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Studying the thermal performance of a Geothermal heat exchanger placed underground the Kirkuk city

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Abstract: The project is concerning about studying and experiencing the rate of underground temperature degree variation round the year for Kirkuk city , by burying a plastic heat exchanger in depth about two meters and installing thermometers on different levels of the specific depth in order to read the temperature of each level of the ground ,then allowing a specific quantity of water to flow from an outer source into the heat exchanger while reading the temperature of the water at the inlet and outlet and the heat transfer between the water and the underground soil.

Results have shown unexpected reading, it was found that the relationship between the geothermal temperature and the climate is a counter relationship, in other wards the rate of temperature degree will increase 2% , every half meter underground depending on the season we are in. Also the project showed that the position of the heat exchanger (whether its vertical or horizontal) have a very big effect on the change in temperature degrees , also the increase in the length of the heat exchanger and the increase in the number of its loops will increase the rate of change in water temperature degrees.

The position of the heat exchanger (horizontal or vertical) depends on the type of the soil, if it was a rocky soil the heat exchanger is better to be placed horizontally and if the soil is loose or sandy it's better placed vertically.

1- introduction

The world has witnessed a vast amount of technological developments and population growth since the industrial revolution; there has been a corresponding increase in the use of resources. Hence, society is becoming increasingly aware of the effects of pollution, toxic waste, global warming, deforestation, resources and ozone depletion. The global energy crisis has led to the development of a number of new low energy systems for building heating and cooling. These systems provide viable alternatives to conventional energy systems, and have the capability to significantly reduce electrical energy usage. Ground Source Heat Pump Systems (GSHPS) have received considerable attention in the recent decades as an alternative energy source for residential and commercial space heating and cooling applications. GSHPS have been the subject of many previous investigations, and have also found practical applications in the past. A Ground Source Heat Pump (GSHP) heating system uses a heat exchanger buried in the ground. The GSHP system has many advantages over the air source heat pump systems which are well known and commonly used in many applications. The advantages are mentioned in the following paragraphs. In addition of reducing purchased energy consumption and low CO2 emissions, GSHPS have a number of environmental and operational advantages which are:

- High reliability (few moving parts, no exposure to weather).
- High security (no visible external components to be damaged or vandalized).

- Long life expectancy (20-25 years and up to 50 years for the ground coil).
- Low noise.
- Low maintenance costs (no regular servicing requirements).
- No boiler or fuel tank.
- No combustion or explosive gases within the building.
- No flue or ventilation requirements.
- No local pollution.

1.2. Literature review

Currently, GSHPS are perhaps one of the most widely used renewable energy resources. GSHPS use the earth's relatively constant temperature as a heat sink for cooling and a heat source for heating. From a thermodynamic perspective, using the ground as a heat source or sink makes more sense than the ambient air because the temperature is usually much closer to room conditions. Seasonal variation of temperature in the earth is small relative to the variation in air temperature. For that reason, the earth is normally at a more favorable source temperature than the outside air. Also, the use of liquid instead of air as the source/sink fluid for the heat pump cycle promotes higher efficiency, which can be attributed to the decrease in difference between the source/sink temperature and the refrigerant temperatures. In addition, the specific heat of water is more than four times greater than that of air.

Instead of producing heat through the combustion of fossil fuels, GSHPS function by concentrating naturally existing heat by collecting the Earth‟s natural heat using loops installed below the surface of the earth or submersed in a lake. The fluid circulating through the loop system is used to transfer the heat to the building. The distribution system of the building is then used to distribute the conditioned air to the various rooms. Furthermore, the heat deposited or rejected (depending on the season) from the home is collected by the means of the circulating fluid in the loops and return to the Earth. GSHPS applications are one of three categories of geothermal energy resources as defined by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) [1]. These categories are: (i) high temperature (>150oC) electric power production, (ii) intermediate and low temperature (<150oC) direct use applications, and (iii) GSHPS applications generally (< 32oC). GSHPS applications are distinguished from the others by the fact that they operate at relatively low temperatures. The term GSHP has become an all-inclusive term to describe a heat pump system that uses the earth, ground water, or surface water as a heat source and/or sink. GSHPS in general consist of three loops or cycles as shown in figure 1.1 and 1.2. The first loop is on the load side and is either an air/water loop or a water/water loop, depending on the application. The second loop is the refrigerant loop inside a water source heat pump. Thermodynamically, there is no difference between the well-known vapor compression refrigeration cycle and the heat pump cycle; both systems absorb heat at a low temperature level and reject it to a higher temperature level. The difference between the two systems is that a refrigeration application is only concerned with the low temperature effect produced at the evaporator, while a heat pump may be concerned with both the cooling effect produced at the evaporator as well as the heating effect produced at the condenser. The third loop in the system is the ground loop in which water or an antifreeze solution exchanges heat with the refrigerant and the earth. GSHPS rely on the fact that, under normal geothermal gradients of about 30oC/km [2]. The earth temperature

