Residential Application/Design Manual

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Guide Revision Table:

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<th>Page</th>
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<td>August, 2010</td>
<td>KT</td>
<td>All</td>
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NOTICE: Local codes supersede any recommendations in this manual.

Overview

If you are reading this manual, you are probably already convinced that a geothermal heat pump is the best system for heating and cooling your home. However, the heat pump is only part of the system. The best geothermal heat pump on the market can appear to be a poor choice to the homeowner if its design and/or installation are not correct for the application. The following sections outline some of the design and application topics that must be considered when installing a geothermal heat pump.

Section 1: System Selection

Roth has a wide variety of models to fit almost any application. Although packaged units are the most popular for new construction, there may be other systems that work better for retrofit applications. Below is an overview of the product lines.

Packaged Water-to-Air Heat Pump

A packaged system like the one in figure 1-1 is a self-contained heat pump, much like a refrigerator or rooftop unit. The refrigerant circuit is sealed, evacuated, and charged at the factory, so the installation of a packaged system does not require any field charging. Section 3 addresses the design of the ground loop or well water system (the “water” portion of the water-to-air heat pump); section 4 covers the duct design (the “air” portion of the water-to-air heat pump).

Figure 1-1: Typical Packaged Vertical Water-to-Air Heat Pump
Advantages of a packaged unit (vs. a split system)
- No field refrigerant charging required
- Matched evaporator and condenser sections
- Higher efficiencies than split systems
- Typically a nicer looking installation
- Internal backup heat

Disadvantages of a packaged unit (vs. a split system)
- Unit is larger than most furnaces or air handlers, which may be an issue for a retrofit application with a small mechanical space
- More difficult to install with natural gas/oil/propane backup
- May require electrical upgrade for backup heat on a retrofit installation
Packaged Water-to-Water Heat Pump

Figure 1-2 shows a typical water-to-water heat pump. Like the packaged water-to-air heat pump, the refrigerant circuit is sealed, evacuated, and charged at the factory, so the installation of a water-to-water heat pump does not require any field charging. Section 3 addresses the design of the ground loop or well water system (the source “water” portion of the water-to-water heat pump); section 5 covers the hydronic design (the load “water” portion of the water-to-water heat pump).

A water-to-water heat pump is the most flexible of any geothermal heat pump, since it can be applied for space heating, space cooling, water heating, floor warming, snow melt, and many other types of applications that need hot or chilled water. The water-to-water unit is in effect a boiler and a chiller in the same box. The most popular application for the water-to-water heat pump is radiant floor heating, but it can also be used with a fan coil(s) to heat or cool the air.

When installing a water-to-water heat pump as a boiler replacement, caution must be exercised when considering water temperatures and water flow rates, especially if the heat delivery system is baseboard convection or radiators. It is likely that a backup boiler will be required for retrofit installations.

The water-to-water heat pump is NOT designed to generate domestic hot water. The water-to-refrigerant (coaxial) heat exchanger is not double-walled, which is required by code. However, a desuperheater option is available, which is designed for generating domestic hot water.

Figure 1-2: Typical Water-to-Water Heat Pump
Desuperheater
The desuperheater option includes a water-to-refrigerant coaxial heat exchanger installed between the compressor discharge line and reversing valve, which is connected to the condenser (air coil in heating, coaxial heat exchanger in cooling). Unlike the source coaxial heat exchanger (water-to-refrigerant heat exchanger, connected to the ground loop or well water system), the desuperheater coax is a double-wall, vented water-to-refrigeration heat exchanger, as shown in figure 1-3.

Water flow rate through the desuperheater coax must be very low to avoid turning the desuperheater into a condenser, and “robbing” too much heat from the main condenser. Typically, about 0.4 GPM per ton is used for desuperheater flow rate. The desuperheater pump operates anytime the compressor is operating (unless the one of the temperature limits is open). Desuperheater is also called DWG (Domestic hot Water Generator) option or DHW (Domestic Hot Water) option.

In cooling, the desuperheater takes some of the heat that would have been rejected to the ground loop via the condenser (coax), and uses it to make domestic hot water. Therefore, the desuperheater produces nearly free hot water (other than the fractional horsepower circulating pump) in the cooling mode. In heating, the desuperheater takes some of the heat that would have been used to heat the space via the condenser (air coil), and uses it to make domestic hot water. Even though the desuperheater is “robbing” some of the heat from the space, it is a very small amount, and the system is heating water at a very high C.O.P. (3.0 to 4.0, depending upon loop temperature), compared to an electric water heater at a C.O.P. of 1.0.

Some geothermal heat pumps turn off the desuperheater pump when back up heat is energized. However, studies show that on an annual basis, the system is more energy efficient when the desuperheater is utilized any time the compressor is running. When the hot water tank is already heated, a thermal switch turns off the desuperheater pump. The pump may also be turned off if the compressor discharge line is too cool.

The desuperheater is normally connected to an electric water heater as shown in figure 1-4. However, if a fossil fuel water heater is desired, figure 1-5 illustrates a dual tank installation, which uses a pre-heat tank to circulate water between the heat pump and the pre-heat tank, and a primary tank (gas, electric, oil, or propane) to increase the water temperature if necessary before it is delivered to the domestic hot water piping. This approach makes the most effective use of the desuperheater and provides double the storage.

NOTE: A dual tank installation is always recommended when a recirculating system is utilized. The recirculating system should be connected to the primary (not the pre-heat) tank.
Figure 1-4: Typical Single Tank Desuperheater Installation

Figure 1-5: Typical Two Tank Desuperheater Installation (Water Heater #1 is Pre-Heat Tank)
Section 2: System Sizing

All geothermal systems require a heat loss/heat gain calculation for proper heat pump/ground loop sizing. ACCA (Air Conditioning Contractors of America) Manual J, HRAI (Heating, Refrigeration, and Air Conditioning Institute of Canada) Manual SAR-R1, or ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers) Handbook—Fundamentals are the only acceptable methods for calculating heat loss/heat gain. This section will discuss the methodology and design of geothermal systems with a proper load calculation.

Heat Loss/Heat Gain Calculations
Most heat loss/heat gain calculations are based upon 2.5% or 1% of the time. In other words, the outdoor temperature in the summer is only hotter than the design temperature 2.5% or 1% of the time on average. Normally, the heating design temperature is referred to as the 97.5% or 99% design condition, and the cooling design temperature is referred to as the 2.5% or 1% 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.

Once the heat loss and heat gain calculations are complete, enter the heat loss/heat gain and design conditions into the GeoAnalyst software (see section 3 for GeoAnalyst software use). Note that GeoAnalyst uses total cooling load for equipment sizing. Check the specifications catalog to make sure that the heat pump has enough sensible cooling capacity to satisfy the sensible cooling load.

NOTE: Some electric utilities specify a winter outdoor design temperature that must be used in order to get a rebate. In many cases, the outdoor design temperature that is specified is colder than the 97.5% or 99% design temperature. Caution should be exercised to avoid over-sizing the system, especially for cooling operation. An oversized system may lead to high humidity complaints because the unit is not running enough in the cooling mode to dehumidify the space. If the rebate requirements cause the system to be oversized by one ton or more, the total installation cost may be less in some cases if the rebate is not used (i.e. larger system with rebate costs more than smaller system without rebate).
### Figure 2-1: Example Manual J Printout

#### Right-J® Worksheet

**Entire House**

**ROTH INDUSTRIES, INC.**

---

**Job:**

Date: Feb 23, 2010

By:

---

**1. Room name**

**2. Ceiling height**

**3. Exposed wall**

**4. Room dimensions**

**5. Room area**

---

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**6. c) AED excursion**

- Envelope loss/gain
  - Air required (cfm): 2060
  - Redistribution: 0
  - Less external load: 0
  - Less transfer:
    - Occupants: 0
    - Appliances: 0
  - Total room load:
    - Heat: 2060
    - Cool: 0

---

**Printout certified by ACCA to meet all requirements of Manual J 8th Ed.**

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**8**

**Section 2: System Sizing, August, 2010**
Determining Heat Pump Size (Water-to-Air All Electric Systems)
Since a heat pump is designed to both heat and cool, sizing can sometimes be confusing. For the most part, air-to-air heat pumps are always sized based upon the heat gain (cooling load) because the capacity of the unit is dependent upon the outdoor air temperature. For example, a typical 3 ton air-to-air heat pump has a heating capacity of about 22,000 Btuh at 27°F outdoor air temperature (OAT) and about 12,000 Btuh at 0°F OAT. Increasing the size of the heat pump to 4 tons only increases the capacity at 0°F to about 15,000 Btuh, an increase of only 3,000 Btuh, which is not significant enough to merit the additional cost. Plus, a larger unit will be oversized for cooling.

A geothermal heat pump is not dependent upon outdoor air temperature, only the ground temperature. For example, a typical 3 ton unit has a minimum heating capacity of about 31,000 Btuh (30°F entering water temperature), regardless of outdoor air temperature. This difference in operation sometimes causes designers to consider larger heat pumps to avoid the use of auxiliary electric heat. However, a larger heat pump requires a larger ground loop, more ductwork (water-to-air units), and possibly larger pumps, which increases the installation costs. Sizing, therefore, should be based upon an economic balance point, which can be determined through the use of the GeoAnalyst software.

Economic balance point is defined as the point where the heat pump is sized to satisfy all of the cooling load and the amount of heating load that is the most economical. In other words, the percentage of the heating load satisfied by the heat pump and the amount satisfied by the backup heat should be based upon an economic decision. For example, if there are only 100 hours per year that the heat pump cannot satisfy the heating load (i.e. backup heat must make up the difference), it would normally not make economic sense to increase the size of the unit to lower the amount of backup heat needed.

Another determining factor in sizing a geothermal heat pump should be the International Residential Code (IRC), which has recently adopted ACCA Manual S as the basis for water-to-air heat pump sizing. Manual S allows the size of the heat pump to exceed the total cooling load by a maximum of 25% in cold climates (does not apply to water-to-water heat pumps). In Canada and the Northern U.S. this requirement may create a situation where the thermal balance point (the point at which the heat pump can no longer keep up with the heating requirements and backup heat is needed) is too high, potentially creating a higher than desired operating cost. In this situation, a two-stage heat pump should be applied. Example 1 below illustrates the use of a two-stage heat pump to provide enough heating capacity, while still satisfying the IRC requirements.

**Thermal Balance Point**
Since thermal balance point will change depending upon geographic location, a method for determining the correct thermal balance point is to review the annual kWh used for the heat pump and the annual kWh used for backup heat, which is shown on the GeoAnalyst summary report. As a general guideline, the annual kWh for backup heat should be 10% of the total annual heating kWh or less to provide an adequate thermal balance point. This method is typically more helpful than attempting to determine a thermal balance point by other means.
**NOTE:** The GeoAnalyst summary report indicates total annual kWh and annual auxiliary kWh for comparison to the guideline mentioned above.

In some climates, the cooling load will always dictate heat pump sizing (i.e. if the heat pump is sized for the cooling load, very little or no backup heat will be required to satisfy the heating load). When sizing for cooling, it is important to look at the specification catalog to make sure that the heat pump has enough sensible cooling capacity to satisfy the sensible cooling load (see “Using the Specification Catalog” later in this section). Considering only total cooling capacity could result in an undersized heat pump in some climates.

**NOTE:** Keep in mind that some retrofit installations will require an electrical upgrade if a packaged unit with electric backup is selected. The unit and backup electric heat are two separate electrical circuits.

---

### Example 1 (Heating Dominate Climate):

Minneapolis, Minnesota  
Heat Loss = 65,000 Btuh (outdoor design temp. = -12°F; indoor temp. = 70°F)  
Sensible Heat Gain = 24,000 Btuh (outdoor design temp. = 89°F; indoor temp. = 75°F)  
Total Heat Gain = 32,000 Btuh

Per Manual S, 25% larger than the total cooling load = 1.25 x 32,000 = 40,000 Btuh

Maximum heat pump size = 3.3 tons (40,000 Btuh)

According to the GeoAnalyst software, a 3 ton unit on the above load would produce a thermal balance point of 17°F with an annual heating cost of $1,255 per year at $0.10/kWh. The heat pump provides about 89% of the heating requirements with backup electric heat needed for the other 11%.

A second GeoAnalyst calculation was done with a 4 ton two-stage unit. The 4-ton unit has a part load (first stage) AHRI cooling capacity of 37,900 Btuh (see table 2-1), which meets the IRC requirements of less than 40,000 Btuh. In the second analysis, the thermal balance point drops to 2°F (no backup heat needed until 2°F outdoor temperature), and the annual heating cost drops to $991 per year at $0.10/kWh. The heat pump now provides about 98% of the heating requirements.

**Table 2-1: AHRI Ground Loop Performance**

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<td>Part Load</td>
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Final selection will depend upon the electric rates (and the anticipated escalation rate). In this example, an annual savings of over $250 per year seems to make economic sense. If the electric rate is higher or lower, the decision may change. GeoAnalyst provides an economic analysis that includes escalation rates for fuel costs.
Example 2 (Cooling Dominate Climate):

St. Louis, Missouri
Heat Loss = 55,000 Btuh (outdoor design temp. = 6°F; indoor temp. = 70°F)
Sensible Heat Gain = 24,000 Btuh (outdoor design temp. = 94°F; indoor temp. = 75°F)
Total Heat Gain = 34,000 Btuh

Per Manual S, 25% larger than the total cooling load = 1.25 x 34,000 = 42,500 Btuh

Maximum heat pump size = 3.5 tons (42,500 Btuh)

According to the GeoAnalyst software, a 3 ton unit would satisfy the cooling load, and produce a thermal balance point in heating of 22°F with an annual heating cost of $565 per year at $0.10/kWh. The heat pump provides about 97% of the heating requirements with backup electric heat needed for the other 3%.

A second GeoAnalyst calculation was done with a 4 ton two-stage unit. The 4-ton unit has a part load (first stage) AHRI cooling capacity of 37,900 Btuh (see table 2-1), which meets the IRC requirements of less than 42,500 Btuh. In the second analysis, the thermal balance point drops to 7°F (no backup heat needed until 7°F outdoor temperature), but the annual heating cost only drops to $497 per year at $0.10/kWh, since there are very few hours per year below 7°F in St. Louis.

