Geothermal Energy Using Water-Source Heat Pumps

By

VIRSTAR Corporation
Geothermal Expertise Since 1978

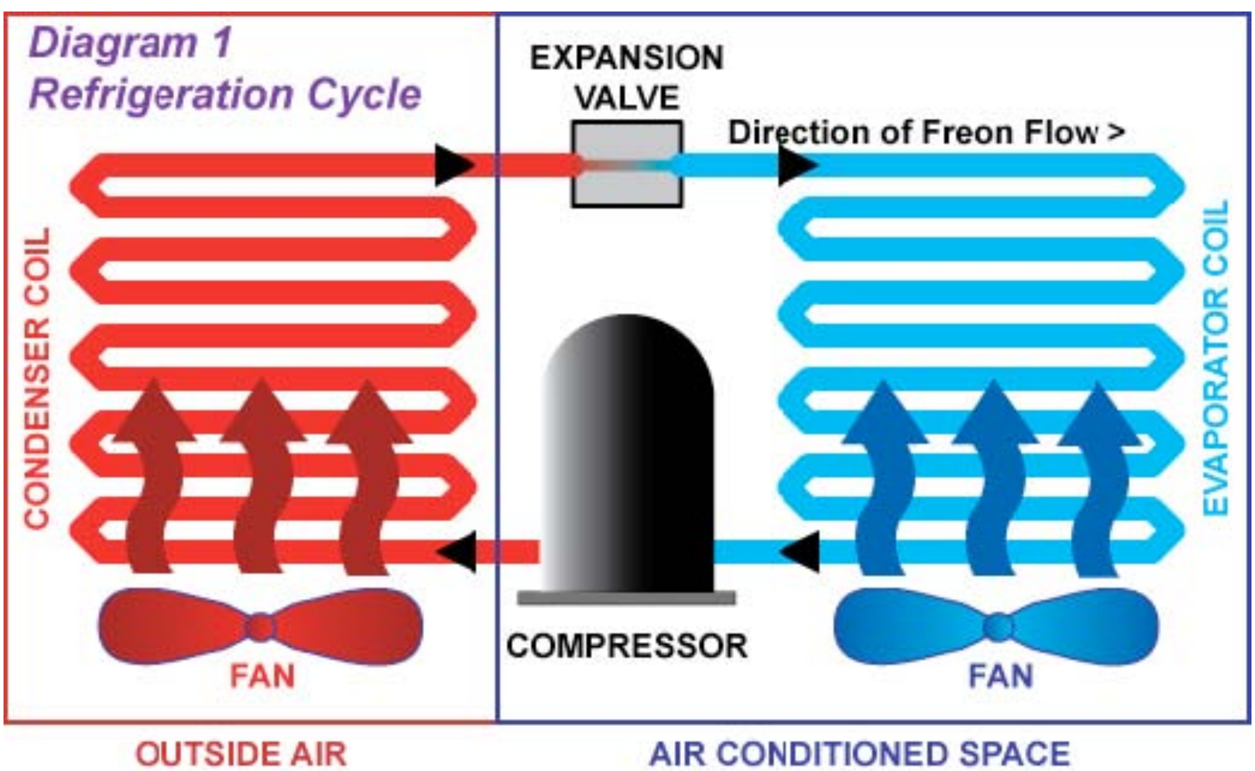
This document discusses the use of *Water-Source Heat Pumps* in *Geothermal Energy Systems* for use in HVAC (Heating Ventilation & Air Conditioning) applications.

The diagrams contained herein are simplified to educate layman readers about the energy saving benefits of using Geothermal Energy, and not intended for use as a design or installation manual. Only an experienced professional should do geothermal system design.

Basic Refrigeration Principals

A *Water-Source Heat Pump* (WSHP) is a type of HVAC equipment that has the ability to both heat and cool using water as its source of energy. WSHP systems are considered to be the most efficient way to both heat and cool available today.

To understand how a WSHP works, you need to first understand the principles behind basic refrigeration (or air conditioning). The *Refrigeration Cycle Diagram* below (Diagram 1) illustrates the basic operation of any air conditioner or refrigerator.



1 The Compressor compresses the Freon Gas, located inside of the coils, causing it to become a very hot liquid under high-pressure, and pushes it into the Condenser Coil (in **Red** above).

