestic use (residential). This manual is focused on both contractors and designers. It provides detailed guidance, focused on the issues to be considered when selecting systems and components and estimating system performance.

Although this manual covers many common applications for our Bosch geothermal heat pumps, system possibilities are numerous and varied. Should you encounter an application that is not covered in this manual or have any questions regarding any of its content, we encourage you to contact your local sales representative or us directly at Bosch Thermotechnology Corp.

This Applications Manual is not a substitute for any of the Bosch geothermal heat pump Installation and Maintenance manuals. All specifications are subject to change.

3 Residential Bosch Geothermal Pump System Applications

The application of Bosch geothermal heat pump systems is increasing rapidly in the residential sector. These systems offer exceptional efficiency because they use the relatively constant temperature of the earth to heat and cool. Heat removed from a residential structure during summer months is collected and then rejected to the earth, then stored for retrieval during the winter months. As the earth's ground temperature is typically more moderate than the outdoor air temperature, the annual energy efficiency is improved. In addition, the stored heat in the earth can then be absorbed during winter months when heating is required, and then used to heat the home. As this heat comes from the ground, it can result in enhanced savings in fossil fuel consumption and provide a reduction in the emission of greenhouse gases, as well as other pollutants.

Today, geothermal heat pump systems are referred to by several different names. These include geothermal, earth-coupled, geoexchange, groundwater, ground-coupled, closed-loop, open-loop, and water-source heat pump systems, just to mention a few. All geothermal heat pump systems are an environmentally sound energy alternative. And, geothermal heat pump systems are becoming more “price-competitive” with conventional conditioning systems.

A Bosch geothermal heat pump system (Fig. 1) will consist of a Bosch geothermal heat pump coupled with a ground heat exchanger to reject or add heat to the structure as necessary. The ground heat exchanger may be a “Closed-loop” system of buried HDPE piping, water pumped from a groundwater well (”Open-loop” system), or a closed-loop system in a large body of water. Other hybrid ground heat exchanger methods also are available.

Fig. 1 Residential geothermal heat pump overview

4 Residential Bosch Geothermal Heat Pumps

Bosch geothermal heat pump systems provide space heating and cooling, as well as water heating (Fig. 2). A complete Bosch geothermal heat pump system is defined as a geothermal unit with all the necessary functional components, except for installation materials. The Bosch geothermal heat pump system includes three principal components (listed below) and as an option, a device called a heat recovery package, or “desuperheater”, which can be factory-added to provide domestic hot water when there is a demand for space heating or cooling with the Bosch geothermal heat pump system. These optional devices make use of excess heat during the cooling cycle and use some of the heat during the heating cycle to supplement hot water production. Dedicated water heaters can be added which operate whenever there is a demand for hot water.

Fig. 2 Residential geothermal heat pump products

- **Geothermal earth connection sub-system:**
  Using the earth as the heat source and heat sink, this sub-system consists of a series of pipes which are commonly called a “ground heat exchanger” or “loop”, or an open well system used to obtain water to pass through the geothermal heat pump.
- **Geothermal heat pump sub-system:**
  Unit (or units) that exchange heat between the fluid and the air that conditions the structure.
- **Distribution sub-system:**
  An air-delivery system that delivers the conditioned air to the structure.

The foundation of any Bosch geothermal heat pump system is the Bosch geothermal heat pump unit itself. The most commonly used unit in these systems is the Bosch self-contained (package) water-to-air heat pump. Bosch offers split systems as well, which allow the condensing section (compressor section) to be located remotely from the air handler section, but still within the structure. Additionally, Bosch offers a water-to-water geothermal heat pump for specific applications. These Bosch water-to-water geothermal heat pumps can heat or chill water for radiant floor applications, chilled water/fan coil applications or domestic hot water generation.

The typical Bosch geothermal heat pump consists of a compressor (rotary or scroll), an air-to-refrigerant coil (or “air” coil), a bi-directional thermal expansion valve, a reversing valve, a unit control board, a bi-directional drier, a water-to-refrigerant coil and various relays and safety devices. These components comprise the basic geothermal heat pump refrigerant circuit to transfer heat to and from the ground to the home (Fig. 3,4,5). All Bosch geothermal heat pump units are designed for HFC-410A refrigerant.

Fig. 3

Fig. 4

Fig. 5

Special Bosch geothermal heat pump features can include two-stage scroll compressors, hermetic rotary compressors, permanent split capacitor blowers (PSC), brushless permanent magnet blowers (BPMs), variable speed electro-commutated blower motors (ECMs), accumulators and specialized blower control boards (Motor Control Interface Boards), as well as other options.

4.1 Bosch Self-Contained (Package) and Split-System Water-to-Air Heat Pumps

Bosch has a variety of choices for self-contained residential geothermal heat pumps. Multiple air flow configurations for most any installation are also available. Several of the Bosch geothermal heat pump offerings are equipped with an exclusive sound package. The compressor is surrounded by a multi-density sound blanket and the units come standard with a provisions to separate a vibrating compressor from the exterior cabinet. This arrangement helps by reducing sound and vibration to an absolute minimum.

4.1.1 Bosch Basic Geothermal Heat Pump Series

Bosch's Energy Star rated basic series water-to-air geothermal heat pump is available from ½ ton through 6 tons in either vertical or horizontal configurations (Fig. 6). This single stage geothermal heat pump unit offers best-in-class energy efficiency and lower operating costs, providing the ultimate value for the money.

Fig. 6 Bosch Basic Geothermal Heat Pump Series

4.1.2 Bosch Two-Stage Geothermal Heat Pump Series

For greater performance, Bosch offers an Energy Star rated water-to-air geothermal ready heat pump equipped with a two-stage compressor and a variety of superior standard features (Fig. 7). An Electronically Commutated Motor (ECM) is factory programmed to vary the air flow based on full or part load compressor operation, resulting in additional energy savings of up to 60% and a greater level of comfort in living areas. All two-stage units in this series are equipped with a Motor Control Interface Board (MCI) providing un-parallel blower control. These 2 to 6 ton units are available in vertical, horizontal, counter flow or split system configurations, providing a modern design to satisfy every application.

Fig. 7 Bosch Two-Stage Geothermal Heat Pump Series (Self-Contained)

Fig. 8 Bosch Two-Stage Geothermal Heat Pump Series (Split System)

4.1.3 Bosch Premium Geothermal Heat Pump Series

The most popular self-contained residential water-to-air geothermal heat pumps are the Bosch Premium two-stage series geothermal heat pumps, compliant with Energy Star Tier 3 criteria (Fig. 9). This luxurious two-stage unit features improved cost, aesthetics, serviceability, sound, power and energy efficiency, and is available in vertical, horizontal, counter flow and split system configurations from 2 to 6 tons. Its energy efficiency makes this unit the best-in-class in operating cost savings. Requiring less energy compared to other manufacturers, these two-stage units achieve the same output to cool or heat a home, helping reduce energy costs. These Bosch Premium Geothermal Heat Pumps offer field configurability (air return and supply discharge) reducing inventory costs, extremely quiet operation, tin-plated hairpin "air" coils, closed-cell (fiber-free) internal insulation and pre-painted sheet metal cabinets. An added feature useful to the contractor is externally mounted fault indication. This feature communicates unit operation without having to remove the door to the circuit board, displaying operating alerts at a glance. This device potentially speeds up service/diagnostics.

This unit can be serviced entirely from the front, offers a removable electrical box and a brushless permanent magnet (BPM) blower, designed similar to variable speed with similar efficiency, but without the programming. Electronics are "built in" providing better performance VS External Static Pressure (ESP) compared to other blowers (PSC).

All in all, this unit provides superior design, durability, reliability, and indoor air quality.

Fig. 9 Bosch Premium Geothermal Heat Pump

4.2 Bosch Water-to-Water Heat Pumps

Bosch's Energy Star rated geothermal ready water-to-water heat pump gives the customer both geothermal heating and cooling as well as the ability to enjoy the benefits of warm radiant floors.

Bosch's Reverse Cycle Chiller/Low Temperature Boiler offers industry leading efficiency at full load heating and cooling, and is even more efficient during part load operation utilizing a two stage scroll compressor (Fig. 10, 11). Unless peak capacity is required, the unit can run at roughly 2/3 capacity at significantly higher efficiencies than with "single speed, single stage compressor after products, maintaining maximum comfort with minimum energy use.

Available from 2 up to 6 tons in a vertical configuration, these exceptional units provide best-in-class operational cost savings that help the consumer by reducing monthly utility bills. The unit comes equipped with many of the exceptional features of the water-to-air unit, including two coaxial style fluid-to-refrigerant heat exchangers, a refrigerant reversing valve, a bi-directional thermal expansion valve metering device, a multi-density sound absorbing compressor blanket, a floating base pan to minimize noise transmission, a bi-directional drier and service ports and the Comfort Alert Diagnostics module.

Bosch's Energy Star rated geothermal ready water-to-water heat pump is able to provide both hot water and chilled water. The water-to-water unit is typically connected to a buffer tank for storing hot or chilled water. The hydronic system components can include radiant floor or fan coil units.

Fig. 10 Water to water heat pump

Fig. 11 Water to water heat pump internal view

4.3 Bosch Air Handling Unit for the Retrofit Market

Bosch offers a complete range of unitary air handlers for both DX and hydronic applications, including cased and uncased DX coils (Fig. 12).

Some of the features include:

- Energy star tier 3 compliant (when paired to our condensing sections)
- ECM 2.3 Constant CFM Motor
- 4-way multi-position (accessory kit required for down flow applications)
- 1" cabinet insulation
- Hydronic connections on top
- Electrical connections on top or sides
- Reduced footprint for additional space savings and for retrofitting existing systems
- Plenum collar on supply outlet

The Bosch Air Handling Unit is a single piece air handler providing the flexibility for installation in any up flow, down flow, or horizontal application. These versatile models may be used with or without electric or hot water heat. A direct drive ECM variable speed motor provides a selection of air volume to match any application. The Bosch Air Handling Unit can be positioned for bottom return air in the up flow position, top return air in the down flow position and end return air in the horizontal position.

Fig. 12 Air handling unit for retrofit market

4.4 Bosch Water-to-Air Geothermal Heat Pump Operation

4.4.1 Heating Cycle

In the heating cycle, the groundwater, or groundwater and antifreeze mixture, circulating in the earth loop is colder than the surrounding ground. This causes the water to absorb energy, in the form of heat, from the earth. The water carries the heat back to the water-to-refrigerant heat exchanger in the geothermal heat pump unit inside the structure (Fig. 13). In the water-to-refrigerant heat exchanger, refrigerant absorbs the heat energy from the water. The water now leaves the water-to-refrigerant heat exchanger at a colder temperature, and circulates through the earth loop to pick up more heat.

The refrigerant gas, which contains heat gained from the earth loop boils to become a low-temperature vapor. The reversing valve sends the refrigerant vapor to the compressor. The vapor is then compressed which reduces its volume, causing it to heat up.

In the compressor, the refrigerant rises in temperature. From the compressor, the reversing valve sends the now-hot gas to the air-to-refrigerant heat exchanger (“air” coil), where the heat is removed by the air that passes over the coil surface, and the hot gas condenses into a liquid. Here, the geothermal heat pump's blower circulates air across the air-to-refrigerant heat exchanger (air coil), increasing the temperature of the air, which is blown through ductwork to heat the structure. After the refrigerant releases its heat to the air, it then flows to the water-to-refrigerant coaxial heat exchanger. When evaporating into a gas, the liquid absorbs heat and cools the water. The heating cycle is completed when the refrigerant flows as a low pressure gas through the reversing valve and back to the suction side of the compressor.

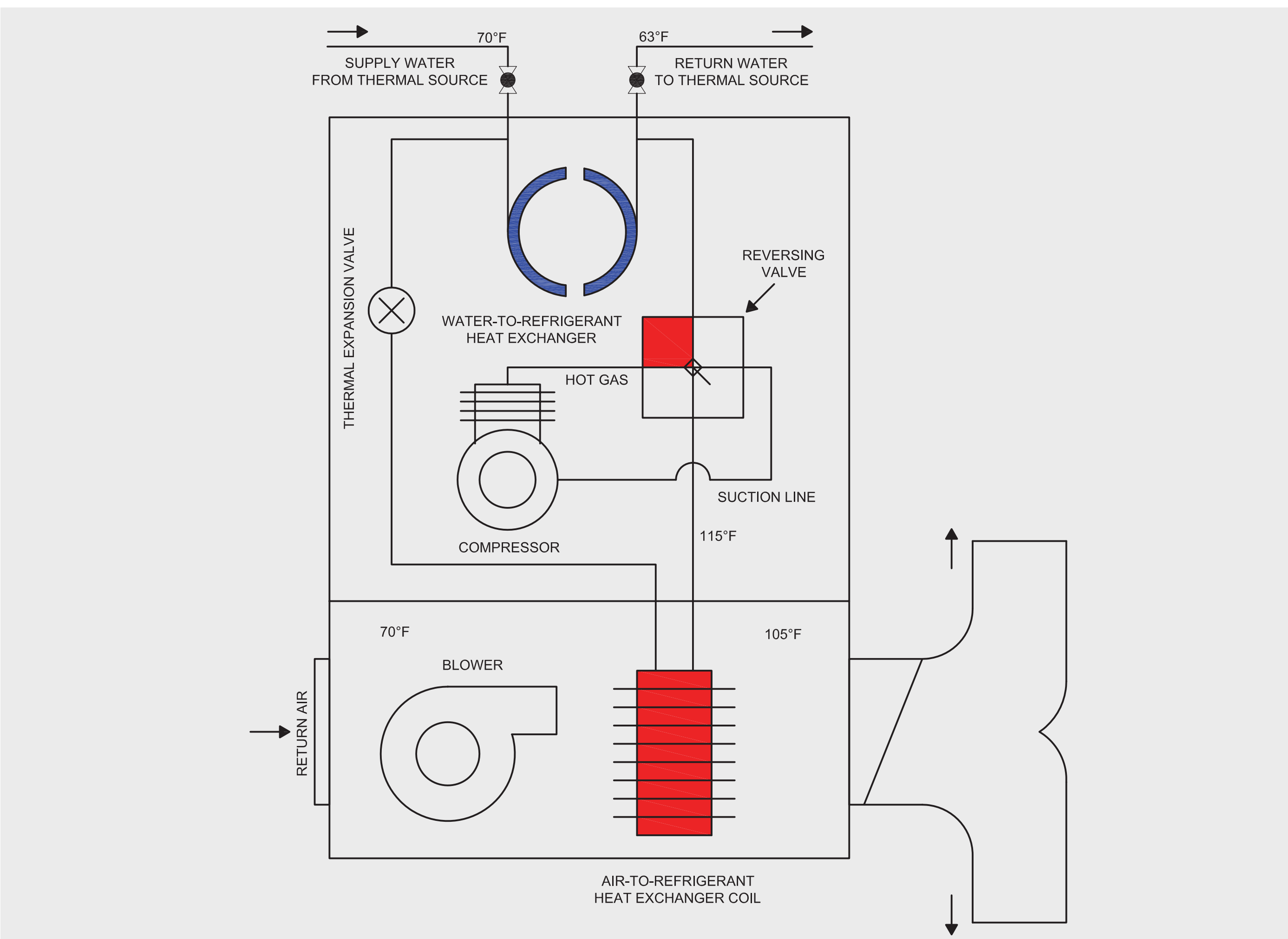

Fig. 13 Water-to-air heating cycle

4.4.2 Cooling Cycle

The cooling cycle is basically the reverse of the heating cycle. The direction of the refrigerant flow is changed by the reversing valve. In the cooling mode, the water circulating in the earth loop is warmer than the surrounding ground. This causes the water to release heat into the earth. The water which is now cooler from traveling through the ground flows to the water-to-refrigerant coaxial heat exchanger in the geothermal heat pump (Fig. 14). In the water-to-refrigerant coaxial heat exchanger, hot refrigerant gas from the compressor releases its heat into the water. This causes the water to increase in temperature, which it releases to the ground.

The refrigerant, which has released its heat energy and became a cold liquid, now, travels to the refrigerant-to-air heat exchanger. The cool, liquid refrigerant enters the refrigerant-to-air heat exchanger during cooling. As it enters the refrigerant-to-air heat exchanger, the temperature of the refrigerant is relatively cool (around 50 degrees). Here the geothermal heat pump's blower circulates warm, humid air across the cold refrigerant-to-air heat exchanger. The refrigerant in the refrigerant-to-air heat exchanger absorbs the heat energy from the air (and dehumidifies the air) and travels to the compressor, which raises the pressure so it will move through the system. The increased pressure from the compressor causes the refrigerant to heat up. The refrigerant picks up heat from the structure air via the return duct system and transfers it directly to the groundwater or water and antifreeze mixture. The heat is then pumped outside, into the underground piping (in the case of a closed-loop system) to start the cycle again. Some of this excess heat can be used to pre-heat domestic hot water.

Unlike air-source heat pumps, geothermal heat pumps do not require a defrost cycle. Temperatures underground are much more stable than air temperatures, and the geothermal heat pump unit itself is located inside; therefore, the same problems with frost do not arise.

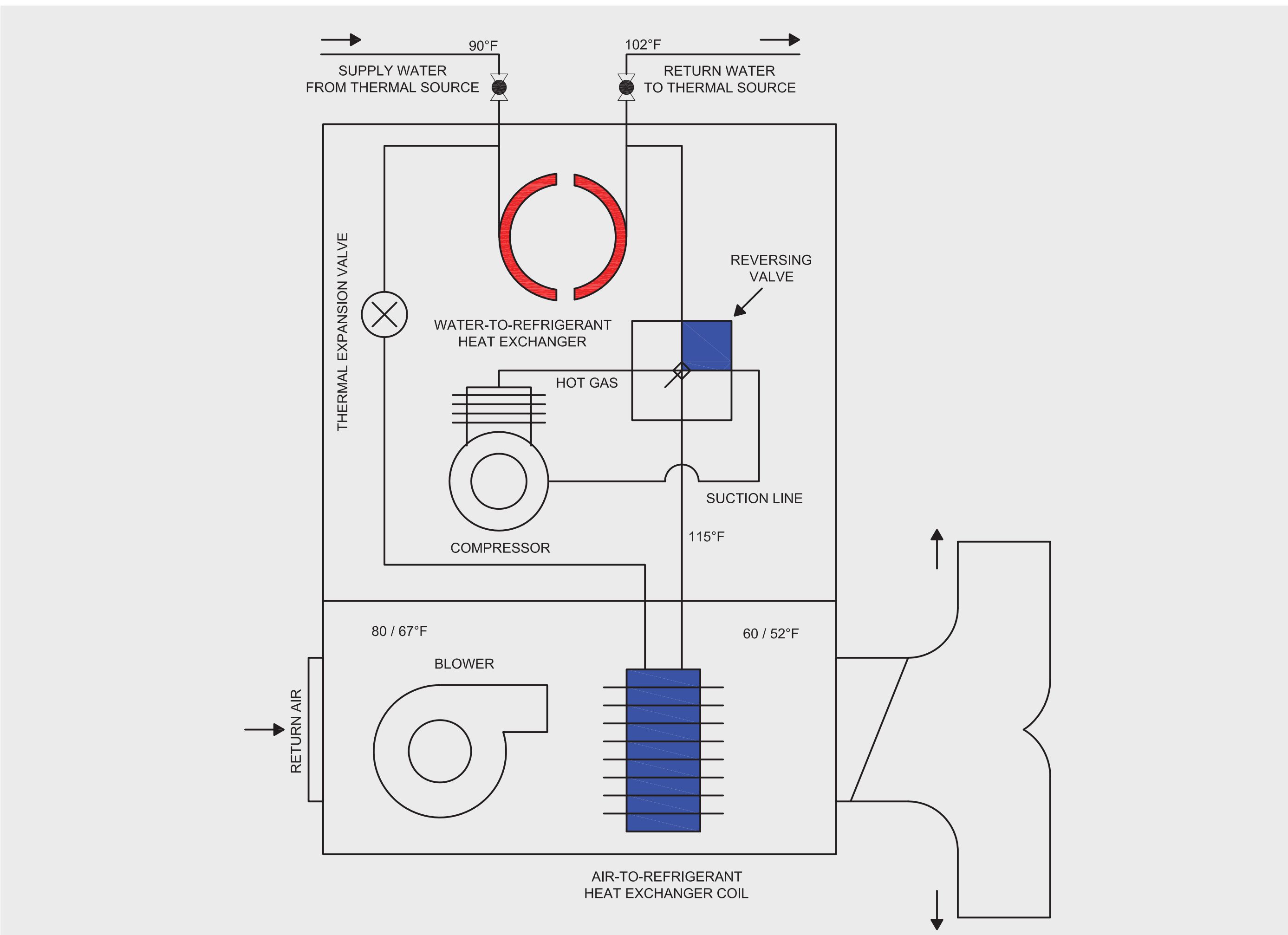

Fig. 14 Water-to-air cooling cycle

4.5 Bosch Water-to-Air Geothermal Heat Pump Ratings

One of the most confusing aspects of water-to-air geothermal heat pump technology is equipment ratings. These heating and cooling performance values are useful for comparing units of the same type (i.e., air-source heat pump to air-source heat pump or geothermal heat pump to geothermal heat pump). Unfortunately, the ratings used for different types of equipment (furnaces, air-source heat pumps, geothermal heat pumps) are not generally consistent making comparisons difficult. As a result, it is useful to know what the ratings values include and what they don't.

For many years, ratings obtained for water-source heat pumps were tested using two specific sets of criteria: the three standards developed by the Air Conditioning, Heating and Refrigeration Institute (AHRI), AHRI Standards 320, 325, and 330 (1998), and the single standard developed by the International Organization for Standardization (ISO), ISO Standard 13256-1 (1998) (Table 1).

Water-to-Air Geothermal Heat Pump Ratings							
		ARI 320	ISO/AHRI 13256-1 WLHP	ARI 325	ISO/AHRI 13256-1 GWHP	ARI 330	ISO/AHRI 13256-1 GLHP
Cooling	Entering Air - DB/WB ˚F	80/67	80.6/66.2	80/67	80.6/66.2	80/67	80.6/66.2
	Entering Water - ˚F	85	86	50/70	59	77	77
	Fluid Flow Rate	*	**	**	**	**	**
Heating	Entering Air - DB/WB ˚F	70	68	70	68	70	68
	Entering Water - ˚F	70	68	50/70	50	32	32
	Fluid Flow Rate	*	**	**	**	**	**

Tab. 1

* Flow rate is set by 10˚F rise in standard cooling test
** Flow rate is specified by the manufacturer

Note: Part load conditions not shown.
WLHP = Water Loop Heat Pump
GWHP = Ground Water Heat Pump
GLHP = Ground Loop Heat Pump

On January 1, 2000, the AHRI adopted the ISO standard as the basis for its certification programs (Fig. 15). The standard developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), Standard 90.1 (1999), referenced both the AHRI standard and the ISO standard until October 29, 2001, when the ISO standard was designated as the exclusive standard on that date.

ISO 13256-1-1998 serves as the basis for AHRI's Water-Source Heat Pump Certification Program. The standard establishes rating criteria and procedures for measuring and certifying water-to-air heat pump and/or brine-to-air heat pump equipment performance. In this way, products are rated on a uniform basis so that buyers and users can properly make selections for specific applications.

Fig. 15 Certification logos

Today, all manufacturers, including Bosch, have their water-to-air geothermal heat pumps tested and certified by a combination of the Air Conditioning, Heating, and Refrigeration Institute (AHRI) for their cooling capacities and their operating efficiencies, and the ISO 13256-1 standards (Fig. 15). In general, water-to-air geothermal heat pumps are rated based on one of the four standards by the AHRI (Table 1). These standards are ARI-320 (ARI/ISO 13256-1 Water-Source Heat Pumps), ARI-325 (ARI/ISO 13256-1 Groundwater-Source Heat Pumps), ARI-330 (ARI/ISO 13256-1 Ground-Source Heat Pumps), and ARI-870 (Direct Geoexchange Heat Pumps). Notice that the reference to the particular AHRI standard also includes the ISO standard as well.

For water-source heat pumps (the type of heat pump used in all water-to-air geothermal heat pump systems), cooling performance is defined by an index called EER (Energy Efficiency Ratio). This is the cooling effect produced by the unit (in Btu/hr) divided by the electrical input (in watts) resulting in units of Btu/watt-hr.

Heating performance is defined by the index called COP (Coefficient of Performance). This is the heating effect produced by the unit (in Btu/hr) divided by the energy equivalent of the electrical input (in Btu/hr) resulting in a dimensionless (no units) value.

For both COP and EER, the larger the numerical value, the less electricity required to operate it.

Both the COP and EER values for water-to-air geothermal heat pumps are single point (valid only at the specific test conditions used in the rating) values only. This in contrast to the seasonal values (HSPF and SEER) published for air-source heat pump equipment. COP and EER are not the same as, or valid for use in comparison to, SEER and HSPF.

4.6 Bosch Geothermal Heat Pump Equipment Sizing

There is nothing more important than an accurate load estimate, or load calculation, for a successful Bosch geothermal heat pump system (water-to-air or water-to-water). This is the most important step in the design process. These load calculations must always be performed with a comprehensive industry-accepted load calculation procedure, either manually, or with a recognized software program. Proper load calculations are critical and may even reveal if the particular installation could benefit from an integrated system.

The sizing of the circulation pumps, the distribution system and the ground heat exchanger, or “ground loop” are all derived directly from the sizing of the Bosch geothermal heat pump equipment. Overestimating the heat loss or heat gain means over-sizing the system. The extra cost of the oversized system is unnecessary. In fact, it may result in the selection of a different type of system. If an oversized system is installed, it may be inefficient and uncomfortable. If the system is undersized it will not do an adequate job of heating and/or cooling the home.

The most important first step in the design of a geothermal heat pump installation is an accurate load calculation of the structure’s heat loss and heat gain.

Additionally, the related energy consumption profile and the domestic hot water requirements are important as well. This load calculation of the cooling and heating loads on a residential structure is used in determining the size of geothermal heat pump equipment required to maintain comfortable indoor air conditions. This load calculation will also allow accurate sizing of the Bosch geothermal heat pump system associated ground heat exchanger, or “ground loop”. This is very important because the capital cost of a Bosch geothermal heat pump system is generally higher than for other conventional systems and economies of scale are more limited.

There are multiple load calculation procedures available in the HVAC/R industry. There are also computer programs and procedures that accompany most all of them. Some of the accepted calculation methods are available from ACCA (Air Conditioning Contractors of America), HRAI (Heating, Refrigeration and Air Conditioning Institute of Canada) and ASHRAE (American Society of Heating Refrigeration and Air Conditioning Engineers).

Today, in the HVAC/R industry, ACCA offers the Manual J® Residential Load Calculation (8th Edition) procedure (Fig.16). This is the full version and is the official standard for residential load calculations, and is required by many building codes around the country for calculating heating or cooling loads for residential applications. Most other methods follow the concepts of Manual J. This method is used widely by contractors, and is the only load calculation procedure currently approved by the American National Standards Institute (ANSI). Either a whole house or room-by-room load calculation may be used for equipment sizing, but a room-by-room load calculation should always be used for duct sizing.

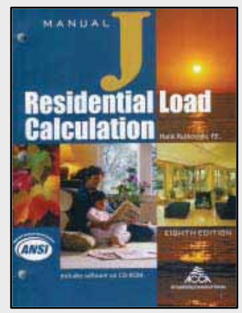

Fig. 16 Residential load calculation literature

ACCA also released an abridged version of the eighth edition of Manual J entitled Manual J Abridged Edition (MJ8-AE), which provides complete instructions for estimating heat loss and heat gain for single-family, single-zone residential structures (Fig.17). MJ8-AE is sufficient for learning the Manual J procedures and undertaking load calculations on a variety of home applications. It is considered representative of MJ8 and simpler to use. Over-sizing a Bosch geothermal heat pump system will significantly increase installation cost for little operational savings and will increase operation under part load. Frequent cycling can occur reducing equipment life and operating efficiency. Conversely if the system is undersized, design conditions may not be met and the use of other heating sources such as electric heating will reduce the overall system efficiency.

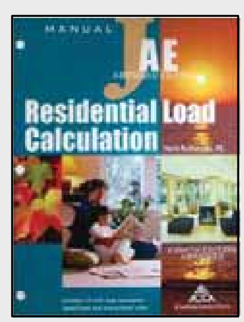

Fig. 17 Residential load calculation literature

Once the heat loss and heat gain has been determined by utilizing an acceptable method, the Bosch geothermal heat pump equipment should be selected using the current Bosch equipment specifications. An example capacity table is provided (Table 2).

Capacity Data - Full Load	Cooling - all performance at 950 CFM and 8.0 GPM						
Entering Fluid Temp. (˚F)	Entering Air Temp. (˚F)	Total Capacity (MBtuH)	Sensible Capacity (MBtuH)	Sensible to Total Ratio	Power Input (kW)	Heat of Reject (MBtuH)	EER
50	70˚db 61˚wb	27.31	18.01	0.66	1.19	31.36	23.0
60		26.05	17.32	0.67	1.34	30.62	19.5
70		24.78	16.69	0.67	1.49	29.87	16.6
85		22.89	15.82	0.69	1.72	28.76	13.3
100		21.00	15.02	0.72	1.95	27.65	10.8
50	75˚db 63˚wb	29.26	21.55	0.74	1.19	33.34	24.5
60		27.91	20.73	0.74	1.35	32.51	20.7
70		26.56	19.97	0.75	1.50	31.68	17.7
85		24.54	18.94	0.77	1.73	30.44	14.2
100		22.51	17.98	0.80	1.96	29.20	11.5
50	80˚db 67˚wb	32.13	23.80	0.74	1.20	36.23	26.7
60		30.65	22.89	0.75	1.36	35.28	22.6
70		29.17	22.06	0.76	1.51	34.32	19.3
85		26.95	20.92	0.78	1.74	32.90	15.5
100		24.73	19.87	0.80	1.97	31.47	12.5
50	85˚db 71˚wb	34.99	26.07	0.75	1.21	39.12	28.9
60		33.38	25.08	0.75	1.37	38.04	24.4
70		31.77	24.17	0.76	1.52	36.97	20.9
85		29.36	22.92	0.78	1.76	35.35	16.7
100		26.94	21.77	0.81	1.99	33.73	13.5

Tab. 2

(EFT Range (Standard) 50˚F to 100˚F)

Following the tenants of ACCA, the unit selected must meet 100% of both the calculated structure sensible and latent loads at design conditions for the locale for cooling. ACCA Manual S is typically used as the basis for water-to-air heat pump sizing. Manual S allows the size of the water-to-air geothermal heat pump to exceed the total cooling load (sensible plus latent) by a maximum of 25% in colder climates (does not apply to water-to-water geothermal heat pumps). Typically, for milder and warmer climates, 125% of the calculated sensible structure load is the upper limit for sensible capacity. Latent capacity is unlimited.

Since the equipment capacity is directly related to the EWT/EFT (Entering Water Temperature/Entering Fluid Temperature), the type of heat source or heat sink must be considered when sizing equipment. For example, an open-loop system in the Northeast U.S. will typically operate at approximately 50°F water year around, but a “Closed-Loop” system in Texas may see temperatures ranging from 60°F to 95°F, which will have an effect on the capacity of the Bosch geothermal heat pump in both the heating and cooling modes.

Because a Bosch geothermal heat pump operates in both heating and cooling, it's rare that a particular series will exactly match both the calculated cooling and heating load calculations, except possibly in moderate climate locations year round. Sizing a Bosch geothermal heat pump for cooling is the industry-recommended method, regardless of locale, since normally heating needs are less prevalent. Most design methodologies prescribe this process, and it is prevalent in the southern portion of the U.S.

However, in colder climates such as the northern portion of the U.S., Bosch geothermal heat pump equipment equipped with single stage compressors that is sized for the cooling gain could result in short cycling in the summer and poor dehumidification. A Bosch single stage geothermal heat pump that is not running very often may not provide sufficient dehumidification, and can result in comfort and indoor air quality (IAQ) problems as well. Additionally, single stage equipment which is sometimes sized only for the cooling load could result in excessive use of auxiliary electric heaters during winter, increasing operating cost.

If a Bosch geothermal heat pump equipped with a single stage compressor is sized for the full heating loss load calculation in a colder climate, it will most likely be over-sized for cooling needs. Bosch provides exceptional two-stage geothermal heat pump equipment designed to alleviate this occurrence. Our two-stage geothermal heat pumps are equipped with a Copeland Two-Stage, Single Speed compressor (Fig. 18).

Fig. 18 Bosch series two-stage geothermal heat pumps

This compressor can operate at approximately 67% capacity in the cooling mode in colder climates during the summer and provide increased dehumidification. But, when cooling needs are excessive for that particular climate (which is often the case) the Bosch two-stage geothermal heat pump can shift to 100% capacity and remove the heat from the structure. The use of these two-stage Bosch geothermal heat pumps is recommended for colder climates, as they will more closely match the calculated heat loss of the home and therefore be able to meet the heating needs of the structure better. This newer technology may also include ECM blowers that can help provide the appropriate capacities at design conditions and at part-load conditions. Proper Bosch geothermal heat pump equipment sizing is still important in this situation, but installers are provided with flexibility by utilizing the two stage compressor geothermal heat pumps in northern climates.

Regardless of location, local codes and/or electric utility program requirements always supersede any recommendations in this application manual.

Installers should always observe design conditions when calculating structure cooling and/or heating loads. Most heat gains and heat loss load calculations are based upon 1% (or 2.5%) of the time. Most load calculations are based on the 1%, but always check with local authorities if in question. This means that the outdoor temperature in the summer is only hotter than the locale design temperature 1% of the time on average. Normally, the heating design temperature is referred to as the 99% design condition, and the cooling design temperature is referred to as the 1% (or 2.5%) design condition. Either way, the load calculation will provide a basis for designing a system that will handle virtually all of the heating and cooling, regardless of outdoor temperature.

The indoor design conditions should be based on customer needs and requirements. As a default, installers should observe the following nominal indoor design conditions:

- Summer cooling design point: 75ºF at 50% relative humidity
- Winter heating design point: 70ºF at 30% relative humidity

The purpose in this method is simply establishing the temperature differentials for use in the cooling and heating load calculations.

Once the load calculation has been completed for the structure for both heat gain and heat loss, the installer must pay attention to the sensible and latent loads determined from the load calculations. The load calculation is typically based on peak load conditions (the design day) for cooling. For summer cooling, this generally occurs on a hot day and the peak sensible condition results from the peak dry bulb at that time. If the weather is not very hot or it is raining it is natural to expect the outdoor condition may be in the low 80Fs with a higher relative humidity (especially if it is raining or at night). Since the equipment is normally sized for peak dry bulb temperature during a hot day, it is typically oversized when operating at non-peak, part-load duty (the other 99% of the time), meaning that latent removal capability may be short when really necessary.

Once a load calculation has been determined and the sensible and latent loads established, there is really no need to add extreme safety factors. Nor should the installer unnecessarily oversize the equipment by introducing conservative design criteria to increase the cooling requirements as this is detrimental to determining the actual proper loads.

The required capacity is not necessarily the sum of the peak individual room loads of a residential structure as some homes may have large levels of glass, or rooms with large loads that peak at different times than other rooms, especially with newer larger homes. Upsizing equipment in the belief that bigger is better is never a proper solution and always a problem with customers who think getting a bigger unit for nearly the same money is economically a smart purchase. Contractors and installers must always explain the benefits of using properly sized equipment to customers, especially with more expensive geothermal heat pump systems.

As a guide, for geothermal heat pumps in warm climates, generally good design is to select equipment that is within 15%-20% of the calculated cooling load. For geothermal heat pumps in colder climates, generally good design is to select equipment that is closer to 125% of the calculated cooling load, increasing the systems heating ability by compressor heat, not auxiliary heat. However, if the equipment is oversized in colder climates more than approximately 25% of the total structure cooling load, it is possible to experience poor humidity control during the summer months. On the other hand, sizing geothermal heat pumps in colder climates nearer to the 115% of calculated cooling loads mark can result in increased electric supplemental heating requirements during winter months.

Generally, the safest approach for geothermal heat pump contractors and installers is to always observing the Bosch sizing, selection and application guidelines, meaning the equipment must be able to meet the sensible and latent cooling requirements at summer design conditions without being oversized. However, the selected equipment should also have the capacity to handle the latent load at full-load operation (peak dry bulb conditions) and at part-load operation (peak dew point conditions).

When discussing moisture control, the actual application sensible to total ratio occurring in the conditioned space is really more important than the design sensible to total ratio and is largely a function of the coil apparatus dew point. This application sensible to total ratio is dependent on how the equipment is actually operated and controlled, and on the latent loads generated within the home, including infiltration.

As the heat gain decreases, the home's sensible load decreases while its latent load typically remains the same, resulting in a decreasing space sensible to total ratio requirement (i.e., 0.75 to 0.65, or lower). This means that the latent removal requirement is a higher percentage of the total load. Yet as the total load decreases, the latent capabilities of most single stage geothermal heat pumps are generally less able to meet the changing sensible to total ratio requirements of the structure. Thus, it is extremely important to have appropriate and accurate load calculations to ensure that the geothermal heat pump meets both sensible and latent loads at full and part-load conditions. This is critical when geothermal heat pump systems operate with continuous fan while the compressor cycles which is possible with many installations. Bosch's two stage compressor systems solve this issue in most situations.

In general, the following guidelines may be used when sizing Bosch geothermal water-to-air heat pumps:

- Heat pump sensible cooling capacity (shown as "Sensible Capacity-MBtuH" in the equipment data) should be within 100-125% of the design cooling sensible load at the maximum loop EWT/EFT (for mild and warm climates).
- In most areas of the U.S., Bosch geothermal heat pump total cooling capacity at design conditions should not exceed 125% of the total sensible load. In colder climates where heat loss may be more than twice the heat gain, this may not always be possible, and consideration should be given to installing Bosch two-stage equipment which may utilize a variable speed ECM blower.
- Depending upon the locale climate, the Bosch geothermal heat pump may need some amount of auxiliary heat to satisfy the heating load of the particular structure at design conditions. This auxiliary heat is typically electric heaters sized for at least 90% of the structure heat loss at winter design conditions.
- In southern climates, the geothermal heat pump may provide 100% of the heating, but for most installations, auxiliary heat will allow the use of a smaller geothermal heat pump and avoid over sizing the equipment for cooling.
- In some applications, fossil fuel (i.e., natural gas, # 2 fuel oil, LP) is utilized in lieu of electric heat as the auxiliary heat source to satisfy the heating load of the particular structure at design conditions, as well as the emergency heating requirement if a system's refrigeration cycle fails. This scenario is often utilized with air-source heat pumps, and the configuration for a self-contained (packaged) air-source heat pump is referred to as "dual-fuel". If the application involves an air-source heat pump split-system, the configuration is referred to as an "add-on heat pump". Geothermal heat pumps may be utilized for these applications as well, but are less prevalent. Control of this form of heating is critical (as it is with air-source heat pumps) and should prohibit the simultaneous operation of the fossil fuel furnace and the geothermal heat pump when operating in the heating mode (compressor heat).

4.6.1 Equipment Selection Examples

A Bosch water-to-air geothermal heat pump is never dependent upon outdoor air temperature as an air-source heat pump, only the ground temperature, associated groundwater temperature and soil conditions (for close-loop applications). First, we will examine equipment selection for a heating dominant climate utilizing two different size Bosch geothermal heat pumps, then equipment selection for a cooling dominant climate utilizing two different size Bosch geothermal heat pumps.

Example 1:

Following the recommended industry criteria of selecting the equipment to meet the cooling load calculation, we first examine the Bosch three (3) ton geothermal heat pump as the possible choice for this application, and the associated Bosch data (Table 3). As a the Bosch two (2) ton geothermal heat pump is too small, we must examine the next size up, the Bosch three (3) ton geothermal heat pump.

Example 1:

- **Heating Dominate Climate**
- **Minneapolis, Minnesota** [typical entering fluid temperature (EFT) of 47°F]
- **Load Calculation Sensible Heat Loss** = 65,000 Btu/h (outdoor design temperature = -12°F; indoor design temperature = 70°F)
- **Load Calculation Sensible Heat Gain** = 24,000 Btu/h (outdoor design temperature = 89°F; indoor temperature = 75°F)
- **Load Calculation Latent Heat Gain** = 8,000 Btu/h
- **Total Heat Gain (Sensible plus Latent)** = 32,000 Btu/h (slightly larger than a 2-½ ton unit)
- **Per Manual S, 25% larger than the total cooling load** = 1.25 x 32,000 Btu/h = 40,000 Btu/h
- **Maximum Bosch water-to-air geothermal heat pump size** = 3.3 tons (40,000 Btu/h Cooling Capacity)

Unit selected: Bosch three (3) ton

Capacity Data - Full Load	Cooling - all performance at 1200 CFM and 9.0 GPM						
Entering Fluid Temp. (˚F)	Entering Air Temp. (˚F)	Total Capacity (MBtuH)	Sensible Capacity (MBtuH)	Sensible to Total Ratio	Power Input (kW)	Heat of Reject (MBtuH)	EER
50	70˚db 61˚wb	36.10	23.53	0.65	1.67	41.81	21.6
60		34.64	22.76	0.66	1.86	41.00	18.6
70		33.18	22.08	0.67	2.05	40.19	16.2
85		30.99	21.16	0.68	2.34	38.97	13.3
100		28.80	20.36	0.71	2.62	37.75	11.0
50	75˚db 63˚wb	38.68	28.14	0.73	1.68	44.43	23.0
60		37.12	27.23	0.73	1.87	43.52	19.8
70		35.56	26.41	0.74	2.06	42.61	17.2
85		33.22	25.33	0.76	2.35	41.24	14.1
100		30.87	24.37	0.79	2.64	39.87	11.7
50	80˚db 67˚wb	42.47	31.08	0.73	1.70	48.26	25.0
60		40.75	30.08	0.74	1.89	47.20	21.6
70		39.04	29.17	0.75	2.08	46.14	18.8
85		36.47	27.98	0.77	2.37	44.56	15.4
100		33.91	26.92	0.79	2.66	42.97	12.8
50	85˚db 71˚wb	46.25	34.05	0.74	1.71	52.08	27.1
60		44.39	32.95	0.74	1.90	50.88	23.3
70		42.52	31.96	0.75	2.10	49.68	20.3
85		39.73	30.65	0.77	2.39	47.88	16.6
100		36.94	29.49	0.80	2.68	46.08	13.8

Tab. 3
(EFT Range (Standard) 50˚F to 100˚F)

We find that when looking at the Bosch three (3) ton geothermal heat pump system cooling capacity at full load, we see that at an Entering Fluid Temperature of 50°F (the typical shallow groundwater temperature for the location is 47°F per Bosch Geo Solutions software) and at 75°Fdb, 63°Fwb Entering Air Temperature (EAT) (return air temperature), (typical ACCA load calculation criteria for cooling), the total capacity of the unit is 38,680 Btu/h, with 28,140 Btu/h sensible capacity (73% of total capacity). This leaves 10,540 Btu/h latent capacity. The installer should meet 100% of both sensible and latent capacity of the calculated cooling load. The calculated sensible load is 24,000 Btu/h and this unit provides 28,140 Btu/h. The latent load is 8,000 Btu/h and this unit provides 10,540. Therefore, this Bosch three (3) ton geothermal heat pump will comply with typical sizing criteria selecting the unit to meet cooling load requirements at summer design conditions for Minneapolis, MN.

As the Bosch three (3) ton geothermal heat pump will not be operating at the cooling outdoor design temperature of 88°F except during the warmest summer days, the unit will revert to low cooling or part load capacity most of the cooling run time. Examining the actual bin hours for

Capacity Data - Part Load	Cooling - all performance at 1000 CFM and 9.0 GPM						
Entering Fluid Temp. (˚F)	**Entering Air Temp. (˚F)**	**Total Capacity (MBtuH)**	**Sensible Capacity (MBtuH)**	**Sensible to Total Ratio**	**Power Input (kW)**	**Heat of Reject (MBtuH)**	**EER**
50	70˚db 61˚wb	26.07	16.75	0.64	0.81	28.82	32.3
60		24.94	16.16	0.65	0.95	28.18	26.3
70		23.82	15.62	0.66	1.09	27.55	21.8
85		22.13	14.90	0.67	1.31	26.5	16.9
100		20.44	14.24	0.70	1.52	25.64	13.4
50	75˚db 63˚wb	27.94	20.05	0.72	0.81	30.71	34.4
60		26.74	19.35	0.72	0.95	29.99	28.0
70		25.53	18.71	0.73	1.10	29.28	23.2
85		23.73	17.85	0.75	1.31	28.21	18.1
100		21.92	17.07	0.78	1.53	27.14	14.3
50	80˚db 67˚wb	30.68	22.15	0.72	0.82	33.46	37.6
60		29.36	21.38	0.73	0.96	32.64	30.5
70		28.04	20.67	0.74	1.11	31.81	25.3
85		26.06	19.72	0.76	1.32	30.58	19.7
100		24.08	18.86	0.78	1.54	29.34	15.6
50	85˚db 71˚wb	33.42	24.28	0.73	0.82	36.22	40.6
60		31.98	23.43	0.73	0.97	35.29	33.0
70		30.55	22.65	0.74	1.11	34.35	27.4
85		28.39	21.61	0.76	1.33	32.94	21.3
100		26.24	20.67	0.79	1.55	31.54	16.9

Tab. 4
(EFT Range (Standard) 50˚F to 100˚F)

Minneapolis, MN per the Bosch Geo Solutions software program (see Table 5), the accumulated hours between 75ºF and 85ºF outdoor ambient is approximately 800. Operating at part load during these temperatures will improve humidity removal and still meet the structure heat gain. If the outdoor temperature approaches the actual cooling design temperature of 88°F, the Bosch three (3) ton geothermal heat pump will shift to high cooling or full load capacity to meet the structure cooling needs. At these high outdoor ambient conditions, the Bosch three (3) ton geothermal heat pump will meet approximately 97% of the maximum limit, per ACCA Manual S.

Examining the part load specifications (Table 4) for the Bosch three (3) ton geothermal heat pump unit at 50°F EFT (the typical shallow groundwater temperature for the location is 47°F per Bosch Geo Solutions software), we find that at 75°Fdb, 63°Fwb Entering Air Temperature (EAT) (return air temperature), the unit will produce a total capacity of 27,940 Btu/h with 20,050 Btu/h sensible capacity (72% of total capacity). This leaves 7,890 Btu/h latent capacity.

During milder summer days, this Bosch three (3) ton geothermal heat pump will run at part load and still provide the necessary cooling needs for the structure, meeting the majority of the heat gain at moderate outdoor temperatures as well as the latent load. This operation mode will require less electrical power to operate and will enhance latent heat removal (dehumidification), resulting in improved indoor temperature and air quality conditions

As the installation location is to be Minneapolis, Minnesota, a colder climate, the installer should examine the heating ability of the unit closely.

Bosch Geo Solutions Software Data

Bin (˚F)	Bin Hrs	Bldg Load (Btuh)	EWT (˚F)	HPCap (Btuh)	Run Time	Pwr (kW)	Auxillary (kWh)	HP (kWh)	Geo HW (Btuh/yr)	Aux HW (Btuh/yr)	Aux HW (kWh
97	8	48000	59	40918	100%	2.12		20	17,746	0	0.00
92	50	39111	58	39111	100%	1.93		10	110,910	0	0.00
87	136	30222	57	30222	100%	1.20		152	301,677	0	0.00
82	285	21333	56	29944	71%	1.15		233	462,677	169,513	60.70
77	442	12444	54	30097	41%	1.13		206	405,859	574,589	205.76
72	613	3556	53	30250	12%	1.11		80	155,835	1,203,920	431.14
67	701	0	52		0	0				1,554,960	556.85
62	704	0	51		0	0				1,561,620	559.23
57	614	2407	50	25188	10%	2.69	0.00	100	275,335	1,086,64	389.14
52	552	6420	49	24922	26%	2.66	0.00	243	660,510	563,941	201.95
47	478	10432	47	24656	42%	2.64	0.00	345	930.051	130,253	46.64
42	487	14444	46	24390	59%	2.61	0.00	492	1,080,268	0	0.00
37	552	18457	45	24124	77%	2.59	0.00	719	1,224,452	0	0.00
32	653	22469	44	23858	94%	2.57	0.00	1046	1,448,491	0	0.00
27	591	26481	43	26481	100%	2.54	0.00	1351	1,310,962	0	0.00
22	475	30494	42	30494	100%	2.52	0.00	886	1,053,650	0	0.00
17	379	34506	40	31597	100%	2.49	328.64	946	840,701	0	0.00
12	313	38519	39	31017	100%	2.48	669.78	775	694,300	0	0.00
7	242	42531	38	30554	100%	2.46	863.88	595	536,807	0	0.00
2	190	46543	37	30091	100%	2.44	931.71	464	421,460	0	0.00
-3	131	50556	36	29627	100%	2.43	817.15	318	290,585	0	0.00
-8	81	54568	35	29164	100%	2.41	613.31	195	179,675	0	0.00
-13	45	58580	33	28700	100%	2.39	400.76	108	99,819	0	0.00
-18	16	62593	32	28237	100%	2.38	163.84	38	35,491	0	0.00

Tab. 5

Examining the corresponding full load heating data (Table 6) for the Bosch three (3) ton geothermal heat pump (compressor operating at 100% ability), we find that at 50°F EFT (the typical shallow groundwater temperature for the location is 47°F per Bosch Geo Solutions software) and 70°F Entering Air Temperature (EAT) (return air temperature), we determine the total capacity for heating is 35,970 Btu/h. Our calculated heat loss at design conditions is 65,000 Btu/h at -11°F outdoor temperature. We will be able to meet approximately 55% of the structure heat loss with the three (3) ton unit capacity at design conditions if the outdoor ambient falls to -11°F. Examining the actual bin hours for Minneapolis, MN (see Table 5), we find that the Bosch three (3) ton geothermal heat pump providing compressor heating will operate until the structure balance point of approximately 20°F outdoor temperature without auxiliary heating being required.

