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An overview of Geothermal heat pumps as energy efficient and environmental friendly systems

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ABSTRACT: The major threats that human being is facing nowadays are the Climate change, depletion of the fossil fuels at a rapid rate and energy costs. A significant portion of world energy consumption is consumed by domestic heating and cooling. And heat pumps, due to their higher utilization efficiencies as compared to conventional heating and cooling systems, offer an attractive solution to this problem. Among the types of heat pumps, the Geothermal heat pump or Ground-source heat pump is a highly efficient, renewable energy technology for space heating and cooling. The Ground-source heat pump uses the Earth as a heat sink in the summer and a heat source in the winter. And the Earth, having a relatively constant temperature, warmer than the air in winter and cooler than the air in summer, offers an excellent heat source in winter and heat sink in summer.. This paper will discuss an overview of the types of heat pumps, its operation, benefits of using geothermal heat pumps, soil characteristics, and overview of some experimental works. Finally it will briefly discuss the opportunity of using these energy efficient systems (EES) in the HVAC market of South Korea.

Key words Geothermal heat pump, Air-to-air heat pump, Climate Change, Heat Source

1. Introduction

Using fossil fuels and low-efficiency electrical equipments for heating during the winter season is one of the major causes of climate change. The depletion of fossil fuels at a rapid rate and energy costs have generated a need for efficient energy utilization. Especially after the recent oil shocks, the engineers are searching for renewable energy sources. In this context renewable energy, combined with energy efficiency, offers a viable and potent solution to countering these problems.

One of the most energy-efficient ways to provide heating and cooling in many applications is the use of heat pumps as they use renewable heat sources in the surroundings. Even at temperatures that are consider to cold, air, ground and water contain useful heat that is continously replenished by the Sun. By applying a little more energy, a heat pump can raise the temperature of this heat energy to the level needed. Similarly, heat pumps can also use waste heat sources such as from industrial processes or ventilation air extracted from buildings. Due to their less usage of primary energy than conventional heating systems, heat pump is an important technology for reducing emissions of gases that harm the environment. Among the types of heat pumps, the Geothermal heat pump is an

energy-efficient and environmental friendly way of conditioning (heating and cooling) buildings. The Geothermal heat pump uses the Earth as either a heat source, when operating in heating mode, or a heat sink, when operating in cooling mode. The ground is a thermally more stable heat exchange medium than air, unlimited and always available. Therefore even in colder climatic conditions, a Geothermal heat pumps maintains a high level of performance. The Geothermal heat pump system consists of a sealed loop of pipe buried vertically or horizontally in the ground and connected to a heat pump through which water/antifreeze solution is circulated.

2. Geothermal heat pump VS Air-to-air heat pump

In heat pump technology, the difference between the temperature where the heat is absorbed (source) and the temperature where the heat is delivered (sink) is called the "Lift". The larger the lift, the greater the power input required by the heat pump. This forms the basis for the efficiency advantage of Geothermal heat pump over Air-to-air heat pump. An Air-to-air heat pump must remove heat from cold outside air in winter and deliver heat to hot outside air in summer. In contrast, a Geothermal heat pump retrieves heat from relatively warm soil (or ground water) in winter and delivers heat to the same relatively cold soil(ground water) in summer. The Geothermal heat pump technology relies on the fact that at depth the Earth has a relatively constant temperature, warmer than the sir in winter and cooler than the air in summer. A Geothermal heat pump can transfer heat stored in the Earth into building during the winter, and transfer heat out of the building during summer.

Geothermal heat pumps have several advantages over Air-to-air heat pumps as: (a) They consume less energy to operate. (b) They tap the Earth or ground water, a more stable energy source than air. (c) They do not require supplemental heat during extreme low out side temperature. (d) They use less refrigerant. (e) They have a simpler design and consequently less maintenance. (f) They do not require the unit to be located where it is exposed to weathering. Their main disadvantage is the higher initial capital cost, being about 30-50% more expensive than Air-to-air heat pumps. This is due to the extra expense and effort to bury heat exchangers in the Earth. However, once installed, the annual cost is less over the life of the system, resulting in a net savings [1].

Studies show that approximately 70% of the energy used in a Geothermal heat pump system is renewable energy from the ground. The Earth's constant temperature is what makes a Geothermal heat pump one of the most efficient, comfortable and quiet heating and cooling technology available today. While they may be more costly to install than the regular heat pumps, they can produce markedly lower energy bills,30-40% lower, according to estimates from the U.S Environmental Protection Agency[2].

