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Engineering Technical College Al-Najaf

Study of Thermal Parameters of Vertical Geothermal Heat Exchanger in Engineering Technical College Najaf

A Thesis

Submitted To the Department Of Mechanical Engineering Techniques of Power in Partial Fulfillment of the Requirements for Master of Thermal Technologies Degree in Mechanical Engineering Techniques of Power

BY

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((بسم الله الرحمن الرحيم))

اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ (١) خَلَقَ الْإِنْسَانَ مِنْ
عَلَقٍ(٢)اقْرَأْ وَرَبُّكَ الْأَكْرَمُ(٣)الَّذِي عَلَّمَ
بِالْقَلَمِ(٤)

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ليطغى (٦)

صدق الله العلي العظيم

سورة العلق (ص٥٩٧)

Dedication

To the imams of guidance and lamps of darkness... the people of the house of prophecy and the locus of the message (peace be upon them) in honor of all of them

To the soul of my father who... he gave us everything he had so that we could fulfill his hopes

To my dear mother .... my first teacher in this life who carried me and bore me and was patient over everything and all her prayers for me were success in all aspects of life, study and work

To my brothers and sisters.... who shared with me the burden of life and were my support in my life's journey, may God reward them on my behalf.

To my family... my wife, my companion, and my precious children who helped me overcome the difficulties of life

To my good teachers, and to everyone who taught me a letter and I became a slave to him with my knowledge. I ask God to guide them all.

DISCLAIMER

I confirm that the work submitted in this thesis is my own work and has not been submitted to other organization or for any other degree.

Signature:

Name : Waleed Abdulhamza Asker

Date : 9 / 11 /2021

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Alloh ,the creater is thanked for rvery thing befor all. Iwould like thank you, master, and thank you for encouraging the completion of this investigate on the confront that I trust you may be fulfilled with me. I thank the deanship of the Technical Engineering College/Najaf, the teaching professors, for all their great efforts. I thank the department head of Power Mechanics, **Prof. Dr. Dhafer M.Hachim,** for his efforts and continuous support to accomplish this work. I would like to express my sincere appreciation to the supervisor, **Asst. Prof. Dr. Tahseen Al Badri**, for his supervision and insight to total the inquire about and for this he gave me his exhortation and gave me his profitable time and information. Much obligation and appreciation are to all the specialists within the division, research facilities and workshops, who have given me the vital technicalities from measuring gadgets for conducting exploratory works for the purposes of finishing inquire about necessities. Last but not least; I would like to present my profound appreciation for my family for their support all through my life.

Waleed Abdulhamza Asker

2021

SUPERVISOR CERTIFICATE

I certify that this thesis, entitled “**Study of Thermal Parameters of Vertical Geothermal Heat Exchanger in Engineering Technical College Najaf**" submitted by **Waleed Abdul Hamza Askar,** was prepared under my supervision in the Department of Mechanical Power Engineering Refractories, Technical Engineering College / Najaf, Al-Furat Al-Awsat Technical University, as a partial fulfillment of the requirements for the master's degree in Refractory engineering.

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In view of the available recommendation, I forward this thesis for debate by the examining committee.

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ABSTRACT

The current study aims to study the thermal parameters of the vertical heat exchanger. The vertical heat exchanger was chosen as a source of heat , which was implemented on the grounds of the Technical College of Engineering in Najaf / Al-Furat Al-Awsat Technical University. The heat exchanger consists of a tube with a length of (2m) and an outer and inner diameter (14.5, 14.2 cm), respectively, containing two polyethylene tubes to enter and the exit of the liquid with a diameter of (2.5 cm) for both tubes.

The continuous operation mode (short time) was tested for four and a half hours daily from (8:30 am -12:30 pm) for a period of three and a half months (November, December, January, February) at the entrance temperature (40.50 ,60 °C) °C and liquid volume flow rates (2.5, 1, 1.5, 0.5 LPM) for dry soils.

Where the total heat transferred to the soil, the heat transmitted by conduction to thermocouples at a distance (0.6m) and the heat stored in the soil, as well as the calculation of Fourier number and the heat saturation percentage of the soil were calculated.

The best total heat transferred to the soil after four and a half hours of continuous operation was at inlet temperature (60°C) and flow rate (2LPM) and its value (192.44W),

The best conductive heat transfer (Q0.6m) was at inlet temperature (60°C) and flow rate (2LPM) and its value (61.522W)

The best Soil stored heat (Q stored) was at inlet temperature (60°C) and flow rate (2LPM) and its value (168.78W)

The best soil heat saturation ratio was at the inlet temperature (60°C), flow rate (0.5LPM) and its value (0.7168).

At the inlet temperature (50°C) the value of the heat stored in the soil (Q stored) was very low due to the high moisture content of the soil due to precipitation during the test period.

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Nomenclatures

Symbol	Definition	Unit
Δp	Pressure drop	*Pa*
Ai	Inside surface area of pipe	m^2
Ao	Outside surface area of pipe	m^2
Cp	working fluid's specific heat	*kJ/kg.°C*
Cw	Specific heat of water	*kJ/kg.k*
D	Depth of soil	*m*
di	inside diameter of the pipe	*m*
*D*o	outside diameter of the pipe	*m*
K_{pipe}	thermal conductivity of pipe	*W/m.°C*
K_{soil}	Thermal conductivity of soil	*W/m .°C*
K_w	thermal conductivity of water	*W/m.°C*
L	Length of the pipe	*m*
$\dot{m}$	Mass flow rate of fluid	*kg/s*
$\dot{Q}$ e, exp	Heat exchange rate per unit length	*W/m*
Q exp	Total experimental heat exchange rate	*W*
T_{amb}	ambient weather temperature	*°C*
Ti	water temperature inside the pipe	*°C*
To	water temperature outside the pipe	*°C*
Ts	temperature of soil surface	*°C*
U	Overall heat transfer coefficient	$W/m^2.k$
$\dot{V}$	rate of volumetric flow	m^3/s
α	Thermal diffusivity	m^2/s
P_w	Density of water in the pipe	kg/m^3

ΔT_w	(Tin-Tout) Overall temperature difference of fluid	°C
µ	Dynamic viscosity	kg/m.s
COP	The coefficient of performance	-
E	Roughness inside pipe	mm
ε_{exp}	Exchanger energy effectiveness	-
Ƒ	Coefficient of losses	-
h_w	Convection heat transfer coefficient	W/m.K
I	Electrical current	A
LMTD	Log mean temperature difference	°C
Nu	Nusselt number	-
P	Power required to operate the pump	W
Q	Theoretical heat transfer rate	W
R_{conv}	Convection thermal resistance	K/W
R_{pipe}	Conductive thermal resistance	K/W
R_{soil}	Thermal resistance of soil	K/W
S	heat exchanger external surface	-
S_x	heat exchanger external surface at x section	-
T_g	Ground temperature	°C
T_w	Fluid temperature	°C
V	Electrical voltage (220)	Volte

LIST OF ABRIVATIONS

Symbol	**Description**
BHE	Borehole heat exchanger
CFD	Computational fluid dynamics
EAHE	Earth to air heat exchangers
EAHX	Earth air heat exchanger
EATHE	Earth air tunnel heat exchanger
EWHE	Earth to water heat exchangers
GCHP	Ground coupled heat pomp
GE	Geothermal energy
GHE	Ground heat exchanger
GHEs	Ground heat exchanger system
GHPs	Ground heat pump system
GSHPs	Ground source heat pump system
GTHE	Ground tube heat exchanger

CHAPTER ONE

INTRODUCTION

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INTRODUCTION

1.1 Introduction

Geothermal is an expression derived from two Greek terms, thermal and geo, which express heat and earth, respectively. Geothermal energy means heat in the ground. This energy is classified as renewable energy and is obtained from inexhaustible sources of fossil fuels. Geothermal energy sources do not depend much on external factors Like the sun and wind it is by far the most renewable and efficient.[1] .

1.2 Geothermal Energy (GE)

One of the well-known facts is that the inner parts of the Earth are very hot, as most estimates indicate that the temperature ranges between 200-1000 °C at the base of the earth's crust, and the high temperature ranges between 3500-4500 °C in the center of the Earth. [2]

Heat is mainly transmitted by conduction from inside the earth to the surface of the soil, and this heat transfer leads to an increase in the temperature by an average of 25-30 ° C / km in the high depths of the crust. Wells for geothermal output are typically more than 2 km deep. The amount of heat energy that earth produces is staggering. Thermal energy in the ground is sufficient to meet the energy needs of all countries in the world.

Geothermal energy provides electrical energy in more than 25 countries. Five of them receive 15-22% of the national electricity supply from the production of geothermal energy,and the countries that use geothermal energy directly, more than 78 countries in shower, cooling and heating applications. At the end of 2020. and geothermal energy use worldwide reached 57 TW/y of electricity power and 76 TW/y for use of direct[2],[3].

According to some studies, geothermal energy is cheaper, more efficient and cleaner than all other fossil fuels. Geothermal energy is obtained without burning any fossil fuels and with low emissions of carbon dioxide, nitrous oxide or sulfur gas by geothermal power plants. For example, in Iceland, Reykjavik is known as the cleanest city in the world because almost 95% of buildings use geothermal energy.[4]. The energy known as geothermal energy can be extracted and used in many ways anywhere on the surface of the earth, and it is a practical option available to all Iraqi farms. Humans use geothermal energy to generate electric power and for cooling and heating purposes in buildings and greenhouses and many other uses, as well as geothermal energy can be produced on wide range, 24 hours a day without emitting any greenhouse gases, making it the unfeasible and sustainable alternative to reduce dependence on global warming and fossil fuels.[1]. Most applications of geothermal energy have been identified as efficient cooling and heating for residential areas. This efficiency is 20 - 40 % greater than the cooling systems currently in use 50 - 70 % greater than the conventional heating systems and There are also very low utility bills for this high efficiency.

Iraq climate can be defined as a hot, dry, semi-tropical one. The temperature often reaches 50 °C in August and July, and the average temperature in the summer is approximately 40 °C. These climatic conditions cause an increase in the temperature in the summer and a decrease in the winter, and this leads to an increase in electricity consumption due to the use of air conditioning systems that provide appropriate comfort conditions. Iraq is located within the middle east, with a territory 437,072 km^2 it has a population of approximately 36 million people. This country suffers from major problems such as the lack of electricity, which is likely to increase with the passage of time. Approximately 70% of electrical energy is consumed locally, and electric heaters and air conditioners occupy a large part of this percentage of electricity consumed in the winter and summer months. [5]. Because Iraq is suffering from a severe shortage of electric power production, geothermal energy can be a better alternative to reduce the consumption of electrical energy, as geothermal energy is environmentally friendly and clean energy. Thus, earth tube heat exchanger (ETHE) could be the ideal system and option for harnessing alternative energy (geothermal energy) low cost without affecting the standard of living.

1.3. Types of ground heat exchangers

The heat pump unit can be connected in the GHPS system to the geothermal heat exchanger in two general types, denoting closed - loop and open - loop ground heat exchangers[6] . These two ground heat exchangers are introduced in the following sections. To select appropriate type of geothermal system, It is critical to investigate heat flow, geology, fluid dynamics, hydrogeological system, faults and fractures, local rock sequence and stress system [7],[8].

I.3.1. Open-loop heat exchangers

An open-loop ground heat exchanger system is a system that pumps water from a water source to provide heat for the heat pump, the heat pump's water is discharged into drains, groundwater, or surface water bodies. The discharged water can be used for a variety of applications, such as irrigation, consumption, and so on. Most installations are based on a well-doublet scheme in a shallow aquifer including an extraction well, which pumps groundwater, and an injection well where the cooled or warmed water is injected back into the same aquifer at the same rate, but at a different temperature.

The depth of the wells is typically less than 50 m. depending on the type of water intake and outflow sources, open-loop heat exchanger systems can be connected in a variety of ways. [9] , a typical open-loop heat exchanger is shown in Fig 1.1.

Figure I.1. A typical open-loop ground heat exchanger [10]

When compared to closed loop systems, open loop systems are thought to offer higher thermodynamic performance and a cheaper cost. [11]. However, the system is not available in water shortage areas and its environmental risk is higher due to water pollution.

I.3.2. Closed-loop heat exchangers

The closed-loop ground heat exchangers are the most frequently applied ground heat exchangers[12], They can be buried horizontally, vertically, or obliquely, and a heat carrier medium is circulated within the heat exchanger to transfer heat from the earth to a heat pump or vice versa.[10]. There are also closed-loop heat exchangers installed in rivers or seas to absorb or reject heat for buildings beside waters[13] .

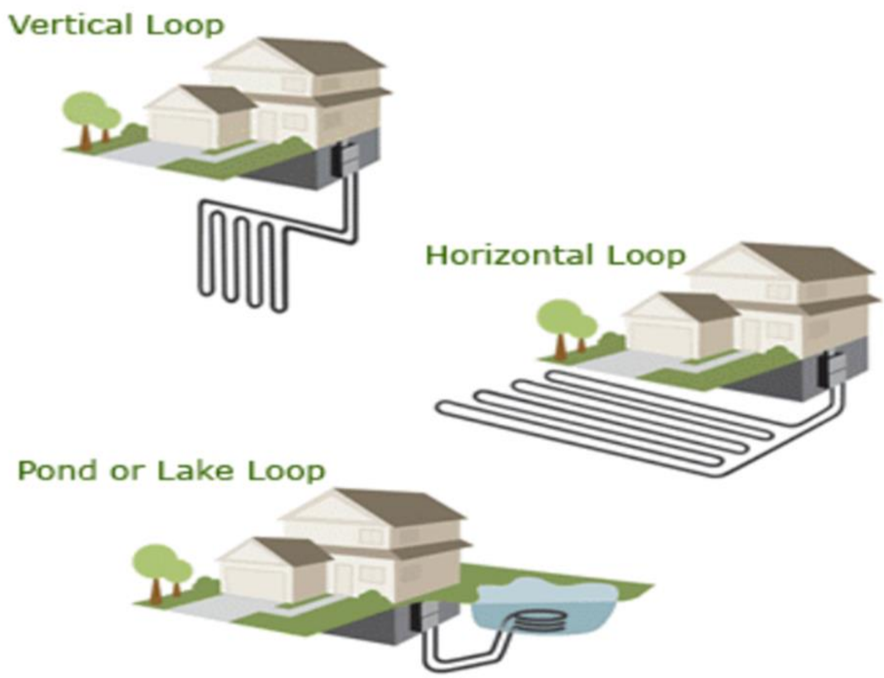

Figure I.2. Three typical closed-loop ground heat exchangers:

(a) BHE (b) energy pile and (c) HGHE Three typical

closed-loop ground heat exchangers are shown in Fig I.2. BHE (Fig I.2-a) is commonly installed vertically beneath the ground surface, commonly ranging between 20 and 200 m. The ground heat exchanger is traditionally surrounded by grout, and the diameter for the borehole ranges between 10 and 15 cm[14]. To satisfy the energy demand of a building, multi-boreholes are conventionally drilled with at least 4.5 m of spacing between 2 boreholes[9] .

1.4. Thermal Properties Near the Ground Surface

The soil and rocks that are located between (200-300 m) below the ground surface act as a heat sink that grows in reaction to two sources of heat. The first source is heat flux from the ground interior, with an average (87 * 10-3 W /(m²·K). The cause of this heat is the gradual cooling of the ground interior and radioactive decay in the crust, where temperatures exceed (60 °C) at depths of (1-2 km) with thermal gradients varying from (0.5-1.5 °C) every (30 m). The second source is the surface temperature which graded from (5 to 50 °C). Its differential can vary from a location to another, often due to the variability in air temperature, which is variable seasonally. There is a relationship between the soil temperature and depth in the various seasons for wet and dry soils as shown in Fig (1.3), where the outer curves represent the gradation of the wet soil temperature with the difference in depth, and the internal curves represent the dry soil. The difference between the curves is due to the different thermal conductivity of the soil[15]. Studies also show that temperature differences near the surface of the earth decrease at certain depths in the soil, and the temperature stays fairly stable at distance (2-5 m), as shown in the fig (1.4). It is attributable to the increased thermal inertia of the Earth surface, as well as the influence of time lag between the changes in temperature of surface,

on the temperature of soil at different depths. As a result ، solar irradiation activity is not absorbed into the soil at very deep levels [16]. Accordingly, the GHE installation site was chosen at a depth (2 m).

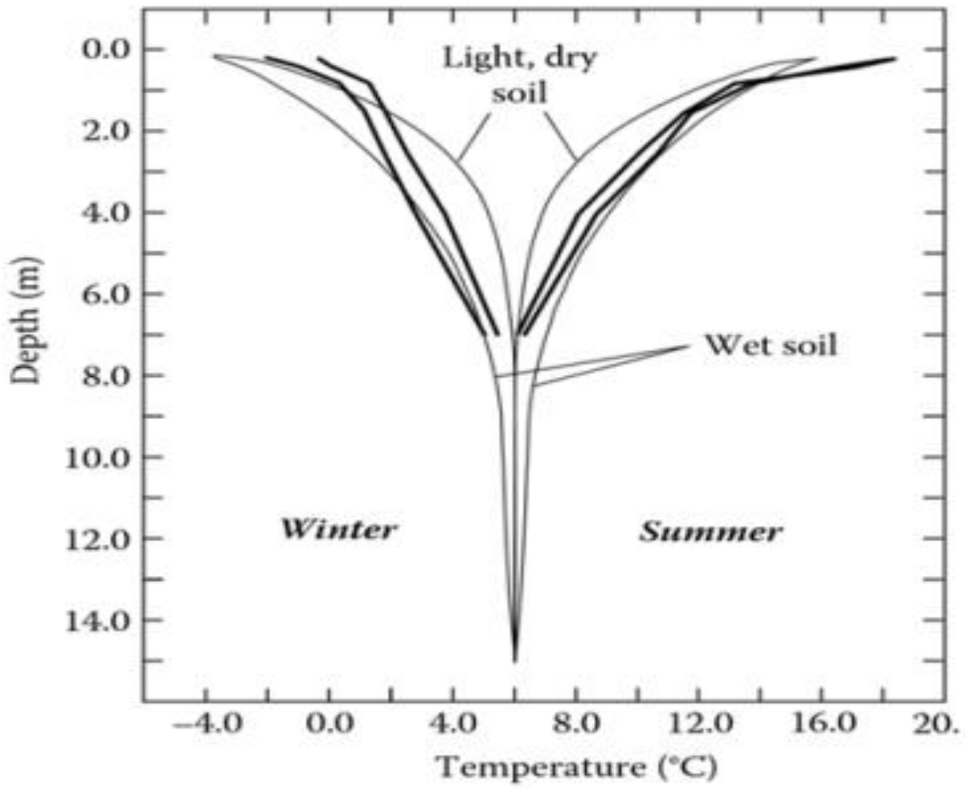

Figure. 1.3 A relationship between the ground temperature and depth for the different seasons of the year[15]

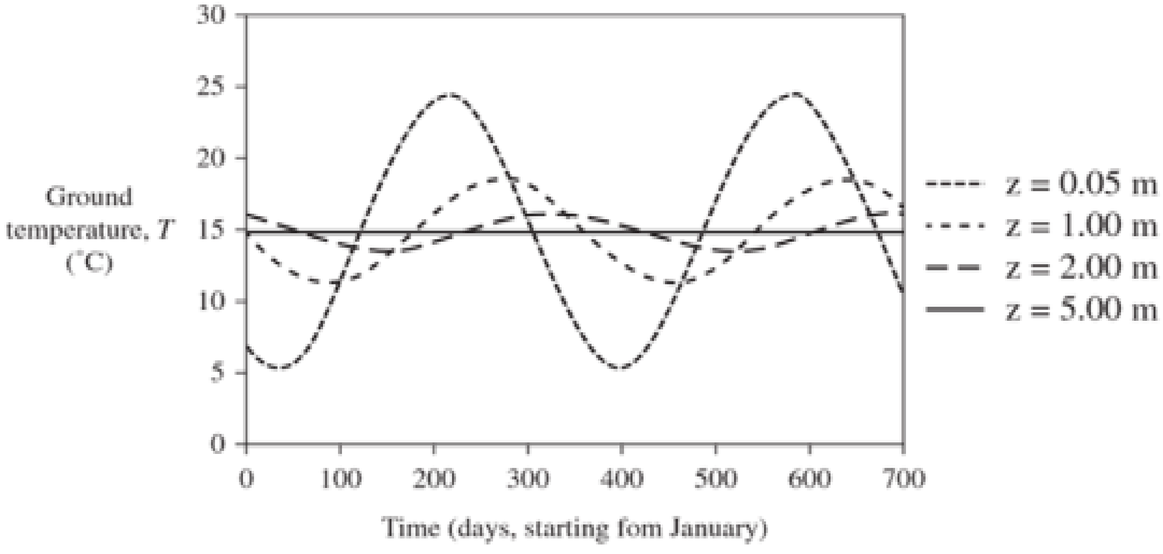

Figure. 1.4: Ground temperature difference with time at different depths[16].

1.5 Geothermal Applications

Because geothermal energy is a major source of electric power, it also provides a variety of options for air conditioning (heating and cooling), swimming pools, and agricultural applications. The first is (geothermal power stations), and the second is (ground source heat pumps). It is used to cool homes in the summer and heat them in the winter. Energy generation and direct usage are the two main types of geothermal applications.

