Geothermal Heat Pumps for Small Buildings

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Introduction:

Geothermal Heat Pump information is widely available on the internet, but often repetitive, and always consisting of the same basic scientific principle. This course uncovers the mystery, takes an in-depth look at features, and addresses the applied science of these heat pumps, with practical application and sample photos that the professional engineer, contractor or design professional expects. It is used as part of a 12 hour college course on Ground Source Energy.

Geothermal Heat Pump systems save substantial operating costs compared to electric or fossil fuel methods. Water Source or Geothermal or Ground Source Heat Pumps all refer to the same machine (WSHP's, GHPs or GSHPs). A **GSHP** provides an efficient way to move heat from the ground into a building, or move heat from a building into the ground. The 40 to 50 degree Fahrenheit ground heat is of course not harvested free like a hot spring or deep earth heat source, but is amplified by using some electricity, (and not as much as other less efficient systems.) The simple comparison is to the refrigerator that cools the inside while heating its outside coil. For the professional who designs and specifies or installs a geothermal system for a small building, two separate components are involved.

1. The outside ground heat exchange (GHX or GHEX) loop discussed in the separate SUNCAM.com course 029.
2. The inside heat pump and heat distribution system, which is the topic of this course.

A client may call a local HVAC contractor with geothermal credentials, who will provide the heat pump brand they regularly install. But others will be interested in knowing and comparing features, beyond seeking the most tonnage for the lowest price.

There are two general types of geothermal systems:

1. Closed loop with water and antifreeze, such as biodegradable Propylene Glycol.
2. Open loop that always has three requirements:
    1. A reliable source of abundant water (thousands of gallons per day)
    2. An acceptable recipient water body, other than a sanitary sewer, or unapproved aquifer or well. In NY discharge 1 million gals/yr with a permit.
    3. Pure water that is contaminant free to minimize filtering, as specified. Scaling might require an annual maintenance contract to clean off with muriatic acid.

While an open loop with fresh and consistently warm 50 degree water can be 15% more energy efficient, the filtration and discharge issues are often overwhelming, and the simpler systems rely on the closed loop with propylene glycol antifreeze solution. Direct Exchange (DX) systems drilled at an angle by a track drill with copper tubing and refrigerant inside are also more complicated systems, sending the refrigerant directly through the ground and heat pump compressor and condenser. The GSHPs discussed here for small buildings are the ones mostly used, i.e. conventional closed loop GSHPs. There are numerous variations with merit. The closed loops with biodegradable antifreeze in water solution are either horizontally trenched or bored or within vertical drilled wells. All-in-One GSHPs reverse flow to heat in winter and cool in summer, all at the touch of the thermostat. (Set and Forget). For loop field efficiency, adding heat back into the ground in the summer is prudent. For simplicity of instruction and for clarity, most of the operation theory in this course is explained for Heating Mode, and can be simply reversed for Air Conditioning. Heat from the earth in winter becomes heat to the earth in summer. Heating in northern states becomes more economical when 600 to 800 gallons per year from a #2 diesel fuel oil system, can be replaced with a 3 ton GSHP.

Most information about heat pumps is available on line from the manufacturers themselves. Each company describes its own product, without allowing the specifying engineer or designer to compare and decide which features are most important. This course addresses these issues:

1. The encyclopedia type definition of what GSHPs are, their history, and how they work, with photos and diagrams of the inner workings, including
    a. the compressor
    b. the condenser at the air handler
    c. the ground loop to refrigerant heat exchange coil.

2. Parameters such as the Coefficient of Performance and the Energy Efficiency Rating. BTU/hr sizing. Refrigerant details, working temperatures, water flow, safety controls.

3. The major Manufacturers, Distributors and Dealers, with the trade organizations involved such as:

AHRI - Air conditioning and Heating Research Institute, www.ahrinet.org
ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers, www.ASHRAE.org
ACCA - Air Conditioning Contractors of America www.ACCA.org
IGSHPA (pronounced Iggspahh) - International Ground Source Heat Pump Association www.IGSPHA.OKState.edu
GSHPC - Geothermal Heat Pump Consortium www.Geoexchange.org on line forum

4. Ancillary features of interest like desuperheaters for domestic hot water generation and flow controller pumps, air handler, flushing kits, a water to water GSHP, etc.

5. GSHPs in Academia and Assembly.

The Chapter titles are:

Heat Pump History and Contemporary Status:

From the U.S. Department of Energy:
http://www.zebralliance.com/docs/geothermal_report_12-08.pdf

GSHPs started in the 1950's using Florida groundwater or canal water. (Lord Kelvin's original concept preceded this in the mid 1800's.) In the 1960's, the closed loop was developed in California, and systems spread to the east coast where they were made to operate at greater temperature differentials in the 1970's and 80's.

Approximately 60,000 GSHPs were installed each year, and 600,000+ units are operational. This number increased dramatically in 2008 when oil reached $150 per barrel. At least 16 manufacturers produce small GSHPs for residential and small commercial uses. Major companies are Climatemaster, Florida Heat Pump (Bosch), Water Furnace International and Trane. McQuay International, Mammoth and regional companies make GSHPs too.

At the 2009 IGSHPA convention these and companies such as Bard, ECONAR, Enertech (Geo Comfort, Hydron Module & TETCO Geothermal), Geofinity, Geo Master, Geo Furnace, Ice Kube Systems, Rheem and Spectrum were also present. Carrier and others source brands from companies such as Bryant.

Other well known Manufacturers and Suppliers include: Addison Products Co., Compax, Inc., Comfort-Aire (Century), Hydro Delta Corp., Hydro-Temp Corp., Millbrook Industries, and The Whalen Company.

No brands are endorsed here, but these samples (and those you may submit to www.SUNCAM.com for consideration that supplement knowledge in this course) are listed for the practical education of the professional design engineer, contractor or building inspector. In general, assembly of components for American distribution is done in the United States.

Throughout this presentation, various internet web site links are provided for the reader's knowledge, and as footnotes, but they are not required reading for the test questions.

At http://www.renewableenergyfocus.com/view/4759/us-shipments-of-geothermal-heat-pumps-surge-40/, the DOE report is updated to 2008 when energy prices spiked, and 121,243 GSPs for 416,105 tons were produced that year by 23 manufacturers, earning $319 million in shipment revenues. More than half are produced in Oklahoma and Indiana, with 16% being exported outside the country, mostly to Canada. Use is almost equal between residential and commercial. Foreign made GSHPs that use DC electric compressors should be checked for AC (Alternating Current) electrical service. Some rebates have Buy American provisions and Davis Bacon rate stipulations that should be considered during GSHP selection.

From the 2009 IGSHPA Exhibition Hall in Dallas before opening:
A GSHP package unit with air handler on the left, and a Split GSHP on the right.

GSHP units are classified as

*Packaged (about the size of a refrigerator with Gavelin or Stainless Steel cabinets that have higher warrantee life) or

*Split as half sized to be connected with a copper refrigerant line set to a separate air handler, or

*Combo for an air and hydronic unit.

GSHP System Process

Interior components:

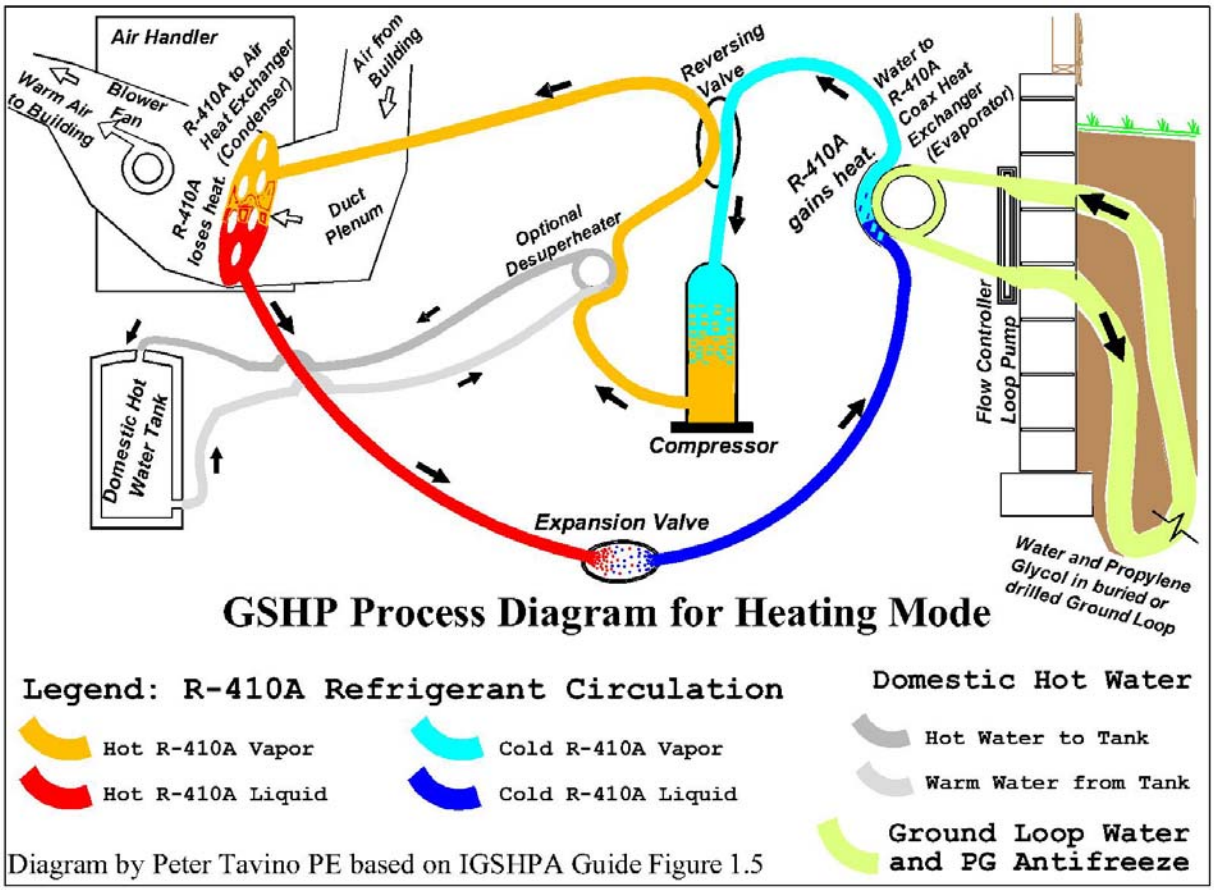
A Copeland dual stage compressor. (Compare to two gears in a car).

Variable speed with three or more stages is being introduced for more efficiency, but the two stage compressor has proved reliable and efficient. It has approximately 67% of capacity in Stage 1 and 100% of capacity in Stage 2. The conventional single stage compressor is less efficient, but saves capital cost. (just over $3000 for a three ton All-In-One GSHP). In Air conditioning mode, to address humidity, stage one of two can be prioritized, along with air handler blower controls discussed later.

Step one is that the Compressor uses electric power to compress the refrigerant that is secured within the copper line set tubing. R-11 and R-12 refrigerants are no longer used in GSHPs because they deplete the ozone layer. R-22 is being phased out now. Some major manufacturers have recently discontinued it. The refrigerant with about 6% more efficiency than R-22 is R-410A, also marketed as Puron, Genertron R410A and/or AZ-20. It operates at higher pressure than R-22, and is safely handled only by trained and EPA certified technicians who understand the difference between the new and old equipment. Beyond this course, more information on R-410A is here: http://en.wikipedia.org/wiki/R-410A. For further course instruction below, R-410A is used.

The compressor is in the center of the next diagram showing how heat is brought from the earth into the building. This diagram is for Heat Mode in wintertime.

The orange, red, cyan and blue colored lines show the R-410A within its copper or copper and nickel sealed tubing. The yellow green colored line is the sealed water and antifreeze ground loop, similar in color to real propylene glycol and water antifreeze solution.



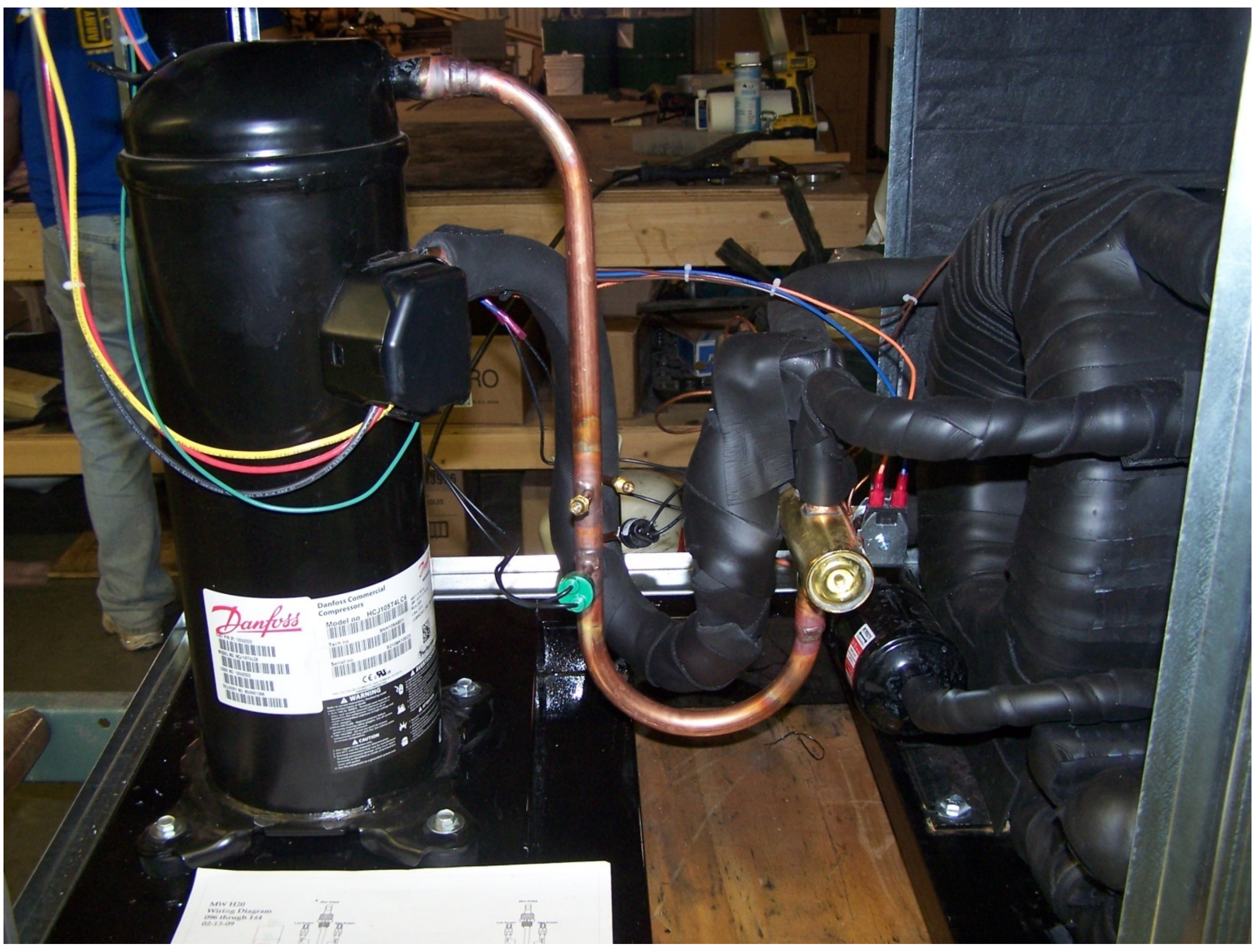
Heat Mode Diagram Figure 1.
(Similar to Figure 1.5 in the Closed-Loop GSHP Systems
Original 1988 Installation Guide distributed by IGSHPA)

The compressor uses electricity to literally compress the R-410A, and heats it up as hot vapor. Changes of Phase in thermodynamics follow Gay-Lussac's Law. When gas molecules are compressed, temperature rises.

$$\frac{P1}{T1} = \frac{P2}{T2}$$

(The domestic hot water tank option shown above will be addressed later.)

The hot R-410A vapor in its insulated copper tube line kit passes through the cylindrical brass reversing valve, as shown below, before it is sent to the condenser coil. In heating, flow is in one direction. In cooling, flow is reversed here.



The R-410A then flows to the air handler and duct system in a cabinet space that can be separate from the heat pump itself, for a Split GSHP, (especially in a retrofit) or the GSHP and blower fan can be in one larger cabinet package unit. The R-410A to air exchanger looks like a simple metal radiator, with much copper or steel tubing exposed to the air flow. The condensing process occurs here for heating.

The circular blower fan moves clean warm air across the condenser where the air is heated before transport to the duct system and building interior. GSHPs in small buildings normally heat the R-410A to a maximum of 110 degrees. The air handler blows this hot air into the duct system.

See the sample photos with an air handler below.