Capacity Data - Full Load Heating

Entering Fluid Temp. (˚F)	Entering Air Temp. (˚F)	Total Capacity (MBtuH)	Power Input (kW)	Heat of Abs. (MBtuH)	COP
50	60	38.04	2.33	30.08	4.8
60		42.34	2.47	33.92	5.0
70		46.64	2.60	37.75	5.2
80		50.93	2.74	41.59	5.5
50	70	35.97	2.37	27.87	4.4
60		40.03	2.51	31.46	4.7
70		44.09	2.65	35.05	4.9
80		48.16	2.79	38.64	5.1
50	80	33.55	2.42	25.27	4.1
60		37.33	2.57	28.57	4.3
70		41.11	2.71	31.87	4.4
80		44.89	2.85	35.17	4.6

Tab. 6

(EFT Range (Standard) 25˚F to 80˚F)

The structure balance point is the outdoor temperature for the particular structure where heat output from the compressor meets the heat loss of the structure due to construction details. The compressor will not be able to meet the heat loss requirements for the structure at this outdoor ambient of approximately 20°F or lower.

Supplemental heating (electric coils) will be necessary to provide heating assistance to the compressor at this structure balance point outdoor temperature and below, energizing for longer time periods as outdoor ambient drops. When outdoor temperatures are warmer than 20°F and heat loss is excessive (i.e., doors open, windows open, etc.), these supplemental heaters will energize, but will occur only for a short period of time. The supplemental heaters will also operate in the emergency heat mode if the compressor fails. These heaters must be sized to meet the total structure heat loss at design conditions to adequately provide emergency heating if necessary. The size of heater should typically meet 90% of the heat loss of the structure minimum (58,500 Btu/h) at design conditions. This will be a 17 kW heater minimum. The installer should therefore install a 20 kW electric heater for this application.

If the EFT falls at the installation location due to outdoor climate conditions, the installer can determine the approximate heating ability of the Bosch three (3) ton geothermal heat pump as well from published specifications (Table 7). Examining the "Low Temp Heating" full load data for the Bosch three (3) ton geothermal heat pump, we find that at 30°F EFT and 70°F Entering Air Temperature (return air temperature), the full load heating capacity (compressor operating at 100% ability) of the Bosch three (3) ton geothermal heat pump will be 27,310 Btu/h. This provides approximately 42% of the structure heat loss at design conditions. Since outdoor temperatures will not be at design conditions but approximately 1% of the time, the unit will be operating at higher outdoor ambient temperatures. The auxiliary or supplemental electric heater installed in the unit will provide the necessary supplemental heating capacity to help the compressor maintain 70°F in the structure. The auxiliary heaters may be energized longer when outdoor ambient temperatures are cooler during heating months.

If the installation location in Minneapolis, Minnesota is experiencing milder (warmer) winter days, the three (3) ton unit will be able to operate at part load conditions. The installer can determine the capacity of the unit at these conditions as well.

Capacity Data - Full Load Low Temp Heating

Entering Fluid Temp. (˚F)	Entering Air Temp. (˚F)	Total Capacity (MBtuH)	Power Input (kW)	Heat of Abs. (MBtuH)	COP
25	60	26.76	1.99	19.96	3.9
30		28.87	2.06	21.83	4.1
40		33.08	2.20	25.58	4.4
25	70	25.32	2.03	18.39	3.7
30		27.31	2.10	20.15	3.8
40		31.29	2.24	23.66	4.1
25	80	23.62	2.07	16.55	3.3
30		25.47	2.14	18.16	3.5
40		29.18	2.28	21.39	3.7

Tab. 7

(Antifreeze required)
(EFT Range (Standard) 25˚F to 80˚F)

Examining the corresponding part load heating data (Table 8) for the Bosch three (3) ton geothermal heat pump (compressor operating at 67% ability), we find that at 50°F EFT and 70°F Entering Air Temperature (return air temperature), we determine the total capacity for heating of 25,470 Btu/h. Our calculated heat loss at design conditions is 65,000 Btu/h at -11°F outdoor temperature. We will be able to meet approximately 39% of the structure total heat loss with the Bosch three (3) ton geothermal heat pump capacity if it was operating at design conditions. Since we will not be at heating design conditions, the actual structure heat loss will be lower and the compressor will likely be able to meet the structure heating needs adequately. The supplemental heating (electric coils) will be used to meet the portion of structure heat loss not met by the compressor at that condition. The heater will still provide the necessary heating if operating in emergency heat mode (compressor failure).

Capacity Data - Full Load Heating

Entering Fluid Temp. (˚F)	Entering Air Temp. (˚F)	Total Capacity (MBtuH)	Power Input (kW)	Heat of Abs. (MBtuH)	COP
50	60	26.93	1.44	22.01	5.5
60		29.10	1.46	24.13	5.9
70		31.28	1.47	26.26	6.2
80		33.46	1.49	28.38	6.6
50	70	25.47	1.47	20.46	5.1
60		27.52	1.48	22.47	5.4
70		29.58	1.50	24.47	5.8
80		31.64	1.51	26.48	6.1
50	80	23.75	1.50	18.64	4.6
60		25.67	1.51	20.51	5.0
70		27.59	1.53	22.37	5.3
80		29.50	1.54	24.23	5.6

Tab. 8

(EFT Range (Standard) 25˚F to 80˚F)

If the EWT falls at the installation location due to outdoor climate conditions but the structure is experiencing milder (warmer) winter days, the Bosch three (3) ton geothermal heat pump will be able to operate at part load conditions in the heating mode. The installer can determine the capacity of the Bosch three (3) ton geothermal heat pump at these conditions as well.

Examining the “Low Temp Heating” part load data for the Bosch three (3) ton geothermal heat pump (Table 9), we find that at 30°F EFT and 70°F Entering air temperature (return air temperature), the part load heating capacity (compressor operating at 67% ability) of the Bosch three (3) ton geothermal heat pump will be 20,930 Btu/h. This provides approximately 32% of the structure heat loss at design conditions. Since we will not be at heating design conditions, the actual structure heat loss will be lower and the compressor will likely be able to meet the structure heating needs adequately. The supplemental heating (electric coils) will be used to meet the portion of structure heat loss not met by the compressor at that condition. The heater will still provide the necessary heating if operating in emergency heat mode (compressor failure).

Capacity Data - Full Load Low Temp Heating

Entering Fluid Temp. (˚F)	Entering Air Temp. (˚F)	Total Capacity (MBtuH)	Power Input (kW)	Heat of Abs. (MBtuH)	COP
25	60	21.06	1.40	16.27	4.4
30		22.13	1.41	17.31	4.6
40		24.26	1.43	19.39	5.0
25	70	19.93	1.43	15.05	4.1
30		20.93	1.44	16.03	4.3
40		22.95	1.45	18.00	4.6
25	80	18.59	1.46	13.62	3.7
30		19.53	1.47	14.53	3.9
40		21.41	1.48	16.35	4.2

Tab. 9

(Antifreeze required)
(EFT Range (Standard) 25˚F to 80˚F)

In this example, a three (3) ton Bosch geothermal heat pump with a two-stage compressor was selected. This application is acceptable; however the heating needs in the colder climate may require more use of auxiliary heat than desired increasing operating costs in the winter months. Installers in colder climates may consider selecting the next larger size of Bosch geothermal heat pump for meeting the structure heating loss more adequately, but must also consider the cooling capacity of the system in summer months and the effect it may have on comfort. We will therefore examine the abilities of a four (4) ton Bosch geothermal heat pump unit in this colder climate application next.

Example 2:

In this example, we will examine the Bosch four (4) ton geothermal heat pump unit as the possible selection for this application. Our goal is to provide more heating ability with the geothermal heat pump compressor and associated ground heat exchanger than using auxiliary heat. Using the Bosch four (4) ton geothermal heat pump will also result in a lower structure balance point allowing the compressor heat to meet the structure heating needs to a lower outdoor ambient temperature. We will also examine the cooling performance for this situation as well.

At first glance, we find that this selection exceeds the 3.3 ton (40,000 Btu/h) cooling capacity criteria normally used for sizing for cooling. However, using a system with a two stage compressor may prove beneficial in this case.

We find when looking at the Bosch four (4) ton geothermal heat pump system data (Table 10) cooling capacity at full load, we see that at an Entering Fluid Temperature (EFT) of 50°F (the typical shallow groundwater temperature for the location is 47°F per Bosch Geo Solutions software) and at 75°Fdb, 63°Fwb (typical load calculation criteria for cooling), the total capacity of the Bosch four (4) ton geothermal heat pump is 52,460 Btu/h, with 38,150 Btu/h sensible capacity (73% of total capacity). This leaves 14,310 Btu/h latent capacity. The installer should meet 100% of both sensible and latent capacity of the calculated cooling load. The sensible load is 24,000 Btu/h and this Bosch four (4) ton geothermal heat pump provides 38,150 Btu/h. The latent load is 8,000 Btu/h and this Bosch four (4) ton geothermal heat pump provides 14,310. Therefore, this Bosch four (4) ton geothermal heat pump will comply with typical minimum sizing criteria selecting the unit to meet cooling load requirements. As the Bosch four (4) ton geothermal heat pump will not be operating at the cooling outdoor design temperature of 88°F except during the warmest summer days, the Bosch four (4) ton geothermal heat pump will revert to low cooling or part load capacity most of the cooling run time. This will improve humidity removal and still meet the structure heat gain, even though the Bosch four (4) ton geothermal heat pump is theoretically oversized. The increased cooling capacity of the unit also allows an increase in heating capacity provided by the compressor during winter months, more closely aligning with the structure heat loss in a colder climate.

Example 2:

- **Heating Dominate Climate**
- **Minneapolis, Minnesota** [typical entering fluid temperature (EFT) of 47°F]
- **Load Calculation Sensible Heat Loss** = 65,000 Btu/h (outdoor design temperature = -11°F; indoor design temperature = 70°F)
- **Load Calculation Sensible Heat Gain** = 24,000 Btu/h (outdoor design temperature = 88°F; indoor temperature = 75°F)
- **Load Calculation Latent Heat Gain** = 8,000 Btu/h
- **Total Heat Gain (Sensible plus Latent)** = 32,000 Btu/h (slightly larger than a 2-½ ton unit)
- **Per Manual S, 25% larger than the total cooling load** = 1.25 x 32,000 Btu/h = 40,000 Btu/h
- **Maximum Bosch water-to-air geothermal heat pump size** = 3.3 tons (40,000 Btu/h Cooling Capacity)

Unit selected: Bosch four (4) ton

If the summer outdoor temperature approaches the actual cooling design temperature of 88ºF, the Bosch four (4) ton geothermal heat pump will shift to high cooling or full load capacity to meet the structure cooling needs, even though they may be less than in a warmer climate. In this case, the Bosch four (4) ton geothermal heat pump selected meets approximately 164% of the maximum limits, per ACCA Manual S.

Examining the part load specifications for the Bosch four (4) ton geothermal heat pump (Table 11) at 50°F EFT (the typical shallow groundwater temperature for the location is 47°F per Bosch Geo Solutions software), we find that at 75°Fdb, 63°Fwb the unit will produce a total capacity of 40,350 Btu/h with 33,980 Btu/h sensible capacity (84% of total capacity). This leaves 6,370 Btu/h latent capacity. During milder summer days, this Bosch four (4) ton geothermal heat pump will run in part load and still provide the necessary cooling needs for the structure. This operation mode will require less electrical power to operate and will enhance latent heat removal (dehumidification), resulting in improved indoor temperature and air quality conditions.

Capacity Data - Full Load	Cooling - all performance at 1700 CFM and 12.0 GPM						
Entering Fluid Temp. (˚F)	Entering Air Temp. (˚F)	Total Capacity (MBtuH)	Sensible Capacity (MBtuH)	Sensible to Total Ratio	Power Input (kW)	Heat of Reject (MBtuH)	EER
50	70˚db 61˚wb	48.95	31.89	0.65	2.28	56.74	21.4
60		47.04	30.90	0.66	2.51	55.59	18.8
70		45.13	30.01	0.67	2.73	54.45	16.5
85		42.27	28.85	0.68	3.06	52.72	13.8
100		39.40	27.84	0.71	3.40	51.00	11.6
50	75˚db 63˚wb	52.46	38.15	0.73	2.30	60.29	22.9
60		50.41	36.97	0.73	2.52	59.01	20.0
70		48.37	35.92	0.74	2.74	57.74	17.6
85		45.31	34.54	0.76	3.08	55.82	14.7
100		42.24	33.33	0.79	3.42	53.90	12.4
50	80˚db 67˚wb	57.59	42.14	0.73	2.31	65.48	24.9
60		55.35	40.84	0.74	2.54	64.01	21.8
70		53.11	39.68	0.75	2.76	62.55	19.2
85		49.75	38.15	0.77	3.10	60.35	16.0
100		46.39	36.82	0.79	3.44	58.14	13.5
50	85˚db 71˚wb	62.72	46.16	0.74	2.33	70.67	26.9
60		60.29	44.74	0.74	2.56	69.01	23.6
70		57.85	43.47	0.75	2.79	67.36	20.8
85		54.20	41.80	0.77	3.13	64.87	17.3
100		50.54	40.35	0.80	3.47	62.38	14.6

Tab. 10
(EFT Range (Standard) 50˚F to 100˚F)

Capacity Data - Part Load	Cooling - all performance at 1300 CFM and 12.0 GPM						
Entering Fluid Temp. (˚F)	Entering Air Temp. (˚F)	Total Capacity (MBtuH)	Sensible Capacity (MBtuH)	Sensible to Total Ratio	Power Input (kW)	Heat of Reject (MBtuH)	EER
50	70˚db 61˚wb	37.65	28.42	0.75	1.17	41.65	32.1
60		36.39	27.70	0.76	1.37	41.06	26.6
70		35.12	27.08	0.77	1.57	40.47	22.4
85		33.23	26.30	0.79	1.86	39.58	17.9
100		31.34	25.67	0.82	2.15	38.69	14.6
50	75˚db 63˚wb	40.35	33.98	0.84	1.18	44.37	34.2
60		39.00	33.12	0.85	1.38	43.69	28.3
70		37.65	32.38	0.86	1.57	43.02	23.9
85		35.62	31.45	0.88	1.87	42.00	19.1
100		33.59	30.71	0.91	2.16	40.98	15.5
50	80˚db 67˚wb	44.30	37.52	0.85	1.19	48.35	37.3
60		42.81	36.57	0.85	1.39	47.55	30.9
70		41.33	35.76	0.87	1.59	46.74	26.1
85		39.11	34.73	0.89	1.88	45.54	20.8
100		36.89	33.91	0.92	2.18	44.33	16.9
50	85˚db 71˚wb	48.24	41.10	0.85	1.20	52.32	40.3
60		46.63	40.06	0.86	1.40	51.40	33.4
70		45.02	39.16	0.87	1.60	50.47	28.2
85		42.60	38.05	0.89	1.90	49.08	22.5
100		40.19	37.15	0.92	2.20	47.69	18.3

Tab. 11
(EFT Range (Standard) 50˚F to 100˚F)

As the installation location is to be Minneapolis, Minnesota, a colder climate, the designer should examine the heating ability of the unit more closely.

Examining the corresponding full load heating data (Table 12) for the Bosch four (4) ton geothermal heat pump (compressor operating at 100% full load ability), we find that at 50°F EFT (the typical shallow groundwater temperature for the location is 47°F per Bosch Geo Solutions software) and 70°F entering air temperature (return air temperature), we determine the total capacity for heating is 45,810 Btu/h. Our calculated heat loss at design conditions is 65,000 Btu/h at -11°F outdoor temperature. We will be able to meet approximately 70% of the structure heat loss with the Bosch four (4) ton geothermal heat pump capacity at design conditions.

Examining the actual bin hours for Minneapolis, MN using the Bosch four (4) ton geothermal heat pump (see Table 13), we find that the heat pump providing compressor heating will operate until the structure balance point of approximately 10°F outdoor temperature without auxiliary heating typically being required.

Capacity Data - Full Load Heating

Entering Fluid Temp. (˚F)	Entering Air Temp. (˚F)	Total Capacity (MBtuH)	Power Input (kW)	Heat of Abs. (MBtuH)	COP
50	60	48.44	2.96	38.32	4.8
60		52.79	3.05	42.38	5.1
70		57.15	3.14	46.43	5.3
80		61.50	3.23	50.48	5.6
50	70	45.81	3.02	35.52	4.5
60		49.92	3.11	39.32	4.7
70		54.04	3.20	43.13	5.0
80		58.15	3.29	46.94	5.2
50	80	42.72	3.08	32.21	4.1
60		46.55	3.17	35.73	4.3
70		50.39	3.26	39.25	4.5
80		54.22	3.36	42.76	4.7

Tab. 12

(EFT Range (Standard) 25˚F to 80˚F)

Bosch Geo Solutions Software Data

Bin (˚F)	Bin Hrs	Bldg Load (Btuh)	EWT (˚F)	HPCap (Btuh)	Run Time	Pwr (kW)	Auxillary (kWh)	HP (kWh)	Geo HW (Btuh/yr)	Aux HW (Btuh/yr)	Aux HW (kWh
97	8	48000	57	48000	100%	2.01		8	17,746	0	0.00
92	50	39111	56	43370	90%	1.56		70	110,910	0	0.00
87	136	30222	55	43516	69%	1.54		146	301,677	0	0.00
82	285	21333	54	43662	49%	1.52		212	445,674	186,516	66.79
77	442	12444	53	43809	28%	1.50		188	393,182	587,266	210.30
72	613	3556	52	43955	8%	1.48		73	151,859	1,207,900	432.56
67	701	0	52		0	0				1,554,960	556.85
62	704	0	51		0	0				1,561,620	559.23
57	614	2407	50	33957	7%	3.26	0.00	96	295,558	1,066,420	381.89
52	552	6420	49	33571	19%	3.25	0.00	233	710,570	513,882	184.03
47	478	10432	47	33185	31%	3.24	0.00	330	1,002,765	57,540	20.61
42	487	14444	46	32799	44%	3.23	0.00	470	1,080,268	0	0.00
37	552	18457	45	32413	57%	3.22	0.00	688	1,224,452	0	0.00
32	653	22469	44	32027	70%	3.21	0.00	1000	1,448,491	0	0.00
27	591	26481	43	31641	84%	3.20	0.00	1077	1,310,962	0	0.00
22	475	30494	42	31255	98%	3.19	0.00	1007	1,053,650	0	0.00
17	379	34506	40	34506	100%	3.18	0.00	1069	840,701	0	0.00
12	313	38519	39	38519	100%	3.17	0.00	742	694,300	0	0.00
7	242	42531	38	40133	100%	3.16	173.94	764	536,807	0	0.00
2	190	46543	37	39662	100%	3.14	391.86	598	421,460	0	0.00
-3	131	50556	36	39192	100%	3.13	446.19	410	290,585	0	0.00
-8	81	54568	35	38722	100%	3.12	384.73	253	179,675	0	0.00
-13	45	58580	33	38251	100%	3.11	274.20	140	99,819	0	0.00
-18	16	62593	32	37781	100%	3.10	118.99	50	35,491	0	0.00

Tab. 13

Supplemental heating (electric coils) will be necessary to provide heating assistance to the compressor at this structure balance point outdoor temperature and below, energizing for longer time periods as outdoor ambient drops. When outdoor temperatures are warmer than 10°F and heat loss is excessive (i.e., doors open, windows open, etc.), these supplemental heaters will energize, but will occur only for a short period of time. The supplemental heaters will also operate in the emergency heat mode if the compressor fails. These heaters must be sized to meet the total structure heat loss at design conditions to adequately provide emergency heating if necessary. The size of heater should typically meet 90% of the heat loss of the structure minimum (58,500 Btu/h) at design conditions. This will be a 17 kW heater minimum. The installer should therefore install a 20 kW electric heater for this application.

If the EWT falls at the installation location due to outdoor climate conditions, the installer can determine the approximate heating ability of the Bosch four (4) ton geothermal heat pump unit at low temperature situations as well from published specifications.

Examining the “Low Temp Heating” data for the Bosch four (4) ton geothermal heat pump unit at full load (Table 14), we find that at 30°F EFT and 70°F Entering air temperature (return air temperature), the full load heating capacity (compressor operating at 100% ability) of the unit will be 36,840 Btu/h. This provides approximately 57% of the structure heat loss at design conditions. The auxiliary or supplemental electric heater installed in the unit will provide the necessary heating capacity to maintain 70°F in the structure but will be energized longer than when outdoor ambient temperatures are warmer during heating months.

Capacity Data - Full Load Low Temp Heating

Entering Fluid Temp. (˚F)	Entering Air Temp. (˚F)	Total Capacity (MBtuH)	Power Input (kW)	Heat of Abs. (MBtuH)	COP
25	60	36.81	2.74	27.45	3.9
30		38.95	2.79	29.44	4.1
40		43.22	2.87	33.41	4.4
25	70	34.83	2.79	25.31	3.7
30		36.84	2.83	27.17	3.8
40		40.88	2.93	30.89	4.1
25	80	32.49	2.85	22.77	3.3
30		34.37	2.89	24.49	3.5
40		38.13	2.99	27.93	3.7

Tab. 14

(Antifreeze required)
(EFT Range (Standard) 25˚F to 80˚F)

If the installation location in Minneapolis, Minnesota is experiencing milder (warmer) winter days, the Bosch four (4) ton geothermal heat pump unit will be able to operate at part load conditions. The installer can determine the capacity of the unit at these conditions as well.

Examining the corresponding part load heating data (Table 15) for the Bosch four (4) ton geothermal heat pump unit (compressor operating at 67% ability), we find that at 50°F EFT and 70°F entering air temperature (return air temperature), we determine the total capacity for heating of 34,330 Btu/h. Our calculated heat loss at design conditions is 65,000 Btu/h at -11°F outdoor temperature. We will be able to meet approximately 53% of the structure total heat loss with the Bosch four (4) ton geothermal heat pump unit capacity if it was operating at design conditions. Since we will not be at heating design conditions, the actual structure heat loss will be lower and the compressor will likely be able to meet the structure heating needs adequately. The supplemental heating (electric coils) will be used to meet the portion of structure heat loss not met by the compressor at that condition. The heater will still provide the necessary heating if operating in emergency heat mode (compressor failure).

Capacity Data - Full Load Heating

Entering Fluid Temp. (˚F)	Entering Air Temp. (˚F)	Total Capacity (MBtuH)	Power Input (kW)	Heat of Abs. (MBtuH)	COP
50	60	36.30	1.93	29.72	5.5
60		39.48	1.97	32.75	5.9
70		42.66	2.02	35.78	6.2
80		45.84	2.06	38.82	6.5
50	70	34.33	1.96	27.64	5.1
60		37.34	2.01	30.49	5.5
70		40.34	2.05	33.35	5.8
80		43.35	2.10	36.20	6.1
50	80	32.02	2.00	25.19	4.7
60		34.82	2.05	27.83	5.0
70		37.62	2.09	30.47	5.3
80		40.42	2.14	33.11	5.5

Tab. 15

(EFT Range (Standard) 25˚F to 80˚F)

If the EWT falls at the installation location due to outdoor climate conditions but the structure is experiencing milder (warmer) winter days, the Bosch four (4) ton geothermal heat pump unit will be able to operate at part load conditions in the heating mode. The installer can determine the capacity of the Bosch four (4) ton geothermal heat pump unit at these conditions as well.

Examining the “Low Temp Heating” data for the Bosch four (4) ton geothermal heat pump unit (Table 16), we find that at 30°F EFT and 70°F Entering air temperature (return air temperature), the part load heating capacity (compressor operating at 67% ability) of the Bosch four (4) ton geothermal heat pump unit will be 27,770 Btu/h. This provides approximately 43% of the structure heat loss at design conditions. Since we will not be at heating design conditions, the actual structure heat loss will be lower and the compressor will likely be able to meet the structure heating needs adequately. The supplemental heating (electric coils) will be used to meet the portion of structure heat loss not met by the compressor at that condition. The heater will still provide the necessary heating if operating in emergency heat mode (compressor failure).

Capacity Data - Full Load Low Temp Heating					
Entering Fluid Temp. (˚F)	**Entering Air Temp. (˚F)**	**Total Capacity (MBtuH)**	**Power Input (kW)**	**Heat of Abs. (MBtuH)**	**COP**
25	60	27.79	1.82	21.59	4.5
30		29.35	1.84	23.08	4.7
40		32.47	1.88	26.04	5.1
25	70	26.29	1.85	19.99	4.2
30		27.77	1.87	21.38	4.4
40		30.71	1.92	24.18	4.7
25	80	24.53	1.89	18.09	3.8
30		25.90	1.91	19.39	4.0
40		28.65	1.96	21.97	4.3

Tab. 16

(Antifreeze required)
(EFT Range (Standard) 25˚F to 80˚F)

In this example, a Bosch four (4) ton geothermal heat pump unit with a two-stage compressor was selected. This application is acceptable and the heating needs in the colder climate may require the use of auxiliary heat below the structure balance point, but this will be less run time than the Bosch three (3) ton geothermal heat pump in this situation.

Example 3:

In this example, we will examine the Bosch four (4) ton geothermal heat pump unit as the possible selection for this application. Our goal is to provide the required cooling ability with the geothermal heat pump compressor and associated ground heat exchanger. We will be using a system with a two stage compressor.

We find that when looking at the Bosch four (4) ton geothermal heat pump system cooling capacity at full load (Table 17), we see that at an entering fluid temperature (EFT) of 70°F EFT (the typical shallow groundwater temperature for the location is 67°F per Bosch Geo Solutions software) and at 75°Fdb, 63°Fwb (typical load calculation criteria for cooling), the total capacity of the Bosch four (4) ton geothermal heat pump is 48,370 Btu/h, with 35,920 Btu/h sensible capacity (74% of total capacity). This leaves 12,450 Btu/h latent capacity. The installer should meet 100% of both sensible and latent capacity of the calculated cooling load at design conditions (98ºF outdoor ambient). The sensible load is 34,000 Btu/h and this Bosch four (4) ton geothermal heat pump provides 35,920 Btu/h sensible capacity. The latent load is 8,000 Btu/h and this Bosch four (4) ton geothermal heat pump provides 12,450 Btu/h latent capacity. Therefore, this Bosch four (4) ton geothermal heat pump will comply with typical minimum sizing criteria when selecting the unit to meet the structure cooling loads, as well as being less than the maximum allowed by ACCA Manual S.

Example 3:

- **Cooling Dominate Climate**
- **Dallas, Texas** [typical entering fluid temperature (EFT) of 67°F]
- **Load Calculation Sensible Heat Loss** = 35,000 Btu/h (outdoor design temperature = 24°F; indoor design temperature = 70°F)
- **Load Calculation Sensible Heat Gain** = 34,000 Btu/h (outdoor design temperature = 98°F; indoor temperature = 75°F)
- **Load Calculation Latent Heat Gain** = 6,000 Btu/h
- **Total Heat Gain (Sensible plus Latent)** = 40,000 Btu/h (3.3 ton unit)
- **Per Manual S, 25% larger than the total cooling load** = 1.25 x 40,000 Btu/h = 50,000 Btu/h
- **Maximum Bosch water-to-air geothermal heat pump size** = 4.16 tons (50,000 Btu/h)

Unit selected: Bosch four (4) ton

Capacity Data - Full Load	Cooling - all performance at 1700 CFM and 12.0 GPM						
Entering Fluid Temp. (˚F)	Entering Air Temp. (˚F)	Total Capacity (MBtuH)	Sensible Capacity (MBtuH)	Sensible to Total Ratio	Power Input (kW)	Heat of Reject (MBtuH)	EER
50	70˚db 61˚wb	48.95	31.89	0.65	2.28	56.74	21.4
60		47.04	30.90	0.66	2.51	55.59	18.8
70		45.13	30.01	0.67	2.73	54.45	16.5
85		42.27	28.85	0.68	3.06	52.72	13.8
100		39.40	27.84	0.71	3.40	51.00	11.6
50	75˚db 63˚wb	52.46	38.15	0.73	2.30	60.29	22.9
60		50.41	36.97	0.73	2.52	59.01	20.0
70		48.37	35.92	0.74	2.74	57.74	17.6
85		45.31	34.54	0.76	3.08	55.82	14.7
100		42.24	33.33	0.79	3.42	53.90	12.4
50	80˚db 67˚wb	57.59	42.14	0.73	2.31	65.48	24.9
60		55.35	40.84	0.74	2.54	64.01	21.8
70		53.11	39.68	0.75	2.76	62.55	19.2
85		49.75	38.15	0.77	3.10	60.35	16.0
100		46.39	36.82	0.79	3.44	58.14	13.5
50	85˚db 71˚wb	62.72	46.16	0.74	2.33	70.67	26.9
60		60.29	44.74	0.74	2.56	69.01	23.6
70		57.85	43.47	0.75	2.79	67.36	20.8
85		54.20	41.80	0.77	3.13	64.87	17.3
100		50.54	40.35	0.80	3.47	62.38	14.6

Tab. 17

(EFT Range (Standard) 50˚F to 100˚F)

As the four (4) ton geothermal heat pump may be operating at the cooling outdoor design temperature of 98°F a fair amount of the time during the warmest summer days, the unit will typically remain in high stage cooling or full load capacity most of the cooling run time. This will allow humidity removal and still meet the structure heat gain. If the outdoor temperature exceeds the actual cooling design temperature of 98°F, the four (4) ton geothermal heat pump will continue to operate at full load capacity and attempt to meet the structure cooling needs, even though above 98°F outdoor ambient the system cooling capacity will begin to decay. Even though the outdoor design temperature for Dallas, Texas is 98°F, the actual hours that the outdoor ambient will be at this temperature or higher will typically be approximately 1% of the time.

The Bosch four (4) ton geothermal heat pump will always be able to provide sufficient cooling at lower summer ambient temperatures than the cooling outdoor design temperature for our location and the structure cooling loads. The bin hours of temperatures between 75ºF and 95ºF for the location with the Bosch four (4) ton geothermal heat pump installed (per Bosch Geo Solutions software), are approximately 2,500 (Table 18). As the outdoor ambient drops closer to approximately 75ºF, the Bosch four (4) ton geothermal heat pump will begin to revert to low cooling or part load capacity. This will improve humidity removal and still meet the structure heat gain. There should be no need to increase the unit size above the four (4) ton capacity in this case, as the unit size meets the cooling needs, and as the warmer climate location will not require increased heating ability as would a colder climate location.

Bosch Geo Solutions Software Data

Bin (˚F)	Bin Hrs	Bldg Load (Btuh)	EWT (˚F)	HPCap (Btuh)	Run Time	Pwr (kW)	Auxillary (kWh)	HP (kWh)	Geo HW (Btuh/yr)	Aux HW (Btuh/yr)	Aux HW (kWh
102	26	45714	100	45714	100%	3.60		4	43,776	0	0.00
97	228	38571	95	38571	100%	2.46		478	383,884	0	0.00
92	427	31429	91	38235	82%	2.24		787	718,940	0	0.00
87	570	24286	86	38908	62%	2.15		766	959,710	0	0.00
82	852	17143	82	39581	43%	2.06		761	1,434,513	0	0.00
77	1126	10000	77	40254	25%	1.98		553	1,392,698	503,150	180.18
72	899	2857	73	40926	7%	1.89		118	285,847	1,227,800	439.69
67	827	0	67		0	0				1,392,420	498.64
62	701	0	66		0	0				1,180,270	422.67
57	671	2283	65	38957	6%	3.40	0.00	90	296,595	833,168	298.36
52	565	6087	64	38553	16%	3.39	0.00	203	667,521	283,771	101.62
47	556	9891	62	38148	26%	3.38	0.00	327	936,138	0	0.00
42	529	13696	61	37744	36%	3.37	0.00	434	890,678	0	0.00
37	411	17500	60	37340	47%	3.35	0.00	434	692,001	0	0.00
32	205	21304	59	36935	58%	3.34	0.00	266	345,159	0	0.00
27	112	25109	58	36531	69%	3.33	0.00	173	188,575	0	0.00
22	37	28913	56	36127	80%	3.32	0.00	66	62,297	0	0.00
17	11	32717	55	35722	92%	3.31	0.00	22	18,521	0	0.00
12	7	36522	54	36522	100%	3.30	0.00	22	11,786	0	0.00

Tab. 18

Examining the part load specifications for the Bosch four (4) ton geothermal heat pump (Table 19) at 70°F EFT (the typical shallow groundwater temperature for the location is 67°F per Bosch Geo Solutions software), we find that at 75°Fdb, 63°Fwb the unit will produce a total capacity of 37,650 Btu/h with 32,380 Btu/h sensible capacity (86% of total capacity). This leaves 5,270 Btu/h latent capacity. During milder summer days, this Bosch four (4) ton geothermal heat pump will run in part load and still provide the necessary cooling needs for the structure. This operation mode will require less electrical power to operate and will enhance latent heat removal (dehumidification), resulting in improved indoor temperature and air quality conditions

Capacity Data - Part Load	Cooling - all performance at 1300 CFM and 12.0 GPM						
Entering Fluid Temp. (˚F)	**Entering Air Temp. (˚F)**	**Total Capacity (MBtuH)**	**Sensible Capacity (MBtuH)**	**Sensible to Total Ratio**	**Power Input (kW)**	**Heat of Reject (MBtuH)**	**EER**
50	70˚db 61˚wb	37.65	28.42	0.75	1.17	41.65	32.1
60		36.39	27.70	0.76	1.37	41.06	26.6
70		35.12	27.08	0.77	1.57	40.47	22.4
85		33.23	26.30	0.79	1.86	39.58	17.9
100		31.34	25.67	0.82	2.15	38.69	14.6
50	75˚db 63˚wb	40.35	33.98	0.84	1.18	44.37	34.2
60		39.00	33.12	0.85	1.38	43.69	28.3
70		37.65	32.38	0.86	1.57	43.02	23.9
85		35.62	31.45	0.88	1.87	42.00	19.1
100		33.59	30.71	0.91	2.16	40.98	15.5
50	80˚db 67˚wb	44.30	37.52	0.85	1.19	48.35	37.3
60		42.81	36.57	0.85	1.39	47.55	30.9
70		41.33	35.76	0.87	1.59	46.74	26.1
85		39.11	34.73	0.89	1.88	45.54	20.8
100		36.89	33.91	0.92	2.18	44.33	16.9
50	85˚db 71˚wb	48.24	41.10	0.85	1.20	52.32	40.3
60		46.63	40.06	0.86	1.40	51.40	33.4
70		45.02	39.16	0.87	1.60	50.47	28.2
85		42.60	38.05	0.89	1.90	49.08	22.5
100		40.19	37.15	0.92	2.20	47.69	18.3

Tab. 19
(EFT Range (Standard) 50˚F to 100˚F)

Even with the installation location in Dallas, Texas, a milder climate, the designer/installer should still examine the heating ability of the unit closely.

Examining the corresponding full load heating data (Table 20) for the Bosch four (4) ton geothermal heat pump (compressor operating at 100% full load ability), we find that at 70°F EFT (the typical shallow groundwater temperature for the location is 67°F per Bosch Geo Solutions software) and 70°F entering air temperature (return air temperature), we determine the total capacity for heating is 54,040 Btu/h. Our calculated heat loss at design conditions is 35,000 Btu/h at 24°F outdoor temperature. We will be able to meet over 100% of the structure heat loss with the Bosch four (4) ton geothermal heat pump capacity at design conditions. Examining the actual bin hours for Dallas, TX using the Bosch four (4) ton geothermal heat pump (see Figure 34), we find that the heat pump providing compressor heating will operate until the structure balance point of approximately 7°F outdoor temperature without auxiliary heating typically being required. It is unlikely that this application even needs supplemental heat, but the installer should still install electric heaters for use as emergency heat if the compressor fails during winter months. The heater size should be at least 10kW for this application.

Capacity Data - Full Load Heating

Entering Fluid Temp. (˚F)	Entering Air Temp. (˚F)	Total Capacity (MBtuH)	Power Input (kW)	Heat of Abs. (MBtuH)	COP
50	60	48.44	2.96	38.32	4.8
60		52.79	3.05	42.38	5.1
70		57.15	3.14	46.43	5.3
80		61.50	3.23	50.48	5.6
50	70	45.81	3.02	35.52	4.5
60		49.92	3.11	39.32	4.7
70		54.04	3.20	43.13	5.0
80		58.15	3.29	46.94	5.2
50	80	42.72	3.08	32.21	4.1
60		46.55	3.17	35.73	4.3
70		50.39	3.26	39.25	4.5
80		54.22	3.36	42.76	4.7

Tab. 20

(EFT Range (Standard) 25˚F to 80˚F)

5 Ground Heat Exchanger Types

The two most prevalent types of residential geothermal heat pump systems today include “Open-Loop” and “Closed-Loop” ground heat exchangers. They will be referred to as open-loop and closed-loop in this manual from this point forward.

Open-loop geothermal heat pump systems using groundwater were the most widely used type for many years, and are still used today in different locations. An open-loop geothermal heat pump system is a loop established between a water source and a discharge area, in which the water is collected and pumped to a geothermal heat pump unit inside the structure, then discharged to its original source or to another acceptable location. Unlike an air-source heat pump, where one heat exchanger (and frequently the compressor) is located outside, the entire geothermal heat pump unit, or units, is/are located inside the structure.

Open-loop geothermal heat pump systems are characterized by the fact that the main heat carrier, groundwater, flows freely in the underground, and acts as both a heat source/sink and as a medium to exchange heat with the solid earth. The main part of this type of system is groundwater wells, to extract or inject water from/to water bearing layers in the underground (“aquifers”). In most cases, two wells are required, one to extract the groundwater, and one to re-inject groundwater into the same aquifer from which it was drawn, but discharge is also possible to the surface where allowed. Ponds and/or lakes are often used for this type of system as well.

Typically, closed-loop geothermal heat pump systems have two parts dedicated to the fluid flow: a circuit of underground piping (ground loop) outside the structure, and a geothermal heat pump unit inside the structure. Closed-loop geothermal heat pump systems include a ground loop, or “ground heat exchanger” (often called “ground-coupled”), typically made of a vertical or horizontal high-density polyethylene piping array placed in the ground. Using coils of piping placed in a large body of water (pond/lake application) approximately eight feet below the surface is also another acceptable closed-loop system. With pond/lake applications, the water is the source of heat extraction and/or discharge instead of the ground.

A closed-loop geothermal heat pump system (the most common today) works on a simple premise: the earth below the “Frost Line” (usually about six inches to four feet down depending on location) is a constant temperature of normally 40 to 70 degrees year round depending on location (Fig. 19). During winter, heat is removed from the earth through a liquid, such as water or an antifreeze and water solution, upgraded by the geothermal heat pump, and transferred to indoor air. During summer months, the process is reversed: heat is extracted from indoor air and transferred to the earth through the water or antifreeze and water solution.

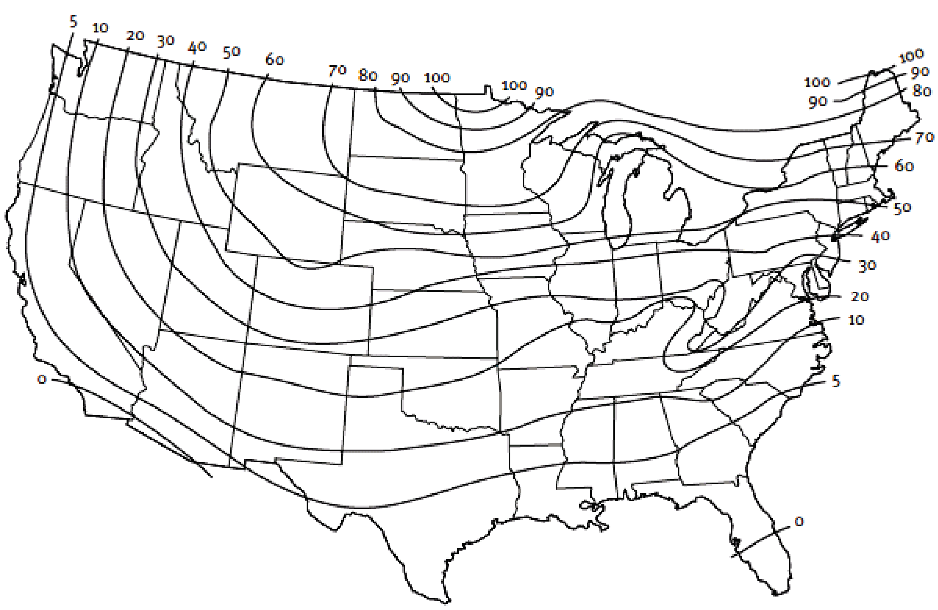

Fig. 19 Extreme Frost Penetration (In Inches) Based on State Averages. Courtesy of http://www.dpwater.com

6 Open-Loop Geothermal Heat Pump Systems

Since groundwater is a relatively constant temperature year-round, it is an excellent heat source and heat sink. The average soil/groundwater temperature of the upper 100 to 200 feet in most of the U.S. is equivalent to the average ambient air temperature of the location. There are seasonal variations to the soil/groundwater temperature of approximately 10 to 20 F degrees, depending on incident solar radiation, rainfall, seasonal swings in overlying air temperature, local vegetation cover, type of soil, and depth in the earth, approaching a constant temperature at a depth of approximately 30 feet (where it is equivalent to the earth's normal thermal gradient). The average soil/groundwater temperature is typically in the range of normally acceptable comfort temperature levels for people by being higher than the air temperature in the winter and lower during the summer.

Open-loop geothermal heat pump systems do not confine fluid to a ground heat exchanger, or “ground loop”. Rather, they extract groundwater (only) directly from a groundwater well or pond and run it through a water-to-refrigerant coaxial heat exchanger within the Bosch geothermal heat pump. Although surface water could often be used, most open-loop geothermal heat pump systems rely on groundwater.

After the transfer of heat between the groundwater and the Bosch geothermal heat pump system occurs, the water is discharged back into a secondary well, into a pond or other body of water, or into a drainage ditch or other acceptable location, depending on local codes (Fig. 20). Local environmental officials should be consulted whenever an open-loop geothermal heat pump system is being considered.

This open-loop geothermal heat pump system method is used less frequently today than a couple of decades ago, but may be employed cost-effectively if groundwater is plentiful and water quality is appropriate. Open-loop geothermal heat pump systems are the simplest to install and have been used successfully in areas where local codes permit. Because open-loop geothermal heat pump systems utilize water on a “once through” basis, they are often referred to as “pump and dump” systems. The performance of the open-loop geothermal heat pump system may degrade over time if water quality issues are present (high mineral or dissolved solids content, etc.) or if the water supply diminishes for any reason.

The Bosch geothermal heat pump is normally provided with a copper water-to-refrigerant coaxial heat exchanger, but often a cupro-nickel water-to-refrigerant coaxial heat exchanger is recommended for open-loop geothermal heat pump systems. This optional water-to-refrigerant coaxial heat exchanger can be ordered prior to unit assembly and helps offset the effects of heavy scale formation or brackish water.

Fig. 20 Open-loop overview

With open-loop geothermal heat pump systems, if the possibility of groundwater use where scaling could be heavy or where biological growth such as iron bacteria could be present, an open-loop geothermal heat pump system is not recommended. If mineral deposits accumulate in the coaxial heat exchanger its heat transfer capabilities can deteriorate over time resulting in loss of capacity and efficiency. Water-to-air coaxial heat exchangers must only be serviced by a qualified contractor or technician, as typically acid and special pumping equipment is required if clogged. If the Bosch geothermal heat pump is equipped with the optional Heat Recovery Package (“desuperheater”) its coil can become scaled and possibly plugged as well.

6.1 Open-Loop Geothermal Heat Pump System Water Quantity

While open-loop systems operate with groundwater that is typically constant in temperature throughout the year, the quantity of water that is pumped will influence the temperatures that the geothermal heat pump experiences.

Bosch geothermal heat pumps used for open-loop systems need differing amounts of water depending on the size of the unit and the Bosch equipment specifications. The water requirement of a specific model is usually expressed in Gallons per Minute (GPM) and is listed in the Bosch specifications for that unit. The groundwater well should be large enough to supply the water needed by the geothermal heat pump in addition to the domestic water requirements.

Generally, an open-loop geothermal heat pump system will use approximately 1-½ to 3 gallons per minute (GPM) per ton of cooling capacity. This equates to 2,160 to 4,320 gallons per day for a typical 3 ton geothermal heat pump unit, depending on the equipment efficiency and the amount of cooling or heating necessary. A groundwater well that may need to supply all the water needs for a home including the Bosch geothermal heat pump system may require a yield of 20-30 GPM to meet the peak flow requirements.

Groundwater occurs below the surface at depths where all the open spaces in the soil, sediment, or rock are completely filled with water. All groundwater, whether from a shallow well or a deep well, originates and is replenished by precipitation.

Groundwater is provided through a normal water cycle in nature (Fig 21).

The typical minimum water flow or GPM for open-loop systems is often based on entering water temperature (EWT) as follows:

- 1.5 GPM when water temperature is above 50ºF
- 2.0 GPM when water temperature is below 49 ºF

In order for a Bosch geothermal heat pump system to operate at its specified heating and cooling capacity and efficiency, the proper groundwater flow rate through the water-to-refrigerant coaxial heat exchanger must be maintained. The groundwater aquifer, source well, and pumping system must be able to supply the required flow rate.

During the winter heating cycle, the open-loop geothermal heat pump system operates by extracting heat from the groundwater, and transferring it to the structure. During the summer cooling cycle, heat is transferred away from the structure by the groundwater.

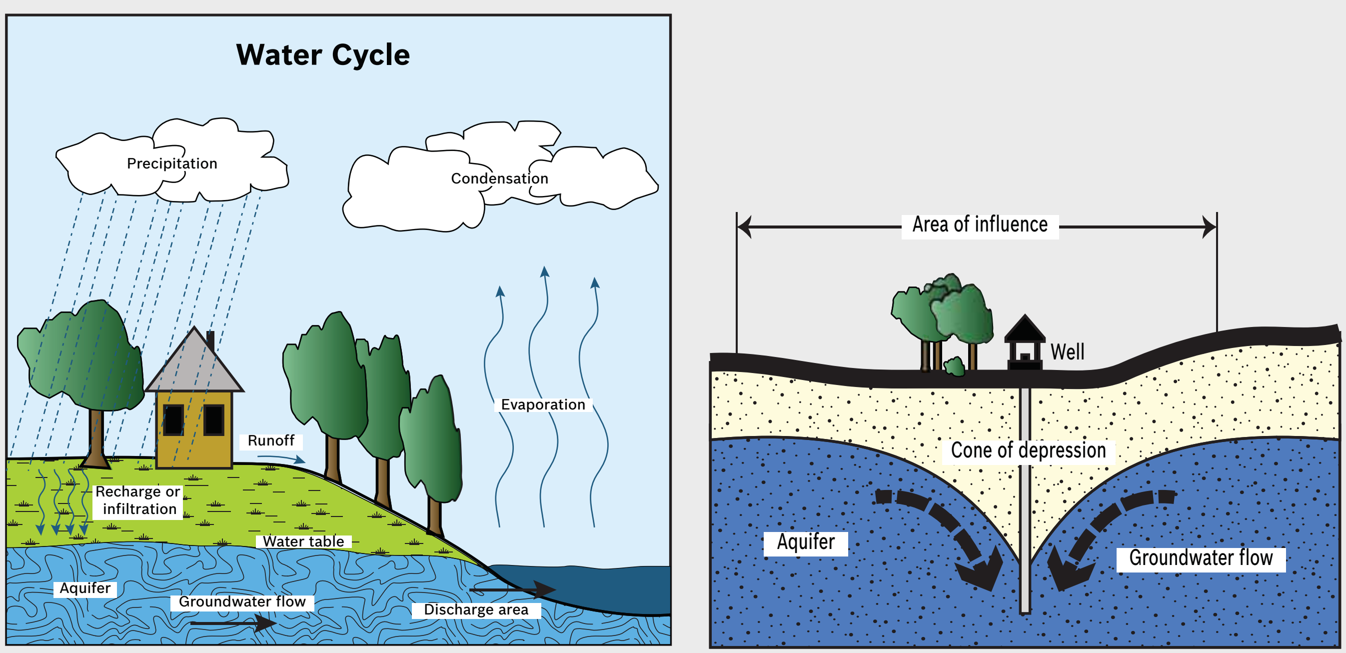

Fig. 21 Water cycle
Courtesy of National Ground Water Association

6.2 Open-Loop Geothermal Heat Pump System Water Quality

Poor water quality can cause serious problems in Bosch open-loop geothermal heat pump system applications. Supply water should be tested for hardness, acidity and iron content before the Bosch geothermal heat pump is installed. Poor water quality can cause mineral deposits to build up inside the Bosch geothermal heat pump water-to-refrigerant coaxial heat exchanger and periodic cleaning will be required. Water from flowing springs, ponds, lakes or river sources are not recommended for Bosch geothermal heat pump use, unless proven to be free of excessive particulate and organic matter. These sediments will contaminate the water-to-refrigerant coaxial heat exchanger in the Bosch geothermal heat pump system and could make it inoperable.

Copper is adequate for groundwater that is not high in mineral content. If the well driller expresses concern regarding the groundwater quality available, or knows of any hazards in the area, it is recommended that proper testing be performed to assure the groundwater quality is suitable for use with the Bosch geothermal heat pump. In conditions anticipating moderate scale formation or in brackish water a cupro-nickel water-to-refrigerant coaxial heat exchanger is recommended.

The principal concerns with an open-loop geothermal heat pump system are corrosion, scaling, encrustation and erosion.

