

# *GeoSource Heat Pump*

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## Handbook

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## *Acknowledgements*

Many people over the years have contributed to the conception, creation, implementation, growth, and education of the ground source heat pump industry. This handbook is an attempt to compile the numerous references and life experiences existing to date.

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# *1 Introduction*

What is a heat pump? A heat pump is a mechanical device used for heating and cooling which operates on the principle that heat can be pumped from a cooler temperature to a warmer temperature (cold to hot). Heat pumps can draw heat from a number of sources, eg, air, water, or earth, and are most often either air-source or water-source.

Although heat pumps have been around for more than a 100 years, the technology has dramatically increased. Not only do heat pumps still operate the common refrigerator, but today, heat pump technology allows us to heat and cool residential and commercial buildings.

Because of modern innovation, people using heat pumps are now able to save 50-70 percent on their annual heating and cooling costs.

## *History*

The heat pump industry goes back a long way beginning in 1824 when Nicholas Carnot first proposed the concept. While heat normally flows from warmer areas to cooler areas, Carnot reasoned that a mechanical device could be used to reverse that natural process and pump heat from a cooler region to a warmer region.

In the early 1850's, Lord Kelvin expanded on the heat pump concept by proposing that refrigerating equipment could be used for heating. Other scientists and engineers sought to develop a feasible heat pump for comfort heating, but none were successfully constructed until the mid-1930s when a few privately financed heat pumps were experimentally installed. These demonstration installations increased after World War II, and it was soon clear that heat pumps could be commercially feasible if completely assembled systems could be made available in quantity. The first heat pump products were available for sale in 1952.

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# *Types of Heat Pumps*

## *Air Source Heat Pump*

The air source heat pump exchanges heat between the outside air and the inside air. When the outside air temperature is between 40°F and 90°F these units are relatively efficient. However, as the temperature difference between the outside and inside air increases, the efficiency of the unit decreases. To overcome the loss of heating capacity these units require auxiliary electric heaters.

## *Water Source Heat Pump*

The water source heat pump exchanges heat between water and the inside air. The water source heat pump is commonly used in commercial buildings using a boiler and cooling tower which keeps the loop water temperature between 60°F and 90°F. As a rule water source heat pumps have a lower operating cost but higher initial cost than air source heat pumps. This difference is due to water side costs of the system rather than air side cost.

## *Ground Source Heat Pump (GeoSource)*

The GeoSource heat pump utilizes the earth as the medium from which heat is extracted. Water is pumped through a heat exchanger in the heat pump. Heat is extracted, and the water is then returned to the ground, either through discharge on a drain field or through a closed earth loop system. Because ground temperatures do not vary as dramatically as outside air temperatures, the heat available for transfer, as well as the unit's operating efficiency remains relatively constant throughout the winter. At depths of 15 feet or more below the ground, the soil maintains a year-round temperature of about 43°F -52°F in this region. So in the summer, it's cooler than the outside air, and in the winter, it's warmer--making it an ideal energy source.

Although the initial installation cost may be higher, annual operating costs are much lower than all other

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types of heating systems. The added savings carry over to summer where cooling costs can be 30%-50% less than the cost of cooling with an average central air conditioning system.

### ***Basic Operation***

The GeoSource heat pump uses water circulating through buried pipes. This water can be from a well, or merely part of a closed network of pipes that is looped horizontally or vertically in the ground. As the ground temperature water reaches the heat pump, its heat is absorbed by a low-pressure liquid refrigerant which then vaporizes. It is then compressed to about 160 degrees and moves to the air heat exchanger. Since the temperature in the house is cooler than the refrigerant, a law of physics takes over and the heat is released. Then, during the summer, the refrigerant's flow is reversed, enabling it to cool the house.



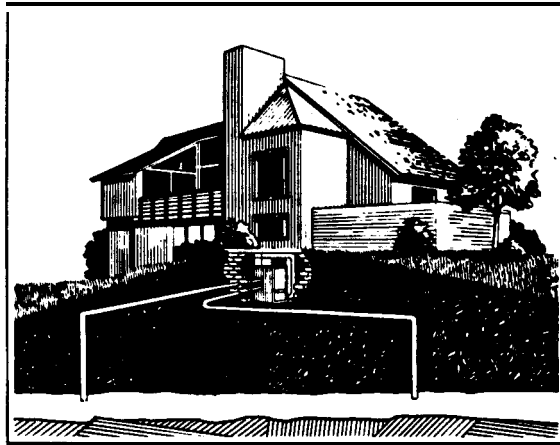
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## 2 Applications

### *Types*

#### *Open System (Well Water)*

If you have an adequate well water supply, you may want to consider a system that uses well water as its heat source. Water from a well, usually the same well that supplies your other water needs, is pumped through the indoor heat pump and then returned to the underground aquifer via an open discharge into a lake, pond or stream.



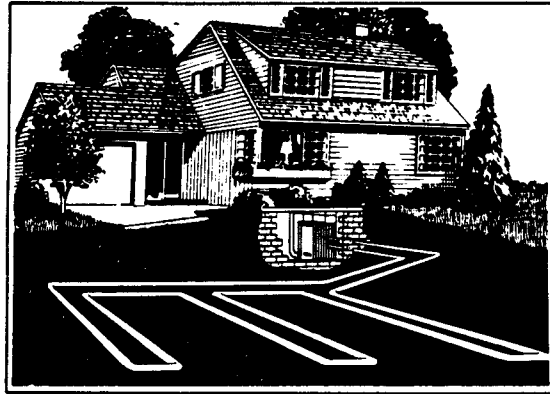
When operating, the system usually requires 1 1/2 gallons of water per minute, for each ton of heating and cooling capacity.

#### *Horizontal Earth Coil System*

Instead of extracting water from the ground and returning it to the ground, this system circulates water through a closed series of horizontal loops. These loops consist of high density polyethylene buried 5 to 6 feet deep or deeper, which allows direct contact with moist soil.

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Approximately 500-600 feet of underground pipe is needed for each ton of heating and cooling capacity required.



The horizontal loop system uses a fixed volume of water. Once the loop has been filled, no additional water is required.

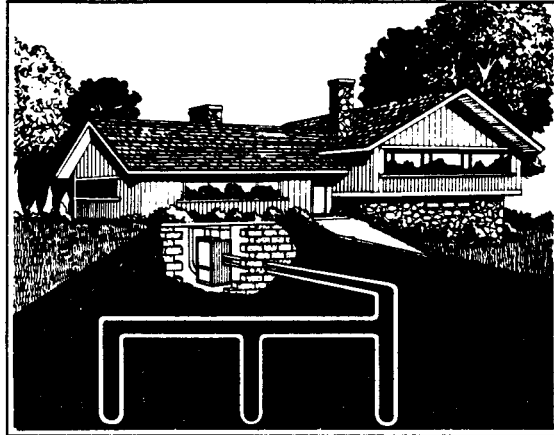
During the winter, water in the loop line absorbs heat from the surrounding earth and transfers it into your home. In the summer, heat from your home is collected by the heat pump, transferred to the water, and pumped through the buried coil, where the heat is absorbed by the cooler soil.

### *Slinky*

A deviation of the straight pipe horizontal earth coil. Slinky pipe is straight pipe laid "coiled" in a trench. A slinky earth coil requires approximately 600-1000 feet of underground pipe per ton but requires substantially less land area.

### *Vertical Earth Coil System*

In the vertical system, a fixed volume of water circulates through a closed loop of pipe buried vertically, usually to a depth of 150-185 feet. Each ton of heating and cooling capacity requires about 340-400 feet of underground piping.



With both the vertical and horizontal systems, the water contains an antifreeze solution. This is to eliminate any possibility of freezing during periods of peak use when cooler return water circulates through the pipes and lowers the temperature of the surrounding soil. Like the horizontal system, the vertical coil is a closed pipe configuration that is filled only once.

## *Configurations*

### *Forced Air*

Forced air systems use a blower to move and circulate air to its proper destination points. The air circulated travels through a series of ducts to heat and cool a structure.

The forced air distribution system is the most commonly used system installed today. There are advantages in using this system. First, an even amount of air flows throughout the ductwork continuously. Secondly, filters can be used to remove 80-90% of the pollutants existing in the air. Lastly, air conditioning would not be possible without a forced air type of system.

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Many configurations of a forced air system are available. For example, a vertical (up flow) type of system is used to replace the conventional furnace in a home. However, where space is limited, a horizontal (counter flow) configuration would be ideal for an overhead installation in a commercial building or crawl space at home.

### ***Hydronic***

Hydronic or hot water heating systems provide a smooth, even heat but no air conditioning. Residential hydronic heating systems are most often found in the northeastern United States and Canada.

Conventional, boiler-fired hydronic systems are usually designed for 160°F water leaving the boiler and a 20°F temperature drop in the water loop. It is common for the piping and circulator pump to be sized for 10 gpm at 6 feet of head pressure. The standard 3/4-inch fin tube baseboard convectors have an average output of 230 Btuh/foot at 120°F entering water temperature.

There are several differences with a GeoSource hydronic heating system. First and foremost, the leaving water temperature is about 120°F instead of 160°F. Second, due to the friction loss in the heat exchanger, the circulation pump must produce at least 18 feet of head pressure. Due to the lower water temperature of a GeoSource system, it often requires 200 linear feet of baseboard coverage or full perimeter baseboard convertors. Cast iron radiators will transfer 70 Btuh/square inch at 130°F entering water. Cast iron radiators are excellent for ground water systems because of their transfer capacity at lower temperatures.

Polybutylene pipe buried in a concrete slab is also an excellent application for the lower temperature of GeoSource hydronic heating.

### ***Domestic Hot Water Heating (Desuperheater)***

Domestic hot water heating using a heat pump can significantly decrease energy costs during both heating and cooling seasons. A desuperheater is a heat exchanger that removes the high-grade (high-temperature) superheat

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available in the refrigerant gases exiting the heat pump compressor. Depending on the heat pump design and operating conditions, superheat temperatures of 200F and greater may be reached. By removing the superheat, desuperheaters can provide a source of hot water typically at a temperature of 160F. For many years, desuperheating systems (commonly known as “heat reclaimers”) have been successfully retrofitted on central air conditioning systems. Industry members reported some 50,000 units installed during 1985 on central air conditioning. During cooling, heat pumps operating to provide air conditioning generate unused heat. This heat can be reclaimed and can therefore be considered a “free” source of energy for generating domestic hot water. During the heating mode, the functions of the condenser and evaporator are reversed by a four-way reversing valve. This requires the desuperheater heat exchanger to be installed between the compressor and the reversing valve. Heating of hot water is not “free” but is provided at a reduced cost based on the heating COP of the heat pump.

On GeoSource heat pumps, desuperheaters may provide most of the domestic hot water required for a typical residence. During summer cooling cycles entering water temperatures are higher, resulting in higher desuperheater temperature. In winter, domestic hot water production will be reduced because of the lower entering water temperatures from both the domestic water supply system and the ground heat exchanger.

### ***Domestic Hot Water Options***

In addition to space heating and cooling, GeoSource heat pumps are available with three specific domestic hot water options:

1. NONE: No hot water preheating capability.
2. SUPPLEMENTAL: Partial preheating (desuperheater) during heat pump operation in the heating or cooling cycle.
3. DEMAND: Year-round total (full condensing water heating) hot water heating on a first priority basis.

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Option 1 - A conventional GeoSource heat pump without provision for domestic hot water preheating. This configuration represents the lowest cost GeoSource heat pump. It is used in buildings with more than one heat pump and where there is no requirement for domestic hot water.

Option 2 - Uses a refrigerant-to-water heat exchanger (desuperheater) installed at the discharge of the heat pump compressor. The hot gas at this point is in a "superheated" condition giving rise to the common name desuperheater. "Free hot water" is available during the cooling season. In the winter, the desuperheater generating domestic hot water competes with the heating load. Since there is generally excess heat pump capacity for many winter hours, domestic hot water efficiency equals heat pump efficiency. If the hot water demand has been met, the circulating pump is shut off.

Option 3 - Total or 100% domestic hot water on a first priority basis simply means that, before any space heating or cooling is accomplished, all domestic hot water requirements are met by the heat pump system. These units have a completely different design. Heat pumps with this feature will have the longest-run cycles. This usually improves heat pump performance and generally reduces the total annual demand and energy cost.

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## *3 Economics*

### *Benefits*

#### *Benefits to Homeowner*

The GeoSource Heat Pump system reduces demand and lowers energy consumption. For the consumer this means lower utility bills. In cases where utilities are providing low-interest loans or incentive programs, the consumer often sees an immediate positive cash flow. In many applications, the ground temperature during mid-winter can be 40 degrees warmer than the coldest air temperature. This significantly increases both the capacity and efficiency of the heat pump system. Depending on geographic location, GeoSource heat pump systems have reduced heating costs 75 % more than electric furnaces and about 50 % more than air-source units. In extreme northern climates, the advantage over air-source heat pumps for heating has been even greater. Also, reduced improvements in cooling costs have been around 25 % over high efficiency conventional air conditioners.

An additional advantage of the system is reduced maintenance. The unit is indoors, which gives the electrical components a greater life expectancy. There are fewer components. For example, the defrost cycle required in an air-source system has been eliminated. Finally, the compressor operates under less severe conditions than air-source heat pumps which have a proven life expectancy that approaches 20 years. Water requirements of the closed-loop system consist simply of a single filling of the ground heat exchanger system. For a residence, this is approximately 50 to 100 gallons. For an open system, where water is discharged to a pond or drainage ditch, a typical heat pump system in the Midwest using six gallons per minute would use under one million gallons each year for both heating and cooling.

