Ground Source Heat Pumps

Lale Valizade

***Abstract*—A heat pump is a device that is able to transfer heat from one fluid at a lower temperature to another at a higher temperature. Ground source heat pumps are generally classified by the type of ground loop. The coefficient of performance (COP) is used to define the heating performance of heat pumps. Both the COP and EER values are valid only at the specific test conditions used in the rating. A ground source pump could reach 450%, compared with an efficient gas boiler of 90% obviously this is a big difference. The cost of equipment, material and installation can be expensive, depending on the type of heat pump installation planned.**

***Index Terms*—Heat Pump, ground source heat pumps, COP, air source heat pumps.**

I. Introduction

A heat pump is a device that is able to transfer heat from one fluid at a lower temperature to another at a higher temperature [1]. Heat pumps can be categorized on the basis of the cold source and hot source that they use. According to the fluid used for the transfer of heat from the cold source to the heat pump, and from the heat pump to the hot source, there may be four types:

AIR-WATER: The heat pump draws heat from the cold source, which consists of air (external), and transfers it to the hot source, which consists of a water circuit (for the heating of the rooms) [2].

AIR-AIR: The heat pump draws heat from the cold source, which consists of air (external), and transfers it to the hot source, which likewise consists of air (that of the heated environment) [2].

WATER-WATER: The heat pump draws heat from the cold source, which consists of water (from lakes, rivers or the water table) and gives it off to the hot source, which consists of a water circuit (for the heating of the rooms) [2].

WATER-AIR: The heat pump draws heat from the cold source, which consists of water (from lakes, rivers or the water table) and gives it off to the hot source, which consists of air (that of the heated environment) [2].

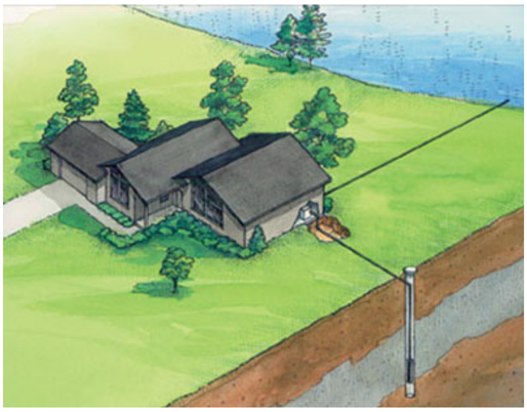
AIR as a cold source possesses the advantage of being available everywhere; in any case, as the temperature of the cold source falls, so does the output supplied by the heat pump. If external air is used, a defrosting system is needed at temperatures of around 0ºC, which entails additional energy consumption. During this phase the heat pump uses the heat of the hot source in order to defrost the battery and so heating ceases for some minutes [2].

WATER as a cold source ensures optimal performance of the heat pump without it suffering from the effects of external climatic conditions; however it entails additional cost, due to the system of water adduction [2].

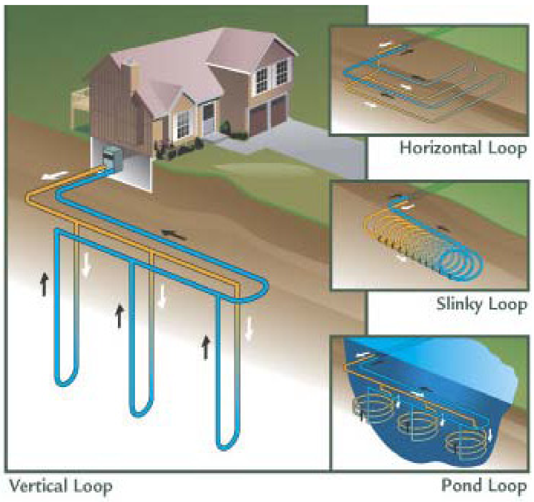
The GROUND as a cold source possesses the advantage of undergoing less temperature changes than the air [2].