First, a blue condenser coil, coated to protect it from corrosion:

This “condenser” is not to be confused with the “compressor”. The condenser is located in the air handler cabinet. It is part of the process, but not part of the Split GSHP. (In the language of the trade, it would be called an “evaporator” because the air conditioning mode is usually used for terminology. A blower fan circulates air from the building across the “condenser”. In heating mode, cool air from the conditioned space blows across the condenser, where the air is warmed for recirculation. It is forced through the duct system and registers into the rooms (where it loses heat to below 100 degrees) until the thermostat request of approximately 70 degrees is satisfied. Unlike fossil fuel systems that operate at 140 degrees, the ground source condenser is not as hot for efficiency, and more air circulation results. This additional ventilation adds to the improved comfort of geothermal heating. It is why baseboard radiators are not always suited to retrofit with geothermal, unless more can be added. Duct sizes are usually adequate, but should be checked if minimal. For larger buildings with 10 ton heat pumps, water to water GSHPs operating at 130 degrees maximum degrees are feasible. They often heat radiant floor systems. There is no change to the air filter operation, or maintenance schedule to collect and remove room dust. A typical GSHP manufacturer might make 3 Water to Air GSHPs for every Water to Water GSHP. The Water to Water can also serve an Air coil.

Because the air flows across the condenser, and removes its latent heat, the R-410A cools, and “condenses” into a warm liquid. It then passes by an expansion valve, where it expands and becomes a cold liquid. It must be expanded so that it is colder than the ground loop water solution that will reheat it.

In a building retrofit, the heat pump condenser could use or replace the existing oil or gas sourced condenser in the existing air handler cabinet. Check age, and compare efficiency against the price of newer condensers when recommending replacement. R-410A at higher pressure will require a new coil. Unless with Water to Water, only R-22 older lower pressure types can be reused, and used for both heating and air conditioning as shown below:

Condenser detail within the air handler cabinet.

Copper tubes circulate R-22 here. (In the field the technician will call this the evaporator coil, referring to its use in cooling mode.)

In this new process, a humidification/dehumidification coil is located next to the condensor (referred to as the "evap coil" per tradition) to regulate moisture output as shown below. Note that most blowers in the air handlers shown are GE ACM blowers, generally running at 1/3 horsepower, and with 60% efficiency.

Modern variable speed blowers are controlled through ECM (Electronically Commutated Motor) boards averaging 400 cfm. Air Filters should have MERV (Minimum Efficiency Reporting Value) of 7.

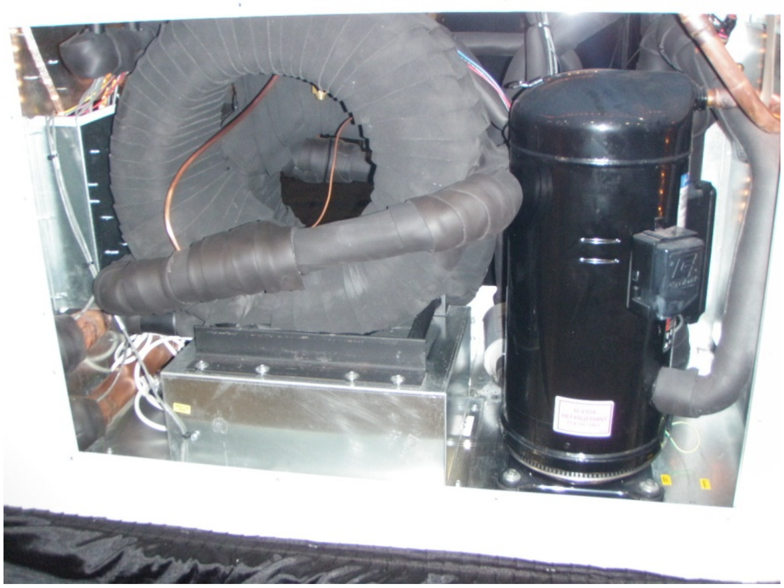
The attached one minute on line video shows how an air source heat pump works (in air conditioning mode) (None are yet available for ground source, but the same principle applies.) http://www.encyclopedia.com/video/B-cnkjjJUaQ-how-heat-pump-works.aspx

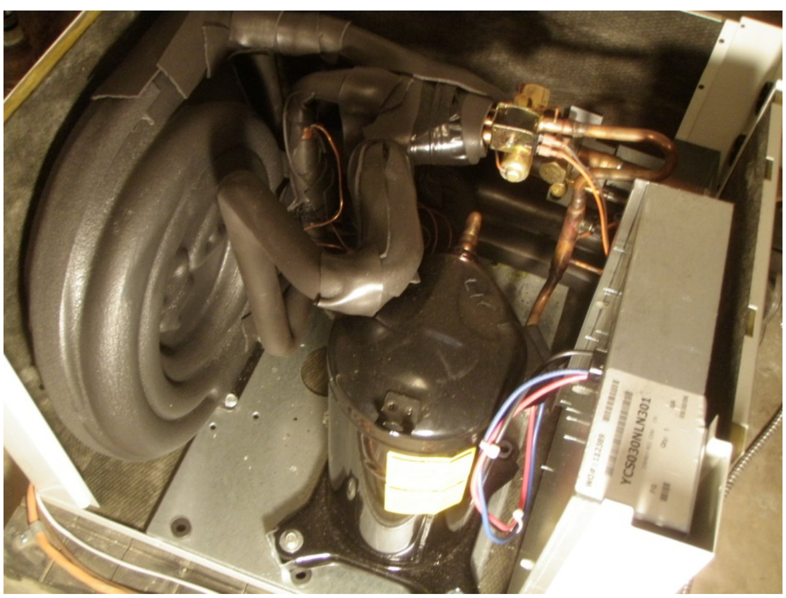
Beside air source heat pumps that are not efficient in freezing weather, there are larger scale "Hybrid" GSHPs that use ground source water and also air source (cooling towers). They can be as efficient as pure GSHPs. http://hpac.com/plumbing-piping-pumping/ground-source-heat-pumps-0909/

The difference between the air source and water source from the ground is at the heat exchanger. It is this efficient transfer of heat from the ground loop fluid to the R-410A refrigerant that makes GSHPs provide more heating or cooling for less electricity. In winter, when the outside air temperature is 30 degrees, the air sourced heat pump uses more electricity than the ground source heat pump making contact with 40 degree loop water for instance.

It is at the heat exchanger where the second law of Thermodynamics occurs. (Heat flows spontaneously from a hot object to a cold object.) Entropy is the tendency for the warmer ground loop water to get cooler as it comes near (but not in direct contact with) the cooler R-410A that then heats up. And in air conditioning, the opposite occurs at the same heat exchanger.

This all important heat exchanger separates the *air sourced* from the *ground sourced* heat pump. Shown as the "Water / Refrigerant Heat Exchanger (Evaporator)" in the diagram above, (Called the "Condenser" in the field) it is assembled in coil configuration as shown below in two separate GSHPs with similar insulated round coils.

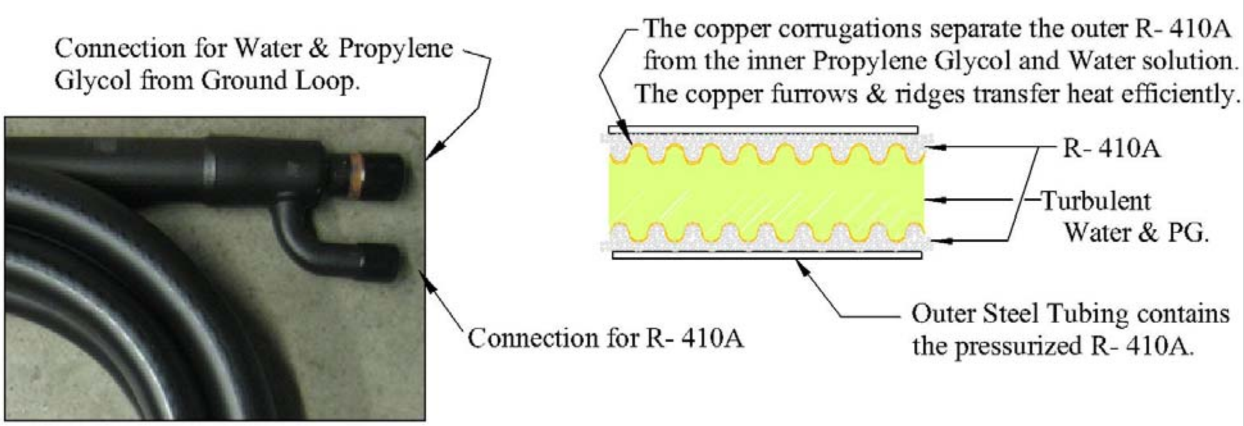




Within the insulation wrap is this heat exchanging coil shown below:

The way the loop water makes good contact with the R-410A refrigerant within this copper and steel coil is the key to efficient GSHP operation.