1.6 Direct Use

In general, geothermal exchange systems consist of a ground coupled heat pump (GCHP) and a ground tube heat exchanger (GTHE), with the heat pump connected to the geothermal heat exchanger to provide heating and cooling for homes, commercial and industrial structures, greenhouses, and other structures. Where the earth is the primary source of energy, the system might be hot or cold depending on the season. The direct use of geothermal energy relies on the temperature of the soil or generally steady groundwater and is available anywhere in the world between (4°C to 30°C) [17]. With the exception of seasonal variations, temperatures at 1-m and beyond are constant. At a depth of 1 m, the low temperature ranges from 21°C in January to 30°C in June. for the same period, the temperature varies between 22 °C and 28.4 °C at a depth of 2 m, and between 24 °C and 29.8 °C at a depth of 3 m. Depending on the global position, in recent decades, ground temperature has been studied[18], [19]. Implementing a GHE system for building cooling is a type of energy source that saves energy and minimizes fossil fuel-related greenhouse gas emissions.

The GHE system also had a lot of potential for greenhouse cooling, as it can control humidity and lower interior air temperature by up to 6 degrees Celsius[20].

The nomenclature of earth tube heat exchangers (ETHE) differs depending on the working fluid.When air is the fluid to be conditioned, earth to air heat exchangers (EAHE) are used, and when water is the fluid to be conditioned, earth to water heat exchangers (EWHE) are used. EWHE heat exchangers were employed in this research. When compared to earth air heat exchangers (EAHE), (EWHE) has a number of advantages [21], as follows:

1. water is used with small diameter tubes, EWHE are less expensive and easier to install.
2. EWHE has a simpler architecture, it requires less maintenance.
3.EWHE uses around 33% less yearly energy.
4. The temperature outside is either hot or cold. Additional temperatures are not required for EWHE.

5. The coefficient of performance (COP) for (EWHE) averaged about 3 compared to 2 for (EAHE).

Because the temperature of the soil remains relatively constant at a depth of 2 m below ground, this energy has been utilised in cooling and heating applications by forcing water or surrounding air into a buried tube. When water or air passes through the buried tube during the summer, heat is transmitted from the air or water to the earth via convection and heat conduction.

During winter, heat is transmitted from the soil to the tube by conduction, then to water or air by convection as the water or air travels through the buried tube [22]. In various parts of the world, practical and theoretical researches and experiments on the ground tube heat exchanger system have been conducted. The goal of this project is to investigate the effects of various parameters on system performance.

Early testing on the performance and capacity of the ground pipe heat exchanger was carried out in the United States. The theory of operation of the ground tube heat exchanger, as well as its numerous applications for heating and cooling in residential, industrial, and commercial structures, make it evident that achieving the intended results and aim takes time. After a period of continuous and long work, there is often a problem with these systems, which is the deterioration or decrease of the thermal performance of heat exchangers, that is caused by the accumulation of heat rejected by the exchanger in the soil around the heat exchanger tubes in the cooling season, and the accumulation of coldness in the soil around the heat exchanger tubes in the heating season. Due to heat and cold accumulation, several experimental and theoretical investigations have shown a deterioration in the thermal performance of heat exchangers and heat pumps that are related to the ground. To supply cooling and heating, an experimental study on the geothermal heat pump system was done. The findings reveal that the system's performance is influenced by operating modes and situations. In the experimental setup, the heat and cold accumulated in the soil during the cooling and heating processes were calculated [23].

The effort and performance of a horizontal geothermal exchanger were studied using numerical simulations. Part of the findings revealed that running the system sporadically increases the amount of heat delivered to the soil more than running it continuously. By doing a CFD simulation of 3D models to establish techniques for enhancing designs for horizontal geothermal heat exchangers, it was proposed that prospective methods for improvement are a result of this work. The GHE operates at a high heat exchange rate before the soil becomes heat saturated as a result of the exchanger's continuous activity, the ground should be allowed to reestablish thermal equilibrium, or at least a portion of it, until the next cycle [24].

1.7 Research problem and objectives of the thesis

According to that literature review, it has been seen that limited studies have been published on study of thermal parameters of vertical geothermal heat exchanger in Najaf city. Besides, the previous experiments concentrated on a nevow variety of operational condition, which are not sufficient to show the process by which the vertical G.H.E caused improvement of thermal parameters.

The present work my be adopted to fill avoid that exists in the literature with the following points.

1- proposed a now rule for thermal parameters of G.H.E to explain the trend of condition and stored energy through the sand soil.

2- investigate a wide range of parameters that were non_investigated from before, such as different airflow rates with different inlet water temperatures.

3- Investigate the effect of furrier number with saturated of sand soil

1.8 Thesis outline

the present thesis divided in to five chapters, as following .

- ❖ the current chapter/chapter one is a general introduction to geothermal energy enhancement and applications.
- ❖ chapter tow present a review of literature that is relevant to the topic of the present thesis. these studies include the most popular geothermal enhancement techniques and applications of G.H.E.
- ❖ chapter three describes the experimental work. A description of experimental apparatus used to investigate the effect of volumetric water flow on heat transfer characteristics of a vertical G.H.E the procedure of the experiments performed and the physical properties of the working fluid are outlined in chapter three .
- ❖ chapter four presents the discussion of the experimental results for various parameters at different operational conditions .
- ❖ chapter five is about the conclusions obtained from the experimental study and provides some recommendations for future work.

CHAPTER TWO

LITERATURE REVIEW

CHAPTER TWO

LITERATURE REVIEW

2.1 The Study of Properties and Ground Thermal Behavior

2.2.1 Thermal Properties of Soil

Thermal properties of soils anywhere are in a state of constant flux, due to daily and seasonal variations. Thermal properties of soil are affected by the volumetric water content of the soil, the air volume fraction and the soil solids volume fraction. These properties are important in every aspect of soil geotechnical and mechanical engineering and they indicate how much energy is being partitioned into a soil profile. The amount of energy distributed across a cross-section of the soil, from the surface to several depths, correlates with thermal properties, such as thermal conductivity, with soil temperature and reflects heat transfer through the solid by radiation, conduction, and convection. Temperatures are hotter at the surface and decrease with depth, depending on the thermal properties of the soil.

N.H. Abu-Hamdeh[26]. studied the effect of bulk density and moisture content on the thermal conductivity of some Jordanian soils through laboratory studies. The soil used was classified as sandy, sandy loam, and loam. The hot wire method was used for experiments. Heating and cooling methods were used to evaluate the thermal conductivity for soil types and the results obtained with the two methods were compared. Thermal conductivity increases with increasing soil density and moisture content.

It was found that the soil had a higher proportion of clay particles the thermal conductivity was lower. Graphical comparisons of the thermal conductivity of both methods, cooling and heating were obtained for each soil type. In general, the heating data yielded thermal conductivities that were slightly higher than those derived from the cooling data. The results of the cooling process show that the conductivity varies with the bulk density and moisture content, and the texture of the soil. In general, for the four soil types used in this study, an increase in moisture content at a given density increases the thermal conductivity. At a given moisture content, an increase in soil density leads to an increase in heat conduction. This is in complete agreement with the results obtained using an electric wire heating process. The heating data yielded a thermal conductivity that was slightly higher than that derived from the cooling data. clay soils had lower thermal conductivity than sandy soils.

Nikiforova, Savytskyi[27]. studied the research and development of physical and thermal properties of different types of soils to meet the challenges of the earth, protected buildings and green roofs, the use of heat pumps to determine the thermal conductivity of the soil, and the analytical dependence where the thermal conductivity and thermal diffusion coefficient of different types of soil (sand and clay) and soil moisture were obtained. Then get empirical data about the thermal conductivity of the soil.

Syaharudin Zaibona, Stephen H. Andersonb[28]. studied to determine the effects of topsoil thickness on the thermal properties of commutative soils. The experiment was conducted at the University of Missouri, Southern Farm Research Center (38°54′N, 92°16W). Plots were planted either to electric grass or corn (Zea mays L.)-soybean (Glycine max (L.) Merr.) in four replicates. Cores of undisturbed soil (7.6 × 7.6 cm) and bulk soil were collected from two depths (10 cm increments) to determine the thermal properties. Thermal conductivity, volumetric heat capacity, and thermal diffusion were measured at 0,33 −100 and −300 kPa soil water pressures. In addition, soil organic carbon (SOC), bulk density (Db) and water content (θ) bent were also included. The results showed that the switch grass treatment had 23% higher concentration, 5-8% higher and 11% lower dB than the row crop treatment. In turn, the switched turf plot showed a 5-7% decrease in D, an 8-9% decrease in D, and a 2-3% increase in CV. The shallower topsoil thickness exhibited increased thermal properties (λ, D and Cv) relative to the deeper topsoil thickness, likely due to higher clay content in the topsoil horizon and associated height θ. This study contributes to a better understanding of the effect of loss of topsoil and perennial vegetation on the thermal properties of soils in degraded landscapes.

José Manuel and újar Márquez[29]. studied a methodology and an indirect measurement system for measuring the thermal diffusion of soil at a given depth by measuring its temperature at that depth from VLEGE very low geothermal systems, which is simple and inexpensive because it can benefit from mandatory geotechnical excavation before construction of a house or building to take temperature measurements at the same time that allows obtaining the actual temperature and geothermal diffusion for the depth of interest. Heat exchange between fluids and the ground is based on the fact that the temperature varies throughout the year depending on the difference between the incoming fluid and the ground and the depth at which the heat exchanger is buried. With depth, the ground temperature change capacity is greatly reduced, and tends to settle in the mean temperature of the place for higher heating and cooling.

Figure 2.1. The relationship between the average monthly temperature and soil depth. [29]

Rock type	Thermal conductivity (W/m.k)			Volumetric Heat capacity ($MJ/m^3.k$)	Thermal Diffusivity (10^6 m^2/s)		
	Min	Typ	Max		Min	Typ	Max
Basalt	1.3	1.7	2.3	2.6	0.5	0.65	0.88
Greenstone	2	2.6	2.9	2.9	0.69	0.90	1
Gabbro	1.7	1.9	2.5	2.6	0.65	0.73	0.96
Granite	2.1	3.4	4.1	3	0.7	1.13	1.37
Peridotite	3.8	4	5.3	2.7	1.41	1.48	1.96
Gneiss	1.9	2.9	4	2.4	0.79	1.21	1.67
Marble	1.3	2.1	3.1	2	0.65	1.05	1.55
Mica schist	1.5	2	3.1	2.2	0.68	0.91	1.41
Shale sedimentary	1.5	2.1	2.1	2.5	0.6	0.84	0.84
Limestone	2.5	2.8	4	2.4	1.04	1.17	1.67
Loam	1.5	2.1	3.5	2.3	0.65	0.91	1.52
Quartzite	3.6	6	6.6	2.2	1.64	2.73	3
Salt	5.3	5.4	6.4	1.2	4.42	4.5	5.33
Sandstone	1.3	2.3	5.1	2.8	0.46	0.82	1.82
Siltstones and argillites	1.1	2.2	3.5	2.4	0.46	0.92	1.46
Dry gravel	0.4	0.4	0.5	1.6	0.25	0.25	0.31
Water saturated gravel	1.8	1.8	1.8	2.4	0.75	0.75	0.75
Dry sand	0.3	0.4	0.55	1.6	0.19	0.25	0.34
Water saturated sand	1.7	2.4	5	2.9	0.59	0.83	1.72
Dry caly/silt	0.4	0.5	1	1.6	0.25	0.31	0.62
Water saturated caly/silt	0.9	1.7	2.3	3.4	0.26	0.5	0.68
peat	0.2	0.4	0.7	3.8	0.05	0.10	0.18

table 2.1 Thermal conductivity, volumetric heat capacity and thermal diffusivity for different kinds of soil.

Zahraa. S. Abdzaid[30]. studied the design and testing of the horizontal two-layer heat exchanger as a closed system to reduce the space required for the installation of horizontal single-layer heat exchangers. Two grids are designed in a serpentine shape where the tubes of the two grids face each other in a stepped manner. When operating the system in dual layer mode, there is a difference in average temperatures (15.96) ° C as shown in fig (2.1). When the system is operated in a single layer mode, the highest difference in the average temperatures is (15.8) and (13.4) ° C as shown in fig (2.2), and therefore the thermal performance coefficient of the heat exchanger for the double layer mode is better than for the single layer mode.

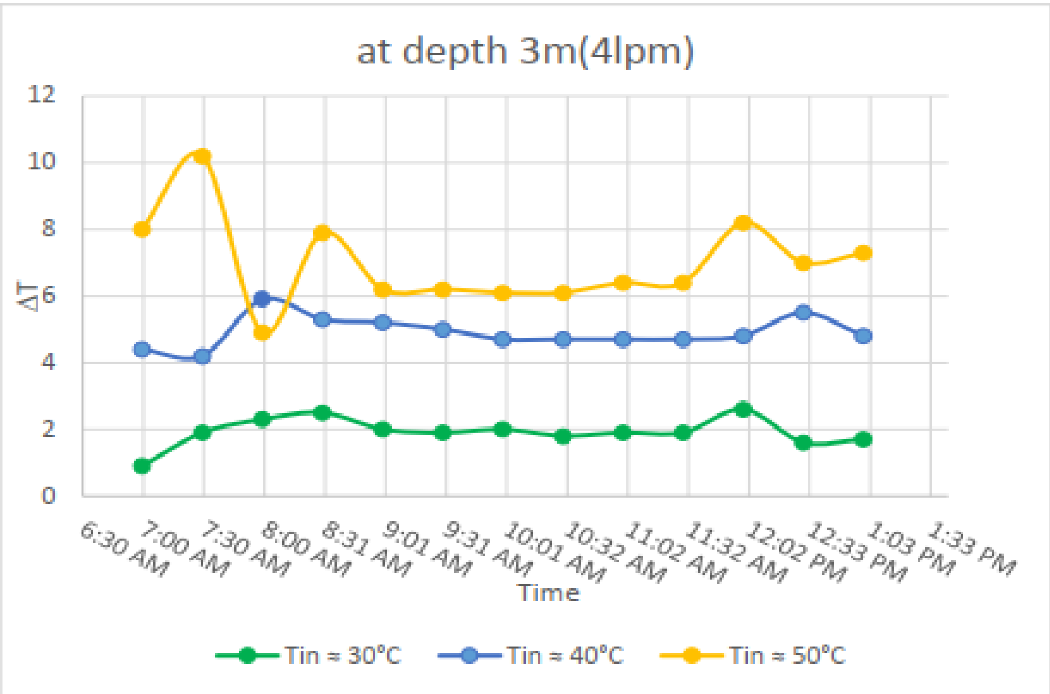

Figure.2.1: the relationship between temperature difference and time when flowrate (4 LPM) and for the first-layer.[30]

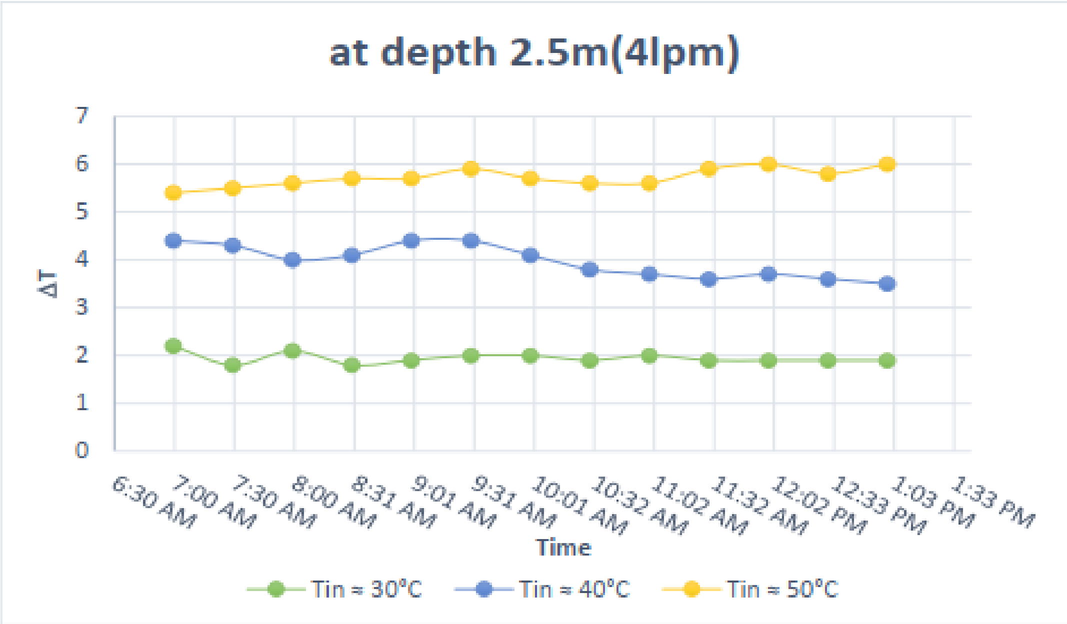

Figure. 2.2: the relationship between temperature difference and time when flowrate (4 LPM) and for the second-layer[30]

Harith Essa[31]. studied the performance of the horizontal two-layer heat exchanger system at the College of Engineering in Najaf in the mode of continuous and alternating operation, and the heat accumulation around the layers of the heat exchanger. The alternating operation mode of the exchanger showed better performance than the continuous operating mode of the exchanger with an improvement in the thermal performance coefficient by 15.9% at a flow rate of 4 liters per minute as shown in fig (2.3), where there was a decrease in the thermal performance coefficient of the geothermal exchanger under the same conditions due to the heat accumulation formed around the layers of the geothermal heat exchanger horizontal.

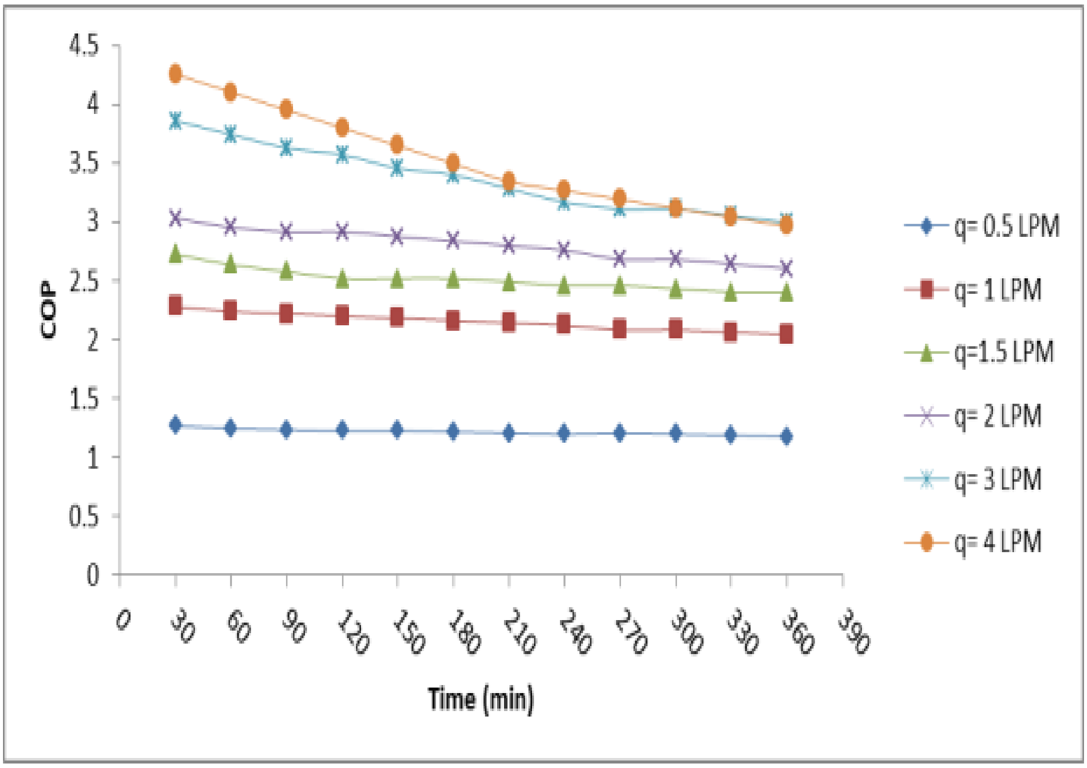

Figure. 2.3: Coefficient of performance for various flow rates at a constant input temperature (40°C) for the alternating operating mode of the heat exchanger. [31]

Tessy Chacko , Renuka[32]. studied soil characteristics and year-round air temperature in Cariapatum , Ker State. The amplitude and phase angles of the first and second harmonics were used to determine the thermal diffusion (ks) of the soil using range and delay methods, as well as the amplitude and phase angles of the first and second harmonics. Both strategies provide similar results. Heat flow has an effect on daily fluctuations. Soil moisture and incoming solar energy. On dry days, the net heat flow is sent to the soil, while on rainy days, it is directed to the air. as shown in fig (2.4).