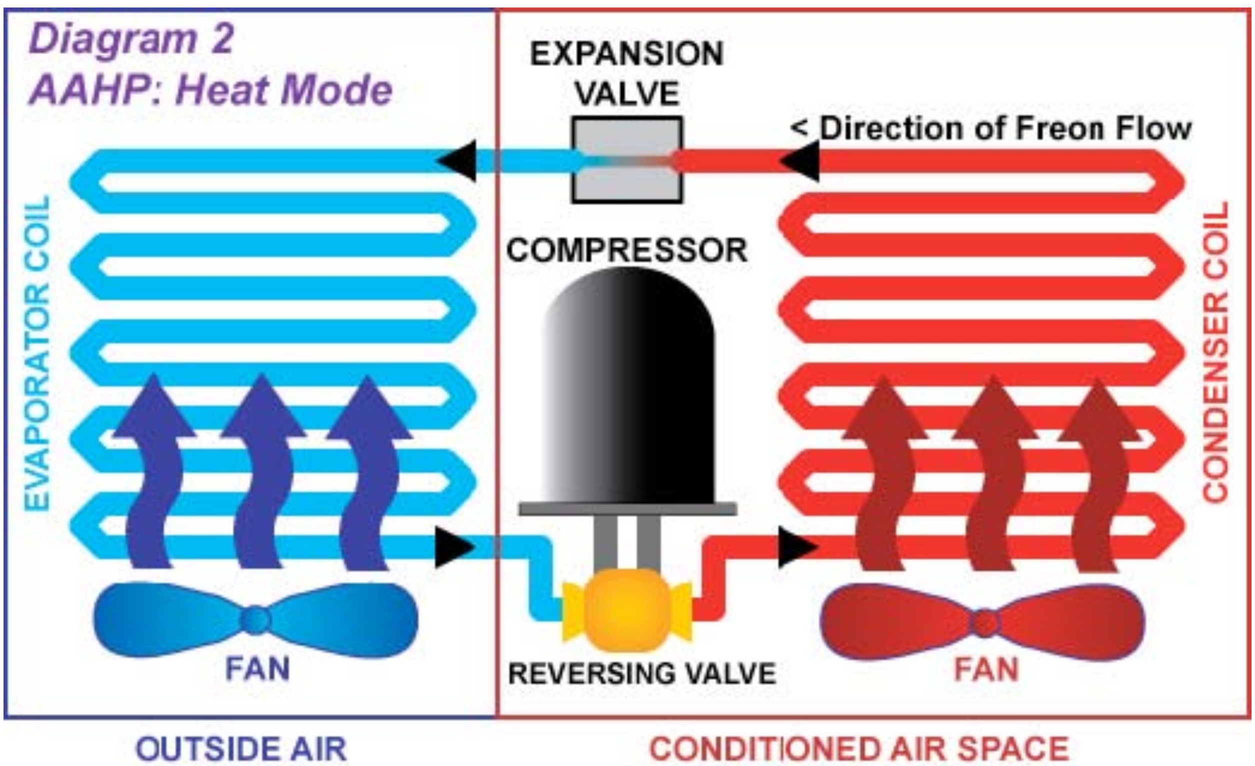
2 The hot high-pressure Freon Liquid runs through the Condenser Coil, losing its heat to the outside air as it flows, and the liquid equalizes to the outside air ambient temperature as it cools.

3 When the cooled Freon Liquid goes through the Expansion Valve, the liquid evaporates back into its gaseous form in the Evaporator Coil (in **Blue** above) and gets very cold in the evaporation process.

4 As the very cold Freon Gas flows through the Evaporator Coil, the Fan blows air over the coil, chilling the air, thereby providing cooling for the Air Conditioning Space, and warming the Freon Gas in the process to the ambient air temperature of the space.

The first commercially available heat pumps were *Air-to-Air Heat Pumps* (AAHP). These HVAC units were exactly like a standard air conditioner with two key exceptions. First, a device called a Reversing Valve was added into the Freon loop, and second, both of the coils were made to be capable of being either a condenser or evaporator coil, as determined by the Reversing Valve flow direction, and handle high pressures.

In cooling mode, the AAHP operation would look exactly like Diagram 1 above. The *Air-to-Air Heat Pump: Heat Mode* diagram below (Diagram 2) illustrates the basic operation of an AAHP heating a conditioned air space.



1 The Compressor compresses the Freon Gas, located inside of the coils, causing it to become a very hot liquid under high-pressure, and pushes it into the Reversing Valve (in **Gold** above).

2 If the system thermostat is set to heating, then the Reversing Valve sends the hot high-pressure Freon Liquid into the coil located in the Conditioned Air Space (in **Red** above). Whichever coil receives the hot high-pressure Freon Gas, as directed by the Reversing Valve, automatically acts as the Condenser Coil and the other coil acts as the Evaporator Coil.