is roughly constant in a zone extending from about 6.1 to 45.7 m deep [3]. This constant temperature interval within the earth is the result of a complex interaction of heat fluxes between the sun, atmosphere, and the earth. As a result, the temperature of this interval within the earth is approximately equal to the average annual air temperature [3].
Nowadays, GSHPS are one of the fastest growing applications of renewable energy in the world, most of this growth occurs in USA and Europe, and also in other countries like Japan and Turkey. At 2010, the worldwide installed capacity was estimated at almost 14 GWth with an annual energy use of 24 TWh. There is round two million GSHPS units have been installed worldwide; with annual increases of 30% have occurred in about 40 countries over the past 10 years [4].

2 .methodology:

Research will be conducted in following three steps:

A:theoretical part

By using the equation calculate heat transfer in Btu/hr , we can calculate latent heat[5,6,7]:

$$Q = \dot{m}.c_p\,.\Delta T \qquad \text{---------------} \qquad (1)$$

And other equation will be used to calculate the flow rate of the fluid which is :

$$\dot{m} = \rho\,.\dot{V} \qquad \text{--------------------------------}(2)$$

In order to have accurate calculation we need to know the effectiveness of the plastic heat exchanger , and which demands the equation for reading the efficiency , which is

$$E_{ff} = E_o/E_i \qquad \text{---------------------------------}(3)$$

2.2 Practical part

Practical measurement will be conducted by using a digital thermometer in the following six steps

- For reading the temperature at inlet of the Heat exchanger it will be labeled as (T_1)
- For reading the temperature at a level of 0.5 m , it will be labeled as (T_2)
- For reading the temperature at a level of 1m , it will be labeled as (T_3)
- For reading the temperature at a level of 1.5 m , it will be labeled as (T_4)
- For reading the temperature at a level of 2.m , it will be labeled as (T_5)

- And finally for reading the temperature at the outlet of the Heat exchanger it will be as (T_6)

And this clearly shown in figure (1)

the picture in figure (1) , illustrates a very simple heat exchanger made of PVC plastic material which have the following characteristics

Thermal conductivity (k) is : 0.15 w/ m.C^0

Dimension of the outer diameter is : 25mm

Dimension of the inner diameter is : 15mm

Depth at which heat exchanger is buried is : 2m

Loop is buried in horizontal way length of each pipe is 1.5m

Total length of heat exchanger is 14m

3. Result and discussion

3.1 Readings and Calculations

Table (1) shows the waters enthalpy at the atmospheric pressure

Table (2) shows the calculations we obtained at a different dates and times

Temperature of water °C	Specific enthalpy of liquid water kh/kg
0.00	0.06
1.00	4.28
2.00	8.49
3.00	12.70
4.00	16.90
5.00	21.11
6.00	25.31
7.00	29.51
8.00	33.70
9.00	37.90
10.00	42.09
11.00	46.28
12.00	50.47
13.00	54.66
14.00	58.85
15.00	63.04
16.00	67.22
17.00	71.41
18.00	75.59
19.00	79.77
20.00	83.95
21.00	88.14
22.00	92.32
23.00	96.50
24.00	100.68
25.00	104.86
26.00	109.04
27.00	113.22
28.00	117.39
29.00	121.57
30.00	125.75
	129.93

Table (1)

$V^{\circ} * 10^{6}$ m^{3}/sec	ΔTw °C	$Q * 10^{3}$ KW	Ei KW	$Eff. = Eo/Ei$
2.1667	4	36.287	0.0334031	**1.088**
0.7	2	5.8618	0.0096548	**0.607**
0.7	3	8.7927	0.019471	**0.4515**
0.7	5	14.6545	0.0361414	**0.405**
4.0833	2	34.1935	0.0211	**1.618**
4.0833	8	136.77	0.0817934	**1.672**
4.0833	10	170.967	0.1073897	**1.592**
6.667	2	55.829	0.019273	**2.8967**
6.667	3	83.744	0.0318994	**2.62525**
6.667	1	27.914	0.033343	**0.83717**
1.667	3	20.939	0.03451	**0.60675**
1.667	3.5	24.429	0.035647	**0.6853**

Table(2) : illustrates differential volumetric flow rate how it effects on :
1- Water temperature ΔTw
2- Heat gain or loose Q
3- Heat exchanger efficiency Eff

3.2. Experimental results for the system for heating operation

in this section, variation of major performance parameters related with the experimental system which is called as "Ground Coupled Heat Pump System) are presented in graphical and table forms for heating and cooling operations . the performance parameters are computed by using measurement values from the experimental GCHPS . the measurement values are the ambient and inside room temperature, temperature of water in the ground loop cycle at different ground depth, pressure and temperature of water used in the heat pump cycle at each inlet and exit states of the systems components .the performance parameters for both of the heating and cooling systems are heat gain or rejection to the testing room, heat gain or rejection from or the ground .