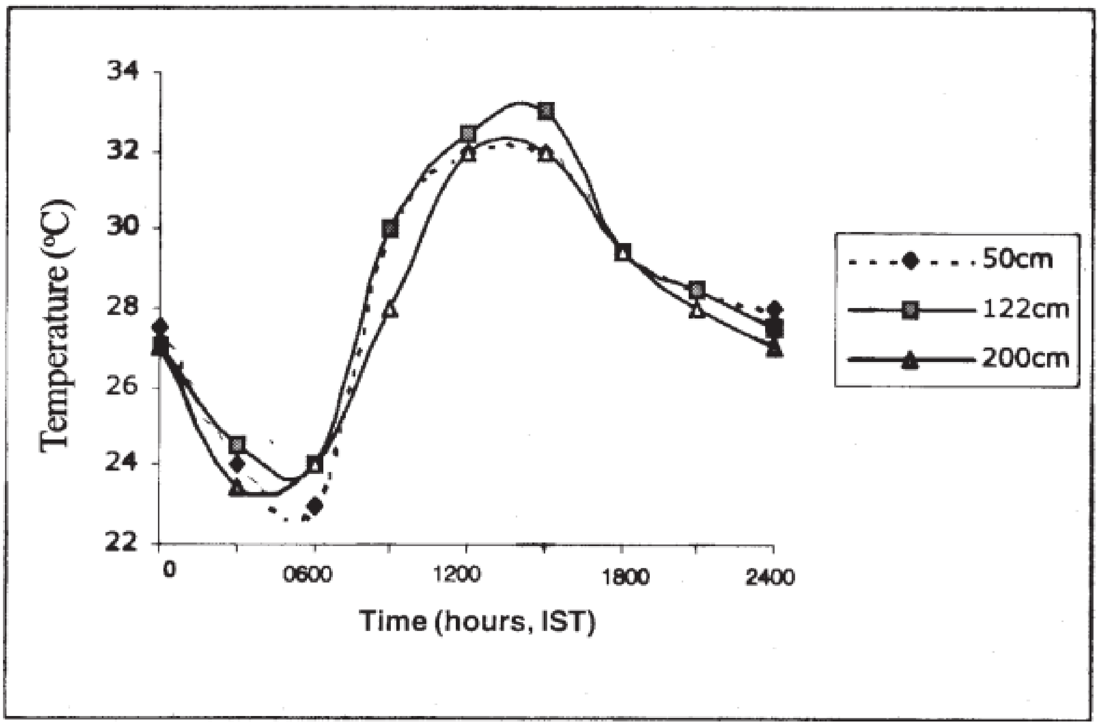

Figure 2.4 on the 22nd of January, 2001, there was a diurnal change in air temperature.[32]

Barbara Larwa, Krzysztof upiec[33]. studied the use of the analytical model of solenoid geothermal exchangers for heat transfer. A comparison was made to the specific GTT values based on the analytical dependence. The inconsistency of the temperature profile relative to the level at which the heat exchanger is observed and compliance with the analytical results and experimental values of one loop is the basis for modeling. as shown in fig (2.5).

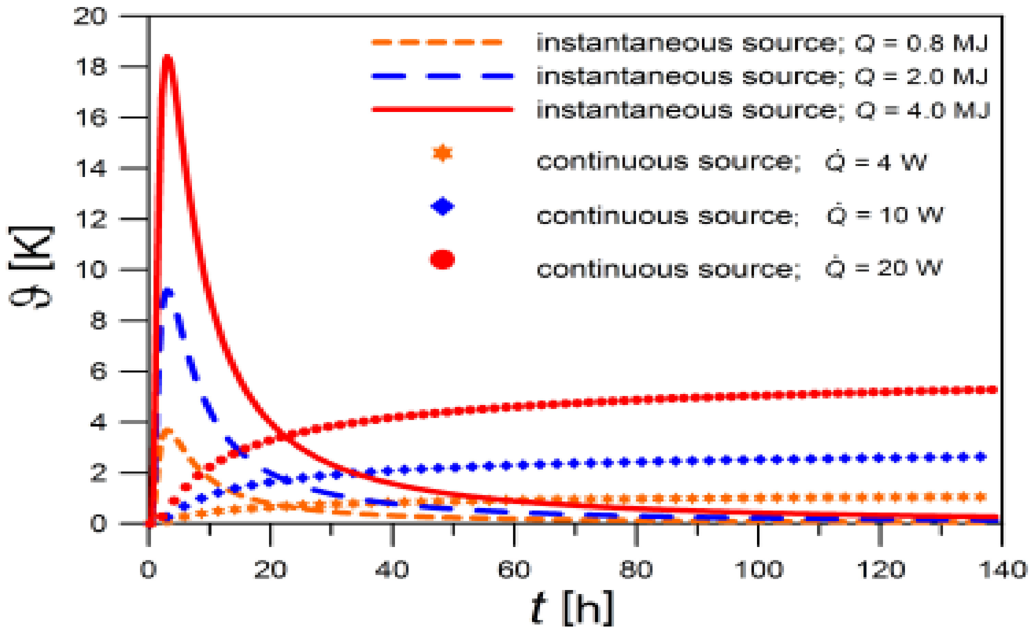

Figure. 2.5 Temperature excesses in point sources: immediate and continuous courses. [33]

Zhao M.[34]. studied the simulation of the geothermal heat exchanger system to know the thermal properties of the soil and the heat transfer mechanism and their effect on the performance of the geothermal heat exchanger. The thermal qualities that gave ground tube heat exchangers their high thermal inertia are directly related to their performance. Conduction, convection, and radiation are used to demonstrate the soil's heat transport process. Except for quick water absorption after irrigation or heavy rain, heat conduction occurs in soil, although the main mode of heat movement is through liquid and solid elements. When the temperature is high, radiation only acts in dry, permeable soils. The thermal conductivity and heat capacity are thus the major characteristics impacting the thermal behavior of the soil, and they can be described together under the concept of thermal diffusivity as shown in the Fig (2.6).

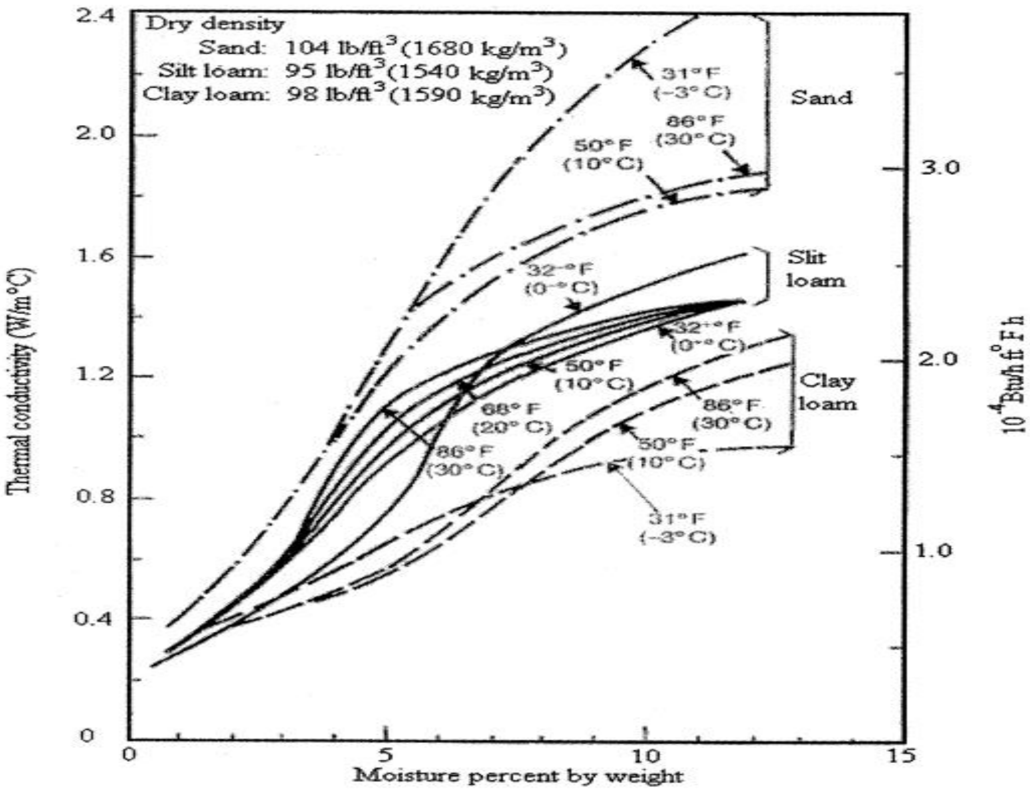

figure.2.6 different soil thermal conductivity as a function of moisture percent by weight.[34]

Quirijn de Jong van Lier[35]. studied the determination of the thermal diffusion of soil from temperature measurements for half an hour using three procedures to calculate the capacity ratio, phase delay and Seaman procedures using soil component parameters to evaluate techniques and methods for determining thermal conductivity for short wave durations with modest temperature differences. The suggested method using the daily phase delay between sine waves to determine thermal diffusion resulted in coherent values for thermal diffusion where the temperature gradient is quite steep over longer periods, especially for depths where the temperature differences are minimal. as shown in fig (2.7).

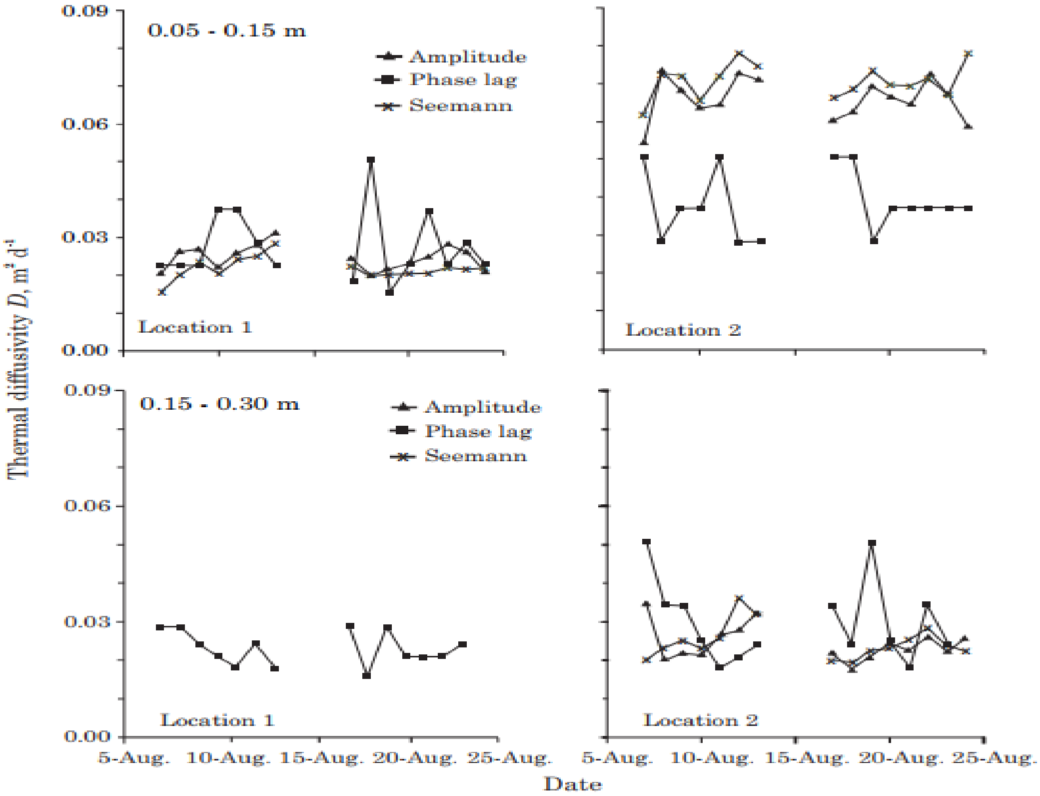

Figure 2.7 The amplitude ratio approach, the phase lag method, and the Seaman method were used to calculate thermal diffusivity D as a function of time for both Locations and both depth intervals. [35]

Eicker and Vorschulze [36]. studied the operation of the low-depth geothermal heat exchanger as an efficient heat sink for building up the energy produced in the summer. Buildings cool down quickly when the annual average ambient temperature is low enough. In conjunction with an active cooling system, a heat exchanger replaces a cooling tower. As an annual average rate for consumption of cold produce electricity, a performance for a double heat exchanger offered results for a ground analysis of a superior performance coefficient ranging between 13-20. The maximum corruption per meter is lower than that of an intended geothermal heat exchanger, ranging from 8 W/m for low depth horizontal heat exchangers to 25 W/m for vertical heat exchangers. The conductivity of the soil determines how much energy was wasted by -30%. Polyethylene U-tubes were used in vertical boreholes with a diameter of 75–220 mm. Thermodynamic conductivity for vertical tube filling material presentation varies by 30% depending on the substance. Energy spaced from 2 W/m in direct cooling application at 20 ° C to 52 W/m in alternative to cooling towers at 40 ° C, depending on temperature for intake to heat exchanger on ground.

Hassanzadeh, Darvishyadegari et al[37]. introduced a new solution to dissipate more heat energy to improve the horizontal direct ground heat exchanger (GSHE) compared to the conservative GSHE. As a buried pipe for a GSHE is equipped with a galvanized bridge, the heat transfer rate between the pipes and the ground is substantially improved when compared to typical GSHEs, according to the results. It has been shown that the strategy for improving heat transmission is more effective in low-conductivity soils than in high-conductivity soils. Finally, the maximum improvements in thermal energy dissipation for Soil I, Soil II, and Soil III were established at 90.45 %, 28.83 %, and 12.57 %, respectively.

Abbas Khalaf Mohammed Shua'ab[38]. The experimental test of the heat transfer properties of the underground heat exchanger was studied. It is made of carbon steel pipes of 50 meters' length and of different internal and external diameters. The pipe is buried 2 meters deep under the soil surface. In the pipe, hot water is employed as a working fluid at volumetric flow rates ranging from 25 to 1 cubic meter per hour, and the input is heated. The water temperature ranges from 50 - 80 degrees Celsius. The water temperature was measured at five equal points by thermocouples placed inside the tube. The dimensions of the underground heat exchanger tube have significant effects on heat transfer type. Heat exchanger tube material had little effect on heat transfer. Experimental and analytical results were compared under experimental conditions and the results were good.

Tetsuo sekiyama and kiyotsune [39]. A study of measuring the moisture content of soil and silt water. The water content in soil and clay is directly related, which can be obtained by sampling and weighing. TED is a method that takes advantage of the thermal qualities of the soil that are different from the soil's water content. The change in thermal quality and the effect of the transfer of soil moisture and soil temperature due to heating is examined. Therefore, the appropriateness of the heat capacity in the thermal method of soil water is examined and also the correlation between quantity, as shown in fig (2.8). temperature rise and changes in soil temperature like ways to compensate for shadows. The thermal method is used to continuously measure the water content in the soil and to make modifications to increase the accuracy. The heating conditions of the heat source is to increase the amount of heat generated in order to increase the sensitivity of the detection of soil and mud water and the contact between the heat source and the soil. The sensitivity of the detection deteriorates is due to the intensity of the accuracy. as shown in fig (2.9).

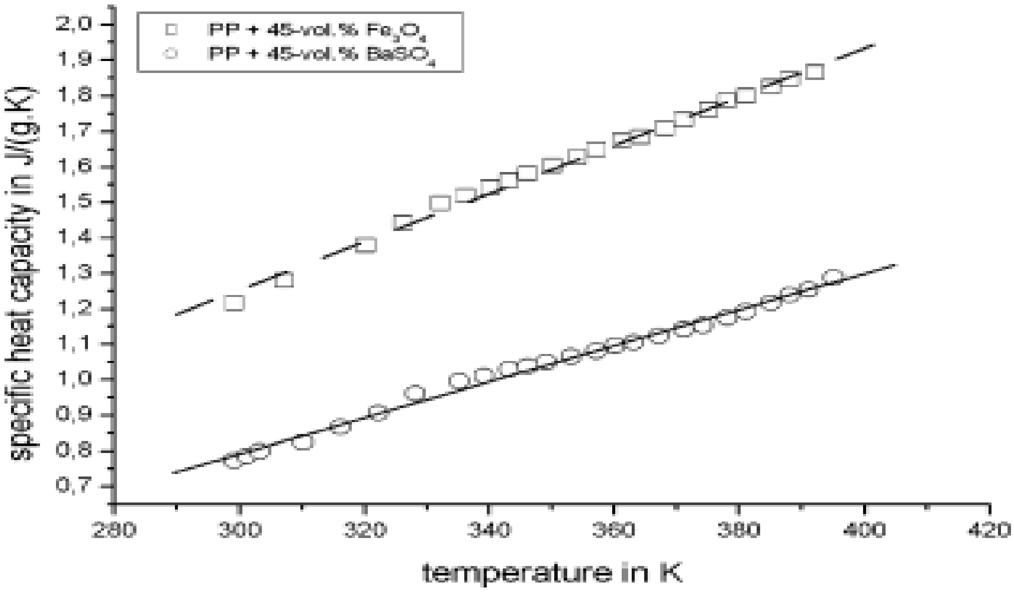

Figure. 2.8. the specific heat capacity of PP filled with 45 vol.% magnetite and barite is temperature dependent. Measured values are represented by symbols, while linear fits are shown by lines.[39]

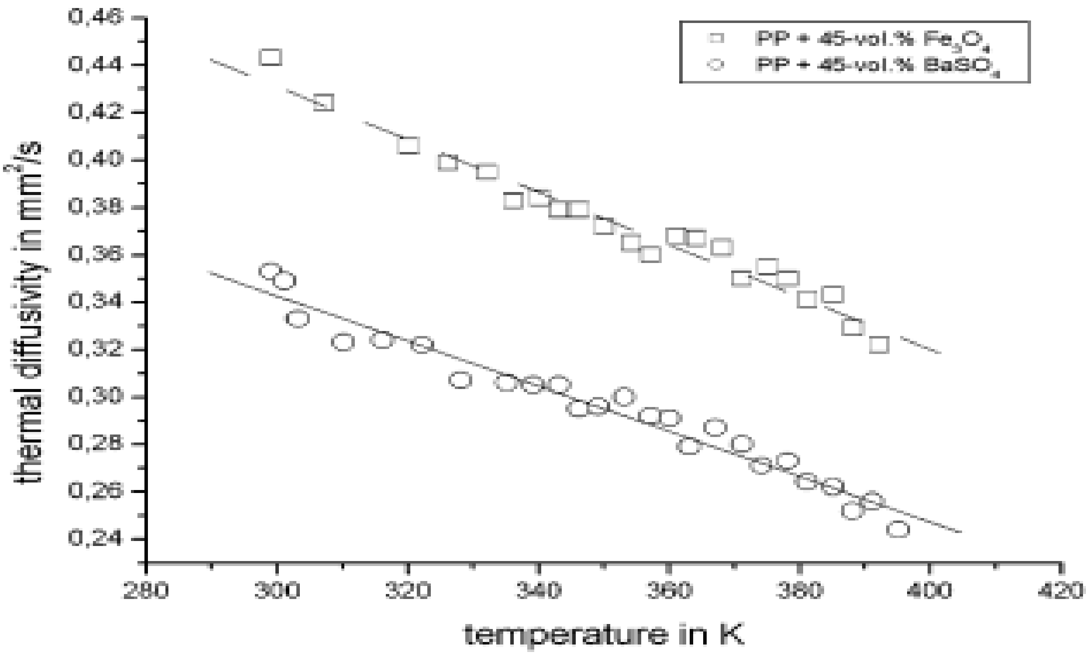

Figure. 2.9 The thermal diffusivity of PP filled with 45 vol.% magnetite and barite is temperature dependent. Measured values are represented by symbols, while linear fits are shown by lines.

Kasim et al. [40]. studied an experimental investigation of soil temperature in the ground in Baghdad, Iraq, in order to establish robust, long-term, and adequate ground heat exchanger systems (GHE). It considered four Baghdad locations: ALSadr City, ALQray'at City, ALJadiria City, and University Technology. To evaluate the thermal properties of soil, you must first ascertain the type of soil and its moisture content. The soil temperature distribution was simulated at eight depths (1, 3 m, 5 m, 10 m, 15 m, 20 m, 25 m, and 30 m) for four cities using MATLAP software over the course of a year. the temperature in ALSadr city ranged from 11 °C to 35.5 °C at a depth of 1 m, according to the data. Because diurnal variations decrease as depth increases, temperatures remain constant at roughly 13 meters and beyond.

The three locations in ALQray'at City, ALJadiria City, and University of Technology have the same behavior as ALSadr City, with the exception that the temperature remains constant throughout the year for the three cities at depths of 14 m, 14.5 m, and 15 m, respectively, as shown in the Fig (2.10).

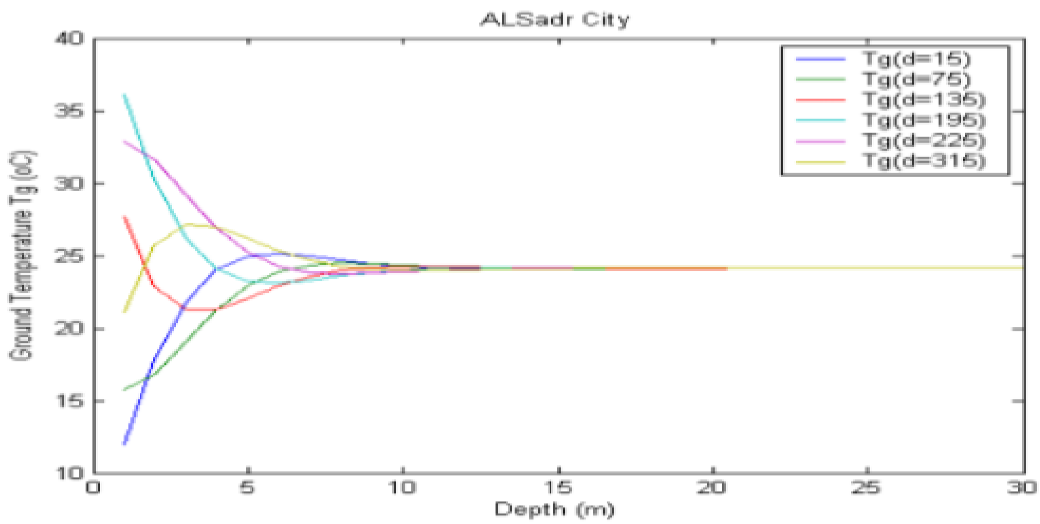

Figure 2.10: distribution of soil temperature in Al-Sadr City in Iraq according to the depth for the days of the year.[40]

Hikmet Esen a, Mustafa Inalli b, Yuksel Esen [41]. studied to show how the well temperature distribution of GCHP systems changes over time. The study interval is 48 hours for a vertical GCHP system that employs R-22 as a coolant and had three single tube geothermal heat exchanger (GHE) built. (GHE) was constructed from polyethylene pipes and installed in a vertical well with depths of 30-60-90 meters and widths of 150 centimeters. (FEM) was created to model the evolution of temperature distribution in the soil around it, the (GHEs) of (GCHPs) work in cooling and heating modes.