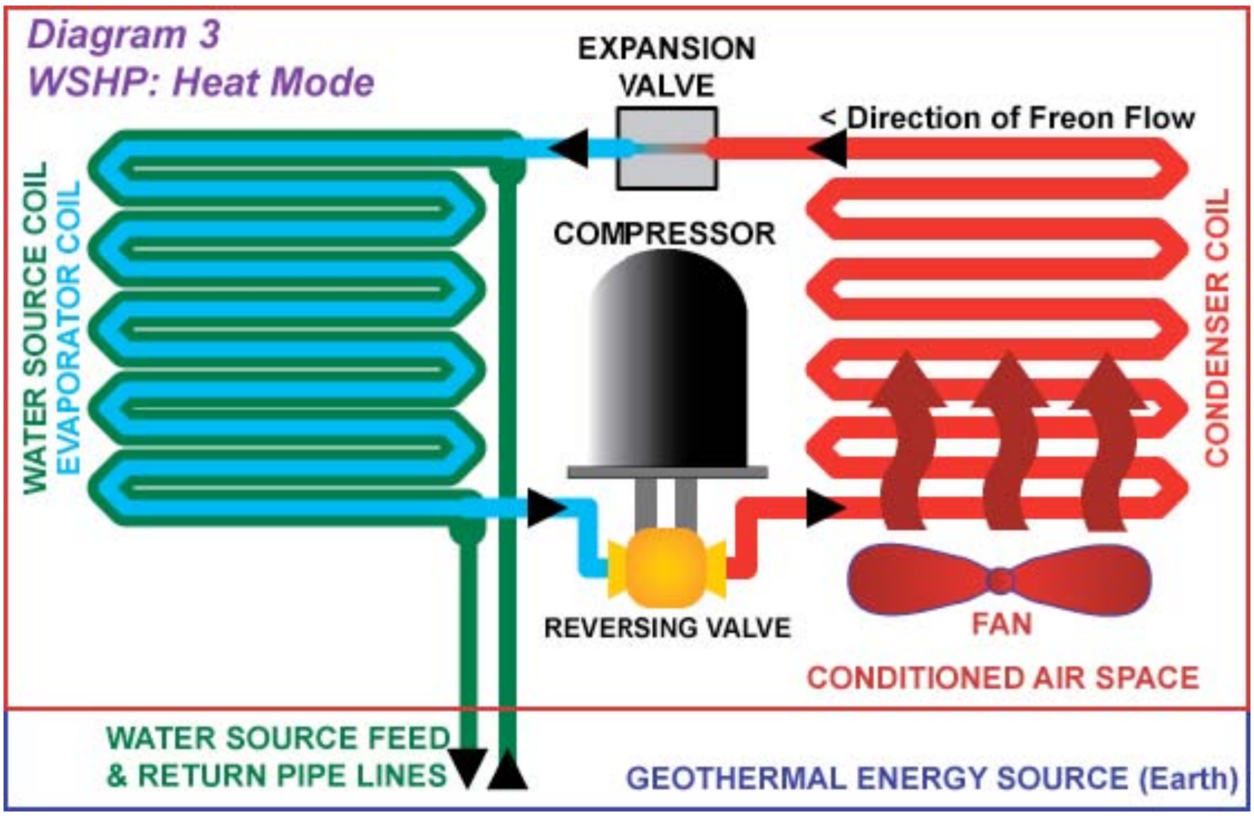
3 As the hot high-pressure Freon Liquid runs through the Condenser Coil, the Fan blows air over the coil, heating the Conditioned Air Space and cooling the Freon Liquid. The liquid cools to the ambient room air temperature as it flows through the Condenser Coil.

4 When the cooled Freon Liquid goes through the Expansion Valve, the liquid evaporates back into its gaseous form in the Evaporator Coil (in **Blue** above) and gets very cold in the evaporation process.

5 As the very cold Freon Gas flows through the Evaporator Coil, the Fan blows outside air over the coil, chilling the outside air and warming the Freon Gas in the process. However, if it is too cold outside, ice will start to form on the coil and block airflow as it builds up. At a certain point of ice buildup, the unit must run a defrost cycle (which uses lots of energy) to clear the ice. For this reason, Air-to-Air Heat Pumps do not work well and are not recommended for use in Northern climates.

With the failure of AAHP systems in Northern climates, heat pump manufacturers began developing heat pumps that utilized water instead of outside air to obtain their energy, and a revolutionary way to heat and cool was born.

Heat pumps that use water for their energy source are called *Water-Source Heat Pumps* (WSHP). The *Water-Source Heat Pump: Heat Mode* diagram shown below (Diagram 3) illustrates the basic operation of a WSHP heating a conditioned air space.



1 The Compressor compresses the Freon Gas, located inside of the coils, causing it to become a very hot liquid under high-pressure, and pushes it into the Reversing Valve (in **Gold** above).

2 If the system thermostat is set to heating, then the Reversing Valve sends the hot high-pressure Freon Liquid into the coil located in the Conditioned Air Space (in **Red** above).

3 As the hot high-pressure Freon Liquid runs through the Condenser Coil, the Fan blows air over the coil, heating the Conditioned Air Space and cooling the Freon Liquid. The liquid cools to the ambient room air temperature as it flows through the Condenser Coil.