Galvanic corrosion occurs when dissimilar metals are used together. For example, using iron or galvanized pipe together with copper pipe will cause problems. Acceptable materials are copper, PVC, polyethylene, polybutylene and rubber.

Scaling is the process where minerals precipitate out of the groundwater and build up or scale on the inside surfaces of the pipes and water-to-refrigerant coaxial heat exchanger in the geothermal heat pump (Fig. 22).

Fig. 22 Scaling Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

Scaling reduces heat transfer and increases pumping costs. The minerals that combine to form scale are normally present to some degree in groundwater. If the water temperature rises suddenly and/or the water pressure drops suddenly, the suspended minerals will be released and form a carbonate scale.

The first step to prevent scaling is to keep all water lines under pressure. The second step is to limit the water temperature rise to approximately 20 degrees in the cooling mode. Most residential geothermal heat pumps don't raise the water more than 10 to 12 degrees when cooling. If a larger rise is noted, the water flow rate should be adjusted. Scaling typically does not occur during the heating mode.

Encrustation is a build-up of a slimy orange-brown deposit caused by iron bacteria that can occur primarily in return wells (Fig. 23). This can clog the system as easily as scales. Keeping the water lines pressurized and free of contact with air inhibits the growth of these bacteria. If it is found, it can be removed with periodic cleaning using a chlorine bleach solution.

Fig. 23 Encrustation
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

Erosion occurs when sand or other particulates prematurely erode the tubing inside the geothermal heat pump. Proper screening or filtering can reduce the number of particles that pass through the geothermal heat pump, and thus minimize erosion (Fig. 24).

Fig. 24 Erosion
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

A well screen with a fine enough mesh to filter out known sand-sized particles found during drilling is necessary. A filter should also be placed between any pressure tank and a geothermal heat pump intake to trap any possible particles. A replaceable cartridge, with the cartridge replaced by a screen, is recommended.

Cupro-nickel has a higher resistance to abrasion than copper.

Table 21 is indicative of typical water quality requirements for open-loop geothermal heat pump systems.

Water Quality Requirements for Open-Loop Geothermal Heat Pump Systems					
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 150°F for direct use and HWG applications, and at 90°F 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 150°F HWG and Direct well, 84°F Indirect Well HX.		
Iron Fouling					
Iron Fe^{2+} (Ferrous) (Baterial 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	–	At H_2S>0.2 ppm, avoid use of copper and copper nickel piping or HX's. Rotten egg smell appears at 0.5 ppm level. Copper alloy (bronze or brass) cast components are OK to <0.5 ppm.		
Ammonia ion as hydroxide, chloride, nitrate and sulfate compounds	All	–	<0.5 ppm		
Maximum Chloride Levels			Maximum Allowable at maximum water temperature		
			50°F	75°F	100°F
	Copper	–	<20 ppm	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
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.		

Tab. 21 Water quality requirements - open loop systems

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.

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 for direct use (groundwater/open loop) and HRP (desuperheater); 90°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 are referenced in Table 21.

Typical open loop piping is shown (Fig. 25). Shut off valves should be included in the open loop piping array at the unit for ease of servicing. Boiler drains or other valves should be placed into the lines to allow flushing of the heat exchanger if necessary. Shut off valves should be installed to allow flow through the coaxial heat exchanger via the boiler drains without allowing flow into the piping system. Pressure/Temperature (P/T) ports or plugs should be installed so that pressure drops and temperatures can be measured during waterside diagnostics, and gallons per minute (GPM) can be determined from manufacturer's specifications. Due to pressure and temperature extremes, PVC SCH40 is not recommended.

In Bosch open-loop geothermal heat pump system applications, water pressure must always be maintained in the water-to-refrigerant coaxial heat exchanger. This can be accomplished with either a control valve or a bladder type expansion tank.

One method of flow control and regulation is by adjusting the ball valve or water control valve on the discharge line. Measure the pressure drop through the unit heat exchanger, and determine the flow rate (GPM) 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 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.

When EWT is below 50°F, 2 GPM per ton is always required for an open-loop geothermal heat pump system.

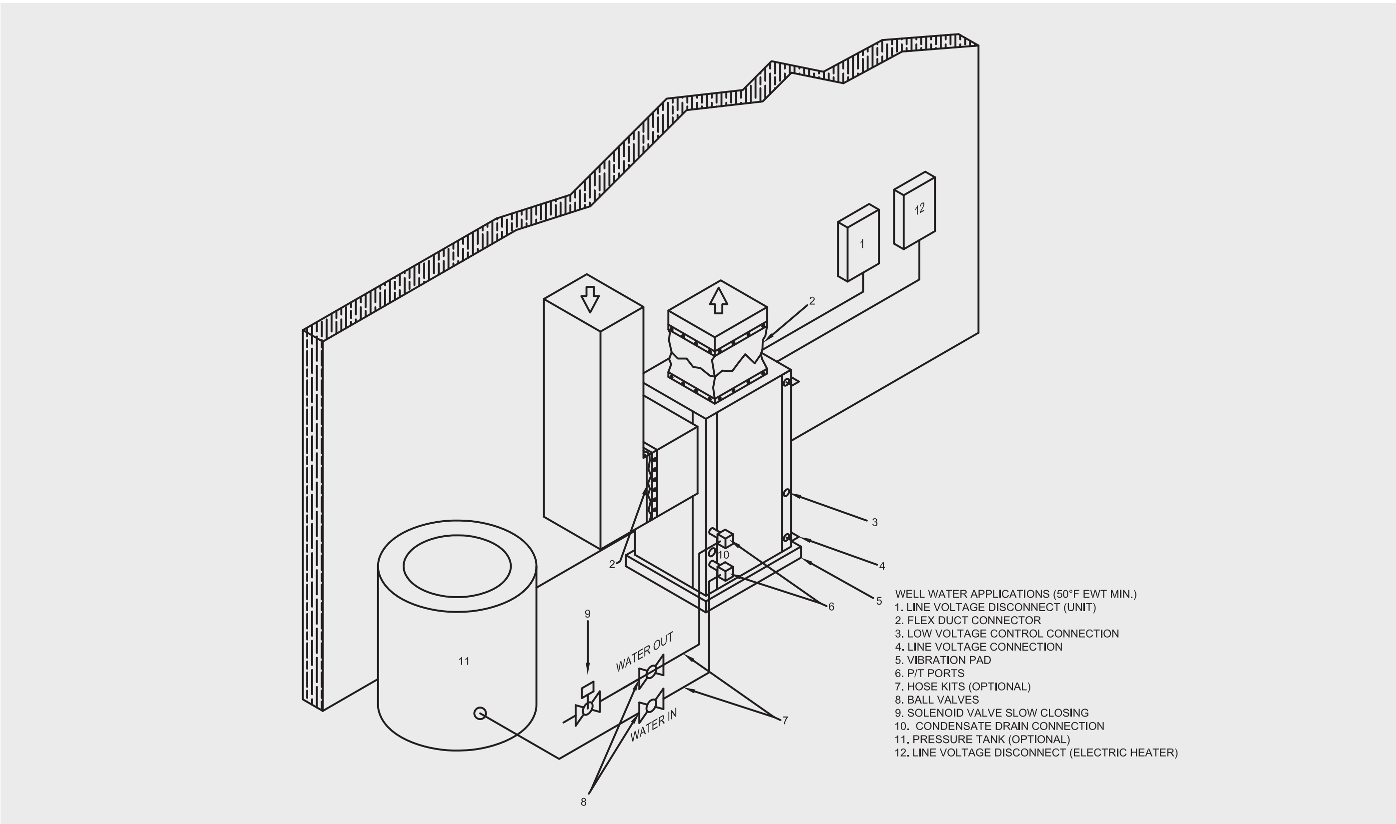

Fig. 25 Well water application

Pressure regulating valves are often used to increase or decrease water flow through the geothermal heat pump in response to refrigerant pressure. In some cases more water may be required in heating than in cooling, or vice versa. With the Bosch geothermal heat pumps, these valves are not required. However, if installed, a pair of valves is required for proper operation, one for cooling (direct acting) and another for heating (indirect acting). A refrigerant tap is provided in the refrigerant line located between the reversing valve and the water-to-refrigerant coaxial heat exchanger for proper monitoring of the refrigerant pressures.

A bladder type 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. When using a single groundwater well to supply both domestic and geothermal heat pump water, care must be taken to insure that the groundwater well can provide sufficient flow for both.

In well water applications, a slow closing solenoid valve must be used to prevent water hammer. Solenoid valves should have a 24 VAC coil and be connected across Y1 and C1 on the interface board for all Bosch equipment. Assure that the VA draw of the solenoid valve, if used, does not exceed the contact rating of the thermostat.

6.3 Open-Loop Geothermal Heat Pump System Water Disposal

The **circulated groundwater** from the Bosch open-loop geothermal heat pump system, with only its temperature changed requires disposal. The discharge water from the Bosch geothermal heat pump is not contaminated in any manner and can be disposed of in various ways depending on local building codes (i.e. discharge well, dry well, storm sewer, drain field, stream or pond, etc.) Most local codes do not allow the use of a sanitary sewer for disposal. Always consult your local building and zoning department to insure compliance in your area.

Disposal can be accomplished by both **surface** and **sub-surface** methods. During severe cold outbreaks, the pumps may require constant use. The largest volumes of water will be produced during the coldest part of winter. The disposal method must be compatible with the volume of water that will be discharged and must be able to handle the extreme weather conditions. During the spring and fall, the volume of water required will be reduced. Because of the expense involved in the construction of a second (return) well, the installer may prefer surface or near surface disposal methods. However, many situations will not allow these methods.

Surface disposal is generally the easiest method for disposing of the used groundwater from the Bosch open-loop geothermal heat pump system. The disposal locations can include on-site or off-site ponds, streams and other bodies of water. Each disposal method poses some environmental and operational disadvantages. The used water may be diverted to a surface water body, such as a lake or stream; however, this action may require a local permit for the discharge. The method of conveyance must be secure to avoid problems with erosion and sedimentation, which can impact the stream or lake. Additional problems may occur in the winter because of freezing conditions.

Long-term impacts to groundwater levels are possible if discharge exceeds recharge. Water may be channeled to a private, on-site collection basin where it infiltrates into the ground. This type of disposal is generally successful only where the basin bottom is composed of highly permeable sands and gravels. Otherwise, infiltration tends to be too slow; periodic maintenance must be done to clean the basin. Along with silting, microbial and bacterial plugging are the chief causes of the permeability reduction. Basins also require large areas of property. Disposal to a private basin would not require a permit.

Another possibility is to discharge water into a storm sewer with permission from the municipality. This option is generally precluded by limited access to the sewer. Also, this method does not recharge the local aquifer. Disposal to sanitary sewers is typically prohibited because of local ordinances. Such discharges can lower a sewage treatment plant efficiency, thereby raising operating costs.

If a return well is used, it must be able to handle the volume of water that passes through the Bosch geothermal heat pump (Fig. 26). Ground aquifer characteristics such as the transmissivity of the area surrounding the well should be considered. Hydrogeological characteristics can be estimated based on the geology of the well area.

The installer should consider other factors including:

1) Distance from existing wells
2) Volume of discharge water
3) Length of the well available for injection of the water
4) Design of the well screen (if used)
5) Local water quality
6) Local and state well construction codes

The return well must be isolated to allow the discharge water to reach the ambient temperature of the aquifer before being withdrawn again. The wells typically should be isolated at distances greater than 100 feet (horizontal distances). Larger capacity wells or wells in thin or poorly transmissive aquifers should have greater isolation distances.

The construction of the return well is critical to the effectiveness of this type of water disposal. A well that is not constructed properly can at some point cause the entire system to fail. Problems often consist of well clogging or slowing because of either poor construction or the development of mineral precipitate that clogs the well.

Several actions can help to prevent precipitation of minerals, although results cannot be guaranteed. The well must be of sufficient diameter and depth to accept the maximum discharge from the Bosch geothermal heat pump system. The screened or open rock portion should be greater than that of the supply well. A return well constructed in rock typically requires twice the capacity as the supply well. An extended pumping test (12-24 hours) is recommended to help determine hydraulic characteristics of the return well. The use of a back valve can help to prevent pressure differences that could result in precipitation of minerals.

Also, the return well should be properly developed to remove fines and stabilize the borehole. Mechanical surging and some types of chemical treatment can promote a stable well, or successfully treat a clogged well.

The rate of discharge acceptance for a return well can be estimated based on values determined from a pumping test of the well. A pumping test is accomplished by pumping the water well at a constant rate for at least an hour. Specific capacity is the observed rate of yield (in gallons per minute) divided by the drawdown resulting from the pumping test. For example, if a well pumps at 10 GPM and the water level drops 5 feet, the specific capacity is two GPM/ft of drawdown.

To push water back into the ground aquifer, the pressure on the column of water must be greater than the pressure resisting flow back into the aquifer. The discharge water will "mound" inside the well until enough pressure is built up to force the water into the aquifer. The term "head" is used to denote the height of the water in the well. The "injection head" is how far the water rises before water will be moved into the aquifer. Injection head depends on many factors including the construction of the well, the discharge rate of the return water, the aquifer's ability to transmit water and how much water is held in the borehole area.

The theoretical value of the injection head can be calculated by dividing the discharge rate by the specific capacity. For example, if 10 GPM is returned to the well that has a specific capacity of two, then the injection head will be five feet. If a positive number results when the injection head is subtracted from the depth to water (static water level) then the water will not overflow at the surface. A specific capacity value of less than 1 GPM/ft may cause overflow at a well that is only 20-25 feet deep. A water injection test can be performed to see how the well reacts. The installer should consider that any decrease in the aquifer transmissivity will result in an increase in injection head. Clogging of the open spaces in a well will eventually bring the water to the surface.

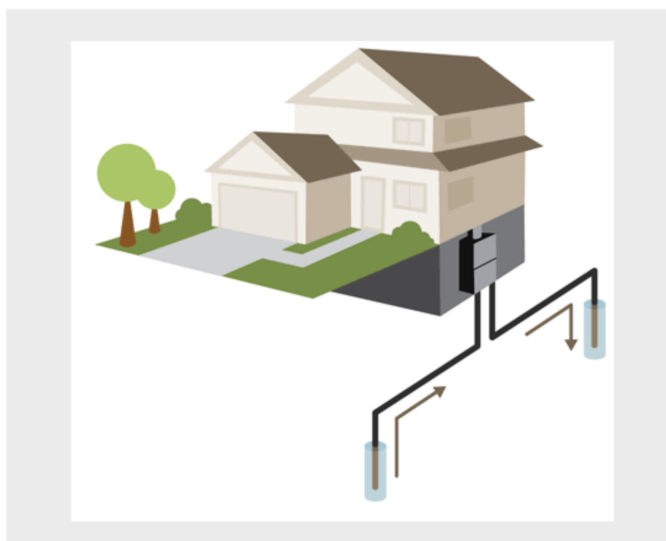

Fig. 26 System water disposal
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

6.4 Open-Loop Geothermal Heat Pump System Design

The design of an open-loop system must consider the performance of the system based on the power requirements of the well pump and geothermal heat pump. With the open-loop system, the greater the groundwater flow (GPM) the more favorable are the temperatures at which the geothermal heat pump will operate. As the groundwater flow is increased, the improvement in geothermal heat pump performance is increasingly compromised by rising well pump power. At some point, increasing well pump power overshadows the gains in geothermal heat pump performance and the total system performance begins to decline. The open-loop system pumping power is normally a much stronger function of flow rate than with closed-loop systems because not only must the pump overcome the circulating head, it must also overcome the head due to the static level in the well and any reinjection head requirements.

The task in open-loop system design is to gather enough information about the well pump and geothermal heat pump to identify these trends and to select the optimum system performance point. It is the system cooling efficiency rating, the Energy Efficiency Ratio (EER), and/or the system heating efficiency rating, the Coefficient of Performance (COP), that should be the focus of the open-loop system design, not simply the performance of the geothermal heat pump.

The typical industry procedure is to evaluate the well pump power required to produce a range of groundwater flows and combine that with the geothermal heat pump performance at those same groundwater flows. The optimum relationship between pumping power and geothermal heat pump performance is established at the design condition and system performance at off peak conditions is maintained by accurate well pump control.

6.5 Water Well Criteria and Terminology

Groundwater wells are the foundation of open-loop systems and certain key terms should be understood for proper design. In any well there will be a water level at which the groundwater stands in the well under non-pumping conditions (Fig. 27).

This level indicates the **water table level** in unconfined (or water table aquifers), or the "**Piezometric**" level (the artesian equivalent of the water table) in confined (or artesian) aquifers, and is known as the "**Static Water Level**" **(SWL)**. When the pump is started, water level will normally drop to a new, lower level referred to as the "Pumping Level". The pumping level is a function of the rate at which the well is being pumped, the greater the rate the lower the pumping level. The optimum groundwater flow rate is a function of many variables, but the greatest influence will typically be the static water level. If the water must be pumped from greater depths then pumping power per unit of water produced is increased.

The difference between the SWL and the pumping level is referred to as the "**Drawdown**". Drawdown at a given pumping rate, divided by the rate, results in a value known as "**Specific Capacity**" measured in Gallons per Minute per Foot (GPM/Ft). The drawdown at a given rate is a function of the "**Cone of Depression**" that forms in the aquifer around the well during pumping. The size and shape of the cone of depression and the depth of the drawdown are a function of the aquifer and its ability to deliver water. At the return well, there is a "**Cone of Impression**" that forms in the aquifer around the well during discharge.

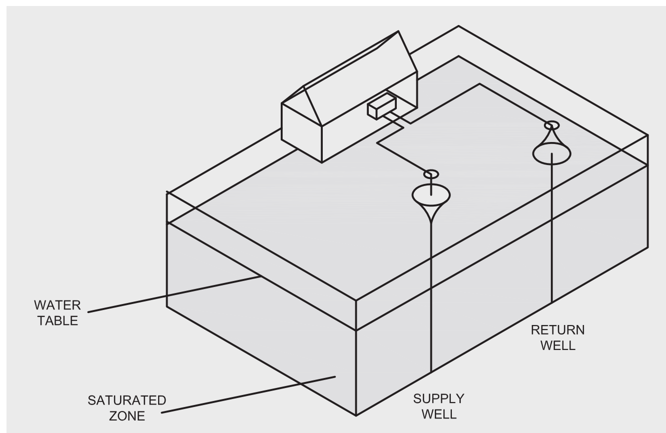

Fig. 27 Water well terminology

Specific capacity is a useful value for indicating the ease with which the aquifer produces water. A high specific capacity value, say, 10 GPM/Ft. typically indicates a "good" well; whereas, a low specific capacity value, say, 0.5 GPM/Ft., would typically indicate a "poor" well. For artesian aquifers, specific capacity will be a constant value over a broad range of flows. In water table aquifers, specific capacity will diminish as pumping rate increases.

The construction of a well is also a function of the aquifer. In rock formations, often the bottom of the well is uncased. This is referred to as "**open-hole completion**". In formations in which there is a tendency to cave, a slotted casing or screen may be used. In very fine sands and in thinly stratified formations, it may be necessary to place a "**gravel pack**" around the screen to provide additional filtering and to increase the permeability of the near well materials.

A key part of the design process is the determination of the well pump power required for a range of ground water flow rates. To calculate these values it is necessary to know something about the performance of the production well in terms of the head (static water level plus drawdown) it imposes on the pump to produce the water. The best source of information is the results of a pump test of the well. This data normally includes pumping water level at 3 different flow rates and the pre-test static water level. From this it is possible to calculate the pumping level at a wide range of flows and to use this data in design steps.

6.6 Groundwater Well Pumps

Open-loop systems typically use **submersible** type well pumps equipped for the most part with nominal 3,600 rpm motors. As a result, they are able to produce a higher flow per unit diameter than line shaft pumps which typically operate at speeds of 1,800 rpm or less. The higher speed of the submersible also results in a greater susceptibility to erosion if significant sand is produced from the well. Submersibles are somewhat more sensitive to voltage variation than surface motors and adequate voltage (allowing for any drop in wiring to the well and down well) should be verified.

Calculating the **head** for a well pump involves some different issues than a similar calculation for a circulating pump. There are 3 main components to the total head: lift, surface losses and injection head.

Lift is composed of the static water level plus the drawdown at the design rate. Its name derives from the fact that this is the vertical distance the water must be "lifted" by the pump to get it to the surface. Data to determine these values comes from the flow test of the well serving the system (preferred) or from information on nearby wells. Also included in the lift is the friction loss in the pump column (between the pump and the ground surface) which is usually on the order of 1 to 3 ft.

Surface losses are those associated with the piping from the well to the structure and equipment (heat exchanger, etc.) and piping from the structure to the disposal point. Unless there are significant elevation considerations or distances involved, surface losses normally amount to less than 40 ft. assuming a 5 PSI loss in the heat exchanger. The type of disposal can have an impact on the total pump head. In surface discharge applications, often a pressure sustaining valve is used to maintain a small (less than 5 PSI) back pressure on the system to keep it full of water.

For **injection head**, the impact may result in added pump head (if a positive pressure is required at the surface) or reduced pump head (if the water level in the well remains below ground surface). Key components in the connection of the production well to the system are shown (Fig. 28).

Not shown in this diagram is a pump column check valve which would be located at the base of the column near the bowl assembly. The check valve maintains the column full of water and in doing so prevents damaging reverse thrust on start up. Submersible motors are equipped with a thrust bearing to resist the down thrust developed in normal operation. When starting with an empty column, a pump can exert a temporary up thrust on the motor which if encountered often enough can result in premature failure of the motor. To prevent this, submersibles should be equipped with a column check valve.

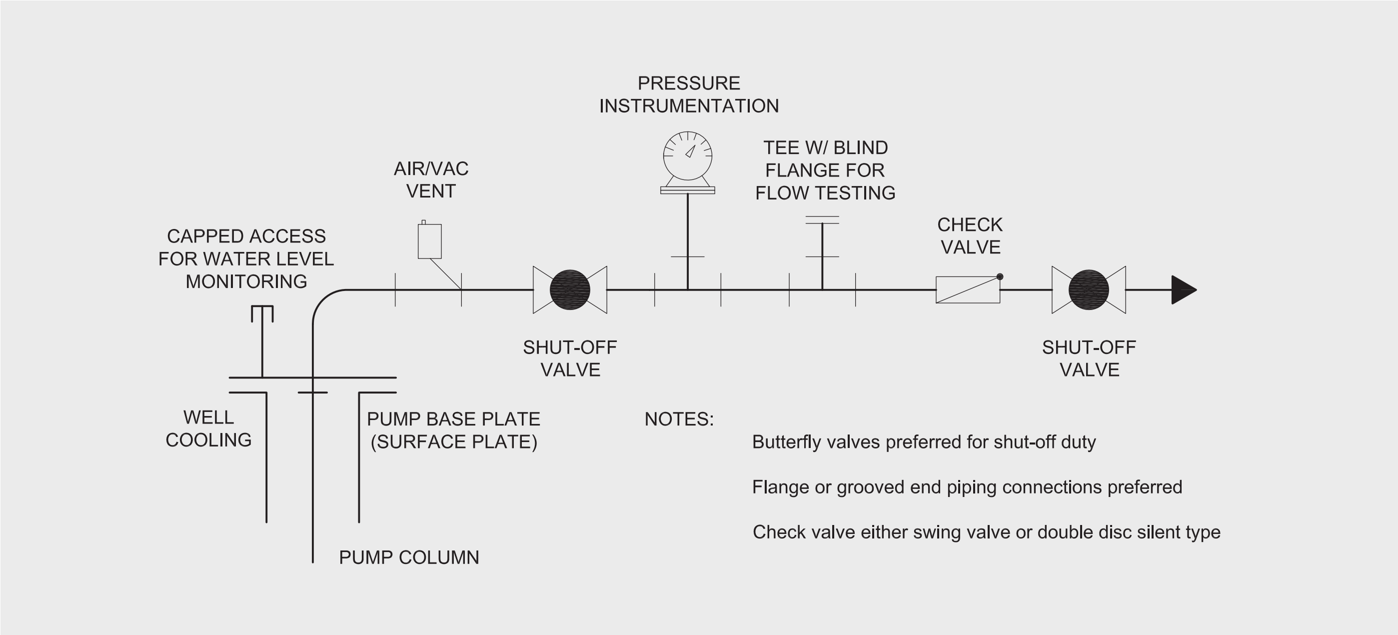

Fig. 28 Production well to system connection

6.7 Geothermal Standing Column System

A standing column well bridges the gap between an open-loop and a closed-loop geothermal heat pump system (Fig. 29). This type of system is simply a vertical re-circulating water-filled bedrock borehole. Heat exchange occurs when water is removed from the bottom of the borehole and returned to the top. Removal of small amounts of water from the domestic groundwater well greatly enhances the heat transfer.

Typically, standing column wells are 250 to 500 feet deep, but can be deeper.

Heat transfer occurs via conductive processes, meaning the heat energy is moving through the rock, molecule by molecule. Heat transfer also occurs via advective processes, meaning water in moving through rock fractures and changing the rock temperature. And finally, convective heat transfer occurs as heat energy and water mix, typically at the surface of and within the borehole.

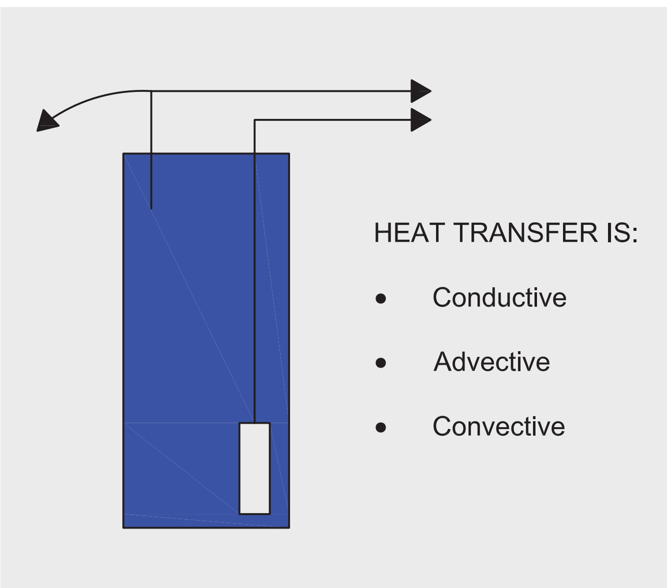

Fig. 29 Standing column system

7 Closed-Loop Geothermal Heat Pump Systems

Closed-loop ground heat exchanger systems have been used since the late 1970s and have become the most common system in residential geothermal heat pump markets. These ground heat exchangers are commonly installed in one of three configurations: vertical closed-loop ground heat exchangers ("vertical loops"), horizontal closed-loop ground heat exchangers ("horizontal loops") and "pond or lake loop". Each configuration uses the moderate temperatures of the earth as a heat source and/ or heat sink (Fig 30, 31, 32). Piping configurations are typically reverse return header type.

Both horizontal and vertical designs are used predominantly and the type installed depends on local practices, site conditions and the geothermal heat pump. The energy efficiency of the system is dependent upon sufficient ground loop to produce favorable water temperatures for the geothermal heat pump. In addition to adequate loop length, individual trenches or boreholes also must be separated sufficiently to avoid thermal interference. Vertical loops are generally more expensive to install than horizontal loops, but require less piping and less land area in most cases.

Fig. 30 Closed loop vertical design

Fig. 31 Closed loop horizontal design

Fig. 32 Closed loop pond or lake design

8 Ground Heat Source or Heat Sink for Closed-Loop Ground Heat Exchangers

Bosch geothermal heat pump systems utilize the sub-surface of the ground as the heat transfer medium for closed-loop ground heat exchangers since it typically remains relatively constant. Typically, ground temperatures are fairly constant from 5 to 30 feet below the surface; below 100 feet, temperatures rise about 1°F for every 100 feet of further depth. Sub-surface temperatures fluctuate more widely near the surface. Soil temperatures can be determined by direct measurement, by design graphs of sub-surface temperature variation and by equations.
An important sizing consideration is that the performance of the Bosch geothermal heat pump depends on the performance of the ground heat exchanger, or "ground loop", and vice versa. It is therefore essential to design and size them together.

The length of ground loop piping required depends on the structure load, soil conditions, loop configuration, local climate and landscaping. Sizing of the ground loop is critical. The more piping used (over-sizing), the greater the output of the system, but since the costs associated with the ground loop typically represent 30% to 50% of the total system costs, over-sizing is uneconomical.

Conversely, under-sizing the ground loop can lead to it running colder and could result in ground temperatures not being able to recover during heat transfer. The ground loop must be sized to meet the peak thermal power but also to deliver energy at no greater rate than the surrounding earth can collect energy over a twelve month period. If a system provides heating and cooling, energy transferred to the ground in summer can be stored and used in winter.

Assuming that other conditions remain constant, the heat that a ground loop can extract will be dependent on the temperature difference between the circulating fluid and the "far field" ground temperature (away from the influence of the heat exchange with the ground loop).

9 Closed-Loop Ground Heat Exchanger Design Considerations

9.1 Series or Parallel Configurations

Typically, closed-loop ground heat exchangers are arranged in either a series or parallel configuration (Fig. 33, 34). Historically, closed-loop ground heat exchangers were all designed using series flow due to the lack of fusion fittings required for parallel configurations. This typically resulted in larger diameter pipe (>1-1/4") being used in an effort to reduce pumping requirements which were due to the increased pressure drop apparent in the piping. As fusion fittings have become available, parallel flow using 3/4" IPS for loops for most geothermal heat pump equipment has become typical.

For the most part, smaller diameter pipe is now used for ground heat exchangers. Larger diameter (>1-1/4") pipe is typically 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 15%. In close-loop designs using the smaller pipe, the pipe length is normally 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.

Parallel systems normally have lower pressure drop and require smaller pumps due to the multiple flow paths of smaller pipes in parallel.

Smaller diameter pipe is typically much easier to handle during installation than larger diameter pipe as well. The "pipe memory" can be problematic for larger pipe when ground heat exchangers are installed during cold weather, and are less apparent with smaller pipe. The smaller pipe also takes less time to fuse and is much easier to prepare for installation.

Series piping configurations typically use **1-¼** inch or **2** inch HDPE pipe.

Parallel piping configurations typically use **¾** inch or **1** inch HDPE pipe for loops and **1-¼** inch or **2** inch pipe for headers and service lines.

Parallel configurations require headers to be either "closed-coupled" short headers or "reverse return header" design.

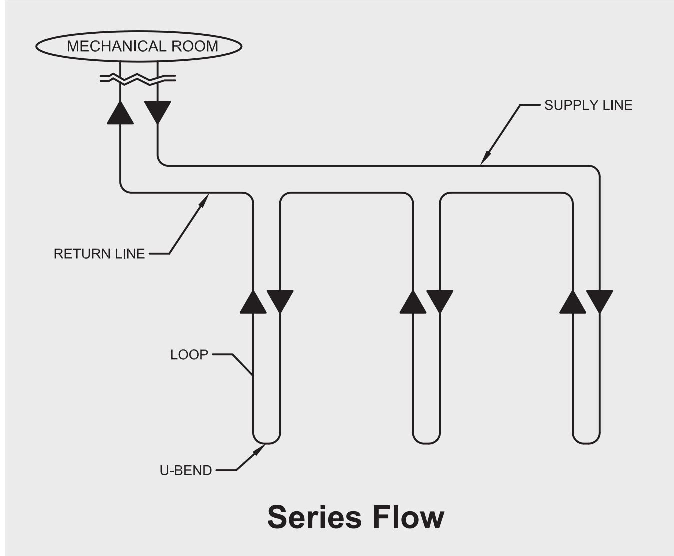

Fig. 33 Series flow configuration
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

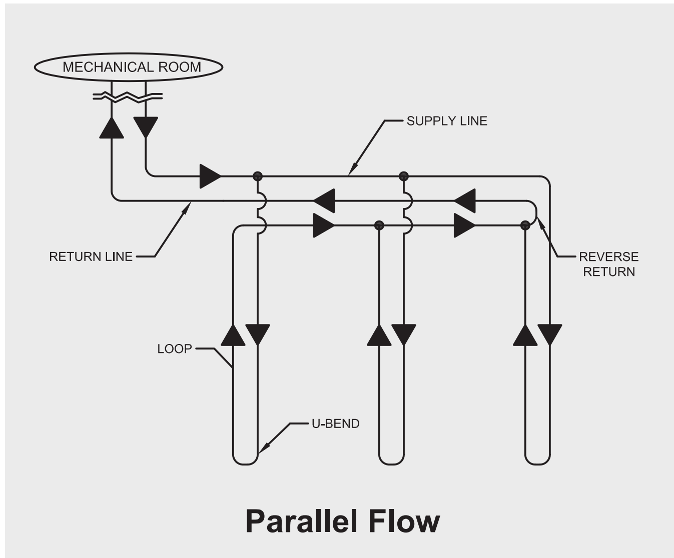

Fig. 34 Parallel flow configuration
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

9.2 Ground Characteristics

The ground moves heat slowly and has high heat storage capability, so its temperature changes very slowly depending on the depth in the ground where a measurement is taken. As a consequence of this low thermal conductivity, the soil can transfer some heat from the cooling season to the heating season. Heat absorbed by the ground during the summer gets used in the winter. This yearly, continuous cycle between the air and the soil temperature results in a thermal energy potential that can be utilized to heat or cool a structure very efficiently with a Bosch geothermal heat pump system (Fig. 35).

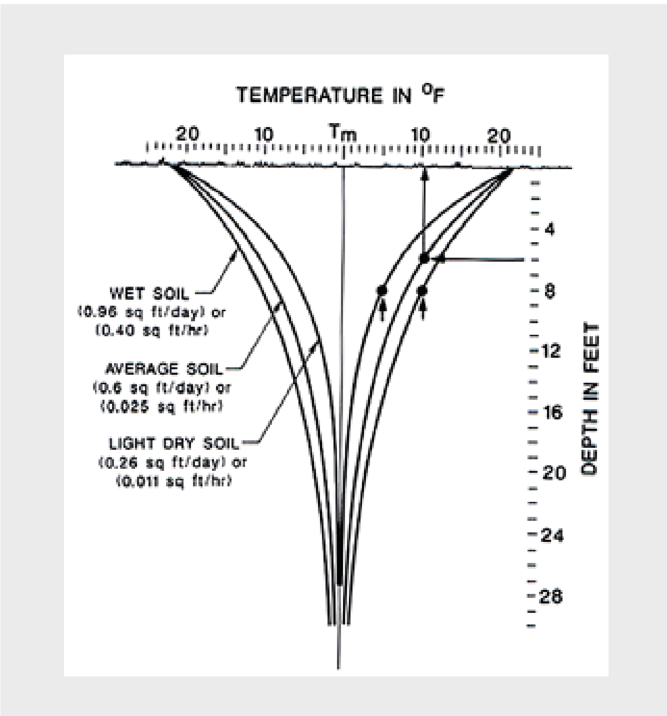

Fig. 35 Ground temperature characteristics
Courtesy of Geo4VA, "Seasonal Temperature Cycles", Virginia Tech, http://www.geo4va.vt.edu/A1/A1.htm, accessed September 2012.

Soil type can also influence the performance of geothermal heat pump system installations. Moist soils such as clay and loam are best (for closed-loop systems). Dry, sandy soils, in contrast, contain millions of tiny air pockets which insulate against the heat-transfer process. In these cases, the installer will need either to extend the piping loop (up to 30 percent) or backfill the bottoms of the trenches with grout or a better soil.

Another ground (thermal) characteristic is that a few feet of surface soil insulates the ground and groundwater below, minimizing the variation in soil temperature in comparison with the temperature in the air above the ground (Fig. 36). This thermal resistivity fluctuation helps shift the heating or cooling load of a structure to the season where it is needed. Thus, the ground is warmer than the ambient air in the winter and cooler than the ambient air in the summer.

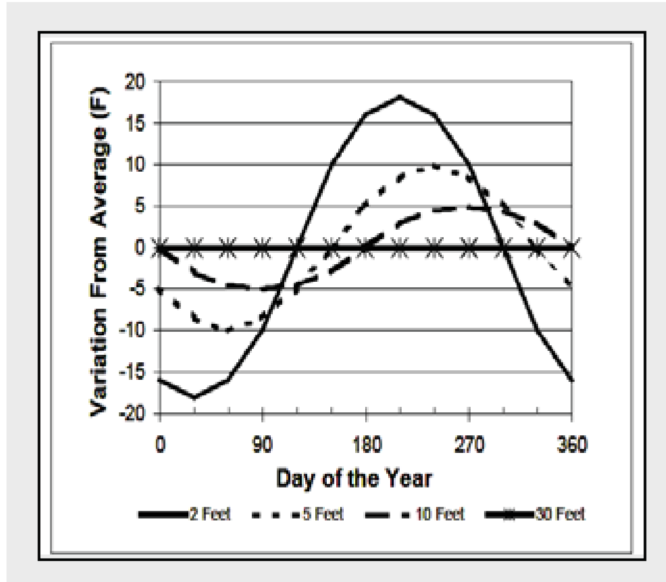

Fig. 36 Ground temperature annual variation
Courtesy of American Society of Heating, Air-conditioning and Refrigeration Engineers Inc., www.ashrae.org

9.3 Soil Analysis

The thermal conductivity of the soil must be analyzed or estimated from local data for any particular geothermal heat pump system installation ground heat exchanger. Resistance to heat transfer in the soil around a buried pipe is a function of the thermal conductivity of the soil, the number, diameter and configuration of the pipes in the trench or bore, and the distance between trenches or boreholes.

Thermal conductivity testing is typically a good approach in the soil analysis if possible. Cost often prohibits this type of test. In any event, composition and soil and rock properties must be considered when designing the ground loop. Soil with good heat transfer properties requires less piping to absorb heat than soil with poor heat transfer abilities. Soil amount available also contributes to system design. Hard rock or soil too shallow to trench will often require vertical ground loops. Ground or surface water availability is also a major deciding factor for what type of ground loop to use. Bodies of surface water can be used as a repository for coils of piping for a closed-loop system.

Thermal conductivity of soil depends on the type of soil. This means the percentage of sand, silt and clay, the density of the soil, and the water content of the soil. Density does not typically change significantly for a given soil type, but the water content can change over time, depending on the soil type and precipitation for that particular locale.

Sandy soils do not hold water well and tend to exhibit large swings in water content and thermal conductivity depending on the season and precipitation.

Clay soils tend to hold water very well and the water content and thermal conductivity will not vary much over time.

Good ground heat exchanger design involves selecting the lowest soil thermal conductivity expected for the particular soil type and installation location. Moisture and thermal stability of soil will generally increase with depth in the soil.

ASHRAE (2005) provides typical thermal conductivity values for different soil types based on work by Salomone and Marlowe (1989). Notice that the normal range expected for each soil type is provided, as well as low values that reflect worst-case scenarios for ground heat exchangers, and high values that reflect analysis of systems where maximum heat transfer rates are predicted (Table 22). The low values are typically satisfactory unless better data is available.

Thermal Conductivity Values per Soil Type

Soil Type	Normal Range[1]	Recommended Values for Design[2]	
		Low[3]	High[4]
Sands	0.35 - 1.45	0.45	1.30
Silts	0.50 - 1.45	0.95	1.30
Clays	0.50 - 0.95	0.65	0.90
Loams	0.50 - 1.45	0.55	1.30

Tab. 22 Thermal conductivity of soil types
Courtesy of American Society of Heating, Air-conditioning and Refrigeration Engineers Inc., www.ashrae.org

[1]) Btu/hr ft F

[2]) Reasonable values for use when no site or soil-specific data available

[3]) Moderately conservative values for minimum heat loss through soil (use in soil heat exchanger or earth-contact cooling applications). Values from Salomone and Marlowe (1989).

[4]) Moderately conservative values for maximum heat loss through soil (use in peak heat loss calculations). Values from Salomone and Marlowe (1989).

The thermal properties for sand and clay soils will typically range from 0.3 to 1.9 Btu/h•ft•F°.

Thermal Properties for Sand and Clay Soils

Soil Type	Dry Density (lb/ft^2)	5% Moist		10% Moist		15% Moist		20% Moist	
		k	α	k	α	k	α	k	α
Coarse 100% Sand	120	1.2 - 1.9	0.96 - 1.5	1.4 - 2.0	0.93 - 1.3	1.6 - 1.2	0.91 - 1.2	–	
	100	0.8 - 1.4	0.77 - 1.3	1.2 - 1.5	0.96 - 1.2	1.3 - 1.6	0.89 - 1.1	1.4 - 1.7	0.84 - 1.0
	80	0.5 - 1.1	0.60 - 1.3	0.6 - 1.1	0.60 - 1.1	0.6 - 1.2	0.51 - 1.0	0.7 - 1.2	0.52 - 0.90
Fine Grain 100% Clay	120	0.6 - 0.8	0.48 - 0.64	0.6 - 0.8	0.4 - 0.53	0.8 - 1.1	0.46 - 0.63	–	–
	100	0.5 - 0.6	0.48 - 0.58	0.5 - 0.6	0.4 - 0.48	0.6 - 0.7	0.37 - 0.48	0.6 - 0.8	0.41 - 0.55
	80	0.3 - 0.5	0.36 - 0.6	0.35 - 0.5	0.35 - 0.5	0.4 - 0.55	0.34 - 0.47	0.4 - 0.6	0.30 - 0.45

Tab.23 Thermal properties of sand/clay soil types
Courtesy of American Society of Heating, Air-conditioning and Refrigeration Engineers Inc., www.ashrae.org.

Most soil is a combination of fine and coarse grain (Table 23). A sieve analysis can be used to determine the percentage of each so that a weighted average can be developed to find an overall conductivity. Moisture content is a major factor, but sand or clay never needs to be heavily saturated to provide good conductivity.

The thermal properties for typical rock are shown (Table 24). There is typically a wide variation in performance. Because of its high porosity, rock generally has lower performance. The 80% range is more conservative and is recommended without more detailed information.

Thermal Properties for Typical Rock

Rock Type	% Occurance in Earth's Crust	k - All Ther. Con. Btu/h•ft°F	K - 80% Ther. Con. Btu/h•ft°F	Cρ Spec. Heat Btu/lb·°F	ρ Density lb/ft³	α (k/ρ Cρ) Ther. Diff. ft²/ day
Igneous Rocks						
Granite (10% Quartz)	10.4	1.1 - 3.0	1.3 - 4.9 1.5 - 2.1	0.21	165	0.9 - 4.3 1.0 - 1.4
Granite (25% Quartz)	10.4	1.1 - 3.0	1.3 - 4.9 1.5 - 2.1	0.21	165	0.9 - 4.3 1.0 - 1.4
Amphibolite	42.8	1.1 - 2.7 0.8 - 2.8	1.5 - 2.2 0.9 - 4.47	0.12	175 - 195 160	1.1 - 4.7
Andesite	42.8	1.1 - 2.7 0.8 - 2.8	1.5 - 2.2 0.9 - 4.47	0.12	175 - 195 160	1.1 - 4.7
Basalt	42.8	1.2 - 1.4		0.17 - 0.21	180	0.7 - 0.9
Gabbro (Cen. Plains)	42.8	0.9 - 1.6		0.18	185	0.65 - 1.15 0.85 - 1.5
Gabbro (Rocky Mtns.)	42.8	1.2 - 2.1		0.18	185	0.65 - 1.15 0.85 - 1.5
Diorites	11.2	1.2 - 1.9	1.2 - 4.7	0.22	180	0.7 - 1.0
Grandiorites	11.2	1.2 - 2.0		0.21	170	0.8 - 4.3
Sedimentary Rocks						
Claystone		1.1 - 4.7				
Dolomite		0.9 - 3.6	1.6 - 3.6	0.21	170 - 475	1.1 - 2.3
Limestone		0.8 - 3.6	1.4 - 2.2	0.22	150 - 475	1.0 - 4.4
Rock Salt		3.7		0.20	130 - 435	
Sandstone	1.7	1.2 - 2.0		0.24	160 - 470	0.7 - 4.2
Siltstone		0.8 - 1.4				
Wet Shale (25% Quartz)	4.2	0.6 - 2.3	1.0 - 4.8	0.21	130 - 165	0.9 - 1.2
Wet Shale (No Quartz)	4.2	0.6 - 2.3	0.6 - 0.9	0.21	130 - 165	0.5 - 0.6
Dry Shale (25% Quartz)	4.2	0.6 - 2.3	0.8 - 4.4	0.21	130 - 165	0.7 - 1.0
Dry Shale (No Quartz)	4.2	0.6 - 2.3	0.5 - 0.8	0.21	130 - 165	0.45 - 0.55
Metamorphic Rocks						
Gneiss	21.4	1.0 - 3.3	1.3 - 2.0	0.22	160 - 175	0.9 - 1.2
Marble	0.9	1.2 - 3.2	1.2 - 1.9	0.22	170	0.8 - 1.2
Quarzite		3.0 - 4.0		0.20	160	2.2 - 3.0
Schist	5.1	1.2 - 2.6	1.4 - 2.2		170 - 200	
Slate		0.9 - 4.5		0.22	170 - 475	0.6 - 0.9

Tab.24 Thermal properties for typical rock
Courtesy of American Society of Heating, Air-conditioning and Refrigeration Engineers Inc., www.ashrae.org.

When discussing pipe properties, typical thermal resistances for four common pipe sizes can be considered (although 1-½" pipe is now becoming more difficult to find) (Table 25). Avoiding laminar flow at design conditions is important to provide good heat transfer. Similar tables exist for various other types of piping.

Using the referenced table, for water, the flow rate should be at least 2.0 GPM for ¾" through 1-¼" pipe, and at least 3 GPM for 1-½" pipe to avoid laminar flow

Pipe Thermal Resistance Based On Borehole Cuttings For Backfilling Around U-Tube

U-Tube Dia.	SDR or Schedule	Pipe (Bore) Thermal Resistance (h•ft•°F/Btu)			
		For water flows above 2.0 US gpm	20% Prop. Glycol Flow 3.0 US gpm	20% Prop. Glycol Flow 5.0 US gpm	20% Prop. Glycol Flow 10.0 US gpm
¾ in. (0.15 ft)	SDR 11	0.09	0.12	NR	NR
	SDR 9	0.11	0.15	NR	NR
	Sch 40	0.10	0.14	NR	NR
1.0 in. (0.18 ft)	SDR 11	0.09	0.14	0.10	NR
	SDR 9	0.11	0.16	0.12	NR
	Sch 40	0.10	0.15	0.11	NR
1¼ in. (0.22 ft)	SDR 11	0.09	0.15	0.12	0.09
	SDR 9	0.11	0.17	0.15	0.11
	Sch 40	0.09	0.15	0.12	0.09
1½ in. (0.25 ft)	SDR 11	0.09[1]	0.16	0.15	0.09
	SDR 9	0.11[1]	0.18	0.17	0.11
	Sch 40	0.08[1]	0.14	0.14	0.08

Tab.25 Pipe Thermal resistance
Courtesy of American Society of Heating, Air-conditioning and Refrigeration Engineers Inc., www.ashrae.org.

[1] Water flow must be at least 3.0 US gpm to avoid laminar flow for these cases.

9.4 Closed-Loop Design Fundamentals

The closed-loop ground heat exchanger is similar to a cooling coil (or an evaporator) in a simple air conditioning (cooling only) system or air-source heat pump during cooling, absorbing heat from the structure to be rejected outside. It can also be compared to the condenser in heating for an air-source heat pump, rejecting heat to the structure. The goal is to transfer heat energy either in the cooling or heating mode to or from the ground heat exchanger and fluid to and from the ground to heat and cool the structure.

The purpose of good ground loop design is to estimate the required loop length (Fig. 37). Software programs exist that can make this design process easier than manual calculations. Bosch offers Geo Solutions Software to Bosch-approved contractors for this purpose. However, both software and manual calculations focus on the estimated structure heating and cooling loads to provide the heat energy transfer rates for sizing the ground loop.

The design supply fluid temperatures must also be estimated. The larger the ground loop for a known structure load, the cooler the supply fluid temperature will be. Lower fluid temperatures improve the geothermal heat pump performance and capacity. Good design must find a balance between geothermal heat pump fluid supply temperature and the capital cost of the ground loop. At steady-state conditions, there is heat transfer from the geothermal heat pump fluid to the ground. Temperature difference between the ground and the fluid in the ground loop provides the impetus for the heat energy to move.

The challenge in ground heat exchanger design is that the ground temperature typically fluctuates dependent upon the type of loop design, vertical or horizontal (Fig. 38, 39). And, for horizontal loops where the pipe is near the surface, the ground temperature can change seasonally with the weather. In all cases, the ground loop itself affects the ground temperature. For good ground loop design, three effects should be considered:

- **Long Term Effect:** This is the change in the ground temperature over many years
- **Annual Effect:** Over the course of a year, the heat load on a loop field will change and this will affect the ground temperature on a monthly basis
- **Short Term Effect:** The actual load on the ground loop will affect the fluid supply temperature

These three effects must be considered to find the required pipe length. The length may be established by the winter heating load requirement or the summer cooling load requirement. If a winter heat loss load establishes the length, the cooling performance should then be estimated with the longer length. This will improve the cooling performance and may allow a smaller geothermal heat pump to be used.