In locations with limited underground water the closed-loop system may be the only choice.

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### ***Benefits to HVAC Contractor***

The contractor benefits from having available to him a total electric system that:

1. Competes in areas with low-cost fossil fuels for those consumers who desire electric heating.
2. Is a higher priced system with excellent paybacks, thus allowing higher profit margins when compared to conventional equipment.
3. Is simple in operation with an expected lifetime exceeding that of conventional gas and electric systems.

All contractors and businessmen who have excellent products with demonstrated desirable performance will benefit from having newly developed products for sale.

### ***Benefits to Utility***

For the electric utility, this system will provide sufficient improvements in efficiency that other fuel users can be convinced to use electric heating and cooling systems. In many cases this can be done without increasing the utility's service size. Gas customers with electric air conditioning can generally be provided heating without an increase in electric service size. Domestic hot water preheating occurs only during heat pump usage and leaves the demand valleys open for conventional hot water heating. Properly marketed, this system should increase kilowatt-hour sales by attracting other fuel users.

### ***Environment***

Environmentally speaking, nature's best friend has to be the GeoSource heat pump. GeoSource Heat Pumps merely move the earth's natural energy from one point and transfer it to another. On the other hand, fossil burning systems strip our land of scarce resources and later emit burned off pollutants into the earth's atmosphere.

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### ***Additional Benefits from Demand Hot Water GeoSource Heat Pumps***

This heat pump has the capacity for space heating, space cooling, and producing 100% of the domestic hot water on demand. This allows the unit to produce domestic hot water with the unit's full capacity at any time.

Three modes of operation are integrated in the design:

1. Space heating.
2. Space cooling.
3. Dedicated hot water heating on demand.

The demand reduction potential is excellent. During summer peak demand periods, 100% of the domestic hot water is generated by the heat pump system as waste heat. This eliminates the water heating load during the summer peak demand period.

### ***C o s t s***

GeoSource heat pumps offer numerous advantages over alternative space heating and cooling systems, including a clean, safe and highly efficient means of providing space heating and cooling utilizing a single machine. However, the greatest factor influencing the purchase decision of most customers is economics. Three major cost factors are considered when comparing heat pump economics with other alternatives: initial cost, operating cost and maintenance cost. Methods used to estimate these costs for various heat pumps follow.

#### ***Initial Cost***

Initial cost includes all expenditures relating to the purchase and installation of a heat pump. These may include:

Equipment: heat pump, wiring, pad, ductwork, flowmeter, earth loop piping, thermostat, etc.

Labor: installing, well drilling, trench digging, etc.

Local fees: taxes, permit fees, etc.

Many utilities offer rebates for the installation of GeoSource heat pumps. These, too, should be considered in the determination of initial cost.

***Initial Cost Considerations For Well Water Systems***

Well water systems require the use of a water supply well. Estimates for supply well drilling can be obtained from a local contractor. Usually the price includes drilling, installed casing, bottom screen, gravel grouting and cement grouting for the top 10 feet. A price quote will usually not include the cost of water system components such as pressure tanks and pumps but cost estimates for these items are provided in Table 3.1. Most drilling estimates range from \$8-12 per foot of depth, meaning that a 100-foot well would probably cost between \$800-1200.

Table 3.1

Water Well  
Pump and  
Pressure  
Tank  
Installed  
Cost

Pump Size	2-Wire Motor	3-Wire Motor	Control Box (3-Wire)	Pressure Tank Nominal Capacity (Gal.)	Unit Cost
1/3 hp	\$350-400	\$300-350	\$50-75	32	\$200-250
1/2 hp	\$375-425	\$325-375	\$50-75	44	\$225-275
3/4 hp	\$450-500	\$400-450	\$60-80	62	\$350-400
1 hP	\$525-575	\$485-525	\$60-80	86	\$350-400

**Initial Cost Considerations For Earth Loop Systems**

Initial cost includes the cost of the earth loop pipes and trenching cost (for horizontal loops) or bore hole cost (for vertical loops). An earth loop heat pump also requires a circulating pump. Circulating pumps keep the water in the system moving through the earth loop and the heat pump. Tables 3.2 and 3.3 provide estimates for some of the installed costs associated with earth loop heat pump systems.

Table 3.2  
Estimated Cost For Horizontal Earth Loop

Trenching Machine		Width	Pipes Per Trench		Cost per lineal ft of trench	
					W/loop Materials and Installation	W/O loop Materials and Installation
Trencher	6-8 in.	1	5 ft	\$1.66-1.76	\$0.82-0.92	
Trencher	6-8 in.	2	4&6 ft	\$3.07-3.17	\$1.18-1.28	
Backhoe	24 in.	1	5 ft	\$2.07-2.22	\$1.23-1.38	
Backhoe	24 in.	2	5 ft	\$3.41-3.80	\$1.52-1.92	

Table 3.3  
Estimated Cost For Vertical Earth Loop

Borehole Diameter	Cost per lineal foot of Borehole
4-6 in	
With Loop Materials and Installation	\$5.65 - 6.90
Without Loop Materials and Installation	\$4.50 - 5.80

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Although the earth loop costs increase overall system cost beyond a conventional heating and air conditioning system the cost of the earth loop can be compared to the consumer purchasing his or her own oil well and supplying energy for the life of their home or business.

### ***Operating Cost***

The operating cost of any HVAC system represents the most significant expenditure over the life of the equipment, often doubling or tripling the initial cost. Operating cost depends on two factors: (1) energy use of the system and (2) the price of the energy used. The owner has much more control over the first factor than the second. If an efficient system such as a GeoSource heat pump is chosen, energy use will always be low. GeoSource heat pump operating costs are not affected by fluctuating energy rates as less efficient systems are.

### ***Estimating Energy Use***

The amount of energy required to heat or cool a home for an entire year is influenced by a variety of factors, including climate, building design, characteristics of the heating and cooling equipment, how the system is operated, and the control system. The most accurate methods are those which allow evaluation of building design, occupant use patterns, heating and cooling characteristics and local weather data on an hour-by-hour basis. Various utilities and equipment manufacturers have developed computer programs which aid analysis of these factors. Simpler estimation methods are available, including the heating and cooling degree day method.

### **Heating Degree Day Method**

The heating degree day method is commonly used to estimate the heating energy consumption of electric resistance heating equipment, fossil fuel-fired furnaces and heat pumps. The heating degree day estimating method is based on two main assumptions:

1. For outdoor temperatures of 65°F and above, on a long term average a home's solar and internal gains will offset heat losses.

2. For outdoor temperatures below 65°F, fuel consumption will be proportional to the difference between the mean daily temperature and 65°F. For example, if the mean temperature is 35°F (65°F-35°F = 30°F difference), twice as much fuel is consumed as on days when the mean temperature is 50°F (65°F-50°F = 15°F difference).

When using the heating degree day method to estimate energy use in a particular home, Table 3.4 provides useful degree day information about various areas of the United States. It lists the long term average annual heating and cooling degree days for different cities.

Table 3.4  
Yearly Average Degree Day Values For U.S. Cities

City, State	Heating Degree Days	Cooling Degree Days	City, State	Heating Degree Days	Cooling Degree Days
Bismark, ND	8960	528	New York, NY	5219	1027
Boston, MA	5634	674	Omaha, NE	6290	1007
Cheyenne, WY	7381	308	Philadelphia, PA	5144	1081
Chicago, IL	6639	713	Pittsburgh, PA	5897	732
Cleveland, OH	6351	670	Portland, ME	7511	292
Detroit, MI	6293	687	Portland, OR	4635	248
Fargo, ND	9250	605	Salt Lake City, UT	6052	958
Great Falls, MT	7750	343	Sioux Falls, SD	9250	605
Indianapolis, IN	5699	902	Seattle-Takoma, WA	5145	134
Madison, WI	7720	424			
Minneapolis, MN	8250	894			

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## Cooling Degree Day Method

The cooling degree day estimation method predicts the cooling energy consumption of conventional air conditioners and heat pumps. It is very similar to the heating degree day method. The cooling degree day value for a given day is calculated by subtracting 65°F from the average temperature of the day. The cooling degree day method is based on the following assumptions:

1. Cooling is not needed when the temperature is 65°F or below
2. Changes in outdoor humidity do not affect energy consumption (since this assumption is not always true, there is a large error factor in cooling degree day calculations)
3. Solar and internal loads remain at constant values (this assumption is not always true, either)

### *Calculating Heating Energy Usage*

The accepted degree day method equation for calculating annual probable energy consumption of any heating system is:

$$E = \frac{Hl \times D \times 24}{Td \times V \times C.O.P.} \times Cd$$

where:

E = energy consumption for the estimate period

Hl = design heat loss, including infiltration and ventilation, in Btuh

D = number of heating degree days for the period

24 = 24 hours per day

Td = temperature difference between maintained indoor temperature and outdoor design temperature, in degrees F

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C.O.P. = The efficiency value of the rated equipment  
(table 3.5)

V = heating value of fuel in units consistent with  
those used for HI and E

Cd = correction factor to account for the influence of  
internal loads, building mass, insulation level  
and base temperature

In addition to the energy consumption predicted by the  
above equation, the energy required to operate a fossil fuel  
heating system's fans and pumps should be estimated.

### *Calculating Cooling Energy Usage*

Average annual cooling degree day values for major  
U.S. cities provided in Table 3.4.

The degree day method for estimating cooling energy  
consumption uses the following formula:

$$E = \frac{Hg \times D \times 24}{Td \times 1000 \times SEER}$$

where:

E = cooling energy consumption, kWh

Hg = design heat gain (cooling load), Btu/h

D = cooling degree days for period

24 = 24 hours per day

Td = temperature difference between maintained  
indoor temperature and outdoor design  
temperature, degrees F

1000 = conversion factor, Wh/kWh

SEER = seasonal energy efficiency ratio, Btu/Wh

Table 3.5  
Coefficients of Performances ( C.O.P.s ) of  
Various Heating Systems

Heating System	C.O.P.
Conventional Gas-Fired Forced-Air Furnace or Boiler	0.60 to 0.70
Conventional Gas-Fired Gravity-Air Furnace	0.57 to 0.67
Gas-Fired Forced-Air Furnace or Boiler with Typical Energy Conservation Devices, Intermittent Ignition Device, Automatic Vent Damper	0.65 to 0.75
Gas-Fired Forced-Air or Boiler with Sealed Combustion Chamber, Intermittent Ignition Device and Automatic Vent Damper	0.70 to 0.78
Gas-Fired Condensing Furnace or Boiler	0.80 to 0.90
Oil-Fired Furnace or Boiler	0.50 to 0.75
GeoSource Heat Pump Well Water System	3.5 to 4.4
GeoSource Heat Pump Earth Loop System	3.2 to 4.3

Table 3.6  
Heating Values  
( V )

Fuel	Unit	Heating Value Of Fuel
Natural Gas	Btu/cu. ft	1,000
Propane	Btu/gallon	91,500
No. 2 Fuel Oil	Btu/gallon	138,000
Electricity	Btu/Watt	3,413

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### *Maintenance Cost*

Maintenance cost is the third major component of a heating or cooling system's total cost. Maintenance includes routine preventive measures as well as any repairs or troubleshooting that may be required. The cost of maintenance includes both labor and materials. Estimated costs for a number of different heating/cooling systems are summarized in Table 3.7. and can vary based on region, weather conditions, availability of qualified servicemen and other factors.

Table 3.7  
Estimated Maintenance Costs  
( 1991 Dollars )

Item	Estimated Cost Per Year
Gas Furnace or Boiler and Air Conditioner	\$40 - \$120
Oil Furnace or Boiler and Air Conditioner	\$70 - \$155
Electric Furnace and Air Conditioner	\$25 - \$100
Electric Resistance	None
Air Source Heat Pump	\$85 - \$160
GeoSource Heat Pump	\$45 - \$115



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## *4 Load Estimating*

A heating or cooling load is defined as the maximum rate at which a building loses heat in winter and gains heat in summer. The size of the load determines the size or capacity of the heat pump chosen. If the cooling or heating load is not estimated correctly, a heat pump may be installed which has either too little or too much capacity. A system with too little capacity will not be able to condition the air of the home to the desired temperature on peak heating or cooling days. Conversely, an oversized heat pump will cycle on and off frequently, causing high humidity in the summer and increased operating costs year round.

A number of techniques have been developed for estimating a building's heating or cooling load which vary in sophistication and accuracy. Two publications that provide detailed methods for calculating loads are the "Cooling and Heating Load Calculation Manual", published by the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE publication number GRP 158), and "Load Calculation for Residential Winter and Summer Air Conditioning, Manual J, 1986", published by the Air Conditioning Contractors of America (ACCA).

### *Heat Transfer*

Buildings gain heat in summer and lose it in winter in three ways: conduction, convection and radiation. Conduction is heat transfer through solid objects, such as metal. Buildings lose or gain heat when it is conducted through windows and doors, as well as walls, floors and ceilings. Convection is heat transfer through air circulation. Buildings lose and gain heat by convection when air filters through cracks, open doors and loose windows. Radiation is given off by all warm objects. It is not absorbed by the medium (air) through which it travels, but instead is absorbed by solid objects (such as walls, furniture, etc.) that are in its path.