Understanding the evolution of temperature distribution for U-tubes and wells for the ground system (GCHP), GHE temperature distribution was used in the modeling reported in this work. The engineering application of the GCHP program relies heavily on numerical expressions. For forecasting the reaction of GHE to heat loading, temperature, (FEM) looks to be more promising.

Steven R. Evett , Nurit Agam [42]. studied the dependence of determining the heat flow diffuse over the soil surface as an average value over a period of time using heat flow plates buried 5-8 cm below the soil surface. For soils based on soil water content, bulk density, and organic matter content, a measure of the average soil temperature at the depth of the common layer is usually used. Several problems in the heat flow plate method limit the accuracy of the soil heat flux values. An alternative method was presented. The gradient flow method was compared with the soil heat flux. The method depends on water content and temperature periodically every half hour.

Sensing at multiple depths within the soil coil and solving Fourier equation for heat flow. A field method was presented to determine the relationship between soil thermal conductivity, water content and bulk density. the method combines determination of soil water content using TDR and soil temperature using thermocouples to collect the data set that was analyzed using analytical and statistical methods to determine the thermal conductivity.

IA Dai-Yong1, SUI Lu-Yan. studied the analysis of the most important factors affecting the thermal conductivity of the soil with the different compositions and water contents of the soil, and the conductivity was determined experimentally, which can provide basic data. For the design of GSHP, the thermal conductivity of the soil geothermal pump system is the main data for its design and it has an important role in the performance of the operation of the ground source heat pump system.

Chulho Lee a, Moonseo Park[43]. conducted a series of in-situ thermal response and effective thermal conductivity tests for six vertical tests. The closed-loop geothermal exchangers were experimentally evaluated and compared with each other to compare the geothermal efficiency of the exchanges in the field The six wells were constructed with different construction conditions. Different fillers (cement versus bentonite, different sections shapes, U-LOOP heat exchange tubes versus three new tubes) and different additives silica sand versus graphite. From the test results, it can be shown that cement injection is characterized by an effective thermal conductivity higher than that of bentonite injection, and graphite works better on silica sand as it is addictive and thermally enhanced. Cement grout provides the highest effective thermal conductivity. The effective thermal conductivity of the grouting both graphite and silica sand is higher than that of grouting wells with silica sand only.

Y. viswanadham and R. ramanadham [44]. studied the difference in heat exchange or temperature change in the surface layers of the soil and its importance in agricultural sciences in tropical latitudes. The amount and thermal diffusion largely determine the temperature change produced in any soil layer when heat was conducted there from an adjacent layer. Therefore, the authors determined the thermal diffusion of soils from the scale and lag methods proposed by Johnson, Davies and Coutts, respectively. The diffusivity values obtained from these methods agree well with each other. The effect of soil moisture on diffusion was studied. Diffusion increases with increased moisture in the surface layers of the soil. The ratio of soil temperature ranges at different depths is found to be approximately constant which is in agreement with the theory of heat flow in soils. The results from the diffusion obtained from these methods are in good agreement with the results of previous workers. Meaning The value of thermal diffusion of red sandy soil in Walter Experimental Site was found to be $6.336 \cdot 10^{-5}$ cm^2/sec. The detailed study of (k) with moisture content is not mentioned due to lack of precision as an instrument for measuring soil moisture content at different depths of soil. The authors are interested in studying the dependence of thermal diffusion on soil moisture.

Lamarche [45]. Studied simulation of the GHE clock for geothermal exchangers in a horizontal configuration. An analytical model based on a new formulation of the finite line source associated to horizontal configurations was developed to simulate the heat transfer between a horizontal heat exchanger and the surrounding ground. The model was compared to a finite element simulation in the case of a simple configuration and display excellent agreement given that the model is 500 0times faster than the numerical simulation.While the configuration might be simple, it illustrates a very important aspect of horizontal systems, namely, different local ground temperatures around pipes at different heights and how this can affect the thermal behavior of the ground exchanger. The model can easily be extended to different inline configurations, which can have parallel branches as well. Extensions to slinky or spiral configurations can also be considered,but in that case, the thermal response factor between pipe sections would be more complex. An extension of the classical work of Claesson and Dunand was also presented as part of this study. It is a future goal to use it to provide potentially better guidelines for horizontal design procedures.

Ceylan [46]. studied, ground heat exchanger for condenser temperature in ground source heat pumps (TKIP) ground heat exchanger (TID) length and an effect for heat pump on performance coefficient (COP) for four different refrigerants (R134a, R407C, R4010A and R404A) were examined during a cooling period. Heat transfer to soil with TID while experimentally investigating, calculations related to a heat pump supposed to work in connection with TID theoretically done.

Horizontal laying under a ground in Çorlu district for Tekirdağ for heat transfer to soil 36 m polyethylene TID embedded by a method was used. It was measured using appropriate probes and all data were recorded via data-logger. 1kW cooling load used COP value for a vapor compression heat pump and a TID length using an amount for heat transferred to the ground. An average TID has been determined using water inlet temperature. the results obtained, compressor power increases with increasing condenser temperature and TID and length was reduced. The greatest coefficient for performance among a coolants examined (COP) and the smallest pipe length was obtained for R134a. TID water inlet temperature is 39.54 from 31.34 ° C. When it increased to ° C، an increase in compressor power for R134a was found to be 38% and a decrease in pipe length was 48%.

Mathur et al.[47]. conducted a numerical study with a three-dimensional model of the effect of the thermophysical properties of the soil on the performance of the heat exchanger of the ground air tunnel; for three types of soil with three various thermal diffusivity, in terms of drops of temperature, the rate of heat exchange and COP using commercial software FLUENT. The COP was determined by analyzing the reduction in GATHE system's air temperature, heat transfer rate, soil temperature. The system operated continuously for 12 h period. The numerical results showed reasonable reception with previous experimental results shown in the table (2.2). EATHE results with soil J and F were very close to each other because of the similar soil thermal conductivity even after continuous 12 h of operation. So, it can be concluded that soil thermal conductivity plays a significant role that influenced EATHE thermal performance.

Hence, with higher thermal conductivity soil, maximum drop in air temperature and heat transfer achieved as shown in the table (2.3).

Table 2.2: soil properties

soil	location	Density (kg. m^{-3})	Specific heat capacity (J. $kg^{-1.}$ k^{-1})	Thermal conductivity (w. $m^{-1.}$ k^{-1})	Thermal diffusivity (m^2/sec)	Reference
soil A	Ajmer (India)	2050	1840	0.52	$1.37*10^{-7}$	Bansal
soil J	Jodhpur (India)	1740	1553.14	1	$4.37*10^{-7}$	Chandra
soil F	Presles (France)	1500	880	1.280	$9.69*10^{-7}$	Boithias

Table 2.3: Air temperature change with time along the tube for different soil types

Length of pipe (m)	Air temperature (°C)											
	1 h			3 h			6 h			12 h		
	A	J	F	A	J	F	A	J	F	A	J	F
0	46.20	46.20	46.20	46.20	46.20	46.20	46.20	46.20	46.20	46.20	46.20	46.20
10	37.42	36.49	36.49	38.5	37.51	37.45	39.27	38.17	38.01	39.98	38.75	38.51
20	32.46	31.48	31.48	33.64	32.52	32.45	34.56	33.24	33.07	35.49	33.83	33.51
30	29.46	29.09	29.09	30.79	29.85	29.80	31.59	30.40	30.26	32.43	30.79	30.52
40	28.46	27.96	27.96	29.12	28.43	28.4	29.73	28.76	28.66	30.33	28.98	28.81

Xiaozhao Li1,a, Liang Cao[48]. In this study, the current ideal prediction models for thermal conductivity of soil were not suitable for this purpose, the SEM images of soil samples were captured and digitized using the binary transformation process using the self-developed software package - ImgAnsys for image analysis, and the processed images successfully entered into ANSYS and were analyzed on the basis of a two-dimensional transient heat transfer model.

It was found that the simulation results were also in close agreement with the experimental results, which can explain the feasibility of this new. In this paper, a reasonable numerical modeling method was based on real soil texture. The back analysis calculated using the finite element method is applied to study the thermal conductivity of soil. The conclusions are as follows: The ideal calculation models may not be typical of the thermal conductivity of porous materials mainly because these ideal models cannot reflect the actual internal texture of the soil and its effect on the macroscopic thermal properties. as shown in the fig (2.11)

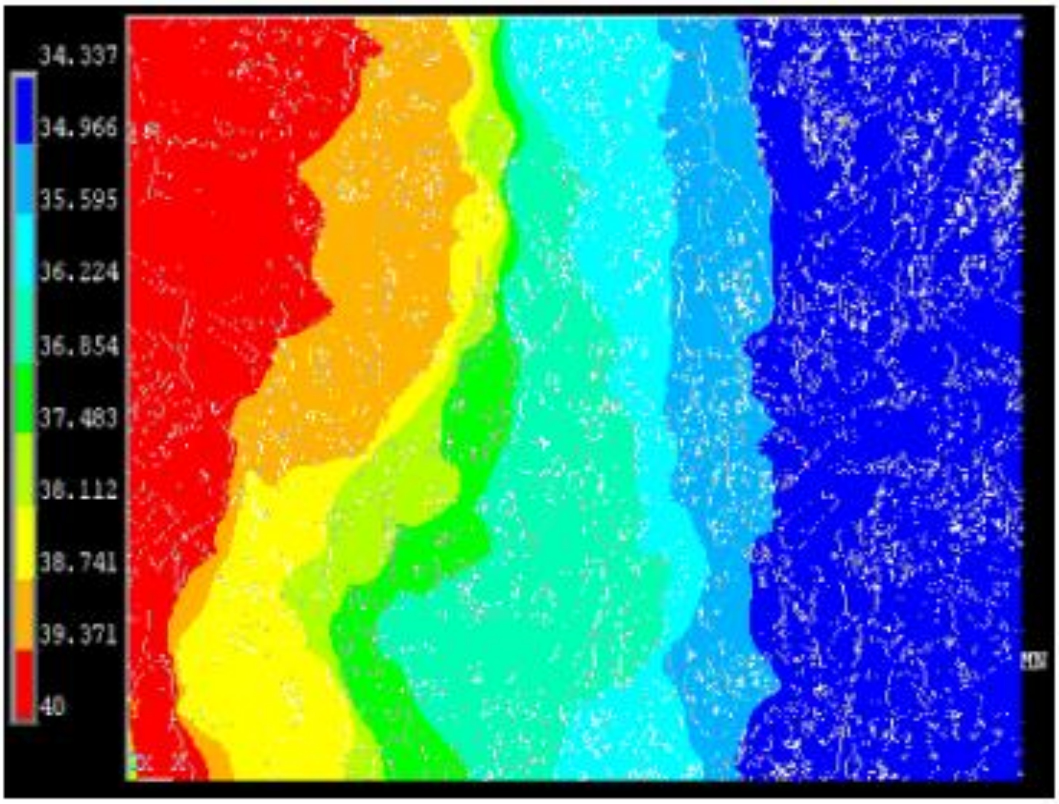

Figure.2.11 The Process of image treatment and temperatur distribution analysis (silty sand -S1).[48]

Table 2.4 Comparison between simulation and experimental results of thermal conductivity

Soil type	Number of specimens	porosity	ATNRB (°C)	Thermal conductivity (W/m .K)			Relative error (%)
				SP	BANS	ER	
Silty sand	S1	0.377	34.454	3.370	0.216	0.274	- 21.17
	S2	0.367	36.083	2.370	0.305	0.278	9.71
	S3	0.457	35.377	3.370	0.213	0.249	- 14.46
	S4	0.400	37.177	3.370	0.240	0.267	- 10.11
Silty	S5	0.387	37.372	1.940	0.296	0.433	- 31.64
	S6	0.326	34.374	1.940	0.364	0.498	- 26.91
Silty caly	S7	0.324	32.386	1.051	0.344	0.479	- 28.18
	S8	0.325	34.354	1.139	0.305	0.424	- 28.07

Angelo Zarrella, Massimiliano Scarpa[49]. They studied the short time step performance of U-shaped dual well thermostat exchangers, Modeling and Measurements**.** In this time range, the heat capacity of the well is generally neglected. The heat capacity of the well consists of fillers and heat transfer fluid and mostly affects the behavior of the short time step when hourly or shorter time periods were taken into account. The analysis of the short time steps of the axial and dual heat exchangers in the form of U-characterized by a scalar capacitive impedance model, knowing the thermal behavior of BHEs in short time steps necessary for detailed simulation of GCHP systems, should be taken into account in the reinforced coaxial heat exchanger analyzed and also compared from common double U tube by response test measurements. Under the same conditions, an improved axial heat exchanger can cause computational errors that couldn't be neglected in a short time step.

Table (2.5) Summary of Literature Survey

No	Author	Title	Methods	Results
1	Harith Essa et al (2020)	Experimental study of single and double geothermal heat exchanger with continuous and alternative modes	Experimental testing of the performance of the two-layer geothermal heat exchanger at the Technical College of Engineering in Najaf in continuous and alternating operation mode	The alternating mode showed better performance than the continuous mode with the highest performance improvement by 15.9 at a flow rate of 4 liters per minute and a lower performance coefficient due to heat accumulation around the layers of the geothermal heat exchanger
2	Zahraa Saleh et al (2019)	Experimental study of underground heat exchanger with double layers	Design and testing of the horizontal two-layer heat exchanger as a closed system, which depends on the transfer of heat from the fluids inside it to the depths of the soil	The system was tested for both layers and the highest value of the performance factor was 8.59 in the two-layer operating mode and 5.9, 5.2 for the first and second layers under the same conditions.
3	Barbara Larwa et al (2019)	Principles of modelling of slinky-coil ground heat exchangers	The study of analytical relationships based on Greene's theory related to the source of the continuous loop, which is the basis for modeling geothermal exchanges	The inconsistency of the temperature profiles with respect to the level at which the heat exchanger was at a depth of (0.5) m is a result of the heterogeneous soil temperature profile and the influence of the environment

No	Author	Title	Methods	Results
4	José Manuel Andújar Márquez et al (2016)	Ground thermal Diffusivity Calculation by Direct Soil Temperature Measurement. Application to very Low Enthalpy Geothermal Energy Systems	It presents a methodology and an indirect measurement system for measuring the thermal diffusion of soil at a specific depth by measuring its temperature	The ability to change the earth's temperature decreases significantly with depth and tends to settle in the average temperature of the place to obtain higher heating and cooling
5	Mathur et al (2015)	Transient effect of soil thermal diffusivity on performance of EATHE system	A numerical study of a three-dimensional model that studies the effect of the thermal physical properties of the soil on the performance of the heat exchanger	Soil thermal conductivity plays an important role in affecting the thermal performance of EATHE in the case of soils with high thermal conductivity
6	Angelo Zarrella et al (2014)	Short time-step performances of coaxial and double U-tube borehole heat exchangers: Modeling and measurements	Short time step performance study of U-shaped dual-well thermostat exchangers	Knowledge of thermal behavior of BHEs in short time steps for analytical simulation of GCHP systems by response test measurements under the same conditions.

No	Author	Title	Methods	Results
7	Nikiforova , Savytsky et al (2013)	Methods and results of experimental researches of thermal conductivity of soils	Research and development study in the thermal and physical properties of different types of soil (sand and clay) and soil moisture	Determining the thermal conductivity of the soil by the analytical dependence method to determine the coefficient of thermal conductivity of the soil and soil moisture and obtaining the regression equations for the thermal conductivity as a function of soil brick
8	H. M. Danelichen et al (2013)	Soil Thermal Diffusivity of a Gleyic Solonetz Soil Estimated by Different Methods in the Brazilian Pantanal	Soil temperature is an important factor due to interactions between soil, energy and exchange with the atmosphere	Thermal diffusion of the soil was determined by amplitude, logarithmic, arc and phase methods at a depth of 0.01, 0.03, 0.15 m. Significant differences appeared during the study period as a function of the volumetric water content of the soil.

2.3 Scope of The Present Work

From a survey of the literature, it can be summarized as follows:

1. According to the literature review, there is a lack of empirical data and design correlates of horizontal and vertical heat exchangers used by researchers to study the thermal properties of soils.

2- The current study aims to calculate the total heat transmitted to the soil, the heat transmitted by conduction, and the heat stored in the soil at different temperatures and flow rates for short operating periods using the vertical heat exchanger as a heat source, as well as the heat saturation rate of the soil.

CHAPTER THREE

EXPERIMENTAL WORK

CHAPTRE THREE

EXPERIMENTAL WORK

INTRODUCTION

This chapter displays the equipment, devices, and experimental methods used to perform the experimental work, which will be divided into three parts. The first part shows the experimental setup, system components and equipment. The second part explains the measurement tools. Part three describes the specification for the practical part, experimental procedures, and calibration of measuring instruments and thermocouples as a feature of standard thermometer readings.

3.1 Experimental Set-up

This experimental work was implemented in Engineering Technical College, Al-Najaf, Al-Furat Al-Awsat Technical University, Iraq, and below is a brief description of the basic components of the system used and soil.

3.1.1 The thermal properties of soil

Determining the thermal properties of the soil and the effect of moisture on other thermal properties is important for its direct influence on the performance parameter of the GHE system. Soil temperature was examined in Najaf Governorate, southwest of Iraq (31.9760718°N 44.364692°E). Twelve K-type thermocouples were installed. Eight thermocouples were installed around the exchanger at a distance of 60 cm, two at the inlet and outlet of the power source, and two for measuring the surface temperature of the heat exchanger and the average temperature inside the heat source. Thermal properties of the soil, thermal conductivity, volumetric heat capacity and soil density were calculated in the laboratories of the University of Kufa / College of Engineering / Nano Laboratory. on the soil.

3.1.2 The Experimental Rig

A vertical heat exchanger was placed as a power source in the soil of the Technical College of Engineering in Najaf at a depth of 2 meters. The dimensions shown were 2m long, 14.5cm outside diameter and 14.2cm inner diameter. The heat exchanger was fed with hot water with different temperatures of 40-60 ° C at different flow rates of 0.5-2 L/min with each temperature during the winter period and the duration of the experiment was more than 105 day. The ground surface temperature was measured at a depth of one meter by regular thermocouples installed around the exchanger, as well as the surface temperature of the external exchanger and the average temperature inside the exchanger by thermocouples, and the results were obtained. as shown in Fig (3.1)

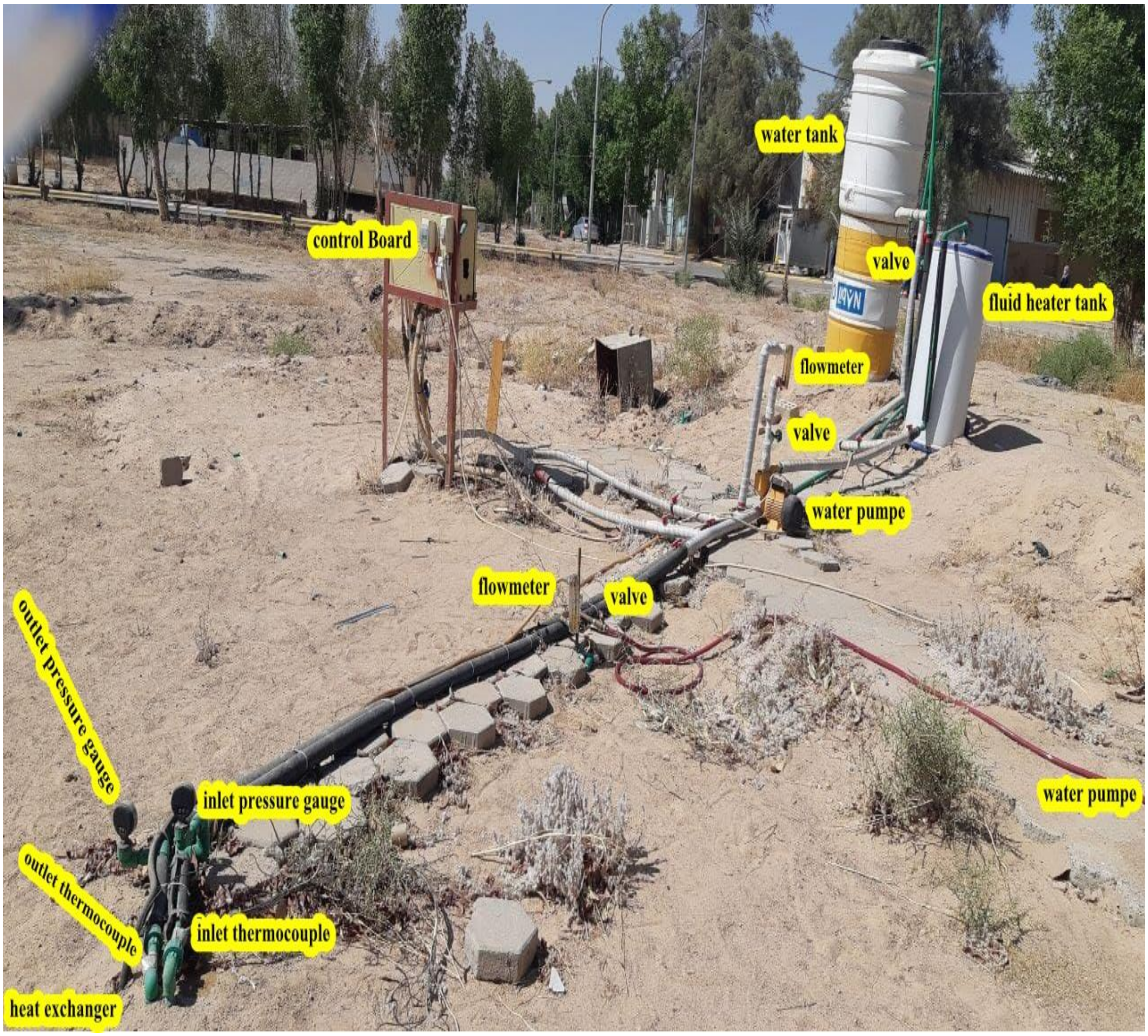

Figure 3.1 The system used in the work

3.1.2.1 Vertical geothermal heat exchanger (GHE)

The vertical geothermal heat exchanger consists of a 2-meter-long wrought iron tube with an outer diameter of 14.5 mm and an inner diameter of 14.2 mm as shown in Fig (3.2). The hot water is circulated inside the heat exchanger by the electric pump.

