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Application of Low Temperature Geothermal Energy through Heat Pumps in Heating and Air-Conditioning Systems

Liu Xueling , Zhu Jialing

Geothermal Research and Training Center of Tianjin University, China.

lxlaln@hotmail.com

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ABSTRACT

A water-to-water geothermal heat pump running on R-22 was applied to recover heat energy from low temperature geothermal energy for heating and air-condition for a hotel which area is 6000m^2. The heat pump used geothermal water between 13~18ºC and provided water between 40~45º C in winter, and used geothermal water between 13~16ºC and provided water between 7~10 º C in summer. The economics and environment effects are discussed. It is indicated that using low temperature geothermal water through a heat pump to heat and refrigerate saves basic energy and protects the environment.

1. INTRODUCTION

From 1999 to 2000, heating using geothermal water increased in China. But in heating using geothermal water, only in the coldest days can the heat of the geothermal water be used completely; in most days of winter the geothermal heat is only used partially and the temperature of discharged geothermal water is high. This not only wastes geothermal energy, but also pollutes the environment, and the cost of drilling wells to reach higher temperature geothermal water is expensive.

In recent years, with the development of the heat pump technique, heat pumps are being used to extract heat from lower temperature source, such as low temperature geothermal water, discharged geothermal water, air or ground, for heating.

In the US, there is new interest in geothermal heat pumps as a way to use low temperature geothermal resources for space heating. For example, a geothermal heat pump was installed in the Daniel Boone High School in Washington County, resulting in □37000 saving per year [1]. Another geothermal heat pump system was designed to absorb heat from 30ºC well and supply 52~65ºCtemperature water to Grant County Courthouse central heating system in Ephrata, Washington, resulting in an 80% decrease in energy consumption and an 85% decrease in the Courthouse fuel bill [2].

Now, in China, there are many projects using heat pumps for space heating in winter and cooling in summer, which use geothermal water around 15~30 º C by drilling wells to around 200~400m depth. In this paper, an instance of using heat pump to heat in winter and cool in summer is introduced, with wells drilled to about 200m and water at about 13~18 º C in winter and 13~16 º C in summer. In addition, the economics of heating and cooling through heat pump are analyzed.

2. THE SITUATION OF THE PROJECT USING HEAT PUMP TO HEATING

The area of the building required to heat in winter and cool in summer is about 6000m^2.The heat pump extracts heat or cold directly from the shallow groundwater from a well of around 200m depth. In this system, two wells are drilled, one as a production well, and the other as a reinjection well. The two wells are both around 200m depth. The production well and reinjection well are interchanged in winter and summer, i.e. the production well in winter is the reinjection well in summer, and the reinjection well in winter is the production well in summer. The system of the heat pump for heating and cooling is shown in Fig. 1 and Fig. 2.

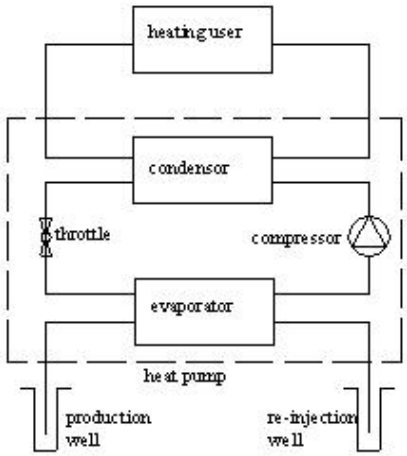

Figure 1: Diagram of Heat Pump System for Heating

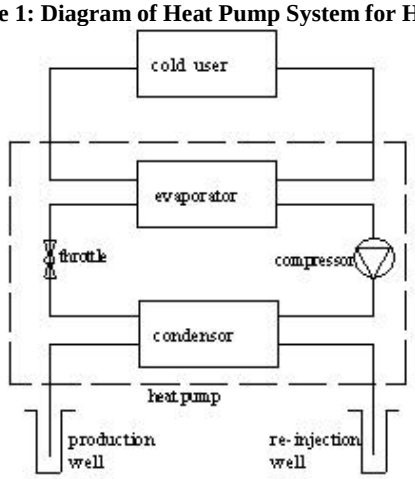

Fig. 2. Diagram of Heat Pump System for Cooling

2. THE RUNNING PARAMETERS OF THE HEAT PUMP SYSTEM

Running data of the heat pump system for heating and cooling in one year were collected. The main data collected

were the temperature and the fluxes of the production well and reinjection well. The data were noted every two hours in all the heating and cooling days. Then the data were analyzed to obtain the temperature curve of the two wells for heating, the flow curve of the two wells for heating and the temperature curve of two wells for cooling, as shown in Figs. 3, 4, and 5.