Fig. 37

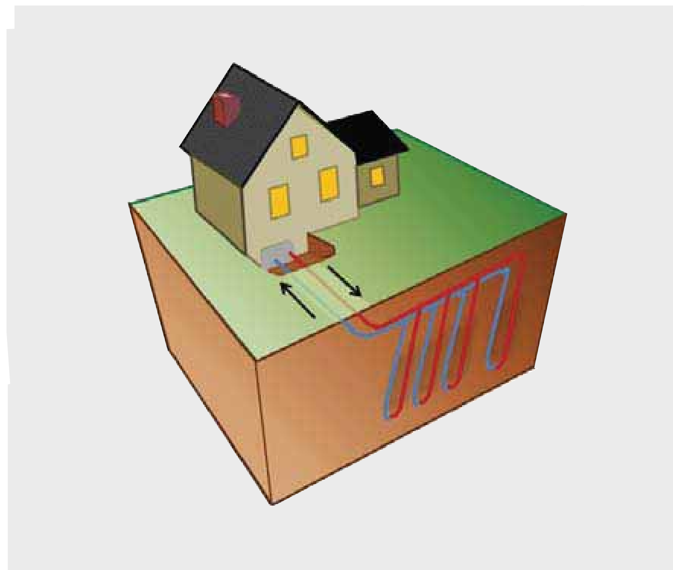

Fig. 38 Vertical Ground Heat Exchanger

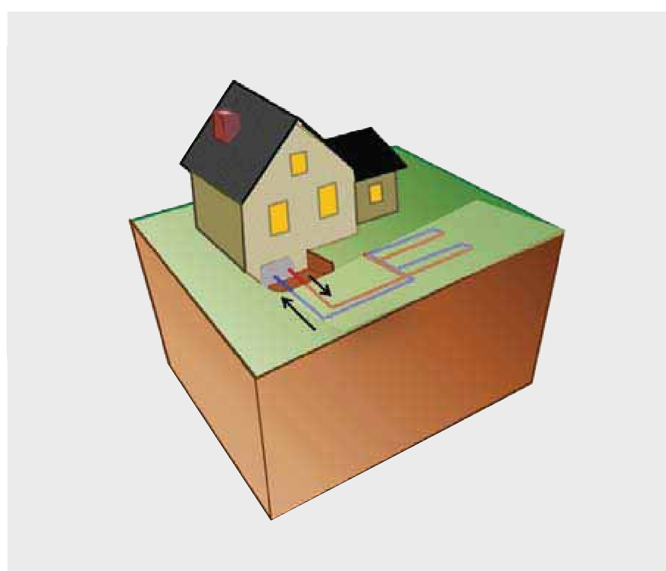

Fig. 39 Horizontal Ground Heat Exchanger

9.5 Soil & Groundwater Temperature

The average soil/groundwater temperature of the upper 100 to 200 feet in most places in the continental U.S. is equivalent to the average ambient air temperature of approximately 60°F to 74°F. The map shown (Fig. 40) indicates the approximate groundwater temperatures in the U.S. There are seasonal variations to the soil/groundwater temperature of approximately 20°F approaching a constant temperature at a depth of approximately 30 feet where it is equivalent to the earth's normal thermal gradient. The undisturbed ground temperature will typically remain constant throughout the year below 30 ft. Above 30 ft. the ground temperature will typically change with the season.

It is this constant soil/groundwater temperature which Bosch geothermal heat pump systems utilize for heating and cooling. Even if soil temperatures rise to 90°F during the summer or even 50°F during the winter, these systems can still utilize the 90°F soil temperature to provide adequate cooling during summer. During winter, the system operates when the air temperature is less than the soil/groundwater temperature.

The temperature difference between the ground and the fluid in the ground heat exchanger drives the heat transfer, so it is important to determine the ground temperature. At depths of less than approximately 6-½ feet the ground temperature will show marked seasonal variation above and below the annual average air temperature. As the depth increases the seasonal swing in temperature is reduced and the maximum and minimum soil temperatures begin to lag the temperature at the surface. At a depth of about 5 feet the time-lag is approximately one month.

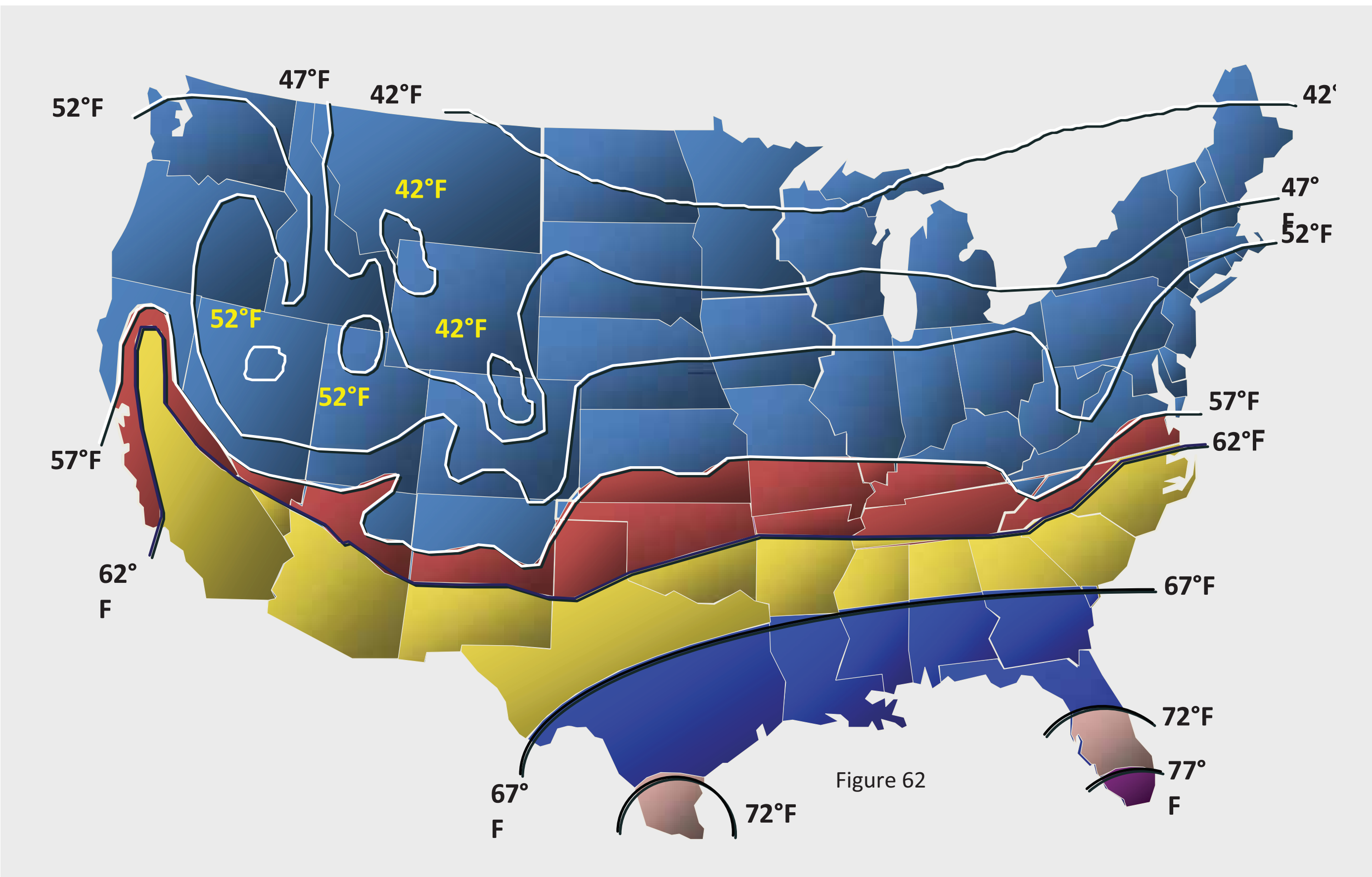

Fig. 40 Approx. ground water temperatures
Courtesy of epa.gov., accessed September 2012

9.6 Piping

Piping should be as specified in the International Ground Source Heat Pump Association (IGSHPA) standards for closed loop heat pumps (Fig. 41). Current practice is the use of high-density polyethylene (HDPE) PE345434C or PE355434C with a UV stabilizer of C, D, or E as specified in American Society for Testing and Materials (ASTM) D-3350 with the following exception: this material shall exhibit zero (0) failures (FO) when tested for one-hundred, ninety-two (192) hours or more under ASTM D-1693, condition C, as required in ASTM D-3350. Cross-linked polyethylene (PEX-A) is also suitable for ground heat exchanger use but is less commonly used even though it is IGSHPA-approved. New piping materials may be developed which meet all IGSHPA and ASTM requirements for these systems.

Fig. 41
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

HDPE is suitable for use as the buried ground heat exchanger for a Bosch geothermal heat pump system. This piping is typically joined by heat fusion for all Iron Pipe Size (IPS) dimensions. HDPE is manufactured according to dimension ratios to determine wall thickness. Dimension ratio (DR) is the ratio of the outside pipe diameter to the wall thickness. DR relates to the pressure rating for the pipe. Factors affecting the pressure rating of pipe include the material it is made from, wall thickness and temperature. Never use pipe where the system working pressure exceeds the manufacturer's specified maximum working pressure. Heat transfer resistance in a major concern for HDPE piping and the thermal conductivity of this pipe is approximately 0.225 Btu/hr-ft.-F.

Vertical piping wall thickness for a particular borehole should be no less than that of "Standard Dimensions Ratio" (SDR) eleven (11) (outside diameter). SDR11 is the ratio of the diameter of pipe and the thickness of the pipe's wall; the outside diameter of the pipe is eleven times the thickness of the wall.

Pipe selection for ground heat exchangers should include being large enough to keep pumping power requirements to a minimum, but small enough to ensure turbulent flow in the circulating fluid. This practice will typically maximize heat transfer between the fluid and the pipe wall. Always size the pipe to achieve a flow of 1 to 4 feet of head loss per 100 feet of pipe for any type of circulating fluid. This will ensure the proper balance between minimal pumping power needs and material costs, while maximizing thermal performance.The recommended maximum pressure drop for a close-loop system is 4 feet of head loss per 100 feet of pipe. The chart shown (Table 26) provides approximate maximum flow rates for water based on 4 feet of head loss per 100 feet of pipe. HDPE utilizes heat fusion methods such as butt fusion, socket fusion, sidewall fusion, and electro-fusion to join the material, which creates a joining system stronger than the pipe itself.

Approx. Maximum Flow Rates For Water Based On 4 Feet Of Head Loss Per 100 Feet Of Pipe

Nominal Dia. (in.)	SDR 11 HDPE	SDR 17 HDPE	Sched 40 Steel	Sched 80 Plastic	Copper Type L
¾	4.5	-	4	3	3.5
1	8	-	7	6	7
1¼	15	-	15	13	13
1½	22	-	23	21	20
2	40	-	45	40	44
3	110	140	130	125	130
4	220	300	260	250	260
6	600	750	800	750	800
8	1200	1500	1600	1500	-
10	2200	2600	3000	-	-
12	3500	4200	4600	-	-

Tab. 26 Per ASHRAE recommended head loss of 4 ft. water 100 ft. of pipe (courtesy of www.ashrae.org)

Multipliers for antifreeze mixtures:
20% propylene glycol = 0.85 20% methanol = 0.90

9.7 Pipe Fusion Methods

The three basic types of HDPE pipe joining methods that are used for earth coupled applications are socket fusion, butt fusion, and sidewall fusion. In all processes the pipe is melted together to form a joint. The preferred method for 2" and smaller diameter pipe is typically socket fusion, because it allows the tolerance of mating the pipe to be much greater, the socket fusion joint is 3 to 4 times the cross sectional area of a butt fusion joint in sizes under 2" and therefore tends to be more forgiving of operator skill level, and joints are frequently required in difficult trench conditions. Once the pipe diameter gets over 2", socket fusion loses its advantages, and butt fusion is typically the method of choice. Butt fusion requires a different fusion machine, which is larger and less maneuverable. All technicians doing fusion joints should be certified by the pipe manufacturer or the geothermal heat pump manufacturer, as well as IGSHPA.

Another fusion method available is Electro-fusion (EF), where joining pipes means incorporating an electrical heating coil. When electrically activated the welding machine melts the surface of the pipes and/or pipes/ fittings together resulting in complete fusion.

Another more recent connection method is a compression method referred to as the “Stab” method. The fitting used for this method features an internal seal and is an all plastic fitting that contains no metal parts (Fig. 42). This method is approved by IGSHPA. Several manufacturers offer these cost effective joining devices. They provide simple assembly and only require the installer use a chamfer tool. Note: Earth loop systems require a hydrostatic test of typically 40-50 PSI before backfilling to test for leaks.

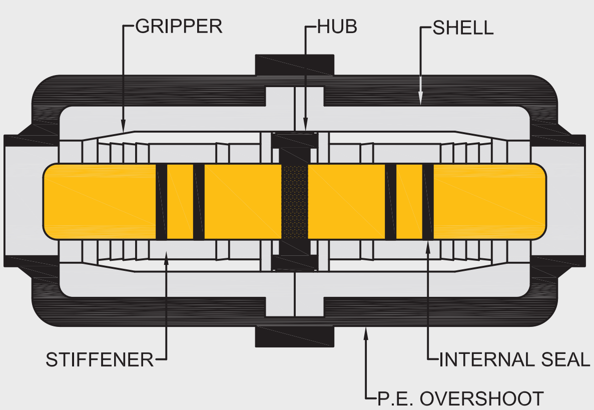

Fig. 42 Pipe fusion - Stab method
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

Socket fusion joins two ends of pipe by fusing each pipe end to a socket fitting. This requires two heat fusion procedures for each joint. This method requires the technician to assemble the required equipment and tools prior to fusing. Complete tool kits for socket fusion are available (Fig. 43). These include an appropriate power supply, a heater plate with correct socket faces, a depth gauge, a cold ring, tubing cutters, a temperature-sensing device, and clean, dry cotton rags.

Fig. 43 Socket fusion tool kit

The steps involved include correctly preparing the socket fusion machine, cleaning and heating the socket faces to the proper temperature, properly preparing the pipe ends and fittings for fusion, using a proper depth gauge and cold ring, simultaneously heating the pipe and fitting, properly fusing the pipe and fitting and testing for leaks.

After the fusion process, and completing the specified cooling and waiting time, remove the cold ring clamp and the socket fitting holder. A good joint will have a uniform melt ring that is flat against the socket fitting and perpendicular to the pipe.

Visually check the joint for uniformity and to assure no gaps or voids exist (Fig. 44, 45). There should be no un-bonded areas between the fitting and the pipe.
Allow an additional 10 minutes undisturbed cooling time before testing, backfilling, or stressing the joint.

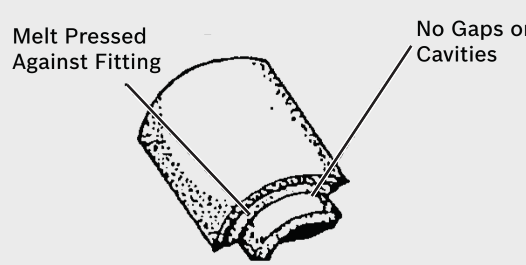

Fig. 44 Socket fusion
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

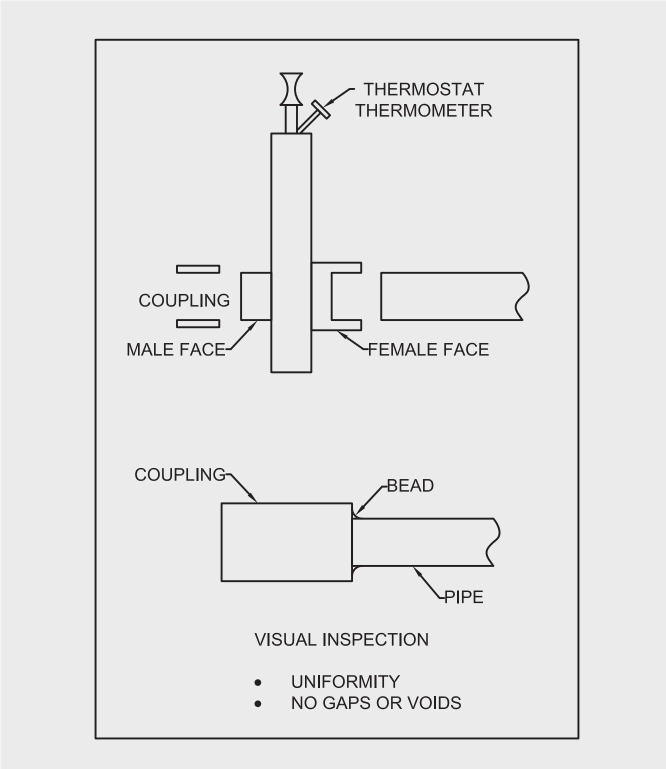

Fig. 45 Socket fusion joint inspection

Butt fusion is the joining procedure where two pipe ends are simultaneously heated to a plastic state by a heater plate and brought together to form the heat-fused joint (Fig. 46, 47). A single heat fusion process is used to form the joint between the two pipe ends. This process is performed by using specially designed machines which provide for securely holding the two pieces of pipe to be fused, aligning them, trimming and squaring their ends, heating the surfaces to be joined with a heater plate, and butting them together while they remain in a plastic state, producing a double rolled back bead. This method requires the technician to assemble the required equipment and tools prior to fusing. Then he/she must prepare the fusion machine correctly, clean and heat the heater to the proper temperature, prepare the pipe ends properly for fusion, heat the pipe ends and fuse the pipe properly.

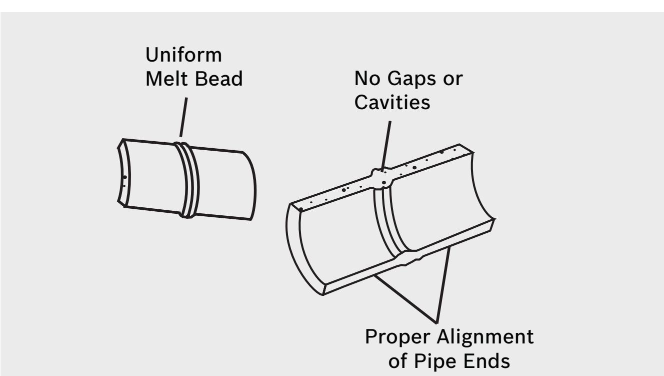

Fig. 46 Butt fusion
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

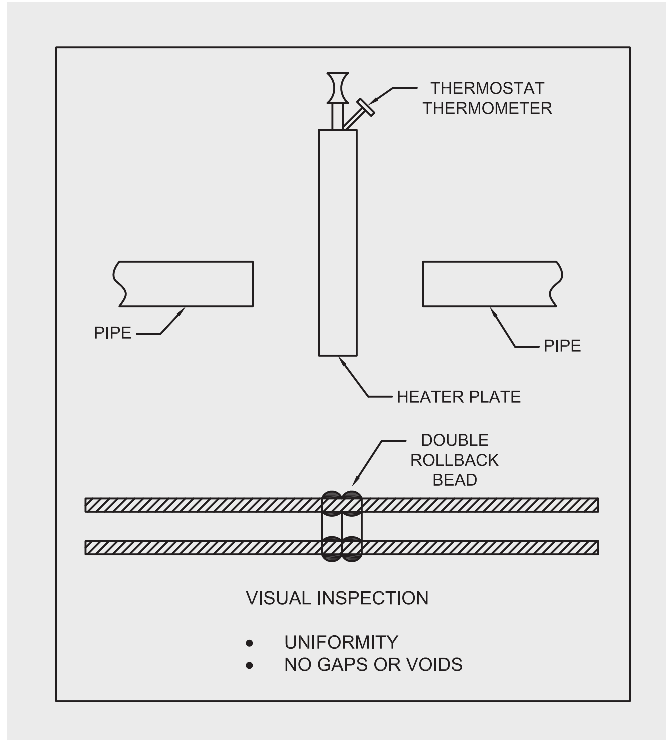

Fig. 47 Butt fusion visual inspection

Sidewall butt fusion joining is used when joining the concave surface of a service saddle to the convex surface on the sidewall of a pipe (Figure 71). This procedure involves heating these surfaces with appropriate convex- and concave-shaped heaters and then butting these surfaces together.

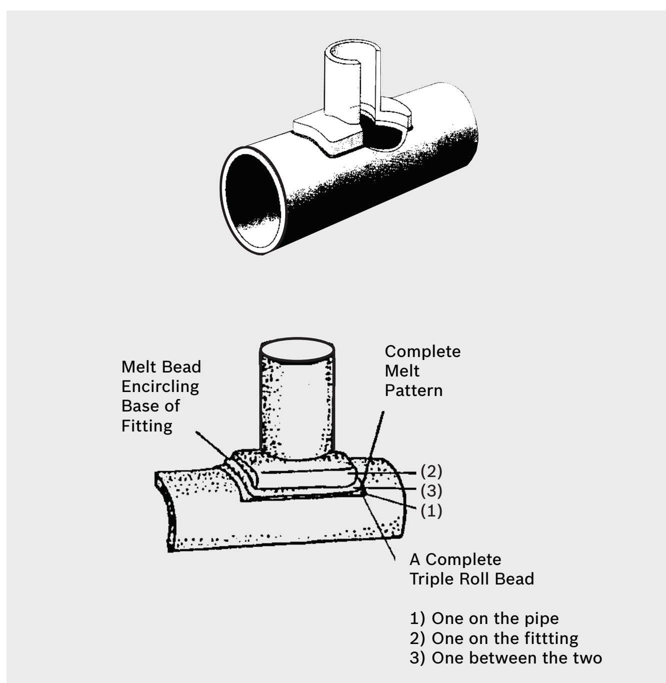

Fig. 48 Sidewall butt fusion Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

HDPE pipe is heat fused and joined using both socket and butt fusion procedures. Material, grade, density and other variables help determine if the particular grade of pipe can be fused with either method. Some HDPE materials cannot be socket fused. HDPE pipe for typical residential ground heat exchangers is socket fused.

Both socket and butt fusion yield highly reliable joints when properly performed. These joints are typically stronger than the pipe itself. Typical fusion times are shown in Table 27.

Typical Fusion Times

Pipe Size	Socket Fusion Time (Sec.)	Butt Fusion		Holding Time	Curing Time
		Time (Sec.)	Bead in. [mm]		
¾" 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.
1¼" IPS	12 - 15	15	1/16 - ⅛ [1.6 - 3.2	60 sec.	20 min.
1½" IPS	15 - 18	15	1/16 - ⅛ [1.6 - 3.2]	60 sec	20 min.
2" IPS	18 - 22	18	⅛ [3.2]	60 sec	20 min.

Tab. 27

Aways use a timing device.

9.8 Heat Transfer Fluids (Antifreeze)

In areas where minimum entering loop temperatures can drop below 40°F, or where piping may be routed through areas subject to freezing, antifreeze is required (Fig. 49). Alcohols and glycols are commonly used as antifreeze. This heat transfer fluid is needed to transfer heat between the ground heat exchanger and the Bosch geothermal heat pump system when a closed-loop system is used. The antifreeze should exhibit acceptable heat transfer and pumping characteristics, be safe to install, reasonable in cost, provide corrosion protection to system materials, and not produce an unacceptable risk to the environment in the event of a system leak.

Fig. 49 Heat transfer fluids

The antifreeze is normally placed in the system from inside the structure after the entire ground heat exchanger (or “loop field”) is completed, pressure tested, flushed, and purged. The concentration of the antifreeze solution should be checked to assure proper freeze protection. Freeze protection should be maintained to approximately 15°F below the lowest expected entering loop temperature. The volume of the ground heat exchanger and the volume of the structure piping will determine the amount of antifreeze needed for the desired protection. If concentrate is added, time for proper mixing will need to be considered. At the antifreeze add point there should be identification posted of the antifreeze material, manufacturer, and other identifying information. Additionally, antifreeze must always be transported in identified containers.

Several different types of antifreeze are available for use with Bosch closed-loop geothermal heat pump systems. These include but are not limited to methanol, propylene glycol, ethanol, and urea. The geothermal industry has historically used methanol, propylene glycol and ethanol for most applications.

Methanol has been the first choice for many installers of geothermal heat pump systems and has delivered outstanding performance in closed-loop ground heat exchangers for over 20 years. This toxic antifreeze works very well because it is typically less expensive to buy and flows better (has low viscosity) down to approximately 15°F than other types of antifreeze available. Methanol has relatively good heat transfer ability as well. However, it is extremely poisonous to humans and other animals in any form and evaporates quickly. This process can result in asphyxiation if an installer or other person fails to follow all of the safety precautions for the substance. Methanol is also highly flammable in concentrations greater than 25%, and can cause an explosion.

Several states in the US have outlawed methanol use in closed-loop ground heat exchangers buried deeper than approximately 20 feet, and other states have outlawed its use in all closed-loops in an effort to protect the groundwater if the closed-loop should leak. However, even with a closed-loop leak, methanol tends to biodegrade rapidly.

Propylene glycol is used in the food preparation industry and is considered non-toxic and non-corrosive. Only food grade propylene glycol is recommended for geothermal use to prevent the corrosion inhibitors (often present in other mixtures) from reacting with local water. Unfortunately, propylene glycol has exhibited some viscosity problems at lower temperatures that limit its use as antifreeze for flowing fluids with closed-loop geothermal heat pump systems. It is however acceptable in systems anticipating loops temperatures no colder than approximately 40°F. These systems typically use antifreeze because of low ambient conditions (outside plumbing, etc.). When loop temperatures are below 40°F, the fluid becomes very difficult to pump and heat transfer decays. Propylene glycol is relatively expensive and exhibits the poorest heat transfer of all antifreezes for geothermal use. It has also been known to form “slime-type” coatings inside geothermal piping. Installers should always use proper design principles when considering its use in ground heat exchangers, as it is possible with poor design for the fluid flow to be too fast in the summer and too slow in the winter.

Ironically, propylene glycol's low toxicity makes it the only closed-loop antifreeze many states allow for ground heat exchanger use. Many sources recommend propylene glycol, but only for closed-loop ground heat exchangers that have been properly sized and designed by a knowledgeable ground heat exchanger designer or by using an industry-accepted software program such as Bosch’s Geo Solutions.

Ethanol or grain alcohol is also used by many installers for geothermal heat pump closed-loop ground heat exchangers. It has similar characteristics to methanol and flows well. It also exhibits relatively good heat transfer abilities, while providing good freeze protection down to approximately 15°F in most situations. As with methanol, ethanol is also very flammable in concentrations greater than 10% and can cause explosions and asphyxiation. The U.S. Bureau of Alcohol, Tobacco, and Firearms (ATF) limits its distribution. Ethanol used for geothermal applications must not be denatured with any petroleum based product. Denaturing agents that are petroleum based can damage polyethylene pipe.
Recommended levels of antifreeze solutions used in geothermal heat pump applications are shown in Table 28.

Recommended Levels of Antifreeze Solutions

Type	Minimum Temp for Low Temp Protection			
	10°F [-12.2°C]	**15°F [-9.4°C]**	**20°F [-6.7°C]**	**25°F [-3.9°C]**
Methanol	25%	21%	16%	10%
100% USP food grade Propylene Glycol	38%	25%	22%	15%**
Ethanol*	29%	25%	20%	14%

Tab. 28

* must not be denatured with petroleum based product.
** Not recommended without inhibitors

Antifreeze will change the properties of the closed-loop ground heat exchanger fluid. Adding antifreeze will generally lower the thermal capacity of the fluid and increase the viscosity, which will increase pumping requirements. Also, the “Reynolds number (Re)” (for calculating flow – typically 2,100 minimum) will decrease and raise the flow rate (GPM) at which laminar flow begins. The “Reynolds number (Re)” expresses the ratio of inertial (resistant to change or motion) forces to viscous (heavy and gluey) forces. To offset these effects, the design flow rate (GPM) may need to be increased. Most closed-loop ground heat exchanger design software programs (such as Bosch’s Geo Solutions) include a range of antifreezes and take into account the change in properties.

A potential negative effect of all geothermal heat pumps is the release of antifreeze solutions to the environment. These chemicals are generally mixed with water when used as a heat exchange fluid and can be released via spills or corrosion of system components. Always check with local codes and authorities concerning acceptable antifreeze use and procedures.

The antifreeze mixture used in the Bosch geothermal heat pump system also has an effect on the system economics, including the cost of the antifreeze, the change in pipe resistance, Bosch geothermal heat pump performance and the change in pumping requirements.

All alcohols (methanol and ethanol) should be premixed and pumped from a reservoir outside of the home if possible, or introduced under the water level to prevent fumes. The installer can calculate the total volume of fluid in the piping system by using the chart shown (Table 29). Then use the percentage by volume shown in the previous table for the amount of antifreeze necessary. Ground heat exchanger software programs can also determine the volume of fluid in the piping system. Antifreeze concentration should always be checked using a well mixed sample and a hydrometer to determine the specific gravity and protection level.

Fluid Volume (gal [L] / 100' Pipe)		
Pipe	**Size**	**Volume (gal) [L]**
Copper	1"	4.1 [15.5]
	1.25"	6.4 [24.2]
	2.5"	9.2 [34.8]
Rubber Hose	1"	3.9 [14.8]
Polyethylene	¾" IPS SDR11	2.8 [10.6]
	1" IPS SDR11	4.5 [17.0]
	1.25" IPS SDR11	8.0 [30.3]
	1.5" IPS SDR11	10.9 [41.3]
	2" IPS SDR11	18.0 [68.1]
	1.25" IPS SCH40	8.3 [31.4]
	1.5" IPS SCH40	10.9 [41.3]
	2" IPS SCH40	17.0 [64.4]
Unit Heat Exhanger	Typical	1.0 [3.8]
Flush Cart Tank	10" Dia x 3ft [254mm x 0.9m]	10 [37.9]

Tab. 29

9.9 Closed-Loop Configuration

An installer must use good judgment and knowledge when determining the type of ground heat exchanger to install. Some of the factors that must be considered include the yard or lot size and the probable cost of excavation. For example, a one inch horizontal pipe ground heat exchanger will require significantly more trench than a six inch horizontal pipe ground heat exchanger. Labor is also an important consideration for the ground heat exchanger. Additionally, it could be necessary to utilize the larger diameter pipe ground heat exchanger simply due to limited ground space for installation.

Most installers will develop ongoing knowledge of different ground heat exchanger options and the most cost effective design for various situations. This understanding over time will allow the most effective application for later installations.

For most horizontal ground heat exchangers, the depth of the piping is typically around 5 to 6 feet below the surface. This is often due to trench safety concerns and the volume of earth (soil) that must be moved. For most vertical ground heat exchangers, parallel-series ground heat exchanger designs prove more economical due to increasing drilling costs. This design incorporates a piping arrangement where a circuit will travel down and then up through two or more consecutive boreholes (series) to provide the required total length for the application.

Soil moisture content and different soil types can have an impact on the earth ground heat exchanger design as well. Damp or saturated soil types will typically require shorter ground heat exchangers that those used for dry soil or sand.

Ground heat exchanger design is often a compromise between pressure drop and turbulent flow in the ground heat exchanger pipe when considering effective heat transfer. To achieve an effective and acceptable Reynold’s Number the following recommendations should be followed during the design phase:

- 3 gallons per minute (GPM) per ton of cooling capacity should be maintained for smaller systems
- For larger systems, slightly less GPM is acceptable (2.5 - 2.7 GPM per ton of cooling capacity)
- It is difficult to select pumps to attain exactly 3 GPM per ton of cooling in most cases and is typically not cost effective
- One circuit per nominal ton of cooling capacity (adjustable to two circuits per ton if necessary)

9.10 Underground Piping Installation Criteria

Piping, fittings and joints must be compatible with the heat transfer fluid, antifreeze and must be corrosion resistant. All piping, fittings, joints and other materials used in closed-loop ground heat exchangers should meet the standards referenced by the National Groundwater Association (NGWA) in its Guidelines for the Construction of Vertical Boreholes for Closed Loop Heat Pump Systems. All underground piping joints should be either socket or butt joints, thermally fused according to the piping manufacturer's specifications. Glued or clamped joints should never be used below ground with closed-loop ground heat exchangers. Joints must not leak after assembly.

Flushing, air purging and pressure testing are part of the standard installation process for closed-loop ground heat exchangers. Pressure testing should be conducted at a minimum of 100 psi for at least 30 minutes with no observed leaks.

Underground piping should be installed following standards set by the International Ground Source Heat Pump Association (IGSHPA) in Closed-Loop / Geothermal Heat Pump Systems - Design and Installation Standards.

Special attention should be paid to avoid sharp bends in piping and remove sharp-edged rocks or other material in the trench backfill. Either can cause damage to the piping, potentially causing loss of system integrity and fluids. Trenches should be constructed and backfilled in accordance with manufacturer's specifications. Backfill should be seeded and covered after settling has taken place. Filled excavations should be periodically monitored and erosion controls should be maintained until settling is complete and permanent ground cover is in place.

All horizontal closed-loop trenches and vertical boreholes must be constructed to prevent contamination from occurring or spreading to groundwater. Underground horizontal closed-loop ground heat exchangers should be installed parallel to surface contours whenever possible.

The recommended design today for closed-loop ground heat exchangers is the reverse return header layout (Fig. 50). This approach distributes the flows and pressures more evenly across the system, making it more inherently balanced.

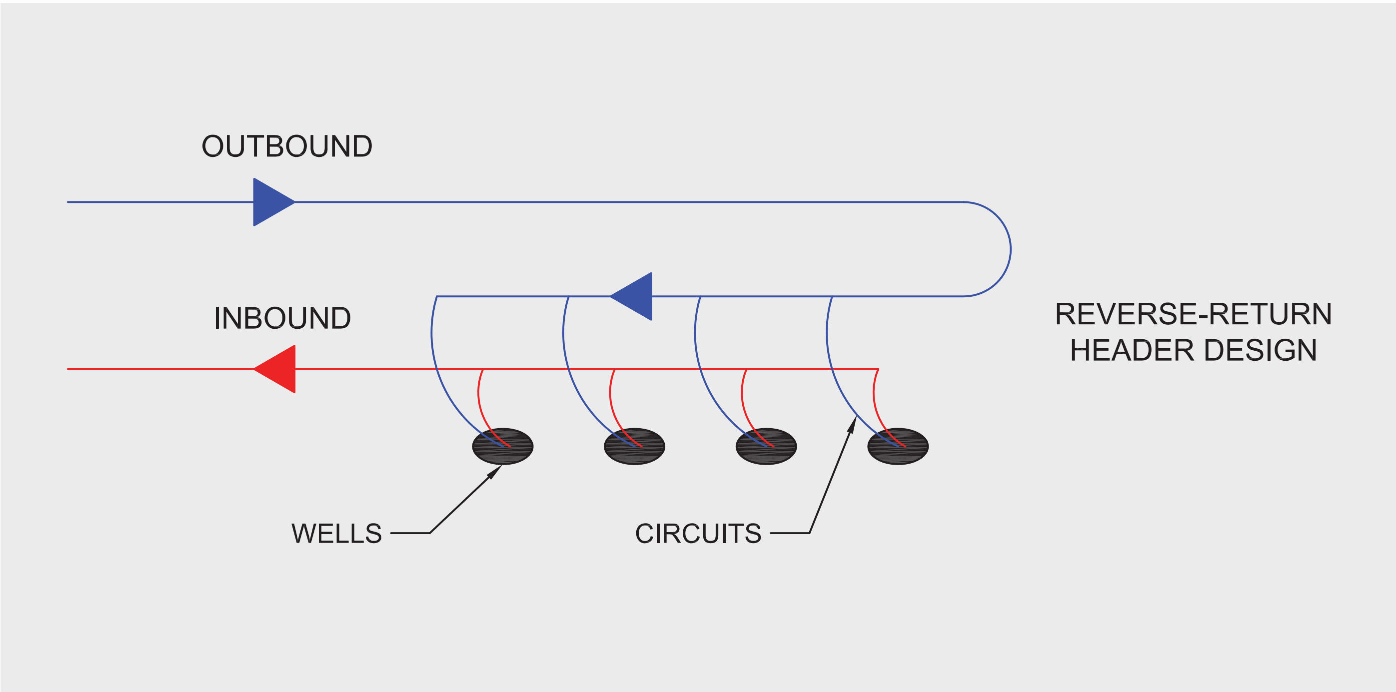

Fig. 50 Reverse return piping

9.11 Closed-Loop Header Design

A closed-loop header is simply a series of larger diameter horizontal pipes that connects the geothermal flow center to each of the smaller diameter circuits located within each borehole. Parallel ground heat exchanger headers are typically designed with consideration for pressure drop and the ability to purge air from the ground loop. A typical header for capacities up to 15 tons of cooling is shown (Fig. 51).

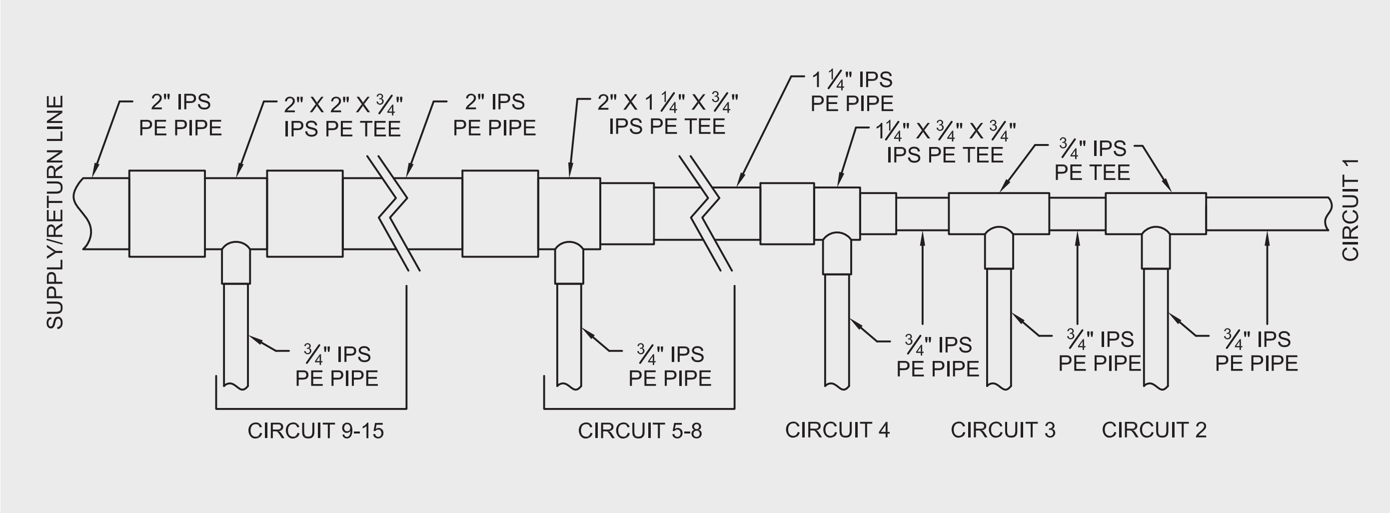

Fig. 51 Header capacities up to 15 tons of cooling

The header shown next (Fig. 52) is designed for capacities up to a nominal 5 tons of cooling. It uses 1-1/4 inch IPS pipe for circuits 4 to 7, and ¾ inch IPS for circuits 1-3, allowing minimum pressure drop while maintaining 2 Feet per Second (FPS) velocity under normal flow conditions. This means the header is actually self-flushing, as typical flushing criteria outlined by IGSHPA requires a minimum of 2 FPS to purge a ground heat exchanger for field use.

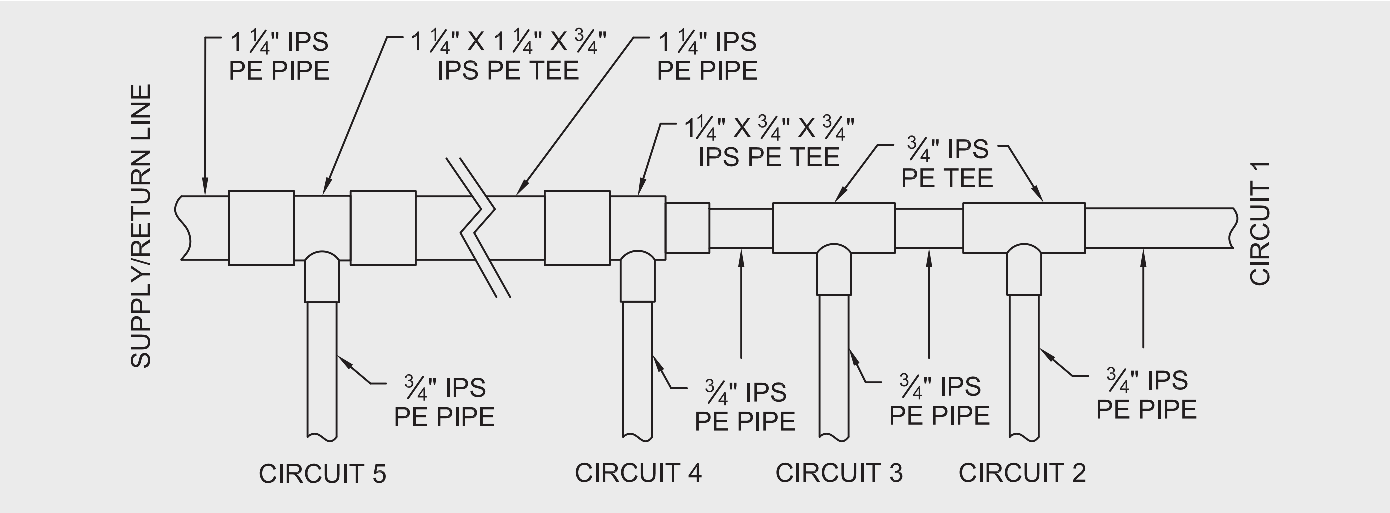

Fig. 52 Header capacities up to 5 tons of cooling

To determine the flushing requirements for any ground heat exchanger using the header styles shown, multiply the number of circuits by the flushing flow rate of each circuit.

Header layouts are more cost effective with short headers. This means the installer must centrally locate the header with relationship to all circuits, and then bring the circuits to the header.

Some installers use a “closed header” as shown (Fig. 53), at the end loops to balance flow more evenly.

Fig. 53 Closed header
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

10 Vertical Closed-Loop Ground Heat Exchangers (Vertical Loops)

Many installers prefer vertical loops as ground surface requirements for them are much lower than horizontal loops (Fig. 54). Vertical loop configurations are the most expensive of all of the closed loop configurations due to the fact that large boreholes must be drilled down to a suitable depth, piped and then filled with a thermal grouting compound. These types of closed-loop systems are ideal for areas where land surface space is limited and the required area needed to cool and/or heat the structure with a horizontal loop exceeds what is available. Also, in situations where the earth is rocky close to the surface or when the geothermal heat pump system is retrofitted to an existing structure and limited land disturbance is required, the vertical loop configuration is a more appropriate choice. The number of boreholes is directly related to the depth of the boreholes, that is, fewer boreholes for deeper boreholes. The depths of the boreholes will generally depend on the needs of the structure as well as the cost.

With vertical loops the heat exchange takes place along the vertical drilled borehole walls. Only a small diameter hole is normally required for each ton of geothermal heat pump cooling capacity. Minimal spacing is required between boreholes, and is typically 10 feet for residential applications. Vertical loops make a geothermal closed-loop application possible for almost any home that has a small yard, driveway or sidewalk. Vertical loops can even be installed underneath the foundation if permitted by local codes. The borings for vertical loops should be at least 25 feet away from any septic systems. Un-grouted borings would be considered wells and should be placed 100 feet from any septic system.

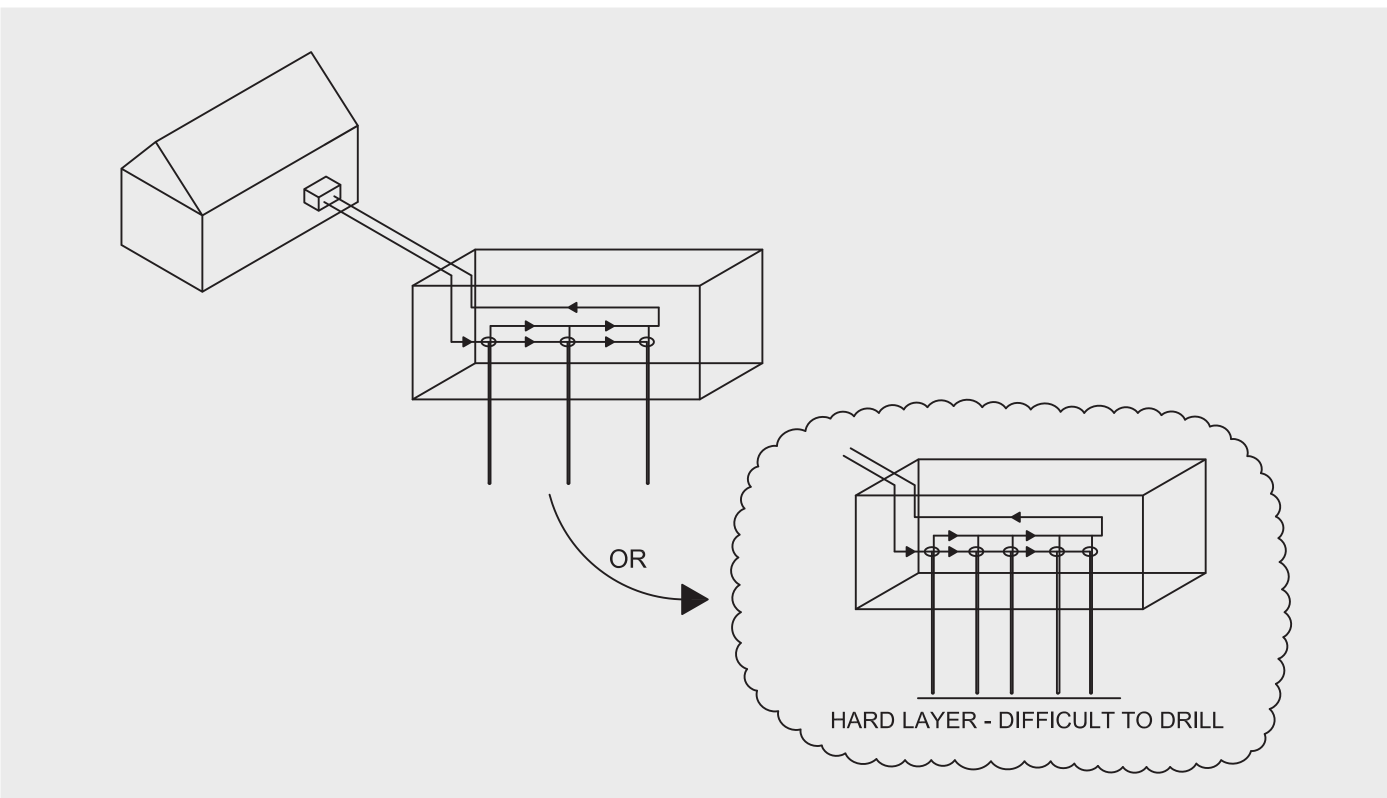

Fig. 54
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

Vertical loops require a contractor to use well-drilling equipment to normally bore a 4-6 inch diameter vertical hole in the ground. These vertical boreholes are typically anywhere from 150-450 feet deep. Sometimes the depth could be outside this range depending on the specific situation and ground conditions. Next, a single pipe loop with a U-bend at the bottom is typically inserted into the drilled hole (Fig. 55). Occasionally multiple loops are inserted into the same borehole. After the pipe (or pipes) is/are inserted, the hole will typically be filled from bottom to top with grout.

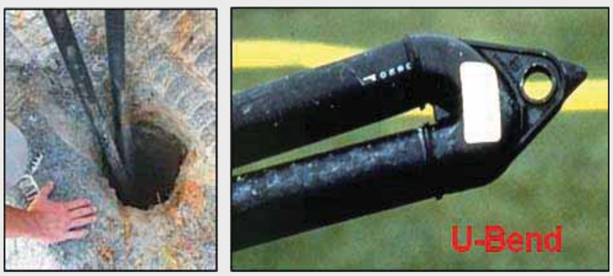

Fig. 55 Single loop with U-bend

Each vertical pipe is then connected to a horizontal pipe (header), which is also buried underground. The horizontal pipe then carries fluid in a closed system to and from the Bosch geothermal heat pump unit. Vertical loops are generally more expensive to install, but require less piping than horizontal loops because the earth at deeper depths is cooler in summer and warmer in winter.

The vertical ground loop should be designed using the appropriate ground thermal characteristics (conductivity and diffusivity) for the site. These parameters may be determined from existing information (local well logs, United States Geological Survey (USGS), state geology department data), a test bore, or a loop test. The thermal characteristics of the native material must be adjusted for the borehole diameter, the type of grout/fill, and the pipe diameter.

When dealing with vertical loops, many factors affect the thermal resistance of the ground loop. These include the pipe properties, flow rate, backfill and grout properties, soil properties and fluid properties.

10.1 Groundwater Effects

Groundwater movement through the borehole field can have a large impact on its performance. Groundwater recharge (vertical flow) and groundwater movement (horizontal flow) can all carry away large amounts of heat. Evaporation can also cool the surface soil and improve horizontal loop performance.

The presence or absence of groundwater also influences total borehole length requirements. Groundwater movement assists in heat diffusion and can help overcome an imbalance in the annual thermal loads (cooling dominated loads) to prevent long term temperature buildup in the ground around the loops. The loop installer/designer should account for the presence or absence of groundwater in the loop design.

It is assumed that a smaller borehole diameter is also less likely to permit aquifer contamination by water movement through the borehole. Long-term changes in localized ground or groundwater temperatures can occur if the system heating and cooling loads are not balanced. For borehole-to-borehole spacing, the installer/designer should consider the depth of the borehole, the loop field arrangement, drilling method, drilling and geologic conditions, the annual thermal loading and land surface restrictions.

Larger systems with larger loads require more space between boreholes. The annual thermal loading should be considered for larger systems for long-term thermal changes in the subsurface. Subsurface thermal changes can negatively impact the efficiency of the system. Increases of groundwater temperatures of neighboring property are highly unlikely with a properly operating closed loop geothermal heat pump system. The drilling contractor may also be concerned about drilling into other boreholes at depth, which is more likely with closer borehole spacing. Larger system loop fields may be divided into separate clusters or circuits to accommodate flushing, purging and leak detection/repair. The number of boreholes per circuit will depend on borehole depth, spacing, heat extraction or rejection load, and site layout.