Figure 3. illustrate hourly variation of temperature for ambient air, water , ground (for dates from (12 December to March 27) . at a different ambient air temperature . Temperature variations in the ground at a different depth are shown in the figure "T2 ", "T3 "and "T 3" are pipe surface temperatures at depth of 0.5m , 1m , and 1.5m respectively . it seems the temperature increases with respect to depth. Source temperature has important effect on Coefficient of performance (Cop) . it understood that the main effective parameter on the ground heat exchanger performance is the variation of ground (source) temperature.
We found from our observation , that the temperature of the outlet water increased ,which means , that the water had gain this rate of increasing temperature from the same soil , where the heat exchanger is buried ,and whenever the greater the depth is , the greater of different in temperature we can obtain .The heat exchanger is working here like a heat pump --- and if we can applied this small project at a vast place , it will a great benefit to use the hot water in the winter to heat the residential houses , especially remote places where there is no electricity or running water , and vice versa , we can used in summer to cool houses . and by this way people can accomplish a lot of things one them saving money, moreover protecting the environment from pollution .

Hourly variations of measured inlet and outlet temperature of aqueous with calculated Q for the heat exchanger are indicated in figure 4.

We can see there are augmentation for the heat Q , reaching the maximum value of heat up to 170 KW , when the difference in reading temperature in the outlet in inlet is reached the maximum value which 10 C° .

The outlet water temperature of the GHE (Ground Heat Exchanger) is approximately higher than the ambient temperature and this because the rejection of the heat contained in the water to the ground source during winter , which is a good sign to this for heating season , same reason we can use this for cooling in the summer season , and whenever the depth is big the difference in temperature between the water circulating and deep in the ground well be also bigger .

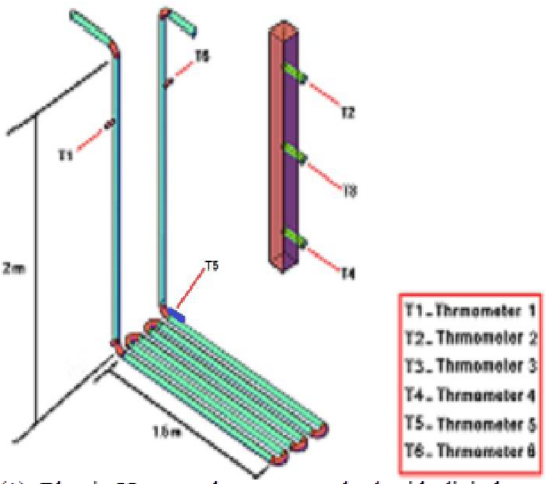


figure (1) :Plastic Heat exchanger attached with digital thermometers at different levels