If a third analysis is run with a 2 ton unit, the heat pump would not have enough capacity to satisfy the cooling load. Therefore, the 3 ton is the best selection from an economic standpoint. Final selection will depend upon the electric rates (and the anticipated escalation rate). In this example, if a 4 ton unit with an annual savings of only $68 per year ($565 - $497 = $68) is selected, there would be a long payback of the additional investment. If an electric rate is used, the decision may change. GeoAnalyst provides an economic analysis that includes escalation rates for fuel costs.
Determining Heat Pump Size (Water-to-Water Systems)

Like water-to-air heat pumps, economics must be considered for water-to-water applications. Although there are numerous water-to-water systems installed that provide 100% of the heating load, a larger system (and ground loop) is required, which increases installation costs. If the system is not sized for 100% of the heating load, a method of backup heat must be selected. Table 2-2 shows the available choices for backup heat.

There are a variety of applications for heating and cooling with water-to-water heat pumps. The most popular use of a water-to-water heat pump is radiant floor heating. However, if designed for lower water temperatures, fan coils may also be used for forced air heating with hot water generated from a water-to-water heat pump. Likewise, the heat pump can chill water for forced air cooling using a fan coil. Floor warming is a popular application in some parts of North America, where the hot water generated by a water-to-water heat pump is circulated through a radiant floor system to maintain a warm floor, but not provide the entire heating needs. Normally, a forced air system (water-to-air heat pump or fan coil) provides the balance of the heat needed to satisfy the design heat load.

When sizing a water-to-water heat pump, the same guidelines apply as with water-to-air heat pumps. An accurate heat loss/gain is still required. Geo Analyst should be used to help determine the economic and thermal balance point. The only difference is the delivery method for heating and cooling.

**NOTE:** Virtually all water-to-water applications need a buffer tank between the heat pump and the hydronic load. The heat pump usually needs a much higher water flow rate than the hydronic load (e.g. radiant floor heating). Operating without a buffer tank can cause refrigeration circuit problems.

### Table 2-2: Backup Heat Methods for Water-to-Water Heat Pumps

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<th>Method</th>
<th>Location</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<td>Backup boiler or A.S.M.E. rated water heater</td>
<td>Load side of heat pump¹</td>
<td>Lowers heat pump capacity and loop required, and installation costs in most cases</td>
<td>May require two-stage aqua-stat and/or additional controls. Also normally requires a condensing boiler or mixing valve.</td>
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<td></td>
<td>Source side of heat pump²</td>
<td>Lowers heat pump capacity and loop required, and installation costs in most cases</td>
<td>Load water temperature is still limited by the maximum heat pump leaving water temperature</td>
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<tr>
<td></td>
<td></td>
<td>Warmer water increases heat pump capacity</td>
<td>May not be enough of an increase in capacity to satisfy load</td>
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<tr>
<td>Electric heat in air handler used for air conditioning</td>
<td>Separate system</td>
<td>Lowers heat pump capacity and loop required, and installation costs in most cases</td>
<td>Requires larger electrical service and wiring. Cooling and heating zones may not be the same, especially with radiant floor.</td>
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<tr>
<td>Separate water-to-air unit used for air conditioning could also be used for heating</td>
<td>Separate system</td>
<td>Eliminates need for electric backup or backup boiler.</td>
<td>Increases loop requirements. Cooling and heating zones may not be the same, especially with radiant floor.</td>
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</table>

¹ See section 6 for buffer tank design.
² Boiler would be installed between the ground loop and the heat pump "Water (Source) In."
Using the Specification Catalogs
The specification catalogs include performance data at various entering water temperatures for both heating and cooling operation. This is the same data that is loaded into GeoAnalyst for use in sizing geothermal heat pumps. Figures 2-3 and 2-4 show examples of a typical 3 ton water-to-air specification for both heating and cooling modes. Column headings are explained below each of the figures. Figure 2-5 is an example of a 3 ton water-to-water heat pump. Since most of the column headings are the same for the water-to-water data, only the ones that are different from water-to-air are explained below the data.

Heating Definitions

**CFM:** Cubic Feet per Minute is the airflow through the heat pump. Nominal CFM is shown, but the heat pump CFM may be adjusted based upon the application requirements.

**EWT:** Entering Water Temperature (°F) is the temperature of the water coming from the ground loop or well water into the heat pump. Roth geothermal heat pumps are designed to operate between 30°F and 90°F EWT in the heating mode.

**GPM:** Gallons Per Minute is the flow rate in U.S. gallons per minute through the heat pump. Three flow rates are shown, which correspond to the type of application selected. Below is an explanation of each of the three flow rates.

- **Lowest flow rate:** The lowest flow rate is approximately 1.5 to 2.0 gpm per ton, and is used for open loop (well water) applications when the EWT is 50°F or higher. Each specification catalog has a page towards the front of the catalog labeled “Water Flow Selection.” It is very important to do this calculation for open loop systems to make sure that the leaving water temperature (LWT) will not be too close to freezing. Higher flow rates than the lowest shown may be required for open systems, depending upon the EWT.
- **Highest flow rate:** The highest flow rate is approximately 3.0 gpm per ton, and is the nominal (optimum) flow rate for closed loop systems.
- **Middle flow rate:** The middle flow rate is approximately 2.25 gpm per ton, and is the nominal (optimum) flow rate for closed loop systems.

**WPD:** Water Pressure Drop is the pressure drop across the water-to-refrigerant coaxial heat exchanger at the flow rate listed to the left. WPD is shown in PSI (pounds per square inch) and in FT (feet of head). PSI is actually PSIG (“G” is for gauge pressure), and is normally used when servicing the equipment. Checking the pressure drop across the heat exchanger with a pressure gauge is a quick way to estimate flow rate. FT is used for sizing pumps. Most pump curves show gpm as a function of FT.

**EAT:** Entering Air Temperature (°F), sometimes referred to as return air temperature (RAT), is the air entering into the heat pump.

**HC:** Heating Capacity is the heating output in MBtuh \((M = \text{thousands of Btu per hour})\). For example 30.2 MBtuh = 30,200 Btuh.
**Figure 2-3: Heating Performance Data – 3 Ton Packaged Water-to-Air Unit**

### Performance Data:

**3.0 Ton, 1200 CFM, Heating**

<table>
<thead>
<tr>
<th>EWT</th>
<th>GPM</th>
<th>WPD</th>
<th>PSI</th>
<th>FT</th>
<th>EAT</th>
<th>HC</th>
<th>HE</th>
<th>LAT</th>
<th>KW</th>
<th>COP</th>
<th>HE</th>
<th>LAT</th>
<th>KW</th>
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### Notes:

1. Desuperheater Capacity is based upon 0.4 GPM Flow per nominal ton at 90°F entering hot water temperature.
2. Extrapolation data down to 25°F for heating and interpolation between CFM, EWT & GPM data is permissible.
3. See Flow Rate Selection in the specifications catalog for proper application.
Heating capacity is the amount of heat extracted from the ground loop plus the waste heat used to power the compressor and fan. Since there are 3.413 Btu per kilo Watt (KW), KW can be converted to Btuh and added to the heat of extraction to get heating capacity.

Example: In the above performance data at 30°F EWT, 9.0 gpm, and 70°F EAT, HC = 30.7, HE = 21.8 and KW = 2.63. To convert KW to MBtuh, multiply 2.63 by 3.413. The result is 8.97 MBtuh. COP = Output (HC) ÷ Input (KW converted to MBtuh) = 30.7 ÷ 8.97 = 3.42, which is the COP in above heating performance data.

**Heating with Desuperheater:** Heating with Desuperheater uses the same column headings as the Heating columns, but the performance has been adjusted to reflect the new values when the desuperheater is running. In the heating mode, the desuperheater is piped between the compressor discharge and the air coil. Therefore, when the desuperheater is operating, a small amount of heating capacity is being diverted to the water tank, thereby reducing the heating capacity slightly. However, since the condenser (air coil) appears larger when in series with the desuperheater coil, efficiencies are slightly higher.

**HE:** Heat of Extraction (MBtuh) is the amount of heat that is being extracted or absorbed (sometimes called heat of absorption) from the ground loop or well water by the heat pump refrigeration circuit.

**LAT:** Leaving Air Temperature (°F), sometimes referred to as supply air temperature (SAT), is air temperature leaving the heat pump.

**KW:** Kilo Watts is the power required to run the heat pump compressor, fan, and controls at that specific condition.

**COP:** Coefficient Of Performance (MBtuh/MBtuh) is the efficiency of the heat pump at that specific condition. COP is defined as the output in MBtuh divided by the input in MBtuh. HC is already shown in MBtuh. KW needs to be converted to MBtuh to calculate COP.
Cooling Definitions

**CFM:** Cubic Feet per Minute is the airflow through the heat pump. Nominal CFM is shown, but the heat pump CFM may be adjusted based upon the application requirements.

**EWT:** Entering Water Temperature (°F) is the temperature of the water coming from the ground loop or well water into the heat pump. Roth geothermal heat pumps are designed to operate between 50°F and 100°F EWT in the cooling mode.

**GPM:** Gallons Per Minute is the flow rate in U.S. gallons per minute through the heat pump. Three flow rates are shown, which correspond to the type of application selected. Below is an explanation of each of the three flow rates.

- **Lowest flow rate:** The lowest flow rate is approximately 1.5 to 2.0 gpm per ton, and is used for open loop (well water) applications when the EWT is 50°F or higher. Each specification catalog has a page towards the front of the catalog labeled “Water Flow Selection.” Even though the lowest flow rate will be sufficient for cooling operation, since the unit is a heat pump, it is very important to do this calculation for open loop systems to make sure that the leaving water temperature (LWT) in heating will not be too close to freezing. Higher flow rates than the lowest shown may be required for open systems, depending upon the EWT. It is normally not cost effective to operate at a different flow rate in cooling than in heating.

- **Highest flow rate:** The highest flow rate is approximately 3.0 gpm per ton, and is the nominal (optimum) flow rate for closed loop systems.

- **Middle flow rate:** The middle flow rate is approximately 2.25 gpm per ton, and is considered the minimum closed loop flow rate. Residential closed loop systems should be designed for nominal flow rate, but flow rates may be slightly reduced (no lower than the middle flow rate) if the nominal flow rate would cause the system to be designed for a larger pump, thereby adding unnecessary Watts to the system. For example if a single flow center pump can provide 8 gpm for a 3 ton system (greater than the minimum of 7 gpm), it would be wasteful to install two pumps to achieve 9 gpm, nominal flow.

**WPD:** Water Pressure Drop is the pressure drop across the water-to-refrigerant coaxial heat exchanger at the flow rate listed to the left. WPD is shown in PSI (pounds per square inch) and in FT (feet of head). PSI is actually PSIG (“G” is for gauge pressure), and is normally used when servicing the equipment. Checking the pressure drop across the heat exchanger with a pressure gauge is a quick way to estimate flow rate. FT is used for sizing pumps. Most pump curves show gpm as a function of FT.

**EAT DB/WB:** Entering Air Temperature DB/WB (°F), sometimes referred to as return air temperature (RAT), is the air entering into the heat pump. DB (Dry Bulb) is the actual measured temperature (°F) using a thermometer. WB (Wet Bulb) is the temperature measurement that reflects the physical properties of air and water vapor, which represents the relative humidity of the air at the listed DB temperature.

**TC:** Total Cooling Capacity is the total cooling output in MBtuh (M = thousands of Btu per hour). TC includes both the sensible cooling capacity (SC) and latent capacity (LC). Therefore, TC = SC + LC. TC is the amount of heat extracted from the air to be rejected to the ground loop or well water system.
### Figure 2-4: Cooling Performance Data – 3 Ton Packaged Water-to-Air Unit

#### 3.0 Ton, 1200 CFM, Cooling

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<th>EWT</th>
<th>GPM</th>
<th>WPD</th>
<th>Performance Data:</th>
</tr>
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<td>EAT</td>
<td>SC</td>
</tr>
<tr>
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<td>SC</td>
<td>HR</td>
<td>KW</td>
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#### Performance Data:

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<th>WPD</th>
<th>EAT</th>
<th>DB/ WB</th>
<th>Cooling</th>
<th>Cooling with Desuperheater</th>
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<td>EAT</td>
<td>SC</td>
<td>HR</td>
<td>KW</td>
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<td>10.1</td>
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### Notes:

1. Desuperheater Capacity is based upon 0.4 GPM Flow per nominal ton at 90°F entering hot water temperature.
2. Extrapolation data down to 25°F for heating and interpolation between CFM, EWT & GPM data is permissible.
3. See Flow Rate Selection on page 20 for proper application.
**SC**: Sensible Cooling Capacity is the amount of cooling capacity in MBtuh, not including LC. In other words, SC is only associated with the temperature drop, not the moisture removal.

Example: In the above performance data at 90°F EWT, 9.0 gpm, and 75/63°F EAT, TC = 34.4, and SC = 26.0. To find the latent capacity, subtract SC from TC. $LC = TC - SC = 34.4 - 26.0 = 8.4$ MBtuh at 1,200 CFM. When CFM is lowered, the air flow through the air coil will be slower, allowing more moisture to be removed from the air, and increasing LC.

**HR**: Heat of Rejection (MBtuh) is the amount of heat that is being rejected to the ground loop or well water by the heat pump refrigeration circuit. HR includes the amount of heat extracted from the air (TC) and the waste heat from the compressor and fan. Since there are 3.413 Btu per kilo Watt (KW), KW can be converted to Btuh and added to TC to get HR.

Example: In the above performance data at 90°F EWT, 9.0 gpm, and 75/63°F EAT, TC = 34.4, and KW = 2.73. To convert KW to MBtuh, multiply 2.73 by 3.413. The result is 9.32 MBtuh. $TC + KW = 34.40 + 9.32 = 43.72$ MBtuh, which is the HR shown above (rounding errors do not allow the example to come out to exactly 43.4).