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## *Flow of Heat*

Heat always flows from a warmer to a colder object or substance. Heat flow can be slowed by certain insulators, but it cannot be stopped. The flow of heat through a building's envelope--windows, doors, walls, floors and roof--depends on three factors: the area involved, the indoor/outdoor temperature difference and the material properties of the envelope element.

Heat transfer through a building element is proportional to the area of the element. For example, a 20 foot square window conducts half as much heat as a 40 foot square window. The difference between the indoor and outdoor temperatures also affects heat transfer proportionately. For example, if the indoor temperature is 75°F and the outdoor temperature is 35°F (40°F difference), twice as much heat is conducted as when the outdoor temperature is 55°F (20°F difference).

The material properties of the building envelope can be stated in terms of the following factors: conductivity, conductance, resistance and overall coefficient of heat transfer.

**\*Conductivity** is the ability of a material to conduct heat. Good conductors include all metals. Poor conductors are called insulators, and they include materials such as wood, Styrofoam, fiberglass and felt. **Thermal conductivities** defined as the amount of heat (Btu's) that passed through a homogenous material one inch thick and one foot square in area, in an hour's time, with a temperature difference of 1F between the outer and inner surfaces. The symbol for thermal conductivity is "K," and it is expressed in Btu/h-F-in-sq. ft. The higher a material's K value, the better a conductor it is.

**\*Conductance** relates conductivity to the thickness of a material. It is defined as a measure of the rate of heat flow for the thickness of a material or an air space (either more or less than one inch), one foot square in area, at a temperature difference of 1F.  $C = K/X$  The lower the conductance, the higher the insulating value.

**\*Resistance** is a measure of a material's ability to slow

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heat transfer. **Thermal resistance** is symbolized by “R” and is computed by taking the numerical reciprocal of the conductance(C). Resistance is expressed in sq.ft-F-j/Btu. A material with a high R value is a good insulator.

**\*The overall coefficient of heat transfer (“U”)** is a summation of the resistance of all the materials in a building element. It is expressed in Btu/h per sq.ft. of area per degree F temperature difference and is computed by taking the reciprocal of total resistance:  $U = 1/R$

As an example of U value calculation, consider a two foot by four foot stud wall with brick veneer (Figure 4-1), which has a combined resistance of 12.89 sq.ft.-F-h/Btu. In calculating the overall coefficient of heat transfer, the effect of convection at the inside and outside surfaces should also be included (see Table 4-1). The total effective resistance is:

Outside air film resistance: 0.25

Wall resistance: 12.89

Inside air film resistance: 0.68

Net effective resistance: 13.82(sq.ft.-h/Btu)

Therefore,  $U = 1/13.82 = 0.072$  Btu/h-sq.ft.-F

Figure 4.1  
Wall Section

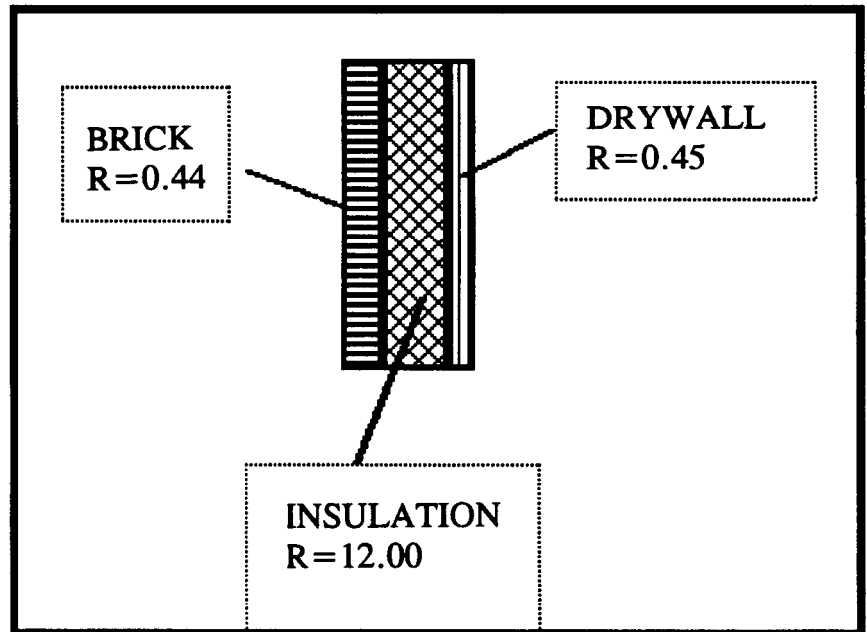


Table 4.1  
 Wall Air Film Resistance  
 (Sq.Ft.-F-h/Btu )

	SUMMER 7.5 mph wind	WINTER 15 mph wind
Outside Surface	0.25	0.17
Inside Surface	0.68	0.68

### *Design Conditions*

Design conditions are the indoor and outdoor temperatures that a heat pump system is designed to handle. Indoor design conditions are based on the desired comfort of the conditioned space. Recommended indoor design temperatures are 70F for heating and 75F for cooling (see table 4.2). Also for cooling, the design relative humidity should be about 50 percent.

Table 4.2  
 Indoor Design  
 Temperatures

Structure	Winter ( F )	Summer ( F )
Residences	70	75
Offices	70	72
Churches	68	73
Schools	70	72
Retail Stores	68	72
Warehouses	65	78

Outdoor design conditions for a system are based on the climate of the particular area. Detailed information about local temperature conditions can be obtained from (table 4.3).

The temperature values in these columns indicate that the average outside temperature will be below the value in the table 97.5 percent of the time (for cooling) or above the value in the table 97.5 percent of the time (for heating) during the cooling or heating season.

Table 4.3  
Outdoor Design Temperatures  
and Moisture Conditions

Location	Winter		Summer			
	97.1/2% Design Db	Htg DD Below 65° F	2.1/2% Design Db	Coincident Design Wb	Grains Diff 55%RH	Grains Diff 50%RH
<b>IOWA</b>						
Ames	-6	-	90	74	30	37
Burlington	3	6120	91	75	35	43
Cedar Rapids	-5	6600	88	75	38	45
Clinton	-3	-	90	75	36	33
Council Bluffs	-3	6610	91	75	35	42
Des Moines	-5	6610	91	74	29	36
Debuque	-7	7380	88	73	28	35
Fort Dodge	-7	7070	88	74	33	40
Iowa City	-6	6404	89	76	44	51
Keokuk	0	6404	92	75	33	40
Marshalltown	-7	6850	90	75	36	43
Mason City	-11	7790	88	74	33	40
Newton	-5	-	91	74	29	36
Ottumwa	-4	-	91	74	29	36
Sioux City	-7	6960	92	74	27	34
Waterloo	-10	7370	89	75	38	45
<b>Minnesota</b>						
Albert Lea	-12	--	87	72	23	30
Alexandria	-16	--	88	72	22	29
Bemidji	-26	10203	85	69	09	16
Brainard	-16	--	87	71	18	25
Duluth	-16	9890	82	68	10	17
Fairbault	-12	--	88	72	22	27
Fergus Falls	-17	--	88	72	22	27
International Falls	-25	10600	83	68	08	15
Mankato	-12	8310	88	72	22	29
Mpls/St.Paul	-12	8250	89	73	26	33
Rochester	-12	8295	87	72	23	30
St.Cloud	-11	8890	88	72	22	29
Virginia	-21	--	83	68	08	15
Wilmar	-11	--	88	72	22	29
Winona	-10	--	88	73	28	35

Table 4.3 Continued

Location	Winter		Summer			
	87-1/2% Design Db	Htg DD Below 65 F	2-1/2% Design Db	Coincident Design Wb	Grains Diff 55%RH	Grains Diff 50%RH
<b>Montana</b>						
Billings	-10	7150	91	64	00	00
Butte	-17	9730	83	56	00	00
Helena	-16	8190	88	60	00	00
Lewiston	-16	8586	87	61	00	00
<b>North Dakota</b>						
Bismark	-19	8960	91	68	00	02
Fargo	-18	9250	89	71	15	22
Grand Forks	-22	9930	87	70	12	19
Jamestown	-18	-	90	69	02	09
Minot	-20	9610	89	67	00	00
<b>South Dakota</b>						
Aberdeen	-15	8620	91	72	17	24
Brookings	-13	-	92	72	15	22
Pierre	-10	7550	95	71	04	11
Rapid City	-07	7370	92	65	00	00
Souix Falls	-11	7840	91	72	17	24
Watertown	-15	8390	91	72	17	24
<b>Wisconsin</b>						
Ashland	-16	-	82	68	10	17
Eau Claire	-11	7970	89	73	26	33
Green Bay	-09	8100	85	72	26	33
LaCrosse	-09	7530	88	73	28	35
Madison	-07	7720	88	73	28	35
Millwaukee	-04	7470	87	73	29	36
Wausau	-12	8490	88	72	22	29

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## *HEAT LOSS*

Heat loss from a home during the heating season results primarily from three factors: conduction heat loss, outdoor air infiltration and duct heat loss. Heat losses are calculated for each conditioned room of the house. Simplified procedures and forms such as those found in “ACCA Manual J” can be used for this purpose.

### *Conduction Heat Loss*

Heat is lost by conduction through a home’s walls, roofs, doors, and floors above unconditioned spaces. The rate of conduction heat loss depends upon two factors: the indoor/outdoor temperature difference and the thermal resistance of the building’s envelope. The greater the difference between the indoor and outdoor temperatures, the greater the rate of heat loss. Thermal resistance affects heat loss as well; the more resistance the building material has, the slower the rate of heat loss. The building’s overall resistance to heat flow is measured in terms of the U value. Conduction heat loss can be represented by the following equation.

$$Q = U \times A \times T$$

where

U = overall coefficient of heat transmission

A = area of the building material

T = indoor/outdoor temperature difference,  
degree F

When calculating a building’s design conduction heat loss, T is the building’s design temperature difference, which is the temperature difference between the indoor and outdoor design conditions.

For example, if a 10 foot by 20 foot wall had a U value of 0.09 and the design temperatures were 70F and 0F, the design rate of conduction heat loss through the wall would be calculated as follows:

$$\begin{aligned} Q &= U \times A \times T \\ &= 0.09 \text{ Btu/h-sq.ft.} \cdot \text{F}(10 \text{ ft.} \times 20 \text{ ft.})(70\text{F}-0\text{F}) \\ &= 1,260 \text{ Btu/h} \end{aligned}$$

---

## *Outdoor Air Infiltration*

Air that enters a home from the outside must be heated to keep the inside space at the desired temperature. The first step in calculating infiltration is to estimate the number of heating season air changes for the entire house (Table 4.4). Once the air changes are known, infiltration in cubic feet per minute can be calculated as follows:

$$\text{CFM} = V \times \text{AC} / 60 \text{ where}$$

$V$  = volume of space, cu.ft.  
 $\text{AC}$  = air changes per hour  
 $60$  = conversion factor, hours/minutes

The following equation is then used to calculate heat loss due to infiltration:

$$Q = 1.1 \times \text{CFM} \times T$$

where 1.1 = a constant  
CFM = infiltration of outdoor air, cu.ft./min.  
T = indoor/outdoor temperature difference

As an example, consider a 1,800 sq.ft. house with a volume of 14,400 cu.ft. the house is of average construction with one average fireplace. Air changes per hour can be determined from Table 4.4 as 0.8 for the envelope plus 0.2 for one fireplace for a total of 1.0 air changes per hour. Infiltration air quantity is:

$$\text{CFM} = (14,400 \text{ cu.ft.} \times 1.0) / 60 = 300 \text{ cu.ft./min.}$$

Heat loss due to infiltration is determined as:

$$Q = 1.1 \times 300 \times (70-0) \\ = 23,100 \text{ Btu/h}$$

Table 4.4  
Heating Season  
Air Changes  
(per hour)

FLOOR AREA	900 OR LESS	900-1500	1500-2100	OVER 2100	FIRE-PLACE ADD
BEST	0.4	0.4	0.3	0.3	0.1
GOOD	0.8	0.7	0.6	0.5	----
AVERAGE	1.2	1.0	0.8	0.7	0.2
FAIR	1.7	1.3	1.0	0.8	----
POOR	2.2	1.6	1.2	1.0	0.6

### *Duct Heat Loss*

Heat losses also occur through ducts located in unconditioned spaces. These losses depend on duct size, shape, construction and length, as well as on insulation, velocity and temperature difference across the duct wall. Table 4-5 can be used to estimate heat loss through ducts located in unconditioned spaces.

As an example, assume that the room being served by the duct has a heat loss of 5,000 Btu/h and the duct is located in an attic with R4 insulation. The winter design temperature is 6°F. The loss through the duct work is calculated as follows:

$$\begin{aligned} \text{Duct loss} &= 0.15 \text{ (Table 4.5)} \\ &\quad \times 5,000 \text{ Btu/h} \\ &= 750 \text{ Btu/h} \end{aligned}$$

Table 4.5  
 Duct Heat Loss  
 Multipliers

LOCATION	DUCT LOSS MULTIPLIERS
Duct Location and Insulation Value	
Exposed To Outdoor Ambient:	
Attic, Garage, Exterior Wall, Open Crawl Space-None	.30
Attic, Garage, Exterior Wall, Open Crawl Space-R2	.20
Attic, Garage, Exterior Wall, Open Crawl Space-R4	.15
Attic, Garage, Exterior Wall, Open Crawl Space-R6	.10
Enclosed in Unheated Space:	
Vented Or Unvented Crawl Space or Basement-None	.20
Vented or Unvented Crawl Space Or Basement-R2	.15
Vented or Unvented Crawl Space or Basement-R4	.10
Vented or Unvented Crawl Space or Basement-R6	.05
Duct Burled In or Under Concrete Slab:	
No Edge Insulation	.25
Edge Insulation R Value = 3 to 4	.15
Edge Insulation R Value = 5 to 7	.10
Edge Insulation R Value = 7 to 9	.05

---

The cooling load is made up of two-kinds of heat gains: sensible heat and latent heat. **Sensible heat** is the heat that can be sensed by the dry bulb thermometer. **Latent heat** cannot be sensed by a dry bulb thermometer, but it can be felt by people as moisture (humidity). An electric heat pump in the cooling mode addresses both types of heat, by removing both sensible heat and latent heat from the conditioned space.