4 When the cooled Freon Liquid goes through the Expansion Valve, the liquid evaporates back into its gaseous form in the Evaporator Coil (in **Blue** above) and gets very cold in the evaporation process.

5 In a WSHP, the Evaporator Coil is a tube sealed inside of another larger tube filled with water and called the Water Source Coil (in **Green** above). This is known as a *Tube-In-A-Tube Heat Exchanger*.

6 As the very cold Freon Gas flows through the Evaporator Coil, the water in the Water Source Coil flows over the Evaporator Coil, chilling the water and warming the Freon Gas in the process. Since water from the Earth is a constant temperature (approximately 54°F in the Northeast), the WSHP is not subject to freezing like an AAHP unit, and operates without any problem regardless of outside temperatures. Because it has a constant source of 54°F energy, the WSHP is extremely efficient; up to 300% more efficient than conventional heating systems according to the US Department of Energy.

Since the energy that Water-Source Heat Pumps utilize comes from the ground, they are also known as *Ground Source Heat Pumps* (GSHP). The name for a system that utilizes the Earth as its energy source is called a *Geothermal Energy System* (Geo), and there are many different types of Geo Systems. In this paper we focus only upon Geo Systems that use water from the Earth (i.e.- well water) as their energy source.

A heat pump does not generate energy from fuel, but rather "pumps" or transfers heat from one place to another. In the case of a WSHP in heating mode, it pumps heat from water in the Earth into the building to be heated, whether it is a home, a school, an office building, or any other type of structure. In cooling mode, the process simply reverses and the building heat is pumped into the Earth. Below is a picture of an actual Water-Source Heat Pump (Diagram 4) annotated to reference Diagram 3 above.