II. Ground Source Heat Pumps

Ground source heat pumps are generally classified by the type of ground loop (see Fig. 1). Market share of each type varies by country depending on site characteristics, promotion, and applications [3].



a) Open Loop



b) Closed Loop

Fig. 1. Residential Ground Loops

Open loop systems, or "groundwater source" heat pumps, shown in Fig. 1 (a), are the oldest and cheapest type of GSHP system, assuming the groundwater is suitable for use. Open loop systems have been in common use since the 1970's. In such systems, groundwater is used as the heat carrier and is brought directly to the heat pump. The water is discharged

Manuscript received October 26, 2012; revised January 22, 2013.
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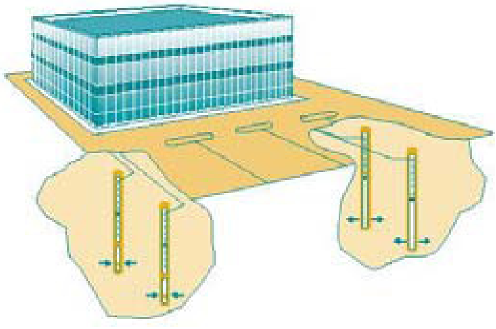
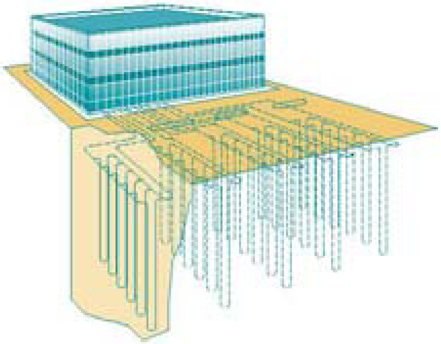
either back into the well or into a body of surface water. These systems require an ample, shallow, and pure supply of groundwater. Because of their effect on the community groundwater, municipal regulations sometimes inhibit the installation of open loop systems [3].

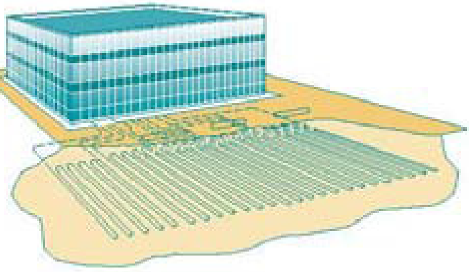
Closed loop, or ground coupled, systems use a loop containing water or a glycol solution through the ground loop and use a refrigerant loop to transfer the heat to the heat pump (Fig. 1. b). The ground loop can be laid vertically or horizontally in the ground, or occasionally laid in a pond or lake [3].



a) Open Loop (Groundwater)



b) Vertical Closed Loop



c) Horizontal Closed Loop. [3]

Fig. 2. Commercial/Institutional Ground Loops

The vertical configuration involves a borehole drilled to a depth of 150 to 220 ft per ton of capacity. The vertical loop has a smaller ground surface area requirement, typically 200-400 ft^2 (5-10 m^2/kW), which makes it more feasible for small properties, but it adds on significant drilling costs to the total installation cost of the system [3].

The horizontal loop is usually a less expensive option, because it only involves digging a 4-5 ft trench as opposed to a deep well. However, it requires much more space, and the ground temperature is subject to seasonal fluctuation at shallow depths. The horizontal trench length ranges from 125 to 300 ft per ton of capacity. The length of pipe necessary is a function of system size, climate, soil/rock thermal characteristics and loop type. The ground surface area necessary for a typical horizontal loop ranges from 2000 ft^2 to 3500 ft^2 per ton (50-90 m^2/kW) [3].

A variation of the horizontal loop is the spiral, or "slinky," loop configuration in which the piping is laid out in an overlapping circular fashion. This configuration requires less ground area but more pipe length and pumping energy than a basic horizontal setup [3].

In a pond loop, the ground loop is submerged in a lake or a pond. If a suitable body of water is available, this design is an economical option, because it involves minimal digging. Direct exchange systems run refrigerant through the ground loop to exchange heat directly. Such systems do not have to use a pump, but require a much greater copper tube length and refrigerant charge. They are not commonly used [3].