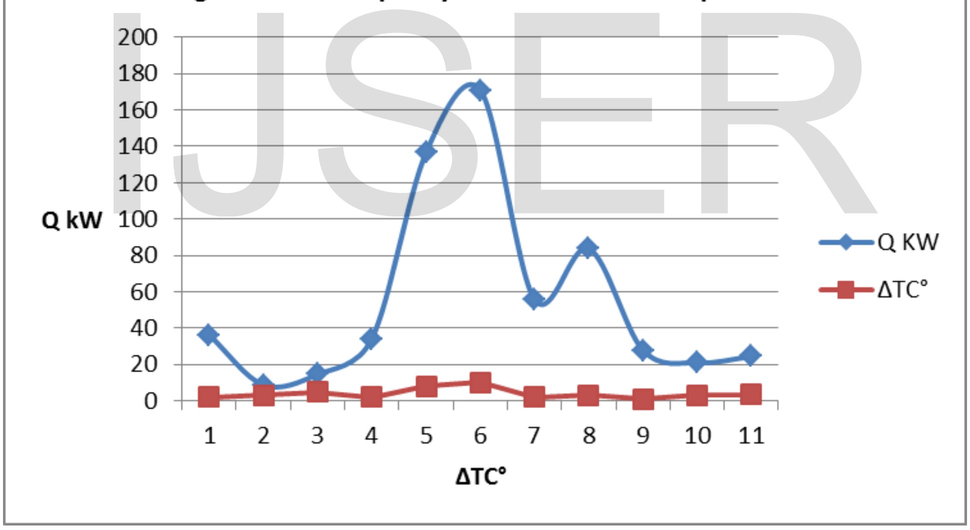
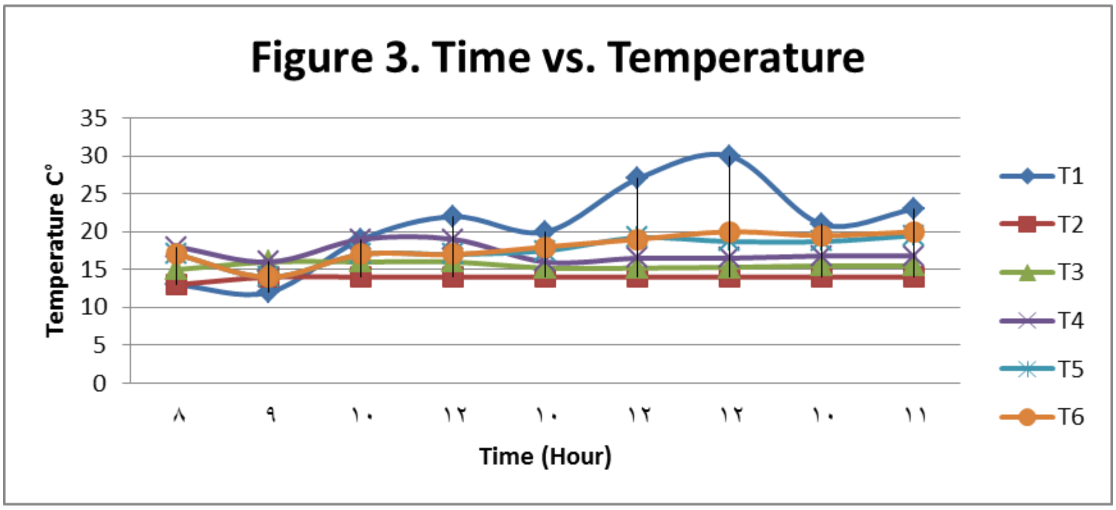


Figure 4. Heat Capacity vs. variation of Temperatue



4. Conclusion

The ground or as we called mother earth acts as a very large store of heat energy. It can be used as a heat source in winter or a heat sink in summer. The ground can be used to moderate the temperature in buildings standing on it. A ground heat exchanger can be used to extract heat energy from the ground in winter season to transfer the heat into houses . at the same time, it can be used to provide a very efficient mechanism for heat rejection from buildings , free of all carbon emissions on site. It can make use of solar energy stored in the ground to provide one of the most energy-efficient ways of heating or cooling houses . since, most heat pumps units having reverse cycle can be used for both heating and cooling of the houses the GHE system is environmental friendly, economic, space saving, safely, reliably, less maintenance, long cycle life, and effective devices .

The main advantages of this kind of system is many but in brief those are the most common advantages:

The main advantage of the GHE over the other conventional systems is that the heat extract or reject is maintain within the circulating fluid through the ground cycle, not release it to the ambient and pollutants the environment .

Experimental result show that ground temperature near around the pipe GHE increases in cooling season and decrease in heating season as a result of heat transfer with intermediate fluid . increase in temperature during cooling season is not desired condition since increase in source temperature causes lower heat gain or lose . this situation is also valid for heating season. Since, the lower source temperature gives the lower heat gain or lose.

Soil properties are important factors should be taken into consideration in the design and construction of GHE for heat pump application to insure long life and longer life of the system. The properties should be tested by excavation of the earth at different depth before construction of the GHE .

REFERENCES

[1] ASGARE, 1995 *Handbook, HVAC Applications.* American Society of Heating, Refrigeration and Air –conditioning Engineers, Inc.

[2] Grant, M.A, I. G. Donaldson, and P.F. Bixley, 1982 *Geothermal Reservoir Engineering. Academic Press*

[3] Hart, D.P. and R. Couvillion, 1986. *Earth- Coupled Heat Transfer*. National Water Well Association, Dublin, OH

[4 , ,6] DOE FUNDAMENTALS HANDBOOK , THERMODYNAMICS, HEAT TRANSFER, AND FLUID FLOW
[5] NATIONAL AERONAUTICS AND SPACE AMINSTRATION , General thrust Equation ,
Glenn Research Center.

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