**KW**: Kilo Watts is the power required to run the heat pump compressor, fan, and controls at that specific condition.

**EER**: Energy Efficiency Ratio (MBtuh/KW) is the efficiency of the heat pump at that specific condition. EER is defined as the output in MBtuh divided by the input in KW. TC is already shown in MBtuh, and input power is shown in KW.

Example: In the above performance data at 90°F EWT, 9.0 gpm, and 75/63°F EAT, TC = 34.4, and KW = 2.73. $EER = \frac{Output \ (TC)}{Input \ (KW)} = \frac{34.4}{2.73} = 12.6$, which is the EER in the above cooling performance data.

**Cooling with Desuperheater**: Cooling with Desuperheater uses the same column headings as the Cooling columns, but the performance has been adjusted to reflect the new values when the desuperheater is running. In the cooling mode, the desuperheater is piped between the compressor discharge and the water-to-refrigerant coaxial heat exchanger. Therefore, when the desuperheater is operating, any amount of capacity that is being diverted to the water tank reduces the amount of heat being rejected to the ground loop or well water. Since the condenser (water coil) appears larger when in series with the desuperheater coil, efficiencies and cooling capacities are higher during desuperheater operation, and the hot water generated is essentially "free" waste heat.

**DH**: Desuperheater water Heating capacity is the amount of heat (MBtuh) that is being delivered to the domestic hot water tank when the unit is operating in cooling.
**Figure 2-5: Performance Data – 3 Ton Water-to-Water Unit**

### 034 Performance Data:
**3.0 Ton, Full Load Capacity**

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<table>
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</tr>
</tbody>
</table>

* See Page 19 for Application Notes
Definitions

EST: Entering Source Temperature (°F) is the same as EWT for water-to-air units. However, since a water-to-water unit has two coaxial (water-to-refrigerant) heat exchangers, they must be identified according to the function. Source is the ground loop or well water heat exchanger; load is the hot or chilled water heat exchanger, connected to the radiant floor system, chilled water air handler, etc.

GPM: See water-to-air data for definition. In the performance data, GPM is assumed to be the same for the load as the source.

WPD: See water-to-air data for definition. Since the source and load GPM is assumed to be the same, the WPD is also the same for the source and load.

ELT: Entering Load Temperature (°F) is the temperature of the water entering into the load connections of the heat pump. ELT is typically the water temperature returning from the buffer tank (see section 6 for buffer tank design).

HC: See water-to-air data for definition.

HE: See water-to-air data for definition.

KW: See water-to-air data for definition.

LLT: Leaving Load Temperature (°F) is water temperature leaving the heat pump from the load heat exchanger. LLT is typically the water temperature being delivered to the buffer tank (see section 6 for buffer tank design).

COP: See water-to-air data for definition.

DH: See water-to-air data for definition. Substitute air coil for load coil.

TC: Total Cooling Capacity is the total cooling output in MBtuh (M = thousands of Btu per hour).

HR: See water-to-air data for definition. Substitute air coil for load coil.

EER: See water-to-air data for definition.

DH: See water-to-air data for definition.
GeoAnalyst Overview
GeoAnalyst is the most comprehensive residential design and application software for geothermal systems on the market today. No other software has as many features. Even more important, the loop-sizing portion uses “pure” IGSHPA algorithms, not manufacturer-adjusted loop sizing formulas. The ease of use and user configurability provides users with an accurate system analysis, which includes free updates.

Ground Loop Types
Before using GeoAnalyst, it is important to have a basic understanding of ground loop types and configurations, since the software will only provide accurate information if the correct inputs are used. This understanding will also affect pump sizing and loop layout.

Vertical Loops
Vertical loops are normally used where space is at a premium or where drilling costs are low. Figures 3-1 and 3-2 illustrate the two types of vertical closed loop systems. The vast majority of vertical loops are like the one in figure 3-1. When using ¾” polyethylene (PE) pipe, most loops are designed for one bore per ton. The bore depth is normally between 125 and 300 foot deep, depending upon geographic location. The “U” bend at the bottom joins the two pipes, creating one closed loop circuit. The loop in figure 3-2 is used when space is limited for the bore field. Although two pairs per bore only gains about 15% shorter bores, there are some cases where 15% could mean the difference between being able to get the loop installed or not. Another twist on the vertical loop design would include two shorter bores in series when drilling conditions are very difficult. For example, two 75-foot bores in series performs about the same as a single 150-foot bore.

NOTE 1: GeoAnalyst calculations are based upon the assumption that the vertical bores are properly grouted (per IGSHPA guidelines). If proper grouting is not used, loops may not perform as predicted. In fact, improperly grouted bores could lead to even greater problems, depending upon the formations and/or aquifers disturbed.

NOTE 2: Calculations for vertical loops are based upon 10 foot spacing between bores.
**Horizontal Loops**

Horizontal loops are designed for applications where there is plenty of space for the ground loop and/or where drilling tends to be expensive or difficult. Figures 3-3 through 3-12 show the variety of pre-configured horizontal loops that may be designed with GeoAnalyst. If none of those options are appropriate, GeoAnalyst provides a user-defined horizontal loop type as shown in figure 3-13.

**NOTE:** All horizontal loop calculations are based upon 10 foot spacing between trenches.

Horizontal loop designs are based upon available land and the excavation equipment used. 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. For example, loops in figures 3-3, 3-4, 3-7, and 3-8 are designed for excavation with a trencher. Loops in figures 3-4, 3-5, 3-6, 3-9, 3-10 and 3-11 are designed for excavation with a backhoe or track hoe.

The single pipe loop in figure 3-3 is not common, but may be used if there is plenty of land. To complete the circuit, each trench must go out and circle back to the starting point. If using ¾" PE pipe, there is usually one trench per ton. The top view of a parallel circuit design might look like a flower petal. If the loop is designed as one large series pipe (not recommended except for 1-1/2 to 2 ton systems), the pipe diameter must be larger, typically 1-1/4" PE or larger.

**Figure 3-4: Two-Pipe Loop (Trencher or Backhoe)**

Two-pipe loops are more common with trencher installations. If a backhoe is available, more pipes are typically added to the trench, as in figure 3-5 or 3-6. Each two-pipe loop is a circuit. For example, the bottom pipe in the trench on the right in figure 3-4 may be sending fluid out to the trench, and the top pipe may be returning.
fluid from the trench (it does not matter which pipe is outgoing and which one is incoming). At the end of the trench, the bottom pipe loops around and comes back on top. Therefore, these two pipes are considered to be one closed loop circuit. If using \( \frac{3}{4} '' \) PE pipe, there is usually one two-pipe trench per ton.

A four-pipe loop allows the installer to use about 60 to 70% of the trench needed for a two-pipe loop because more pipes are in the trench. For example, if 250 foot of two-pipe trench (500 foot of pipe) is needed, only about 150 foot of four-pipe trench (600 foot of pipe) may be needed for the four-pipe loop. This design allows installation on smaller lots. The four-pipe loop has two circuits per trench, so when using \( \frac{3}{4} '' \) PE pipe, one trench can normally handle two tons of equipment. Since the four-pipe loop has an even number of circuits, there may be more or less circuits than tons, depending upon the equipment size. For example, a 5 ton heat pump may need either two trenches (four circuit) or three trenches (six circuit), depending upon pressure drop (related to pump sizing) and Reynolds number (a measurement of turbulence of the fluid).

A six-pipe loop continues the theme of “more pipes in the trench equals less trench.” This design allows the installer to use about 85 to 95% of the trench needed for a four-pipe loop. Continuing the example from above with 250 foot of trench (500 foot of pipe) for a two-pipe loop and 150 foot of trench (600 foot of pipe) for a four-pipe loop, the six-pipe loop only needs 135 foot of trench (810 foot of pipe). The six-pipe loop has three flow paths or three circuits per trench. Therefore, one trench could be used for a three ton system, which will limit the amount of excavation needed, especially for a retrofit installation.

The slinky loop continues the discussion of more pipes in the trench. The slinky design provides a method for increasing the density of the pipe in the trench by coiling the pipe to achieve the effect of more pipes per foot of trench. Vertical slinky loops, as shown in figure 3-7 and 3-8 are designed for installation with a trencher. Due to the configuration of the
pipe, the vertical slinky loop is no longer popular because it is very difficult to backfill unless the soil is very fine (e.g. sand) or flowable backfill is used. Horizontal slinky loops, as shown in figures 3-9 and 3-10 are used more frequently than vertical slinky loops because they are easier to install and backfill. A backhoe is used with a horizontal slinky.

Slinky loops may be an extended design like figures 3-7 and 3-9 or a compact design like figures 3-8 and 3-10. Continuing the example from above with 250 foot of two-pipe trench (500 foot of pipe), 150 foot of four-pipe trench (600 foot of pipe) and 135 foot of six-pipe trench (810 foot of pipe), the extended slinky (4 foot of pipe per foot of trench) needs about the same amount of trench as the six-pipe loop (just slightly more at 140 foot of trench, 560 foot of pipe), and the compact slinky (8 foot of pipe per foot of trench) needs about 70 to 75% of the trench required for an extended slinky or six-pipe loop (95 foot of trench, 760 foot of pipe).

The design of the slinky provides one circuit per trench. Like the horizontal two-pipe loop, the slinky loop is typically designed with one trench per ton when ¾" PE is used. Pressure drop must be considered when using the compact slinky or six-pipe loop, as circuits can become quite long.
Another type of horizontal loop that is popular in Northern climates is the racetrack loop. Notice in figure 3-11a that all of the pipes are at the same level. In colder climates, the frost line is deeper, so multi-level loops like the four-pipe or six-pipe loop are more difficult to install. Safety regulations such as the U.S. OSHA (Occupational Safety and Health Administration) or the Canadian Ministry of Health OSH make it more difficult to dig deeper trenches without creating safety violations or shoring the walls to prevent cave-in. Therefore, digging a wider and deeper trench is sometimes more cost-effective. Figure 3-11b shows a top view of the racetrack loop. In figure 11b, there are 10 pipes, which would provide 5 circuits for a 5 ton installation. GeoAnalyst allows the input of trench depth and number of pipes. The distance between pipes is always 12 inches.
Horizontal bore loops are ideal for retrofit applications, since there is very little excavation. Only a small square hole is needed for headering the pipes. Like the horizontal two-pipe or slinky loop, a horizontal bore loop has one circuit per trench, and therefore one trench per ton is used with ¾” PE pipe. It is important to consider the equipment used for horizontal boring, so that a good grouting process is possible. Otherwise, the pipe may not be in good contact with the soil. Most horizontal bore machines are capable of boring down 8 to 12 feet, so horizontal bore loops are good applications even in colder climates.

If none of the loop types discussed so far meet the requirements for the installation, GeoAnalyst provides a user-defined option. As shown in figure 3-13, the user inputs the number of pipes and the number of total trenches. Then, each pipe is entered based upon Cartesian coordinates (i.e. X and Y axis). The help file in GeoAnalyst shows a detailed example of a user-defined loop.

Pond Loops
The last type of closed loop system is the pond loop. A pond loop is the least expensive closed loop system, since the only excavation required is the trenching between the pond and the header pit near the home. The mat loop is recommended for heating dominated climates, since the larger surface area allows better heat exchange when extracting heat from the water. The coil loop is recommended for cooling dominated climates. It is much easier to reject heat to a pond than to extract heat. The surface of the pond is essentially a natural cooling tower, so there is no need to install the mat loop in cooling climates. The mat takes up more space than the coil and requires additional labor. Like the two-pipe or slinky loop, each coil or mat is a circuit. One coil or mat is needed per ton.

When considering a pond loop, a number of design considerations must be taken into account, which follow:
• The pond must be a pond year-around. Even in the shallowest conditions, the pond must be 8 to 10 feet deep at the location where the loop is installed.
• In a heating dominated climate a spring-fed pond or fast moving body of water (e.g. stream, river) should be avoided, as the loop will become too cold for heat transfer.
• A minimum of ½ acre of surface area is required for a residential installation of 3 to 5 tons. A larger body of water is always better.
• The pond should not be too far from the home. More than 200 to 300 foot distance is normally not practical, since the pump size must be increased. Plus, with large distances to the pond, the installation may become a horizontal loop by default (i.e. the supply and return lines become a loop).
• Some public and private bodies of water have restrictions, not allowing pond loops.
• A pond loop must always be a closed loop. Using pond or lake water directly will increase heat pump maintenance.

**Figure 3-14: Pond Loop (Mat Type)**

**Figure 3-15: Pond Loop (Coil Type)**

**Open Loop Systems**
An open loop (well water) system is the only type of loop modeled in GeoAnalyst that is not a closed loop. Open loop systems work well, and are the least expensive type of geothermal system. However, water quality is crucial for a successful installation. Section 4 addresses water quality and open loop considerations.

**Figure 3-16: Well Water (Open Loop) System**
Using GeoAnalyst
The program opens in the “Project” tab. Project name/location, weather data, and system comparisons tab may be input on this screen. Before going to the other tabs, select up to six systems by clicking on the “Add System” button. As systems are added, they will show up along the bottom of the screen, as shown below see figure 3-17 (“System 1 – Geo” is the only system currently shown).

Next, click on the “Utilities” tab, and enter the appropriate rates. If there are several utilities in the area, the “Save Utilities Only” button allows files to be saved that can be loaded later on. As many files may be saved as necessary. A file may be loaded later on by clicking on the “Load Utilities Only” button.

Then, click on the “Loads” tab to enter design conditions. Enter the heat loss/heat gain, water-heating information, and select the “Heating Offset” slide switch position. The “Heating Offset” slide switch provides a more realistic load for equipment sizing and operating costs. Many of today’s homes can maintain thermostat settings without requiring any heating when the outdoor temperature is in the 50s (°F). This is a result of greater internal gains from appliances, lights, and people. It is also a function of how much solar gain offsets the heating load, and the thermal mass of the home (better insulation, windows, etc.). Likewise, the home may need cooling due to internal gains unless the windows are used for cooling.