One prominent manufacturer, Packless Industries www.Packless.com uses a patented process with the coaxial principle of a tube within a tube design. From the corrugated inner copper tube, good thermal contact (but no physical contact) is made in the coaxial heat exchanger. The fluids purposely flow parallel to each other to maximize evaporation in heating mode, and opposite each other to maximize condensing during air conditioning.



Coaxial Heat Exchanger Coil

Note that Packless uses copper for closed loop and Cupro-nickel for open loop coax. Copper is about 5% more efficient but not as durable. There are 8 rifles per inch in a Packless compared to 6 per inch in a Turbotec. Both hold about 1 gallon of R-410A.

To complete the cycle from Figure 1, the warmer R-410A now as a cold vapor, goes back to the compressor where it is more efficiently compressed to hot vapor again, and sent to the condenser.

Terminology also reverses for the cooling system. The Heat Condenser becomes the AC Evaporator, and the expansion valve becomes the reducing valve, etc.

It is very important that the entire GSHP system be approved by AHRI for certain state and utility rebates. Hooking up an approved GSHP to an air handler that is not approved by AHRI, can be problematic for rebaters. Although the system will work well, and meet efficiency Verification standards, the lack of matching assembly certification can be a reason for rebate denial. Energy Star and tax credit requirements are also jeopardized. To see if the proposed unit is certified for a combined GSHP and air handler coil (referred to by AHRI as the Indoor Model) consult with the AHRI website here: http://www.ahridirectory.org/ahridirectory/pages/wbahp/defaultSearch.aspx Simply find the GSGP manufacturer from the drop down box, type in the first three numbers of the GSHP model number, and see the available matching assemblies, or vice versa. For example, ECONAR and 170 or Climatemaster and 026. During business hours, AHRI technical assistance operators can answer chart reading questions. Certificates are downloadable. Because R22 refrigerant is being phased out, air handler coils must in almost all cases be replaced by R410A coil indoor models. Some common coil manufacturers are not on the approved list. In one example, Bryant/Carrier and Rheem were the only approved matches to the ClimateMaster split unit GSHP proposed.

One way to verify installed performance during commissioning is to use the Verification of Installed Performance (VIP) form here: http://www.cl-p.com/home/saveenergy/rebates/VIP_Closed_Loop_Worksheet.xls First developed in 2000, it is popular in some states. Some utility company rebaters require the GSHP to run at $\geq$ 85% of the rated Coefficient of Performance (COP, as described below) based on incoming water temperature. The designer should be familiar with the content of this form, which might be utilized once the system is operational. The category pull downs help you input data to this form. Use your field readings for the amperage, pressure and temperature at the ports, and take temperature readings in the air handler plenum. The actual COP is computed within the form software at the end of the form, and the building owner can be assured of adequate efficiency. It follows the Heat of Extraction or Heat of Rejection formula Q = K (T1- T2) x GPM where K = 485 for PG antifreeze or 500 for water alone. Field check must be close to HE or HR specked.

Coefficient of Performance COP

This efficient heat exchange causes the Coefficient of Performance (COP) to be more than three times better than direct electric heat. For closed loop, the standard COP of 3.3 (and 3.6 for open loop) means that 1000 kilowatts of electric power give the same heating as 3300 kilowatts of electric heat. GSHPs save electric cost. COP is the fraction of heating to energy consumption.

According to IGSHPA, the exact definition of COP = $\frac{\text{Heating Capacity in BTU/hour}}{\text{Power Input in BTU/hour}}$

A conventional plug in electric heater has a COP of only 1.0. The higher the COP, the more cost efficient it is, depending on equipment, refrigerant and especially the incoming loop water temperature. Saving electricity is key.

A theoretically perfect machine with "Carnot COP" has no losses of heat dissipated by the compressor and pumps and fans, etc. that are accounted for in the real COP.

The COP is $\leq$ Temperature of the incoming warm loop water divided by the temperature drop as the loop water returns to the ground, in absolute units.

From Wikipedia:

$$COP\ heating = \frac{(Q1 - Q2)}{(W1 - W2)} \leq \frac{Temp.\ hot}{(Temp.hot - Temp.cool)}$$

Where Q1 – Q2 differential is the amount of heat sent to a hot recipient body at Temperature hot, and W1 – W2 is the compressor work.

Temperatures used are not Fahrenheit, but in Absolute Units.

As ground temperatures cool in the winter, the "source" heat differs more from the "sink" heat inside the building that stays fairly constant at 68-70 degrees desired. This differential is called the "lift." As lift increases, more electricity is required to attain the same result. COP thus changes as a function of this temperature change, but remains in the range of 2 to 3. Energy Star Standards are set by AHRI, the Air conditioning and Heating Research Institute (formerly ARI, the Air conditioning Research Institute).

http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=1468

The ongoing testing program rates closed loop GSHPs under AHRI-330 at 32 degrees source heat and 77 degrees source cooling, including pumping costs to circulate the antifreeze solution through the loop field. AHRI-325(50) for open loop with source temperature of 50 degrees including pumping is more efficient if the three requirements for water use can be met.

In summary, to reduce the greatest cost that comes from winter heating, select a GSHP that is efficient at the low (30 to 40 degree) loop water temperatures that will prevail.

During air conditioning, the EER = the Energy Efficiency Rating is the reverse for the cooling mode. A COP of 3 equals an EER of 10.2 because the BTU conversion to a watt hour is 3.412. The Seasonal EER (SEER) for real working conditions reach 15 and 16 easily and can be as high as 25-30 for expensive state-of-the-art systems with advances made in the industry. (Highest luxury heating model available is COP 5.0.) Specifying a new GSHP in the 3.5-4.0 range is common.

As in most specification selections, GSHP products require minimal standards, such as Energy Star ratings, and the specifier must decide if the added expense for higher quality and efficiency is justified. One guide to help from the Federal Energy Management Program is here: http://www1.eere.energy.gov/femp/procurement/eep_groundsource_heatpumps.html#when

Selecting the Properly Sized GSHP

One ton of heat pump capacity equals 12,000 BTU per hour, and a typical 2000 sq. ft. home 3 ton GSHP produces 36,000 BTU per hour. By calculating the heat loss from R values and air leaks, the capacity needed for various sized buildings is computed. ACCA *Manual J* or the ASHRAE *Handbook of Fundamentals* may be used to determine Heat Loss/ Heat Gain more precisely, along with the corresponding residential equipment GSHP sizing loads. The methodology is the same for all types of heating and cooling systems. (ACCA *Manual D* is for ducts.) Degree Days and Bin Hours can be used in software programs to more specifically determine the Load profile.

For a quick analysis of the heat loss, designers can easily measure the building envelope, to compute walls, ceilings and fenestration areas, and arrive at a reasonable BTU/ hour design.

Heat Loss Rate = Area times Temperature differential
divided by the Thermal Resistance of the assembly.
http://hyperphysics.phy-astr.gsu.edu/Hbase/thermo/heatloss.html

$$\frac{Q}{R} = \frac{\text{(Area) x (Temp interior – Temp outside)}}{\text{Thermal Resistance of building components}}$$

This example determines loss through walls with insulation rated at R-10:

Consider a 40' x 30' building with an 8' high ceiling.
Area = (80 + 60) x 8 =1120 sq. ft.
For inside temperature of 70 and outside at 0 degrees,
The rate of heat loss through the walls alone is:

$$\frac{Q}{R} = \frac{1120 \text{ sq. ft. } x\ (70 - 0)}{10} = 7840 \text{ BTU / hour}$$

Adjust for fenestration, add ceilings and floors, and infiltration air leaks, and leaks of ductwork in unconditioned space. Find the total BTU/ hr. required to heat the building. Suppose that it totals 23,000 BTU/hr. Because they are manufactured to the nearest half ton, select a GSHP with Heating Capacity of 24,000 BTU/hr that might have Cooling Capacity of 30,000 BTU/hr rated at 2 ½ tons. (Tonnage is an AC term, but used for GSHP heat.) Sizing smaller will require more auxiliary heat. And 115 volt service is inadequate for strip heaters.

An old rule of thumb used to be that tonnage selection should be for the peak sensible cooling load, with an increase of 25% to account for the heating load. But with advances in GSHP technology throughout the years, for northern heating climates, the procedure is to now select a GSHP that can handle 100% of the heating load, or slightly less. Choose a unit that is within 25% for cooling mode. Some rebaters require 95% annual capability before backup must kick in. The two speed compressor can use the 67% first stage to address latent (humid) heat during cooling. All the capacities in first and second stage heating and cooling are tabulated on the Performance charts. And the blower fan control can be adjusted as well, so that summer time air is cool, yet not humid and "clammy". Far north regions with frequent subzero temperatures might not be suitable for GSHPs. But air to air Heat Pump efficiencies here are poorer than down south where heating is with warmer outside air.