Ground source heat pumps can be applied in a variety of residential, commercial, and institutional settings. In addition, a number of community based systems have been installed in various countries around the world. The size of individual units ranges from about 1.5 tons for small residential applications to over 40 tons for commercial and institutional applications. As shown in Fig. 2, larger commercial applications can involve numerous rows of piping connected either in series or in parallel [3].

In the U.S., the capacity of most units is sized for the cooling load and is consequently oversized for the heating load, except in northern climates where the primary load is the heating load. In Europe, the capacity is usually sized for heating load, often to provide base load, with peak load provided by fossil fuel [3].

III. Defining Heat Pump Efficiency

Heat pump efficiency is defined as the useful energy delivered, divided by the energy supplied to perform that function. The heating energy delivered by a heat pump is the sum of the heat extracted from the heat source and the energy needed to drive the cycle (i.e., compressor motor energy). The cooling effect delivered by a heat pump includes only the energy extracted from the source. The coefficient of performance (COP) is used to define the heating performance of heat pumps. COP is defined as the ratio of heat delivered by the heat pump and the electricity supplied to the heat pump to deliver the useful heat. Therefore, the overall COP should include an allowance for pumping and fan energy, as indicated in the following equation:

A. $COP_{Heating}$ = (Useful Heating Energy) / (Compressor and Fan and Pump Energy)

COP can also be used to define a heat pump's cooling efficiency. In this case, the only difference is that the compressor and fan energy are not present in the useful cooling energy term. However, it is common in the industry to express the cooling efficiency in terms of its energy efficiency ratio (EER). The EER is equivalent to the COP with the exception that the heat from the source is expressed in Btu/h instead of W or kW [4].

B. $COP_{Cooling}$ = (Useful Cooling Energy) / (Compressor and Fan and Pump Energy)

Useful cooling energy = heat removed from room

EER vs. COP:

C. EER= COP ×3.413

Both the COP and EER values are valid only at the specific test conditions used in the rating. These conditions are usually more advantageous than those met in the field. In addition, COPs and EERs are usually reported without consideration for pump energy. These values are useful mainly for comparing equipment. The COP or EER of a heat pump is closely related to the temperature lift of the heat pump. The greater the lift, the lower the efficiency [4].

IV. COP Variation in Heat Pumps

Table I represents COP variation with output temperature in heat pumps.

TABLE I: COP Variation with Output Temperature in Heat Pumps [5]

Pump type and source		High-efficiency air source heat pump (ASHP), air at −20 °C	High efficiency ASHP, air at 0 °C[l]	Ground source heat pump (GSHP), water at 0 °C	GSHP, ground at 10 °C
COP variation with output temperature	35 °C	2.2	3.8	5.0	7.2
	45 °C	2.0	2.8	3.7	5.0
	55 °C	-	2.2	2.9	3.7
	65 °C	-	2.0	2.4	2.9
	75 °C	-	-	-	2.4
	85 °C	-	-	-	-

V. Advantages and Disadvantages of Ground Source Heat Pumps

Some advantages and disadvantages of the heat pumps are listed in the following tables that help us to compare them together. Table II and Table III give us advantages of the air source and ground source heat pumps. Table IV and Table V express some disadvantages of the air source and ground source heat pumps.

TABLE II: Advantages of Air Source Heat Pumps

heat pumps	Advantages
air source heat pumps	- Air source heat pumps (Air to Air) have few moving parts, which reduces maintenance requirements. However, the outdoor heat exchanger and fan should be kept free from leaves and debris, if not damage may occur [6],[7]. - reduce fuel bills, due to their efficiency. - the air source heat pump could have an efficiency of up to 330% [6],[7] - can be used in conjunction with other renewable technology [6],[7]