The “Heating Offset” allows the user to customize equipment/loop sizing, and operating costs based upon the home characteristics. An average setting indicates that heating is not needed until 55°F outside air temperature (OAT), and cooling is needed at 65°F OAT. A low setting calls for heating when the OAT is 60°F, and calls for cooling when the OAT is 70°F. If the slide switch is set to high, heating is needed at 50°F OAT, and cooling is needed at 60°F OAT.

NOTE: It is very important to match the design conditions with the heat loss/heat gain. In figure 3-17, Belleville, IL is the selection for weather and soil data. The heating and cooling design temperatures are automatically loaded into the Loads tab (see figure 3-19). In this example, 6°F is used for heating design, and 92°F is used for cooling design. These temperatures are fine if the heat loss/heat gain calculations were made at those conditions. However, if they were calculated at different design conditions, the design temperatures must be changed in the Load tab.

Example:
Heat Loss = 55,000 Btuh at 0°F outside and 70°F inside (temperature difference = 70°F) Heat Gain = 36,000 Btuh at 95°F outside and 70°F inside (temperature difference = 20°F)

To compare loads at various design conditions, divide the heat loss or gain by the temperature difference. In this example, the heat loss is 785.7 Btuh per °F (55,000 ÷ 70) and the heat gain is 1,800 Btuh per °F (36,000 ÷ 20).

Suppose the user simply entered 55,000 Btuh for heating and 36,000 Btuh for cooling, but did not change the design conditions. The temperature differences have changed. The heating temperature difference is now 64°F (70 – 6) and the cooling temperature difference is now 17°F (92 – 75). Using the method above, the loads are now 859.4 Btuh per °F for heating and 2,117.7 Btuh per °F. The loop and equipment selection will be incorrect because the loads that were keyed in did not match the loads that were calculated.
To summarize, the heat loss and heat gain MUST match the original design conditions, or the values entered into the software will be incorrect, causing the calculations to be incorrect. “Garbage in = Garbage out.”

Once data has been entered into the “Project,” “Utilities,” and “Loads” tabs, each HVAC system can be designed. Simply click on the desired system along the bottom of the screen. See the help topic for the particular system for details on each of the HVAC choices.

**NOTE:** The other tabs (“Economics,” “Operating Cost Summary,” and “Graphs” cannot be selected until the systems (Geo, air-to-air, etc.) have been calculated.

**Figure 3-17: Project Tab**
Figure 3-18: Utilities Tab

Figure 3-19: Loads Tab
System 1 - Geo
A variety of pre-configured loop types may be selected (a vertical loop is shown on the screen below), or a user-defined horizontal loop may be entered if one of the pre-configured loops is not representative. Follow the steps below to determine loop/equipment sizing.

1. Select the loop type from the drop down box.
2. Enter the bore (vertical loops) depth or trench (horizontal loops) depth.
3. Select the pump(s) that will be used. If the combination of pumps is not shown, the user may select “User Specified Watts.”
4. Click on the “Select Pipe Type” button, and select the appropriate pipe to be used in the ground loop. “Specify,” allows the user to input pipe specifications if one of the pre-configured choices is not appropriate.
5. Click on the “Select Soil” button, and select the soil for which the ground loop will be designed. Some soils are more typical for certain types of loops as shown in figures 3-23 and 3-24. There is also a “Specify” choice, which if selected, will allow the user to enter the thermal conductivity and thermal diffusivity for soils not shown in the pre-configured list. This is particularly useful for thermally enhanced grouting material that may be used in some vertical loop applications. The run hours for most residential applications should be set to 300 hours based upon typical minimum-maximum equipment and loop sizing. The run hours are a monthly estimate of contiguous run time in the design month, and will vary based upon heat pump sizing. Contact technical services before changing the run hours to make sure that the loop will not be sized incorrectly.
6. Select the unit series/model, backup type, and water heater type. There is
Figure 3-21: Pipe Type Window

Figure 3-22: Soil Type Window

See tables below for typical soils used in vertical and horizontal loop configurations.
### Vertical Loops

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Cond</th>
<th>Diff</th>
<th>Description</th>
<th>Occurence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense Rock</td>
<td>2.00</td>
<td>0.050</td>
<td>Dense/wet granite, limestone, and quartzite</td>
<td>Rare</td>
</tr>
<tr>
<td>Average Rock</td>
<td>1.40</td>
<td>0.040</td>
<td>Typical granite, limestones, and sandstone</td>
<td>Very Common</td>
</tr>
<tr>
<td>Heavy Soil Saturated</td>
<td>1.40</td>
<td>0.035</td>
<td>Mostly sand and gravel - high static water table, for 70% of the installed loop</td>
<td>Common</td>
</tr>
<tr>
<td>Heavy Soil Damp</td>
<td>0.75</td>
<td>0.025</td>
<td>Silt or clay - deeper static water table, for 30% or less of the installed loop</td>
<td>Somewhat Rare</td>
</tr>
<tr>
<td>Heavy Soil Dry</td>
<td>0.50</td>
<td>0.020</td>
<td>Silt or clay with very little moisture throughout the year</td>
<td>Extremely Rare</td>
</tr>
<tr>
<td>Light Soil Damp</td>
<td>0.50</td>
<td>0.020</td>
<td>Coarse-textured soil that drains rapidly - deeper static water table, for 30% or less of the installed loop</td>
<td>Extremely Rare</td>
</tr>
<tr>
<td>Light Soil Dry</td>
<td>0.20</td>
<td>0.011</td>
<td>Coarse-textured soil that drains rapidly - very little moisture throughout the year</td>
<td>Extremely Rare</td>
</tr>
<tr>
<td>Sand (or Gravel)</td>
<td>0.44</td>
<td>0.018</td>
<td>Sand or gravel with very little moisture throughout the year</td>
<td>Extremely Rare</td>
</tr>
<tr>
<td>Silt</td>
<td>0.96</td>
<td>0.025</td>
<td>Silt - deeper static water table, for 30% or less of the installed loop</td>
<td>Somewhat Rare</td>
</tr>
<tr>
<td>Clay</td>
<td>0.64</td>
<td>0.021</td>
<td>Clay - deeper static water table, for 30% or less of the installed loop</td>
<td>Somewhat Rare</td>
</tr>
<tr>
<td>Loam</td>
<td>0.52</td>
<td>0.022</td>
<td>Equal proportion of sand/silt; not more than 20% clay</td>
<td>Somewhat Rare</td>
</tr>
<tr>
<td>Saturated Sand</td>
<td>1.44</td>
<td>0.036</td>
<td>Sand or gravel/sand - high static water table, for 70% of the installed loop</td>
<td>Common</td>
</tr>
<tr>
<td>Saturated Silt or Clay</td>
<td>0.96</td>
<td>0.025</td>
<td>Silt or clay - high static water table, for 70% of the installed loop</td>
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### Horizontal Loops

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</tr>
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<td>0.040</td>
<td>Typical granite, limestones, and sandstone</td>
<td>Not possible</td>
</tr>
<tr>
<td>Heavy Soil Saturated</td>
<td>1.40</td>
<td>0.035</td>
<td>Mostly sand and gravel - high static water table; water standing in trench throughout the year</td>
<td>Somewhat Rare</td>
</tr>
<tr>
<td>Heavy Soil Damp</td>
<td>0.75</td>
<td>0.025</td>
<td>Silt or clay - deeper static water table; no water in trench except during spring (moist soil)</td>
<td>Very Common</td>
</tr>
<tr>
<td>Heavy Soil Dry</td>
<td>0.50</td>
<td>0.020</td>
<td>Silt or clay with very little moisture throughout the year; no water in trench throughout the year</td>
<td>Rare</td>
</tr>
<tr>
<td>Light Soil Damp</td>
<td>0.50</td>
<td>0.020</td>
<td>Coarse-textured soil that drains rapidly - deeper static water table; soil is damp, but no water in the trench throughout the year</td>
<td>Rare</td>
</tr>
<tr>
<td>Light Soil Dry</td>
<td>0.20</td>
<td>0.011</td>
<td>Coarse-textured soil that drains rapidly - very little moisture throughout the year</td>
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</tr>
</tbody>
</table>

Figure 3.23: Typical Soils for Vertical Loops

Figure 3.24: Typical Soils for Horizontal Loops
also a checkbox for the desuperheater option if desired.

7. Click the “Calculate” button to review the equipment/loop sizing and operating costs.

**Bin Report**
The “Bin Output” tab shows more detail regarding the specific operating conditions at the various outdoor temperature bins. Figure 3-25 is an example bin report. Sections of the report are labeled by letters A through N, which are explained below.

A: The first column lists the five degree temperature bins (°F).

B: The second column lists the number of hours per year (20 year average) at the particular bin. In this example, there are 271 hours per year at the 22°F bin. In other words, there are 271 hours per year between 19.5°F and 24.5°F outdoor air temperature.

C: The building load is taken from the Loads tab (see figure 3-19).

**NOTE:** The bin report example in figure 3-25 is based upon a heat loss of 55,000 Btuh at 6°F outside and 70°F inside. Notice that the building load at 7°F outside is 41,250 Btuh and the load at 2°F outside is 45,547 in column, which is less than the original 55,000 Btuh load (by interpolating, it can be determined that at 6°F, the load is approximately 42,400 Btuh). This difference is due to the Heating Offset that was selected in the Loads tab (see paragraph on “Heating Offset” just below figure 3-18).

D: The Geo HW column shows the annual hot water usage by bin temperature in Btuh.
E: The Aux HW column shows the Btuh needed per year by bin temperature that is needed to make up for what the desuperheater is not able to generate (i.e. how much the main water heater will have to generate). Notice that the Aux HW Btuh are greater in the milder temperatures, since the heat pump is not running (the desuperheater only runs when the compressor is energized).

F: The Aux HW (kWh) column is used to total up the amount of heat needed from the water heater, based upon the Btuh requirement in column E.

G: This section of the report shows the hours per year that the heat pump cannot satisfy the thermostat in the cooling mode. In this example, the designer has chosen to ignore the 21 hours per year, since the heat pump satisfies the load at 92°F outdoor air temperature, which is the design condition for the example location.

H: In section H, the unit still shows 100% run time, but the unit capacity is matching the building load. When the two loads are equal (Bldg Load and HPCap), this indicates that the heat pump is capacity modulating (i.e. running on part load, switching to full load, and back to match the load). This would not occur with single speed units. The report would look like section I.

I: When the heat pump capacity is more than the building load, the Run column shows percentage run time. For example, at the 77°F bin, the heat pump has 26,447 Btuh of capacity (in part load with the two-stage heat pump example), but the building only needs 16,000 Btuh. Therefore, the unit is running 60% of the time (cycling with the thermostat) in part load.

J: Section J indicates no heating or cooling needed during these temperatures.

K: Section K (heating) is like section I (cooling). The unit is cycling on part load.

L: Section L (heating) is like section H (cooling). The unit is capacity modulating.

M: Section M (heating) is like section G (cooling). The unit capacity is less than the building requires. Unlike cooling, however, there are quite a few hours per year that the unit does not meet the building load, and therefore needs some form of backup heat. In the example, a packaged unit with electric backup was selected.

N: Based upon the additional heat needed (see section M), this section shows the amount of auxiliary kWh need per year to make up for the difference between the unit capacity and the building load.

**Air-Source Heat Pumps**

To compare an air-source heat pump add the system in the Project tab. Follow the steps below to select a heat pump and calculate operating costs.

1. Select the efficiency of the heat pump from the drop down menu.
2. Enter the nominal tons and backup heating type.
3. If electric backup is chosen, the program assumes that the heat pump will be used for all of the heating needs with electric heat coming on when necessary unless a lockout temperature is selected. If a fossil fuel backup is selected, a cut off temperature must be entered to tell the program the outdoor temperature at which the compressor will be turned off, and the backup heating system will be allowed.
4. Select the hot water type from the drop down menu.
Figure 3-26: Air-to-Air Heat Pump

Figure 3-27: Furnace/Air Conditioner
5. Click the “Calculate” button to review the equipment sizing and operating costs.
6. The “Bin Output” tab shows more detail regarding the specific operating conditions at the various outdoor temperature bins.

**Gas/Oil/Propane/Electric Furnaces**
To compare a furnace/air conditioner system add the system in the Project tab (electric, gas, propane, or oil heat). Follow the steps below to select a system and calculate operating costs.

1. Select the furnace efficiency from the drop down box (not applicable for electric furnaces).
2. Select the efficiency of the air conditioner from the drop down menu.
3. Enter the nominal tons.
4. Select the hot water type from the drop down menu.
5. Click the “Calculate” button to review the equipment sizing and operating costs.
6. The “Bin Output” tab shows more detail regarding the specific operating conditions at the various outdoor temperature bins.

**Economics**
GeoAnalyst provides a number of different options for comparing the operating costs and cashflow of conventional systems to geothermal heat pumps. Follow the steps below to create comparisons for cash or financed purchases. Later in this section, the sales proposal will be discussed.

1. Click on the “Economics” tab, and enter the installed cost, energy credit (if applicable), and loan information (if applicable).
2. Click on the Operating Cost Summary tab, and select the systems to compare by clicking the radio box for the reference system. The reference system...
is the system that will be used as the basis for the calculations. For example, in figure 3-29, the geothermal system is the reference. Therefore, the air-to-air system is compared to geothermal, and the propane system is compared to geothermal. There would not be a comparison between the air-to-air system and the propane system with this selection.

The calculations in the Operating Cost Summary show a simple cash payback in years. The annual and monthly loan payments (if applicable) are shown in the Economics tab. In the example shown above (figure 3-28), the annual loan payment for geothermal is $203 more per year than the propane system. The operating cost savings (figure 3-29) are $2,064 per year for geothermal vs. propane.

**Figure 3-29: Op Cost Summary**

In this example, there is a positive cash flow from the first day of operation (i.e. the additional monthly payment is less than the monthly cost savings).