In the South, a smaller all-in-one GSHP will meet the higher peak heating design outside temperatures in the 30 degree range, for the limited hours within a year that it would be required. Zone maps are available, but calculate temperature differentials based on your region.

From the above equation (not example), to air condition outside 105 degrees, Delta T = 35 degrees or exactly half of the heat loss rate of 7840 BTU / hr = 3920 BTU/ hr, as computed above, so typical GSHPs are oversized in cooling mode. Remember to add cooling loading from appliance and light heat, etc. including the GSHP. ACCA software is useful for this.

Air conditioning predominant climates should address sensible and latent cooling loads. The sensible load is the dry bulb temperature of the thermostat. The latent load also accounts for relative humidity. An overly large GSHP might not run frequently enough when air conditioning is needed, and might not remove enough humidity. The air handling blower can also address this, delivering 365 cfm/ton for cooling, and 410 cfm/ton for heating.

For a retrofit, simply confirm and replace the same tonnage unit that is removed. But be aware that many existing air conditioners, air source heat pumps, and oil/gas fired furnaces are oversized.

As with more specific ground loop field design, designers can pay a nominal fee to use software available from Geo Connections, Inc. of South Dakota, www.geoconnectionsinc.com which is affiliated with IGSHPA. By completing the 73 item worksheet (and 12 for ducts) a specific GSHP tonnage will be determined. In addition, trained dealer representatives of the GSHP manufacturers can size units based on building wall and ceiling areas and R factors. Another link is www.Geokiss.com, and a simple online Res Load Calculator is here: http://www.shophmac.com/info-center/hvac-calculators/heat-load-calculator.php

And another source is IGSHPA or a manufacturer's Windows ready GeoAnalyst downloaded for $50 per year. ClimateMaster and Enertech offer it.

By selecting a small GSHP, cost savings can be attained, and a backup system can be used for the days when outside temperatures drop below design. Be sure the loop field is not overtaxed with the frequent cycling on peak demand days, lest Entering Water Temperature (EWT) drops and so COP efficiency drops. Back up can be a separate electric floor heater, an older existing fossil fuel system or auxiliary electric strip backup within the air handler. A small heat pump will also run more frequently (than about 1 third of the time on cold days or 4 to 5 cycles per hour) and operating costs will increase. Some controls shut off GSHPs if the thermostat is not satisfied in 15 minutes, and switch temporarily to more electrically expensive backup.

At a recent Connecticut Society of Professional Engineers meeting, a PE who had installed a GSHP and horizontal loop field at his new home reported that he also installed a gas back up heating system, but had never needed or used it.

Keep within the conventional uses, of about three tons for a 2000 sq. ft normally insulated and sealed home in the mid north. In sizing GSHPs remember that good judgment is needed, but the penalty is slight loss of efficiency, not a malfunctioning system. Over sizing or under sizing by a half ton will not greatly change the much lowered monthly electric bill.

Installing the GSHP by the Manual

With the shipment arrival of the 200 to 250 pound split GSHP will be a homeowner's manual for Installation, Operation and Maintenance. By referring to the model number, various tables will show operating specifics. The Manual should also include a Warranty Certificate good for five to ten years. The major GSHP manufacturers are rated by how quickly they respond to Warrantee issues. And home owners need to know that maintenance for a problem will not be costly or monopolized by only a few contractors in the region.

On line manuals can be consulted at any time by the geo-designer interested in the GSHP specifics before it arrives. A sample 50 page Manual is here:

http://www.docs.hvacpartners.com/idc/groups/public/documents/techlit/97b0048n01.pdf

The manual will compare indoor and outdoor versions of its GSHP product line. Noise can be a factor in a basement, but there is more efficiency in the semi conditioned space. All units must be kept level, and sealed against rodents. Indoor units cannot freeze or be in humid areas. The desiger must select a location in the basement or utility room that is accessible. If that is uncertain, some GSHPs on display at the 2009 IGSPHA convention such as Bard Manufacturing Company showed panels that can be removed from either side for future maintenance. There is a left or right duct exit from the air handler portion. Water connections can be from both sides. The filter rack flips to either side and the strip heater can be accessed from two sides. Packaged units can be horizontal or vertical with upflow or downflow.

Layout for access to where the loopfield HDPE enters through the concrete and to the air handler and possibly hot water tank must be considered. GSHPs must be placed on soft dampening air or neoprene type pads to muffle sound and vibration. Installing in drop ceilings is discouraged because of maintenance access issues.

Two stage split GSHPs being installed in a crawl space.
On the left: a two ton unit (26,400 Btu/hr cooling or 19,500 Btu/hr heating)
Right: a three ton unit (37,300 Btu/hr cooling or 27,000 Btu/hr heating)
Part load first stage cooling is 20,800 Btu/hr. (left) and 27,100 Btu/hr. (right)

Condensor (Evaporator) coils must be compatible with R-22 or R-410A refrigerants, and warnings on proper handling are given. Air handler characteristics must match the GSHP tonnage as shown in the charts. For example, a 3 ton GSHP might require 48 degree Evaporator Temperature, 1200 cubic feet per minute air handing, and a heat capacity of 37-42 MBTU/ hour.

The manual also reminds the HVAC installer about the outside HDPE solid or heat fused loop. Inside connections can be conventional, and fusing is not required, but Schedule 40 PVC is discouraged, especially during the 50-100 psi pressure test conducted usually before backfilling. Insulating interior rubber pipe to avoid sweating is recommended.

The interior piping can be made to withstand the low operating pressures of 5 to 10 psi, or up to 30 to 50 psi if the required flow of 9-10 gpm for a three ton GSHP is achieved. At least a positive 3 psi is needed in the loop to activate the flow controller pump. Lower pressures from a canister type system generally prolong equipment life. Gages on the system allow monitoring. The environment of varying pressures and freezing temperatures, must be addressed throughout. Freezing loop pipe outside can damage a nearby water supply line. Loop pipe not ready for use that collects water without antifreeze can be damaged, even though HDPE can withstand a blow from a sledge hammer.

The installation guide will describe how to set the low water temperature jumper and the purge and charge sequence of the antifreeze solution loop. A Flush Cart with 1.5 HP is needed for a pressurized closed loop. This charging, testing and all leak testing and other work with the R-410A is done by EPA certified technicians. They may improvise with a large pail and pump, or use a specially constructed unit such as this Flush Cart that may be purchased or rented:

All air and debris is removed out of the loop, and the addition of the 15-25% Propylene glycol solution is made easy with a flush cart. No dirt or debris can enter the loop, so the filter in the flush cart is removed as shown. And GSHPs should never operate during construction when dirt and debris could foul the condensor coils.

Flushing requires more pump power than circulating. Sometimes a Fire Truck pump is strong enough. Retrofitting a house with 115 volt service might only power a 1 to 1 1/2 hp pump. Two weeeks after installation, loops might expand and contract so purge air again. A way to check if a loop has air is to check pressure, remove an ounce of water and PG and see if pressure dropped which it will if undesirable air is in the loop pipe.

Other factors concerning the GSHP installation involve supplying adequate electric power. The manual should be checked to be sure a typical 30 or 40 amp whip supplied by an electrician will be sufficient. Wire run length is inconsequential. Provide a drain pad where condensation could occur at the air handler, but it is not needed at the Split GSHP.

R410A HVAC technicians check required superheat and subcooling to be sure unit is not overcharged or undercharged. Linesets should not be >50', nor 20' in rise, so attic handlers might be better supplied by water than R410A.

Flow Center Pump Controller and Low Voltage Controls

Flow Controller: The pump that circulates the water & antifreeze solution in the earth loop.

	
Grundfos Flow Controller Model AFCG2C1 With earth loop pipes above and heat pump rubber pipes below, as installed. Approximate purchase cost is $700.	*A Grundfos Flow Controller on display at the IGSPHA Exhibition.* *Below GSHP and Flow Controller installed*.

For small commercial and residential, circulating pumps are usually single stage, and not variable speed.

Installation, Operation & Maintenance Instructions for the Flow Controller AFCG2C1 model shown above is here:
http://www.climatemaster.com/downloads/97B0015N01.pdf

From that 32 page booklet are these two charts on pages 16 and 23 reproduced below.
For the three ton heat pump under consideration for a typical small building, and 3 x 3 = 9 gallons per minute flow required (Minimum of 2.25) the Flow Controlling pump can be sized from the curve shown below.