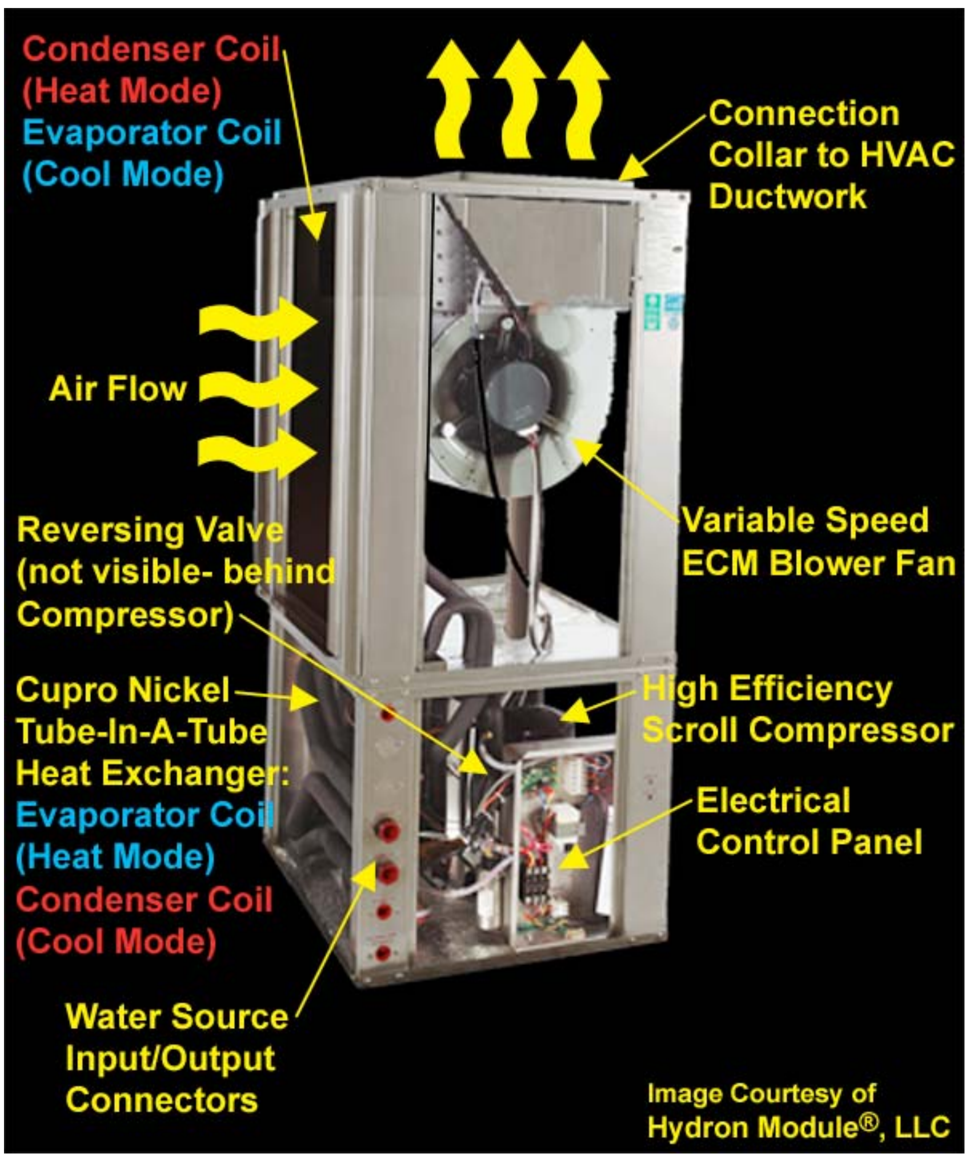
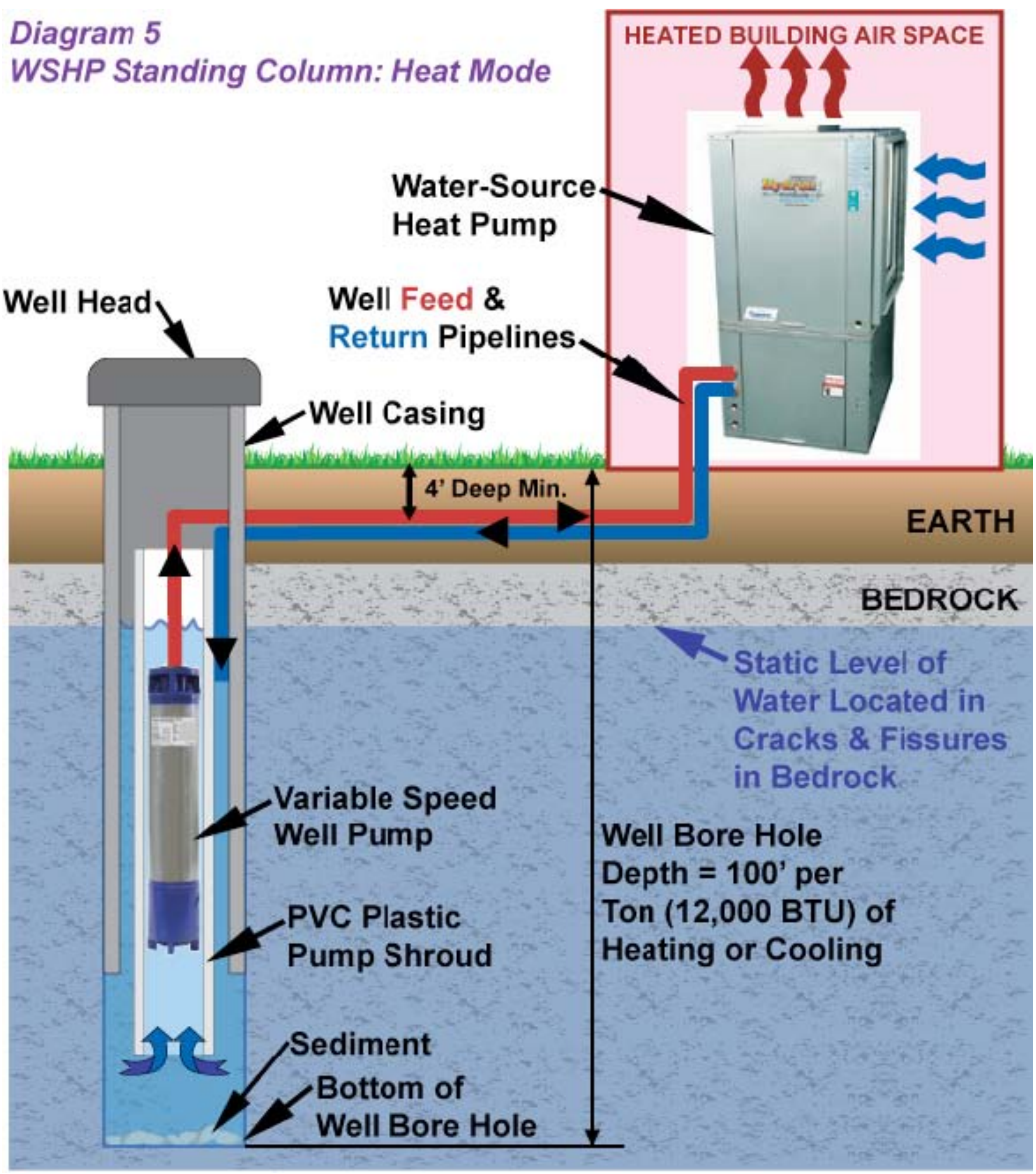


Diagram 4: Water-Source Heat Pump Unit

The *WSHP Standing Column: Heat Mode* diagram below (Diagram 5) illustrates the *Standing Column* method for utilizing well water with a Water-Source Heat Pump.