**Graphs**

The Graphs tab helps to summarize the Economics and Operating Cost Summary tabs. In figure 3-30, the bottom line is geothermal; the middle line is the air-to-air system; the top line is the propane system. When neither check box is selected (figure 3-30), the graph only displays operating costs over 20 years (includes escalation rates entered in Utilities tab). When the Total Cash Flow box is checked (figure 3-31), the graph displays both operating costs and owning costs (e.g. loan payments). The Cumulative box (figure 3-32) changes the graph to show total costs over 20 years (can be selected...
Figure 3-30: Graphs (Neither Check Box Selected = Operating Costs Only)

Figure 3-31: Graphs (Total Cash Flow Check Box Selected = Operating and Owning Costs)
Figure 3-32: Graphs (Cumulative Box Selected = Total 20 Year Cash Expenditures)

with or without Total Cash Flow box). The scale on the right hand side is the 20 year cost instead of the annual cost when the Cumulative box is selected.

**NOTE:** The bottom line in figure 3-30 that dips below 0 indicates that the tax credit is being applied to the operating costs. Since the tax credit is more than the operating costs, the graph is drawn negative. This also applies to the Total Cash Flow graph.

**Proposal**
If the reports from the Economics tab and Operating Cost Summary tab are not detailed enough, GeoAnalyst provides a sales proposal report. In the Project tab, a green button on the right hand side of the page is labeled “Proposal.” Click on the button to enter into the sales proposal module. The proposal is a customizable report that uses the information from the Economics and Operating Cost tabs to create 10-page sales proposal to help dealers explain the benefits of geothermal technology and their company.

**NOTE:** The proposal will not generate a meaningful report unless data has been entered into the Economics and Operating Cost Summary tabs.

**Pressure Drop**
Like the Proposal module, Pressure Drop is a separate module available in the GeoAnalyst software. The Pressure Drop module can be accessed from the Project tab. Click on the blue “Pressure Drop” button to enter the pressure drop module. To begin a pressure drop calculation, follow the steps below.

**NOTE:** The unit model numbers and loop lengths do not transfer from the Geo system calculations window, since the loop can be configured many different ways, and there could be more than one unit, since the Geo system portion can only calculate one unit at a time.
1. In the System Information tab (figure 3-33), enter the antifreeze type and percentage, the number of parallel loop piping circuits (see above discussion on loop types for an explanation of the circuits associated with each loop type).

2. Select the pump configuration. If there is only one unit, choose “Central Pumping Station,” which is the standard choice for residential installations with one unit and one flow center. If there is more than one unit, the selection depends upon the piping arrangement. If there will be one pump for all units, select “Central Pumping Station.” If each unit will have its own pump and check valve, select “Each Unit Has Its Own Pump.”

3. If Central Pumping is used, the pump(s) must be selected in the System Information tab as shown in figure 3-33. If each unit will have its own pump, the pump selection will not show up in the System Information tab (see figure 3-36).

4. In the Units tab (see figure 3-34 for a “Central Pumping Station”), select the number of units and the unit model number(s). Also select the length of hose if applicable. The 1-1/4” PE pipe between the unit and flow center is normally 0 if there is only one unit/one flow center, and there is a hose kit used between the unit and flow center.

5. In the Units tab (see figure 3-36 for “Each Unit Has Its Own Pump”), select the number of units and the unit model number(s).
Figure 3-34: Pressure Drop – Units (Central Pumping Station)

Figure 3-35: Pressure Drop – System Information (Each Unit Has Its Own Pump)
number(s). Also select the length of hose if applicable. The 1-1/4" PE pipe between the unit and flow center may be 0 if there is a flow center mounted at each unit (i.e. there is a hose kit from the unit to the flow center, and the flow centers are piped in parallel to the main loop). In order to calculate a reliable number, all pumps in parallel must be the same.

**NOTE 1:** If pumps are in parallel, a check valve is required at each unit to insure that there is not short-circuiting within the inside piping system, bypassing the ground loop.

**NOTE 2:** When a parallel pumping design is used, it is possible that when all units are running that there will not be enough pump head to overcome the pressure drop of the loop due to the nature of pumps in parallel. For example, two pumps in parallel will double the flow rate, but the head will stay the same; two pumps in series will double the head, but the flow rate will stay the same. The pressure drop curves will indicate if flow is sufficient. The designer will have to decide on the best approach for the application. In many cases, it makes much more sense to install separate loops for each set of two units when there are multiple units installed. The simplicity of the piping and pumps will far exceed any advantages of multiple units sharing one loop for most residential applications.

6. In the piping tab (see figure 3-37), enter the inside piping, supply/return piping, and loop circuit piping.

Figure 3-36: Pressure Drop – Units (Each Unit Has Its Own Pump)
**NOTE:** The pressure drop software is based upon parallel piping for the ground loop system, which is why the number of circuits must be entered in the System Information tab. Since the total flow rate will be divided between the various loop circuits, the pressure drop calculation only needs the length of one circuit.

Example:
The system is a 3 ton heat pump with a vertical loop. As discussed in the Loop Types section, systems with ¾" PE pipe normally have one parallel circuit per ton. Therefore, this example would have three vertical bores. Each bore has two pipes, connected by a U-bend at the bottom of the bore hole, creating one circuit. The flow rate of the system (9 GPM) is divided equally between the three parallel circuits at 3 GPM, so the pressure drop of each circuit should be very similar if the bores are close to the same depth.

7. Enter the pipe size and total circuit length (see figure 3-37).

Example: Suppose the 3 ton system above needs 450 foot of bore based upon the Geo System calculation portion of GeoAnalyst. The three parallel circuits would then be 150 foot each (450 ÷ 3). The total circuit length must include the pipe going down the bore hole and the pipe going back up, or 300 foot (150 x 2), as shown in figure 3-37.

8. Once all of the data has been entered, click on the Pressure Drop Chart tab (see figure 3-38) to view the system curve (piping system and heat pump) and the pump curve. The pump curve is the dashed line; the system curve is the solid line. If the flow rate is not adequate for the unit(s), either the pump selection is not correct or the loop layout/design has too much pressure drop. For
example, if the supply and return lines are very long, they may need to be upsized from 1-1/4" to 2".

**NOTE:** Reynolds number is shown on the Pressure Drop Chart tab (see figure 3-38). The Reynolds number, a measure of turbulence, should be between greater than 2500 to provide sufficient heat transfer through the loop piping system. For systems with propylene glycol, a Reynolds number of 2000 or greater is acceptable, but 2500 or greater is better.

9. The last tab in the program is the Flushing tab (see figure 3-39). In order to purge all of the air from the system, a velocity of 2 feet per second (fps) is required through each of the system components and loop circuits. The flushing requirements indicate how much flow and head will be required from the flush cart to achieve 2 fps. Also shown in the Flushing tab is the amount of antifreeze required.

**Figure 3-38: Pressure Drop – Pressure Drop Curves**
Figure 3-39: Pressure Drop – Flushing

Total Fluid in Loop: 50 gallons

Flushing Requirements: 16 gpm @ 49 Feet Head

Total Antifreeze Required: 11 gallons
Section 4: Load Design – Forced Air Systems

Ductwork Design

Ductwork design for geothermal systems is really no different than ductwork design for any other residential HVAC system. New ductwork should be designed based upon Air Conditioning Contractors of America (ACCA) Manual D, Heating Refrigeration and Air Conditioning Institute of Canada (HRAI) Air System Design, or Sheet Metal and Air Conditioning Contractors National Association (SMACNA) Duct Design Manual. If the heat pump is being installed with existing ductwork, the ductwork must be verified to make sure it can handle the air volume required by the unit being installed.

For new installations (or systems that include ductwork replacement), a room-by-room heat loss/heat gain must be calculated to determine airflow requirements for each room. A good starting point for CFM requirements is 0.02 CFM/Btuh for heating and 0.034 CFM/Btuh. Multiply the heat loss for each zone by 0.02 and the heat gain for each zone by 0.034. Use the larger of the two calculations as the CFM for each zone.

Once the heat pump is selected in GeoAnalyst, determine the actual CFM for the heat pump. Nominal airflow is 400 CFM per ton. However, units with ECM fan have the most flexibility in design. For example, the 3 ton (two-stage) unit with ECM fan can operate between 1,105 and 1,430 CFM. A lower CFM will increase supply temperatures in heating and increase latent capacity (dehumidification), but will slightly decrease the sensible heating and cooling capacities. Always use the full load CFM for design of two-stage systems. Once the equipment CFM has been selected, it must be re-distributed for each of the room loads based upon the calculations mentioned above (see “CFM % of tot.” and “Actual CFM” columns in figure 4-1). The new CFM can now be used to determine ductwork sizing.
# Figure 4-1: Example Room-by-Room Heat Loss/Heat Gain Calculation

**Right-J® Worksheet**

**Entire House**

ROTH INDUSTRIES, INC.

---

### Job: Right-J® Worksheet

**Entire House**

1. **Room name**
2. **Exposed wall**
3. **Ceiling height**
4. **Room dimensions**
5. **Room area**

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<th>Or</th>
<th>HTM (Btu/h/°F)</th>
<th>Area (ft²) or perimeter (ft)</th>
<th>Load (Btu/h)</th>
<th>Area (ft²) or perimeter (ft)</th>
<th>Load (Btu/h)</th>
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---

### 6 c) AED excursion

| Envelope loss/gain | 25076 | 12980 | 12326 | 6515 |

### 12 a) Infiltration

| Occupants @ 230 | 4603 | 336 |

### 13 Internal gains:

| Appliances @ 1200 | 0 | 0 | 0 | 0 |

### Subtotal (lines 6 to 13)

| 35635 | 13756 | 16929 | 6853 |

### Less external load

| 0 | 0 | 0 | 0 |

### Redistribution

| 0 | 0 | 0 | 0 |

### Subtotal

| 35635 | 13756 | 16929 | 6853 |

### Duct loads

| 0% | 0% |

### Total room load

| 35635 | 13756 | 16929 | 6853 |

---

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Consider velocities when selecting registers and grilles (see table 4-1). Maximum recommended face velocity for a supply outlet used in a residential application is 750 FPM. Maximum recommended return grille velocity is 400 FPM. Systems with higher velocity are likely to have noise problems. In buildings where ceilings are 8 feet or more, at least 50 percent of the return air should be taken back to the heat pump from the ceiling or high sidewall location and not more than 50 percent from the floor or low sidewall location. Turning vanes should be used on any run over 500 CFM.

### Geothermal Considerations

Although duct design for geothermal systems is like duct design for any residential HVAC system, there are considerations that must be taken into account for packaged heat pumps, since a compressor-bearing unit will be installed inside the home. Geothermal heat pumps are very quiet, but care must be exercised not to transmit any vibration through the ductwork. All sheet metal supply and return plenums should be isolated from the unit by a flexible canvas connector or through the use of duct board plenums to prevent transfer of vibration to the ductwork.

If the heat pump is installed in a non-insulated space, metal ductwork should be insulated on the inside with fiberglass insulation or similar to prevent heat loss/gain and to help absorb air noise. Figures 4-2 and 4-3 illustrate the points made in this section.

### Table 4-1: Maximum Velocities

<table>
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<th>Location</th>
<th>Supply</th>
<th>Return</th>
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<td>Main Ducts</td>
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<tr>
<td>Branch Ducts</td>
<td>700 FPM</td>
<td>600 FPM</td>
</tr>
<tr>
<td>Grills, Registers, Diffusers</td>
<td>750 FPM</td>
<td>400 FPM</td>
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The geothermal unit comes with an ECM Motor or PSC 3-speed blower motor. For maximum performance, the blower speed should be set to maintain between 350 and 450 CFM/ton. Changing the wires (for PSC) at the blower will change the blower speed.
Figure 4-3: Ductwork Illustration with Zoning

- Never install a takeoff on or near a reducer or on an end cap, or near an end cap. Exceptions may apply.
- Takeoff runs should never be installed on a reducer. Takeoffs should be installed 6" before a reducer and at least 24" in 36" past any reducer.

Note: A bypass damper is almost always required for zoning systems.
Section 5: Load Design – Hydronic Systems

Water-to-Water Heat Pump
Design Temperatures
Water-to-water heat pumps are very flexible when designing a hydronic heating or cooling system. Radiant floor systems, which are typical for new construction heating applications, normally use relatively mild water temperatures. When designing or retrofitting an existing hydronic heating system, it is especially important to consider maximum heat pump water temperatures (see figure 5-1) as well as the effect water temperatures have on system efficiency. Baseboard radiation, radiators, fan coils, and other types of existing heat distribution systems typically use hotter water temperatures.

Heat pumps using R-410A refrigerant are not designed to produce water above 120 to 125°F. Efficiency must also be considered when choosing design temperatures. The efficiency of the heat pump decreases as the temperature difference (TD) between the heat source (ground loop or well water system) and the load water (the distribution system) increases. Figure 5-2 illustrates the effect of source and load temperatures on the system. The heating capacity of the heat pump also decreases as the temperature difference increases.

As the temperature difference between the source and the load increases, the Coefficient of Performance (COP) decreases. When the load entering water is 110°F from a 30°F earth loop, the TD is 80°F, and the COP is approximately 3.1. If the entering load water is 90°F (same earth loop temperature), the TD is 60°F and the COP is just under 4.0, significantly increasing the efficiency.

If the water temperature of the earth loop is 90°F, and the distribution system requires the same temperature, a heat pump would not be needed. The system would operate at infinite efficiency, other than the cost of pumping the water through the distribution system. When using the various types of hydronic heat distribution systems, the temperature limits of the geothermal system must be a major consideration. In new

Figure 5-1: Heating Operating Conditions for Scroll Compressors – Water-to-Water Units
construction, the distribution system can easily be designed with the temperature limits in mind. In retrofits, care must be taken to address the operating temperature limits of the existing distribution system.

Distribution Systems - Radiant Floor Heating
Radiant floor heating has been used for centuries. The Romans channeled hot air under the floors of their villas. In the 1930s, architect Frank Lloyd Wright piped hot water through the floors of many of his buildings. Some home builders' surveys have shown that, if given a choice, most new home owners prefer radiant floor heat over other types of systems. A 1" diameter pipe can carry as much heat as a 10" x 19" rectangular duct carrying hot air at 130°F. Radiant floor heating is a very efficient means of heating a building.