While total cooling load is a measure of heat gain, it is not equal to the total heat gain. Heat gain can come from a variety of sources, including conduction, the sun, people, electric motors, lighting, appliances, infiltration, ventilation and ducts. However, these sources of heat gain are never at their maximum points simultaneously. It is difficult therefore, when making a load calculation, to choose the month and time of day when the load components combine to produce the design or maximum cooling load.

Following are discussions of the various sources of heat gain and how to calculate heat gain for each.

### *Conduction Heat Gain*

Conduction heat gain functions on the same principle as conduction heat loss, with only two differences. One is that in the case of conduction heat gain, the outside air is warmer than the inside air, so heat is conducted into the home rather than out of it. The other difference relates to the fact that when the sun strikes the walls, roof and windows, heat is radiated directly into the home. A solar heat gain factor must also be taken into consideration for conduction heat gain which is not included in the heat loss calculation.

Solar heat gain for a particular home depends on many factors, including size of the home, east-west orientation, time of day and time lag for heat to travel from the outer to the inner wall. In general, homes have the greatest solar gains on their east and west sides, and the amount of heat gain is influenced by the angle at which the rays strike the surface and the color of the surface. Because of the earth's rotation, the angle at which light hits a building's surface is constantly changing. The angle is also dependent on latitude and time of day and year.

Sun that strikes a building at a 90 degree angle is more likely to be absorbed than if it strikes at another angle. Whatever solar heat is absorbed and not reflected increases the surface temperature of the roof, window or wall. Colors also affect the solar heat gain. Lighter colors reflect more light than darker colors, which absorb it more and cause the surface temperature to increase.

Table 4.6  
Equivalent Cooling Load  
Temperature Difference

Design Temp. Diff. Deg. F	10		15			20			25		30		35	
	L	M	L	M	H	L	M	H	M	H	H	M	M	
<b>Daily Temp. Range</b>														
<b>WALLS AND DOORS</b>														
1. Frame & veneer-on-frame	17.6	13.6	22.6	18.6	13.6	27.6	23.6	18.6	28.6	23.6	28.6	33.6		
2. Masonry walls, 6-h. block or brick	10.3	6.3	15.3	11.3	6.3	20.3	16.3	11.3	21.3	16.3	21.3	26.3		
3. Partitions, frame masonry	9.0	5.0	14.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0		
4. Wood doors	17.6	13.6	22.6	18.6	13.6	27.6	23.6	18.6	28.6	23.6	28.6	33.6		
<b>CEILINGS AND ROOFS</b>														
1. Ceilings under naturally vented attic or vented flat roof - dark	38.0	34.0	43.0	39.0	34.0	48.0	44.0	39.0	49.0	44.0	49.0	54.0		
- light	30.0	26.0	35.0	31.0	26.0	40.0	36.0	31.0	41.0	36.0	41.0	46.0		
2. Built-up roof, no ceiling - dark	38.0	34.0	43.0	39.0	34.0	48.0	44.0	39.0	49.0	44.0	49.0	54.0		
- light	30.0	26.0	35.0	31.0	26.0	40.0	36.0	31.0	41.0	36.0	41.0	46.0		
3. Ceilings under unconditioned rooms	9.0	5.0	14.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0		
<b>FLOORS</b>														
1. Over unconditioned rooms	9	5.0	14.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0		
2. Over basement, enclosed crawl space or concrete slab on the ground	0	0	0	0	0	0	0	0	0	0	0	0		
3. Over open crawl space	9.0	5.0	4.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0		

---

If the latitude, orientation and color of a building are known, conduction heat gain can be calculated accurately using the following equation:

$$Q = A \times U \times CLTD$$

This equation is similar to the equation used to calculate heat loss, except that the factor T has been changed to CLTD. CLTD stands for equivalent “cooling load temperature difference,” and it takes into account not only the indoor/outdoor temperature difference, but also solar gain and heat transmission from the wall to the room air by radiation, convection and conduction. Table 4.6 provides total equivalent cooling load temperature differentials for calculating heat gain in homes for walls, doors, ceilings, roofs and floors. Note that this table has been simplified by ACCA to provide only average CLTDs which eliminate orientation and time of day. The daily temperature range was calculated by taking the average difference between the daily high and low temperature of the day for a given location. A high daily range means there is a large difference in temperature between night and day. Buildings with a high range are able to cool down at night so their heat gain is less during the day.

### ***Solar Heat Gain Through Glass***

When the sun shines through glass, heat is transferred almost instantaneously into the space. Solar heat gain is perhaps the biggest source of heat gain to a house. The rate of gain depends on latitude, time of day and year, window orientation, shading, type of glass and other factors.

A simplified methodology based on use of heat transfer multipliers (HTM) is presented in “ACCA Manual J”. An HTM is defined as the amount of heat that flows through one square foot of glass at a given temperature difference. Solar heat gain is calculated by simply multiplying the area by the HTM. The multipliers (see Table 4.7) take into account the combined effect of radiation and conduction through vertical glass for various exposures and skylights. However, they do not take infiltration into account.

Table 4.7  
Glass Heat Transfer Multipliers  
( Cooling )

	Single Pane	Double Pane	Triple Pane
Design Temp. Diff.	15 20 25 30 35	15 20 25 30 35	15 20 25 30 35
DIRECTION WINDOW FACES                      NO INTERNAL SHADING			
N	27 31 35 39 43	21 23 25 27 29	18 19 20 21 22
E and W	85 89 93 97 101	70 72 74 76 78	63 64 65 66 67
S	44 48 52 56 60	36 38 40 42 44	31 32 33 34 35
DRAPERIES OR VENETIAN BLINDS			
N	18 22 26 30 34	14 16 18 20 22	11 12 13 14 15
E and W	52 56 60 64 68	44 46 48 50 52	38 39 40 41 42
S	28 32 36 40 44	23 25 27 29 31	19 20 21 22 23
ROLLER SHADES - HALF DRAWN			
N	21 25 29 33 37	18 20 22 24 26	15 16 17 18 19
E and W	64 68 72 76 80	57 59 61 63 65	50 51 52 53 54
S	34 38 42 46 50	29 31 33 35 37	25 26 27 28 29
AWNING, PORCHES, OR OTHER EXTERNAL SHADING			
All Directions	27 31 35 39 43	21 23 25 27 29	18 19 20 21 22

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## *Heat Gain From People and Equipment*

The amount of heat and moisture people add to a space depends on age, state of activity, environmental influences and duration of occupancy. Normally 300 Btu/h of sensible load and 230 Btu/h of latent load (Note: this includes an allowance for latent loads of appliances and plumbing fixtures) is added for each person expected to occupy the home (usually estimated as twice the number of bedrooms). The heat gain from people should be added to the load in the rooms that are occupied during peak load conditions, such as the family room or dining room in residences and meeting rooms in commercial buildings. The most common heat producing equipment in the conditioned space are those used in the kitchen for food preparation. Normally only 1,200 Btu/h of sensible heat gain is added to the load for the kitchen. Although kitchen appliances actually have more output than 1,200 Btu/h, this estimate is reasonable since they are not in use all of the time.

## *Heat Gain Due to Infiltration*

Infiltration adds both sensible and latent heat to the cooling load for the house. The equation used to calculate sensible heat gain due to infiltration is the same as that used for heat loss, namely:

$$Q = 1.1 \times \text{CFM} \times T$$

where 1.1 = a constant  
CFM = infiltration, in cu.ft./min.  
T = outdoor/indoor temperature difference, or design temperature differences

The value for infiltration (CFM) is calculated in the same way that infiltration heat loss is calculated, except that (Table 4.8) should be used to determine summer air changes per hour.

When calculating infiltration latent heat gain, the value GR is used. GR is the difference in moisture between the outdoor and indoor design conditions. Table (4.3) provides such information.

The following equation is used to calculate heat gain due to infiltration:

$$Q = 0.68 \times \text{CFM} \times \text{GR}$$

where 0.68 = a constant

CFM = infiltration, cu.ft./min.

GR = design difference for outdoor/indoor moisture

Latent heat gain due to infiltration load is calculated for the entire house--not separately for each room because single zone residential heat pumps cannot differentiate latent capacity in different rooms.

Table 4.8  
Cooling  
Season Air  
Changes  
( Per Hour)

FLOOR AREA	900 OR LESS	900-1500	1500-2100	OVER 2100
Best	0.2	0.2	0.2	0.2
Average	0.5	0.5	0.4	0.4
Poor	0.8	0.7	0.6	0.5

### *Heat Gain From Ducts*

The only ducts which need to be considered for estimating cooling load are those that are located in unconditioned spaces. Duct heat gain varies depending on duct size, shape, length, construction, insulation and other factors. In general, however, ducts running through a basement (whether insulated or uninsulated) have heat gains of about 5 to 15 percent of the room's total sensible gain. Uninsulated ducts in attics and garages can have heat gains as much as 30 percent of the total sensible heat gain of the space that they service.

Many local codes and/or utilities require that ducts located in unconditioned space or exposed to ambient temperatures be insulated. Their recommendations should be followed.

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## *5 Air Distribution*

The air distribution system makes possible the circulation of the conditioned air from the heat pump to the various rooms in the house and then back to the heat pump. The system must be designed with consideration for the heat pump's capacity, sound level and quantity of supplied air. The goal of an effective air distribution system is to provide constant temperature and humidity control throughout the house without noticeable air stratification or air noise. This goal can be accomplished best when the duct design is simple and direct, ensuring both good performance and low cost.

### *Ventilation*

It is very important that any building have adequate ventilation. This ventilation may be natural, such as infiltration, or mechanical. If a building was not ventilated, there would be a buildup of carbon dioxide, water vapor and various impurities such that a person may become ill. Poor ventilation may result in respiratory problems due to a buildup of dust and trace amounts of gases and volatile organic vapors.

In the past fresh air entered the structure by infiltration. In most residential applications there is no formal make-up air system. Instead the infiltrated air is captured by the return air system. However, it is better to collect and clean this air than heat or cool it in order to provide comfort.

How much air is needed? This question is usually answered in air rotations per hour and recommended fresh air CFM's.

Table 5.1  
Recommended Air Rotations

Structure	Air Rotations / Hour	
	Heating	Cooling
Home	3 - 6	6 - 9
Office/Store	5 - 8	6 - 12
Public Assembly	5 - 10	6 - 12

Recommended Air Rotations For Various Types of Occupancies

Occupancy classification	Fresh air in cfm per human occupant
Residential	
General living areas	5
Bedrooms	5
Kitchens	20
Basements, utility rooms	5
Mobile homes	5
Hotels, motels	
Bedrooms (single, double)	7
Living rooms (Suites)	10
Corridors	5
Lobbies	7
Conference rooms (small)	20
Assembly rooms (large)	15

Table 5.2  
Required Fresh Air

---

## *Duct Design*

Ducts are controlled air passages that work on the principle of air pressure difference. The supply side moves air by pressurizing it with the blower, but the return air comes back by atmospheric pressure, it is for this reason that return ducts should be equal to or up to 20 percent larger in cross sectional areas than supply ducts.

### *Sizing Methods*

#### *Equal Friction Method*

Air conditioning and heating system ductwork is generally designed by the equal friction method. This method seeks the same pressure loss through each duct. The friction loss of each component is added to arrive at the total friction loss of run. Most heat pumps are designed for a total resistance of 0.5 inches water column.

However, the unit itself accounts for 0.2 inch w.c. leaving 0.3 inch w.c. of available external static pressure. The supply register and return grill are assumed to have 0.03 inch w.c. each.

Total Resistance	0.50 inch w.c.
Unit Resistance	0.20
Avail. External Static Pres.	0.30
Supply & Return Grills	0.06
Total Design Static Pres.	0.24

The total design static pressure must then be divided between the supply and return ducts. It is commonly divided 60 percent for supply and 40 percent for return. In order to increase efficiency, the designer might select a total design static pressure of 0.20 inch w.c.

Total Return Static Pres.	0.08 inch w.c.
Total Supply Static Pres.	0.12
Total Design Static Pres.	0.20

Next, the supply and return duct runs are calculated in terms of total effective length. The fittings are expressed in terms of equivalent length of straight duct. The ducts are sized to provide the total static pressure required. For an example of this method, see Manual D, Duct Design for Residential Equipment, Air Conditioning Contractors of America.

Generally the velocity from supply registers should range between 250 and 450 feet per minute. Return grills should not exceed 600 cfm to prevent excessive noise. Trunk ducts should terminate 6 inches from the wall to allow room for expansion.