1. In a Standing Column WSHP system, the Well Pump is enclosed inside of a PVC plastic pipe (called a "Shroud") that runs from several feet above the well's Static Level all the way to the bottom of the well. The Shroud acts like a big drinking straw and enables the Well Pump to draw water from the bottom of the well while being physically located near the top of the well (more energy efficient).
2. The depth of the well is determined from the amount of heating or cooling that is needed. A home of 2,000 sq.ft. needs approximately 4 tons (48,000 BTU/Hour) of heating/cooling and would require a well depth of 400' (100' per ton) plus the static level distance and an extra 25' or so to allow for sediment build up.

3 The Well Casing is a steel tube that is fitted into the Well Bore Hole after drilling that prevents surface water from contaminating the well water and keeps dirt and unstable rock from collapsing into the Well Bore Hole. The Well Casing is driven into the Bore Hole until it is substantially imbedded into stable Bedrock. A depth of 80' or more is typical. The Well Head is a cap for the Casing.

4 The Variable Speed Well Pump is sized to match the water flow needs of the Water-Source Heat Pump. For example, a 4-ton Hydron Module WSHP requires a 9.0 GPM (gallons per minute) water flow at full capacity operation, but only 6 GPM at low capacity operation. The Variable Speed Well Pump adjusts its pumping speed automatically to match the WSHP's needs, thereby saving energy. If the same well is used for the domestic water supply, this Pump also automatically compensates for water use in the home, and it does it so fast that a person in the shower when the WSHP turned on would not notice any change in water pressure. The Pump holds constant pressure at all times.

5 When the WSHP is told by the thermostat that it needs to provide heat, the Well Pump begins flowing water from the bottom of the well (approximately 54°F) through the Well Feed Pipeline (in **Red** above) into the Water Source Coil inside of the WSHP unit. The well water warms the Freon gas in the Evaporator Coil and leaves the WSHP much colder (approximately 42°F).

6 The cold well water flows back to the well through the Well Return Pipeline (in **Blue** above) that ends at the top of the well between the Shroud and the Casing at a point below the well's Static Level. (The Static Level is also known as the height of the local "Water Table".) As the cold return water enters the top of the well, it flows between the Shroud and the Casing (a 1" wide space) and absorbs heat from the surrounding Bedrock as it flows toward the bottom of the well.

7 By the time the return water reaches the bottom of the Shroud, it has been warmed by the Earth back to its normal (54°F) temperature. The water is now ready to be used all over again. This is the main advantage of the Standing Column system; no water is consumed during normal operation. This is an *Open Loop* system that recycles the same water, but can take in new water from the aquifer as needed. It uses non-reactive (no rust) HPDE piping and Cupro Nickel Heat Exchangers (Nickel is a natural anti-bacterial material), so the water is never exposed to any other sources of contamination. The water is filtered before it enters the WSHP (filter not shown) and actually returns to the well cleaner than it was originally!

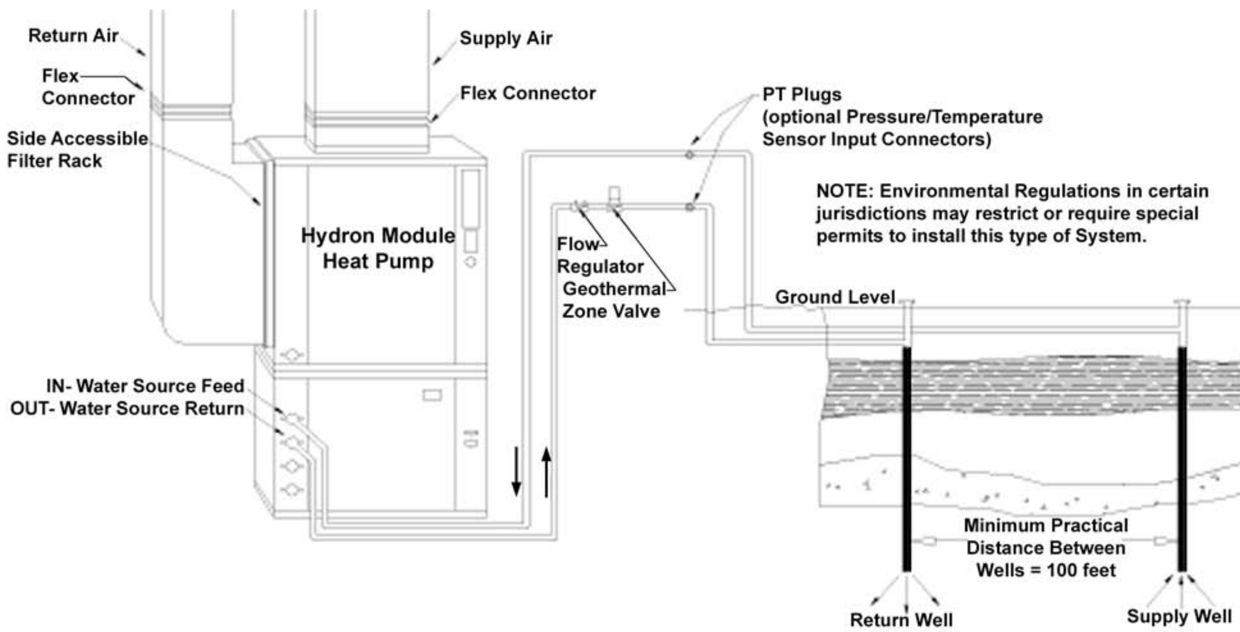
In the Northeastern USA, water from the typical well is a constant temperature (approximately 54°F) during the entire year. As such, severe outdoor temperatures do not affect the WSHP's operation. Yes, it runs longer on very cold or very hot days, but its efficiency remains constant. In fact, the Hydron Module® unit shown in Diagram 4 & 5 above is manufactured and widely used in South Dakota; a place where winter temperatures of **-40°F** and summer temperatures of **110°F** are common.