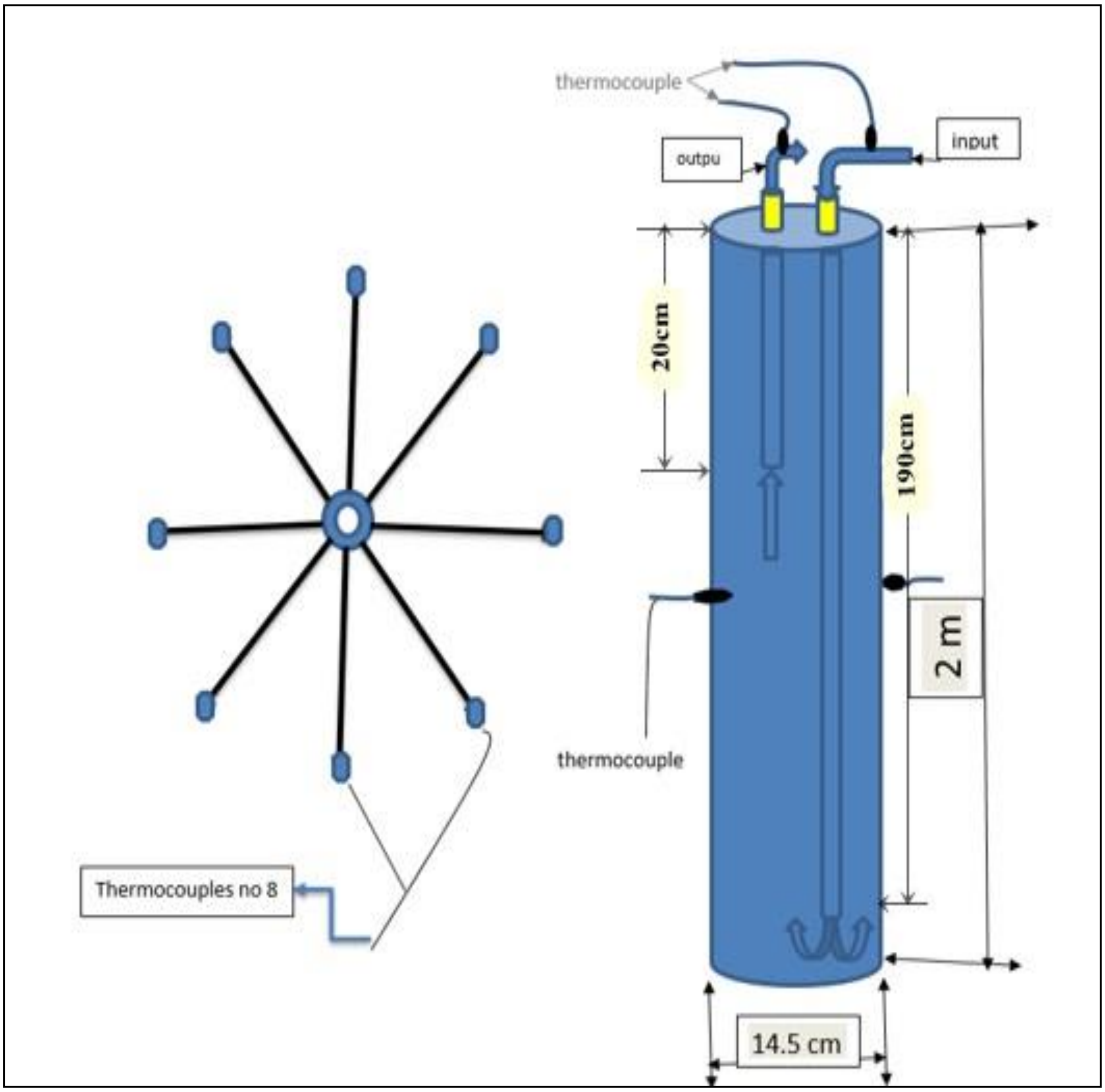

Figure. 3.2: Expering of the geothermal heat exchanger, installed to the depth (2 m)

3.1.2.2 The Electric water Pump

The electric pump is installed between the thermostatic mixing valve and the control panel, which circulates water through the geothermal heat exchangers and the entire system as shown in the fig (3.3) with the specification table (3.1).

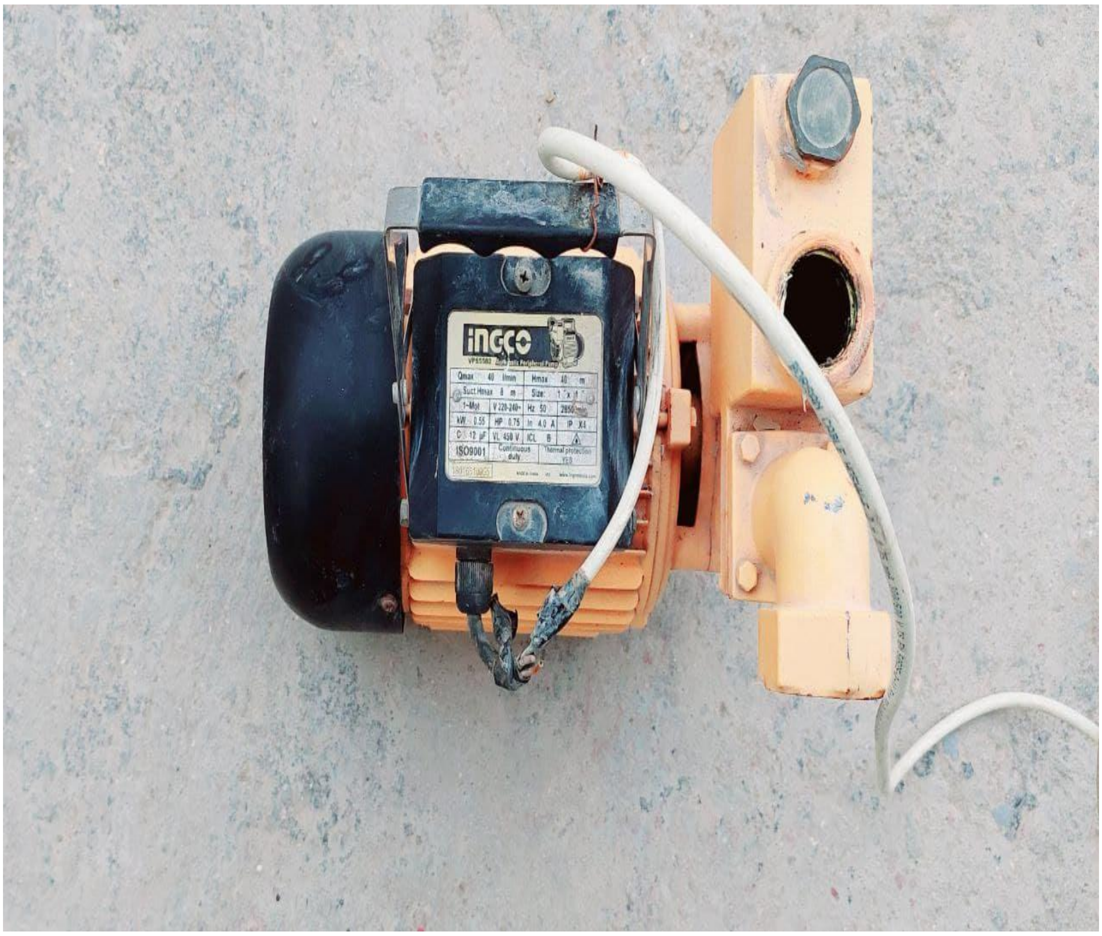

Figure. 3.3: the used Electric water Pump

Table 3.1: Electric water Pump specifications.

Q_{max} L/min	H_{max} m	horse power hp	capacity Kw
10- 35	35	0.5	0.37

3.1.2.3 The water of tank

this tank has a capacity of (250 L) of the plastic to provide the system with the water required to circulate inside the geothermal heat exchanger. as shown in Fig (3.4).

Figure. 3.4: Water tank (250) Liters.

3.1.2.4 Water Heater

This heater with a capacity of 140 liters is installed between the electric pump and the water tank, and it is equipped with an electric heater (Ricoh, type. RT, 3000W) and a thermostat (Jomo, type STM2) and is insulated with glass wool to supply the system with water at the required design temp of different temp as shown in Fig (3.5).

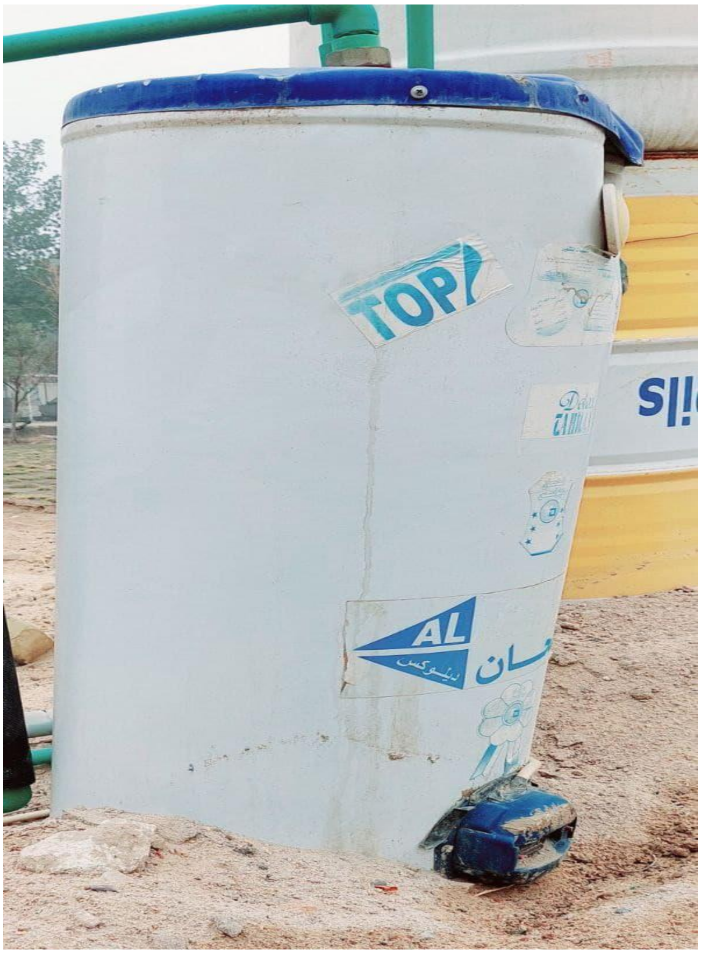

Figure. 3.5: Electric water heater (140) liter

3.1.2.5 hydration system

The humidification system consists of a water tank, a pump, a flow meter, a valve and a polyethylene pipe installed in a circular motion around the heat exchanger at a depth of 1 m and perforated with regular holes of equal diameters as shown in the fig 3.6

Figure 3.6 hydration system

3.1.2.6 Control Panel

The control panel is a box containing manual and electrical control valves and a Two-flowmeters used to measure volumetric flow rate of water entering and leaving the heat exchangers and the temperature sensors of the entry and exit fluid for the geothermal heat exchanger connected to the Data logger and the Inlet and outlet water pressure gauge from the system.

3.1.2.7 Working Fluid

Pure water was used as a main working fluid in this experimental work because water is an available liquid with high heat transfer capacity, inexpensive and has physical properties shown in table (3.2).

Table 3.2: Physical Properties of liquid Water

T (°C)	ρ (kg/m3)	Cp (J/kg K)	k (W/m.K)	Total Dissolved Salts (mg/L)
10	999.7	4188	0.5674	105
20	998.2	4183	0.5861	105
30	995.7	4183	0.603	105
40	992.2	4182	0.6178	105
50	988	4181	0.6305	105
60	985	4181	0.6341	105

3.2 Measuring the soil thermal conductivity

Soil thermal conductivity, volumetric heat capacity and density were practically calculated for the type of soil in Najaf Governorate specifically (31.9760718°N 44.364692°E) in the study area is sandy soil when examined according to standard tests: (sand 88.13%, silt 6.33%, clay 5.54% with a percentage of High gypsum (up to more than 28%) and at different temperatures, the thermal properties of the soil were determined at the University of Kufa / College of Engineering / Nanotechnology Laboratory, according to what is shown in the table (3.3).

Table (3.3) thermal properties of soil

soil samples	Thermal Conductivity (W/m.K)	Dry density (kg/m^{3})	volumetric heat capacity(MJ/m^{3}.k)
1	0.2761	1285	1.365
2	0.304	1285	1.454
3	0.305	1285	1.431
4	0.29	1285	1.455

3.3 Measuring Devices

3.3.1 Flowmeter

The flowmeter is a glass scale that measures volumetric flow rate within measurement limits of 0.5 to 4 liter per minute, the first flowmeter is installed at the main inlet tube of geothermal heat exchangers and the second flowmeter is installed at the main outlet pipe of GHE. The flow rate is controlled through the flowmeter by manual control valve, as shown in Fig (3.6).

Figure 3.6 flow meter

3.3.2 Data Logger Device

device that measures temperatures and has many channels, as shown in Fig (3.7). After the cooling process, the surface temperature of the Photovoltaic panel and the temperature of the inflow water to the channel and the temperature of the output water from the channel, should all be measured. A specific kind of the data logger selected is (AT4532) with Thirty-two channels. This device permits the use of Kind K and Kind T thermocouples with read accuracy of 0.2 % ± 1oC).

Figure. 3.7 Shows the temperature data Logger.

3.3.3 Pressure-gauge

The inlet and outlet water pressure of the geothermal exchanger system for all flow rates used in the experiment is measured by a mechanical pressure gauge (1bar) with an accuracy of (±1.6%) as shown in the Fig (3.8), to determine the rate of liquid pressure drop in the GHE tubes with a different water flow rates.

Fig 3.8: Shows the pressure gauge

3.4 The Aspects which the Experimental Work Investigated

There are many factors that influence the ground heat exchanger system performance. In this work, the effect of different entry temperature and different flow rates are to be studied and the use of different operating modes on the performance of the GHE system are also handled. The following variables have been taken into account in this study:

1. Working fluid temperature is from (40 to 60 °C).

2. The average volumetric flow rate of the fluid during the system is from (0.5 to 2 LPM) .

3. Measuring the ground temperature at by means of thermocouples installed under the ground Continuous operation short time to ground heat exchanger.

3.4.1 Study of the the effect of inlet temperature and flow rate

The effect of inlet temperature and volumetric flow rate on the thermal properties of the soil is studied by using the vertical heat exchanger to determine the best inlet temperature with the best volumetric flow rate of the liquid. The test was conducted for a period of four months (November, December, January, February) 2020-2021 to know the thermal properties of the soil as well as the effect of moisture on the thermal properties of the soil during different working conditions and for short operating periods.

3.5 Experimental Procedure

After connecting the device to the trial model, then the system is checked according to the following steps:

1- A data logger was used, being connected to twelve thermocouples, that were distributed around the heat exchanger, at the inlet and outlet of the liquid and at the soil surface at a depth of (1m) and the readings were recorded every (60) minutes by a data logger connected to the computer to save the data. The system operates daily from eight in the morning until twelve in the evening

2- Flow rate is measured by a glass flowmeter. It is controlled by a manual valve to change the flow rate for each condition.

Various flow rates (0.5, 1, 1.5, 2 LPM) were checked during the continuous operation mode of the power source vertical heat exchanger.

3.6 Thermal Analysis of the GHEs

Thermal analysis or study of a system relies on first and second law thermodynamics. First law deals with the energy equilibrium of a system, while
second statute deals with energy and the entropy of a system, It gives an accurate analysis of the system. The combination of the first and second laws of thermodynamics is critical to the study of system energy and performance, which gives detailed knowledge of system performance assessment and optimization[50].

3.6.1 Experimental Calculation

a- Thermal Diffusivity Calculation

Thermal diffusivity of samples was calculated using the experimental value of specific heat, thermal conductivity and bulk density from equation below

$$\alpha = \frac{K}{\rho \cdot Cp} \quad \ldots \qquad (3.1)$$

Where؛

α = Thermal diffusivity in m^2/s

k = Thermal conductivity W/m. k

ρ = Bulk density in kg/m^3،

Cp = specific heat capacity in J/kg. K

b- Heat exchange rate (Q)

The rate of heat exchange is determined using the following equation (3.2)[51].

$$Q_{exp} = m \cdot cp\ (T_{in} - T_{out}) \ \ldots \tag{3.2}$$

Where:

Q e, exp : is heat exchange rate in the GHEs (W)

ṁ : is mass flow rate (kg/s).

Cp: is the mean water specific heat (j/kg .k) .

Tin and Tout: is the water inlet and outlet temperatures.

c) Heat exchange rate per unit length ($\bar{Q}$)

The rate of heat exchange per unit length of the ground heat exchanger tube is
determined using eq. (3.3)[52] .

$$Q = \frac{Q_{e.exp}}{L} \ \ldots \tag{3.3}$$

Where:

L = is the total tube length of the (GHE).

To measure the energy efficiency of the ground heat exchanger, depending on the principle of efficiency of energy. It is calculated by the actual heat exchange rate ratio (Q exp) and a maximum rate of exchange (Q max) is theoretically possible[52].

$$\varepsilon_{exp} = \frac{Q_{exp}}{Q_{max}} \ \ldots \tag{3.4}$$

Then exchangerenergyefficiencyiswritten.

$$\varepsilon exp = \frac{Tout - Tin}{To - Tin} \quad \ldots$$

(3.5)

Where:
To: is ground temperature (°C)

d-The amount of heat lost to the external environment

$$Qs = \frac{2\pi LKs\ \Delta Ts}{ln(^{Do}/_{Din})} \ldots \qquad (3.6)$$

Qs: Heat lost in the soil (W)

L: Heated part length (m)

Ks: Thermal conductivity of the soil ($W\cdot m^{-1}\cdot k^{-1}$)

ΔTs: The average temperature difference between the surface of the exchanger and the couplings installed around the exchanger (°C)

D_o , D_{in}; The outer and inner diameter of the soil around the power source.

CHAPTER FOUR

RESULTS AND DICUSSIONS

Chapter Four

Results and discussion

4.1 The study of the thermal properties of the soil

4.1.1 Heat exchange rate (Q) of soil

* Inlet temperature (40 °C) and flow rate (0.5 LPM)

The fig (4.1) shows the relationship between the total heat transferred, heat transferred by conduction, and heat stored in the soil at the inlet temperature (40C) with a liquid flow rate of (0.5LPM). In the first hour of operation, the value of the total heat transferred was (153.98912287W). The heat transmitted by conduction of thermocouples is at a distance of (0.6m) (19.41960573W). And the heat stored in the soil (135.569517W), and after an hour of operation, the total heat transfer value was (137.548208W). And the heat transferred by conduction of thermocouples at a distance of (0.6m) (19.90917563W). And the heat stored in the soil (117.6390324W). After four and a half hours of continuous operation, the total heat transferred became (83.74013424W). The heat transmitted by conduction of the thermocouples at a distance of (0.6 m) is (30.79394624W) and the heat stored in the soil (52.946188W). The heat transmitted by conduction increases with the passage of time as a result of heating and a decrease in the moisture content of the soil with a clear decrease in the heat stored in the soil.