TABLE III: Advantages of Ground Source Heat Pumps

heat pumps	Advantages
ground source	- ground source heat pumps (Ground to Air) have no regular maintenance [6],[7] - reduce fuel bills, due to their efficiency [6],[7] - a ground source pump could reach 450%, compared with an efficient gas boiler of 90% obviously this is a big difference [6],[7]. - With ground source heat pumps there are no corrosion or degradation issues with the buried plastic pipes, consequently there will never be a need to replace the pipes due to degradation [6],[7]. - Ground Source heat pumps benefit in that, due to the prolonged thermal retention qualities of the soil, they can provide both warming in the winter and reverse cooling in the summer [6],[7]. - CO2 emissions from heat pumps are considerably less than gas or oil fired heating systems and due to the low grade energy source utilized by heat pumps are considered a renewable energy source [6],[7]. - Ground Source heat pumps benefit in that, due to the prolonged thermal retention qualities of the soil, they can provide both warming in the winter and reverse cooling in the summer [6],[7]. - can be used in conjunction with other renewable technology [6],[7].

TABLE IV: Disadvantages of Air Source Heat Pumps

heat pumps	Disadvantages
air source heat pumps	- Air source heat pumps become less efficient at extracting heat from the air when the external temperatures become low. - Air source heat pumps can be noisy, due to the fan and generally are not aesthetically pleasing. [6],[7].

TABLE V: DISADVANTAGES OF GROUND SOURCE HEAT PUMPS

heat pumps	Disadvantages
ground source	- The cost of equipment, material and installation can be expensive, depending on the type of heat pump installation planned. Preferably ground to air heat pumps would be installed alongside or part of another development to your home [6],[7]. - Due to the coils laid underground, a reasonable amount of land would be needed for ground source heat pumps. This is more of a requirement than a disadvantage [6],[7]. - Ground Source heat pumps work best when incorporated within an under floor heating system, and as such are generally only suitable for properties with a larger floor area [6],[7]. - Relatively high installation costs [6],[7]. - Need electricity to operate - the generation of which has its own CO2 emissions which need to be accounted for [6],[7]. - Require electricity to drive the pump [6],[7]. - For water heating purposes, an auxiliary heat source is required [6],[7]. - Require large trench to be dug during installation, especially for the horizontal loop system [6],[7]. - Use toxic refrigerants [6],[7]. - Heating performance depends on the weather conditions [6],[7]. - Least effective when ground temperature is low [6],[7]. - Manufacturers' claims of COPs (Coefficient of Performance) of 3-4 are not generally being realized in practice where COPs of around 2 are more common [6],[7].

VI. CONCLUSION

It is found that Ground source Heat Pumps are some types of heat pumps that they have many advantages unlike their disadvantages. Their most important benefit is high efficiency (High COP), and they can provide both warming in the winter and reverse cooling in the summer. CO_2 emissions from heat pumps are considerably less than gas or oil fired heating systems and due to the low grade energy source utilized by heat pumps are considered a renewable energy source and that is why they are becoming more and more common in the world.

REFERENCES

[1] Heat pumps comparison, what is a heat pump and how it works?. [Online]. Available: http://www.robur.com/technology/heat-pumps-comparison/page-1.html

[2] Heat pumps comparison, types and applications of heat pumps. [Online]. Available: http://www.robur.com/technology/heat-pumps-comparison/page-2.html

[3] W. Goetzler, R. Zogg, H. Lisle, and J. Burgos, "Ground source heat pumps: overview of market status, barriers to adoption, and options for overcoming barriers," pp.17-19, Feb, 2009.

[4] Natural Resources Canada, "Commercial earth energy systems: a buyer's guide," pp. 41-43, 2002.

[5] Heat pump. [Online]. Available: http://en.wikipedia.org/wiki/Heat_pump

[6] Advantages & disadvantages of heat pumps. [Online]. Available: http://www.energy-measures.com/heat_pumps/advantages_disadvantages_of_heat_pumps.php

[7] Ground source heat pumps disadvantages. [Online]. Available: http://www.rhiadvisor.co.uk/ground-source-heat-pumps-disadvantages

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