3. Overview of experimental stidies on Geothermal heat pumps

In order to make use of low

temperature, resource, an experiment was performed by Arif Hepbasli and M..Tolga Balta. The system was designed, constructed and tested in Nigde University Turkey and has been successfully operated since 2005 [1].

To validate the effects of the parameters such as the buried depth of earth-coupled heat exchanger, mass flow rate of the water-antifreeze solution and sewer water on the performance of a horizontal Ground-source heat pump (GSHP) system used for space heating, an experiment was performed. The average performance coefficients of the system in different trenches, at 1m and 2m depths, were obtained as 2.66 and 2.81 respectively[3].

In order to make use of the disposed geothermal water at 35℃, a water-to-water geothermal heat pump was designed. This geothermal heat pump uses geothermal water at 35℃ temperature and provides clean water at 45℃ for floor heating network. The overall coefficient of performance was obtained as 2.8[4].

Arif Hepbasli performed an experiment for the cooling performance evaluation of a vertical ground-source heat pump system in Izmir, Turkey. He used ground heat exchanger of vertical-single U-bend type with a boring depth of 50m[5].

The geothermal heat pumps have been effectively utilized for heating the buildings especially in those areas where the variation of soil temperature at a certain depth e.g. at 0.5m or 1m is small as compared to variation in ambient temperature. In this context the ground heat exchanger was placed in a vertical borehole with 55m depth. The heat extraction rate per meter of the borehole was determined as 33.6W/m[6].

An experiment was performed on a solar-assisted ground-source(geothermal) heat pump system for green house heating[7].The use of a municipality water reticulation system as a heat source/sink resulted in an annual improvement of 13% in capacities and an annual improvement of 14% in coefficient of performance[8].

4. Effect of Soil type and moisture content on the performance of geothermal heat pump

In geothermal heat pump applications, deposition or extraction of thermal energy from the ground is accomplished by using a ground heat exchanger. The operation of this ground heat exchanger induces a simultaneous heat and moisture flow in the surrounding soil. The transfer of heat between the ground heat exchanger and adjoining soil is primarily by heat conduction and to a certain degree by moisture migration. Therefore, it depends strongly on the soil type, temperature and moisture gradients[5].

Three different soils (sand, silty loam and silty clay), with five different degrees of saturation (0 ,12.5, 25, 50 and 100%) were used to find the effect of moisture content and soil type. It was found that for high coefficient of performance, keep the soil moisture value as high as possible above dry soil conditions. The best performance of the geothermal heat pump was obtained for sand at all degrees of saturation, as compared to silty loam and silty clay[9].

5. Geothermal heat pumps and heat sources in Korea

With the rapid technological development, the HVAC market of Korea has been expanding very rapidly and represents an attractive market for the investors. There are some well-known R&D organizations striving for promoting the use of geothermal heat pumps in Korea. Among these are the KEMCO-Korean Energy Management Corporation (funding of R&D policy), KIER-Korean Institute for Energy Research and KIGAM-Korean Geological Service (important for searching geothermal potential).

The use of Geothermal heat pump can drastically reduce the emissions of harmful gases by reducing the fossil fuels consumption. Winters are very cold in Korea and air-to-air heat pump's efficiency may drastically reduce during the extreme low outside temperatures, therefore Geothermal heat pumps offer an efficient heating system as compared to air-to-air heat pump.

In the extreme cold winter conditions of Korea, the use of Geothermal heat pump for greenhouse air conditioning has many advantages over other heating systems like steam or hot water radiation system and hot air unit heaters. Their ability to perform the multi-function of heating, cooling and dehumidification certainly make them a best alternative as compared to other heating systems.

The exhaust gas heat from industry and clean sewage water represents an excellent heat source for heat pump utilization and an alternative concept of heat supply for cities in Korea. The installation of Geothermal heat pumps will protect Korea from future energy price increasing and will bring renewable energy to Korean community.

6. Conclusion

Pollutions emissions, rapid depletion of fossil fuels and increasing price of energy are amongst the main problems that the world is facing nowadays. In this context renewable energy combined with energy efficiency is a viable solution to this problem. Earth, underground water, exhaust gases from industries and sewage water represent a good alternative heat sources. The main advantage of Geothermal heat pump is the relatively constant temperature of the Earth and less usage of primary energy. Therefore it maintains high level of performance even in the extreme colder climatic conditions like Korea.

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