Comfort is improved with radiant floor systems. A room with radiant floor heating will have an average floor temperature of 80-85°F with an overall room temperature at occupant level of 68-70°F. Forced air system temperatures near the ceiling often reach 90-100°F, which can be 20-30°F higher than the temperature at the floor (see figure 5-3). Radiant floor heating is more comfortable because heat is directed to occupant level. Radiant floor heating systems may also lower operating costs, since a lower thermostat setting is typically used for this type of system as compared to forced air (normally 2-3°F lower than forced air systems). The lower heat loss at the ceiling with a radiant floor system lowers the temperature difference between the ceiling and the outside, resulting in a smaller heat loss, which lowers the heat pump capacity required to heat the structure and lowers operating costs.

Most people who own radiant floor heating systems feel that the most important advantages are comfort and quiet operation. Radiant floor systems allow even heating throughout the whole floor, not just in localized spots as with other types of heating systems. The room heats from the bottom up, warming the feet and body first. Radiant floor heating also allows for lower water temperatures, which increases COP, thus lowering energy consumption and operating costs. Radiant floors operate between 85-130°F, compared to other hydronic heating systems' range of 130-160°F.

Combining the advantages of radiant floor heating with the advantages of geothermal technology provides comfort and savings. Plus, water-to-water units can share the same ground loop with the water-
Some of the factors affecting the heating capacity of a floor heating system are as follows:

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

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

Distribution Systems - Baseboard Radiation Heating

Baseboard radiation is typically designed to operate with 160-200°F water or steam. Baseboard radiators are usually constructed of copper tube with closely spaced aluminum fins attached to provide more surface area to dissipate heat, as shown in figure 5-4. The factors affecting the amount of heat given off by fin tube radiators are the water temperature, water flow, air temperature, pipe size and fin size/spacing. A decorative cover is normally fitted over the fin tube.

In some cases, water-to-water heat pumps can replace a boiler that was used to generate hot water for baseboard radiation. For example, if an existing home has been well insulated, it is possible that the heat loss of the home has decreased enough to allow lower water temperatures. Otherwise, a backup boiler or another source of backup heat will usually be required. Manufacturer’s data on the baseboard convector should be consulted to determine the Btuh/ft. of radiation at lower water temperatures. Another alternative for baseboard radiation is double-stack convection, where there are two rows of fin/tubes within the enclosure. This denser design allows for the use of cooler water temperatures.
Distribution Systems - Cast Iron Radiation Heating
Retrofit applications for hydronic/geothermal heat pump systems are often required to work with existing cast iron radiators. Typically, cast iron radiator systems, as shown in figure 5-5, operate with water temperatures of 125-200°F. As with baseboard systems, if an existing home has been well insulated, it is possible that the heat loss of the home has decreased enough to allow lower water temperatures. Cast iron radiators can operate well with design water temperature as low as 110°F. However, when operating at lower temperatures, the heat emission rate is substantially less below 140°F. To determine heat emission for cast iron radiators, calculate the surface area of the radiator (Surface Area = W x H), and refer to table 1-1 for output capacity.

Distribution Systems - Fan Coils for Heating and Cooling
Fan coils consist of a hot water coil and/or chilled water coil (usually copper tubing with aluminum fins) and a blower to move the air over the coil. The term “fan coil unit” typically applies to smaller units, which are installed in the zone or area where the heating or cooling is needed. The term “air handler” normally refers to larger units. Fan coils are available in many different configurations, sizes and capacities from a number of manufacturers. A typical fan coil unit is shown in figure 5-6. Fan coils typically have one or two coils. Air is heated by hot water circulated through a hot water coil. Chilled water is circulated through the coil if cooling is needed. Depending upon the application, the unit will include one coil for both heating and cooling (hot water/chilled...
water) or a coil dedicated to heating (hot water) and another coil specifically for cooling (chilled water).

Fan coil units have been used to heat buildings using water temperatures as low as 90-100°F, but as with radiators/baseboard convectors, heating capacities fall dramatically when operated below design temperatures. It is always better to use a fan coil designed for lower heating water temperatures. The performance data in tables 5-2 show fan coils that are designed for the lower temperatures associated with water-to-water heat pumps.

NOTE: If fan coils will be used for both heating and cooling, the designer must thoroughly understand the homeowner's needs. Switchover from heating to cooling can be a problem with multiple fan coils connected via a two-pipe system, since the entire system must either be using chilled water or hot water. A four-pipe system provides much better comfort, but increases installation and operating costs. In many cases, it is more cost-effective to use a separate water-to-air unit for space cooling if individual zones could require heating or cooling simultaneously.

### Tables 5-2: Hydronic Air Handler Performance Data

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<th>GPM</th>
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#### Chilled Water Cooling Capacity – 80/67°F EAT (DB/WB)

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#### Entering Air Correction Factors

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### Tables 5-2: Hydronic Air Handler Performance Data

#### Entering Air Correction Factors

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Section 5: Load Design – Hydronic Systems, August, 2010
Distribution Systems - Other Hydronic Cooling Options

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

Distribution Systems - Hybrid Applications

Hydronic systems do not always need to provide 100% of the heating load. Floor warming applications, for example are an excellent means of providing warm floors without being designed to carry the full heating load. With floor warming, a water-to-air unit can provide the remainder of the heating required and all of the cooling needed. Likewise, a baseboard or radiator system could be used in combination with forced air heating, especially for retrofit applications, where the heat pump may not be able to provide hot enough water for the distribution system.

Domestic Hot Water

High efficiency domestic water heating is an advantage of using water-to-water heat pumps. COP ratings in the 3.0 to 6.0 range are common. Operating efficiencies, therefore, are three to six times more efficient than electric resistance water heaters (COP = 1.0). Depending upon electricity and fossil fuel (natural gas, oil, propane) rates, water-to-water heat pumps typically heat water for one-fourth to one-half the operating costs of fossil fuel boilers and water heaters.

Most water-to-water heat pumps require a secondary heat exchanger to meet code requirements. Potable water must be isolated from the refrigerant circuit by a double walled heat exchanger or through the use of a secondary heat exchanger like an indirect water heater.

Figure 5-7 shows two different types of indirect water heaters. The one on the left is an example of a typical indirect water heater designed for 160°F boiler water. The boiler water is sent through the heat exchanger, and the potable water is stored in the tank. This type of water heater is not suitable for use with a heat pump system.

Figure 5-7: Indirect Water Heaters (Burnham Brand Standard High Temperature Boiler Type on the Left; Turbomax Brand Lower Temperature Heat Pump or Solar Type on the Right)
works well with hotter water temperatures, but not very well with heat pump water temperatures. The indirect water heater on the right has a larger mass of copper heat exchangers, and will work well with lower water temperatures, since there is significantly more area for heat exchange. Plus, the piping is reversed for this type of indirect water heater. The potable water flows through the heat exchanger; the heat pump (labeled boiler water in the diagram) is on the outside of the heat exchanger.

Maximum water temperature is about 115-120°F with an indirect water heater like the one on the right (figure 5-7). If hotter water is required, an electric, natural gas, or propane water heater may be used as a booster when connected in series with the indirect water heater. One source of water heaters like the one shown above on the right (figure 5-7) is Turbomax in Montreal, Quebec. Some indirect solar water heaters will also operate with lower water temperatures.

**Snow Melt**

Although snow melting is now considered somewhat controversial due to the energy use, geothermal systems are quite capable of heating sidewalks and driveways for melting snow. As with any hydronic heating system, the load calculation is the first and most important step in designing a reliable and cost-effective snow melt system. Consult the ASHRAE HVAC Applications Handbook for slab piping design and temperature requirements.

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

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

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

**Buffer Tanks**

Virtually all water-to-water heat pumps used for hydronic applications require a buffer tank to prevent equipment short cycling and to allow different flow rates through the water-to-water unit than through the hydronic delivery system. Following are considerations for buffer tank sizing:

- The size of the buffer tank should be determined based upon the predominant use of the water-to-water equipment (heating or cooling).
- The size of the buffer tank is based...
upon the lowest operating stage of the equipment. For example, a water-to-water heat pump with a two-stage compressor or two compressors may be sized for first stage capacity, reducing the size of the tank (as long as a two-stage aqua-stat is used).

- Pressurized buffer tanks are sized differently than non-pressurized tanks (see guidelines below).

Pressurized buffer tanks (see tank on the left in figure 5-8) for predominately heating applications should be sized at one U.S. gallon per 1,000 Btuh of heating capacity (10 U.S. gallons per ton may also be used) at the maximum entering source water temperature (EST) and the minimum entering load water temperature (ELT), the point at which the water-to-water unit has the highest heating capacity, usually 50-70°F EST and 80-90°F ELT. For predominately cooling applications, pressurized buffer tanks should be sized at one U.S. gallon per 1,000 Btuh of cooling capacity (10 U.S. gallons per ton may also be used) at the minimum EST and the maximum ELT, the point at which the water-to-water unit has the highest cooling capacity, usually 50-70°F EST and 50-60°F ELT. Select the size of the tank based upon larger of the calculations (heating or cooling).

Non-pressurized buffer tanks (see tank on the right in figure 5-8) must also be sized based upon predominate use (heating or cooling) and based upon the lowest capacity stage. Requirements for storage are less according to the manufacturer of the HSS series non-pressurized buffer tank. Using the same conditions for maximum heating or cooling capacity mentioned above, non-pressurized buffer tanks require 6 U.S. gallons per ton.

If an electric water heater will be used as

Figure 5-8: Buffer Tanks (Bock brand pressurized tank on the left; B & D Manufacturing’s HSS non-pressurized tank on the right)
a buffer tank, the water heater must be A.S.M.E. rated (rated for heating) in order to qualify as a buffer tank. Also, when using an electric water heater as a buffer tank, there are fewer water connections. Alternate piping arrangements may be required to make up for the lack of water connections.

**NOTE:** Roth has an adapter fitting available for Marathon electric water heaters that allows the element connections to be used for connection to the water-to-water heat pump. If using an electric water heater, the T & P (Temperature and Pressure) valve (also called “pop-off” valve) must be replaced with a 30 psi valve.

**Controls Selection**

One of most important design aspects of any hydronic application is the control selection. Unlike a water-to-air heat pump, which is normally controlled by a thermostat in the space being conditioned, there are many variables that must be addressed with hydronic applications. Following are some considerations that must be addressed when selecting controls:

**Design Temperatures/Buffer Tank Control:**

Design temperatures will depend upon the selection of the distribution system. If heating/cooling with fan coils or producing domestic hot water, the best approach is a constant buffer tank temperature, using an aqua-stat to control the heat pump. However, if heating will be accomplished with a radiant floor system, outdoor temperature reset should be considered. As Figure 5-2 shows, the efficiency of the heat pump is a factor of the difference in temperature between the source and the load. The heat loss or heat gain of a building varies with the weather. As the outdoor temperature decreases, the heat loss of the building increases. If cooler water can be used when the outdoor temperature is above the design temperature, the COP of the heat pump increases significantly. Outdoor temperature reset allows the buffer tank temperature to change based upon the heating load (i.e. outdoor temperature).

**System staging:** Water-to-water and heat pumps may be sized to handle the entire heating load, or a smaller system may be desired with some method of backup heating. For example, if the heat pump can handle the load 90% of the time and a backup boiler is used for temperatures near design conditions, the heat pump and ground loop installation costs will be decreased. Every application is different, however, so backup heat should be selected based upon the individual application. When the heat pump will not be providing 100% of the heating load, the controls must be able to handle the logic for backup heat. There are many methods for providing backup heat, some of which are listed below.

- **Hydronic heating for first stage/boiler for backup:** Controls must be able to activate backup heat when first stage cannot keep up with the load. Depending upon the nature of the backup needed (backup heat for higher heating temperature or backup heat for increased capacity) the controls must be able to activate backup heat as described below.

**NOTE:** If not using a condensing boiler, a mixing valve is required to keep the boiler heat exchanger from condensing. Consult boiler manufacturer’s literature for piping details.
- **Backup heat for increased capacity:** When more capacity is needed, but the water temperature remains the same (for example radiant floor heating), a boiler is normally piped in parallel with the buffer tank (see drawing M4-4). In this arrangement, a two-stage aqua-stat is used. First stage activates the heat pump; second stage activates the boiler. The heat pump will continue to heat the buffer tank, but as the tank temperature drops (i.e. the radiant floor is pulling more heat from the tank than the heat pump can supply), the boiler will assist in maintaining the temperature supplied to the heating distribution system.

- **Backup heat for higher heating temperature:** When a higher temperature than the heat pump can produce is needed (for example baseboard radiation), a boiler is normally piped in series with the buffer tank (see piping diagram M4-16). An aqua-stat is typically used to control the heat pump (first stage heating), and another control activates the boiler. The other control could be a second aqua-stat with a higher set point. Drawing E4-17 shows wiring with a two-stage aqua-stat for the buffer tank. When the second stage is engaged in the buffer tank, a relay activates the boiler (higher temperature) aqua-stat. A two-stage wall thermostat could also be used. First stage activates a pump for the baseboard radiation; second stage activates the boiler and its pump. If the return water coming back from the baseboard radiation to the buffer tank is hotter than the aqua-stat setting, the heat pump will remain off. If the wall thermostat downstages to first stage heating, the boiler will be de-energized, and the baseboard radiation pump will pull water from the buffer tank. When the tank temperature drops below the aqua-stat setting, the heat pump will be energized to maintain tank temperature.

- **Floor warming with forced air backup heat:** This application normally uses a floor sensor to control the floor warming system. The floor warming system piping is connected to the buffer tank, and an aqua-stat controls the heat pump. A wall thermostat is connected to a fan coil or water-to-air heat pump, which provides forced air heating when the floor warming system cannot maintain temperature in the space.