Table 5.3 Diffuser Air Flow

<b>Suggested Air Flow for Common Sizes of Floor Diffusers</b>		
<b>Size</b>	<b>Min CFM</b>	<b>Max CFM</b>
2 1/4 x 10	20	50
2 1/4 x 12	40	65
2 1/4 x 14	50	80
4 x 10	60	100
4 x 12	75	120
4 x 14	80	140
6 x 10	100	170

<b>Suggested Air Flow for Common Sizes of Ceiling Diffusers</b>		
<b>Size</b>	<b>Min CFM</b>	<b>Max CFM</b>
6	40	70
8	70	125
10	120	190
12	170	275

---

It is important to use care in designing ducts. A poorly designed duct system will cause a GeoSource heat pump to operate inefficiently. However, a well designed duct system will cause customers to say it is the quietest, most comfortable system they have ever had. There are now computer programs available which will help one design a good duct system quickly.

#### ***Velocity Reduction Method***

This method starts with a known velocity at the fan. The ducts are sized to progressively lower the velocity at each junction or branch of the trunk duct. For return air the process again starts at the fan and progressively lowers velocities. This method is seldom used for residential ductwork.

#### ***Static Regain Method***

This method is well suited for high velocity commercial installations with long runs and many branches. The ducts are designed so that the increase in static pressure at each takeoff is equal to the pressure loss on the next section of ductwork. Although this method makes balancing easier, it also results in very large ducts at the end of long runs.

#### ***Constant Velocity Method***

This method is used for exhaust systems carrying particulates. These ducts should be designed by a trained engineer. For information on this method consult the "ASHRAE Handbook" 1981 Fundamentals.

#### ***Fire and Smoke Control***

Commercial ductwork systems must consider fire and smoke control. A trained engineer will provide for fire and smoke control in ducts. For information on this subject refer to the National Fire Protection Association (NFPA) "Fire Protection Handbook".

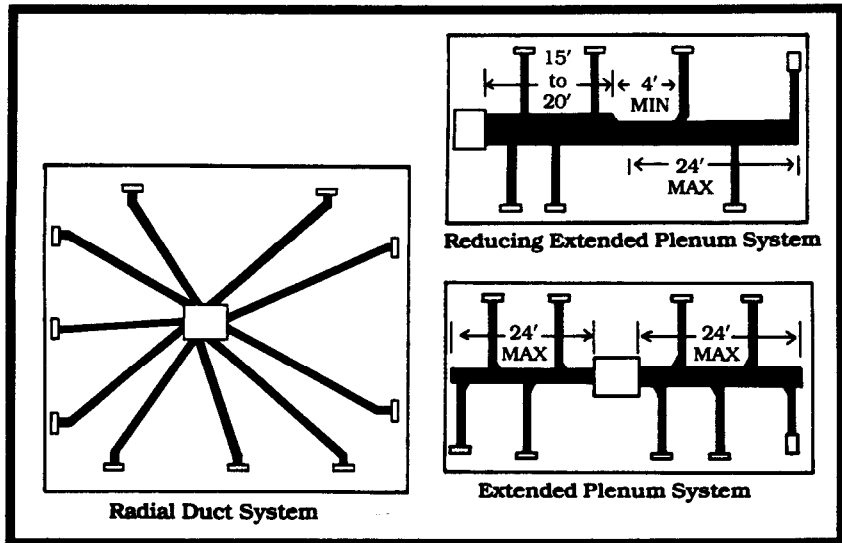
## *Heat Pump Volume*

As a rule, GeoSource heat pumps move 350 to 450 cfm per ton of unit capacity.

## *Types of Residual Duct Systems*

There are four basic types of residential supply duct systems: extended plenum, redwing extended plenum, radial and perimeter.

Figure 5.1  
Common Duct  
Systems



Return air duct systems are either central or a number of return grills in several rooms. Please note that return grills are not located in kitchens or bathrooms because of odors and germs.

## *Placement of Registers and Grills*

Registers and grills should be placed so that stagnation of the air in the room is avoided. Locate supply register located on floor or outside wall and return grill low on inside wall.

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## *Air Balance and Noise Attenuation*

Balancing is a manual technique in which the air flow to each outlet is adjusted with hand dampers until the proper quantity of conditioned air is supplied to each room. When the ducts are not sized properly, extensive balancing may be needed. Detailed information about air balancing can be found in "ACCA Manual 6; Adjusting Air Condition Systems". The system will run as quietly as possible if the elbows and fittings are designed well. Lining the duct will also lower the noise level. Duct liner should be installed on either side of the unit, about six feet long on each side. Lined elbows with turning vanes and 90 degree elbows also attenuate noise. To assure quiet operation, the air velocities in main supply ducts should be kept between 700-900 fpm, 600 fpm in branch ducts, and 500 fpm in branch risers. Flexible connections (using canvas or neoprene connectors) are also necessary in order to isolate equipment vibrations from metal ductwork.

Ductwork noise attenuation is especially crucial for GeoSource Heat Pumps, since the compressor is located indoors within the air handling unit. These systems should use vibration dampening boots or fiberglass duct board supply and return plenums to attenuate compressor and fan noise.



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# *6 Open System Design (Well Water)*

## *Water Requirements*

The first step in pump sizing is to determine the amounts of water needed. In the case of a house with a GeoSource heat pump there are two separate needs, domestic water (drinking) and heat pump water. A rule of thumb for domestic water needs is 75 gallons per day per person or 1 gpm per outlet (Water Systems Council-WSC). The WSC rule is based on peak demand rather than average need. The amount of water required for the heat pump will range from 1 1/2 - 2 gpm per ton of capacity. To determine the heat pump's water requirement consult the Engineering Specifications.

There are two types of water well pumps which are likely to be encountered when working with water source heat pump applications. They are the jet pump and submersible pump.

The jet pump is commonly used on driven sand point wells and in areas where the water table is relatively close to the surface. The jet pump operates by means of a water venturi nozzle which it uses to help draw water up from the well. While this method can be reasonably efficient at shallow suction lifts ranging from 0 to 10 feet, the efficiency of a jet pump is reduced as the suction lift increases. The maximum suction lift on most jet pumps is from 22 to 24 feet. While the jet pump is one of the most inexpensive pumping systems to install, its use on GeoSource heat pump applications should be limited to areas where the water table is within 10 feet of the pump.

The stopwatch and 5-gallon pail are used to time the flow of a known volume of water. Recording the time required to fill a 5-gallon pail is an accurate, low-cost method of measuring flows less than 20 gpm. Commercial water meters can be mounted in line to record the volume of water flow in one minute. Some of these meters are accurate to within + 1 percent.

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## *Pressure Tanks*

The pressure tank is typically the only part of the water well system inside the building. Whenever possible GeoSource heat pump systems should be operated on the diaphragm or bladder type of pressure tank. Older style galvanized, air charged water tanks which allow for oxygen contact with the water can cause precipitation of iron within the tank and plumbing system. In several cases this iron precipitation can carry over into the water heat exchangers of a GeoSource heat pump and create a maintenance requirement.

The average life of a well pump is seven years, but that will be shortened considerably if the pump is short cycled. Short cycling occurs when the pump is started less than one minute after it stopped. A pump will last longer running constantly than starting and stopping. Therefore, the pump in conjunction with the pressure tank should be sized so that the pump will have a minimum off cycle of one minute or more.

**RULE OF THUMB:** Choose a pressure tank with a “drawdown” of 200% of heat pump flow.

## *Open System Piping*

GeoSource heat pumps must have a uninterrupted supply of water. When a well is supplying both domestic needs and a GeoSource heat pump, the heat pump supply pipe should be plumbed directly to the pressure tank. Schedule 40 PVC or copper pipe is recommended for both supply and return lines. 3/4 inch pipe can be used for flow rates up to 8 gpm. Use 1 inch pipe for flow rates up to 15 gpm.

Thermometer wells and isolation valves should be used on both supply and discharge lines. On the discharge side of the heat pump a flow control should be mounted next to the heat pump, then a solenoid valve and flow meter.

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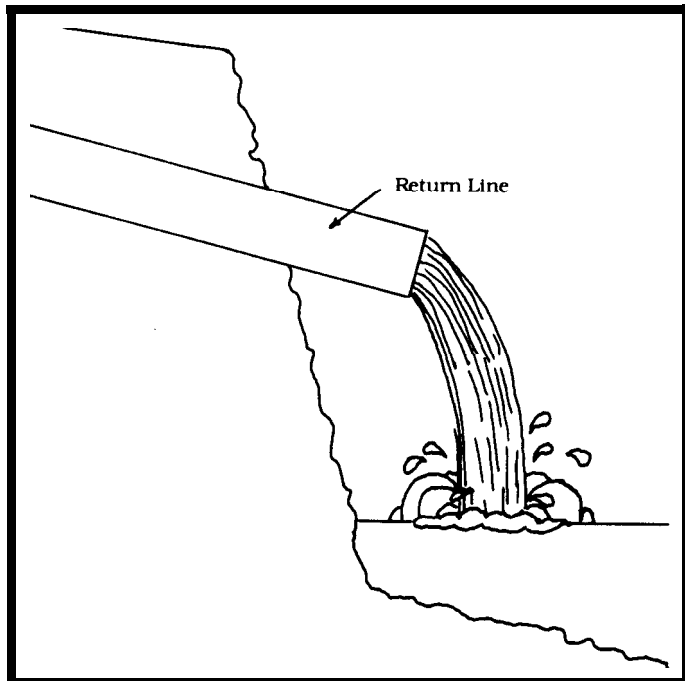
## *Water Discharge*

After the water flows through a GeoSource heat pump it must go somewhere. Since this water is as safe and sanitary as the water entering the heat pump there are no health problems associated with disposal of this water. Water flows through heat pumps in pipes under pressure without contacting air. The only change to the water is a change of temperature between 5F and 15F.

### *Return To Surface Water*

A pond, lake or stream can be used to accept water discharged from a GeoSource heat pump. When using a pond or lake it is important to size the pipe large enough to minimize friction loss and to lay it so that gravity will flow the water to the pond, lake or stream. Be careful to construct the discharge pipe so that it does not freeze in the winter. Not only should the pipe be buried below the frost line near the building, but also low enough to prevent freezing at the edge of the pond.

Figure 6.1  
Discharge  
Above  
Pond



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A second disposal method is the drain field. This method is practical in a porous soil such as sand but not in clay. The drain field is essentially a trench in the ground filled with gravel. Discharge water flows into the gravel and then seeps through the sandy soil to the water table below.

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## *7 Earth Loop Design*

The earth loop in a GeoSource earth loop system is the supply line of energy for the consumer's heat pump. Careful consideration must be given to its design, materials and installation to assure the consumer years of dependable, worry-free operation.

### *Materials*

A completed GeoSource earth loop system will consist of the heat pump equipment (including thermostat, etc.), a series of buried pipes outside the building, an antifreeze and water solution and a circulator pump to transfer the fluid to and from the earth loop. The heat pump used with an earth loop must be capable of operating efficiently and provide a comfortable output temperature with inlet earth loop temperatures down to 25F. The heat pump should be safety certified by A.R.L., abide by Northland Heat Pump Association (NHPA) standards and be certified to CSA C446. The underground pipe buried outside must be either a high density polybutylene or high density polyethylene manufactured for earth loop applications and tested by ASTM standards for such usage. This type of pipe has been in service by both the gas and electric utilities for many years and has an estimated life span of over 200 years and normally carry 50 year warranties.

### *Loop Fabrication Practices*

#### Heat Fusion

Heat fusion is the process in which plastic pipe materials are aligned, cleaned or trimmed, heated to their melting point, brought together, and allowed to cool to form.

For reliability, all underground piping joints must be thermally fused rather than mechanically coupled.

- 
1. Heat fusion joining results in a joint which is stronger than the pipe itself.
  2. The connection or joint is all plastic, eliminating corrosion problems.
  3. Industry standards (ASTM, PPI) recommend thermal fusion for proper joining.

Training programs in the correct methods of heat fusing are available from the manufacturers of pipe and fusion machines, eg. Vanguard Plastics.

### *Methods of Heat Fusion*

#### **Socket Fusion Joining**

In the socket fusion method, the two pipe ends are joined by fusing each pipe end to a socket fitting. This requires two heat fusion procedures for each joint.

#### **Butt Fusion**

The butt fusion procedure is where the two pipe ends are simultaneously heated to a plastic state by a heater plate and brought together to form the heat-fused joint. A single heat fusion process is required to form the joint between the two plastic pipe ends. The butt fusion process is performed by using specially designed machines which provide for securely holding the two pieces to be fused, aligning them, trimming and squaring their ends, heating the surfaces to be joined with a heater plate, and butting them together while they remain in a plastic state which produces a double rollback head.

#### **Usage**

Polyethylene is heat fused and joined using both butt and socket procedures. Material grade, density, etc., will determine if the particular grade can be fused with either method. Some high-density polyethylene materials cannot be socket fused.

Polybutylene in the sizes used in earth heat exchangers is socket fused.

Both fusion procedures when properly done yield highly reliable joints that are stronger than the pipe itself.

## *Antifreeze Solutions*

Water. Water is the least expensive and most readily available circulating fluid. Water has a relatively low viscosity and high thermal conductivity which can yield low frictional pressure drops and high heat transfers coefficients.

The purity and softness of the water are important. The presence of impurities, as ions or dissolved solids, can play a significant role in scale build-up, heat exchanger fouling, and pump maintenance and life in open systems. This would not be a major concern in a closed earth loop system.