Headers should be designed to maintain uniform fluid velocities and to facilitate flushing and purging during construction and balanced flow during normal operation. The use of close coupled header designs instead of extended or reduced header designs will generally eliminate the need for reverse return piping. However, reverse return is common for the industry. Headers may be field fabricated or prefabricated.

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. Many installers simply direct all trenches into a common pit area which allows the use of an “L” type header (Figure 56). This design helps achieve reverse return flow by installing the headers in a mirror image configuration.

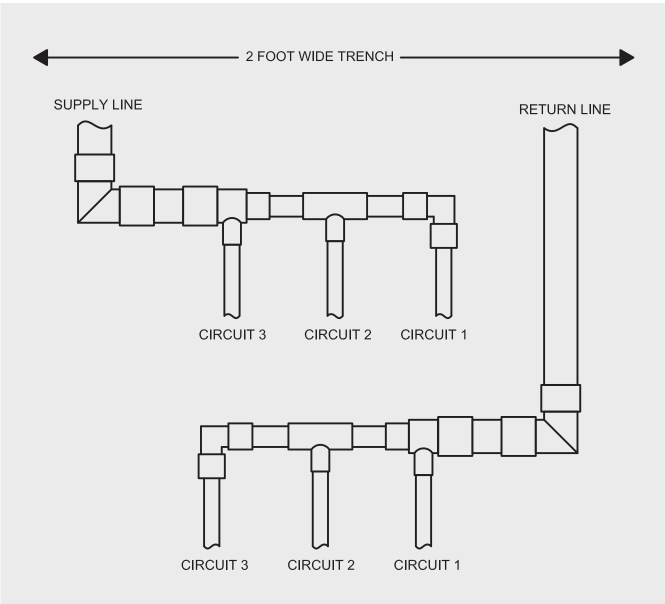

Fig. 56 L-type header

10.2 Piping Installation and Borehole Alignment

Installation of the piping into the borehole is never perfect. Under most conditions, the contractor/installer can follow typical installation practices. Two typical examples are shown below (Fig. 57, 58).

Alignment of a borehole is never perfect either, and under most conditions, the installer can typically keep alignment within practical limits by exercising good judgment and care. Borehole alignment is more critical when utilizing deeper boreholes. Misalignment of boreholes is typically related to the type of the material penetrated while boring, the trueness of the surface or bridge casing, the tension of the cable tool drilling line, and the pull-down force on the drill pipe when using rotary drilling. The borehole should be aligned so that the closed-loop piping can be placed into the entire borehole depth, while assuring that borehole and piping do not intersect other boreholes and piping.

For vertical earth loops, regulations which govern water well installations also apply to vertical ground heat exchanger installations. Vertical ground loop applications typically require multiple boreholes. The boreholes typically are a minimum of approximately 10 feet apart. In more cooling dominated climates such as the southern portion of the U.S., 15-20 feet is typical.

Available geothermal software programs like Bosch Geo Solutions can provide detailed information concerning loop lengths based on borehole spacing.

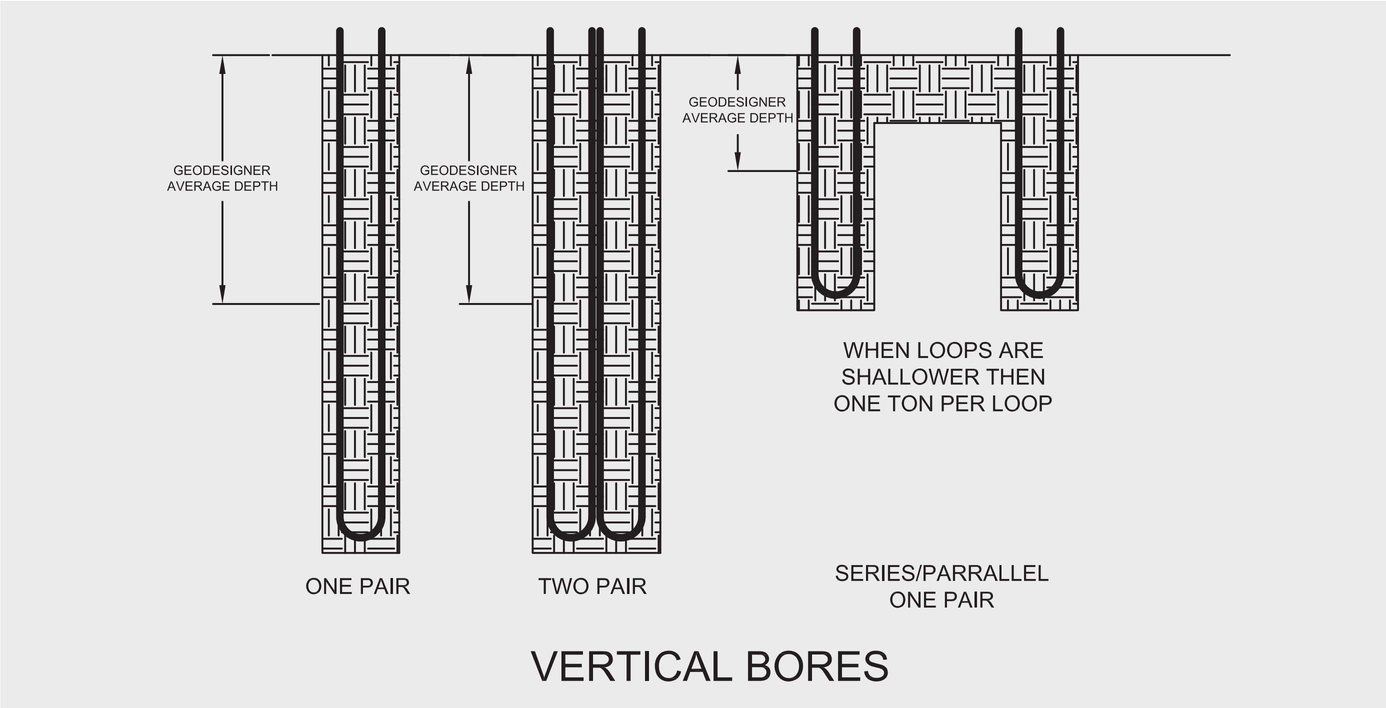

Fig. 57
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

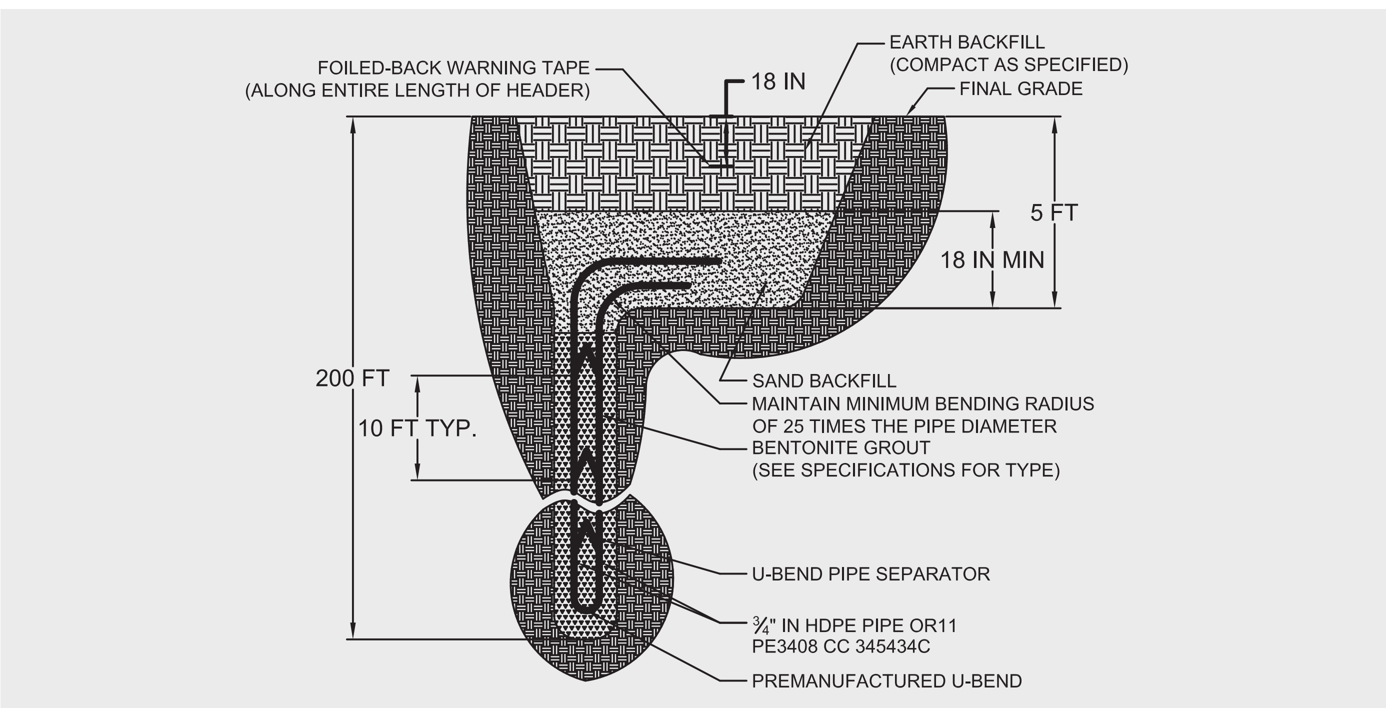

Fig. 58
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

10.3 Loop Field Identification

Because the loop field will be buried and out of sight, it is important to identify the location of the boreholes in case header repairs are needed or excavation work needs to be performed. Typical methods are shown (Figure 59).

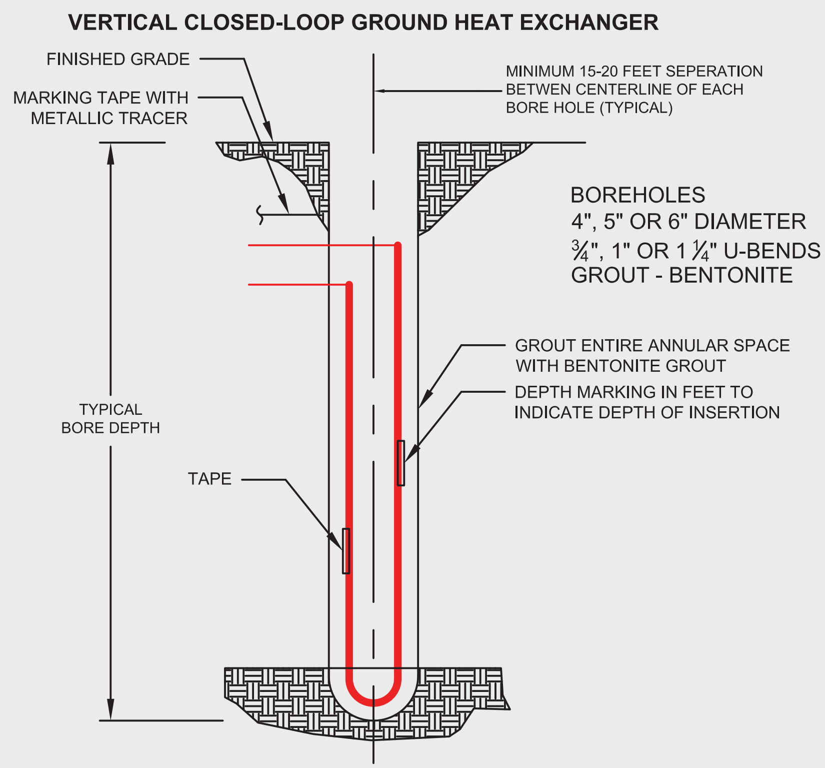

Fig. 59 Vertical closed-loop ground heat exchanger
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

A recommended practice is to utilize conductive tracer wire (sometimes known as locator wire), or magnetic tape, so that boreholes and buried piping can be located in the event that construction is planned near a ground heat exchanger loop field, or if repairs to the loop field are necessary (Fig. 60). Tracer wire and magnetic tape responds to electromagnetic locating equipment above ground. The tracer or magnetic tape should be laid in horizontal trenches and along the supply and return lines between the header and structure. The wire or tape should be laid in a continuous loop and be buried at least 24 inches deep. The ends of tracer wire must be accessible at the surface in a test port or terminated above final grade at the structure foundation with a permanent label indicating the nature of the wires. Tracer wire access locations need to be clearly identified.

Fig. 60 Conductive tracer wire

If possible, plastic tags or labels reading "Geothermal Lines Buried Below" or plastic “Caution” tape should be placed in the backfill approximately twelve inches below the final surface elevation.

10.4 Location of Vertical Closed-Loops

The following minimum horizontal separation distances typically should be maintained when installing a vertical (or horizontal) closed-loop ground heat exchangers (Fig. 61, 62):

- 50 feet from a household drinking water well
- 75 feet from a public water supply well
- 25 feet from an on-site wastewater system serving a single-family dwelling
- 10 feet from a buried water service line or sewer line
- 10 feet from a property boundary

Water lines and sewer lines that are crossed by piping or header piping should be protected by insulation and not less than 3 feet of separation. Local health department permitting ordinances may require different minimum horizontal separation distances.

Fig. 61

Fig. 62

10.5 Borehole Construction

Prior to borehole construction, the installer should always locate and mark all existing underground utilities, piping, etc. All ground heat exchangers should be installed for new construction before any sidewalks, patios, driveways, and other construction has begun. During construction, always accurately mark all ground heat exchanger piping on a plot plan as an aid in avoiding potential future damage.

During construction, installers should minimize the potential for the introduction of contaminants into an open borehole. During breaks in drilling, boreholes that are left open should be protected from direct precipitation, surface water inflow and access by animals and/or people. The installer should ensure that any open borehole is securely covered to prevent the entrance of contaminants, and prevent a safety hazard for animals and people if construction is not complete and they must leave the borehole site for any reason. The borehole should be secured to prevent collapse if the drilling rig is to be removed from the site before borehole completion. Boreholes should never be left open for more than ten days and efforts should be made to avoid having multiple open boreholes on the site at any particular time.

During construction of a borehole for a vertical closed-loop system installation, drilling fluid consisting of a bentonite clay viscosifier and water mixture should be circulated to form a filter cake on the borehole wall to minimize borehole collapse. The borehole should be kept full of bentonite drilling fluid until the loop piping is installed. Before grouting, the drilling fluid in the borehole should be thinned until the drilling fluid density is lower than the grout density.

Surface water should not be used as a source of water during the drilling of a vertical closed-loop system borehole (unless it is obtained from a municipal water supply system). Water that is used for drilling purposes should be potable water that contains a free chlorine residual of not less than 10 milligrams per liter. Chlorine test strips are a quick way to check chlorine residual levels.

Unique geologic conditions may require alternative construction practices. When necessary, a temporary casing should be used to maintain borehole stability in unconsolidated materials.

Where flowing or artesian conditions are possible during construction, the installer should implement appropriate measures to control or eliminate upward flow in the borehole.

If mineshafts, fractures or caverns are encountered in consolidated material, the borehole should be packed or sealed above and below the void. Other methods may be used as necessary to preserve borehole stability. When drilling through caves, mines, or other cavities the lower portion of the casing should be grouted in accordance with design specifications and a packer or similar bridging device used to facilitate grouting above the cavity. If rapid loss of grout material occurs during placement, coarse material such as sand, gravel, crushed stone, dry cement or other bridging materials approved for use may be used in the zones in which the loss is occurring. The remainder of the annular space should be grouted in accordance with grout manufacturers and design specifications. Casing should be installed, as necessary, in the case of voids which may cause the loss of excessive amounts of grout.

10.6 Typical Methods Used for Vertical Borehole Construction

10.6.1 Air Rotary Drilling

Air Rotary Drilling is used to construct vertical boreholes in rock formations (Fig. 63). High pressure, high volume compressed air is forced down the drill string to flush cuttings out of the borehole. A Down Hole Hammer (DHH) is attached to the bottom of the drill string and used to break rock in a process similar to a jack hammer breaking concrete. No fluids are reclaimed or re-circulated when using this method.

Fig. 63
Courtesy of Durbin Geothermal

10.6.2 Mud Rotary Drilling

Mud Rotary Drilling is the most common method used in vertical borehole construction (Fig. 64). It is often viewed as the most efficient method of drilling unconsolidated or soft overburden formations as well. Fluid, usually clean water with engineered bentonite additives is circulated from a mud tub through a suction hose by a mud pump and forced down the drill string through portals in the drill bit to flush cuttings out of the borehole while the bit is fed down the hole. The fluid and cuttings are then run through a series of separation chambers so that the solids can be removed and the fluid re-circulated.

Fig. 64
Courtesy of Durbin Geothermal

10.6.3 Combination Air and Mud Rotary Drilling

Combination Air and Mud Rotary Drilling is typically used when unstable formations are found on top of hard rock formations (Fig. 65). The process is relatively simple but more time consuming than either separate method. The mud rotary method is used to drill down to the bedrock zone. When it is necessary to stabilize the formation steel casing is inserted into the hole. The air rotary method is then used to complete drilling to the desired depth. Once the loop has been inserted and the borehole has been properly grouted the steel casing can be removed from the hole.

Fig. 65
Courtesy of Durbin Geothermal

10.7 Vertical Borehole Backfill

Backfill plays a major part in performance when discussing vertical boreholes. Air gaps or separation should be avoided as air is a natural insulator.

Grout is the most common material for vertical ground loop backfill. It can seal vertical boreholes off from surface water penetration. Standard grout actually has poor conductivity, so the borehole diameter should be minimized to limit the grout's effect. Thermal resistance adjustments for other borehole backfills or grouts are shown in the table provided (Table 30). There may be local code requirements to grout the entire borehole, or the borehole may penetrate multiple aquifers that need to remain isolated.

Thermal Resistance For Borehole Backfills

Natural Soil Cond.	0.9 Btu/h•ft•°F		1.3 Btu/h•ft•°F			1.7 Btu/h•ft•°F	
Backfill or Grout Conductivity	0.5 Btu/h•ft•°F	2.0 Btu/h•ft•°F	0.5 Btu/h•ft•°F	1.0 Btu/h•ft•°F	2.0 Btu/h•ft•°F	0.5 Btu/h•ft•°F	1.0 Btu/h•ft•°F
4 in. Bore							
¾ in. U-tube	0.11 (NR)	-0.05	0.14 (NR)	0.03	-0.02	0.17 (NR)	0.05
1 in. U-tube	0.07	-0.03	0.09	0.02	-0.02	0.13 (NR)	0.04
5 in. Bore							
¾ in. U-tube	0.14 (NR)	-0.06	0.18 (NR)	0.04	-0.04	0.21 (NR)	0.06
1 in. U-tube	0.11 (NR)	-0.04	0.14 (NR)	0.03	-0.02	0.16 (NR)	0.05
1¼ in. U-tube	0.06	-0.03	0.09	0.02	-0.02	0.12 (NR)	0.04
6 in. Bore							
¾ in. U-tube	0.18 (NR)	-0.07	0.21 (NR)	0.04	-0.05	0.24 (NR)	0.07
1 in. U-tube	0.14 (NR)	-0.06	0.17 (NR)	0.03	-0.04	0.21 (NR)	0.06
1¼ in. U-tube	0.09	-0.04	0.12(NR)	0.03	-0.02	0.15 (NR)	0.05
1½ in. U-tube	0.07	-0.03	0.09	0.02	-0.02	0.11 (NR)	0.04

Tab. 30

- (NR) Not Recommended
- Air Gaps add 0.2 to 0.4 h•ft•°F/Btu to Bore Resistance
- Note some adjustments are negative, which indicates a thermal enhancement and a lower net thermal resistance compared to natural backfills.

Various sources in the industry are available indicating the thermal conductivities for enhanced grouts. Enhanced grouts can significantly improve the borehole performance, which can lead to fewer or shallower boreholes. However, it is more costly. Each project is unique and a job-by-job analysis is required to evaluate whether enhanced grouts will actually reduce the installation cost. A table with enhanced grout data is shown (Table 31).

Thermal Conductivities for Enhanced Grouts

Grouts and Additives	K (Btu/h•ft•°F)	Thermal Enhanced Grouts	k (Btu/h•ft•°F)
20% Bentonite	0.42	20% Bentonite - 40% Quartzite	0.85
30% Bentonite	0.43	30% Bentonite - 30% Quartzite	0.70 - 0.75
Cement Mortar	0.40 - 0.45	30% Bentonite - 30% Iron Ore	0.45
Concrete @ 130/150 lb/ft³	0.60 - 0.80	60% Quartzite - Flowable Fill (Cement + Fly Ash + Sand)	1.07
Concrete (50% quartz sand)	1.1 - 1.7		

Tab. 31

10.8 Proper Grouting

The “approved” method of grouting a vertical borehole is called “Tremie” grouting. It is sometimes also referred to as pressure grouting. Once the vertical loop has been installed into the borehole, another hose must be run down to the bottom of the borehole. It is necessary that the Tremie hose reach the bottom of the borehole before the grouting process begins. By pumping from the bottom of the hole up, water in the hole is completely displaced with high solids, low permeability bentonite grout.
The grout provides a median of heat transfer between the loop pipe and the earth and protects from surface contaminants.

Typically, grouting is performed with a rig or trailer-mounted grout unit (Fig. 66). This includes:

- Grout/Slurry Mixing Tank
- Grout/Slurry Pump
- Tremie Line Hose Reel
- Flexible HDPE Tremie Pipe

Fig. 66 Trailer mounted grout unit
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

10.9 Vertical Closed-Loop Grouting Recommendations

The borehole should be grouted immediately after pipe installation, ideally within 24 hours and in accordance with the grout manufacturer's mixing and installation requirements (Fig. 67)). Drilling fluids should be flushed from the borehole prior to pipe installation, with the exception of boreholes where groundwater exhibits artesian conditions. Grouting should be completed in a manner that prevents the introduction of surface or near surface contaminants into an aquifer, the interchange of water from different aquifers, or the loss of natural artesian pressure from an aquifer.

The void space between the vertical closed-loop system piping and the borehole should be grouted in a continuous operation from bottom to top using grout placement procedures set forth in the IGSHPA Grouting for Vertical Heat Pump Systems, Engineering Design and Field Manual.

A Tremie pipe (grout pipe) not less than 1¼ inches nominal diameter should be placed to the bottom of the borehole before grouting. The Tremie pipe may be used to push the closed-loop piping into the borehole. The Tremie pipe should be removed from the borehole upon completion of grouting. Grout should be pumped through the Tremie pipe till the density of the grout flowing from the borehole at the ground surface equals the density of the grout being pumped in. The installer should monitor each borehole for settling for a period of not less than 12 hours. Additional grout should be added if necessary and the monitoring period should be extended until the settling of grout stops. A borehole drilled using horizontal directional drilling techniques should be grouted by pumping grout as the Tremie pipe is retracted through the borehole. Grout manufacturers' product specifications should always be followed for mixing and pumping grout.

Fig. 67
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

10.10 Grout Material

Grout material is typically used to ensure contact between the inserted pipe and the earth and helps promote heat transfer (Fig. 68). The grout material also serves to seal the hole off from any aquifers or groundwater supplies that may have been penetrated during the drilling process.

Fig. 68

A proper grout for vertical loops will have the following properties:

- high thermal conductivity to allow heat transfer
- low viscosity to allow the grout to wrap around the pipe
- low shrinkage volume to ensure that the grout will not pull away from the pipe
- low permeability to prevent the migration of antifreeze solution in the event of a line breakage

Grout materials, which do not include drilling muds, fluids or gels, are typically divided into two types:

- cement-based
- bentonite-based

Cement-based grouts with 5-10 percent bentonite are occasionally used. However, cement-based grouts are prone to shrinkage and heat of hydration and they may not adhere to the HDPE plastic pipe.

Therefore, bentonite-based grouts are typically recommended in lieu of cement-based grouts (Fig. 69). Silica can be added in specific proportions to both grout types to increase thermal conductivity ability.

Fig. 69
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

Bentonite sealing materials typically include high solids (powdered or granular) bentonite. High solids bentonite can be pumped before its viscosity is lowered. These grouts will usually require higher pumping pressures than cement grouts.

In several states, pure bentonite grout with approximately 20 percent solids content has become the standard for sealing vertical loops in borings. This type of grout is composed of at least 20 percent solids content by weight of bentonite when mixed with water.

To determine the percentage, the weight of bentonite is divided by the weight of the water plus the weight of the bentonite. For example, if 75 lbs. of powdered bentonite and 250 lbs. of granular bentonite were mixed in 150 gallons of water (at 8.33 lbs. per gallon), the percentage of high-solids bentonite is approximately 20 percent [325 ÷ (1,251 + 325) x 100].

Volume required to backfill a U-tube borehole is typically expressed in Gallons per 100 Feet of Borehole as indicated in this typical chart (Table 32).

Gallons per 100 Feet of Bore Hole Required to Backfill

	Diameter of Bore							
U-tube Dia.	**3.5"**	**4.0"**	**4.5"**	**5.0"**	**5.5"**	**6.0"**	**6.5"**	**7.0"**
¾"	41	56	74	93	114	136	163	191
1"	-	51	69	88	109	133	154	186
1¼"	-	-	60	80	101	124	150	177
1½"	-	-	-	73	94	117	143	170

Tab. 32

10.11 Grouting Procedures

Grouting is a highly variable operation in which many things can go wrong. Many factors can affect the behavior of the grout including components, ratios, temperature, chemical compositions of the water and bentonite, pH, etc. For example, inappropriate mixing ratios can lead to ineffective seals. Also, improper emplacement techniques may lead to gaps in the seal. For each type of bentonite, the manufacturer's instructions must be followed. In addition, it is critical for the contractor to be experienced and prepared for the grouting operation. Different bentonite types and mixing ratios can produce much different viscosities and setup times.

“Closed-Loop” vertical bore holes should be grouted in one continuous operation from the bottom to the top using a “Tremie” or conductor pipe (Fig. 70). For high solids bentonite grout, the type of pumps used includes positive displacement pumps such as piston, gear and moyno (progressive cavity) pumps. A paddle mixer is typically used to mix the grout.

Fig. 70 Tremie / Conductor Pipe

Pelletized and coarse-grade bentonite also can form good seals, but problems exist in the placement of this type of bentonite. Because pelletized and coarse-grade bentonite is poured down the borehole, extreme care must be taken so that the particles do not bridge above the bottom of the hole. At least 2 inches of space should exist around the heat exchanger pipe if this method is used. When groundwater is not in the borehole, water must be added often to hydrate the bentonite. Because of the potential for gaps in the seal, this method is generally not suitable for the deep borings that are required for the heat exchanger pipes. However, this method is excellent for sealing abandoned borings. Emplacement of dry bentonite granules by air injection into a saturated borehole can be accomplished. Quartz sand can be added to increase the viscosity and conductivity of the grout. Air injection of bentonite can produce high percentage solids content of bentonite.

11 Horizontal Closed-Loop Ground Heat Exchangers (Horizontal Loops)

Horizontal closed-loop ground heat exchangers, or “horizontal loops,” are typically installed using a bulldozer, a backhoe, a vibratory plow, a chain excavator (chain trencher) or horizontal boring machine (Fig. 71). Excavation costs for horizontal loops are normally less expensive than the costs for vertical loops, but significantly more land space is typically required. With rural installations, horizontal loops can be a very cost effective method of heat transfer for the Bosch geothermal heat pump.

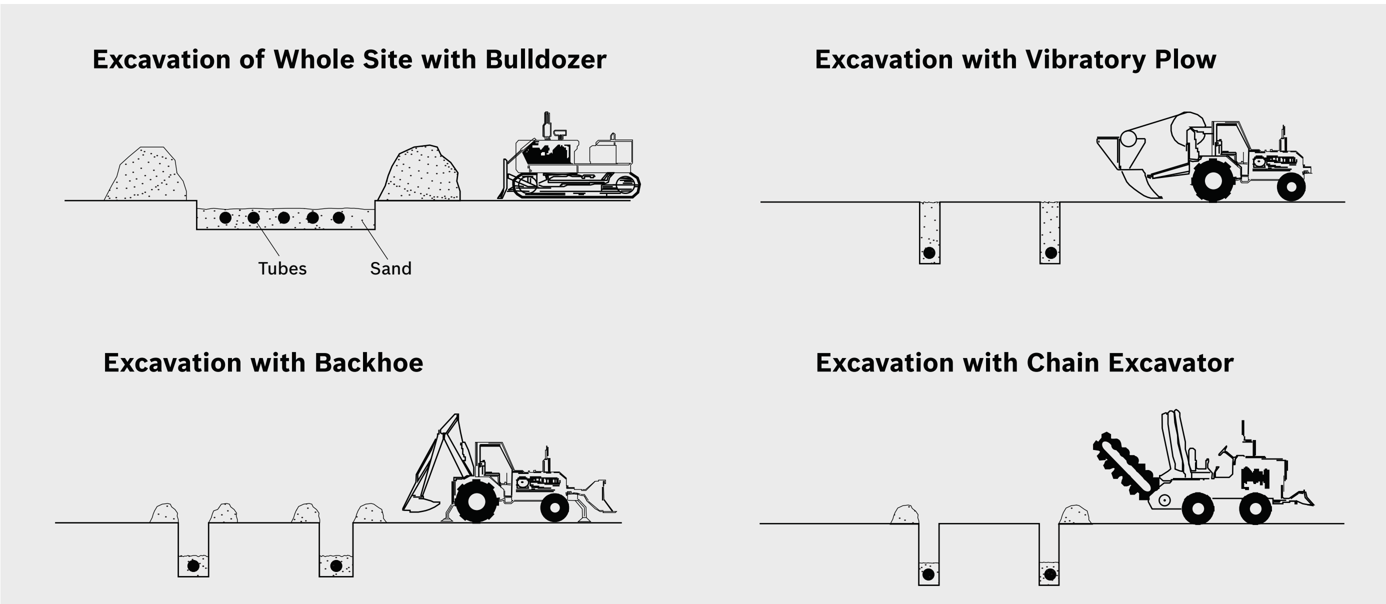

Fig. 71 Excavation equipment
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

To install a horizontal loop, installers typically dig trenches 5-8 feet below the ground surface and then install a series of HDPE pipes that comprise the geothermal ground heat exchanger. The trenches are then backfilled, ensuring that no sharp rocks or debris are present to damage the pipes.

When retrofitting a home with a Bosch geothermal heat pump system, a horizontal loop installation may pose more problems because landscaping will have already been completed. However, horizontal boring equipment is making it possible to retrofit geothermal heat pump systems into existing homes with minimal disturbance to lawns (Fig. 72). Horizontal boring (Horizontal Directional Drilling - HDD) machines can even allow entire systems to be installed under existing structures or driveways, in accordance with local codes and ordinances. The trenches for horizontal loops should be at least 25 feet away from any septic systems. Heat from the pipes can increase biological growth in the septic tanks, which could lead to costly septic system repairs.

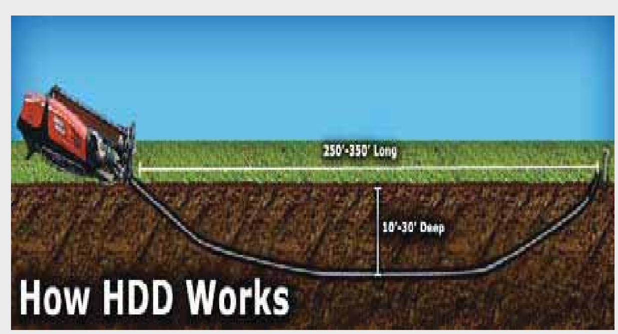

Fig. 72

Another type of horizontal configuration is called the "Slinky™" loop (Fig. 73). While this horizontal loop will require less land area, it will generally require more pipe than a parallel type horizontal loop configuration. As with a horizontal loop the earth is excavated to a depth of about 5-8 feet and the pipe is coiled like a flattened "Slinky™" and then buried (either horizontally or vertically in the excavation).

Fig. 73 "Slinky" loop
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

Pond or lake loops are one of the most cost-effective closed-loop installations available today (Fig. 74). These closed-loop heat exchangers typically require limited excavation from the structure to the pond or lake. Pond or lake loops require a minimum of about ½ acre of land per ton of cooling capacity and a minimum depth of 8 to 10 feet for proper and efficient heat transfer to occur. Like other closed loop installations, pond or lake loops utilize polyethylene pipe, but are typically laid out in a coil or "Slinky™" arrangement (discussed later).

Surface water (lake or pond loops) are less common for residential applications since fewer homes are located on or near a suitable body of water. Additionally, environmental concerns often are concerns when using natural ponds and lakes. Ponds and lakes are good heat rejecters, but often less efficient heat producers. Even so, pond and lake loops can be 30% to 60% of the cost of a vertical or horizontal loop.

Fig. 74 Pond or lake loop

11.1 Horizontal - Loop Layout

The deeper a horizontal ground loop the more stable the ground temperatures. A typical horizontal loop system consists of buried polyethylene pipe containing water and antifreeze solution, which is circulated by means of a small pump. Fluid runs through the pipe in a closed system in a certain order. Many loop layouts exist (Fig. 75).

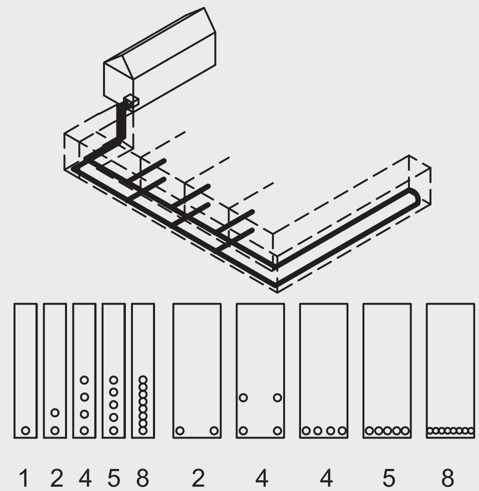

Fig. 75
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

The typical length of a trench must be based on the amount of pipe in the trench, burial depth, and average ground temperature and conductivity.

The typical extremes of normal ground temperature are 44ºF for the northern continental US and 70ºF in the southern US. The lengths should provide a maximum loop temperature of approximately 90ºF entering the geothermal heat pump in normal applications. In homes with excessive run times this temperature will typically be 3ºF to 5ºF higher. The typical recommendations for vertical ground loops is ft. of bore per ton for ¾" and 1-1/4" HDPE, which will operate about 5ºF cooler than the horizontal loops.

The greater the distance between buried horizontal closed-loops, the higher the efficiency. Industry guidelines suggest that there should be 10 feet between sections of buried loop, in order to allow the pipe to collect heat from the surrounding earth without thermal interference from the neighboring loop (Fig. 76). This spacing can be reduced under certain conditions. It is common to bury one set of loops above another set with a deeper trench. A "rule of thumb" is "more ground mass is always better than less". Another "rule of thumb" is "more piping, more fluid and deeper is good practice".

Fig. 76

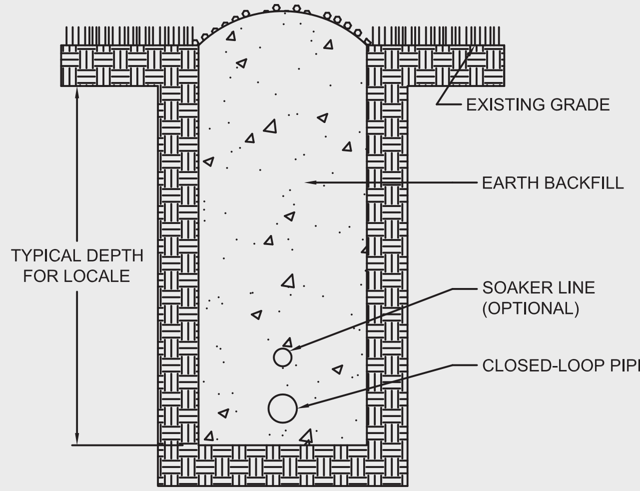

Fig. 77
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

The most common horizontal heat exchanger is two pipes placed side-by-side in the same trench. Other horizontal loop designs use four or six pipes in each trench, if land area is limited. Regardless of the arrangement chosen, all piping for antifreeze solution systems should be at least polyethylene (or approved equal) with thermally fused joints (as opposed to barbed fittings, clamps, or glued joints), to ensure leak-free connections for the life of the piping. Other piping materials also exist and must be approved by IGSHPA for use with Bosch geothermal heat pumps.

Properly installed, these pipes will last anywhere from 25 to 75 years. They are unaffected by chemicals found in soil and have good heat-conducting properties.

Horizontal loop installations typically use trenches anywhere from 6 to 24 in. wide. This leaves bare areas that can be restored with grass seed or sod.

Generally, the more pipes that are added to a horizontal trench (provided there is adequate spacing), the shorter the trench. Since pipe is relatively inexpensive compared to excavation, most horizontal loops have multiple pipes in the trench to maintain shorter trenches. Available excavation equipment however could change the number of pipes that can be placed in a trench.

A single pipe loop is typically not common, but may be used if there is plenty of land (Fig. 77). To complete the circuit, each trench must go out and circle back to the starting point. If using ¾" pipe, there is usually one trench per ton of cooling capacity required for the structure. A parallel circuit design might look like a flower petal. If the ground loop is designed as one large series pipe (not recommended except for 1-½ to 2 ton systems) the pipe diameter must be larger, typically 1-¼" or larger.

The use of multiple pipes in a trench reduces total trench length substantially. If a double layer of pipe is laid in the trench, then the two layers should be set approximately 2 feet apart to minimize thermal interference (Fig. 78).

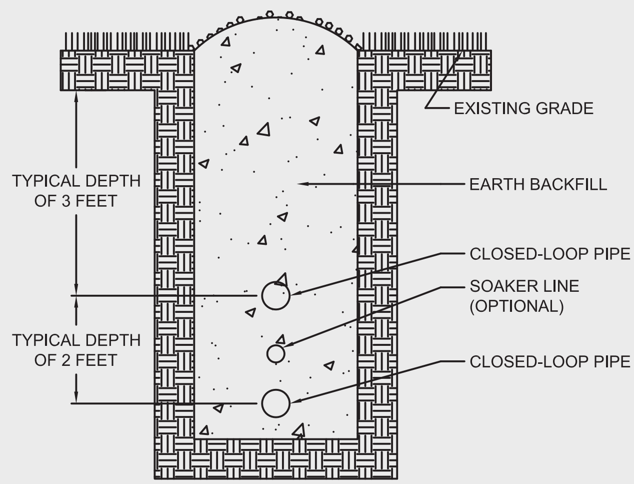

Fig. 78
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

Example:
A 1-½ inch series horizontal system with pipes at 5 feet and 3 feet is installed. After installing the first pipe at the 5 foot depth, the installer should partially backfill to the 3 foot depth using a depth gauge stick or other measurement device prior to installing the second pipe. The return line will be running closest to the surface and the supply line will be running beneath it. This arrangement will maximize the overall system efficiency by providing warmer water in the heating mode and colder water in the cooling mode.

Two pipes in the same trench, one above the other, separated by approximately 2 feet of earth requires a trench typically 60% as long as a single pipe trench. The total length of pipe would be approximately 120% as long as a single pipe. This results due to the heat transfer effect between the two pipes.

When laying a double layer of pipe, installers should be careful to avoid kinks when making the return bend.

Two-pipe ground loops are more common with trenched installations (Fig. 79). If a backhoe is available, more pipes are typically added to the trench. Each two-pipe ground loop is a circuit. If using ¾" pipe, there is usually one two-pipe trench per ton of cooling capacity required. Typically, the two pipes are spaced a minimum of 24 inches apart in the trench at the average depth determined for the locale.

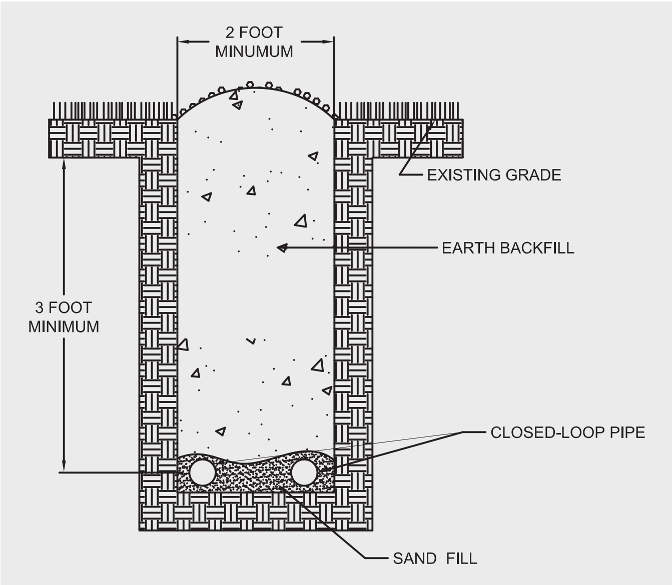

Fig. 79
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

A four-pipe ground loop allows an installer to utilize 60 to 70% of the trench necessary for a two-pipe ground loop as more pipes are located in the trench (Figure 80). If, for example, 250 feet of a two-pipe trench (500 feet) is necessary, only approximately 150 feet of four-pipe trench (600 feet) is necessary for the four-pipe ground loop. This arrangement allows installers to utilize smaller land areas.

A four-pipe ground loop typically has two (2) circuits per trench, so if ¾" pipe is used, one trench can typically handle a two (2) ton geothermal heat pump. Typically, the four pipes are spaced a minimum of 24 inches apart horizontally and vertically in the trench, with the upper two pipes at the average depth determined for the locale.

As four-pipe ground loops have an even number of circuits, there may be more or less circuits than tonnage, depending on the geothermal heat pump equipment capacity.

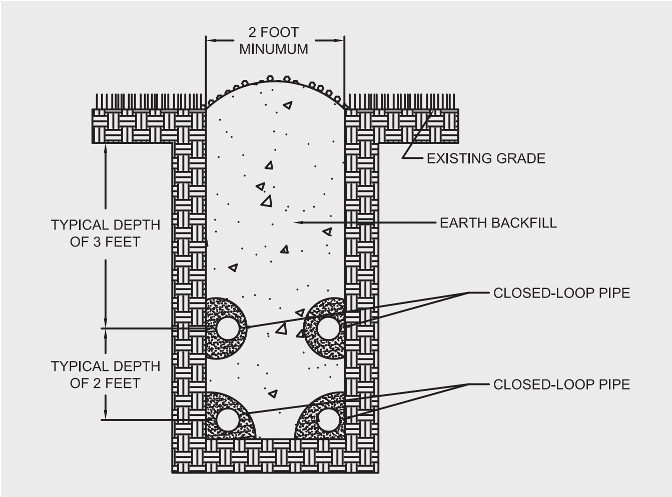

Fig. 80
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

For example, a five (5) ton geothermal heat pump could use either two (2) trenches with four (4) circuits, or three (3) trenches with six (6) circuits, depending on the pressure drop and the Reynolds number.

A six-pipe ground loop uses more pipes in the trench so there is less trench (Figure 81). This design allows the installer to use about 90% of the trench necessary for a typical four-pipe ground loop. For example, 250 feet of trench is necessary for a two-pipe ground loop (500 feet of pipe). 150 feet of trench is necessary for a four-pipe ground loop (600 feet of pipe). A six-pipe ground loop typically has three (3) flow paths of three (3) circuits and only needs approximately 135 feet of trench (810 feet of pipe). Subsequently, one trench could be used for a three (3) ton cooling capacity system. This could limit the amount of excavation necessary, especially for retrofit applications.

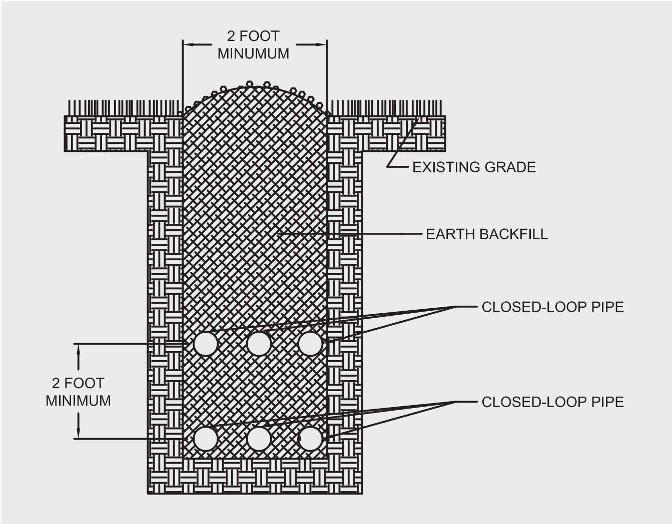

Fig. 81
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

Typical horizontal loop design parameters:

- Limited tonnage due to land area
- Backhoe or trench excavation typical (Fig. 82)
- In areas with any rock typically backhoe only
- One circuit and 3 Gallon per Minute (GPM) per ton of cooling capacity
- ¾" HDPE piping
- Pipe per ton of cooling capacity:
  - Cold climates: 400 to 1,000 Feet
  - Warm climates: 700 to 1,800 Feet

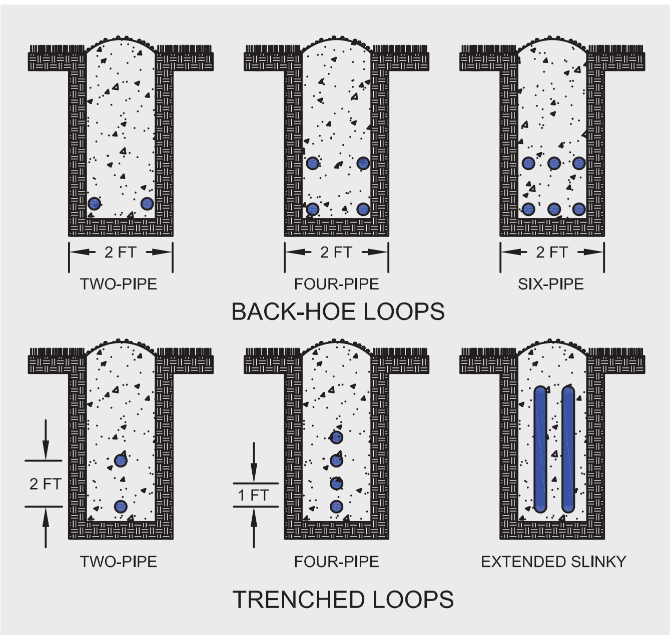

Fig. 82
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

A horizontal ground coupled system with the piping buried in a trench will typically have different depths based the location of the system in a colder or warmer climates. For the U.S., this is identified in the map provided (Fig. 83).

Pipe depths in the Northern Zone should be 3 to 5 feet, as excessive depth will reduce the ability of the sun to recharge the heat used in winter. The Bosch Geo Solutions software program will help determine the appropriate depth for these applications.

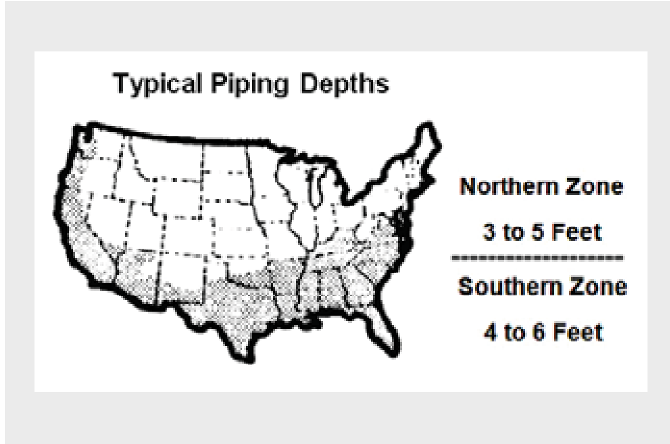

Fig. 83

Pipe depths in the Southern Zone should be 4 to 6 feet, so that the high temperature of the soil in late summer time will not seriously affect system performance. The Bosch Geo Solutions software program will help determine the appropriate depth for these applications.

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

Installers should always backfill a trench by hand when changing direction.

If it is necessary to join two pipes together in a trench, always use the fusion technique for greater strength and durability. Then mark fitting locations for future reference by magnetic tape or wire, or by inserting a steel rod just below grade. These marking devices allow the use of a metal detector to find joints in pipes.

Trenches can be located closer together if a pipe in the previous trench can be tested and covered before the next trench is started. This also makes backfilling easier. Four to five feet spacing is typically a good recommendation. In those areas with dry climates and heavy clay soil, heat dissipated into the soil may reduce the thermal conductivity of the soil significantly. In such cases, the installer may need to specify additional feet of pipe per ton of capacity. A few inches of sand may also be added in with the pipe, or a drip irrigation pipe buried with the top pipe to add occasional small amounts of water.

11.2 Trench Safety

DANGER:
No person should enter any trench excavated for a ground loop installation that is at a depth of 5 feet or greater. The Occupational Safety & Health Administration (OSHA) requires cave-in protection for anyone in any excavation 5 feet deep or more.

This requirement was established to maintain a safe working environment for persons working in excavations (Fig. 84). OSHA's Standards contain the specific information for employee safeguards in excavations.

Cave-in protection as defined by OSHA will not be present during a ground loop installation. Therefore, the loop must be installed into any 6 feet deep trench by dropping it into the trench from the ground surface. In some cases, the loop may not fall to the bottom of the trench or lie flat on the bottom of the trench. Loop installers will need to develop a tool to position the loop from the ground surface. A 10-foot to 12-foot long section of eithera furring strip, 2"x3" stud or 2"x4" stud can be used to position the ground loop from outside the trench.

Fig. 84

11.3 “Slinky™” Ground Heat Exchangers

A variation of the horizontal ground heat exchanger often used today is the “Slinky™” loop horizontal closed-loop system (Fig. 85). This arrangement ties the pipe into large coils that overlap each other, allowing for large lengths of pipe to fit into much smaller trenches. This design is a horizontal closed-loop array for area of less land and shorter trenching. The ground heat exchanger is typically laid flat in a circular pattern at the bottom of a trench. Fluid circulates through the ground loops.