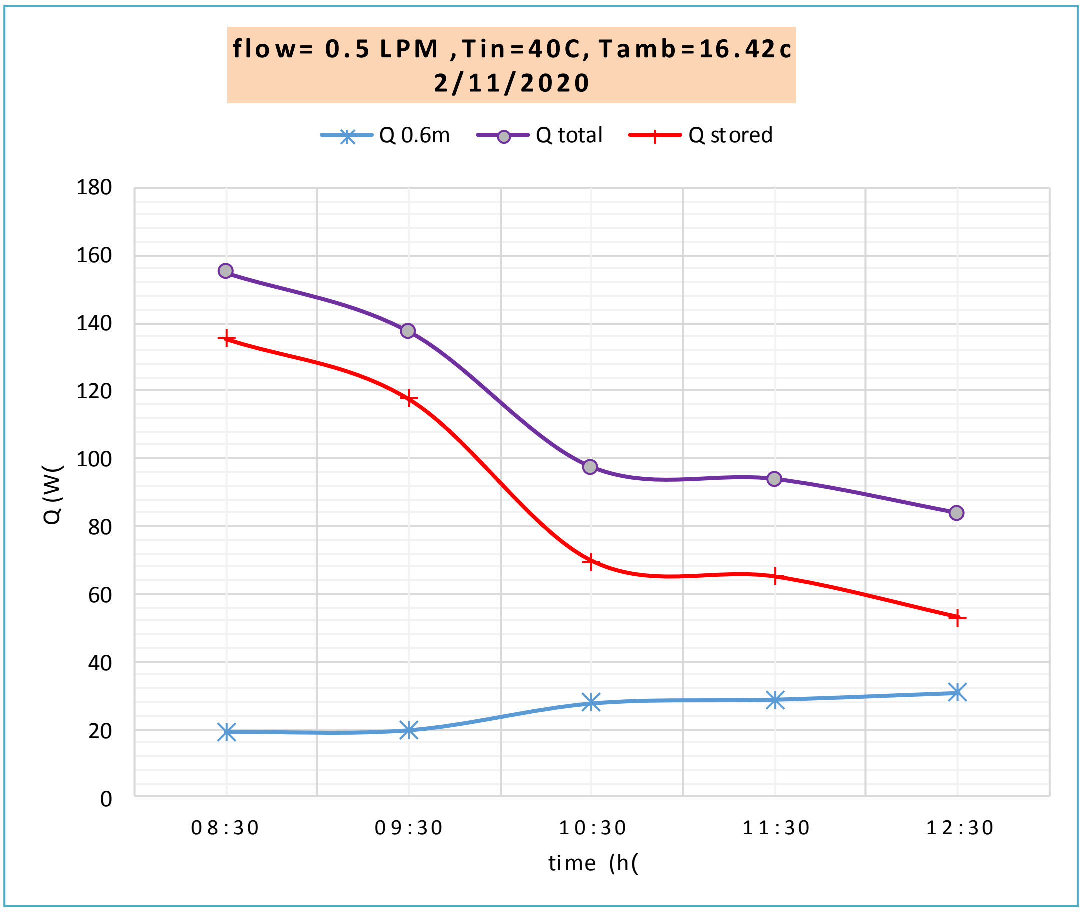

Figure (4.1) shows the relationship between total heat, heat transferred by conduction, and heat stored at temperature (40 °C) and flow rate (0.5 LPM)

* Inlet temperature (40 °C) and flow rate (1 LPM)

The fig (4.2) shows the relationship between the total heat transferred, heat transferred by conduction, and heat stored in the soil at the inlet temperature (40C) with a liquid flow rate of (1LPM). In the first hour of operation, the value of the total heat transferred was (202.9821856 W). The heat transmitted by conduction of thermocouples is at a distance of (0.6m) (24.64168459W). And the heat stored in the soil (178.340501W), and after an hour of operation, the total heat transfer value was (120.562016W). And the heat transferred by conduction of thermocouples at a distance of (0.6m) (27.301681W). And the heat stored in the soil (93.26033496W). After four and a half hours of continuous operation, the total heat transferred became (73.70581513W). The heat transmitted by conduction of the thermocouples at a distance of (0.6 m) is (30.82658423W) and the heat stored in the soil (42.8792309W). The heat transmitted by conduction increases with the passage of time as a result of heating and a decrease in the moisture content of the soil with a clear decrease in the heat stored in the soil.

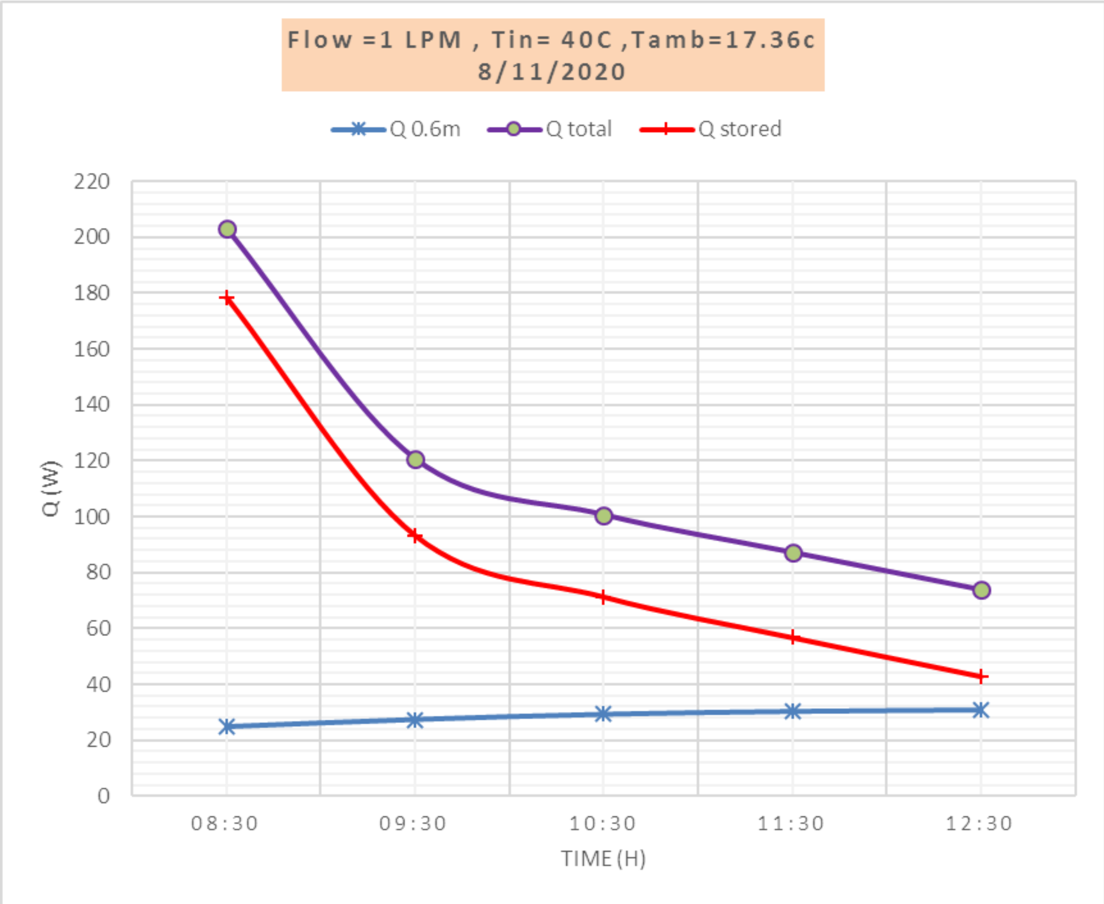

Figure (4.2) shows the relationship between total heat, heat transferred by conduction, and heat stored at temperature (40 °C) and flow rate (1 LPM)

* Inlet temperature (40 °C) and flow rate (1.5 LPM)

The fig (4.3) shows the relationship between the total heat transferred, heat transferred by conduction, and heat stored in the soil at the inlet temperature (40C) with a liquid flow rate of (1.5LPM). In the first hour of operation, the value of the total heat transferred was (302.9741977W). The heat transmitted by conduction of thermocouples is at a distance of (0.6m) (25.78401434W). And the heat stored in the soil (277.1901833W), and after an hour of operation, the total heat transfer value was (241.0860106W). And the heat transferred by conduction of thermocouples at a distance of (0.6m) (25.9472043W). And the heat stored in the soil (215.1388063W). After four and a half hours of continuous operation, the total heat transferred became (90.46075518W). The heat transmitted by conduction of the thermocouples at a distance of (0.6 m) is (31.65885305W) and the heat stored in the soil (58.80190214W). The heat transmitted by conduction increases with the passage of time as a result of heating and a decrease in the moisture content of the soil with a clear decrease in the heat stored in the soil.

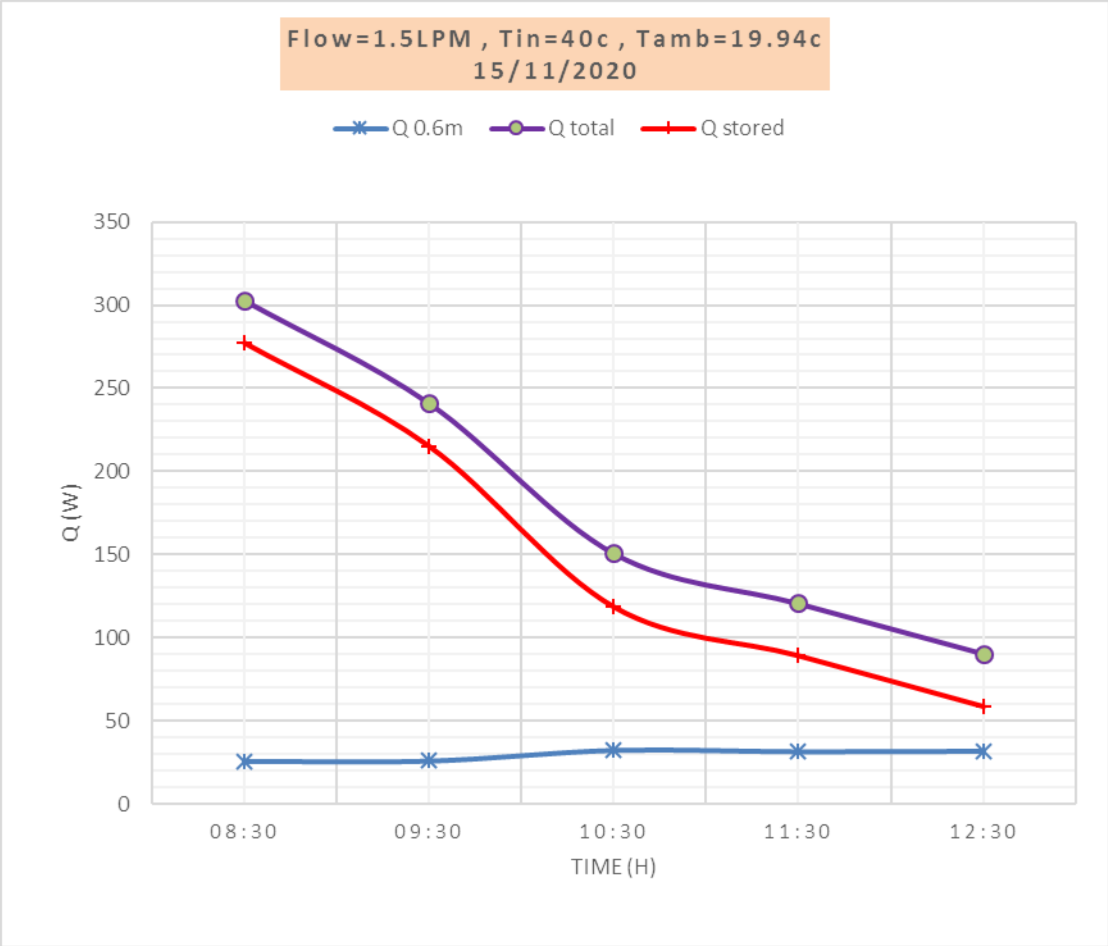

Figure (4.3) shows the relationship between total heat, heat transferred by conduction, and heat stored at temperature (40 °C) and flow rate (1.5 LPM)

* Inlet temperature (40 °C) and flow rate (2 LPM)

The fig (4.4) shows the relationship between the total heat transferred, heat transferred by conduction, and heat stored in the soil at the inlet temperature (40C) with a liquid flow rate of (2LPM). In the first hour of operation, the value of the total heat transferred was (281.595939W). The heat transmitted by conduction of thermocouples is at a distance of (0.6m) (26.56732616W). And the heat stored in the soil (255.0286129W), and after an hour of operation, the total heat transfer value was (240.987973W). And the heat transferred by conduction of thermocouples at a distance of (0.6m) (29.03149462W). And the heat stored in the soil (211.9564424W). After four and a half hours of continuous operation, the total heat transferred became (93.71753107W). The heat transmitted by conduction of the thermocouples at a distance of (0.6 m) is (32.27897491W) and the heat stored in the soil (61.43855616W). The heat transmitted by conduction increases with the passage of time as a result of heating and a decrease in the moisture content of the soil with a clear decrease in the heat stored in the soil.

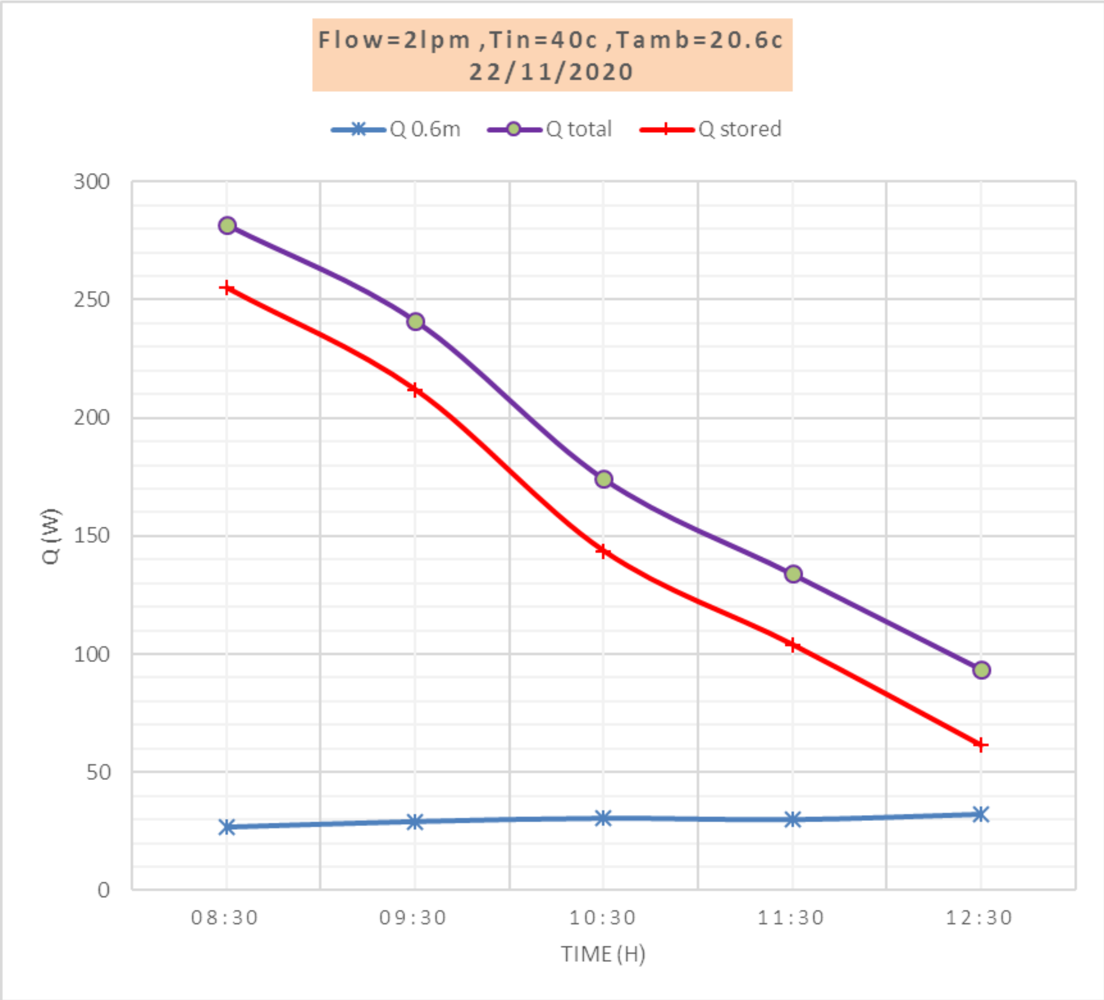

Figure (4.4) shows the relationship between total heat, heat transferred by conduction, and heat stored at temperature (40 °C) and flow rate (2 LPM)

* Inlet temperature (50 °C) and flow rate (0.5 LPM)

The fig (4.5) shows the relationship between the total heat transferred, heat transferred by conduction, and heat stored in the soil at the inlet temperature (50C) with a liquid flow rate of (0.5LPM). In the first hour of operation, the value of the total heat transferred was (127.726312W). The heat transmitted by conduction of thermocouples is at a distance of (0.6m) (45.90533692W). And the heat stored in the soil (81.8209748W), and after an hour of operation, the total heat transfer value was (114.768643W). And the heat transferred by conduction of thermocouples at a distance of (0.6m) (46.01956989W). And the heat stored in the soil (68.749073W). After four and a half hours of continuous operation, the total heat transferred became (69.0296364W). The heat transmitted by conduction of the thermocouples at a distance of (0.6 m) is (47.8146595W) and the heat stored in the soil (21.2149769W). The heat transmitted by conduction increases with the passage of time as a result of heating and a decrease in the moisture content of the soil with a clear decrease in the heat stored in the soil.

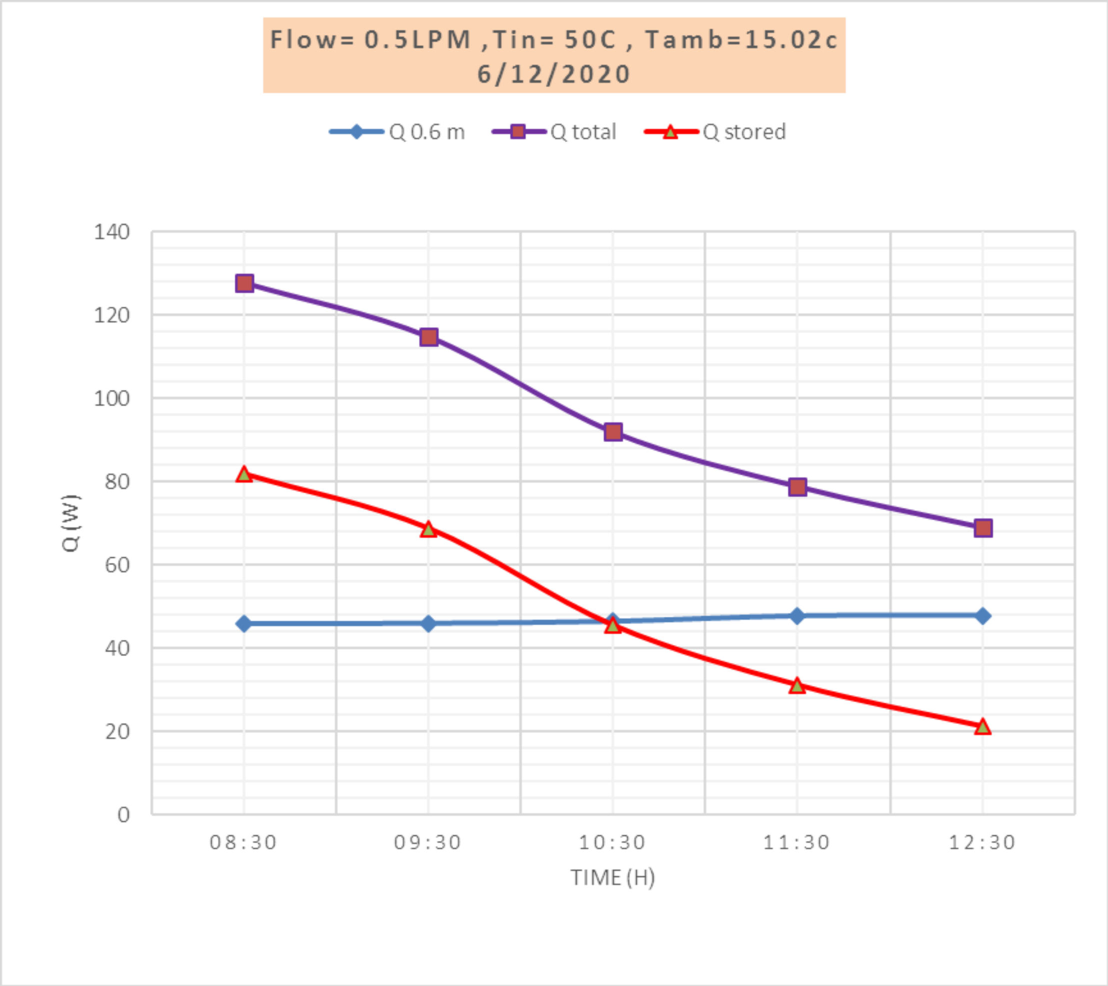

Figure (4.5) shows the relationship between total heat, heat transferred by conduction, and heat stored at temperature (50 °C) and flow rate (0.5 LPM)

* Inlet temperature (50 °C) and flow rate (1 LPM)

The fig (4.6) shows the relationship between the total heat transferred, heat transferred by conduction, and heat stored in the soil at the inlet temperature (50C) with a liquid flow rate of (1LPM). In the first hour of operation, the value of the total heat transferred was (222.702287W). The heat transmitted by conduction of thermocouples is at a distance of (0.6m) (45.36681004W). And the heat stored in the soil (177.335477W), and after an hour of operation, the total heat transfer value was (190.188037W). And the heat transferred by conduction of thermocouples at a distance of (0.6m) (45.36681004W). And the heat stored in the soil (144.821227W). After four and a half hours of continuous operation, the total heat transferred became (124.9107717W). The heat transmitted by conduction of the thermocouples at a distance of (0.6 m) is (46.32963082W) and the heat stored in the soil (78.5811397W). The heat transmitted by conduction increases with the passage of time as a result of heating and a decrease in the moisture content of the soil with a clear decrease in the heat stored in the soil.