First consider the 25% propylene glycol antifreeze solution chart (Consult PG solution recommendations for desired antifreeze temperature on its container.) (Consult the SUNCAM geothermal trench design course, for 1000LF of 1 ¼" ground loop pipe.) From table below, read 2.07' of head per 100' = 20.7' of head total resistance due to HDPE skin friction. Add in the pressure drop across the heat pump and the interior rubber piping according to the additional chart (use about 7') and note that even the small single pump capacity just meets 27.7' at 9 gpm.
Recall that there is no additional head despite burial depth, because the closed loop is pressurized, to at least 3 psi recommended, or less with a free standing column. This allows the addition of water and propylene glycol, as the loop expands and contracts with temperature changes, and requires no flush cart. An optional Hydronic Diaphragm Expansion Tank with Bladder (under $70) will keep pressure more stable, and can be outfitted with a pressure gage

that the building or home owner can monitor to be sure the system operates as designed. This operating pressure does not affect interior skin friction pumping pressure, and is also independent of R-410A pressure.

Other than changing air filters at the air handler, there is no more **future maintenance** expected than would be expected for a refrigerator or air heat pump appliance. Any condensation pan should be properly outlet drained. The GSHP cabinet should be sealed dust free. The propylene glycol closed system should last many years.

Open loop water source from a deep well does involve pumping electricity depending on the ground water level, which subtracts from the COP, but uses water almost always at 50 degrees. Because the source water for open loop supply is warmer than closed loop, 2 gpm, not 3 gpm per ton is approximately required. Flow controller pumping differs from closed to open loop.

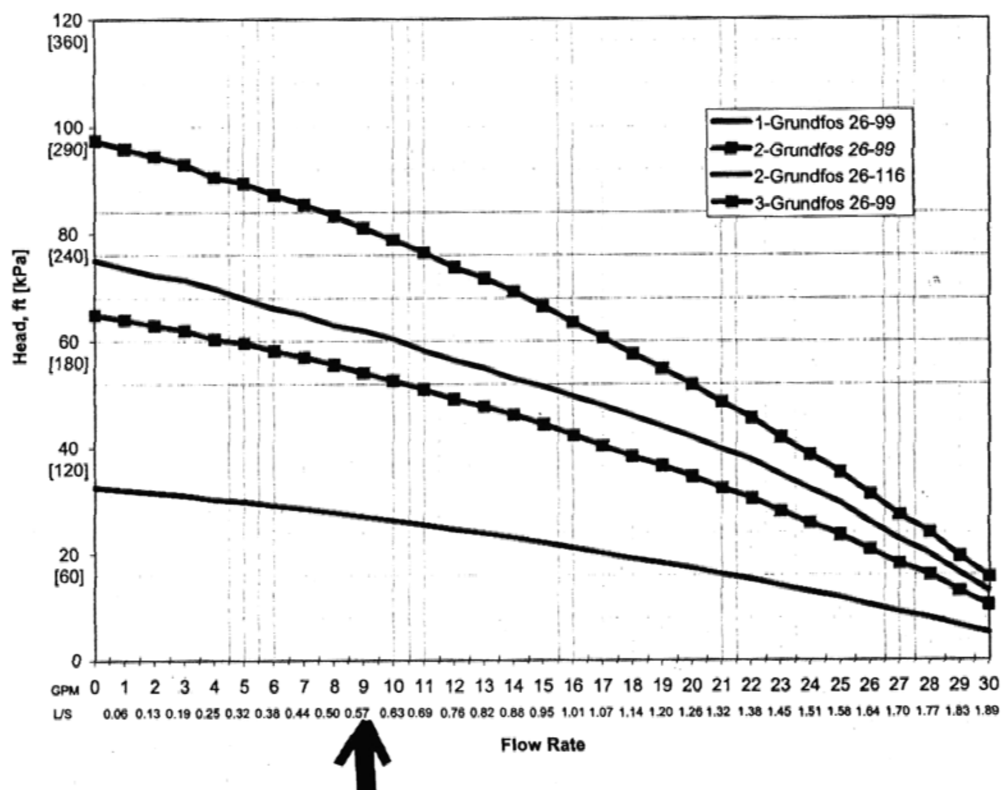
Of course the larger 2" ground loop pipe has even less resistance, and if ¾" slinky loops are used, and 4 of them enter a fused manifold, flow is 9/4= 2.25 gpm = 1.77' of head per 100'.

Check the IGSHPA Manula to be sure flow in the 2" HDPE loop pipe is turbulent for good heat excgange. Although the smaller HDPE loop field sizes are easier to install, the head loss is greater as shown, and electricity used to power the Flow Controller contributes to the overall COP and EER. A 3 ton GSHP that requires a second Flow Controller at 1/6 horsepower will add 200 watts of additional power, effectively reducing the COP, with little added benefit.

The charts refer to SDR11 and Sch. 40 pipe that is not used for ground loop piping (HDPE is), but the internal skin friction is similar. The chart in this booklet shows 1, 2 or 3 Model 26-99 pumps in combination. Without exceeding the flow controller capacity, select the model that best fits.

FLOW CONTROLLER PUMP CURVES

Chart 2: Flow Controller Performance



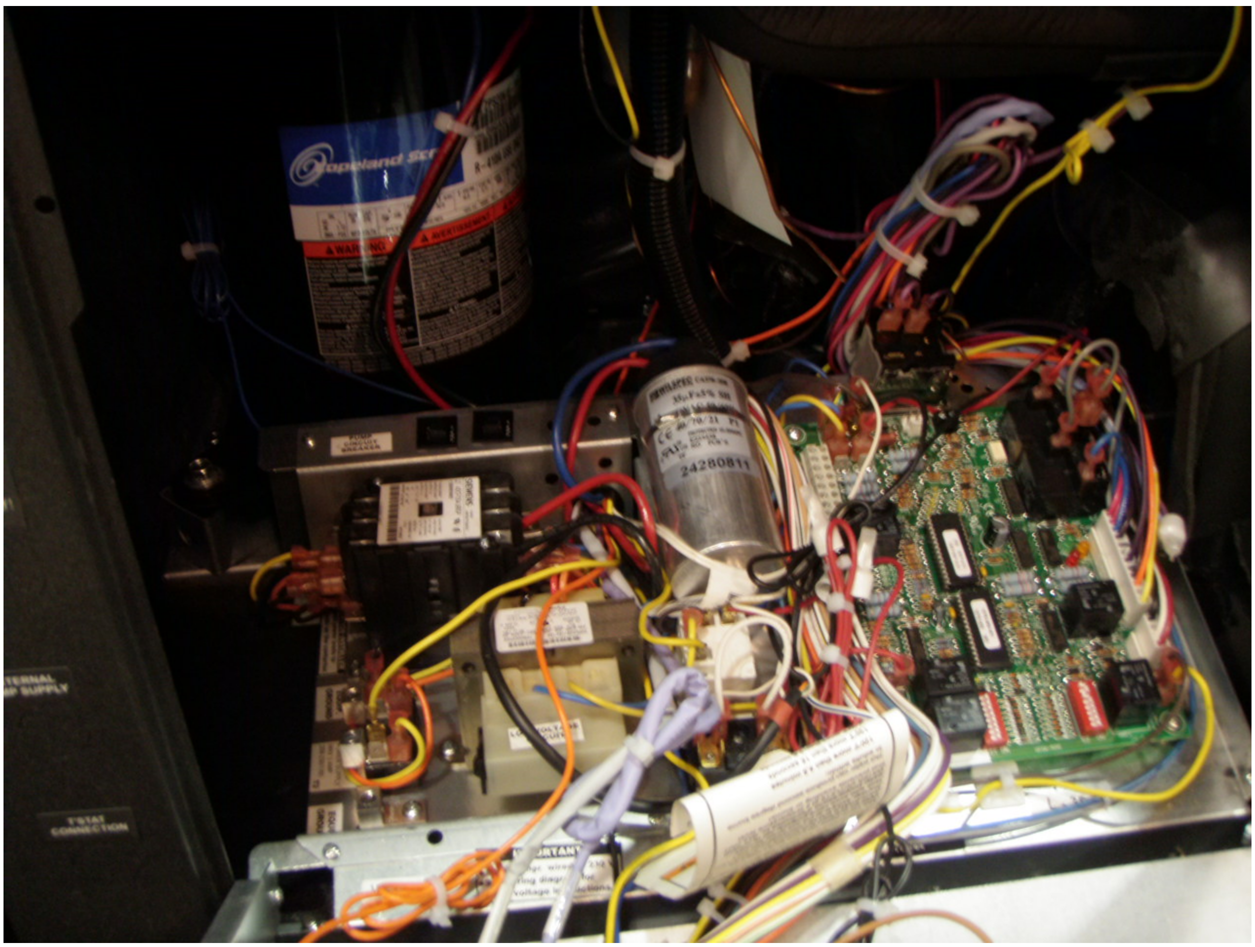
GEOTHERMAL CLOSED LOOP DESIGN

Table 6b: Polyethylene Pressure Drop per 100ft of Pipe
Antifreeze (30°F [-1°C] EWT): 25% Propylene Glycol by volume solution - freeze protected to 15°F [-9.4°F]