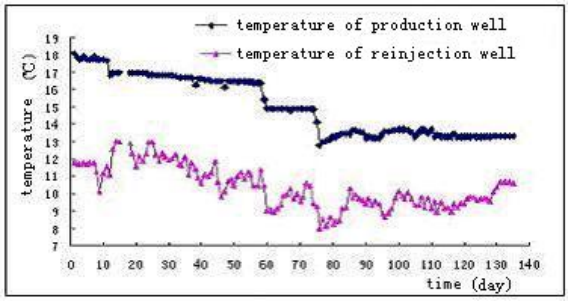

Fig. 3. The Temperature Curve of Two Wells For Heating

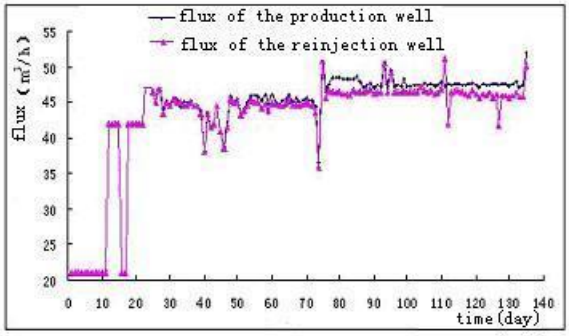

Fig. 4. The Flow Curve of Two Wells For Heating

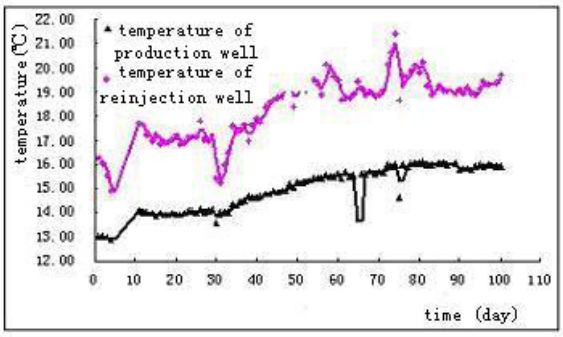

Fig. 5. The Temperature Curve of Two Wells For Cooling

In winter, the heat pump extracted heat from the underground water with temperature of about 13~18ºC and provided about 40~45ºC water for space heating. From Fig. 3, we can see that the temperature of the production well dropped slowly with the heating time. In the beginning of the heating season, the temperature of the production well was 18ºC□in the 60th day the temperature rapidly dropped to 16.5ºC and in the 72nd day the temperature rapidly dropped to 12.8ºC, then the temperature rose as the heating subsided, until at the end of the heating season the temperature of the production well had risen to 13.5ºC. The temperature of the production well dropped with time because the flux of the reinjection water increased and its temperature is lower than the production water, but in the 60th day and 72nd day, the temperature of the production well dropped rapidly because in the 60th day and 72nd day, the temperature of the environment dropped suddenly and the well is shallow, then influenced the temperature of the production well. So we say that the temperature of the well is influenced not only by the flux of the reinjection water, but also influenced by the environment temperature.

From Fig. 4, we can see that the flux of reinjection was almost equal to the flux of production. This indicates that the geothermal water was largely returned to the well after the heat pump extracted heat from it, i.e. the heat pump used only the “heat” of the geothermal water, not the “water”. So the system gave no any pollution to the geothermal water and attained good environmental effects.

In summer, the heat pump extracted cold from underground water with temperature of about 13~16ºC to cool the room. From Fig. 5, we can see that the temperature of the production well rose with the cooling time. At the beginning of cooling, the temperature of the production well was 13ºC □then the temperature rose as the increase of the flux of the reinjection water, until at the end of cooling the temperature of the production well rose to 16ºC.

From Fig. 3 and Fig. 5, we can see that the temperature of the well dropped in winter and rose in summer, i.e. the heat pump extracted heat from underground water in winter and reinjected heat to the underground water in summer.