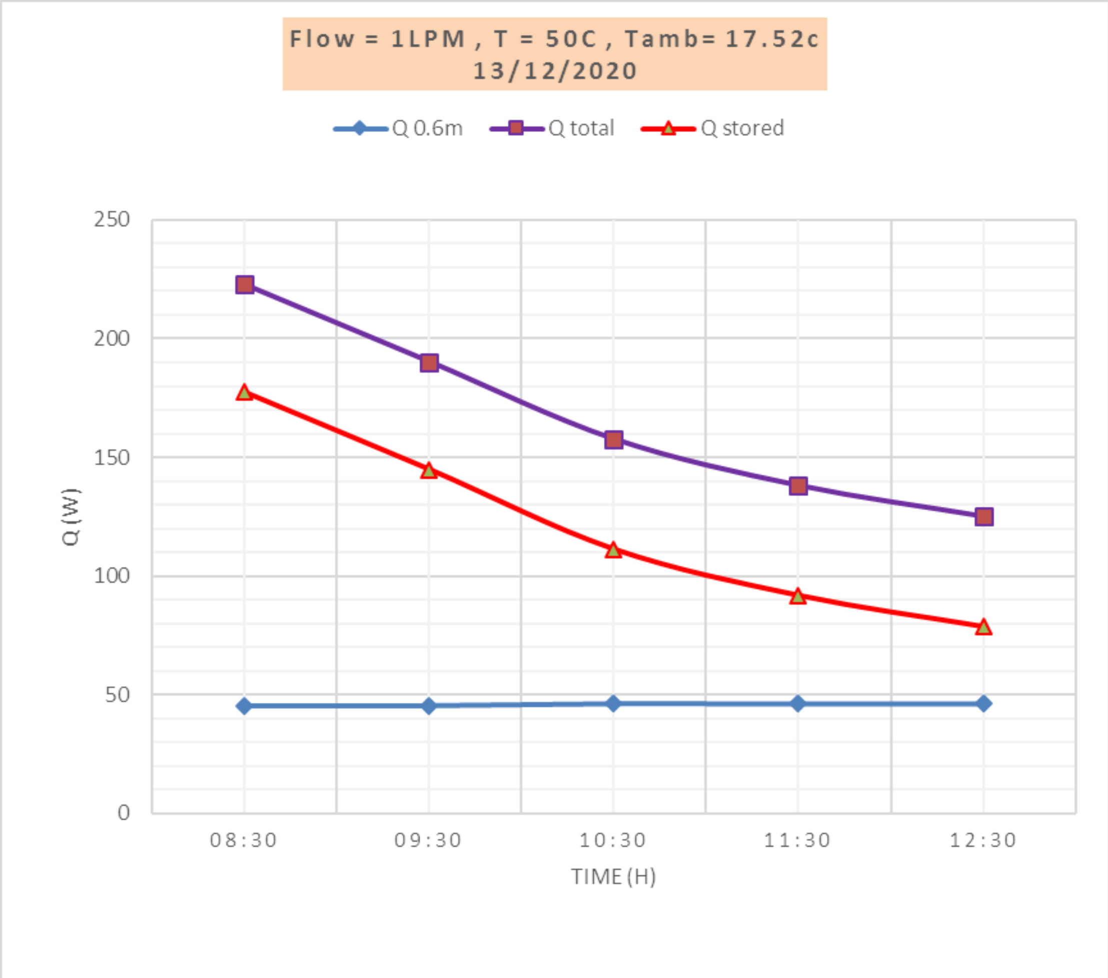

Figure (4.6) shows the relationship between total heat, heat transferred by conduction, and heat stored at temperature (50 °C) and flow rate (1 LPM)

* Inlet temperature (50 °C) and flow rate (1.5 LPM)

The fig (4.7) shows the relationship between the total heat transferred, heat transferred by conduction, and heat stored in the soil at the inlet temperature (50C) with a liquid flow rate of (1.5LPM). In the first hour of operation, the value of the total heat transferred was (232.952053W). The heat transmitted by conduction of thermocouples is at a distance of (0.6m) (47.32508961W). And the heat stored in the soil (185.626963W), and after an hour of operation, the total heat transfer value was (212.081938W). And the heat transferred by conduction of thermocouples at a distance of (0.6m) (46.34594982W). And the heat stored in the soil (165.735989W). After four and a half hours of continuous operation, the total heat transferred became (118.819061W). The heat transmitted by conduction of the thermocouples at a distance of (0.6 m) is (43.7022724W) and the heat stored in the soil (75.1167882W). The heat transmitted by conduction increases with the passage of time as a result of heating and a decrease in the moisture content of the soil with a clear decrease in the heat stored in the soil.

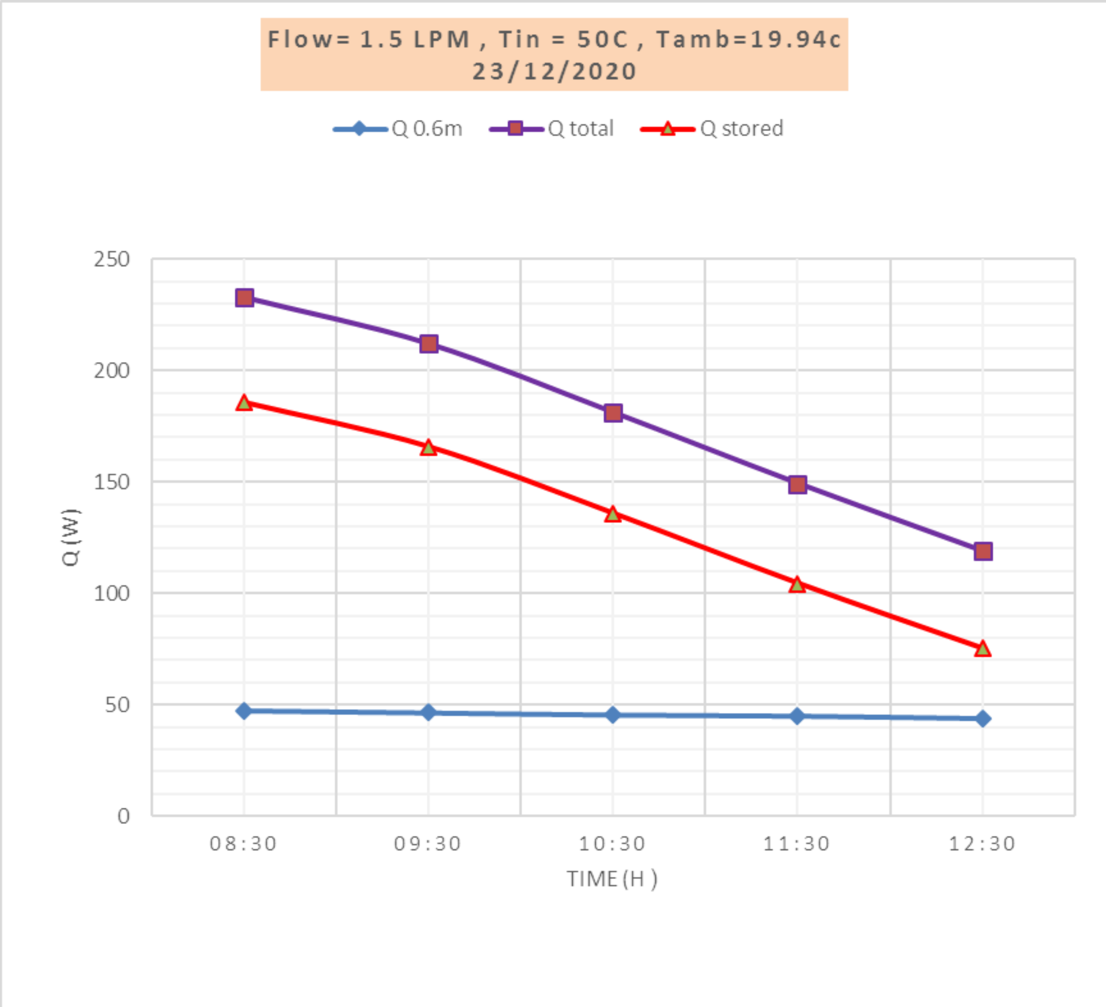

Figure (4.7) shows the relationship between total heat, heat transferred by conduction, and heat stored at temperature (50 °C) and flow rate (1.5 LPM)

* Inlet temperature (50 °C) and flow rate (2 LPM)

The fig (4.8) shows the relationship between the total heat transferred, heat transferred by conduction, and heat stored in the soil at the inlet temperature (50C) with a liquid flow rate of (2LPM). In the first hour of operation, the value of the total heat transferred was (320.866187W). The heat transmitted by conduction of thermocouples is at a distance of (0.6m) (48.22263441W). And the heat stored in the soil (272.643552W), and after an hour of operation, the total heat transfer value was (262.722766W). And the heat transferred by conduction of thermocouples at a distance of (0.6m) (42.88632258W). And the heat stored in the soil (219.836443W). After four and a half hours of continuous operation, the total heat transferred became (117.992844W). The heat transmitted by conduction of the thermocouples at a distance of (0.6 m) is (46.24803584W) and the heat stored in the soil (71.9732745W). The heat transmitted by conduction increases with the passage of time as a result of heating and a decrease in the moisture content of the soil with a clear decrease in the heat stored in the soil.

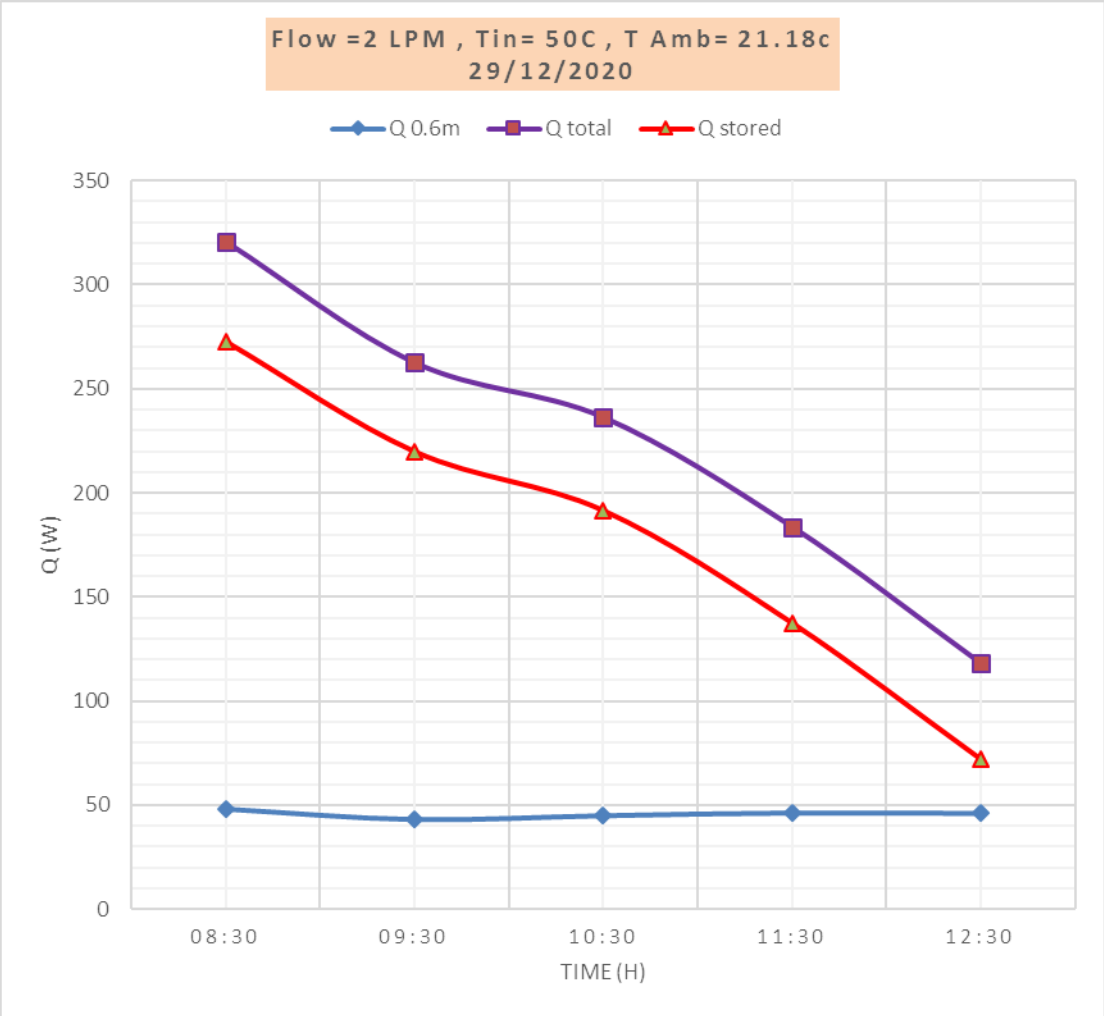

Figure (4.8) shows the relationship between total heat, heat transferred by conduction, and heat stored at temperature (50 °C) and flow rate (2 LPM)

* Inlet temperature (60 °C) and flow rate (0.5 LPM)

The fig (4.9) shows the relationship between the total heat transferred, heat transferred by conduction, and heat stored in the soil at the inlet temperature (60C) with a liquid flow rate of (0.5LPM). In the first hour of operation, the value of the total heat transferred was (196.58407W). The heat transmitted by conduction of thermocouples is at a distance of (0.6m) (48.14103943W). And the heat stored in the soil (148.4430341W), and after an hour of operation, the total heat transfer value was (184.23157W). And the heat transferred by conduction of thermocouples at a distance of (0.6m) (47.11294265W). And the heat stored in the soil (137.1186256W). After four and a half hours of continuous operation, the total heat transferred became (140.91341W). The heat transmitted by conduction of the thermocouples at a distance of (0.6 m) is (46.01956989W) and the heat stored in the soil (94.89383848W). The heat transmitted by conduction increases with the passage of time as a result of heating and a decrease in the moisture content of the soil with a clear decrease in the heat stored in the soil.

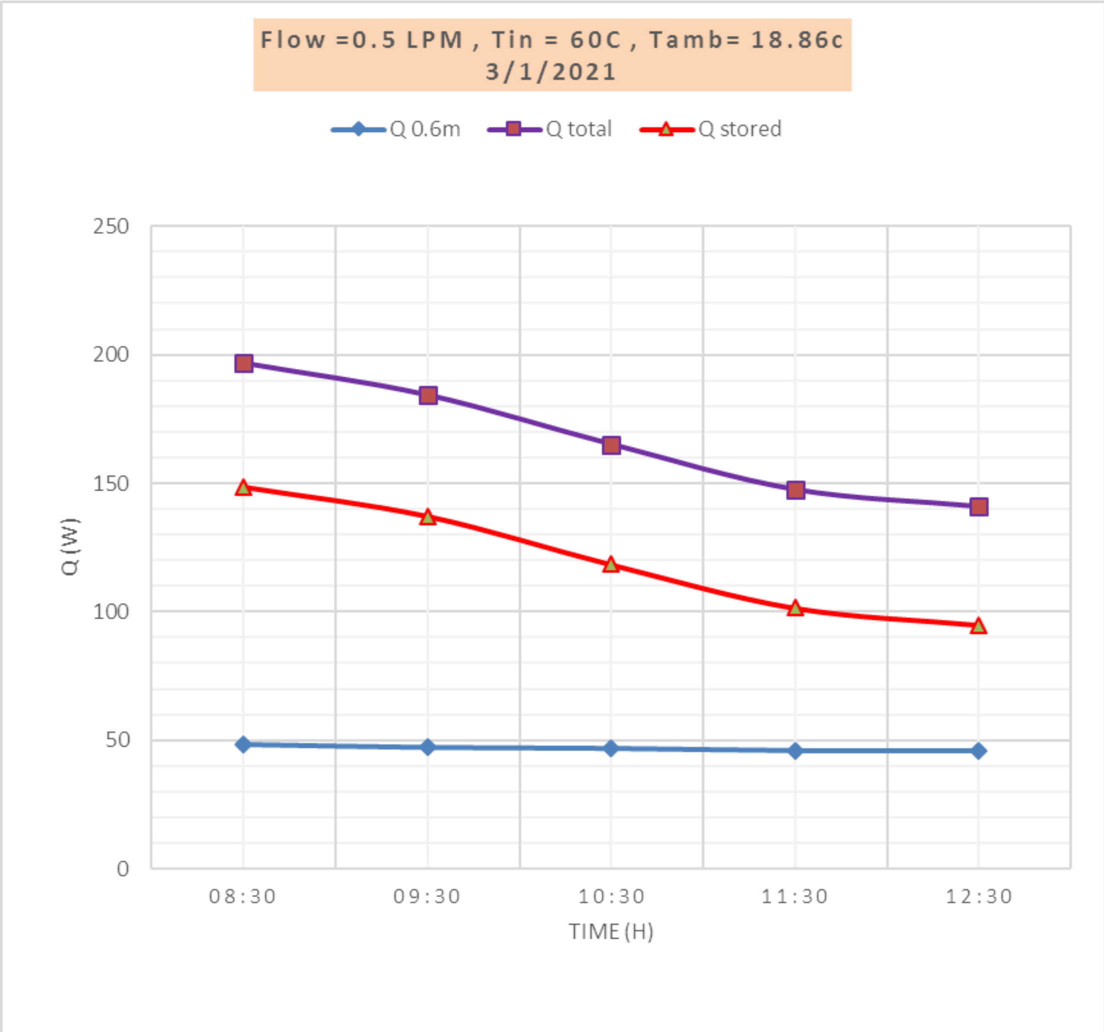

Figure (4.9) shows the relationship between total heat, heat transferred by conduction, and heat stored at temperature (60 °C) and flow rate (0.5 LPM)

* Inlet temperature (60 °C) and flow rate (1 LPM)

The fig (4.10) shows the relationship between the total heat transferred, heat transferred by conduction, and heat stored in the soil at the inlet temperature (60C) with a liquid flow rate of (1LPM). In the first hour of operation, the value of the total heat transferred was (306.66635W). The heat transmitted by conduction of thermocouples is at a distance of (0.6m) (48.46741935W). And the heat stored in the soil (258.1989304W), and after an hour of operation, the total heat transfer value was (277.10558W). And the heat transferred by conduction of thermocouples at a distance of (0.6m) (49.77293907W). And the heat stored in the soil (227.3326377W). After four and a half hours of continuous operation, the total heat transferred became (203.85495W). The heat transmitted by conduction of the thermocouples at a distance of (0.6 m) is (58.09562724W) and the heat stored in the soil (145.7593265W). The heat transmitted by conduction increases with the passage of time as a result of heating and a decrease in the moisture content of the soil with a clear decrease in the heat stored in the soil.

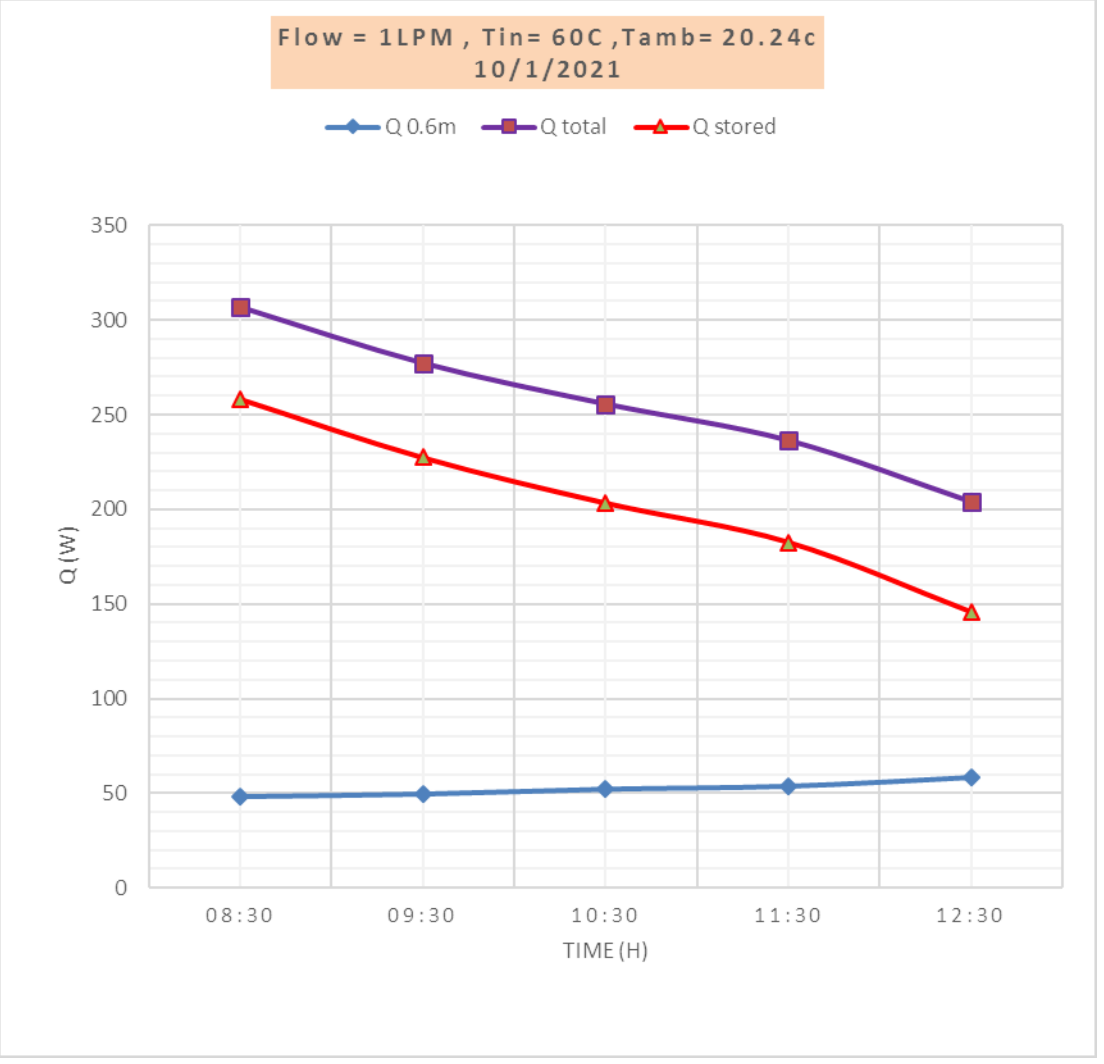

Figure (4.10) shows the relationship between total heat, heat transferred by conduction , and heat stored at temperature (60 °C) and flow rate (1 LPM)

* Inlet temperature (60 °C) and flow rate (1.5 LPM)

The fig (4.11) shows the relationship between the total heat transferred, heat transferred by conduction, and heat stored in the soil at the inlet temperature (60C) with a liquid flow rate of (1.5LPM). In the first hour of operation, the value of the total heat transferred was (446.9W). The heat transmitted by conduction of thermocouples is at a distance of (0.6m) (43.89810036W). And the heat stored in the soil (403.0018951W), and after an hour of operation, the total heat transfer value was (393.69888W). And the heat transferred by conduction of thermocouples at a distance of (0.6m) (50.88263082W). And the heat stored in the soil (342.8162536W). After four and a half hours of continuous operation, the total heat transferred became (230.11358W). The heat transmitted by conduction of the thermocouples at a distance of (0.6 m) is (61.32678853W) and the heat stored in the soil (168.7867894W). The heat transmitted by conduction increases with the passage of time as a result of heating and a decrease in the moisture content of the soil with a clear decrease in the heat stored in the soil.