Table 7.1  
Pure Water  
Physical  
Properties

Pure Water Physical Properties			
Temp (F)	Density (lb/gal)	Viscosity (centipoise)	Thermal/Conductivity (Btu/hr-ft-F)
32	8.344	1.789	0.327
40	8.344	1.550	0.332
50	8.339	1.310	0.338
60	8.334	1.200	0.344
70	8.338	0.979	0.349
80	8.311	0.860	0.355
90	8.303	0.764	0.360
100	8.287	0.682	0.364
110	8.267	0.616	0.368

Note: Specific heat = 1.000 Btu/lbm - F

Water would normally be the chosen earth loop circulating fluid if it were not for its following two disadvantages:

1. Water has a relatively high freezing point of 32F.
2. Water expands upon freezing.

These two disadvantages eliminate water from being the chosen earth loop circulating fluid in northern climates. A fluid with a lower freezing point must be chosen.

Table 7.1 states pure water density, viscosity, and thermal conductivity at various temperatures. Water's specific heat can be taken to be 1.000 Btu/(lbm-F).

Table 7.2  
Methanol Solution Physical Properties

Mean Temperature, F	25	30	35	40
Freezing Point, F	15	20	25	30
Weight % Methanol	13.6	10.0	6.3	2.0
Methanol Mass (1), lbm	131.6	92.7	56.1	17.0
Methanol Volume (2), gal	19.41	13.63	8.29	2.53
Specific Gravity, SG t/59	0.813	0.815	0.811	0.807
Density, lb/gal	8.180	7.546	8.254	8.257
Specific Heat Btu/lbm - F	1.01	1.02	1.025	1.02
Viscosity, Centipoise	3.30	2.70	2.15	1.60
Thermal Conductivity Btu/hr - ft - F	0.286	0.296	0.310	0.324
NOTE: (1) Pounds mass of pure methanol needed per 100 gallons of pure water. (2) Gallons of pure methanol needed per 100 gallons of pure water.				

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### ***Methyl Alcohol (Methanol)***

Methyl alcohol, sometimes referred to as a methanol has been widely used as an antifreeze. Methanol in water offers low cost, low corrosivity, low viscosity, and good thermal conductivity. Methanol water offers relatively low frictional pressure drops and relatively high heat transfer coefficients. Methanol, however, presents the disadvantages of high volatility, high flammability, and high toxicity. Pure methanol has a flash point of 54°F to 60°F. Table 7.2 gives pertinent data for methanol waters at 25°F, 30°F, 35°F, and 40°F.

### ***Propylene Glycol***

Propylene glycol, which is nontoxic, can offer low corrosivity and low volatility, and presents a low flammability hazard. However, propylene glycol yields more viscous solutions.

A reasonable lower limit threshold would be a maximum 25% mixture by volume and operating above 25F. Lower operating temperatures and/or higher concentrations of propylene glycol are not economical when the energy required to pump the fluid and maintain turbulent flow under those conditions is considered.

In order to obtain good heat transfer within the buried pipe system the calculated Reynolds number should not fall below 2500. Table 7.3 gives pertinent propylene glycol properties at 25°F, 30°F, 35°F, and 40°F.

### ***GS4 (Potassium Acetate)***

GS4 is a result of the GeoSource industry searching for a better antifreeze. It has all the positive benefits of methanol but is safe like propylene glycol. It yields exceptional efficiency. It is nontoxic, nonflammable and is biodegradable. A mixture of 30% GS4 allows good corrosion resistance and will be freeze protected to 15°F.

Table 7.3  
 Propylene Glycol Solution  
 Physical Properties

Mean Temperature, F	25	30	35	40
Freezing Point, F	15	20	25	30
Weight % Glycol	23.5	18.3	12.9	5.9
Glycol Mass (1), lbm	256	187	124	52
Glycol Volume (2) gal	29.9	22.0	14.7	6.2
Specific Gravity, SG t/59	1.025	1.018	1.013	1.006
Density, lb/gal	8.55	8.49	8.45	8.39
Specific Heat Btu/lbm - F	0.96	0.97	0.98	0.99
Viscosity, Centipoise	5.3	4.4	4.0	3.7
Thermal Conductivity Btu/hr - ft - F	0.225	0.236	0.25	0.275
NOTE: (1) Pounds mass of pure Glycol needed per 100 gallons of pure water. (2) Gallons of pure Glycol needed per 100 gallons of pure water.				

## *Loop Design and Sizing*

As discussed in previous chapters, earth loops are installed either vertically or horizontally, either with a well drilling rig or a trencher or backhoe. A determination must now be made on the amount of pipe to be buried that

will conduct the proper amount of energy to and from the surrounding earth. See Estimating Earth Loop Heat Transfer, page 66. Much research has been conducted on this subject and “bottom line” numbers are available to us making size selection simple. The following table indicates the requirements needed for a selected zone.

Table 7.4  
Required Earth Loop Lengths

<b>Vertical</b>				
<b>Bored Feet Per Ton</b>		<b>Desired Loop Temp (F)</b>		
170		30		
200		32		
<b>Horizontal</b>				
<b>Pipes Per Trench</b>	<b>Depth</b>	<b>Pipe Length Per Ton</b>	<b>Desired Loop Temp (F)</b>	
1	5	500	30	
1	6	500	32	
2	4,6	550	30	
2	5,7	550	32	

**RULE OF THUMB.** Parallel flow circuits connected to a reverse return reducing header.

**RULE OF THUMB.** One circuit per ton of heat pump capacity -or- if greater utilize a pump bypass valve to allow additional flow to the earth loop.

**RULE OF THUMB.** Maintain each loop circuit length to be within 5% of all circuit lengths.

## *Pumping Requirements*

### *Heat Pump*

Although 3 GPM per ton of heat pump capacity is an acceptable rule of thumb, consideration must be given to check performance tables for proper GPM requirements and corresponding pressure drops.

Table 7.5  
Minimum  
Flow in  
Pipe for  
Turbulence  
(GPM)

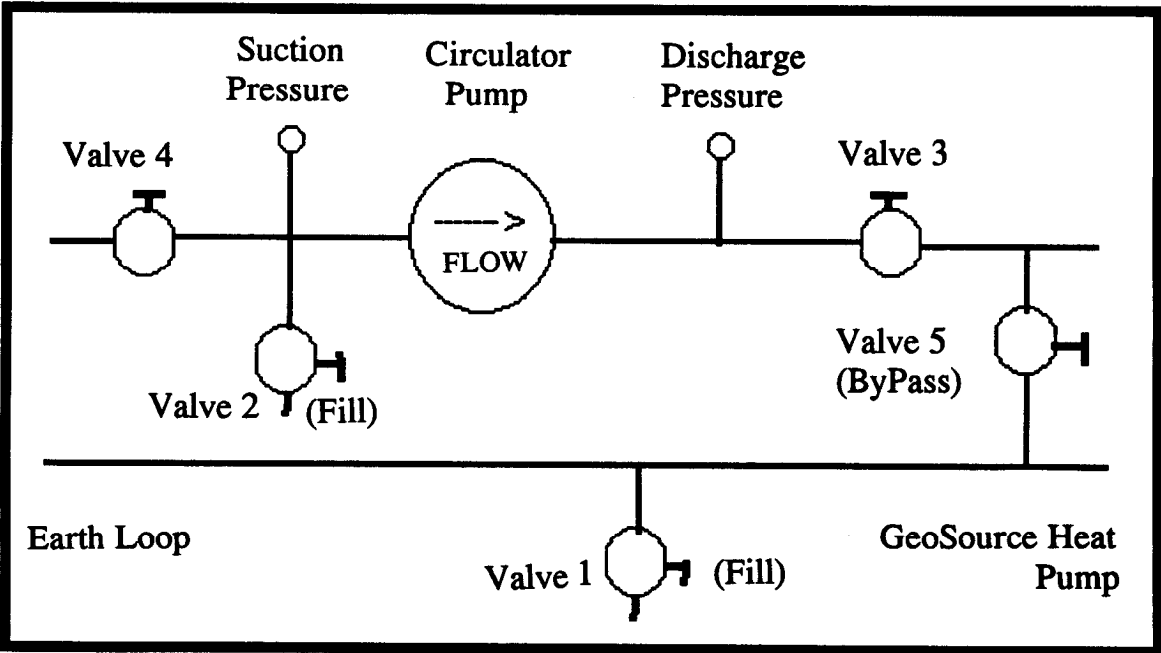
Nominal Pipe Size (Pipe ID)	Water @ 40F	Propylene Glycol-20% @ 25F	Methanol 20% @ 25F
PB (SDR-13.5, CTS)			
1" (0.957)	1.2	3.9	2.7
1 1/4" (1.171)	1.4	4.7	4.9
1 1/2" (1.385)	1.7	5.6	3.9
2" (1.811)	2.2	7.3	5.1
PE (SDR-11)			
3/4" (0.86 )	1.1	3.4	2.4
1" (1.077)	1.3	4.4	3.1
1 1/4" (1.385)	1.7	5.5	3.9
1 1/2" (1.554)	1.9	6.3	4.4
2" (1.943)	2.4	7.9	5.5
PE (SCH 40)			
3/4" (0.824)	1.0	3.3	2.3
1" (1.049)	1.3	4.2	3.0
1 1/4" (1.380)	1.7	5.6	3.9
1 1/2" (1.610)	2.0	6.5	4.6
2" (2.067)	2.5	8.4	5.9

### *Earth Loop*

Determining heat pump flow requirement is simple since data is supplied in the Engineering Specifications; however, you must on your own design the earth loop flow rate for optimum performance. One guideline that is available is Reynolds number requirements, a number established to provide optimum heat transfer between the earth and loop fluid. Table 7.5 outlines required flows to maintain a Reynolds number greater than 2500 which is required for turbulent flow and proper heat transfer.

If these flows are not maintained “lazy loops” will develop, causing lower than desired loop temperatures.

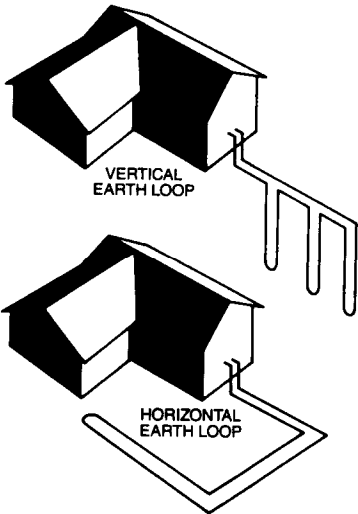
Figure 7.1  
Recommended Piping For Proper Purging and System Flow



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## Determining Pressure Drop

Figures 7.2 and 7.3  
Vertical and Horizontal  
Earth Loops



Pressure drop is the result of fluid flow through a pipe due to frictional losses between the fluid and pipe surface. Pressure drop must be calculated in order to properly size the circulator pump. Determine the pressure drop as follows:

$$\begin{aligned} & \text{Pressure Drop of Heat Pump} \\ + & \text{Pressure Drop of Internal Piping and Components} \\ + & \text{Pressure Drop of Earth Loop} \\ \hline = & \text{System Pressure Drop} \end{aligned}$$

With the presence of antifreeze in the system the fluid viscosity increases and a correction factor must be applied to determine actual system pressure drop as follows:

$$\begin{aligned} & \text{System Pressure Drop} \\ \times & \text{Correction Factor} \\ \hline = & \text{Actual System Pressure Drop} \end{aligned}$$

Correction Factors:	Water	1.00
	Methanol/GS4	1.25
	Propylene Glycol	1.36

## Sizing Pump

Now that water flow requirements and system pressure drops have been determined a circulator pump can be selected. Choose the proper PumpPAK or request a pump that will supply the required water flow rate at the calculated actual system pressure drop (Head).