4. THE ECONOMICS OF HEATING AND COOLING THROUGH HEAT PUMPS

The first investment of the heat pump system is □1700 thousand which includes □320 thousand of drilling wells and □1380 thousand for the heat pump, pipeline and end equipment. Because the system of heat pump is used not only for heating in winter, but also for cooling in summer, in the economic analysis of heat pump running, half of the first investment is accounted in the heating system and the other half is accounted in the cooling system.

The cost of the heat pump system for heating or cooling includes the costs of energy that include electricity and geothermal water, manage use, the equipment maintenance and depreciation. In this system, the geothermal water is mostly returned to the underground, so the geothermal water is free, and the cost of the energy is only the electricity charge.

The cost of heating or cooling through the heat pump using shallow water is shown in Table 1 and Table 2. The comparison of energy use and the manage use of heating through heat pump and through gas boiler and oil boiler is shown in Table 3. The efficiency of the gas and oil boiler is 90%.

From Tables 1, 2 and 3, we can see that the running charge of the heat pump is lower than that of the gas and oil boiler. This is because the heat pump extracts heat from lower temperature resource by consuming high quality electricity, so the efficiency of energy transformation is high. For example, if the COP of the heat pump is 4, the heat pump consuming 1 unit of electricity can recover 4 units of heat. But the gas or oil boiler consumes base fuel, and the burning efficiency can not be 100% so the heat loss is considerable.

Table 1: The cost of heating through heat pump

Serial number	Item	Unit price	Numerical value	Cost
1	Electricity charge (Production well pump Water circulating pump Heat pump Fan-coil Reinjection well pump)	□0.6/kwh	145113 kwh	□87 thousand
2	Pay for worker	□800 /person·month	2	□8 thousand
3	Depreciation			□38.2 thousand
4	Maintaining charge	First invest×1.8%		□15.3 thousand
5	Management charge	(1+2+3+4)×2.5%		□3.7 thousand
6	All cost	1+2+3+4+5		□152.3 thousand
7	Cost of each m^2	(1+2+3+4+5)/area		□24.95 /m^2
8	Running charge	1+2		□95 thousand
9	Running charge of each m^2	(1+2)/area		□15.56/m^2

Table 2: The cost of cooling through heat pump

Serial number	Item	Unit price	Numerical value	Cost
1	Electricity charge (Production well pump Water circulating pump Heat pump Fan-coil Reinjection well pump)	□0.6/kwh	59499kwh	□35.7 thousand
2	Pay for worker	□800 /man·month	2	□6.4 thousand
3	Depreciation			□38.3 thousand
4	Maintaining charge	First invest×1.8%		□15.3 thousand
5	Management charge	(1+2+3+4)×2.5%		□2.4 thousand
6	All cost	1+2+3+4+5		□98 thousand
7	Cost of each m^2	(1+2+3+4+5)/area		16.1 □/m^2
8	Running charge of each m^2	1+2		□42.1 thousand
9	Running charge of each m^2	(1+2)/area		6.9 □/m^2

Table 3: The compare of energy use and the manage use of heating through heat pump and through gas boiler and oil boiler

Name	Gas boiler	Oil boiler	Heat pump
Amount of fuel requirement	48.6×10^3 m^3	45.78×10^3 kg	145113KWH
Unit price of the fuel	□2.5 /m^3	3.0 □/kg	0.6 □/KWH
Cost of the energy	□121.5 thousand	□137.3 thousand	□87 thousand
Manage use	□8 thousand	□8 thousand	□8 thousand
Cost of heating	□129.5 thousand	□145.3 thousand	□95 thousand

However, at present the initial investment of the heat pump is much higher than that of the gas and oil boiler, which causes the cost of heating by heat pump to be high. But the running charge of heat pump is low, and the payback of the capital is quick, also the heat pump can be used for cooling in summer, it has some investment advantage. In addition, the price of the electricity also affects the cost of heating by heat pump, so in a district with cheap electricity price, the heating by heat pump has some advantage.

From the point of view of saving energy and environmental efficiency, the heat pump consumes directly only electrical energy and not base energy, so it saves basic energy and brings no pollution to the environment, and hence attains good environmental effects. So we say that the heat pump is an energy-saving and environment-protecting technology.

5.CONCLUSION

In conclusion, the heat pump is an energy-saving and environment-protecting technology, and heating through heat pump attains good environmental and economic effects. In the days in which environmental questions are severe, heating through heat pumps has a good prospect.

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