Fig. 85 "Slinky™" loop system
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

For example, 800 ft. of ¾ in. pipe can be tied into a “Slinky™” loop with 3 ft. diameter coils and be buried into a trench that is typically 125 - 150 ft. long.

The “Slinky™” design allows the installer to increase the density of the pipe in the trench by coiling it to achieve more pipes per foot of trench.

When first introduced, the “Slinky™” design included both horizontal (Fig. 86) and vertical (Fig. 87) applications. Vertical “Slinky™” loops were designed for installation with a trencher. This design in less popular today as it has been found to be extremely difficult to backfill unless fine soil (e.g. sand) or flowable backfill is used. Today, horizontal “Slinky™” loops are used more frequently than vertical “Slinky™” loops because they are easier to install.

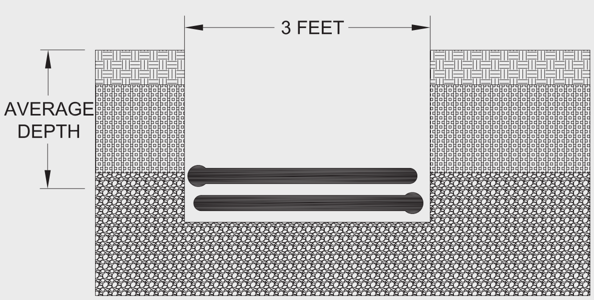

Fig. 86
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

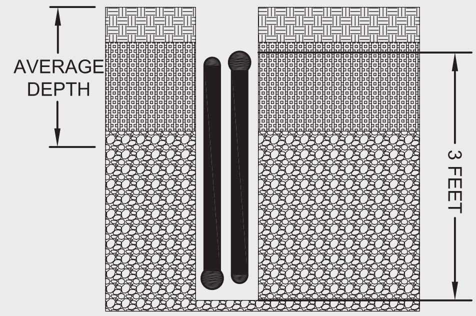

Fig. 87
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

““Slinky™” loops may be a compact or extended design (Fig. 88). The “Slinky™” design typically provides one circuit per trench. Like the horizontal two-pipe loop, the““Slinky™” loop is typically designed with one trench per ton when ¾” HDPE is used. Pressure drop must be considered when using the compact “Slinky™” or the extended “Slinky™” design, as circuits can be lengthy.

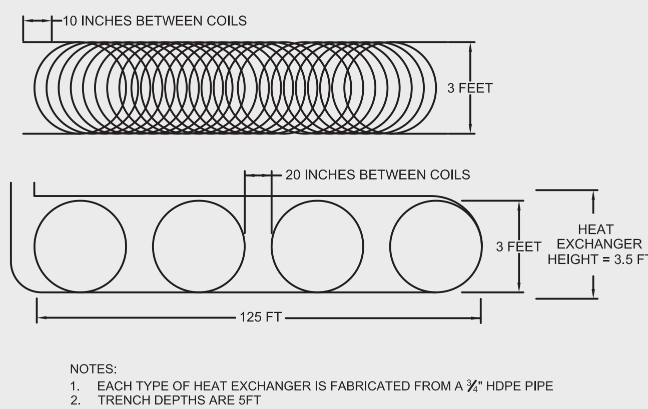

Fig. 88
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

11.4 Racetrack Closed-Loop Ground Heat Exchangers

Another type of horizontal closed-loop application that is popular in moderate to colder climates is the “racetrack” loop (Fig. 89, 90). Typically, all of the pipes used and installed are at the same elevation in a much larger trench, or even a large pit area (Fig. 91). This method is often more cost effective than installing four and six pipe horizontal designs as the depth of the frost line in moderate and/or colder climates is deeper than warmer climates, resulting in more difficulty when excavating. The distance between pipes is typically around one (1) foot.

Fig. 89

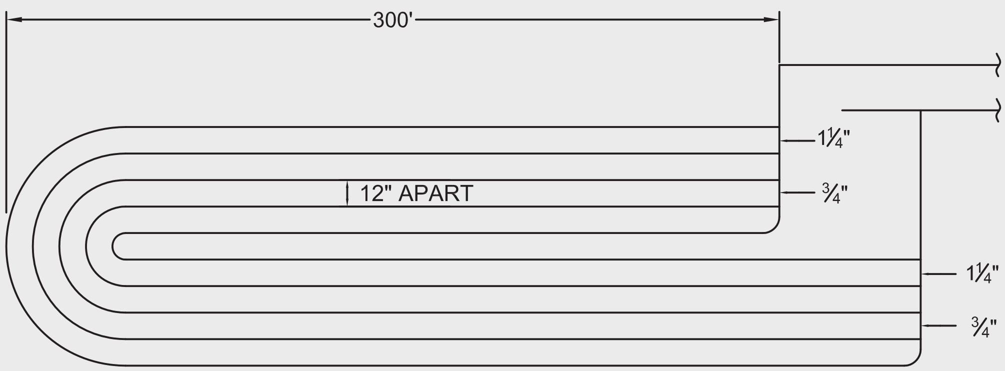

Fig. 90

Fig. 91

11.5 Horizontal Directional Drilling (HDD) Closed-Loop Ground Heat Exchangers

Horizontal bore loops are becoming increasingly more popular today for new geothermal ground heat exchanger installations, especially when customers are concerned about landscaping and excavation (Fig. 92). Typically referred to as Horizontal Directional Boring (HDD), this method has been used in the gas and water industry for quite some time. In fact, HDD is one of the fastest growing techniques for trenchless installation of all types of pipelines.

HDD is also a good method for many retrofit geothermal applications, as there is very little excavation. Only a small square hole is used for headering the pipes. Like a horizontal two-pipe loop or a “Slinky™” loop, a horizontal bore ground heat exchanger loop has one circuit per trench, and typically one trench per ton of cooling capacity. Typically, ¾” HDPE pipe is used with this process. The installer should consider the equipment used for HDD, as a good grouting process is necessary and often difficult unless the equipment has provisions for it. Otherwise, the pipe may not be in good contact with the soil. Most horizontal bore machines are capable of boring down 8 to 15 feet, thus HDD is considered a good application even in colder climate locations.

Fig. 92

11.6 Pond and Lake Geothermal Applications

Pond or lake geothermal applications typically involve either a coil of piping in the body of water, or the use of a "lake plate". Pond and lake heat exchangers, either pond/lake loop, or lake plates, are two of the most cost effective applications of all residential geothermal heat pump systems.

These heat exchangers are utilized when the residential structure is close to a body of surface water (pond or lake). The system functions similarly to a closed-loop ground heat exchanger.

This type of loop system typically require less excavation than vertical or horizontal loops, with the typical piping connected to the loop or lake plate in the body of water a short distance from the structure. There is no boring as with vertical loops, and the only trench excavation (as with horizontal loops) is from the structure to the pond or lake. The pond or lake water provides superb heat transfer to or from the piping, as the thermal conductivity of water (its ability to exchange heat) is considerably higher that the conductivity of any other fluid.

11.6.1 Pond or Lake Coils

With pond or lake piping coils, the piping is simply placed at appropriate levels of the pond or lake to reject heat from the structure to the water during summer months, and absorb heat from the water that is transferred to the structure during winter months. The pipe may be coiled in a "Slinky™" shape to fit more of it into a given amount of space, and are similar to the "Slinky™" design utilized in many horizontal ground heat exchanger applications (Fig. 93).

Fig. 93

Typically, a half-acre of water is usually adequate to support an average residential structure, and IGSHPA recommends a minimum of ½ acre per ton of cooling capacity requirements. The body of water should be within 150-300 feet of the structure to eliminate excessive excavation and reduce installation costs.

HDPE (polyethylene) piping is run to the water underground and then long sections of piping and/or coils are submerged. The piping and/or coils are placed in and anchored at approximately an 8 to 10 foot depth in the body of water. Water in its "heaviest" state is approximately 39ºF and tends to rest in its own isolated temperature layer in the body of water throughout the year. This is where the coil of pipe is ideally placed. In winter, as heat is extracted from the 39ºF water around the loop coils, the water cools and ascends by way of its own convective current upward toward the surface. This draws in "fresh" ambient 39ºF water from the "thermo cline" (thin but distinct layer in a body of water in which temperature changes more rapidly than it does in the layers above or below) directly around the coils. Similarly in summer, as heat is rejected, the warmed water also migrates upward away from the coils as cooler ambient water is drawn back in around them.

The coils of pipe are typically 300 to 500 feet in length, but could be different depending on the load. Typically, the same type of HDPE pipe materials that are used for earth loops are used for pond and lake coil systems. Pipe length requirements per nominal ton of cooling typically are shorter and the piping coils can usually be arranged in a more compact arrangement, as compared to ground heat exchangers.

In some cases, spools of HDPE pipe are fitted with intermittent spacers between the pipe layers to allow convective water flow between them. Often coils are simply spread out flat in a consolidated "Slinky™" array. In each case, the piping coil is usually constructed on shore, somehow lightly weighted (air inside the pipe coils should still keep them moderately buoyant), floated into the pond, and sunk during system filling.

In most applications, ice can form on the surface of the pond or lake during the winter, but the temperature at the bottom of the pond or lake typically remains relatively constant and unfrozen providing an abundant supply of geothermal heat.

In warmer southern U.S. applications the "Slinky™" style is recommended (Fig. 94). Due to pipe and antifreeze buoyancy, pond heat exchangers will need weight added to the piping to prevent floating. Typically fencing or blocks are used.

In colder northern U.S. applications the "Slinky™"/"matt style" is recommended due to its superior performance in heating (Fig. 94). Due to pipe and antifreeze buoyancy, pond heat exchangers will need weight added to the piping to prevent floating. 300 foot coils typically require two 4" x 8" x 16" blocks or 8-10 bricks, and every 20 Ft. 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. Typical southern and northern versions are shown (Fig. 95).

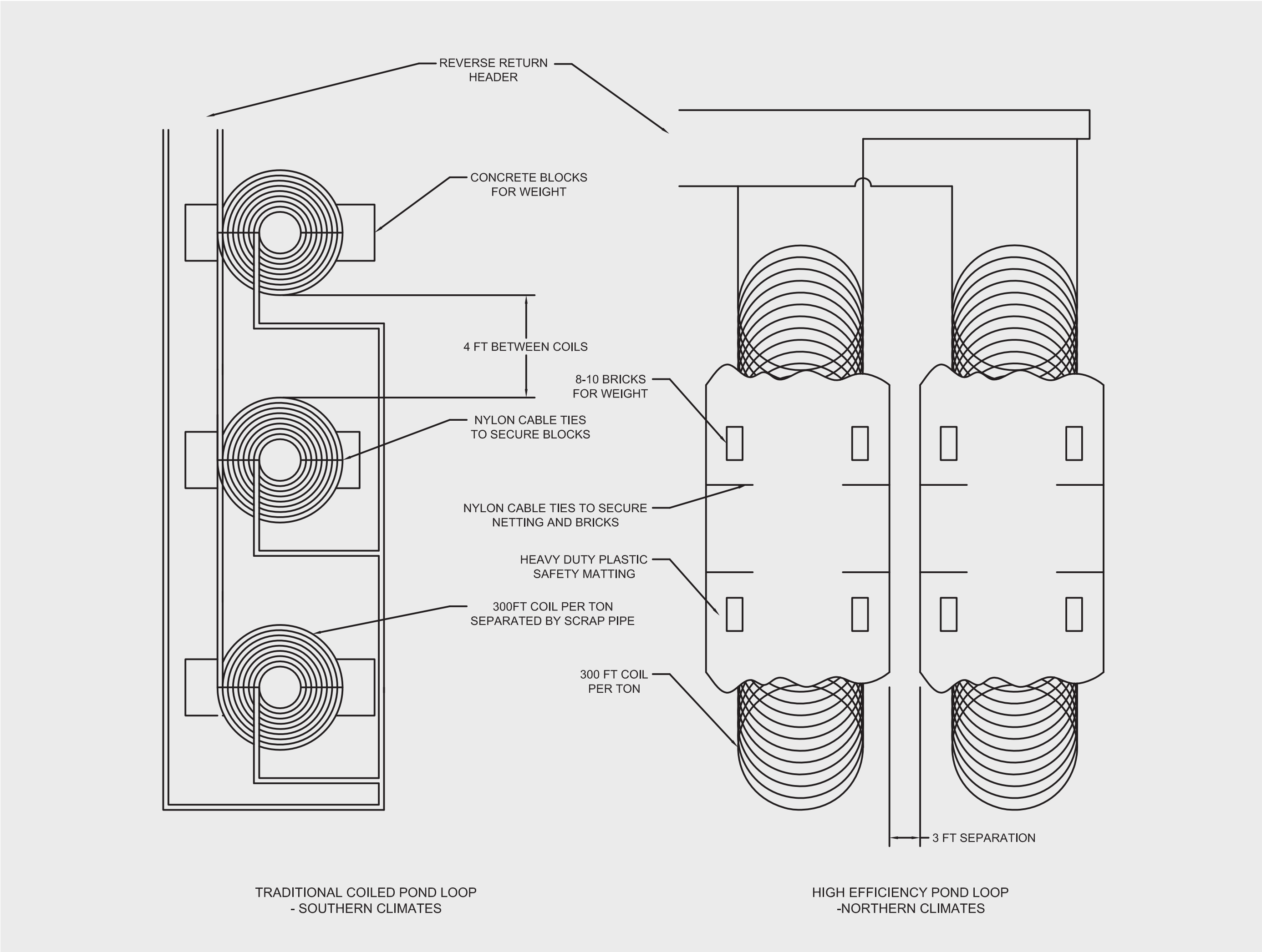

Fig. 94 "Slinky™" matt style

Fig. 95

11.6.1 Pond or Lake Plates

A modular type of stainless steel “plate” heat exchanger is specially manufactured for pond and lake geothermal applications as an alternative to piping and/or coil applications (Fig. 96).

Fig. 96

Several manufacturers have this style of exchanger available for pond or lake geothermal use. The plate must be installed to stand or hang in a vertical submerged position in the body of water. The fluid from the Bosch geothermal heat pump must enter the lowest connection on the exchanger and the fluid flow returning to the geothermal heat pump must exit the highest connection on the exchanger.

In all cases, the body of water must be adequate to accommodate the structure load requirements and the exchanger(s) must be sized by plate manufacturer criteria to meet the load. The exchanger must always be supported off the bottom of the body of water and always above any silt or mud. This is typically accomplished with legs or supports. The exchanger plates can be suspended from piers or docks, but must be secured and protected for the recommended conditions in which they are installed. The recommended minimum installation depth for lake plates is typically 3 to 4 feet below the surface of the body of water (top of plate at this depth). In colder climates, the top of the plate should be below the anticipated freeze layer of the body of water (must be below any ice that forms on the surface).

While pond and lake loop and plate applications remain the most efficient type of loops there are, still a noticeable difference in heat transfer rates between silt and water exist. If part of a loop or plate is in silt and the rest is in water, there can be a loss of efficiency.

Another optional method is available and is referred to as the “Aqua Rack™” style (Figure 97). These pond loops are specially designed and built in a rack to keep the loops above the silt layer and below the freeze layer. The coils are vertically positioned and strapped in place ensuring the best possible spacing for maximum heat transfer and water flow between coils. A minimum pond depth of 12 feet of water is recommended for these devices.

Fig. 97 “Aqua Rack™” style

Proper loop design as well as pond size and depth requirements are specific to each application beginning with whether or not a pond or lake is even suitable enough to function as a geothermal heat source. A properly designed and installed pond or lake system can usually reduce closed-loop installation costs, increase system performance, and offer an appealing aesthetic component that an earth loop cannot provide. But an inadequate pond or lake loop design can lead to mass temperature degradation potentially rendering the system completely inoperable.

12 Residential Structure Pipe Entry/Exit

The entry and exit points from a residential structure should be watertight and constructed to prevent leaks (Fig. 98). Piping sleeves should be used at all entry and exit points. Sleeves should extend a minimum of twelve inches out from the foundation and be constructed and installed in compliance with local building codes and ordinances. Sleeves serve to minimize shearing stresses from fill settling and help minimize damage to the home's foundation.

Fig. 98
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

If at any point the return or supply line will cross a water line, the line should be enclosed in a sleeve until ten feet of separation is achieved. There should be a minimum separation of two feet between the return or supply lines and water or sewer lines.

Installers should always seal and protect the entry and exit points of any ground heat exchanger into a residential structure. Hydraulic cement is recommended.

With a new construction situation exists, installers should attempt to position the pipe in the proper location prior to any wall construction or slab pouring. As piping can wear due to expansion and contraction, it should be protected with a chase through the slab with PVC elbows and sleeves as shown (Fig. 99).

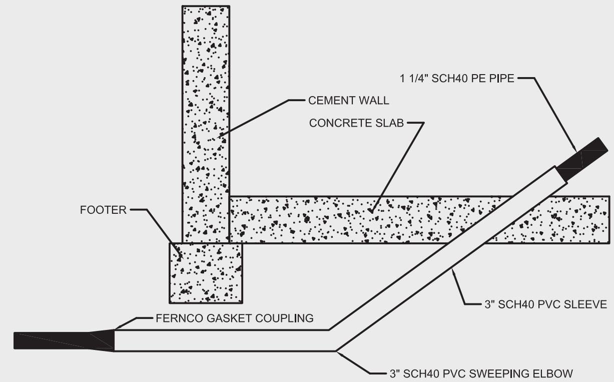

Fig. 99
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

Always trench as close as possible to the footing and bring the pipe up along the outside wall of the footing until it is above the slab. The pipe should enter the structure as close to the slab as construction allows. Always shield and insulate geothermal piping to protect it from damage and the weather as shown (Fig. 100).

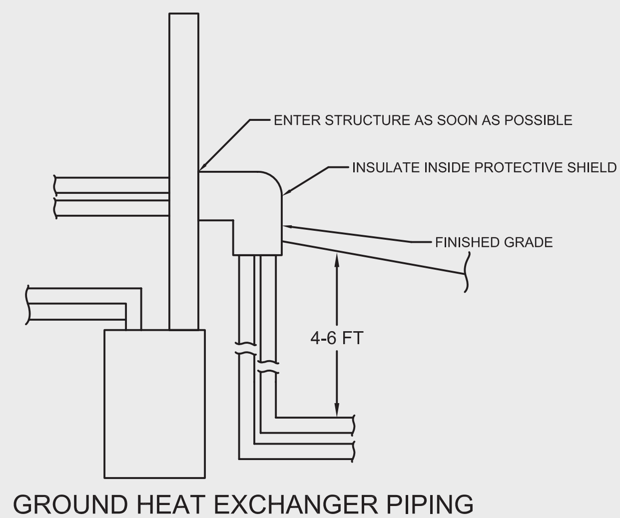

Fig. 100
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

With crawl space applications involving pier and beam for either new or retrofit construction, always bury the pipe beneath the footing and between piers so that it is directly below the point of entry into the structure. Bring the piping into the structure and protect it with insulated shielding if possible as shown (Fig. 101).

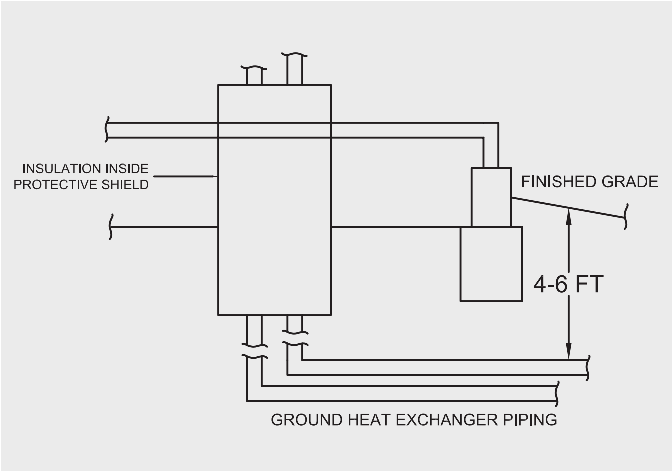

Fig. 101
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

With below grade situations, always bring the pipe through the wall as indicated (Figure 102). If the ground heat exchanger could be subject to freezing, always insulate the piping at least 4 feet into the trench. This will prohibit ice formation near the wall.

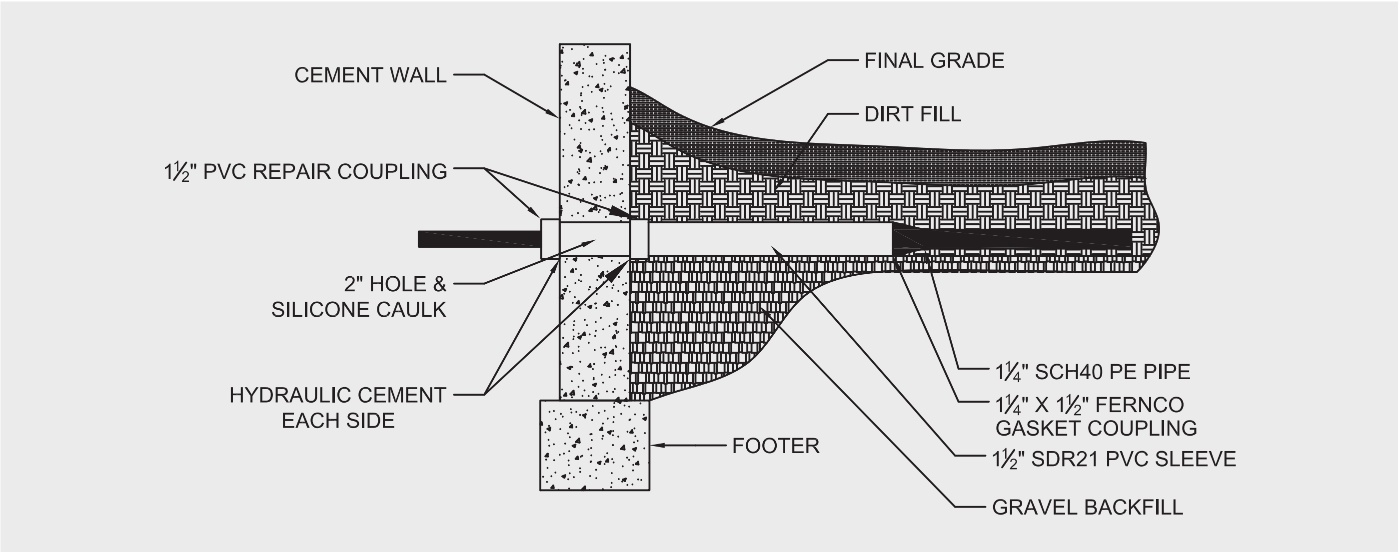

Fig. 102 Below grade wall penetration
Courtesy of International Ground Source Heat Pump Association/Oklahoma State University

13 Interior Piping

Inside the home, the piping from the open-loop or closed-loop system will be connected to the Bosch geothermal heat pump. A typical piping layout is shown for both applications (Fig. 103, 104). Polyethylene pipe provides an excellent no leak piping material. Piping fittings and elbows should be limited to prevent excessive pressure drop.

The installer should always consult the Bosch specifications for piping sizes. Teflon tape sealer should be used when connecting piping to the Bosch geothermal heat pump unit to insure against leaks and possible water-to-refrigerant coaxial heat exchanger fouling. Never over-tighten any connections. Flexible hoses should be used between the Bosch geothermal heat pump unit and the rigid system to avoid any possible vibration and should be limited in length to 10-15 feet per run to reduce pressure drop. Typically, 2 feet of head pressure drop is normal for all closed-loop ground heat exchangers fittings which include 10 to 12 elbows for inside piping to a flow center. Closed cell insulation at least 3/8 inch wall thickness should be used on all inside piping to avoid condensation and possible freezing if ground loop temperatures can fall below 50ºF. All barbed connections should be double clamped. Ball valves should always be used and installed in the supply and return lines for unit isolation and unit water/fluid flow balancing. Pressure/Temperature ports (P/T ports) are highly recommended in both the supply and return lines for system flow balancing and waterside diagnostics. Water flow in Gallons per Minute (GPM) can be accurately determined and set by measuring the water-to-refrigerant coaxial heat exchanger water side pressure drop. The equipment specifications will provide information for water/fluid flow (GPM) vs. pressure drop.

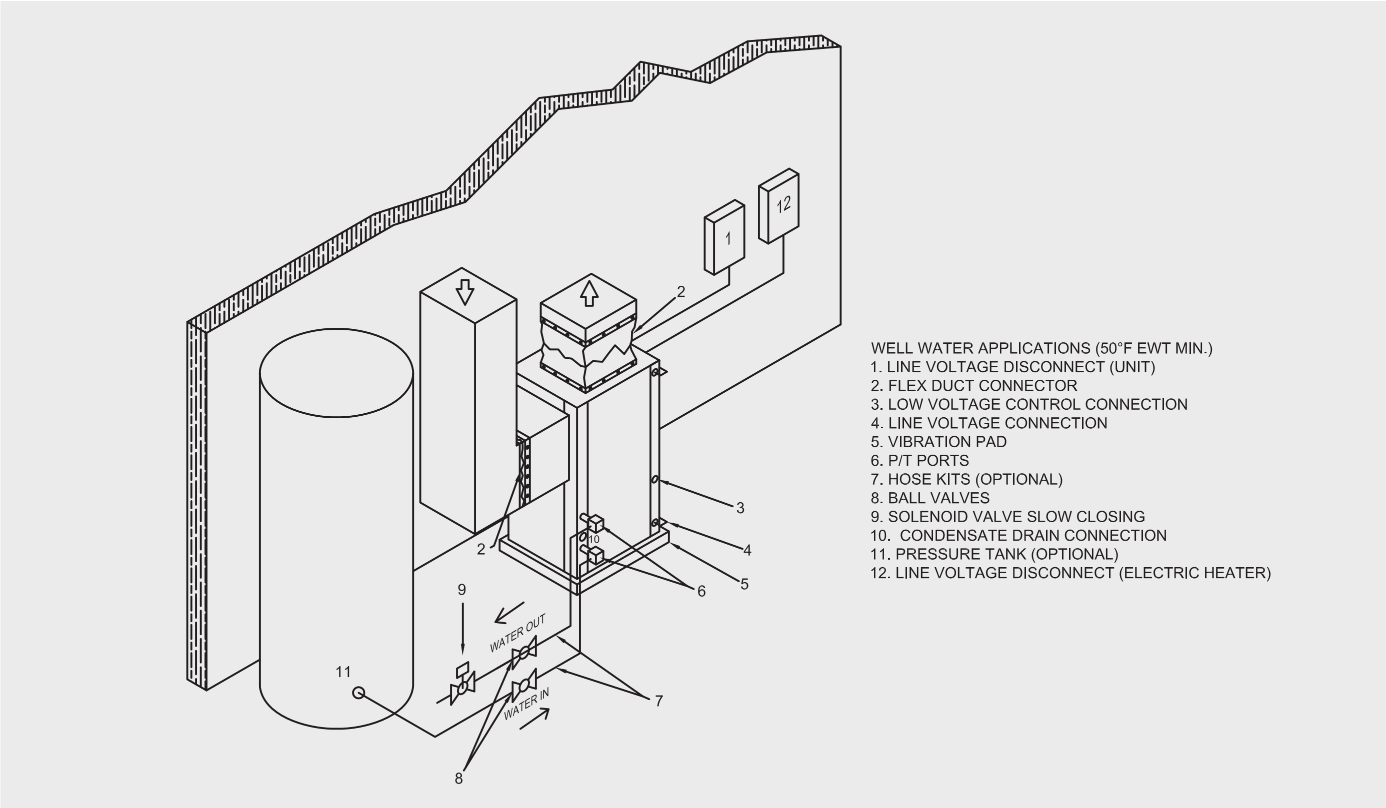

Fig. 103

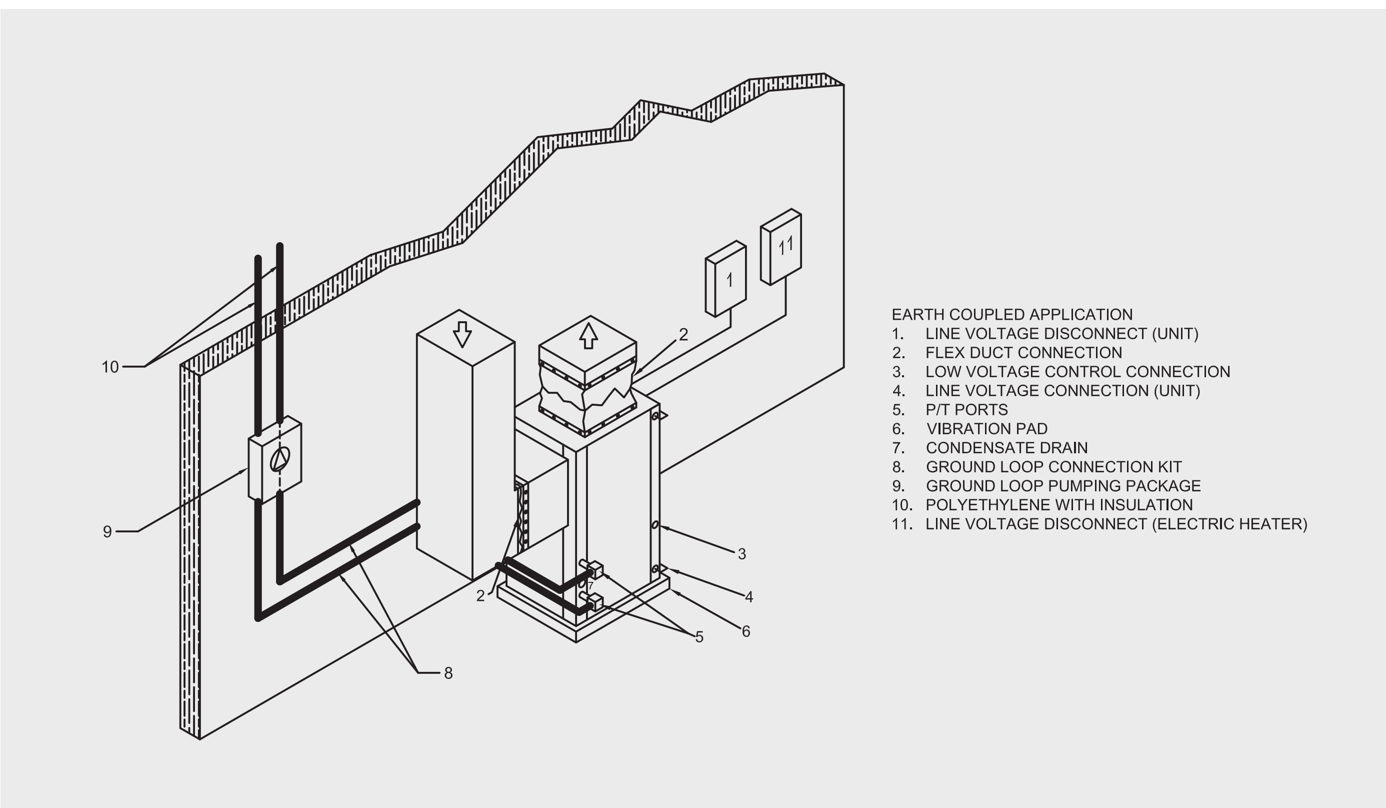

Fig. 104

14 Ground Loop Pumping Package (GLP)

14.1 Flow Centers for Closed-Loop Ground Heat Exchangers

Many closed-loop systems are connected to a “flow center” at the geothermal heat pump unit providing for a common connection to the supply and return lines coming in from the geothermal ground heat exchanger. These flow centers are used as a one stop accessory for circulating fluid in a closed loop system. Flow centers can be either pressurized or non-pressurized. The flow center is a field labor saving device that takes care of a number of issues a loop installer should handle in a field installed pump station.

14.2 Pressurized Flow Centers

Pressurized flow centers are compact, insulated, and easy to mount polystyrene or metal cabinets that contain composite or brass 3-way valves and a pump or pumps (Figure 105). These 3-way valves are used for attaching a flush cart’s hose connections to fill, flush and purge the ground heat exchanger; then the unit side; and then to add antifreeze and circulate the entire system.

Fig. 105 Pressurized flow centers

Pressurized flow centers offer the advantages of being equipped with flush/fill ports and eliminating the possibility of fluid exposure to contaminants.

However, the thermal expansion of ground loop piping may cause the circulating pump or pumps to cavitate without the use of an expansion tank. Any entrapped air will not leave the system over time. Additionally, a flush cart is typically necessary for filling and flushing the ground heat exchanger and ground loop system. Check and isolation valves must also be field installed.

Generally you will see what's referred to as a "one pump” pressurized flow center or a "two pump" pressurized flow center. For many pressurized flow centers, the pumps are typically either a Grundfos UP 26-99 or a Grundfos UP 116, but other brands exist as well. They are close in characteristics but can have system saving, or system detrimental effects.

Flow centers have the pump (or pumps) already installed with all the piping and valves (Figure 106). They are also typically insulated with foam. The connections at the top and bottom of the flow center are for connection to the ground heat exchanger and to the unit. The pipe connections on the side are for the flush cart connections. The front brass cap is for turning the 3-way valve.

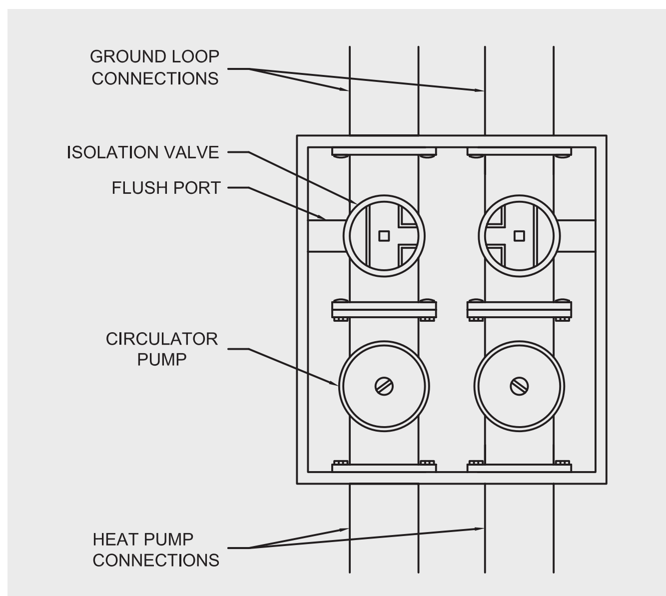

Fig. 106

Proper flow through the ground heat exchanger is extremely important. For example, a 9 GPM system (nominally a 3 ton unit) may have 3 circuits with 3 GPM through each circuit. A properly installed ground heat exchange requires a minimum amount of turbulence in the pipe - measured by the "The Reynolds Number", for efficient heat transfer. The flow in each circuit, size and length of pipe, and antifreeze in the system, are all variables in determining the Reynolds Number.

14.3 Non-Pressurized Flow Centers

Non-pressurized flow centers (Fig. 107) are simply canisters that hold fluid on the suction side of circulating pumps (one, two or three) and include built-in pump protection which eliminates the need for a “flush cart” **when manifolds are indoors**. Flush carts will be discussed in the flushing and purging section.

These non-pressurized flow centers allow the force of gravity to maintain a flooded volute within the device, assuring reliable pump operation. This type of flow center pumps fluid to the geothermal heat pump, and then out to the ground heat exchanger, and then returns the fluid directly back to the flow center.

Non-pressurized flow centers allow any entrapped air within the system to remove itself over time. Also, the circulating fluid level and freeze protection level can easily be monitored and replenished as necessary. These flow centers can directly measure system flow and typically come equipped with check valves and pump isolation valves. Additionally, a flush cart is not necessary to fill and flush the system when a non-pressurized flow center is utilized.

However, these non-pressurized flow centers require a manifold be assembled for the filling and flushing process. A typical example is shown (Fig. 108). Also, the highest point of the piping system cannot be more that approximately 34 feet above the circulating pump or pumps.

Fig. 107 Non-pressurized flow center

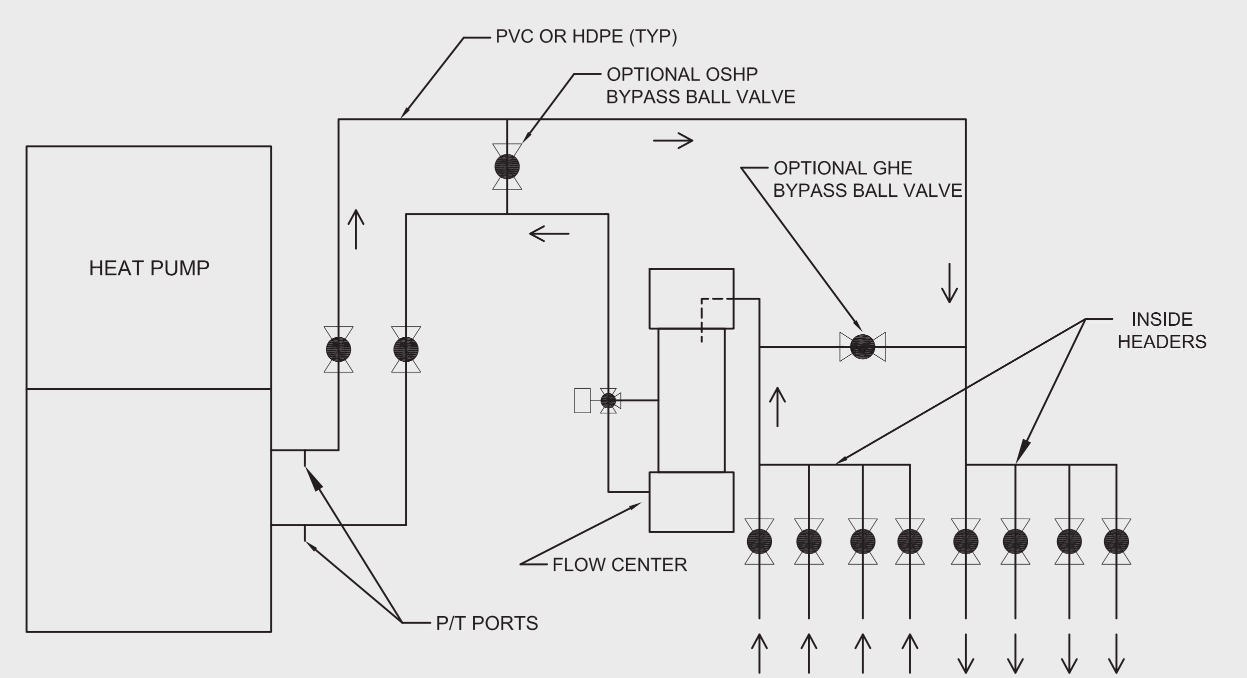

Fig. 108

14.4 General Flow Center Criteria

The pressure drop of the entire ground heat exchanger should be calculated for the selection of the flow center. In general, if basic ground heat exchanger design criteria is followed, units of 3 tons or cooling capacity or less will require only one (1) circulating pump. Units from 3.5 to 6 tons of cooling capacity will normally require a two (2) pump flow center.

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. The Bosch Geo Solutions software program will help in determining the ground heat exchanger pressure drop for accurate flow estimation.

Regardless of the use of either a pressurized or non-pressurized flow center, it must be located between the Bosch geothermal heat pump and the ground heat exchanger. Additionally, the flow center should be located as closed to the Bosch geothermal heat pump unit as possible to limit the length of hoses and associated pressure drop. Ease of future service should always be considered as well when determining flow center placement.

Ground heat exchanger piping is typically polyethylene piping directly into the flow center. These connections can be made with either a fusion or barbed fitting. Other materials may also be used for this connection such as copper piping. Additionally, installers may also install commercially available optional flow meters as well (Fig. 109). This tool is used determine the actual GPM flowing through the system.

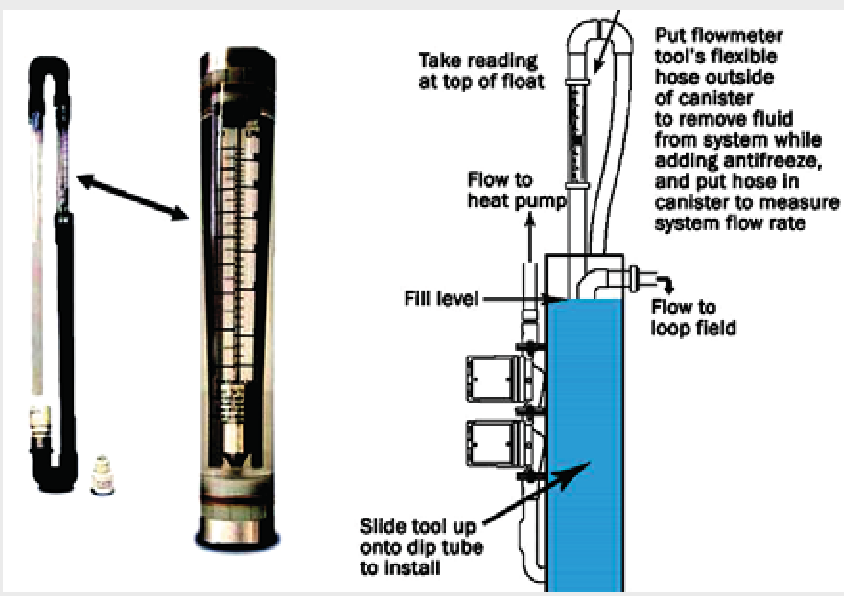

Fig. 109

15 Closed-Loop Flushing and Purging

Once piping is completed between the Bosch geothermal heat pump, the flow center and the ground heat exchanger, the loop is ready for final purging and charging.

A flush cart with at least a 1.5 HP pump is required (and recommended by IGSHPA) to achieve enough fluid velocity in the ground loop piping system to purge any air and dirt particles (Fig. 110).

Fig. 110 Flush cart
Courtesy of Geo Flo

An antifreeze solution is used in most areas to prevent freezing. All air and debris must be removed from the ground heat exchanger piping before operation. Always flush the ground loop with a high volume of water at a minimum velocity of 2 Feet per Second (FPS) in all piping. The following steps are typically followed for proper flushing with a flush cart:

1. Fill the ground loop with water from a garden hose through the flush cart before using the flush cart pump to insure an even fill (Fig. 111). Connect the flush cart hoses to the flow center flush ports using proper adapters. Connect the water supply to the hose connection on the return line of the flush cart. Turn both 3-way valves on the flow center to the flush ports and loop position. Turn on the water supply, making sure the water is of proper quality.

2. Once full, the flushing process can begin (Fig. 112). Do not allow the water level in the reservoir to drop below the pump inlet line to avoid air being pumped back out to the ground loop. Once the water level remains above the water outlet in the reservoir leave the pump running continuously. Catch or filter debris returning from the loop to the reservoir. Once all debris is removed turn the 3-way valve to the flush port/unit position. Make sure the water level is maintained while filling the Bosch geothermal unit. Flush the Bosch geothermal unit until all debris is removed and then return the 3-way valve to the flush port/loop position.

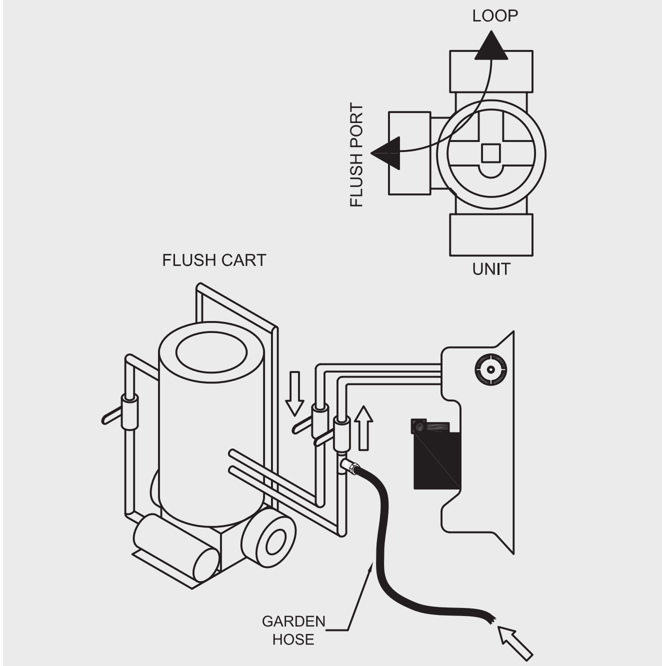

Fig. 111 Flush cart step 1

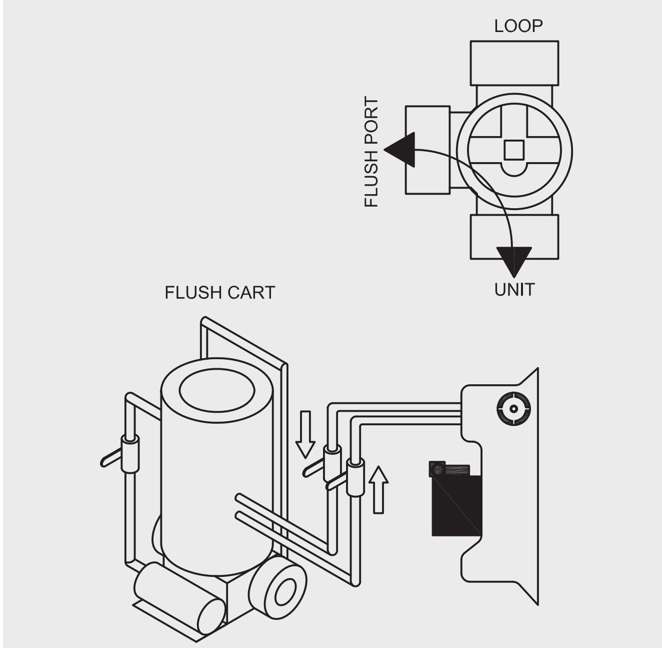

Fig. 112 Flush cart step 2

3. Once all debris is removed make sure the return hose is below the reservoir water level. Continue running the flush cart pump while observing any air bubbles in the reservoir (Figure 113). “Dead head” the pump every so often (surges of 50 PSI) and watch the water level in the reservoir (once all the air is removed there should not be more than a 1" to 2" drop in water level in the reservoir). If there is more than a 2" drop, air is still trapped in the system. The fluid level drop in the reservoir is the only indication of air in the ground loop.

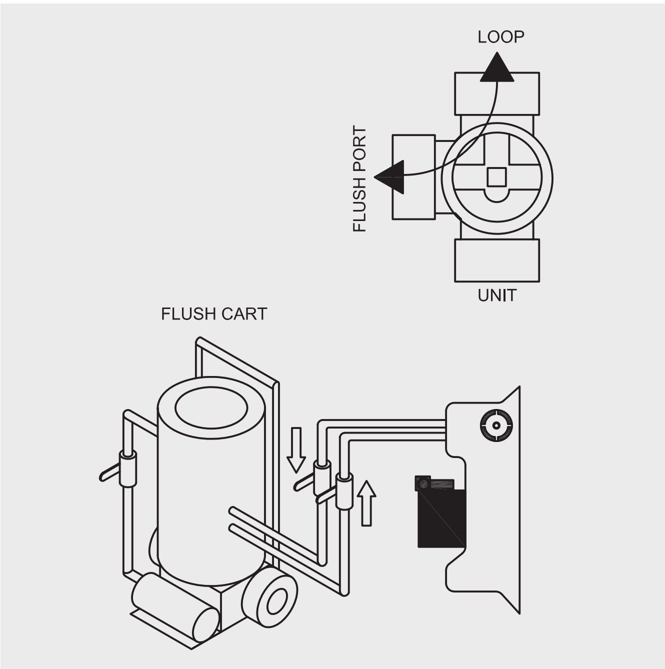

Fig. 113 Flush cart step 3

Antifreeze may be added before, during or after the flushing procedure. However, depending upon which time is chosen, antifreeze could be wasted when emptying the flush cart reservoir.

Purge the ground loop for approximately 2 hours. Once all air is removed from the ground loop, turn the 3-way valve to the flush port/unit position and repeat the purging process. The unit side purge should only take approximately 5 to 10 minutes. While the flush cart pump continues to run, turn the 3-way valve to the flush port/unit and loop position (Fig. 114). Once flushing and purging is complete the system can be pressurized.

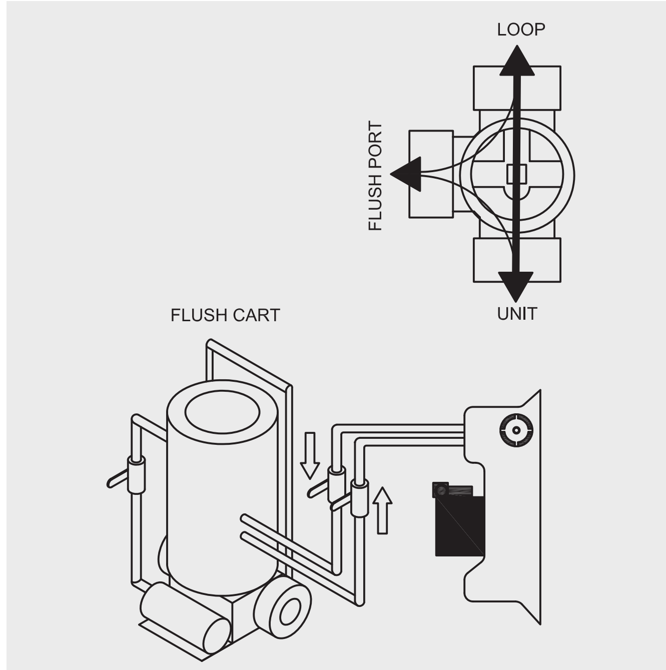

Fig. 114 Flush cart step 4

Always operate the Bosch geothermal heat pump system in either the heating or cooling mode as necessary for a few minutes to condition the ground loop to a homogenous temperature. During this time, installers should perform tool cleanup, piping insulation, etc.