**Table 7.6  
Pipe  
Pressure  
Drop**

**(Head Loss)  
Polybutylene  
SDR 11, CTS**

Tubing Size:	1"	1 1/4"	1 1/2"	2"
Tubing ID in.:	0.957	1.171	1.385	1.811
Flow Rate	Hd Ls	Hd Ls	Hd Ls	Hd Ls
GPM	/100Ft	1100 Ft	/100Ft	/100 Ft
	1"	1 1/4"	1 1/2"	2"
2	0.44	0.16	0.07	
3	0.93	0.35	0.15	
4	1.58	0.59	0.26	0.07
5	2.39	0.90	0.40	0.11
6	3.35	1.26	0.55	0.15
7	4.46	1.67	0.74	0.20
8	5.71	2.14	0.94	0.26
9	7.10	2.66	1.18	0.32
10	8.63	3.23	1.43	0.39
12	12.09	4.53	2.00	0.54
15	18.26	6.84	3.02	0.82
18	25.59	9.59	4.24	1.15
21	34.03	12.75	5.63	1.53
24	43.57	16.32	7.21	1.96
27		20.29	8.97	2.43
30		24.66	10.90	2.96
35		32.80	14.50	3.93
40		41.99	18.56	5.03
45			23.07	6.26

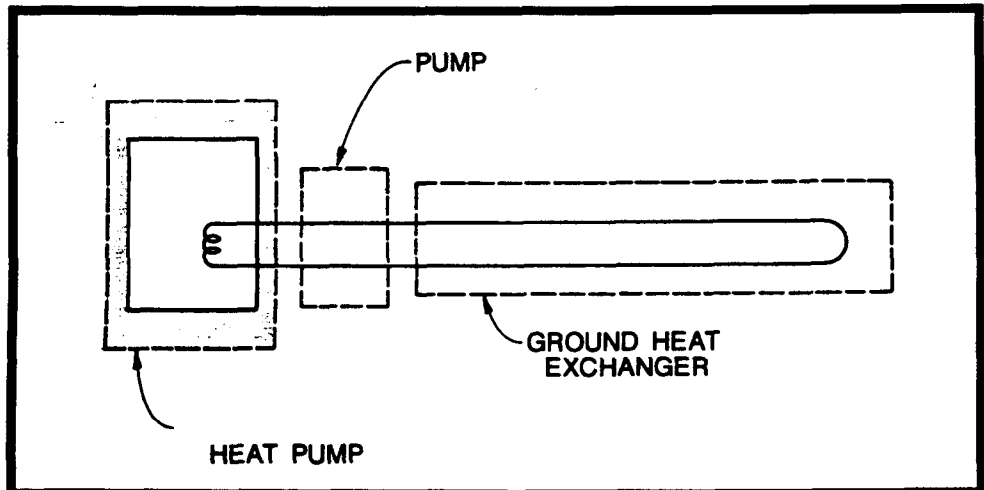
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## System Purging

The GeoSource heat pump and pumping unit is connected to the earth heat exchanger as shown in Figure 7.4 Before operating the system, the following procedural and verification checks must be made to ensure the system will perform properly and as designed:

1. flushing debris from the earth loop
2. purging air from the earth loop
3. verifying earth loop design (pressure/flow)
4. checking for possible flow blockage if design verification does not check
5. charging earth loop with antifreeze
6. pressurizing the earth loop

Figure 7.4  
Heat Pump,  
Earth Loop,  
Pump  
Diagram



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## ***Flushing Debris***

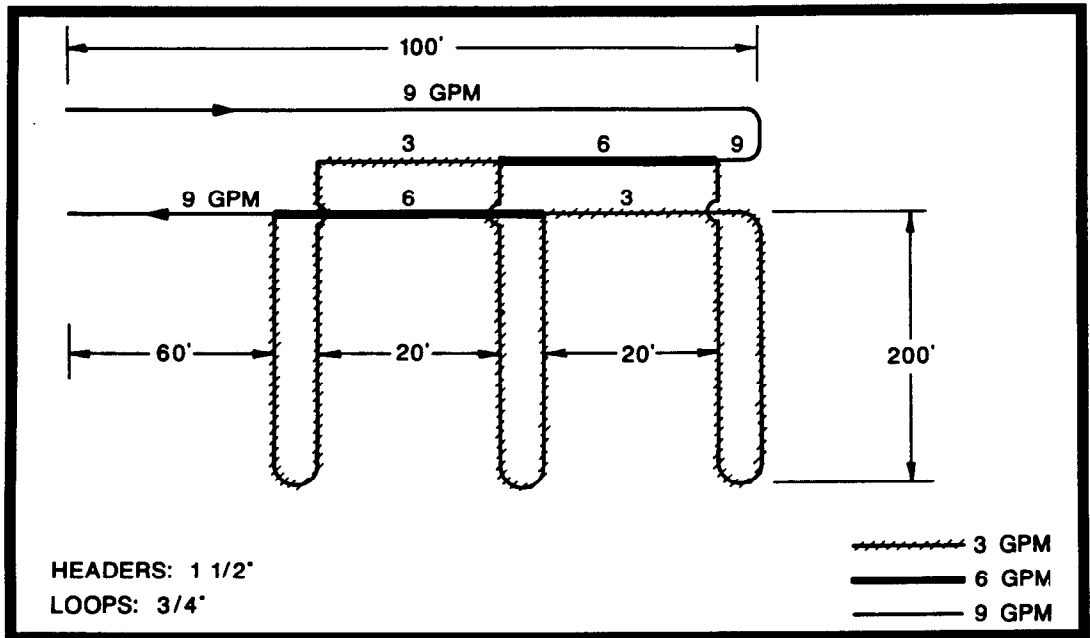
Before operating the system, it must be flushed with water to remove any debris possibly trapped inside during fabrication. This debris may include dirt, pipe shavings, or other foreign objects. While a small amount of dirt may not be harmful to the piping system, bearings in circulating pumps can be damaged by particulates. Taping or fusing on end caps to the pipe's ends before it is placed in the trench will help minimize contamination. If individual loops have been flushed and pressure tested, it is recommended that a permanent seal (such as a fused end cap) be used to ensure nothing can inadvertently enter the pipe.

## ***Purging Air***

In addition to flushing any debris, it is also necessary to purge the system of any air trapped. Failure to do this can biodegrade the GS4 fluid and corrode the metallic components in the circulating system, causing their eventual failure.

Under certain circumstances, excessive air in the system may block water flow in some branches of a parallel ground heat exchanger system. For example, air trapped at the top of one of several vertical ground heat exchanger loops may cause an air column that will prevent flow through the loop when low power flushing is used. In this case, the fluid in the loop will not circulate, and the flow will be restricted to the remaining vertical loops which are air-free. A similar flow blockage due to air also could exist if a horizontal installation is laid at a constant depth in sloping terrain. In this case, elevation changes may result in greater pressure heads than can be overcome by the circulating pump. If sufficient flushing power is used, the air will be removed in all cases.

Figure 7.5  
Reverse  
Return  
Sample  
Diagram



A flow velocity of 2ft/sec in a piping system will completely remove any trapped air in the system. In parallel systems, the required flow rate for air purging in each parallel loop and each section of the header system should be checked to satisfy the flow velocity condition. Recall that the header flow rate decreases as the flow is branched down each parallel loop.

During normal heat pump operating conditions, the header flow (Figure 7.5) at the first loop is 9 GPM (assuming 3 GPM/ton); between the first and second is 6 GPM, between the second and third loop, 3 GPM. The typical circulating pump designed for normal heat pump operation is not capable of removing all trapped air. To remove the air, a fluid velocity of 2ft/sec in each branch must be maintained during air purging.

Table 7.7 shows the required flow head (GPM) to give a velocity of 2ft/sec for a number of typical pipe sizes used in earth loops.

The required flushing flow rate is determined by the number of loops beyond the header end. If a single loop is attached at the header end, the flow rate at the header end must flow through the end loop.

**Table 7.7  
System Purging  
Flow Rates**

Flow Rate (GPM) Required for Debris Flushing and Air Purging to Give an Average Velocity of 2 FPS in Pipe.		
Nominal Pipe Sizing ( inches)	Pipe ID (inches)	Flow Rate (GPM)
Polybutylene, SDR- 13.5, CTS		
1	0.957	4.5
1 1/4	1.171	6.7
1 1/2	1.385	9.4
2	1.811	16.1
Polyethylene, SCH 40		
3/4	0.860	4.3
1	1.077	5.7
1 1/4	1.358	9.0
1 1/2	1.554	11.8
2	1.943	18.4

***Final Step***

Once all debris and air has been flushed and purged from the system and steps 3 and 4 on page 62 are completed the system is now ready to be charged with antifreeze and pressurized. After adding the proper amount of antifreeze chosen, a freeze point check must be made. The solution must be freeze protected to 15°F. Adjustments to add or subtract antifreeze are now **made to** assure adequate freeze protection and proper viscosity of the system. The

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system pump is now operated and a check of the suction side pressure gauge on the pump is made.

Pressurize the system by adding the correctly mixed solution until there is a positive (5 PSIG) reading on the gauge. The system is now complete.

### ***Estimating Earth Loop Heat Transfer***

Information Needed to Calculate Heat Transfer to and from the Earth.

\* Soil Temperature at desired depth

Lowest (Winter) =  $T_L$

Highest (Summer) =  $T_H$

\* Soil “U” Value (1/Resistance of Soil + Resistance of Pipe)

Varies with Soil Composition

Varies with Run Time

\* Heat Pump Capacity and C.O.P. decline as loop becomes colder in the wintertime and capacity and E.E.R. also decline as loop becomes warmer in the summertime. Capacity, C.O.P. and E.E.R. at various loop temperatures can be found in the Engineering Specifications.

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## Determining Soil Temperatures

Wintertime Lowest Temperature ( $T_L$ )

$$T_L = T_M - A_s \times e^{-X_s (Pi/365d)^{1/2}}$$

Summertime Highest Temperature ( $T_H$ )

$$T_H = T_M + A_s \times e^{-X_s (Pi/365d)^{1/2}}$$

Where  $T_M$  = Mean Earth Temperature, °F

$A_s$  = Annual Surface Soil Temperature swing, °F

$X_s$  = Soil Depth, Feet

$d$  = Soil Thermal Diffusivity, ft<sup>2</sup>/day

and  $d$  for various soils equals:

<u>Soil</u>	<u><math>d</math></u>	<u><math>(Pi/365d)^{1/2}</math></u>
Dry Loam	.26	.182
Damp Loam	.35	.157
Dry Sand	.48	.134
Dry Clay	.60	.120
Saturated Sand	.75	.107
Damp Clay	.84	.101

---

**T<sub>L</sub> and T<sub>H</sub> with dry clay in zones 1-4 @ 5 feet**

<u>Zone</u>	<u>T<sub>M</sub></u>	<u>A<sub>S</sub></u>	<u>T<sub>L</sub></u>	<u>T<sub>H</sub></u>
1	43	31	26	60
2	47	29	31	63
3	50	28	35	65
4	52	28	37	67

**T<sub>L</sub> and T<sub>H</sub> with dry clay in zones 1-4 @ 6 feet**

<u>Zone</u>	<u>T<sub>M</sub></u>	<u>A<sub>S</sub></u>	<u>T<sub>L</sub></u>	<u>T<sub>H</sub></u>
1	43	31	28	58
2	47	29	33	61
3	50	28	36	64
4	52	28	38	66

**T<sub>L</sub> and T<sub>H</sub> with dry clay zones 1-4 @ 7 feet**

<u>Zone</u>	<u>T<sub>M</sub></u>	<u>A<sub>S</sub></u>	<u>T<sub>L</sub></u>	<u>T<sub>H</sub></u>
1	43	31	30	56
2	47	29	34	60
3	50	28	38	62
4	52	28	40	64

---

### *Estimating Soil "U" Value*

Soil Type	Run Time 100%	90%	80%	70%
Damp Clay	2.1	2.3	2.5	2.7
Saturated Sand	2.0	2.2	2.4	2.6
Dry Clay	1.8	1.9	2.1	2.3
Dry Sand	1.5	1.6	1.8	2.0
Damp Loam	1.1	1.2	1.3	1.4
Dry Loam	0.7	0.75	0.8	0.9

### *Calculating Lap Length*

Winter

$$L = \frac{\text{Heating Capacity} \times (\text{C.O.P.} - 1/\text{C.O.P.})}{U \times T_{HD}}$$

Where:  $T_{HD} = T_L - T_{MINA}$

Where:

$$T_{MINA} = T_{MIN} - [\text{Heating Capacity} \times (\text{C.O.P.} - 1/\text{C.O.P.}) / (\text{GPM} \times 1000)]$$

Summer

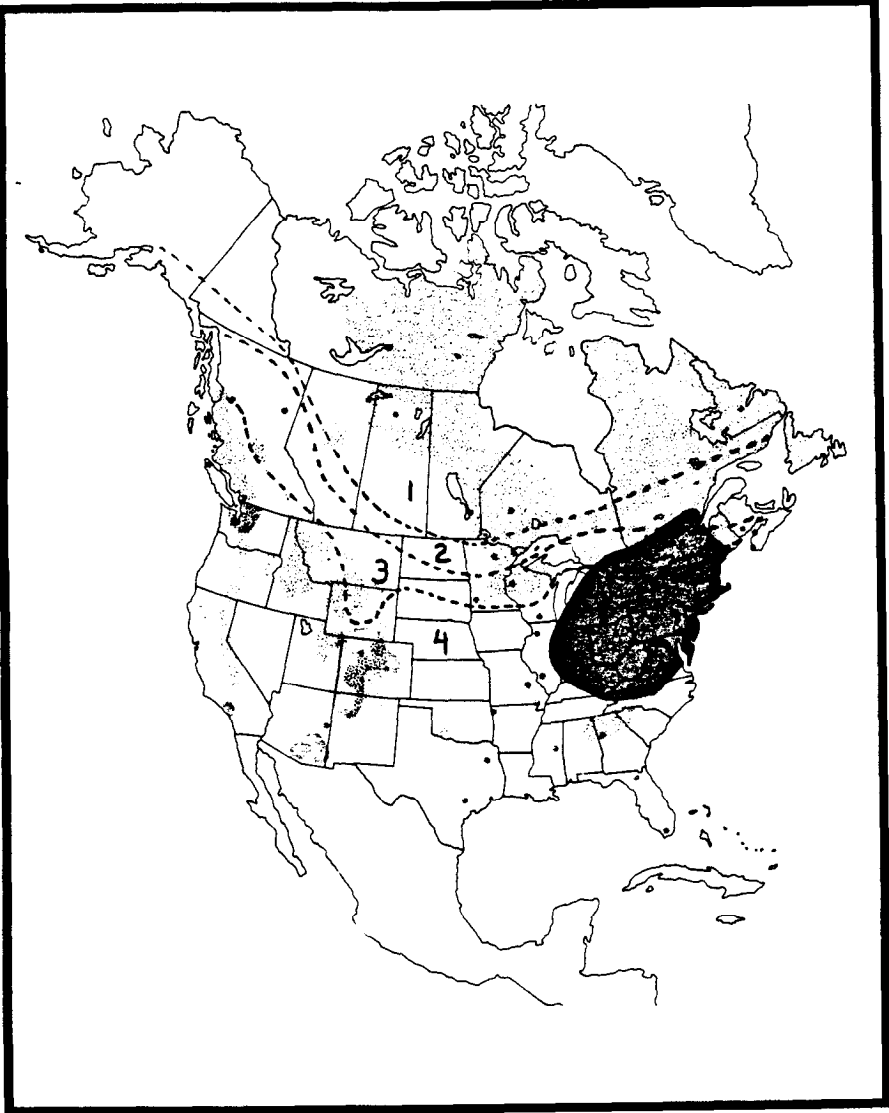
$$L = \frac{\text{Cooling Capacity} \times (\text{E.E.R.} + 3.412/\text{E.E.R.})}{U \times T_{cD}}$$

Where:  $T_{cD} = T_{MAXA} - T_H$

Where:

$$T_{MAXA} = T_{MAX} + [\text{Cooling Capacity} \times (\text{E.E.R.} + 3.412/\text{E.E.R.}) / (\text{GPM} \times 1000)]$$

**Figure 7.6**  
**Zone Map**



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# *8 System Design and Installation*

## *Selecting a System*

Before sizing the proper GeoSource heat pump a survey of the consumers needs must be made. You will need to determine:

1. Structure heat loss and heat gain.
2. Well water or earth loop system.
3. Forced air or hydronic.
4. If cooling is desired.
5. Domestic hot water needs.