In the event that the well gets too hot (in A/C mode) or too cold (in Heat mode) due to prolonged extreme weather conditions (or maybe an addition was added to the home making the well too shallow for the load), a well temperature sensor opens a valve on the Well Return Pipeline and a small amount of water is "rejected" and not returned to the well. This rejected water can be sent to a dry well, a nearby stream or pond, or used to water your garden or lawn.

The rejected water causes the Static Level in the well to fall. This causes new water from the surrounding Bedrock to flow into the Bore Hole and the water level in the column of well water returns to its normal Static Level. Since this fresh water is at the normal Earth temperature (54°F), the well temperature also returns to normal.

There are many other ways to utilize well water with a Water-Source Heat Pump. The following diagrams, provided courtesy of Hydron Module, LLC, illustrate some of the more popular methods.

Hydron Module: Open Loop Well-to-Well System

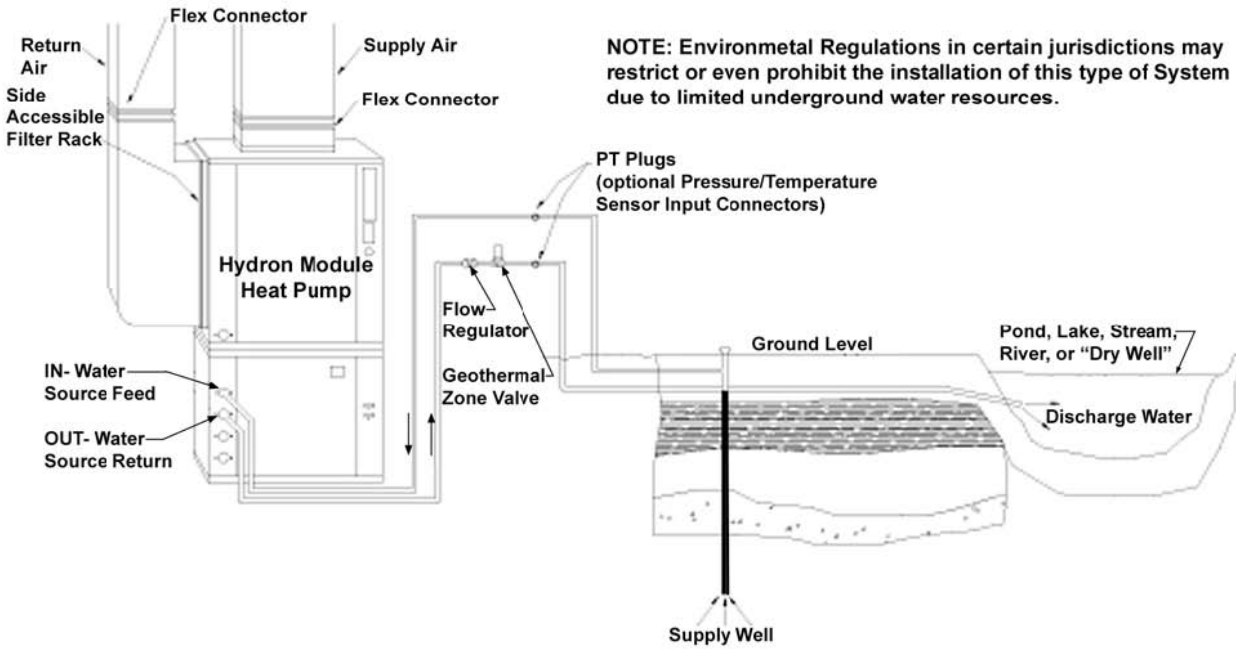


The *Well-to-Well System* illustrated above is called an "Open Loop" system because it discharges (does not cycle or reuse) the well water after the WSHP extracts the energy it needs. The Source Feed Water is pumped from the Supply Well, run through the WSHP once, and "rejected" to another location; in this case, to a second Return Well (that has no pump).