4. Now the final pressurization of the ground loop can be performed (Fig. 115). Close the return line ball valve (dead-head the pump). Allow the flush cart pump to run until there is approximately 50 - 75 PSIG (winter) or 35-40 PSIG (summer) of pressure on the system (whatever the flush cart pump is capable of producing). Turn the return side 3-way valve to the unit/loop position. Turn the supply side 3-way valve to the unit/loop position. Turn the flush cart off, remove the hoses and return the caps to the flow center.

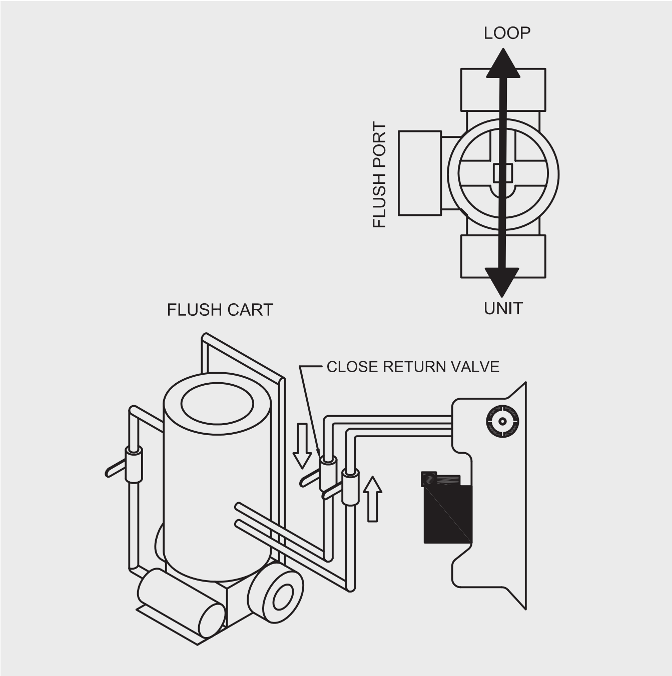

Fig. 115 Flush cart step 5

After this system pressurization, always loosen any plug at the ends of the loop pump motor(s) to allow any trapped air to be discharged and to insure the motor housing has been flooded (not required for “Taco” circulators).

Always insure that the flow center provides adequate flow through the Bosch geothermal heat pump by checking the pressure drop across the heat exchanger and comparing it to the pressure drop tables in the Installation and Maintenance Manual for the particular Bosch geothermal heat pump.

16 Bosch Geothermal Water-to-Water Heat Pump Applications

Bosch water-to-water geothermal heat pump systems (Fig. 116) offer the customer complete flexibility over any other type of geothermal heat pump system since they can be applied for space heating, space cooling, water heating, floor warming, snow melting, and many other types of applications that utilize either hot or chilled water.

All Bosch water-to-water geothermal heat pumps are actually modular reverse cycle two stage chillers and low temperature boilers, providing the best combination of performance and efficiency available today. Safety devices are built into each unit to provide the maximum system protection possible when the unit is properly installed and maintained. All Bosch water-to-water geothermal heat pumps are Underwriters Laboratories (UL) and (cUL) listed for safety, and designed to operate with entering source liquid temperature between 25°F and 110°F.

Bosch water-to-water geothermal heat pumps can be used with most geothermal sources (open and closed systems). They require much less energy relative to typical forced air systems as the need for ducting is eliminated. They can be used for hydronic-based zoning, in combination with thermal storage and off peak electrical rates, as well as with solar thermal input, or in combination with solar photovoltaic systems to produce “net zero” houses. Additionally, they can be dedicated for domestic water heating or serve as ancillary domestic water heating. Bosch water-to-water geothermal heat pumps can be used for producing “process water” in industrial applications, controlled as a staged system to better match loads (multiple units), stacked to save space (multiple units), and used for loads such as pool heating, spa or hot tub heating.

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

Fig. 116 Water-to-water heat pump

16.1 Bosch Geothermal Water-to-Water Heat Pump Components

The Bosch water-to-water geothermal heat pump is equipped with exceptional components (Fig. 117). One of the most advanced components is the Copeland “UltaTech” two-stage compressor. The performance of regular scroll compressors is taken to the next level with these two-stage units. A simple solenoid valve bypasses refrigerant providing two stages of operation. This feature translates into the most efficient unit performance on the market today, ensuring peak performance and energy savings under widely differing operating conditions. And, the unit comes ready for geothermal applications.

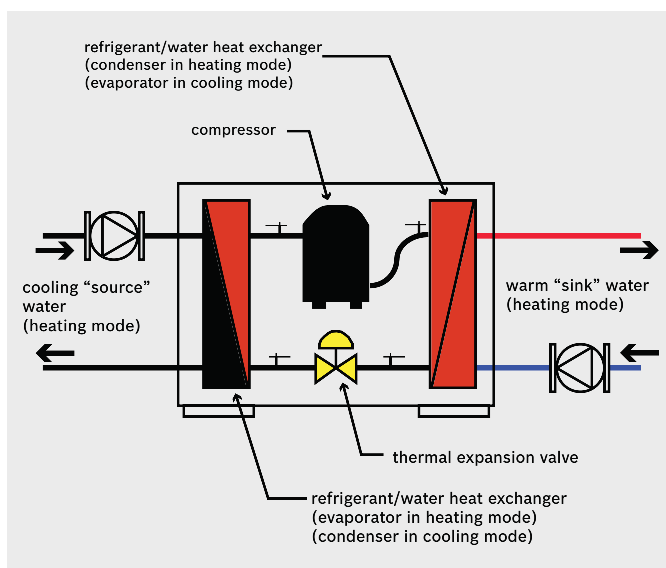

Fig. 117 Water-to-water heat pump internal diagram

All Bosch water-to-water geothermal heat pumps are equipped with two (2) oversized coaxial water-to-refrigerant heat exchangers as standard issue. Customers can choose cupronickel coils if the system is connected to an open-loop system to offset any water quality issues. Both copper and cupronickel coils are designed to allow optimal heat transfer while offering extremely low pressure drop. This unique low pressure flow design reduces the amount of pumping power necessary to achieve optimum water flow in order to maintain the efficiency of the unit. Coaxial heat exchangers are not as susceptible to clogging and freezing as are plate heat exchangers. All Bosch water-to-water geothermal units come standard with wrapped insulated coaxial heat exchangers. This insulation wrap prevents condensation from forming in low temperature operation.

As shipped, all Bosch water-to-water geothermal heat pumps are equipped with controls internal to the system similar to the Bosch water-to-air units. Customers may order an optional external heat pump controller for a more visual control approach (Fig. 118). This controller is recommended in most cases and offers a low cost, simple solution to the control of the water-to-water unit. The control is configurable to provide cooling only, heating only or auto change over control strategies based on the application of the unit in a given system, and has multiple features, including a selectable mode of operation, an adjustable temperature differential for heating and cooling set points, an adjustable auto changeover set point, intelligent auto reset to avoid nuisance hard lockouts, an LED display of control temperature and set points and configurable operation for continuous or cycling operation of the compressor.

Fig. 118

16.2 Bosch Geothermal Water-to-Water Heat Pump Sizing Criteria

When sizing a Bosch geothermal water-to-water heat pump, the same guidelines apply as with Bosch geothermal water-to-air heat pumps. An accurate heat loss and heat gain load calculation still must be completed. The only significant difference is the delivery method for heating and cooling. Like Bosch water-to-air heat pumps, economics must be considered for Bosch water-to-water applications.

Bosch geothermal water-to-water heat pumps sizing is dependent upon the type of hydronic system application (load side - indoor) and the type of ground loop system (source side - outdoor). Since the capacity and efficiency of the Bosch geothermal water-to-water heat pump is directly related to the entering source temperature, care should be exercised to insure that the water-to-water heat pump will provide adequate capacity at design conditions. The complexity of the ground loop sizing can be simplified with the use of the Bosch Geo Solutions software which allows the user to enter the heat loss/heat gain, the water-to-water heat pump size, and the ground loop parameters. An analysis based upon bin weather data is calculated with the software that allows the user to size the equipment/ground loop and obtain annual operating costs. All Bosch geothermal contractors and dealers can acquire and/or access the Bosch Geo Solutions software through the Bosch Way to Grow website or by contacting their Bosch sales representative.

Although there are numerous water-to-water systems installed that provide 100% of the heating load, a larger system and ground heat exchanger is required, increasing installation costs. If the water-to-water system is not sized for 100% of the application heating load, a method of backup heat must be selected.

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

Often, central cooling is not always desired with radiant heating systems. A Bosch water-to-water geothermal heat pump system can provide chilled water to cool the structure, as well as hot water for the heating system. Homes with fan coil units can generally be retrofitted for cooling quite easily. However, problems could arise if the application is using existing fan coils for heating, especially those previously sized for high water temperatures.

A room-by-room calculation should always be performed for all radiant floor system in order to determine the design of the radiation system. Once the heat loss has been calculated and the decision on flooring material has been made for each room, the amount of radiant floor tubing, pipe spacing, water temperature and layout can be determined, based upon the Btu/h per square foot requirements.

Radiant floor heating typically allows occupants to experience the same comfort level with radiant floor heating at approximately 65°F as with a forced air system at approximately 70°F. Installers should realize that a radiant floor system heats objects, not the air. Then, these objects radiate heat, which heats occupants and furnishings to an acceptable and comfortable temperature. Air temperature typically remains near approximately 65°F, and is typically equal from the floor to the ceiling. Forced air heating always heats the air, which heats the occupants and objects. Thus with force air heating, a higher air temperature is necessary in order to bring occupants and objects up to the same temperature as in a radiant heating system. When a radiant floor system is being designed, equipment sizing can be significantly impacted. Typically, the heat loss for the structure decreases by 10-20% over a forced air heating system application. However, Bosch encourages the use of load calculations at actual temperature differences and infiltration rates for equipment sizing, rather than “rules of thumb.”

16.3 Bosch Geothermal Water-to-Water Heat Pumps and Radiant Floor Heating

Heating and cooling with water is commonly referred to as hydronics. Water is considered the most practical, economical and safe heat transfer medium available. The most popular application for Bosch water-to-water geothermal heat pumps is likely radiant floor heating. Some examples are shown (Figure 119).

Bosch water-to-water geothermal heat pumps are an excellent heat source for framed-floor as well as slab-type floor heating systems. The low water temperature required by such floors (usually 95ºF to 110ºF at design load conditions) allows the Bosch water-to-water geothermal heat pump to operate with relatively high capacity and COP. Additionally the mixing device(s) required when coupling a low temperature floor heating system to a conventional boiler are no longer required.

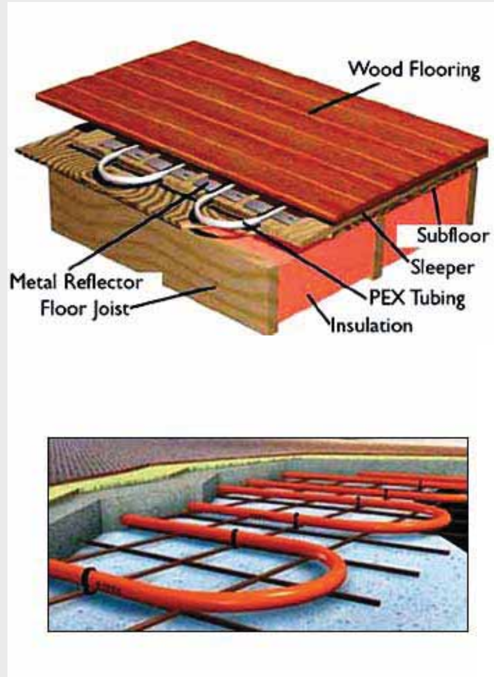

Fig. 119

When considering the use of a Bosch geothermal water-to-water heat pump attached to a radiant floor heating array, a suggested guideline is the combination should provide design heating load output using supply water temperatures no higher than 120ºF.

Radiant floor heating is considered by many as the ultimate form of comfort heating for residential applications. In addition to the advantages of hydronic heating in general, warm floors provide benefits that virtually no other system can match. Unlike many systems that directly heat the air, radiant floor heating gently warms the surfaces of objects in the room as well as the air itself. The warm surfaces significantly reduce the rate of heat loss from the occupants, allowing most to feel comfortable at room temperatures 3 to 5 degrees lower than with other methods of heating.

Bosch water-to-water geothermal heat pumps can be utilized for hydronic heating during the winter months, as well as for superior heat rejection during summer months. These water-to-water geothermal heat pumps extract low temperature heat from closed-loop ground heat exchangers, ponds or lakes, or from open-loop groundwater supply wells, in the winter. They reject heat from the structure to the closed-loop ground heat exchanger, pond or lake, or open-loop groundwater rejection well (or other acceptable rejection site), in the summer.

16.4 Bosch Geothermal Water-to-Water Heat Pumps and Fan Coil Units/Air Handlers

Bosch water-to-water geothermal heat pumps can also be used with a fan coil(s) (air handler) to heat or cool air in a structure if designed for lower water/fluid temperatures (Fig. 120).

Fan coil units (or air handlers) consist of a hot water coil and/or chilled water coil (usually copper tubing with aluminum fins) and a blower to move air over the coil. The term “fan coil unit” typically applies to smaller units, which are installed in the zone or area where the heating or cooling is needed. The term “air handler” normally refers to larger units. Fan coils are available in many different configurations, sizes and capacities from a number of manufacturers, and many are designed to be connected to ductwork. Fan coil units can also be used to replace a forced air furnace in certain situations.

Many fan coil units are designed for use without ductwork. These units are typically mounted in a suspended ceiling space (typically commercial applications) or on a wall.

Fan coils and air handlers typically have one or two coils and a blower. Air is heated by hot water circulated through a hot water coil. Chilled water is circulated through the coil if cooling is needed. Depending upon the application, the unit will include one coil for both heating and cooling (hot water/chilled water) or a coil dedicated to heating (hot water) and another coil for cooling (chilled water). Blowers can be provided to fit different applications, with or without ductwork.

Fan coil units have been used to heat homes using water temperatures as low as 90°F to 100°F. Heating capacities typically decline when operated below design temperatures. Therefore, two coils are typically recommended if the fan coil unit is to be used for forced air space heating. One coil will be used for heating and another coil for cooling. Fan coil size must always be considered as the heating and cooling coils could be very different in physical size. Proper fan coil selection often involves selecting a larger model with multiple fan speeds in order to satisfy the capacity requirements without providing too much air flow. Always follow manufacturers’ criteria when selecting fan coils.

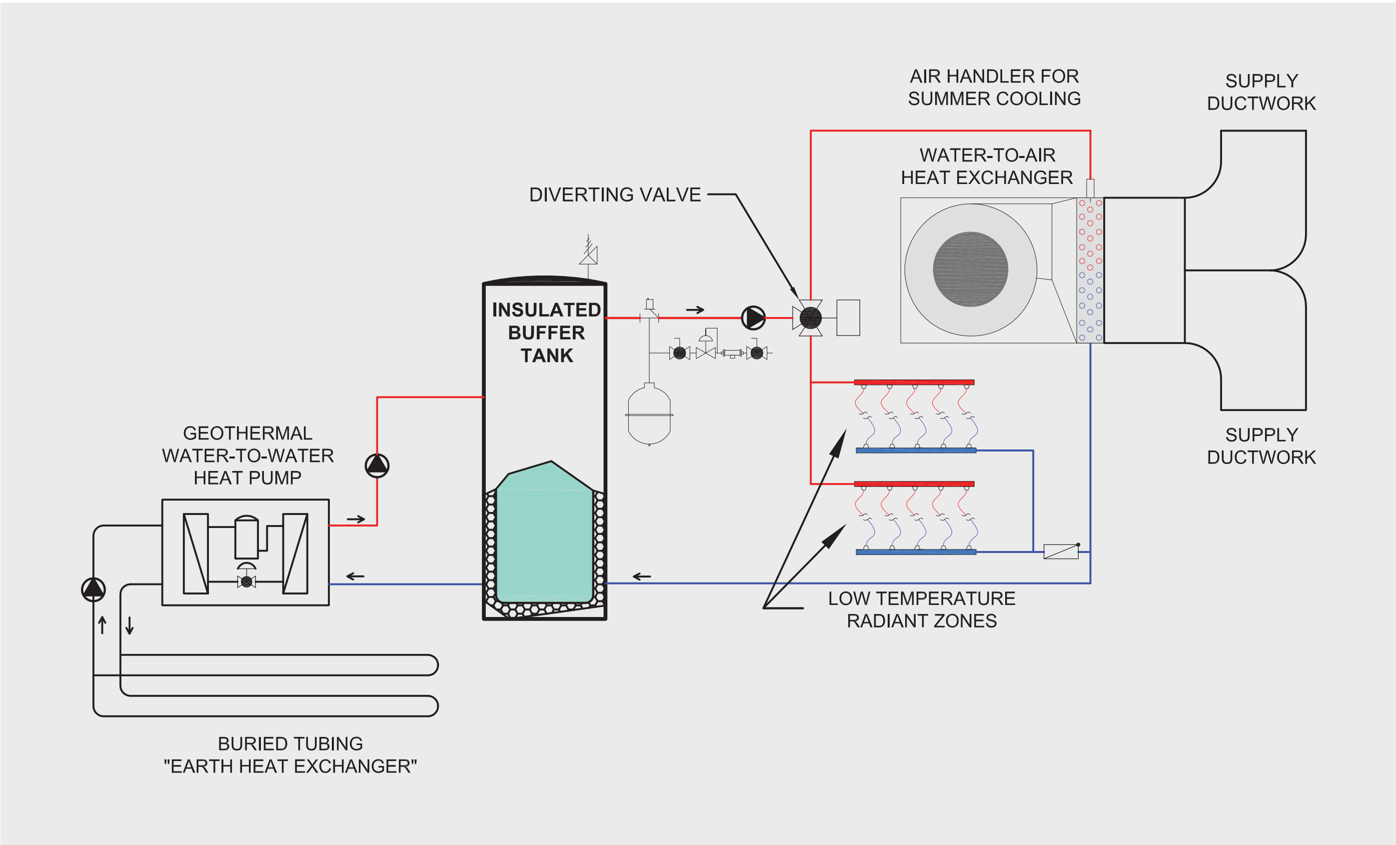

Fig. 120

16.5 Bosch Geothermal Water-to-Water Heat Pump Buffer Tank Application

Typically, all Bosch geothermal water-to-water applications will require a buffer tank (Figure 121) be placed between the water-to-water heat pump and the hydronic load to prevent short cycling and to allow different flow rates through the water-to-water unit than through a connected hydronic heating delivery system.

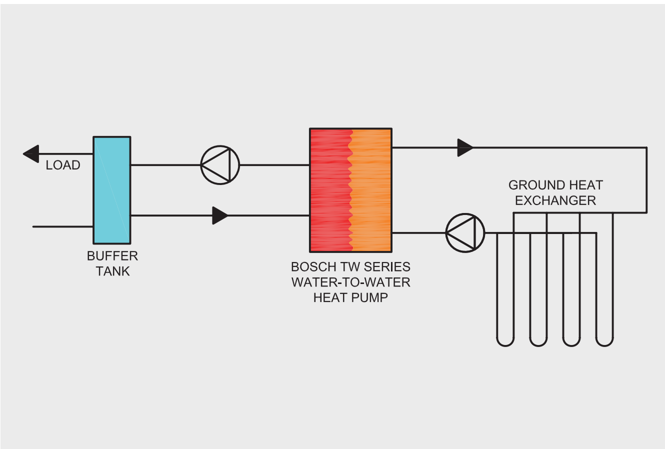

Fig. 121

Bosch geothermal water-to-water heat pumps used in heating applications typically require a much higher flow rate (gallons per minute) than the hydronic load (radiant floor heating system, etc.), and operating the system without a buffer tank can result in refrigeration circuit problems. Typically, the safest approach is to plan for a buffer tank with a water-to-water unit.

A buffer tank is also necessary for chilled water cooling applications if the Bosch geothermal water-to-water heat pump is typically more than 20% larger than the cooling load and/or multiple fan coil units are to be used. Bosch TW Series geothermal water-to-water heat pumps sized for the cooling load in applications with only a single fan coil unit may be able to operate without a buffer tank, but this is not recommended by Bosch as the cooling load is normally much smaller than the heating load.

The size of a buffer tank should be determined based upon the predominant use of the Bosch geothermal water-to-water heat pump (heating or cooling). For heating, buffer tanks should be sized at one U.S. gallon per 1,000 Btu/h of heating capacity at the maximum entering source fluid temperature (EFT) and the minimum entering load fluid temperature, the point at which the Bosch geothermal water-to-water heat pump has the highest heating capacity, usually 50-70°F EFT and 80-90°F EFT. For cooling, buffer tanks should be sized at one U.S. gallon per 1,000 Btu/h of cooling capacity at the minimum EFT and the maximum EFT, the point at which the Bosch geothermal water-to-water heat pump has the highest cooling capacity, usually 50-70°EFT and 50-60°F EFT. Always select the size of the buffer tank based on the larger of the two calculations (heating or cooling). The minimum buffer tank size is typically 40 U.S. gallons for any application.

Electric water heaters typically are good buffer tanks because of availability and low cost. However, they must be A.S.M.E. rated for heating in order to qualify as a buffer tank. Always examine insulation values of the tank, especially if buffer tank is to be used for storing chilled water, as the potential for condensation to form exists. A minimum insulation value of R-12 typically is recommended for storage tanks. When using an electric water heat as a buffer tank, there are typically fewer water connections, and alternative piping arrangements may be necessary.

Bosch geothermal water-to-water heat pumps will attain their highest efficiency when matched with low temperature distributions systems. Installers should always avoid geothermal water-to-water heat pumps in systems requiring design water/fluid temperatures above 120°F.

Depending upon the temperature difference between the entering and leaving load temperatures, the buffer tank and/or domestic hot water tank may require lower settings. For example, if the load pump provides a temperature difference of 5°F when the total pressure drop of the system is considered (piping, valves, heat exchanger pressure drop, etc.), the tank could be set as high as 140°F. However, if the design temperature difference is 10°F, the tank temperature must be lowered to a maximum of 135°F to avoid a leaving water temperature above the maximum allowed, potentially causing nuisan ce lockouts. It is always a good idea to provide a few degrees "buffer" for operating conditions where the temperature difference could be lower.

16.6 Bosch Geothermal Water-to-Water Heat Pump Piping Design

Supply and return piping must be as large as the unit connections on the heat pump (larger on long runs). Never use flexible hoses of a smaller inside diameter than that of the water connections on the unit. The Water-to-Water series units are supplied with either a copper or optional cupronickel condenser. Should your well driller express concern regarding the quality of the well water available or should any known hazards exist in your area, we recommend proper testing to assure the well water quality is suitable for use with water source equipment. In conditions anticipating moderate scale formation or in brackish water a cupronickel heat exchanger is recommended. A well water application (source side) is shown (Fig. 122), as well as an earth coupled application (source side) (Fig. 123).

Proper design of the delivery system is crucial to the Bosch geothermal water-to-water heat pump system performance, reliability and life expectancy. Bosch recommends only type “L” straight length copper tubing for connection between the Bosch geothermal water-to-water heat pump and a buffer tank.

In addition, all piping should typically be rated for 760 PSI at 200°F, and all piping must be insulated. Smaller ¾" tubing requires 1" diameter insulation with a minimum ½" wall thickness. Larger 1" tubing requires 1-⅜" diameter insulation with a minimum ½" wall thickness. Smaller ¾" tubing may be used on Bosch geothermal water-to-water heat pumps up to 3 tons with a maximum of 25 ft. one way and 8 elbows. Larger 1" tubing should be used on Bosch geothermal water-to-water heat pumps up to 6 tons with a maximum of 25 ft. one-way and 8 elbows. Refer to ASTM 388 for detailed information. Local codes supersede any recommendations in this applications manual.

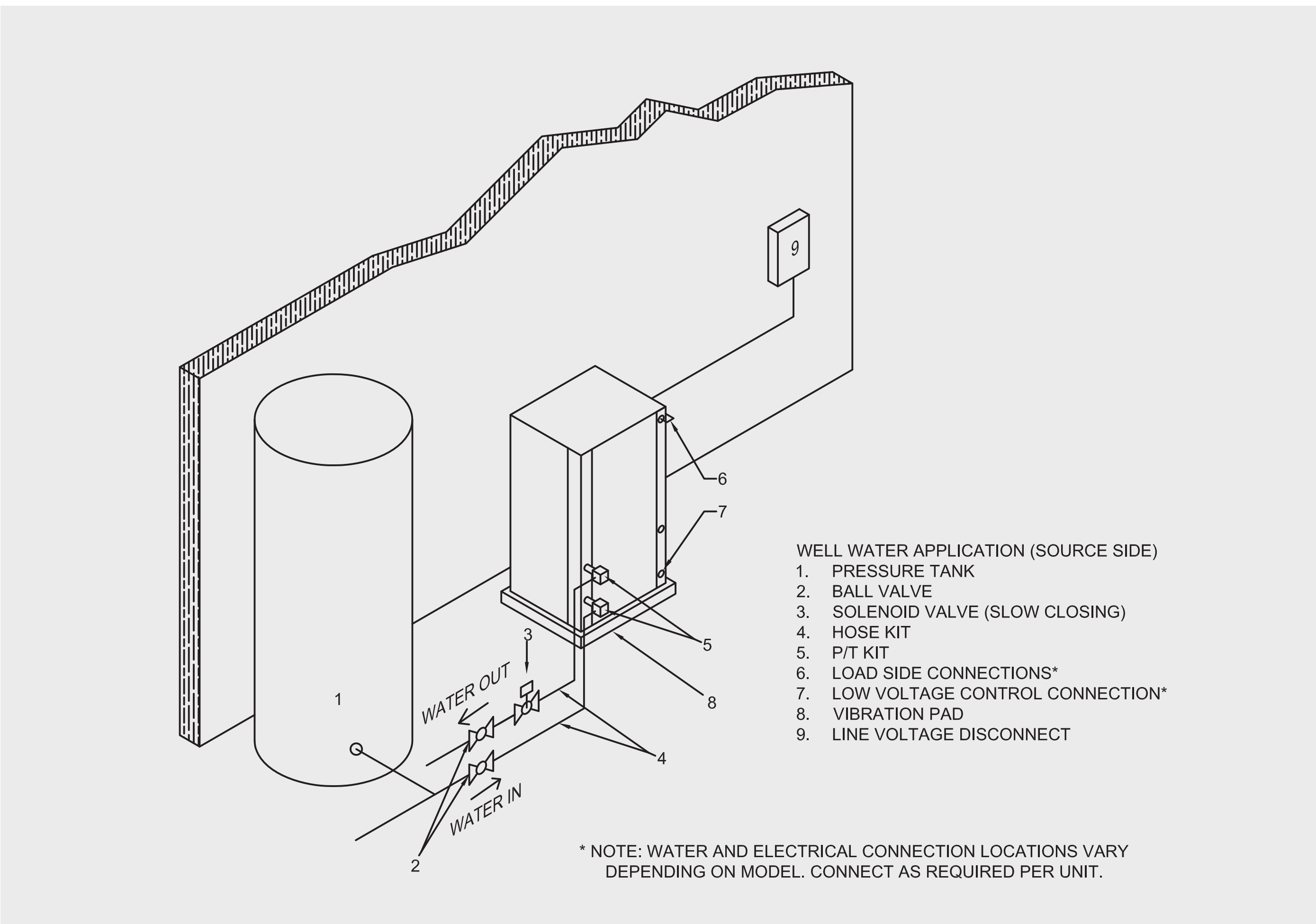

Fig. 122

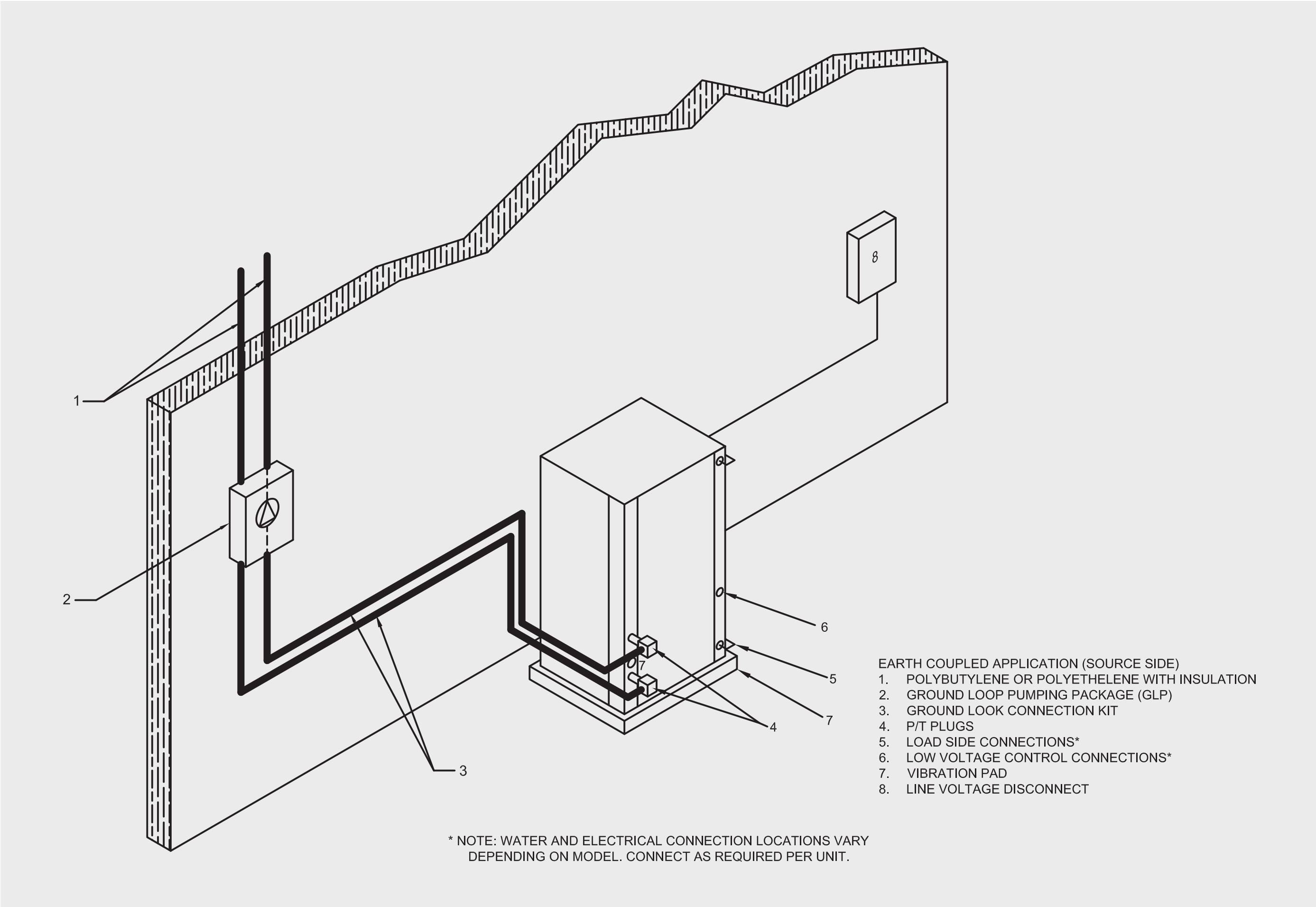

Fig. 123

16.7 Bosch Geothermal Water-to-Water Heat Pump Sequence of Operation

Cooling Mode

Energizing the “O” terminal energizes the unit reversing valve in the cooling mode.

When the thermostat calls for cooling (Y), the loop pump or solenoid valve if present is energized and the compressor will start. Once the thermostat is satisfied, the compressor shuts down accordingly. Note that a fault condition initiating a lockout will de-energize the compressor.

Heating Mode

Heating operates in the same manner as cooling, but with the reversing valve de-energized. The compressor will run until the desired set point temperature on the thermostat is achieved. Once the thermostat is satisfied, the compressor shuts down.

16.8 Bosch Geothermal Water-to-Water Heat Pump Piping System Installation

Once designed, proper installation techniques must be used to insure a problem-free system. When piping is hung, 1-¼" and smaller tubing must be supported every 6 ft.; 1-½" and larger tubing must be supported every 10 ft. Always support the pipe where a transition from horizontal to vertical is made. Plastic coated or copper hangers should be used, allowing enough space for the pipe insulation. Standoff type supports are good for rigid support, wall runs or short runs less than 10 ft. Clevis hangers (held by threaded rod) are good for piping at different heights. Rail type hangers are good for different types of pipe (e.g. water, conduit, etc.). Polyethylene clips are best for small pipes. Always run piping at 90 or 45 degree angles. Local codes supersede any recommendations in this applications manual.

Two types of soldering material may be used for hydronic installations, 50/50 (50% tin, 50% lead) and 95/5 (95% tin, 5% antimony). However, 50/50 may not be used for domestic water piping. Solder type 50/50 ⅛" diameter solder has a melting point of approximately 361-421°F, and is typically applied using a propane torch. Proper flux is always required. An acetylene torch may be used, but care must be taken not to overheat the piping, which can cause the material to become brittle. Solder type 95/5 ⅛" diameter solder has a melting point of approximately 452-464°F, and is typically applied using a map gas torch (propane will work). Proper flux is always required. An acetylene torch may be used, but care must be taken not to overheat the piping, which can cause the material to become brittle.

When preparing copper joints for soldering, tubing should be cut square, and all burrs must be removed. Do not use dented or pitted copper. Clean the inside of the tubing with a brush; clean the outside with emery cloth approximately ½" from the end of the fitting. Debris in the system could cause pump failure or corrosion. Do not put the fitting in a bind before soldering. Flux should be applied as a thin film. Excess flux will end up in the circulating fluid. Rotate a fitting while soldering to spread flux over the entire fitting.

Once the fitting has been prepared, always avoid using too much solder. Typically, a silver ring will appear on the fitting. If solder drips, the joint has excess solder. Excess solder can get into the system circulating fluid. Approximately 0.9" of ⅛" diameter solder is all that is needed for ¾" copper; 1.3" is needed for 1" copper; and 1.7" is needed for 1-¼" copper.

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

When soldering valves and unions, always use care not to overheat the non-metallic components. Always remove synthetic gasket material from dielectric unions before soldering, and always small strips of damp, clean rags when soldering.

17 Bosch Geothermal Heat Pump System Options

17.1 Bosch Cupronickel Coaxial Heat Exchanger

Cupronickel heat exchangers (Fig. 124) are recommended for open loop applications due to the increased resistance to build-up and corrosion, along with reduced wear caused by acid cleaning. Corrosion can often occur due to the water containing a higher level of chemicals.

Fig. 124

Cupronickel refrigerant-to-water heat exchangers have a cupronickel inner water tube and a steel refrigerant outer tube design (Fig. 125), rated typically to withstand 600 PSIG working refrigerant pressure and 450 PSIG working water pressure. All water lines are typically copper.

Fig. 125

The coaxial heat exchanger's convoluted tube has increased heat transfer surface area per unit length. This allows full flow of both water and refrigerant around its entire periphery for improved performance. Thermal performance is enhanced by the convolutions to both the water and refrigerant flows. All cupronickel coils are insulated (Fig. 126).

Fig. 126

17.2 Bosch Heat Recovery Package (HRP)

The Bosch Heat Recovery Package (HRP) is a factory-mounted option (Fig. 127). It consists of a forced pumped unit that employs a circulating pump to move water through a double wall/vented heat exchanger and returns the heated water to a water tank. Typically, these devices are referred to as "desuperheaters", and can provide considerable operating cost savings by utilizing excess heat energy from the Bosch geothermal heat pump to help satisfy domestic hot water needs. The double wall/vented heat exchanger factory-mounted within the Bosch geothermal heat pump eliminates the need to tie into the Bosch geothermal heat pump refrigerant circuit.

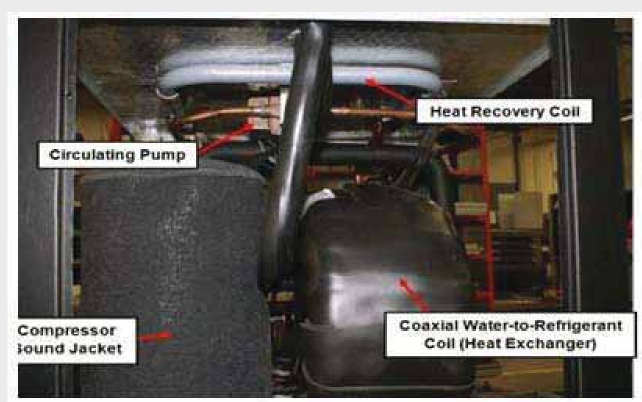

Fig. 127 Typical heat recovery package installation

The water is heated by superheated refrigerant discharge gas from the geothermal heat pump compressor. The HRP is active throughout the year (any time the geothermal heat pump is in operation), providing virtually free hot water when the heat pump operates in the cooling mode. This waste heat of the geothermal heat pump cooling mode captured by the HRP increases the capacity and efficiency of the Bosch geothermal heat pump during summer months. During winter months, the HRP operates at the COP of the particular Bosch geothermal heat pump.

If, during the heating mode, the air temperature is uncomfortable being delivered to the structure via ductwork and supply air outlets, the HRP may need to de-energized. An on/off switch is typically provided on the front of the Bosch geothermal heat pump for the HRP. During the heating mode, the HRP captures heat that is normally used for space heating.

If the HRP is installed in an area where freezing may occur, it must be drained during the winter months to prevent the possibility of the internal double wall/vented heat exchanger from freezing. Heat exchangers that rupture due to freezing will void the HRP warranty as well as the Bosch geothermal heat pump warranty. A typical example of the HRP water piping connections on a unit is shown (Fig. 128).

Electric water heaters are recommended. If a fossil fuel water heater is used, typically a second pre-heat tank is recommended. If the electric water heater has only a single heating element, the dual tank system is recommended to ensure an entering water temperature necessary for the HRP.

Normally, a single water heater tank of a minimum of 52 gallons is necessary to limit installation costs and to use less installation space. However, the dual tank configuration will provide the best efficiency while provided the maximum storage and temperate source water to the HRP.

When configuring the HRP with an existing water heater tank, always turn off electrical or fuel supply. Attach a garden hose to the water heater tank drain connection and run the hose outdoors or to an open drain to allow tank drainage. Close the cold water inlet valve on the water heater tank. Drain the water heater tank by opening the drain valve on the bottom of the tank and opening the pressure relief valve or hot water faucet.

Once the water heater tank is drained, it should be flushed with cold water until the water leaving the drain hose is clear and free of sediment. Then close all valves and remove the drain hose.

Now the HRP water piping can be installed.

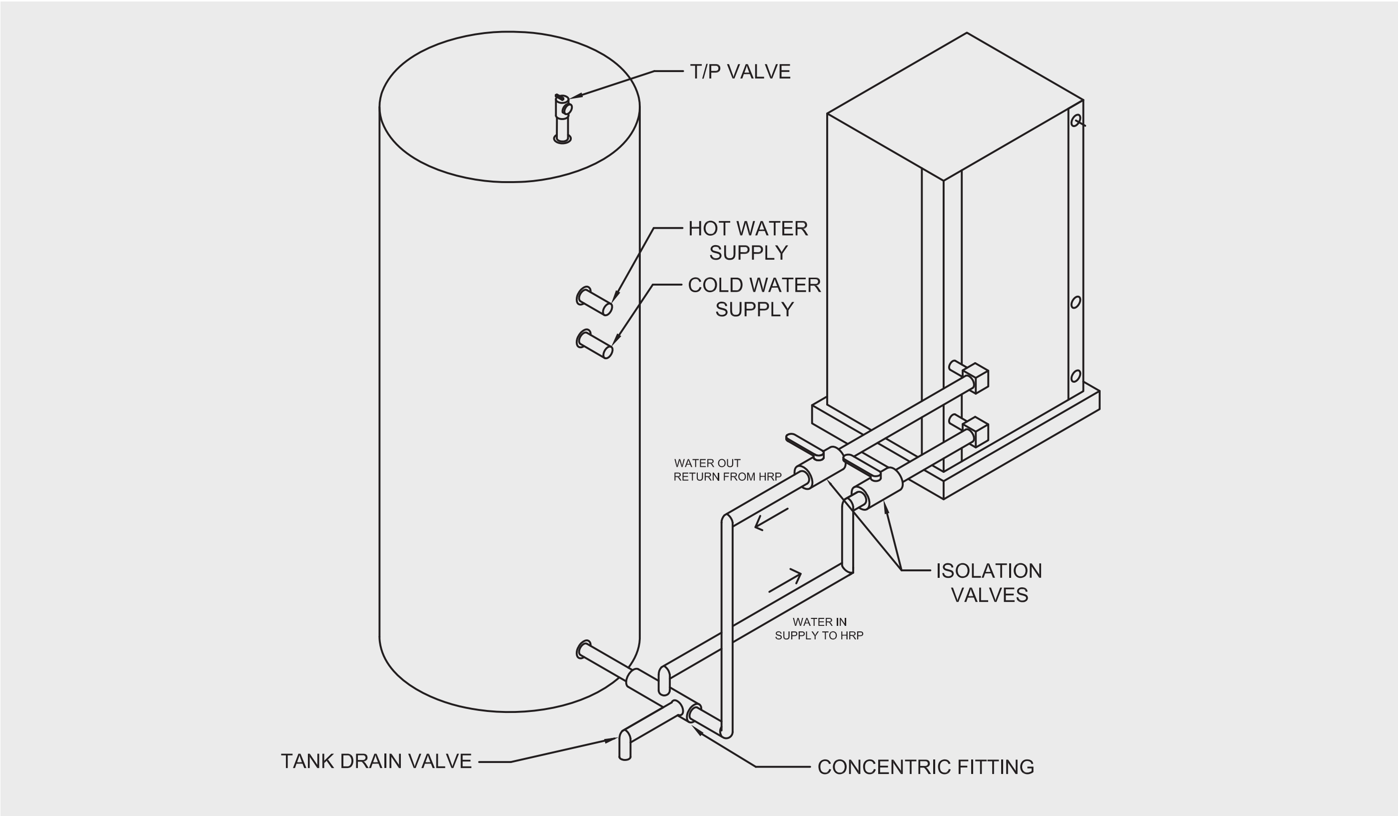

Fig. 128

All hot water piping should be a minimum of 3/8 inch O.D. copper tubing to a maximum distance of fifteen (15) feet. For longer distances but not exceeding sixty (60) feet, use ½ inch O.D. copper tubing. Insulate all exposed surfaces of both the connecting water lines with 3/8 inch minimum wall closed cell insulation. Install isolation valves on the supply and return lines to the HRP.

To refill the existing water heater tank, open the cold water supply to the tank. Open a hot water faucet to vent air from the system until water flows from the faucet then closed the faucet. Depress the hot water tank pressure relief valve handle to ensure there is no air remaining in the water heater tank. Carefully inspect all plumbing for any water leaks and correct as necessary. Purge all air from the HRP by depressing the Schrader valve on the HRP unit heat exchanger. Allow all air to bleed out until water appears at the Schrader valve.

Before restoring power or the fossil fuel source, adjust the temperature setting on the water heater tank thermostat(s) to ensure the maximum utilization of the heat available from the refrigeration system and to conserve the most energy. With water heater tanks equipped with both upper and lower electric heating elements and two thermostats, the lower element should be adjusted to 100ºF, while the upper element should be adjusted to 120ºF. Depending on the specific needs of the customer, the upper element may need to be adjusted accordingly. On water heater tanks with a single heating element and one thermostat, lower the thermostat setting to 120ºF or the "Low" position. After the thermostat adjustment, replace the access cover and restore electrical or the fossil fuel supply to the water heater.

Assure that all valves in the HRP piping system are open. Never operate the HRP pump dry. Turn on the Bosch geothermal heat pump. The HRP pump will not run unless the Bosch geothermal heat pump compressor is energized (the HRP pump should never run if the compressor is not running). Press the HRP switch on the face of the Bosch geothermal heat pump to the "On" position. The HRP pump will operate if the entering water temperature to the HRP is below 120ºF. The HRP pump will not operate if the "On/Off" switch is in the "Off" position.

The temperature difference between the water entering and leaving the HRP should be between approximately 5ºF and 15ºF.

Allow the Bosch geothermal heat pump and the HRP to operate for 20 to 30 minutes to ensure the HRP is functioning properly. The HRP pump will de-energize automatically when the water temperature entering it reaches 120ºF.

The Bosch HRP is typically equipped with a low gas limit which closes at approximately 125°F, and a hot water temperature limit that opens at approximately 140ºF.

17.3 Bosch Hot Gas Reheat (HGR)

The Bosch Hot Gas Reheat (HGR) option is often utilized to maintain a specified humidity level within a conditioned space. When in the reheat mode the return air from the space is cooled, dehumidified and reheated. By reheating the air along a constant sensible heat line the relative humidity of the leaving air is reduced. The leaving air dry bulb temperature is usually 2 to 5 degrees F. cooler than the return air temperature. This will vary model by model. This cycle will continue until the humidistat is satisfied.

The amount of moisture removal capacity of a specific Bosch geothermal heat pump is determined by the unit latent capacity rating. A Bosch geothermal heat pump's latent capacity can be determined by reviewing the specific Bosch geothermal heat pump specification data sheets. Depending upon the entering water and air conditions, a total and sensible capacity can be interpolated from the data sheets. Subtracting sensible capacity from total capacity yields latent capacity. Dividing the latent capacity by 1,069 (BTU/LB of water vapor at 80° DB and 67° WB moist air enthalpy) yields the amount of moisture removal in pounds per hour.

Typical residential reheat applications for the Bosch HGR include:

- Rooms with larger than normal latent loads
- Locations where humidity infiltration is a problem

17.3.1 Refrigerant Flow Path with HGR

In the cooling and heating modes, the refrigerant flow path is identical to standard Bosch geothermal heat pumps. In the reheat the compressor discharge gas is diverted through a reheat valve (Fig. 129) to a reheat coil (Fig. 130) which is located behind the primary air coil. The hot gas then passes though the water to refrigerant coil. At this point the rest of the cooling cycle is completed. There are two (2) check valves to prevent refrigerant flow into the reheat coil during standard cooling and/or heating cycles. A small copper bleeder line is connected to the outlet line of the reheat coil and between the expansion valve outlet and distributor to the air coil. This line is necessary to let any liquid that may have migrated to the reheat coil during reheat to escape during standard cooling and/or heating cycles.

Fig. 129 Reheat valve

Fig. 130 Reheat coil

17.3.2 Sequence of Operation with HGR:

Three modes of operation are available with Bosch geothermal heat pumps equipped with hot gas reheat:

- Cooling mode only
- Heating mode only
- Cooling mode in conjunction with hot gas reheat mode

During cooling, on a call from the front end controller, the blower relay is energized through the "G" circuit run through the normally closed contacts on the reheat relay. The reversing valve is energized through the "O" circuit. The compressor contactor is energized through the "Y" circuit which energizes the cooling relay coil closing the cooling relay normally open contacts and energizing the compressor contactor from the "R" side of the transformer. At the same time the reheat solenoid valve is disabled by opening the normally closed contacts of the cooling relay. (Note: On most front end controllers the "O" terminal is constantly energized when the system's switch is in the cooling position or the auto position.)

During heating, on a call from the front end controller, the blower relay is energized through the "G" circuit run through the normally closed contacts of the reheat relay. The reversing valve is de-energized by the absence of the "O" circuit signal. The rest of the sequence is identical to that of cooling. (Note: The compressor contactor is still energized through the cooling relay contacts.)

During reheat, on a call from the front end controller (humidistat signal) the reheat relay coil is energized through the "H" circuit. The blower relay is energized through the "R" side of the transformer run through the normally open contacts of the reheat relay coil. The "O" circuit is energized thus energizing the reversing valve. The compressor contactor is energized though the "R" side of the transformer run through normally open contacts on the reheat relay. The cooling relay remains de-energized thus the reheat solenoid is enabled. (the reheat mode always operates simultaneously with the cooling mode.)

The best way to control geothermal heat pumps with hot gas reheat is the one which fits the application.

Most other geothermal heat pump compatible thermostats in conjunction with a humidistat are acceptable for use.

"O" output for reversing valve energized in cooling mode required.

When low temperature well water is utilized as the water source (below 55 degrees F), a means of establishing two (2) flow rates, one (1) for the cooling/reheat mode and one (1) for the heating mode is recommended. In the cooling mode at low entering water temperatures and standard flow rates discharge pressures and corresponding discharge gas temperatures are relatively low. At these conditions when the reheat mode is initiated the low temperature discharge gas can condense in the reheat coil thus yielding minimal reheat capacity. A means to reduce the water flow rate and elevate the discharge pressure and temperature in the cooling/reheat mode should be provided. Conversely, at low entering water temperatures in the heating mode system suction pressure is reduced causing a loss in heating capacity. A means of providing higher flow in the heating mode should be provided. The simplest way to accomplish this is to install water regulating valves.

Operating pressures and temperatures in the reheat mode vary slightly from standard cooling mode operating characteristics. The variations are as follows:

- Discharge Pressure: (-) 5 to 20 PSIG
- Discharge Gas Temperature: (-) 5 to 15 Degrees F.
- Suction Pressure: (+) 5 to 10 PSIG
- Suction Gas Temperature: (+) 5 to 10 Degrees F.

17.4 Emerson Comfort Alert™ Diagnostic Module

Many geothermal heat pumps utilize a self-diagnostic device to assist in troubleshooting. The Comfort Alert diagnostics module (CADM) is a breakthrough innovation for troubleshooting heat pump and air conditioning system failures (Fig. 131). The module installs easily in the electrical box near the compressor contactor. By monitoring and analyzing data from the Copeland Scroll ® compressor and the thermostat demand, the module can accurately detect the cause of electrical and system related failures without any sensors. A flashing LED indicator communicates the ALERT code and guides the service technician more quickly and accurately to the root cause of a problem.