- **Hydronic heating for first stage/forced air for backup heat:** This application is similar to the floor warming application above, except the hydronic heating system (radiant floor, baseboard radiation, etc.) serves as first stage heating instead of simply floor warming. For this application, a two-stage wall thermostat is typically installed. First stage heating controls the radiant floor system pumps, and/or zone valves. Second stage heating activates a fan coil or water-to-air heat pump. In some cases, a third stage of heating may be used that activates electric heat in the fan coil or water-to-air heat pump.

**Transformers:** The staging control mentioned above is normally low voltage, and sometimes requires connecting multiple equipment types, each with its own transformer. Relays are needed to isolate the transformers. Alternatively, one large transformer may be used to replace the heat pump transformer, and/or transformers in the other equipment.

**Heating/cooling switchover:** One of the most complicated control decisions for hydronic heating systems is switchover. For example, in the spring and fall, there could be days in which heating is needed at night, but cooling is needed during the day. Radiant floor systems, in particular, do not...
allow for quick switchover times. There are many solutions to the switchover decision, some of which are listed below.

- **Manual heating/cooling switchover:** The easiest way to handle the switchover challenge is with a manual heating/cooling switch. A simple light switch labeled “heating” and “cooling” can be installed near the heat pump or on a wall near the thermostat. The homeowner would have to understand that once the switch is changed to cooling that it will take some time for the system to recover if switched back to heating, and should normally only be switched twice a year.

  **NOTE:** This switch is shown in the wiring diagrams later in this section as an ON/OFF switch.

- **Manual seasonal switchover:** Like the above option, a light switch would typically be used. However, instead of labeling the switch “heating” and “cooling,” the switch would be labeled “hydronic” and “forced air” or “radiant” and “forced air.” This approach would be used when a water-to-air heat pump is providing forced air-cooling. Since the water-to-air heat pump may also be used for forced air heating, forced air could be used to heat the home in the spring and fall when frequent switching between heating and cooling may be needed. In the winter, heating would be accomplished with the hydronic heating distribution system (switch would be in the “hydronic” or “radiant” position in the winter). This approach is very effective and avoids cooling when the hydronic system is still warm (especially with radiant floor systems). An auto-change-over thermostat allows the home owner to set both heating and cooling set points, and then simply change the “hydronic”/”forced air” switch once in the spring and once in the fall.

**Figure 5-9: HBX Geothermal Controller**
• **“Smart” Controls:** Some microprocessor controllers designed for hydronic heating systems have a feature called “warm weather shutdown” (WWSD) which shuts down the heating system automatically based upon outdoor temperature. Although this is a more automatic system, it is important that the homeowner understands exactly what happens during WWSD and when it occurs. HBX Controls (Calgary, Alberta) has a controller that is designed for geothermal heat pumps (see figure 5-9), and includes both a WWSD and a “cold weather shutdown” (CWSD) set point.

**Pump control:** As mentioned earlier, heat pump hydronic heating and cooling systems almost always require a buffer tank because the hydronic system flow rate is normally different from the heat pump flow rate. Typically, there will be a pump(s) on the source side of the heat pump for the ground loop, a pump(s) on the load side of the heat pump that pumps water between the heat pump and the buffer tank, and a hydronic system distribution pump(s). The heat pump load and source pumps should always be energized when the compressor is energized. The hydronic system pump(s) is activated by the hydronic heating/cooling system when hot water or chilled water is required from the buffer tank. Some “smart” controllers (like the HBX control shown in figure 5-9) provide relay outputs for pumps. B & D Manufacturing also provides pump relays for its HSS tank controller.

**Controls Wiring Diagrams**

There are many different ways to control water-to-water heat pumps for hydronic heating and cooling systems. This section provides a number of wiring diagrams for the most common applications. Below each figure is a description of the wiring diagram, followed by the piping diagram that corresponds to the application.
Drawing E4-1: Radiant Floor Heating – Water-to-Water Unit Without Backup Heat
► Use with Piping Drawing M4-1 or M4-2

Notes:
1. P-2 sized based on # of loops
2. Thermostats infloor mod#92016
3. P-2 circ pump to be 115V
4. Flow center parallel pumps 230V wired from unit
5. Infloor zone module #30056 (4XTRA)
6. Pump relay infloor mod#30080
7. Zone valves honeywell pvh413f
8. Transformer to be 75VA minimum
9. P-1 load side pump to be 230V

Drawing E4-2: Radiant Floor Heating – Water-to-Water Unit Without Backup Heat – HSS Controls
► Use with Piping Drawing M4-3

Notes:
- Only one T-stat can be priority HTG & CLG control

B & D Manufacturing -- Control Panel For HSS Tank

Section 5: Load Design – Hydronic Systems, August, 2010
Drawing E4-3: Radiant Floor Heating – Water-to-Water Unit With Boiler Backup

Use with Piping Drawing M4-4

NOTES:
1. P-2 SIZED BASED ON # OF LOOPS
2. THERMOSTATS INFLOOR MOD #29016
3. AQUISTAT JOHNSON CONTROLS #4419
4. P-2 ORC PUMP TO BE 115V
5. FLOW CENTER PARALLEL PUMPS
6. NO DISCONNECTS NEEDED IF PANEL IS IN MECH RM
7. INFLOOR ZONE MODULE 130056 (4XTRA)
8. PUMP RELAY INFLOOR MODE #300000
9. ZONE VALVES HONEYWELL #8043F
10. TRANSFORMER TO BE 75VA MINIMUM

Drawing E4-4: Radiant Floor Heating – Water-to-Water Unit With Electric Element Backup in Buffer Tank

Use with Piping Drawing M4-1

NOTES:
1. P-2 SIZED BASED ON # OF LOOPS
2. THERMOSTATS INFLOOR MOD #29016
3. AQUISTAT JOHNSON CONTROLS #4419
4. P-2 ORC PUMP TO BE 115V
5. FLOW CENTER PARALLEL PUMPS
6. NO DISCONNECTS NEEDED IF PANEL IS IN MECH RM
7. INFLOOR ZONE MODULE 130056 (4XTRA)
8. PUMP RELAY INFLOOR MODE #300000
9. ZONE VALVES HONEYWELL #8043F
10. TRANSFORMER TO BE 75VA MINIMUM
11. STAGE 2 CAN BE GAS BOILER
Drawing E4-5: Radiant Floor Heating/Chilled Water Cooling (Air Handler) with Optional Fan Coil for Heating – Water-to-Water Unit with Optional Boiler Backup

Use with Piping Drawing M4-7
Drawing E4-6: Radiant Floor Heating/Chilled Water Cooling (Air Handler) – Water-to-Water Unit – HSS Controls

Use with Piping Drawing M4-5

B & D MANUFACTURING -- CONTROL PANEL FOR HSS TANK

FAN COIL

T-STAT 1

T-STAT 2

PUMP FUSE 1

PUMP FUSE 2

PUMP FUSE 3

PUMP FUSE 4

PUMP FUSE 5

PUMP FUSE 6

TRANSFRMR

G C Y R

NOTE: TRANSFORMER MUST BE REMOVED FROM FAN COIL

J2

J3

J4

J5

J6

J7

J8

J9

J1

J10

Clg Control

CLG & HTG

NOTE: ONLY ONE T-STAT CAN BE PRIORITY HTG & CLG CONTROL

1 AMP

1 AMP

WATER-TO-WATER UNIT

MAIN UNIT DISCONNECT TO PANEL

FLOW CENTER

JUNCTION BOX

MAIN UNIT

HEAT ONLY

HTG & CLG

24V

110V

40VA

G C Y W R

NOTE: TRANSFORMER MUST BE REMOVED FROM FAN COIL

FLOW CENTER

WATER-TO-WATER UNIT

MAIN UNIT

DISCONNECT TO PANEL

JUNCTION BOX

1 AMP

1 AMP
Drawing E4-7: Radiant Floor Heating/Chilled Water Cooling (Air Handler) – Water-to-Water Unit with Boiler Backup – HSS Controls

Use with Piping Drawing M4-6
Drawing E4-8: Radiant Floor Heating/Chilled Water Cooling (Air Handler) with Optional Fan Coil for Heating – Water-to-Water Unit – HBX Controller
➤ Use with Piping Drawing M4-7

Drawing E4-9: Radiant Floor Heating/Chilled Water Cooling (Air Handler) with Optional Fan Coil for Heating – Two Compressor Water-to-Water Unit – HBX Controller
➤ Use with Piping Drawing M4-10
Section 5: Load Design – Hydronic Systems, August, 2010

Drawing E4-10: Radiant Floor Heating/Separate Cooling System – Two Compressor Water-to-Water Unit – HSS Controls

Use with Piping Drawing M4-11
Drawing E4-11: Radiant Floor Heating – Two Water-to-Water Units

Use with Piping Drawing M4-8

NOTES:
1. P-2 SIZED BASED ON # OF LOOPS
2. THERMOSTATS INFLOOR MOD #4419
3. AQUISTAT JOHNSON CONTROLS #4419
4. P-2 CRC PUMP TO BE 115V
5. FLOW CENTER PARALLEL PUMPS
6. NO DISCONNECTS NEEDED
   IF PANEL IS IN MCH RM
7. INFLOOR ZONE MODULE #3096 (4XTRA)
8. PUMP RELAY INFLOOR MOD #30050
9. ZONE VALVES HONEYWELL #B043F
10. TRANSFORMER TO BE 75VA MINIMUM
Drawing E4-12: Radiant Floor Heating/Forced Air Cooling – One Water-to-Air Unit and One Water-to-Water Unit

Use with Piping Drawing M4-9

NOTES:
1. P-2 PUMP SIZE BY # OF LOOPS
2. THERMOSTATS INFLOOR MOD#30015
3. AQUASTAT JOHNSON CONTROLS #4419
4. P-2 CIRC PUMP TO BE 115V
5. ASPM (PUMP SHARING MODULE) REQUIRED TO SHARE FLOW CENTER
6. NO DISCONNECTS NEEDED
7. F PANEL IS IN MECH RV
8. INFLOOR ZONE MODULE #30056 (4XTRA)
9. ZONE VALVES HONEYWELL #8043F
10. TRANSFORMER TO BE 75VA MINIMUM
NOTE: ZONE MODULE MAY NOT BE PRESENT IF HEATING SYSTEM IS BASEBOARD OR RADIATOR DISTRIBUTION.

NOTES:
1. P-2 SIZED BASED ON # OF LOOPS
2. THERMOSTATS INFLOOR MOD#29016
3. AQUASTAT JOHNSON CONTROLS #A419
4. P-2 OIL PUMP TO BE 115V
5. FLOW CENTER PARALLEL PUMPS 230V WIRING FROM UNIT
6. NO DISCONNECTS NEEDED IF PANEL IS IN MECH RM
7. INFLOOR ZONE MODULE #30056 (EXTRA)
8. PUMP RELAY INFLOOR MOD#30050
9. ZONE VALVES HONEYWELL #V8043F
10. TRANSFORMER TO BE 75VA MINIMUM

Drawing E4-13: Hydronic Heating/Separate Cooling System – Water-to-Water Unit with Boiler Backup for Hotter Water Temperatures

Use with Piping Drawing M4-12
Heat Pump Piping Diagrams
There are many different ways to pipe water-to-water heat pumps for hydronic heating and cooling systems. This section provides a number of piping diagrams for the most common applications. Below each figure is a description of the piping diagram, followed by the wiring diagram that corresponds to the application.

NOTES: Not all components are shown in the drawings below (for example unions are not shown, but are necessary for future ease of service). Drawings are designed to illustrate concepts, and should be used as a starting point for system design. However, standard practices and applicable codes supersede all drawings.

► Use with Wiring Drawing E4-1

**NOTE:**
1. ALL S/R PIPE SIZING DETERMINED BY # LOOPS PER MANIFOLD
2. P" MIN. LINES TO BUFFER TANK FROM HP
3. P-2 PUMP SIZED BASED ON # OF INFLOOR LOOPS
4. REMOVE FACTORY T&P AND REPLACE WITH 3/4" NIPPLE
5. DESUPERHEATER LINES TO BE 1/2" MAX, 30'

- Use with Wiring Drawing E4-1

Drawing M4-3: Radiant Floor Heating/Separate Cooling System – Water-to-Water Heat Pump – HSS Buffer Tank

- Use with Wiring Drawing E4-2
Drawing M4-4: Radiant Floor Heating/Separate Cooling System – Water-to-Water Heat Pump with Backup Boiler for Increased Capacity (not Hotter Water Temperatures) – Standard Buffer Tank

Use with Wiring Drawing E4-3

Drawing M4-5: Radiant Floor Heating/Chilled Water Cooling (Fan Coil) – Water-to-Water Heat Pump – HSS Buffer Tank

Use with Wiring Drawing E4-6
Drawing M4-6: Radiant Floor Heating/Chilled Water Cooling (Fan Coil) – Water-to-Water Heat Pump with Boiler Backup – HSS Buffer Tank

>>> Use with Wiring Drawing E4-7

---

NOTES:
1. ALL S/R PIPE SIZING DETERMINED BY # LOOPS PER MANIFOLD
2. 1” LINES TO BUFFER TANK FROM HP
3. P-2 PUMP SIZED BASED ON # OF INFLOOR LOOPS
4. DESUPERHEATER LINES TO BE 1/2” MAX 30'
5. PUMP COMES WITH TANK FOR DESUPERHEATER
6. CONDENSING BOILER ONLY PLATE HEAT PRESSURIZED

LEGEND
- P/T GAGE
- CHECK VALVE
- BALL VALVE
- BOILER DRIP
- PETER'S PLUG
- BACK-FLOW PREVENTER
- ZONE VALVE
- ZONE AIR HEAT VALVE
- MAKE-UP WATER
- EXPANSION TANK
- BUFFER TANK
- LOAD SIDE PUMP SIZING
- LOAD SIDE PUMP SIZING
- SOURCE SIDE CONNECTIONS
- FROSTED AIR HEAT ZONE VALVE
- DOMESTIC W/H
- HEATING ZONE VALVE
- HEATING ZONE VALVE
- COOLING ZONE VALVE
- 3 TON: 30 GAL
- 4 TON: 50 GAL
- 5 TON: 60 GAL
- 6 TON: 80 GAL
- 3 TON: 30 GAL
- 4 TON: 50 GAL
- 5 TON: 60 GAL
- 6 TON: 80 GAL