The Supply Well must have a very good and constant flow of water since it is being pumped down every time the WSHP runs. If the well runs dry, the entire system will fail. However, it is quite common for wells in close proximity to be drilled into the same aquifer (underground water source). In this case, the water will actually flow from the Return Well to the Supply Well underground, and the water will be recycled in the same manner as the Standing Column except that it returns through the aquifer.

The Supply Well in a Well-to-Well System does not have a Shroud, but you do have the expense of drilling two wells. This System is slightly more efficient than a Standing Column since you are always using fresh ground temperature (54°F) water and have no issues with the well getting too hot or too cold.

In certain communities, environmental regulations restrict the use of Well-to-Well Systems since the Open Loop discharge of water is considered wasteful. Regions that have limited underground water resources are right to have such concerns.



Hydron Module: Open Loop Pump-and-Dump System

The "*Pump & Dump" System* illustrated above is so named because it discharges (does not cycle or reuse) the well water after the WSHP extracts the energy it needs. The Source Feed Water is pumped from the Supply Well, run through the WSHP once, and "rejected" to a body of surface water (pond, lake, stream, river, etc.) or to a "Dry Well" (a large pit filled with sand or gravel with a high rate of drainage).

The Supply Well must have a very good and constant flow of water since it is being pumped down every time the WSHP runs. If the well runs dry, the entire system will fail. Regardless of how faithful you may think your well will be, it is wise to have a backup heating system for a Pump & Dump System.

The Supply Well in a Pump & Dump System does not have a Shroud, but you do have the issue of discharging up to 720 gallons per hour for a 4-ton WSHP. This may flood a small pond, and installing a Dry Well large enough to handle this volume of water can be quite expensive.

This System is slightly more efficient than a Standing Column since you are always using fresh ground temperature (54°F) water and have no issues with the well getting too hot or too cold. But you do have a big issue if the well goes dry.

In certain communities, environmental regulations restrict or prohibit the use of Pump & Dump Systems since the Open Loop discharge of water is, in this case, truly wasteful. Unlike the Well-to-Well System, the Pump & Dump System does not return the water directly to the aquifer. Regions that have limited underground water resources are right to have such concerns.

There are many other ways to supply sufficient energy to Water-Source Heat Pump Systems. The following list gives a brief description of a few other methods.

1 *Reservoir System*- If the building you want to heat/cool is in a city or you want to use an additional source of heat (i.e.- Solar Panels), a WSHP Reservoir System might be the best solution. The WSHP draws its water from a large tank (5,000+ gal.) instead of directly from a well. The water for the tank may come from any source including city water since the water is constantly recycled. It is heated by an outside source such as Solar Panels or another WSHP that is in constant cooling mode (i.e. for an ice rink or refrigeration duty). It is cooled by a Chiller that is located outdoors. This method becomes especially attractive if your "reservoir" is actually an indoor swimming pool. (This is what we have at VIRSTAR headquarters.)

2 *Lake Loop System*- If the building you want to heat/cool is located next to a large body of water (including the Ocean), you might want to consider a WSHP Lake Loop System. To obtain its energy, the WSHP circulates treated water (glycol antifreeze) through a closed loop coiled length of HDPE pipe. The pipe coils are submerged into the body of water, and heat transfer between the relatively warm (+38°F) water and the cold (+18°F) glycol solution provides the energy that the WSHP needs.

3 *Horizontal Ground Loop System*- Similar to the Lake Loop System, the Horizontal Ground Loop System buries the HDPE pipe coils underground in long trenches that are 12' or more deep. At this depth, the soil provides a constant temperature source (approximately 42° in the Northeast) to provide energy for the WSHP. The glycol solution absorbs its energy from the soil and transports it to the WSHP. VIRSTAR does not use this type system in any Northeast installation because of the high level of rock.

4 *Vertical Ground Loop System*- If you don't have a big enough yard to install the long horizontal trenches or you have rock at shallow depths, the Vertical Ground Loop System might be the answer. It inserts a single HDPE pipe coil into each of many small diameter bore holes that are typically drilled to 200' deep. At this depth, the Earth provides a constant temperature source (approximately 54° in the Northeast) to provide energy for the WSHP. The glycol solution absorbs its energy from the ground surrounding the borehole and transports it to the WSHP.

Conclusion

No matter what your heating or cooling needs may be, there is a Water-Source Heat Pump solution to meet your needs. While the cost of installing a WSHP is typically twice as expensive as a conventional HVAC system, the tremendous cost savings in operation allow the systems to pay for themselves in just a few years.

Please consider Geothermal Energy if you are building a new facility or replacing an existing HVAC system. You will not only save money on energy every year, you will also help reduce green house gas emissions and cut our dependency on foreign oil.

Thank You!