Fig. 131

This module does not provide safety protection! The Comfort Alert module is a monitoring device and cannot shut down the compressor directly.

When an abnormal system condition occurs, the Comfort Alert module displays the appropriate ALERT and/or TRIP LED. The yellow ALERT LED will flash a number of times consecutively, pause and then repeat the process. To identify a Flash Code number, count the number of consecutive flashes. Every time the module powers up, the last ALERT Flash Code that occurred prior to shut down is displayed for one minute.

17.4.1 CADM Flash Codes (Table 33)

Troubleshooting Information Solution column may reflect a possible fault that may be one of, or a combination of causes and solutions. Check each cause and adopt “process of elimination” and or verification of each before making any conclusion.

CADM Flash Codes and Solutions

Status LED	Status LED description	Status LED Troubleshooting Information Solution
Yellow "ALERT" Flash Code 3	Short Cycling - Compressor is running only briefly	1. Thermostat demand signal is intermittent 2. Time delay relay or control board is defective 3. If high pressure switch present, go to Flash Code 2 information 4. If low pressure switch present, go to Flash Code 1 information
Yellow "ALERT" Flash Code 4	Locked Rotor	1. Run capacitor has failed (may not be bad, verify) 2. Low line voltage (contact utility if voltage at disconnect is low) - Check wiring connections 3. Excessive liquid refrigerant in compressor 4. Compressor bearings are seized, measure compressor oil level
Yellow "ALERT" Flash Code 5	Open Circuit	1. Outdoor unit power disconnect is open 2. Compressor circuit breaker or fuse(s) is open 3. Compressor contactor has failed open - Check compressor contactor wiring and connectors - Check for compressor contactor failure (burned, pitted or open) - Check wiring and connectors between supply and compressor - Check for low pilot voltage at compressor contactor coil 4. High pressure switch is open and requires manual reset 5. Open circuit in compressor supply wiring or connections 6. Unusually long compressor protector reset time due to extreme ambient temperature 7. Compressor windings are damaged - Check compressor motor winding resistance
Yellow "ALERT" Flash Code 6	Open Start Circuit - Current only in run circuit	1. Run capacitor has failed (may not be bad, verify) 2. Open circuit in compressor start wiring or connections - Check wring and connectors between supply and compressor "S" terminal 3. Compressor start winding is damaged - Check compressor motor winding resistance
Yellow "ALERT" Flash Code 7	Open Run Circuit - Current only in start circuit	1. Open circuit in compressor run wiring or connections - Check wiring and connectors between supply and compressor "R" terminal 2. Compressor run winding is damaged - Check compressor motor winding resistance
Yellow "ALERT" Flash Code 8	Welded Contactor - Compressor always runs	1. Compressor contactor has failed closed 2. Thermostat demand signal not connected to module
Yellow "ALERT" Flash Code 9	Low Voltage - Control circuit < 17VAC	1. Control circuit transformer is overloaded 2. Low line voltage (contact utility if voltage at disconnect is low) - Check wiring connections *Flash Code number corresponds to a number of LED flashes, followed by a pause and then repeated. TRIP and ALERT LED's flashing at the same time means control circuit voltage is too low for operation*

Tab. 33

17.5 Direct Digital Control (DDC)

Specific models of 208/230V Bosch geothermal heat pumps are available with an optional Direct Digital Control.

The Direct Digital Control board also known as DDC (Fig. 132) is used for configure to order applications.

It is BACnet® native which makes it flexible and easy to integrate into existing Building Automation Systems (BAS). The controller provides the end user with a superior amount of information when compared to a traditional thermostat. The controller is programmed in the factory with software versions that suit the different application for the models offered by Bosch. User settings such as the time and schedules can be preprogrammed or also change during the installation of the product.

The controller should be installed on the right side of the unit; mounting holes are available on the DDC panel behind the electrical box as shown (Figure 164).The DDC kit includes all the necessary components required for the installation.

Installers should follow these steps to mount the DDC controller on the side of the Bosch geothermal unit:

- Align the controller with the pilot holes as shown (Fig. 133)
- Secure controller to unit by using (#10) provided screws

Fig. 132 Direct Digital Control

For horizontal units, remove the DDC panel and install the sensors first as directed in the Install sensors section of the Bosch DDC manual (available from Bosch).

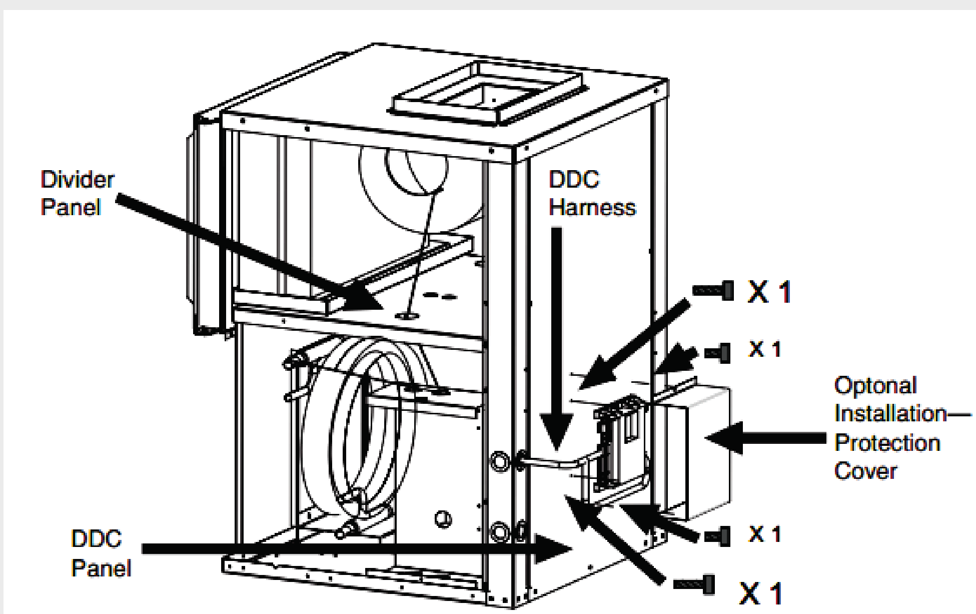

Fig. 133

Two provided sensors must be installed in the blower housing and the condenser water coil respectively. Drill a pilot hole on blower assembly (Fig. 134) to secure the sensor with the provided screw and strap. It is recommended to use a 9/64” diameter metal bit. Use the provided plastic strap and screw to secure the discharge air temperature sensor (metal portion) to the blower housing (Fig. 134).

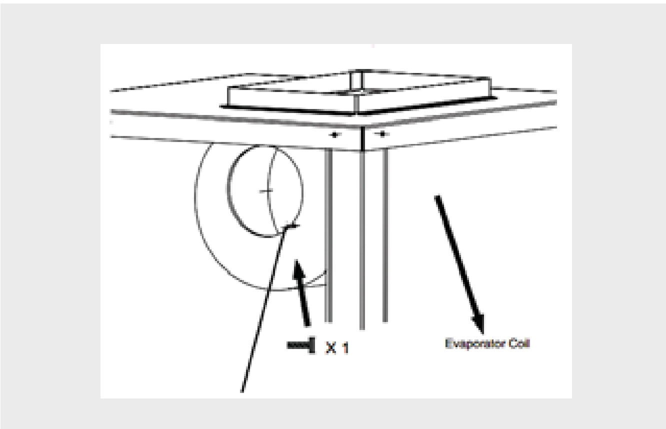

Fig. 134

Use the provided wire tie to secure the sensor to the strap. Fasten the screw by using a screw driver. Do not use a drill as it may strip the screw .Remove the cork insulation and route the sensor wire leads to the electrical box along with the existing wires through the knock out available on the blower divider panel (Fig. 133).

To install the second sensor on the condenser water coil, remove the insulation tape from the top pipe near the corner post of the water coil and place the sensor as shown (Fig. 135).

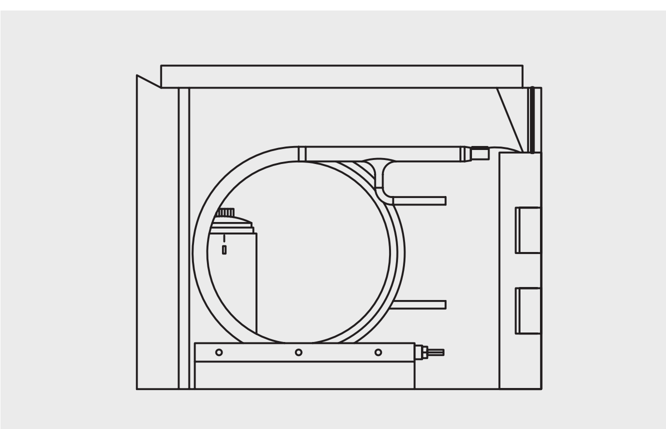

Fig. 135

Use the provided wire ties to secure the sensor to the coil pipe (Fig. 136).

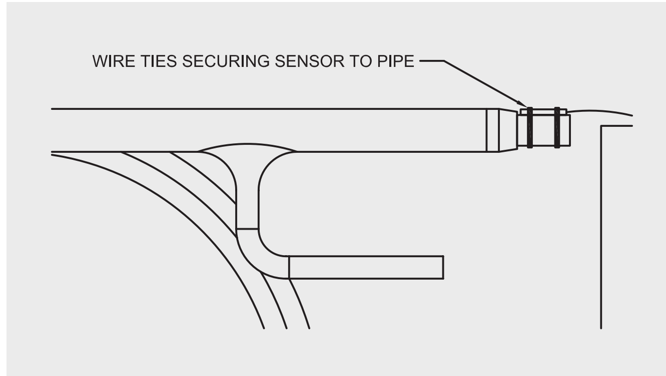

Fig. 136

Use the provided cork insulation tape to cover the sensor completely.

Use the provided insulation tape to cover both the pipe and the sensor (Fig. 137 and 138) respectively.

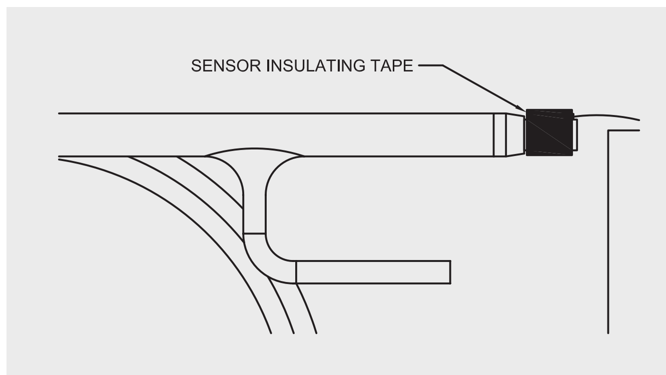

Fig. 137

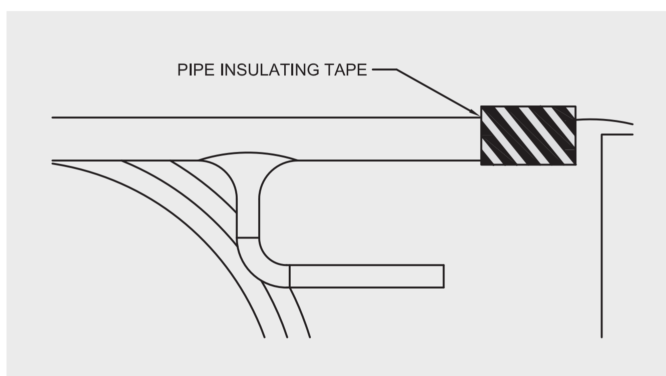

Fig. 138

Finally, route the sensor wire leads into the unit electrical box. Separate and identify the sensors wire leads for the harness connection later.

Rout the wiring harness through the unit corner post and assure the wires are inside the unit electrical box. Terminate the DDC digital output wires on the unit terminal block according to the provided DDC wiring diagram. On units with ECM interface boards, cut the provided terminals and connect the wires on the ECM control board (Fig. 139).

Terminate the DAT and the LWT sensors according to the DDC wiring diagram.

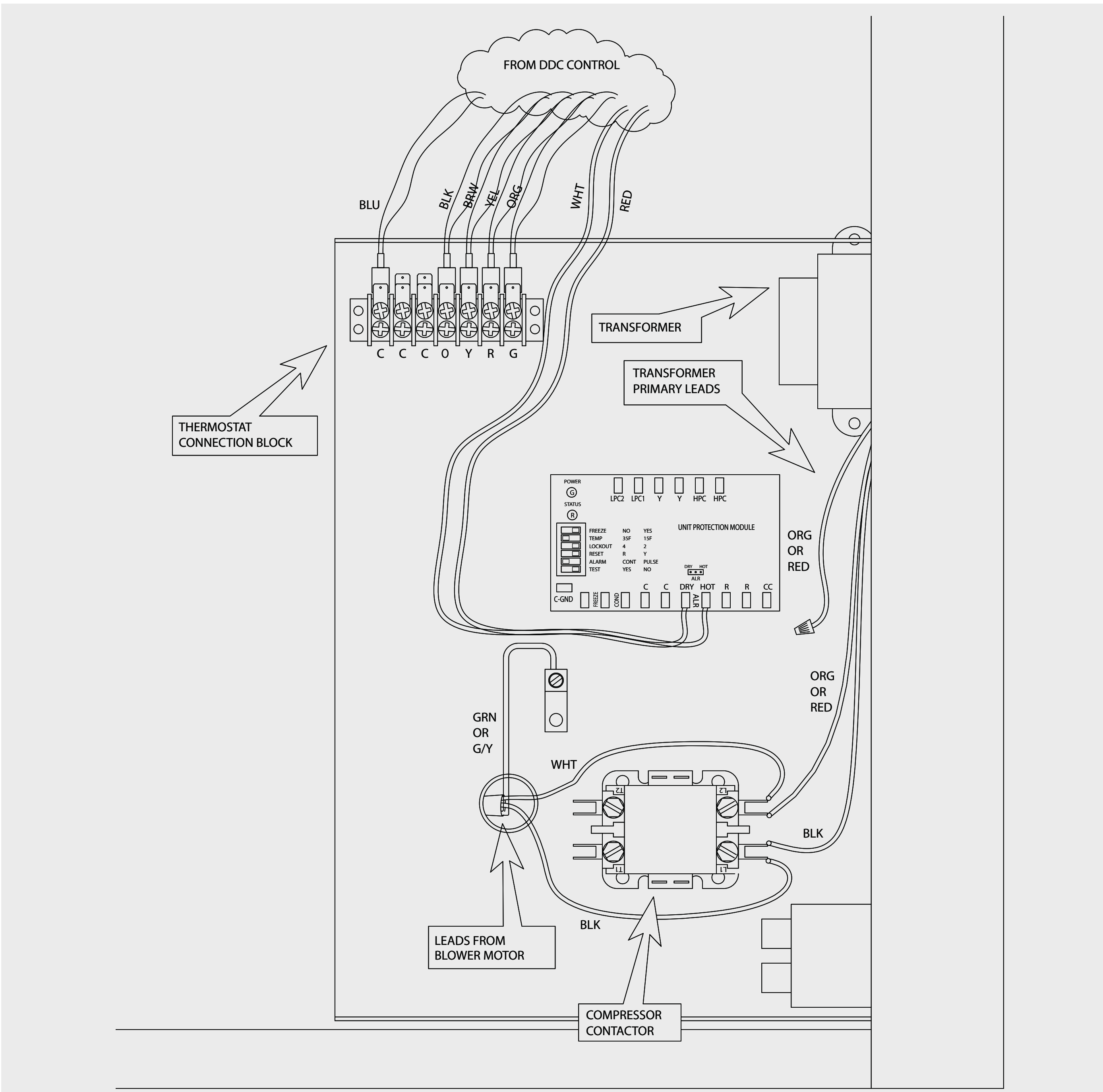

Fig. 139

Terminate/mate the male terminals from the DDC harness with female terminals from the sensors (Fig. 140).

The installer must refer to the DDC and unit wiring diagrams as the ultimate guide for electrical reference. This installation must be performed by a trained and/or certified HVAC/Electrical technician.

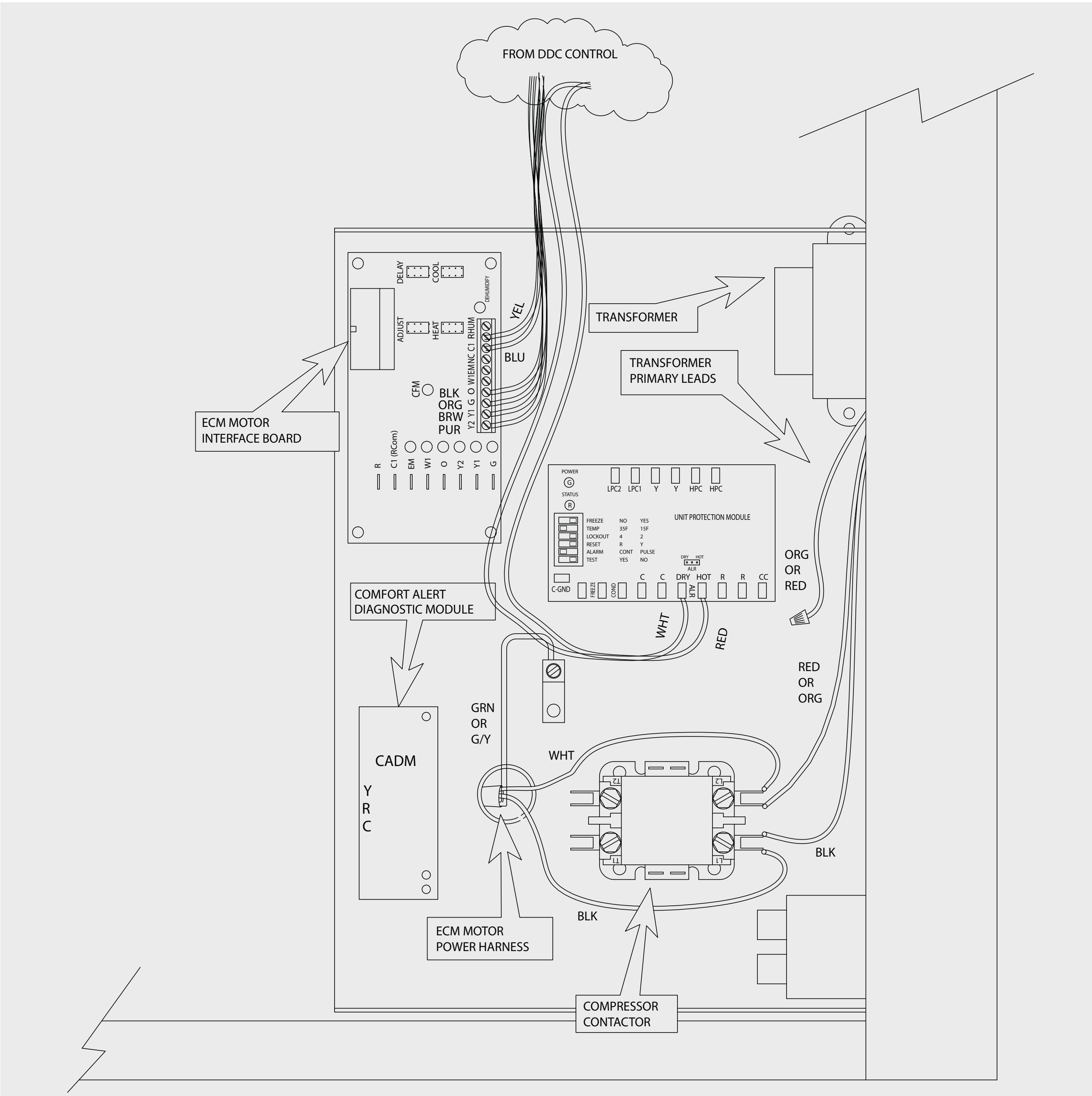

Fig. 140

17.6 Differential Pressure Switch

Specific models of 208/230V Bosch geothermal heat pumps may be equipped with a factory installed Differential Pressure Switch (DPS). The DPS prevents compressor operation if there is inadequate water flow (gallons per minute) through the geothermal heat pump water to refrigerant heat exchanger.

The DPS operates by monitoring the water side pressure drop across the water to refrigerant heat exchanger. When the pressure drop between the water in and water out lines reaches a pre-set value, compressor operation is enabled.

Fig. 141 Differential Pressure Switch (actual design may differ)

17.7 Electric Heat

Internally mounted supplemental electric heat is an available option for specific models of 208/230V Bosch geothermal heat pumps. Electric heating elements can operate along with reverse cycle heating as auxiliary heat or in lieu of mechanical heating (refrigeration heating) as emergency backup heat. Heating elements are available in nominal kW ranges of 5, 10, 15 and 20 - note that not all sizes are available on all models. Internal heat is only available on top blow vertical cabinets, end blow or straight through blow horizontal cabinet or on down blow counterflow cabinets. Always refer to the specific model installation manual for heater selection.
Internal electric heat cannot be provided with hot gas reheat. Units with internal electric heat must have 2 field power supplies.

Fig. 142 Electric Heat

17.8 Sound Package

Specific models of 208/230V Bosch geothermal heat pumps may be equipped with a factory installed sound reduction package option. This option improves the already industry leading noise levels of the heat pump by adding a heavy duty, multi density blanket over the compressor. The materials in the blanket are engineered to attenuate the most objectionable frequencies of sound coming directly off of the compressor shell, further reducing the operating noise of the heat pump.

Fig. 143 Sound Package

17.9 Soft Start (SecureStart™)

Specific models of 208/230V Bosch geothermal heat pumps are available with the SecureStart™ start assist device as either a factory installed option or a field installed accessory. This device reduces starting current for compressors by 25 to 60%. This reduction in starting current can eliminate or greatly reduce "light flicker" during compressor starts and can reduce the required size of back-up transformers. The adaptive technology of the device can also extend compressor life by providing smoother, lower current starts and by protecting the compressor from transient low voltage. Over time SecureStart™ self-adjusts to motor starting current thereby eliminating any manual calibration.

Fig. 144 Soft Start (SecureStart™)

18 Bosch Geothermal System Integration

Bosch Thermotechnology is committed to reinventing energy efficiency by offering smart domestic indoor comfort and hot water solutions through our "Bosch Complete" product portfolio.

Bosch geothermal heat pump products work alone or with our solar thermal water heating, tankless water heating and gas condensing boiler products as an integrated system to provide the opportunity to customize unique energy efficient systems (Fig. 145).

Fig. 145 "Bosch Complete" product portfolio

Our "Bosch Complete" product portfolio includes solar thermal water heating (Fig. 146). Solar collectors contain an absorber that heats up when exposed to both diffused and direct sunlight. The absorber contains pipes to transfer heat fluid. The absorber collects the heat and transports the solar heat to the tank where it can be stored for later use. When the heat transfer fluid in the collectors is warmer than the bottom of the storage tank, the solar controller will turn on the solar loop pump to transport the hot fluid from the collectors through the solar tank coil where the solar energy is then transferred to the stored water. The collectors, the pump station, and the storage tank are connected with supply and return piping that is insulated to minimize heat loss. As the system heats up or cools down, an expansion tank accounts for expansion and contraction of the heat transfer fluid.

Solar thermal water heating is ideal for residential hot water, space heating and pool heating applications, saving substantially on water heating costs while reducing the

Fig. 146 Solar thermal water heating

carbon footprint. Solar thermal water heating offers excellent value and optimal performance using high selective collector absorber coatings. These systems utilize a fiberglass collector frame and solar safety glass for robust and durable construction. Bosch solar thermal water heating systems provide the fastest hydraulic collector connection set on market today. Universal mounting systems are also standard. These systems are designed to facilitate upgrades for future expansion as necessary, and reduce installation cost through "plug and play" components.

The “Bosch Complete” product portfolio also includes tankless water heating (Fig. 147). Bosch offers the most efficient condensing tankless water heaters on the market - up to 98% efficient - which are engineered for maximum efficiency during peak usage time periods in the average home.

Fig. 147 Tankless water heating products

Compared to competitor models, which reach their optimal efficiency during off-peak usage times, Bosch tankless water heating models offer significant savings on utility bills through clean, efficient use when homeowners need it most.

Bosch tankless water heating models feature patented heat exchangers with built-in turbulators that reduce scale for optimal, long lasting performance. Dual-fan and fully modulating vertical burner designs achieve an “even” flame pattern preventing hot-spots and corrosion which reduce operating efficiency and the life of the tankless units.

Bosch features the only condensing ASME certified tankless unit on the market with most models meeting 2012 Low NOx requirements. A variety of models offering 140,000 - 225,000 BTU/hr maximum inputs are available. These tankless units are all compact, offering easy access and 100% serviceable parts, and all have a 20-Year estimated life expectancy. Indoor and outdoor models are both available with freeze protection.

Bosch also provides peace of mind to customers with our 15-year limited residential heat exchanger warranty for all tankless water heating models.

Finally, the “Bosch Complete” product portfolio also includes gas condensing boilers (Fig. 148). These products are ideal for residential space & water heating applications. They are available in 6 condensing wall-mounted models with configurations ranging from 57.2 to 151.6 MBH. All models offer high efficiency - up to 98.7% with low temperature applications (up to 96.1% AFUE). Additionally, units are Energy Star® rated with reliable performance & low emissions. Special insulation within the systems ensures ultra quiet operation, and units are all built with a removable front panel, direct access to the heat cell and a plug-in diagnostics module for easy servicing.

Bosch gas condensing boilers are equipped with a modulating fan assembly allowing the boiler to achieve optimal combustion - ensuring high efficiency throughout the boilers operational range. An aluminum-silicon heat exchanger offers increased flexibility versus traditional stainless steel with highly durable, corrosion resistant heating blocks designed to optimize clean burning combustion.

Bosch gas condensing boilers offer a high strength, plated stainless steel double-pass secondary heat exchanger and burner ensuring consistent temperature output based on demand. Digital thermostats and outdoor reset boiler controls are programmable up to six switching times throughout the day. These controls provide instant access to hot water and heating control with an exclusive keypad safety lock feature preventing unwanted tampering.

Fig. 148 Gas condensing boiler products

18.1 Bosch Geothermal Water-to-Air Heat Pump and Solar Thermal Water Heating Integrated System

"Solar-Geo Assist" Option
The system depicted (Fig. 149) is a Bosch solar-assisted water-to-air geothermal heat pump system. This system is ideal for northern heating dominated markets.

It allows for two operating modes:

1. Domestic hot water production via an immersed heat exchanger in the DHW tank
2. Solar-ground loop assist during the heating season.

18.1.1 Solar Thermal Sequence of Operation:

When the switch-on temperature difference between the collector array and the solar DHW tank is reached, the solar circulator is switched and the diverter valve (SBU module) routes the heat transfer fluid through the solar tanks heat exchanger.

Once the DHW tank reaches its upper limit and solar energy is still available, the diverter valve then routes the solar heat transfer fluid through a brazed flat plate heat exchanger and pre-heats the ground loop heat transfer fluid before it enters the geothermal heat pump. When the heat pump is in cooling mode, the diverter valve directs the heat transfer fluid back to the solar DHW tank, isolating solar from the ground loop.

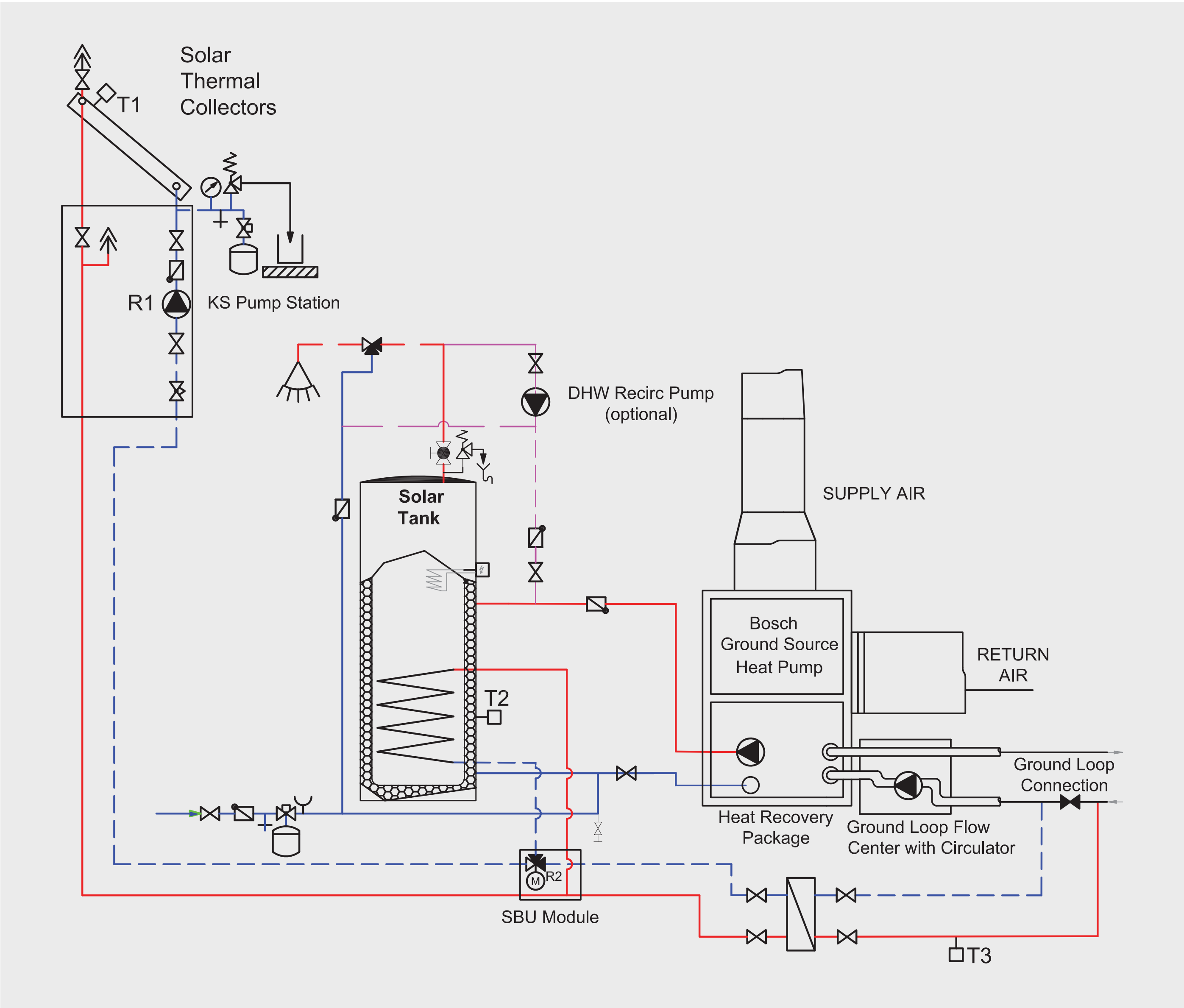

Fig. 149

18.2 Bosch Geothermal Water-to-Air Heat Pump and Tankless Water Heating Integrated System

The system depicted (Fig. 150) is a Bosch water-to-air geothermal heat pump equipped with a Heat Recovery Package (HRP) option from the factory (used for domestic hot water production). It is integrated with a Bosch Tankless Water Heater.

When waste heat is not available or is not enough to provide all of the domestic need, the Bosch Tankless water heater provides the necessary heat. This system is ideal for most climates which require cooling.

It allows for three operating modes:

1. 100 % of the domestic hot water production via the Heat Recovery Package
2. Partial energy provided by the Heat Recovery Package and additional energy provided by the modululating Tankless Water Heater
3. 100% domestic energy provided by the high-output Bosch Tankless Water Heater

18.2.1 Bosch W2A (with Optional HRP) and Tankless Water Heater Sequence of Operation:

Waste heat is recovered during the cooling months via the Bosch water-to-air geothermal heat pump equipped with the optional HRP. Waste heat is collected and stored in an appropriately sized Bosch WST storage tank. When domestic hot water is called for in the home, the water stored in the WST tank passes thru a series of valves. If the hot water stored in the tank is above the required delivery temperature to the fixtures, the water is diverted around the Bosch Tankless Water Heater. If the temperature of the stored hot water does not meet the necessary domestic temperature the flow of hot water is diverted thru the Bosch Tankless Water Heater. The flow activated Bosch Tankless Water Heater modulates to the correct firing rate based on inlet temperature, current flow rate and target supply temperature requirement.

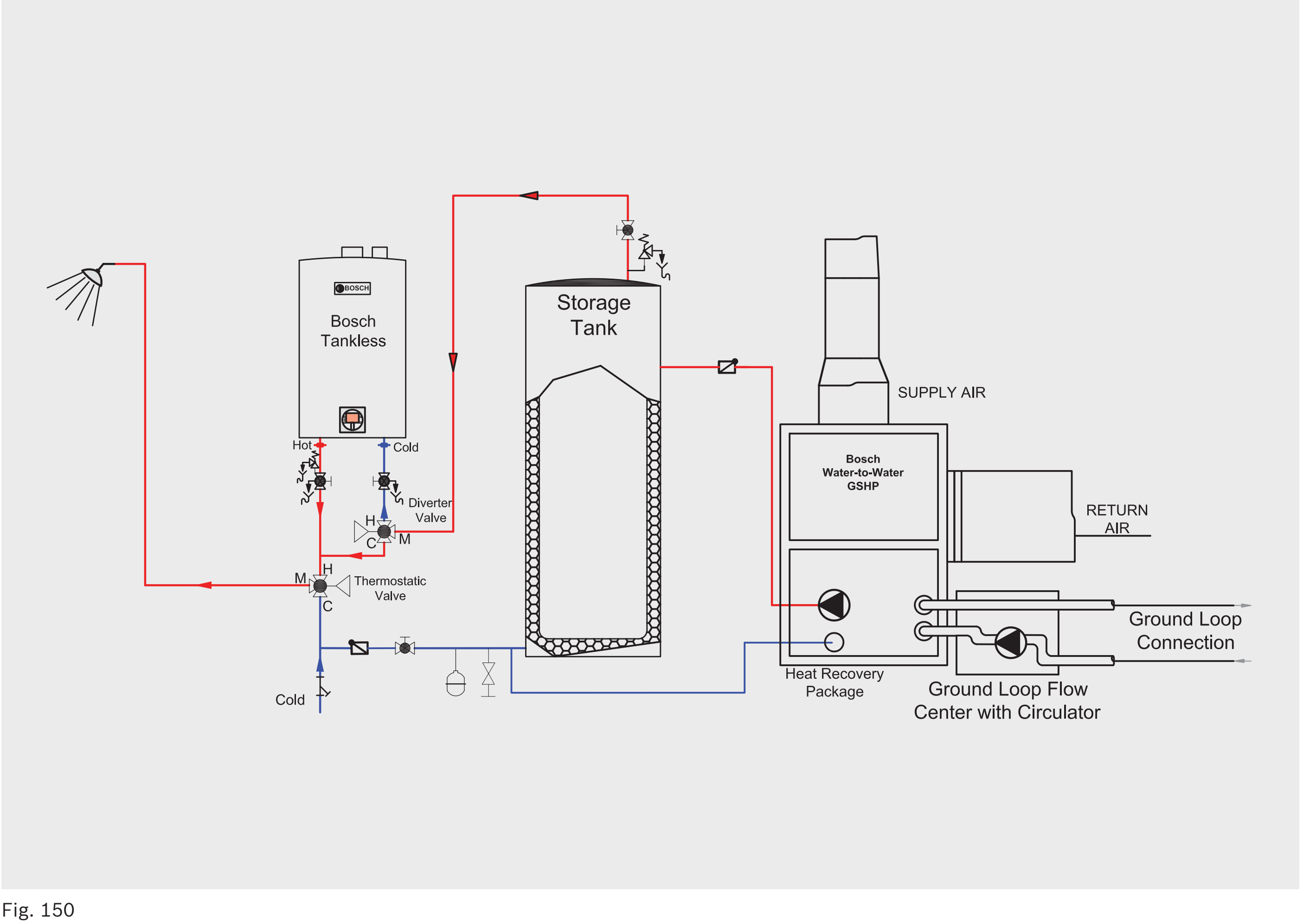

Fig. 150

18.3 Bosch Geothermal Water-to-Water Heat Pump and Condensing Gas Boiler Integrated System

The system shown (Fig. 151) is a Bosch water-to-water geothermal heat pump integrated with a Bosch condensing wall mounted boiler. This system is ideal for heating markets utilizing hydronic system designs with medium to low temperature requirements.

It allows for two operating modes:

1. The hydronic heating requirement during the “shoulder” seasons is provided for by the Water-to-Water heat pump.
2. The condensing boiler assist during colder periods.

18.3.1 Bosch Geothermal Water-to-Water Heat Pump and Condensing Gas Boiler Sequence of Operation

The Bosch Water-to-Water geothermal heat pump provides the majority of the hydronic energy requirement to the structure. This energy is stored in a buffer tank sized according to the size of the Bosch geothermal heat pump. The structure demands energy from the buffer tank independently of the operation of the Bosch geothermal heat pump. The Bosch condensing gas boiler constantly monitors the current temperature of the buffer tank and compares this temperature against the system supply temperature requirement based on outdoor temperature. As long as the current temperature of the buffer tank is maintained at or above the necessary system supply temperature for any given outdoor temperature, the Bosch condensing gas boiler remains de-energized. If the temperature of the buffer tank falls below the necessary temperature requirement, the Bosch condensing gas boiler will boost the temperature of the buffer tank until the necessary temperature is achieved.

The Bosch condensing gas boiler in Figure 151 also heats domestic hot water year round via an indirect domestic hot water tank using a diverter valve (as shown) to prioritize domestic hot water.

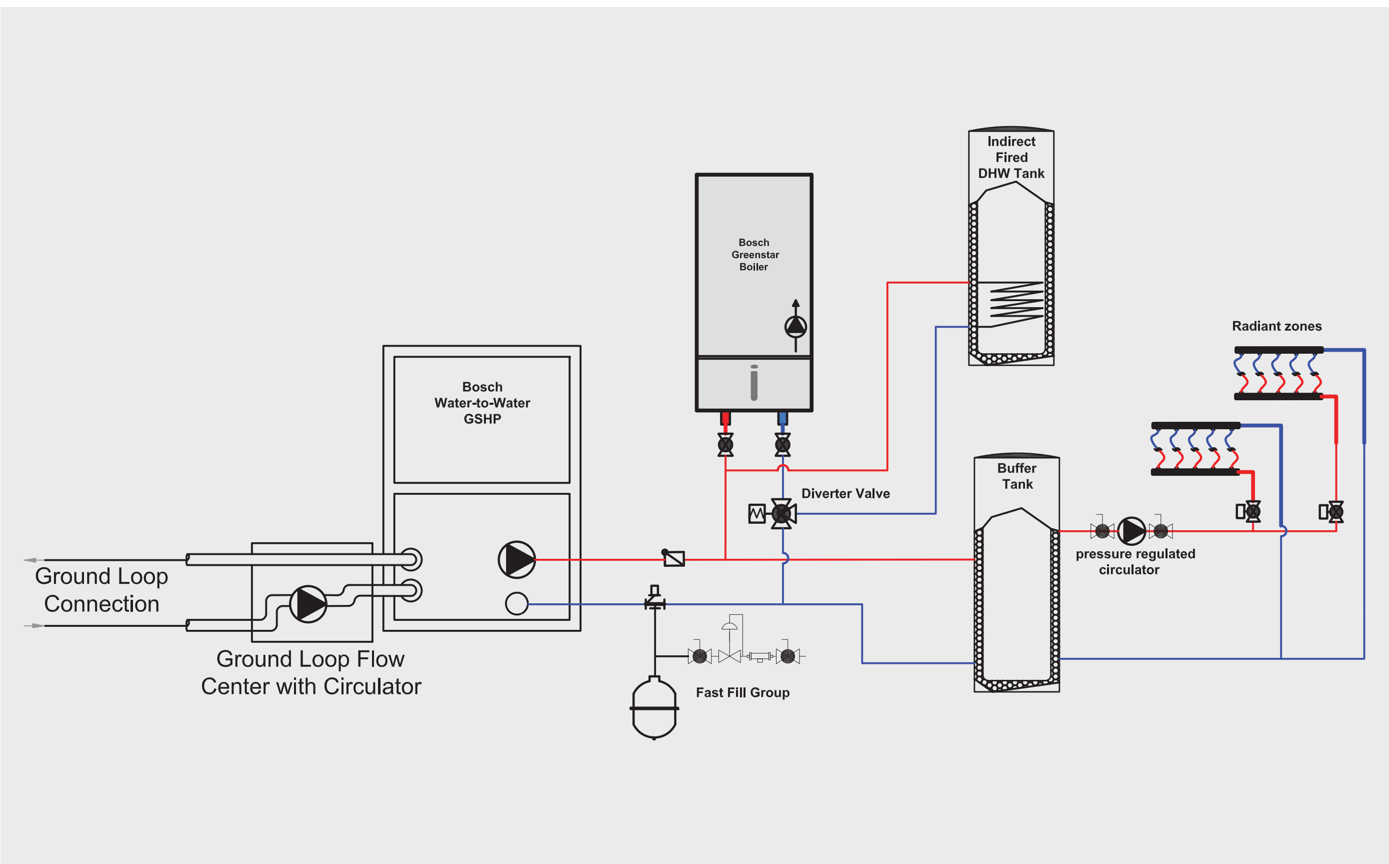

Fig. 151

19 Bosch Complete - Net Zero Energy Home

19.1 Bosch Experience Center at Serenbe (BECS) Project

Just 30 miles south of Atlanta, Georgia, there is a vibrant community known as Serenbe, an award-winning 1,000-acre real estate and sustainable farming development. This eco-conscious development is the community that Bosch chose to partner with to show homeowners Bosch geothermal and other sustainable home products. Serenbe is nestled in the heart of 65,000 acres of forest, now incorporated as the City of Chattahoochee Hills, and protected by a development plan that preserves 70 percent of the area's green space. Serenbe expertly integrates nature, passion, creativity, and community into the development. In the same way, Bosch is showing homeowners how to combine green technologies to create an integrated solution for their homes.
The first Bosch Net Zero Home (Fig. 152) in the US is at Serenbe, located at 10660 Serenbe Lane, and demonstrates the integrated systems approach by combining the following products:

- Geothermal heating and cooling system
- Heat pump water heater
- Solar photovoltaic system
- Energy efficient home appliances
- Controls

Fig. 152 Bosch Net Zero Home

Just as Serenbe integrates different components into its community's development and lifestyle, Bosch has integrated different technologies optimally in the Bosch Net Zero home. The home combines sustainable and energy efficient technologies to first minimize energy consumption and second, generate electricity to meet or exceed this small consumption. This systems approach helps homeowners reduce their monthly utility bills while protecting the environment.

The Bosch Net Zero Home is a 1,650 square-foot structure and features a complete suite of Bosch technologies, such as a geothermal heat pump heating and cooling system equipped with the optional heat recovery package ("desuperheater") for domestic hot water production, solar photovoltaic panels and an electric heat pump water heater. Bosch desires to show homeowners that no one technology is right for everyone, but that a homeowner should consider which products work best for their home and look at an integrated solution.

To maintain the home's indoor temperature at a comfortable level, a Bosch 3-ton geothermal heat pump system (Fig. 153) is installed in the home (TA035-1HZC). Designed and built domestically in Ft. Lauderdale, FL., the technology literally provides American energy from right under your feet for heating and air conditioning for the home. Ground and water temperatures (thermal energy) stay relatively constant throughout the year, allowing the system to provide extremely efficient heating or cooling all year long in virtually any climate. In general, geothermal systems allow for up to 70% savings and quiet operation compared with conventional heating and cooling systems.

Fig. 153 Bosch 3-ton geothermal heat pump

This Energy Star rated Bosch water-to-air geothermal-ready heat pump is equipped with a two-stage compressor and comes with a variety of superior standard features. The luxurious unit features a black cabinet with silver brushed aluminum front and is available in vertical, horizontal, counter flow and split system configurations from 2 to 6 tons providing a modern design to satisfy every application. Its energy efficiency makes this unit the best-in-class in operating cost savings. To provide the best in quiet comfort, the water-to-air geothermal-ready heat pump is equipped with an exclusive sound package. These particular Bosch units come equipped with a variable speed Electronically Commutated Motor (ECM) that is factory programmed to vary the air flow based on full or part load compressor operation, resulting in additional energy savings and a greater level of comfort in living areas. These units are also equipped with a Motor Control Interface Board (MCI) providing un-paralleled blower control and a MERV 11 2-inch air filter. In addition, these units come equipped with a Comfort Alert Diagnostics module to improve serviceability and reduce maintenance compared to systems without this feature.

The Bosch Net Zero Home's geothermal system design includes (Fig. 154):

- Unit: Bosch 3-ton heat pump
- Numbers of ground loops: 5
- Loop design: Vertical closed loop
- Average loop depth: 250 feet
- Number of zones: 2
- Thermostat: Bosch programmable

Fig. 154 Serenbe Geothermal System Design

Additionally, eighteen (18) Bosch rooftop solar photovoltaic (PV) panels (Fig. 155) generate electricity to power the Bosch Net Zero Energy Home, while a Bosch Compress heat pump water heater further utilizes energy efficient heat pump technology for domestic hot water production.

The home generates electricity by using a Bosch Solar Photovoltaic System. The Bosch PV system includes all necessary components, such as modules, inverters and mounting, and is connected to the power grid, converting direct current (DC) generated from sunlight into alternating current (AC). The system creates electricity during the daytime to power the home and feeds any excess energy into the grid of GreyStone Power Corporation. If the energy generated is less than the demand, the additional required electricity is pulled from the grid. Over a year under ideal conditions, the home's energy usage is forecasted to net out at zero, meaning that the home will supply as much energy as it uses. The Bosch PV system includes the solar panels and an inverter that are wired together to convert the direct current generated from sunlight into alternating current used in the home on the power grid.

Fig. 155 Bosch rooftop solar photovoltaic (PV) panels

The Bosch photovoltaic system can endure extreme weather conditions such as rain, snow, storms and hail. The system is long lasting and represents a good investment for homeowners. The PV system also makes an important contribution to the environmentally friendly energy supply.

The Bosch electric heat pump water heater (Fig. 156) uses the heat and humidity from the surrounding air to heat your domestic hot water. The heat pump water heater is twice as effective compared to a traditional tank water heater, leading up to 60% savings in water heating costs. As an extra benefit, the heat pump water heater also cools and dehumidifies the air in the home.

Fig. 156 Bosch electric heat pump water heater

The Bosch Net Zero Home is also outfitted with Bosch home appliances, including an Axxis washer and dryer; a 24-inch DLX Bar Handle dishwasher (BSHX55RL5UC); a 30-inch, single-wall oven (BHBL5450UC); a built-in microwave oven (HMB5050); a five-burner cooking surface (BNET5654UC) and a 21.7 cu. ft. refrigerator (B22CS80SNS), ensuring that the family can store, cook and wash using minimal energy (Fig. 157).

Fig. 157 Bosch Net Zero Home Kitchen

Serenbe is furthermore the home of the Bosch Experience Center that is powered and fully equipped with the full breadth of Bosch products (Fig. 158). Both an education and interaction hub, the center offers consumers, trade professionals and thought leaders the opportunity to learn about Bosch technologies while serving as a world-class gathering spot for discussions on sustainability research and education. The Bosch Experience Center is the first of its kind in North America and offers a functioning demonstration of its home and commercial building energy systems, supporting technologies, tools, appliances and lifestyle applications.

Fig. 158 Bosch Experience Center

The Experience Center is now a destination for a large cross-section of audiences because it provides a clear demonstration of how sustainable technologies for everyday use are readily available, much like conventional technology counterparts currently on the market. The Bosch Experience Center offers functioning demonstrations of (Fig. 159):

- Geothermal heating and cooling
- Solar thermal water heating
- Solar photovoltaic
- Energy-efficient home appliances
- Security and sound systems
- Power tools
- Structural materials by Bosch Rexroth
- Automotive clean diesel technology

Fig. 159 Bosch Experience Center Indoor Comfort Systems Display

Tying into Serenbe's heritage of quality and delicious cooking, the Experience Center is equipped with a professional-grade kitchen featuring Bosch appliances (Fig. 160), winner of the 2012 ENERGY STAR® Sustained Excellence Award, where organically grown food from the community will be prepared by world-renown chefs for a variety of planned events and educational seminars.

Fig. 160 Bosch Appliances

Additionally, the Bosch solar thermal system installed on the Experience Center will heat the domestic hot water at the kitchen tap, and the seven module Aleo solar PV system will generate carbon-free electricity to power the Experience Center (Fig. 161).

Fig. 161 Bosch Solar Panels

The Bosch solar thermal water heating system in the Experience Center uses solar collectors that contain an absorber that heats up when exposed to direct or even diffuse sunlight (Fig. 162). When the collectors are warmer than the storage tank, the solar loop pump will turn on and transport the hot fluid from the collectors to the solar tank where the solar energy is then stored in the water for later use. The collectors, the pump station, and the storage tank are connected with supply and return piping that is insulated to minimize heat loss. As the system heats up or cools down, an expansion tank accounts for safe expansion and contraction of the heat transfer fluid in this maintenance-free and fully automated system.

Fig. 162 Bosch Solar Thermal System

In addition to the initial Bosch Net Zero home at Serenbe, two (2) more new homes, equipped with Bosch products, are under construction – offering a cost-effective suite of sustainable technologies that will serve as a model for U.S. homeowners looking for a more eco-conscious option.

The end goal of both Bosch's Net Zero homes and The Bosch Experience Center is to show how the combination of energy efficient Bosch products are helping produce a new generation of affordable, sustainable homes that greatly reduce demand and monthly costs, and have the potential of giving energy back to the grid.

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