In any GeoSource application a decision must be made, how best to extract stored thermal energy from the earth. Applications where well water is available and discharge to a lake, pond, stream or low lying area is convenient an open system is a excellent choice.

Where supply water or suitable discharge is not available, a horizontal earth loop, or a slinky loop is an option.

If space is at a premium a verticle earth loop system can be installed in a very small area making it a excellent choice for systems restricted by space.

## *Sizing the Heat Pump*

### *Residential*

In residential application in the Northern climates there is little question that a GeoSource heat pump should be sized to 100% of the heating load. Although some nationally recognized HVAC organizations recommend that heat pump sizing to accommodate the heating load be limited to 125% of the cooling load, a growing body of experience with GeoSource heat pumps have shown that sizing to the heat load and over sizing cooling as much as

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200% will enhance the economics of winter time operating by reducing or eliminating the need for supplemental electric heat, and still offer excellent dehumidification in the summer time. This is due to the variable capacity cooling of the GeoSource's high density air coil.

### ***Commercial***

When sizing commercial applications care must be taken. Often cooling load can exceed heating load. A GeoSource system should be sized by heating or cooling load which ever is the largest.

### ***Entering Water***

When sizing to a structures heating and cooling loads you must size the heat pump according to the entering water temperature. Well water systems generally supply a constant 50 degrees entering water temperature, where as a earth loop system sized will supply 25-30 degrees entering water temperature.

#### Model GV421-1-T000

Entering Water Temperature	Capacity (BTUH)
25°F	36,800
50°F	42,000

#### Model GV491-1-T000

Engineering Water Temperature	Capacity (BTUH)
25°F	41,200
50°F	50,800

Using the above table, a structure requiring 41,000 BTUH on a well water application the model GV421-1-T000 would be adequate. If the same structure was installed as a earth loop it would be necessary to use model GV491-1-T000.

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## ***9 Maintenance***

GeoSource heat pumps are extremely well constructed and reliable. Aware of the dependability of GeoSource heat pumps, extended warranties, and long term service contracts are readily available. With proper maintenance, GeoSource heat pumps can have a long and trouble free life.

Basic maintenance is much like all mechanical equipment, they perform best when they are faithfully maintained. Basic maintenance tasks include equipment inspections and routine cleaning.

### ***Filter Inspection***

Throw-away fiberglass filters that are commonly used with heat pumps should be inspected every three months and changed as follows:

1. Turn the heat-cool thermostat switch to OFF and the fan switch to AUTO.
2. If the fan continues to run, wait until it turns off.
3. Change or clean filter, depending on filter type.

Newer types of commercial zig-zag high efficiency filters which are now available for residential applications require less frequent maintenance. Typically, the filtering media needs to be replaced only once per year.

### ***Pre-Season Inspection***

Before each season, the cooling coil, drain pan and condensate drain should be inspected and cleaned as follows:

1. Turn off circuit breakers.
2. Remove the coil access panel.
3. Clean coil by vacuuming it with a soft-brush attachment.
4. Remove any foreign matter from the drain pan.
5. Flush pan and drain tube with clear water.

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## ***Fan Motor Lubrication***

Fan motors should be lubricated every three years or in accordance with motor manufacturer instructions as follows:

1. Locate oiling holes at each end of the fan motor.
2. Lubricate with 16 drops per hold of SAE 10 nondetergent oil.

## ***Return Air Grille Inspection***

Return air grilles should be examined periodically to ensure that no furniture, rugs, etc. are blocking air flow into the home.

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## *10 Glossary*

**Ambient Air**

The surrounding air.

**Air Changes Per Hour:**

Airflow quantity, expressed as the number of times per hour the volume of the house is exchanged with outside air.

**Air Flow:**

The distribution or movement of air.

**Air Source Heat Pump:**

A heat pump that uses as its heat /sink.

**Balance Point:**

The temperature above which the heat pump can provide enough heat for the home without the use of supplemental heating.

**British Thermal Unit: (Btu)**

A heat unit equal to the amount of heat required to raise one pound of water one degree Fahrenheit.

**Coefficient of Performance:**

A ratio calculated by dividing the total heating capacity (Btuh) by the total electrical input (watts) x 3.413.

**Degree Day:**

A measure of the severity and duration of an outdoor temperature deviation above or below a fixed temperature (65F), used in estimating the heating or cooling requirement and fuel consumption of a building for either summer or winter conditions.

**Design temperature, Summer:**

A specific temperature used in calculating the cooling load of a building. The summer design temperature is typically the outdoor air temperature that is exceeded 2.5% or 5% of the time.

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**Design Temperature, Winter:**

A specific temperature used in calculating the heating load of a building. The winter design temperature is typically the outdoor temperature that is exceeded 97.5% or 95% of the time.

**Desuperheater**

A device for recovering superheat from the compressor discharge gas of a heat pump for use in heating or preheating water.

**Energy Efficiency Ratio: (EER)**

A ratio calculated dividing the cooling capacity in Btuh by the power input in watts at any given set of rating conditions, expressed in Btuh per watt.

**Filter:**

A device to remove solid dust and other particles from the air.

**Free Area**

The total minimum area of the openings in the air outlet or inlet through which air can pass.

**GeoSource Heat Pump:**

A heat pump that uses the earth itself as a heat source and heat sink. It is coupled to the ground by means of a earth loop heat exchanger (ground coil) installed horizontally or vertically under ground.

**Heat:**

A form of energy. Heat exists in a substance down to approximately -460F.

**Heat Gains:**

As applied to HVAC calculations, it is that amount of heat gained by a space from all sources, including people, lights, machines, sunshine, etc. The total heat gain represents the amount of heat that must be removed from a space to maintain indoor comfort conditions.

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**Heat Joining:**

Making a joint by heating the mating surfaces of the pipe components to be joined and pressing them together so that they fuse and become essentially one piece.

**Heat Loss:**

The sum cooling effect of the building structure when the outdoor temperature is lower than the desired indoor temperature. It represents the amount of heat that must be provided to a space to maintain indoor comfort conditions.

**Heat, Latent:**

The quantity of heat required to effect a change in state.

**Heat Pump:**

A mechanical device used for heating and cooling which operates by pumping heat from a cooler to warmer location. Heat pumps can draw heat from a number of sources, e.g., air, water, or earth, and are classified as either air-source, water-source, or ground-source units.

**Heat, Sensible:**

Heat that results in a temperature change but no change in State.

**Heat Sink:**

The thermal reservoir to which energy can be added through heat transfer.

**Heat Source:**

The thermal reservoir from which energy is withdrawn through heat transfer.

**Heating Season Performance Factor: (HSPF)**

Total heating output of a heat pump during its normal annual usage period for heating divided by the total electric power input during the same period. Expressed in Btu/watt.

**Humidity, Relative:**

A measurement indicating moisture content of air.

**HVAC:**

Heating, ventilating, and air conditioning.

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**Hydronic:**

A heating or cooling distribution system using liquid piped throughout the building to radiators, convertors or floor pipe.

**Infiltration**

The process by which outdoor air leaks into a building by natural forces through cracks around doors and windows, etc.

**Joint, Socket-Fused:**

A joint in which the two pieces to be heat fused are connected using a third fitting or coupling with a female end.

**Life-Cycle Costing:**

A method of analyzing the cost of HVAC systems that considers all the significant costs of ownership, including the time value of money, initial capital investment, energy costs and maintenance costs over the service life of each system under consideration.

**Natural Convection Currents:**

Air currents created by a buoyancy effect caused by the difference in temperature between the room air and the air in contact with a warm or cold surface.

**Night setback**

Setting the thermostat lower (in heating) at night to reduce the heat loss.

**Outlet Velocity:**

The average velocity of the supply air, measured as it passes through the plane of the opening in the supply outlet

**Performance Factor:**

The ratio of useful output capacity of a system to the input required to obtain it. Units of capacity and input need not be consistent.

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**Purge Pump:**

A high-pressure and high-flow-rate pump used to flush air and debris from the earth loop circuit of a earth loop/GeoSource heat pump system.

**R-Value:**

The resistance to heat flow expressed in units of Sq. Ft. hour Degree F/Btu.

**Refrigerant:**

A fluid of extremely low boiling point used to transfer heat between the heat source and heat sink. It absorbs heat at low temperature and low pressure and rejects heat at a higher temperature and higher pressure, usually involving changes of state in the fluid (i.e., from liquid to vapor and back).

**Register:**

A grille which is equipped with a damper or control valve, and which directs air in a non-spreading jet.

**Return:**

Any opening through which air is removed from a conditioned space.

**Seasonal Energy Efficiency Ratio (SEER):**

A measure of seasonal cooling efficiency under a range of weather conditions assumed to be typical of location, as well as of performance losses due to cycling under part-load operation.

**Simple Payback Method:**

A method for analyzing the cost of HVAC systems which considers only the time it takes for annual energy and maintenance cost savings to offset an initial difference in cost between two systems.

**Supplemental Heating:**

A backup heating system used when a heat pump is operating below the balance point usually electric resistance heat, but natural gas, LPG, or oil heating systems are also used.

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**Therm:**

A quantity of heat equivalent to 100,000 Btu.

**Thermostat:**

An instrument that responds to changes in sensible air temperature, and which is used to directly or indirectly control indoor temperature.

**Throw (Blow):**

The horizontal distance an air stream travels after leaving a horizontal sidewall outlet before the maximum velocity is reduced to the terminal velocity. For a perimeter outlet, throw is the vertical distance the air stream travels before the maximum velocity is reduced to the terminal velocity.

**Ton of Refrigeration:**

A measure of cooling delivered by a heat pump (or other air conditioning system) equal to 12,000 Btu per hour.

**U-Bend:**

A prefabricated close-return pipe assembly used in vertical heat exchangers to connect the two pipes at the bottom of the bore hole.

**Water-Source Heat Pump:**

A heat pump that uses a water-to-refrigerant heat exchanger to extract heat from a boiler source and reject heat to a cooling tower.

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**Table 4.6**  
**Equivalent Cooling Load**  
**Temperature Difference**

Design Temp. Diff. Deg. F	10		15			20			25				30		35	
Daily Temp. Range	L	M	L	M	H	L	M	H	M	H	H	H				
<b>WALLS AND DOORS</b>																
1. Frame & veneer-on-frame	17.6	13.6	22.6	18.6	13.6	27.6	23.6	18.6	28.6	23.6	28.6	33.6				
2. Masonry walls, &in. block or brick	10.3	6.3	15.3	11.3	6.3	20.3	16.3	11.3	21.3	16.3	21.3	26.3				
3. Partitions, frame masonry	9.0	5.0	4.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0				
4. Wood doors	17.6	13.6	22.6	18.6	13.6	27.6	23.6	18.6	28.6	23.6	28.6	33.6				
<b>CEILING AND ROOFS</b>																
1. Ceilings under naturally vented attic or vented flat roof - dark	36.0	34.0	43.0	39.0	34.0	48.0	44.0	39.0	49.0	44.0	49.0	54.0				
- light	30.0	26.0	35.0	31.0	26.0	40.0	36.0	31.0	41.0	36.0	41.0	46.0				
2. Built-up roof, no ceiling - dark	38.0	34.0	43.0	39.0	34.0	48.0	44.0	39.0	49.0	44.0	49.0	54.0				
- light	30.0	26.0	35.0	31.0	26.0	40.0	36.0	31.0	41.0	36.0	41.0	46.0				
3. Ceilings under unconditioned rooms	9.0	5.0	14.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0				
<b>FLOORS</b>																
1. Over unconditioned rooms	9	5.0	14.0	10.0	5.0	19.0	15.0	10.0	20.0	15.0	20.0	25.0				
2. Over basement, enclosed crawl space or concrete slab on the ground	0	0	0	0	0	0	0	0	0	0	0	0				
3. Over open crawl space	9.0	5.0	4.0	10.0	5.0	9.0	15.0	10.0	20.0	15.0	20.0	25.0				