---

Drawing M4-7: Radiant Floor Heating/Chilled Water Cooling (Fan Coil) – Water-to-Water Heat Pump – Standard Buffer Tank

>>> Use with Wiring Drawing E4-5 or E4-8

---

NOTES:
1. ALL S/R PIPE SIZING DETERMINED BY # LOOPS PER MANIFOLD
2. 1” LINES TO BUFFER TANK FROM HP
3. P-2 PUMP SIZED BASED ON # OF INFLOOR LOOPS
4. DESUPERHEATER LINES TO BE 1/2” MAX 30'
5. PUMP COMES WITH TANK FOR DESUPERHEATER SYSTEM

---

W-H W/H

---

Source: Roth
Section 5: Load Design – Hydronic Systems, August, 2010
Section 5: Load Design – Hydronic Systems, August, 2010 Roth

Drawing M4-8: Radiant Floor Heating/Separate Cooling System – Water-to-Water Heat Pumps – Standard Buffer Tank

- Use with Wiring Drawing E4-11

Drawing M4-9: Radiant Floor Heating with Water-to-Water Heat Pump/DX Forced Air Cooling with Water-to-Air Heat Pump – Electric Water Heater Used for Buffer Tank

- Use with Wiring Drawing E4-12
Drawing M4-10: Radiant Floor Heating/Separate Cooling System – Dual Compressor Water-to-Water Heat Pump – Standard Buffer Tank

Use with Wiring Drawing E4-9

BUFFER TANK SIZING:
- 8 TON: 50 GAL
- 10 TON: 80 GAL
- 12 TON: 80 GAL

LOAD SIDE PUMP SIZING:
- 8 TON: P-1=GRUNDFOS UP26-99F
- 10 TON: P-1=GRUNDFOS UP26-116F
- 12 TON: P-1=GRUNDFOS UP26-116F
- P-2: SAME PUMP AS P-1

LEGEND:
- P/T GAUGE
- CHECK VALVE
- BALL VALVE
- BOILER DRAIN
- BACK-FLOW PREVENTER
- WELL FTG

NOTES:
1. ALL S/R PIPE SIZING DETERMINED BY # LOOPS PER MANIFOLD
2. 1.25" MIN. LINES TO BUFFER TANK FROM HP
3. P-3 PUMP SIZED BASED ON # OF INFLOOR LOOPS
4. REMOVE FACTORY T&P AND REPLACE WITH 30#/HP
5. DESUPERHEATER LINES TO BE 1/2"-MAX. 10'

Drawing M4-11: Radiant Floor Heating/Separate Cooling System – Dual Compressor Water-to-Water Heat Pump – HSS Buffer Tank

Use with Wiring Drawing E4-10

 BUFFER TANK SIZING:
- 8 TON: 60 GAL
- 10 TON: 80 GAL
- 12 TON: 80 GAL

LOAD SIDE PUMP SIZING:
- 8 TON: P-1=GRUNDFOS UP26-99F
- 10 TON: P-1=GRUNDFOS UP26-116F
- 12 TON: P-1=GRUNDFOS UP26-116F
- P-2: SAME PUMP AS P-1

LEGEND:
- P/T GAUGE
- CHECK VALVE
- BALL VALVE
- BOILER DRAIN
- BACK-FLOW PREVENTER
- WELL FTG

NOTES:
1. ALL S/R PIPE SIZING DETERMINED BY # LOOPS PER MANIFOLD
2. 1.25" MIN. LINES TO BUFFER TANK FROM HP
3. P-3 PUMP SIZED BASED ON # OF INFLOOR LOOPS
4. DESUPERHEATER LINES TO BE 1/2"-MAX. 10'
Section 5: Load Design – Hydronic Systems, August, 2010 Roth

### Drawing M4-12: Baseboard or Radiator Heating/Separate Cooling System – Water-to-Water Heat Pump with Boiler Backup for Higher Temperatures – Electric Water Heater Used for Buffer Tank

- Use with Wiring Drawing E4-13

#### Load Side Pump Sizing:
- **2 TON:** 1
- **3 TON:** 1
- **4 TON:** 1
- **5 TON:** 1
- **6 TON:** 1

#### Buffer Tank Sizing:
- **2 TON:** 30 GALL
- **3 TON:** 30 GALL
- **4 TON:** 50 GALL
- **5 TON:** 50 GALL
- **6 TON:** 80 GALL

#### Legend:
- **ZONE VALVE**
- **ZONE GAUGE**
- **CHECK GAUGE**
- **VALVE**
- **BOILER VALVE**
- **BOILER DRAIN**
- **PETE'S PLUG**
- **MIXING VALVE**
- **PUMP**
- **W/ ISO FLANGES**
- **SPROVENT**
- **RELIEF VALVE (30-50PSI)**
- **WELL FTG**

**Notice:**
Local codes supersede any recommendations in this manual.

### Drawing M4-13: Radiant Floor Heating (Summer) with Pool Heating (Spring/Fall) via Plate Heat Exchanger – Water-to-Water Heat Pump with Boiler Backup – Standard Buffer Tank

- A specific wiring diagram is not shown for this application, since there are a number of ways to control pool heating systems, depending upon how the circulator pumps are set up. Contact technical services for details on your specific application.
# Retrofit Questionnaire

<table>
<thead>
<tr>
<th>Customer Name: ____________________________</th>
<th>Date: ________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many people live in the house?</td>
<td>Adults ____  Children ____</td>
</tr>
<tr>
<td>How old is the existing equipment?</td>
<td>____ Years</td>
</tr>
<tr>
<td>Any allergies or respiratory concerns?</td>
<td>Yes  No</td>
</tr>
<tr>
<td>Is your home even to humid, or dry during different seasons?</td>
<td>Yes  No</td>
</tr>
<tr>
<td>Any hot or cold spots in the house?</td>
<td>Yes  No</td>
</tr>
<tr>
<td>Do you want a programmable thermostat?</td>
<td>Yes  No</td>
</tr>
<tr>
<td>Are you concerned about ductwork cleanliness?</td>
<td>Yes  No</td>
</tr>
<tr>
<td>Do you feel that your home is properly insulated?</td>
<td>Yes  No</td>
</tr>
<tr>
<td>Any special uses of the home such as frequent entertaining or special equipment?</td>
<td>______________________</td>
</tr>
<tr>
<td>Any special safety concerns?</td>
<td>______________________</td>
</tr>
<tr>
<td>Are their any special landscaping concerns during installation?</td>
<td>______________________</td>
</tr>
<tr>
<td>Are you aware the impact of loop installation on your yard?</td>
<td>Yes  No</td>
</tr>
<tr>
<td>Do you know anyone who has a geothermal system?</td>
<td>Yes  No</td>
</tr>
<tr>
<td>Do your or your spouse work for a utility company?</td>
<td>Yes  No</td>
</tr>
<tr>
<td>What type(s) of energy are available to you?</td>
<td>______________________</td>
</tr>
<tr>
<td>What type(s) of energy are you considering?</td>
<td>______________________</td>
</tr>
<tr>
<td>How long have you lived in this home?</td>
<td>____ Years</td>
</tr>
<tr>
<td>Would you be interested in available financing options?</td>
<td>Yes  No</td>
</tr>
<tr>
<td>What are the 5 MOST important features to you?</td>
<td>______________________</td>
</tr>
</tbody>
</table>

- low cost of operation
- clean operation
- odorless
- no noisy outdoor equip.
- free hot water
- environmentally friendly
- quality components
- equipment appearance
- easy to service
- strong warranty
- humidity control
- long equipment life
- comfortable room temperatures
- quiet operation
- safety of your family
- reliability of equipment
- individual room comfort control
- Price
- Quality

Which is more important price or quality?  

How many proposals have you received to date?  ____

How many more to you wish to receive?  ____

Any other questions?  ______________________

---

Section 6: Worksheets, August, 2010
# Retrofit Walkthrough

## Client Information

<table>
<thead>
<tr>
<th>Name:</th>
<th>Address:</th>
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<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>City/State or Province:</td>
<td></td>
</tr>
<tr>
<td>Phone:</td>
<td>Best time to contact: am pm</td>
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</table>

## Exterior Equipment

<table>
<thead>
<tr>
<th>Make:</th>
<th>Age:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model:</td>
<td>Serial #:</td>
</tr>
<tr>
<td>HP/AC ect.:</td>
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<tr>
<td>Location:</td>
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<tr>
<td>Condition:</td>
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<tr>
<td>Noise Level:</td>
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<tr>
<td>Capacity (Hot/Cold Extremes):</td>
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## Client Information

<table>
<thead>
<tr>
<th>Window/Door Leaks:</th>
<th>Other Problems:</th>
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<tr>
<td>Lot Description:</td>
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<tr>
<td>Loop Preference:</td>
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<td>Loop Obstacles:</td>
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<td>Loop Location:</td>
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<tr>
<td>Building Penetration:</td>
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<tr>
<td>Attic/Ceiling Insulation:</td>
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<tr>
<td>Construciton Traffic Path:</td>
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<tr>
<td>Future Additions (Pool):</td>
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<tr>
<td>Pets, Neighbors, Other Considerations:</td>
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<tr>
<td>Rough Heated Sq. Ft.:</td>
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<tr>
<td>Crawl/Slab/Basement/Attic:</td>
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<tr>
<td>Other Notes:</td>
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</tbody>
</table>
## Interior Observations

<table>
<thead>
<tr>
<th>Electric Outlets:</th>
<th># of Fireplaces:</th>
<th>Blower Door Test:</th>
<th>Window/Door Leaks:</th>
<th>Make:</th>
<th>Age:</th>
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## Duct System

<table>
<thead>
<tr>
<th>Supply:</th>
<th>#</th>
<th>@CFM</th>
<th>Total</th>
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<tbody>
<tr>
<td>Size:</td>
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<table>
<thead>
<tr>
<th>Return:</th>
<th>#</th>
<th>@CFM</th>
<th>Total</th>
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<tbody>
<tr>
<td>Size:</td>
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</table>

Total CFM Capability: | Grand Total |
Basic Supply Size (8x20): |
Basic Return Size (8x24): |
Supply Air Test: |
Return Air Test: |
Insulation: |
Cold/Hot Rooms: |
Duct Notes: |
Geo Site Survey

Client Name: ________________________________ Date: ___________ Phone: _________________
Address: _____________________________________________________ Surveyed by: ___________

□ New Construction □ Retrofit

GeoAnalyst performed by: ______________ Phone: __________ E-mail: ______________________

Soil conditions: ________________________________________________________________________

Special regulations and requirements: __________________________________________________

Permit Number: __________________________

Owner’s preference on location of loop: ________________________________________________________________________________________________

Locate property lines, existing structures, future construction, utilities, and services. Also locate the geo unit, ground loop, and penetration, etc. Final "as-built" should be done upon completion.

Scale 1 square = _________ ft.

Power Lines
__overhead
__underground

Telephone
__overhead
__underground

TV Cable
__overhead
__underground

Water Well
Depth _____ft
__City Water
__Natural Gas
__Propane
__City Sewer
__Private Sewer
__Easements
__Fuel Lines
__Lawn Sprinkler
__Drain Tile
__Bldg. Penetration
__Unit Location
__Existing Unit
__Pond Size
__Other

Drawn by: _________________________________________________________
Date: ________________

Accepted by: _______________________________________________________
Date: ________________
As Built Site Layout

Company: ________________________________
Address: ______________________________________
City: __________________ State or Province: __________________
Postal Code: __________________ Phone: __________________

Directions to job site:

Instructions
1. Please select the type of loop installed.
2. Draw the GCL as installed. Locate the GCL to property lines, existing structures, and/or other permanent landmarks.
3. Provide a profile view of the site.
4. Attach Site Survey or locate all applicable items from the Site Survey Checklist.

Geothermal Closed Loop System As Built Site Layout

Determine:

SCALE = _______ : ________

N Profile

Profile

E

Number of Coils = ______
Width = __________ 
Depth = ______ , ______

Backfill = __________

Roth 86

Section 6: Worksheets, August, 2010
# New Construction Questionnaire

**Customer Name:** _____________________________________________  **Date:** _______________________

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
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<tbody>
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<tr>
<td>____ Years</td>
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<td>Do you want a programmable thermostat?</td>
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<tr>
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<td></td>
<td></td>
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<tr>
<td>________________________________________________________________________</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there a lake or pond within 100 yards of the home?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any special safety concerns?</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>Are you aware the impact of loop installation on your yard?</td>
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<td></td>
</tr>
<tr>
<td>Yes  No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you know anyone who has a geothermal system?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes  No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do your or your spouse work for a utility company?</td>
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<td></td>
</tr>
<tr>
<td>Yes  No</td>
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<td></td>
</tr>
<tr>
<td>What type(s) of energy are available to you?</td>
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<td></td>
</tr>
<tr>
<td>What type(s) of energy are you considering?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>________________________________________________________________________</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How long do you plan to be in this home?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>____ Years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Would you be interested in available financing options?</td>
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<tr>
<td>Yes  No</td>
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<td>What are the 5 MOST important features to you?</td>
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<tr>
<td>low cost of operation  quality components  comfortable room temperatures</td>
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<tr>
<td>clean operation  equipment appearance  quiet operation  safety of your family</td>
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<tr>
<td>odorless  easy to service  strong warranty  reliability of equipment  individual room comfort control</td>
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<tr>
<td>no noisy outdoor equip.  humidity control  long equipment life</td>
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<tr>
<td>free hot water  environmentally friendly  odorless  equipment appearance</td>
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<td>________________________________________________________________________</td>
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<tr>
<td>Which is more important price or quality?</td>
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<td>□ Price  □ Quality</td>
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<td>How many proposals have you received to date?</td>
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<td>How many more to you wish to receive?</td>
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<td>Any other questions?</td>
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<td>________________________________________________________________________</td>
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