Flow Rate	3/4" IPS SDR11			1" IPS SDR11			1-1/4" IPS SCH40			1-1/2" IPS SCH40			2" IPS SCH40		
	PD (ft)	Vel (ft/s)	Re	(ft)	Vel (ft/s)	Re	PD (ft)	Vel (ft/s)	Re	PD	Vel (ft/s)	Re	PD	Vel (ft/s)	Re
1	0.42	0.55	636	0.14	0.35	507	0.04	0.21	389	0.02	0.16	346	0.01	0.10	278
2	1.41	1.10	1271	0.48	0.70	1013	0.15	0.43	798	0.07	0.32	692	0.02	0.19	528
3	2.86	1.66	1919	0.98	1.06	1534	0.30	0.64	1187	0.15	0.47	1017	0.04	0.29	806
4	4.74	2.21	2554	1.63	1.41	2041	0.50	0.86	1595	0.24	0.63	1363	0.07	0.38	1056
5	7.01	2.76	3190	2.41	1.76	2548	0.74	1.07	1985	0.36	0.79	1709	0.11	0.48	1333
6	9.64	3.31	3826	3.31	2.11	3054	1.02	1.29	2393	0.49	0.95	2056	0.15	0.57	1583
7	12.62	3.87	4473	4.33	2.47	3575	1.34	1.50	2782	0.64	1.10	2380	0.20	0.67	1861
8	15.94	4.42	5109	5.47	2.82	4082	1.69	1.72	3190	0.81	1.26	2726	0.25	0.76	2111
9	19.59	4.97	5745	6.73	3.17	4589	2.07	1.93	3580	1.00	1.42	3073	0.30	0.86	2389
10	23.56	5.52	6380	8.09	3.52	5095	2.49	2.15	3988	1.20	1.58	3419	0.37	0.96	2667
11	27.83	6.08	7028	9.56	3.87	5602	2.94	2.36	4377	1.42	1.73	3743	0.43	1.05	2917
12	32.41	6.63	7663	11.13	4.23	6123	3.43	2.57	4767	1.65	1.89	4090	0.50	1.15	3195
13	[redacted]			12.80	4.58	6630	3.94	2.79	5175	1.90	2.05	4436	0.58	1.24	3445
14				14.58	4.93	7136	4.49	3.00	5564	2.16	2.21	4782	0.66	[illegible]	[illegible]

Programmable Control Panel on a GSHP

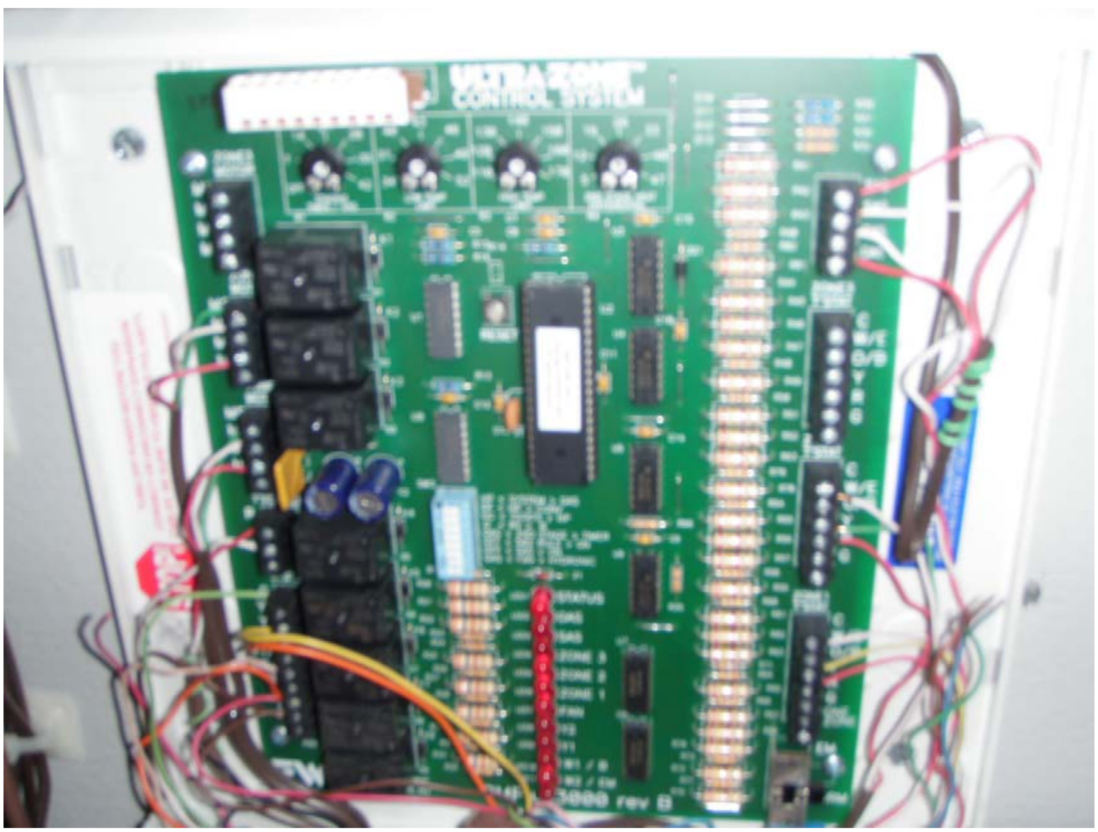
An overview for the building professional is given, but complicated low voltage controlsystems should be wired by experienced technicians. A Control Panel circuit board inside the split cabinet of a GSHP, located next to the compressor is shown first.



In addition to this circuitry, an accessible Control Panel is added usually to the air handler, and it is wired from the thermostat(s) to the GSHP circuitry above, and to the blower fan. Two simple heat control features are that (1) the GSHP activates and warms the coil before cold air blows across it when heat is demanded, and (2) the blower fan stays on after the GSHP has turned off to provide the remaining heated air to the conditioned space.

Sample information on electronic controls is available in the 16 page Technical Bulletin that comes with purchase of a system such as the BMPlus Zone Control System, or on line at http://www.ewccontrols.com/acrobat/090375a0228.pdf

It is a technical bulletin to guide the technician, made available by EWC (Excellence Without Compromise) Controls, Inc. The installed BMPlus Zone Control System is shown below. In the Technical Bulletin is a diagram of this image below with a Legend describing the purpose of each Light Emitting Diode (LED). A blinking light means power is coming to the board.



When the panel is wired, the Dip Switch Settings should be ink recorded on the form within the Bulletin to document the type of GSHP, thermostat controls, Reversing Valve signal, and timers for the two stage compressing and multiple zone controls, etc.

Advanced controls can ignore a defective thermostat or wiring problem that requests simultaneous heating and cooling, while continuing to serve legitimate zones.

Among the seven built-in delay timers in the example are:

Start-up delay timer- Fixed at 3 minutes.
Short Cycle timer - Fixed at 3 minutes.
Change over timer - Fixed at 4 minutes.
Opposing Call timer - Fixed at 5 to 20 minutes.
(Homeowner should be told that switching from heat to air conditioning should take 5 to 20 minutes, but only to occur a few times a year.)
Second Stage timer – Off, but adjustable from 7 to 42 minutes.
Supply air timer - Fixed at 3 minutes.
Purge delay timer - Fixed at 1.5 minutes.

Look for separate Lock out boards and ECM boards (Electronically Commutated Motor) to control the air handler.

Sophisticated control panels can detect incoming loop water temperature, and adjust automatically. And this programmable Smart Control Panel directly on the GSHP is a new feature, that keeps efficiency high by monitoring incoming loop water temperature, to decide if backup strip heater is necessary or not. Another feature is its interaction with photovoltaic cells on the roof, powering the GHSP when the sun shines.

Hot Water, A Water to Water GSHP and A College Lab

A desuperheater Hot Water Generator (HWG) for making domestic hot water:

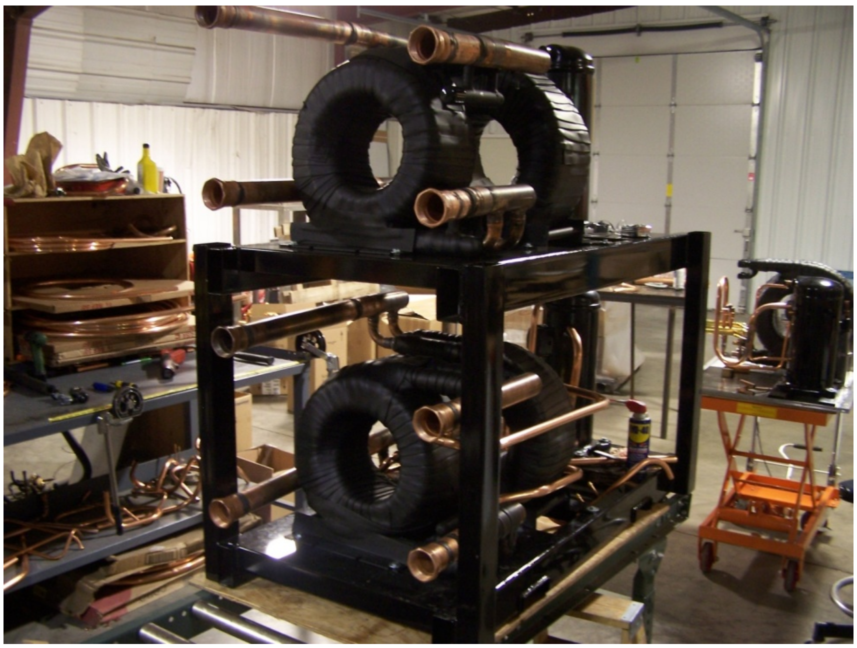
A decision must be made whether to add the HWG at the beginning or not, since it can be an add on later at little extra cost. Sometimes the desuperheater comes as a standard feature with the GSHP and can be removed to save perhaps $300-$400. Connect in line to an insulated 50 gallon or larger storage tank. Heat recovery is efficient in summer time and warm climate. But be sure it is efficient to run a large GHP in Spring and Fall just to heat water when it would not normally run. And size the pump and loop for the additional peak wintertime load during heating season. It might be prudent in a retrofit to use hot warter during the summer only. Use can be 3000 to 6000 BTU/hr. Safety lock out is 130 degrees.

Note the 30% residential tax credit with the IRS, because water to water GSHPs which were not covered now are, Grey area issues remain such as duct work cost, etc. The EPA did write to GSHP manufacturers July 29, 2009, telling them that Water to Water is now under consideration for the tax credit.
http://www.northeastgeo.com/pdf/GHP_Spec_Revision_Memo.pdf This would apply to both desuperheaters and water to water GSHPs.

Update: In December, 2009, the EPA began rating some water to water GSPs as Energy Star for the tax credit: http://contractormag.com/news/ahri-geothermal-pumps/.

A sample pump module kit installation manual is here: http://www.bardhvac.com/digcat/volume_3_cd/install_pdf_file/2100-517(B).pdf. It describes control board sequence of operation, how the heat recovery unit operates, thermistor sensors, and how to clean the coil with phosphoric acid if scaling occurs.

Assembling Large Water to Water GSHPs:



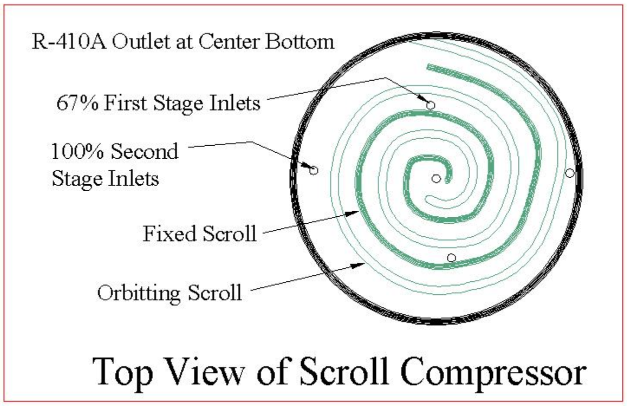
Geo Furnace Manufacturing of South Dakota builds 15 ton water to water heat pumps as shown above. These larger units can achieve 125 degree output water, and peak to 145 degrees.


Special thanks to Aaron Sorenson EIT, for these three photos above, and three earlier ones.

Another Water to Water Company, Ice Kube Systems makes a GSHP that has no reversing valve, and cruises at 120 degrees with peak of 145 degrees. But their smallest unit at 7.5 tons handles about 7500 sq. ft. This sometimes has application for heating swimming pools. Steam heat can't be converted, but radiators can if adequately sized, and radiant heating systems can be retrofit. Water to Water GSHPs not on AHRI.net can be reviewed at www.EnergyStar.gov

Recent advances do allow smaller tonnage units to be used for radiant heating, and expect more water to water GSHP applications in the future.

ClimateMaster uses this image from its Factory Floor in a marketing package. The 16 Copeland Compressors on the pallet are ready for installation in the GSHP cabinets. A diagram below on how scroll compressors operate. Simply energize the solenoid to go to Stage 2.



Copeland 1 ½ to 5 tons.

Console GSHPs that are placed within the living space, like a piece of furniture or appliance.

These are less than one ton to heat or cool one large room only. The issue of noise is a factor because the compressor is not silent, and each console requires its own dedicated Flow Controller. Look for advances by the GSHP manufactures to make these more and more suitable for installation.

> New Advances by Daikin and Mitsubishi use water source for their Variable Refrigerant Volume (VRV) technology. One GSHP with multiple R410A lines to various air handlers, can serve several zones at once. These are gaining new ground source heating and cooling applications in the Spring of 2010. Look for more advances in Soft Start technology to save on electricity at start up. An energy saver device that uses efficient soft start technology is the GeoStart that costs about $300-$400, but can reduce electric start up by 2/3.

GSHP in the College Laboratory:

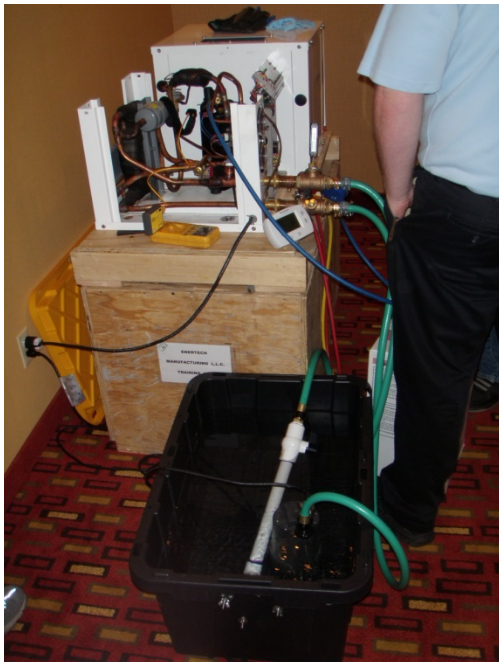
Here is how today's college students are taught. The large blue water tank at this Eastern Maine Community College HVAC lab acts like a ground loop field so that technician students can work on and learn about the white Split GSHP to the right.

Sample college web sites discussing GSHP:

Oregon Institute of Technology:
http://geoheat.oit.edu/bulletin/bull25-3/art1.pdf

Virginia Tech:
http://www.geo4va.vt.edu/A3/A3.htm

Manufacturers conduct educational seminars about their specific GSHPs, which bring a wealth of knowledge to the HVAC contractors and designers who attend. Here is an Enertech Manufacturing demonstration one ton portable GSHP, used to train technicians to work with, and to test superheating and sub-cooling of R410A.



Close up image below: Note the insulated coax on the left, the grey drier near it, the TVX (thermal expansion valve) swirl at the top, the central brass reversing valve, the black compressor and the electronic control boards on the right. The temporary blue line for testing, connects to the R-410A supply.

Conclusion

Ground Source Heat Pumps are an efficient way to harvest a natural resource from nature. The limited thermal property of the soil is not expected to provide vast benefit to the land owner, but does allow the technology of ever more efficient heat pumps to warm or cool a small residential or commercial building easily. Reducing energy usage by substantial factors is a worthy goal to pursue.

The time has ended when HVAC designers specify only the systems with which they are most familiar. Under the leadership of the engineering and building construction professions, GSHP system utilization is poised to expand dramatically. Whether for new construction or retrofit, GSHPs make good economic sense. It is not the low hanging fruit, but the fruit on the ground! GSHPs meet three important national energy policy goals: Lower dependence on foreign fossil fuels, local energy jobs and cleaner air.

Leverage the base knowledge from this course by returning to the many web site links. This will familiarize you with the details of GSHPs. Consider taking classroom style IHSHPA installer certification training, which will be easy after passing this course. Use your analytical, mechanical electrical and construction experience skills to help small building energy users take advantage of the many benefits offered by Ground Source Energy.