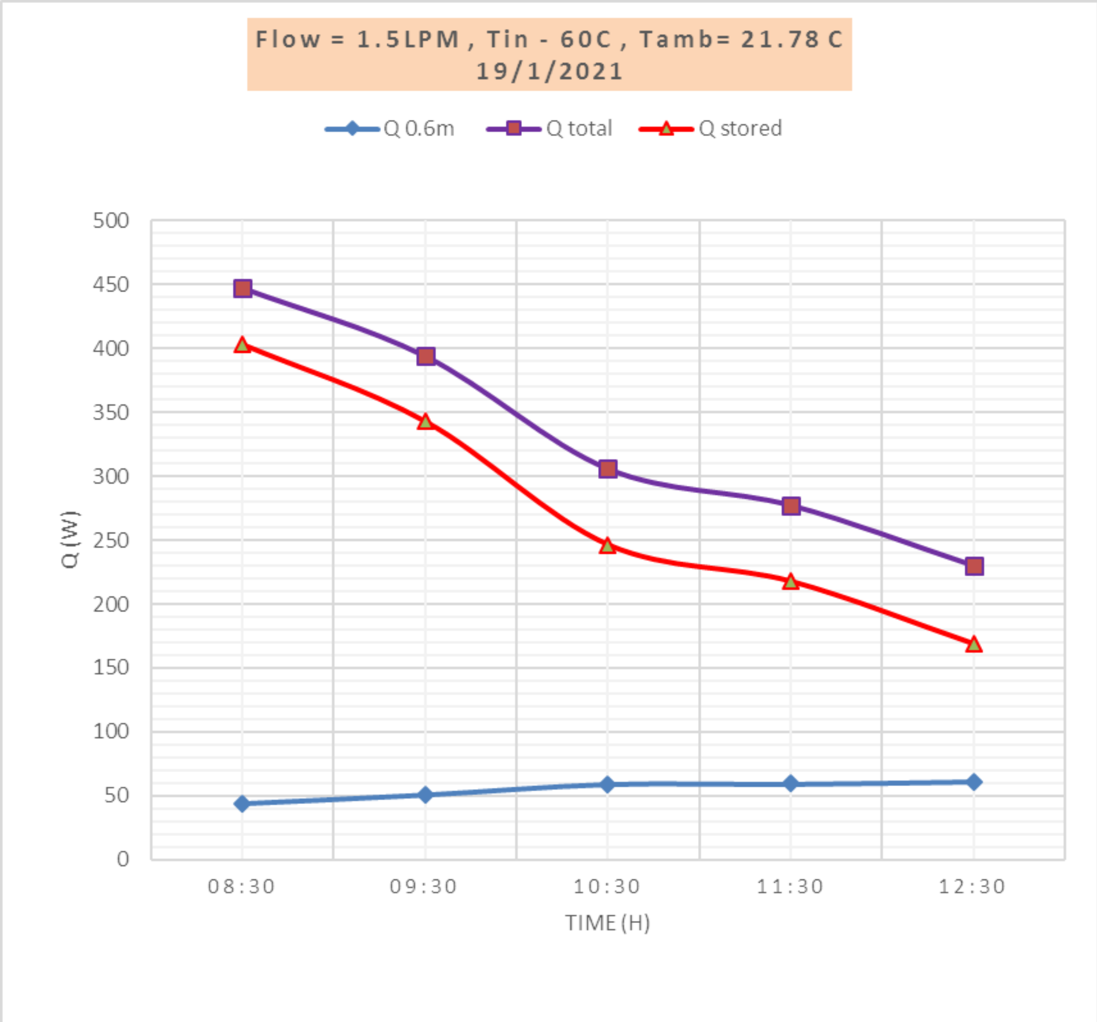

Figure (4.11) shows the relationship between total heat, heat transferred by conduction, and heat stored at temperature (60 °C) and flow rate (1.5 LPM)

* Inlet temperature (60 °C) and flow rate (2 LPM)

The fig (4.12) shows the relationship between the total heat transferred, heat transferred by conduction, and heat stored in the soil at the inlet temperature (60C) with a liquid flow rate of (2LPM). In the first hour of operation, the value of the total heat transferred was (515.23541W). The heat transmitted by conduction of thermocouples is at a distance of (0.6m) (60.95145161W). And the heat stored in the soil (454.283959W), and after an hour of operation, the total heat transfer value was (414.06933W). And the heat transferred by conduction of thermocouples at a distance of (0.6m) (61.16359857W). And the heat stored in the soil (352.9057323W). After four and a half hours of continuous operation, the total heat transferred became (192.44398W). The heat transmitted by conduction of the thermocouples at a distance of (0.6 m) is (61.52261649W) and the heat stored in the soil (130.921361W). The heat transmitted by conduction increases with the passage of time as a result of heating and a decrease in the moisture content of the soil with a clear decrease in the heat stored in the soil.

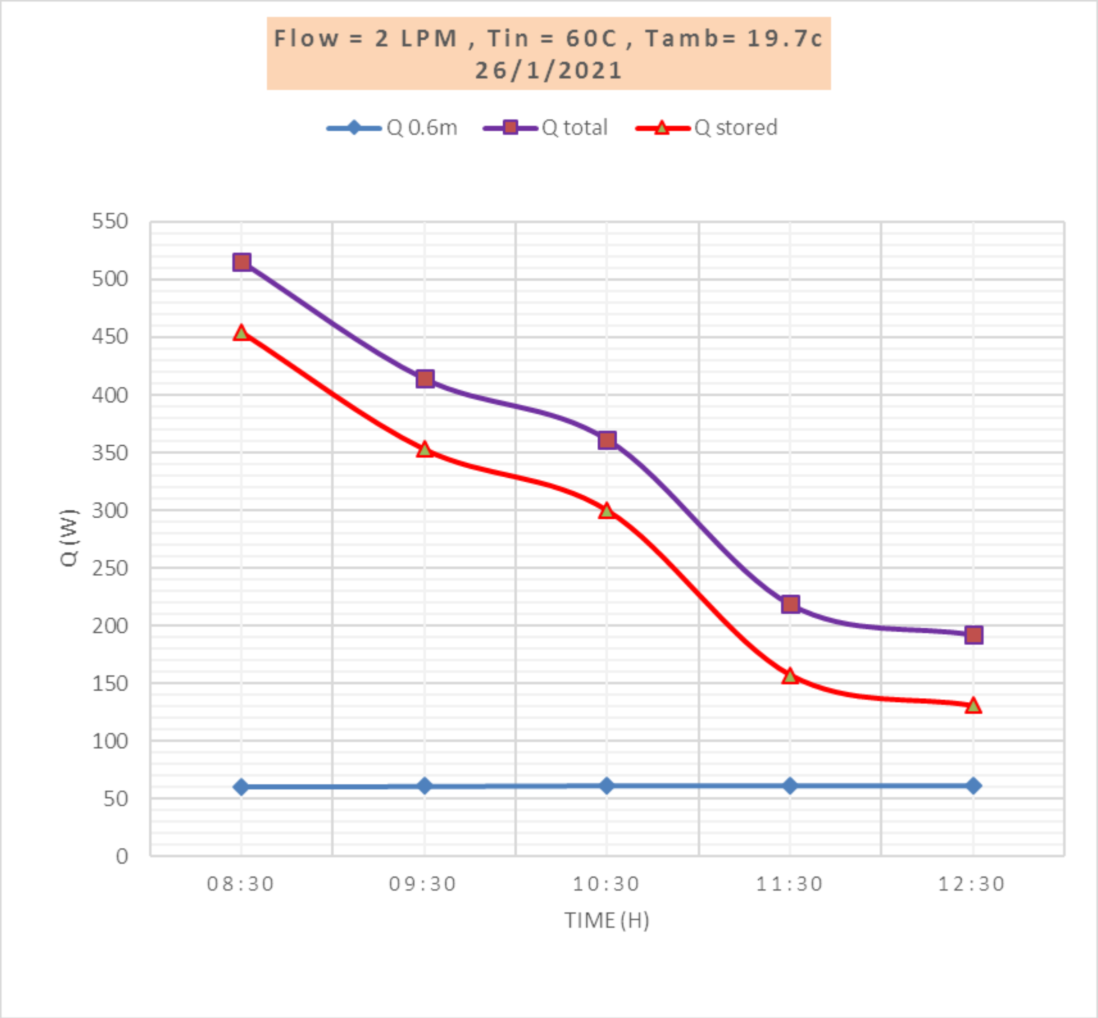

Figure (4.12) shows the relationship between total heat, heat transferred by conduction, and heat stored at temperature (60 °C) and flow rate (2 LPM)

4-2 **The relationship between the furrier nember and ratio of heat saturation of the soil**.

*At inlet temperature (40 °C) and flow rates (0.5-2 LPM)

The fig (4.13) shows the relationship between furrier no and the heat saturation rate of the soil at the entrance temperature (40C) and fluid flow rates (0.5, 1, 1.5, 2 LPM) Furier No is the ratio between the heat transferred by conduction and the heat stored in the soil, where we find that in the first hour of operation With flow rates (0.5, 1, 1.5, 2 LPM), the ratio of heat transmitted by conduction of thermocouples at a distance of (0.6 m) to heat stored in the soil is (0143244633, 0.138172117, 0.093019219, 0.104173904) respectively, and after an hour of operation for the same flow rates, the percentage of The heat transmitted by conduction of thermocouples at a distance of (0.6 m) to the heat stored in the soil (0.169239539 ,0.292746976 ,0.120606806 ,0.136969154) and the heat saturation rate of the soil (0.887470073 ,0.593953679 ,0.795731163,0.855793368) respectively and after four and a half hours of continuous operation and for the same rates Flow The ratio of heat transmitted by conduction to thermocouples at a distance of (0.6 m) and heat stored in the soil (0.581608373 ,0.718916445 ,0.538398451 ,0.525386287) and soil heat saturation ratio (0.540296846 ,0.363114698 , 0.298575773,0.332808532) respectively, as the percentage of heat transmitted by conduction to heat stored in the soil by a certain amount increases with the passage of time depending on the percentage of soil saturation with heat.

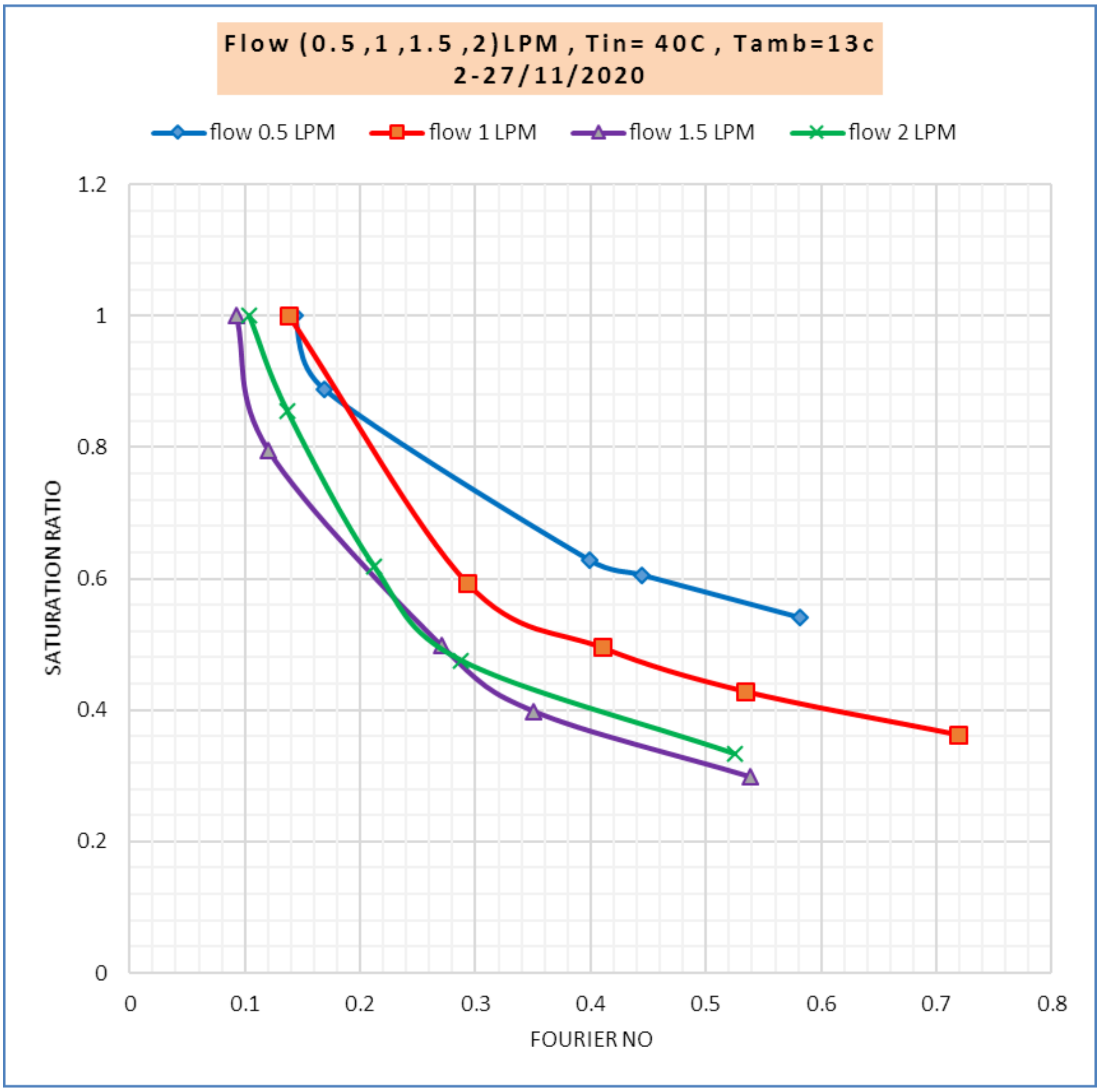

Figure (4.13) shows the relationship between Furrier Number and the heat saturation rate of the soil at temperature (40 °C) and flow rate (0.5-2LPM)

*At inlet temperature (50 °C) and flow rates (0.5-2 LPM)

The fig (4.14) shows the relationship between furrier no and the heat saturation rate of the soil at the entrance temperature (50 °C) and fluid flow rates (0.5, 1, 1.5, 2 LPM) Furier No is the ratio between the heat transferred by conduction and the heat stored in the soil, where we find that in the first hour of operation With flow rates (0.5, 1, 1.5, 2 LPM), the ratio of heat transmitted by conduction of thermocouples at a distance of (0.6 m) to heat stored in the soil is (0.56104608 , 0.25582478 , 0.25494728 , 0.17687062) respectively, and after an hour of operation for the same flow rates, the percentage of The heat transmitted by conduction of thermocouples at a distance of (0.6 m) to the heat stored in the soil (0.66938459 , 0.31326078 , 0.27963721 , 0.19508286) and the heat saturation rate of the soil (0.898551295 , 0.854001273 , 0.910410259 , 0.81879231) respectively and after four and a half hours of continuous operation and for the same rates Flow The ratio of heat transmitted by conduction to thermocouples at a distance of (0.6 m) and heat stored in the soil (2.25381625 , 0.58957698 , 0.58179101 , 0.6393803) and soil heat saturation ratio (0.540449618 , 0.560886788 , 0.510058011 , 0.367732249) respectively, as the percentage of heat transmitted by conduction to heat stored in the soil by a certain amount increases with the passage of time depending on the percentage of soil saturation with heat.

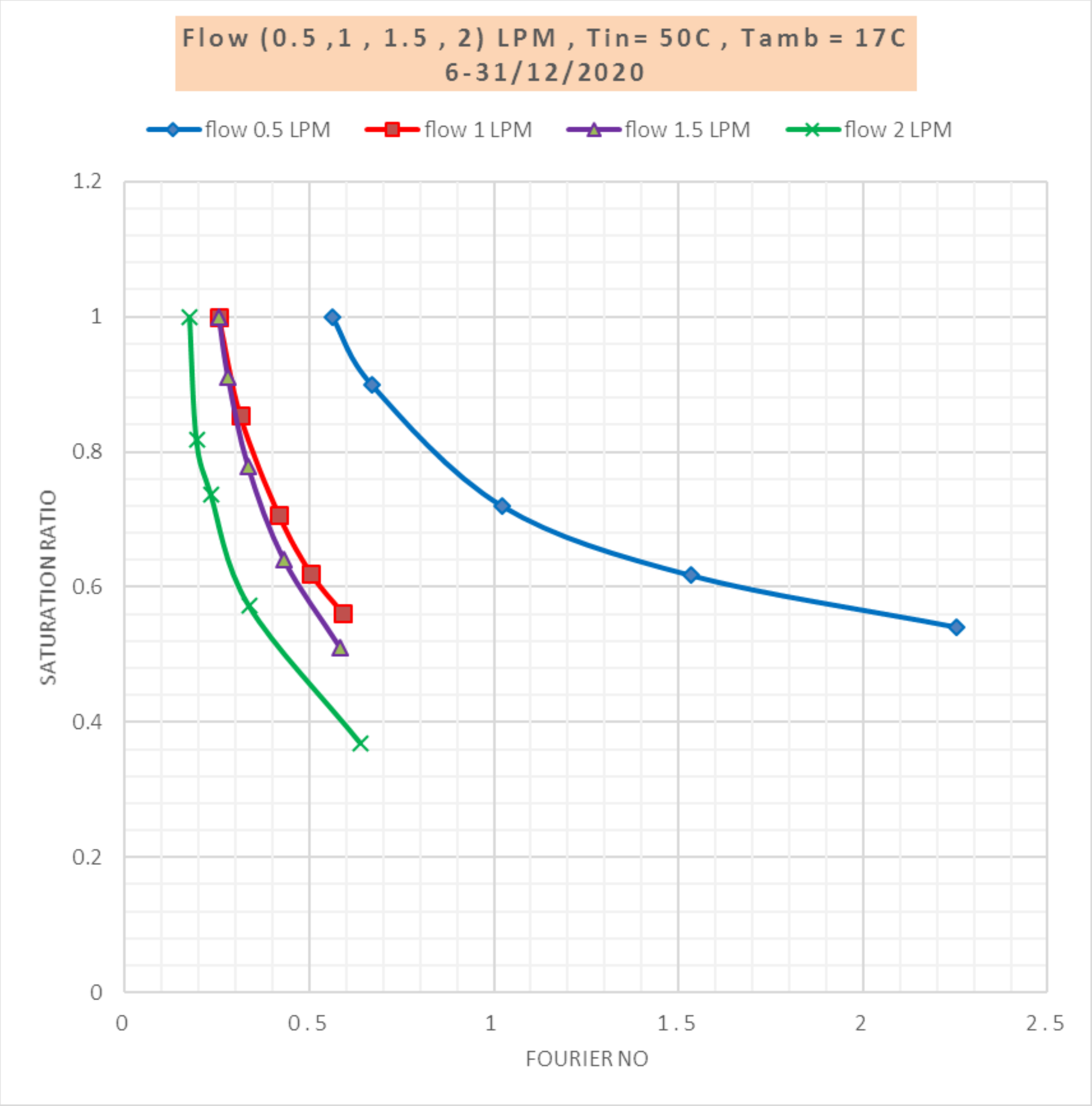

Figure (4.14) shows the relationship between Furrier Number and the heat saturation rate of the soil at temperature (50 °C) and flow rate (0.5-2LPM)

*At inlet temperature (60 °C) and flow rates (0.5-2 LPM).

The fig (4.15) shows the relationship between furrier no and the heat saturation rate of the soil at the entrance temperature (60 °C) and fluid flow rates (0.5, 1, 1.5, 2 LPM) Furrier No is the ratio between the heat transferred by conduction and the heat stored in the soil, where we find that in the first hour of operation With flow rates (0.5, 1, 1.5, 2 LPM), the ratio of heat transmitted by conduction of thermocouples at a distance of (0.6 m) to heat stored in the soil is (0.32430649 , 0.18771348 , 0.10892778 , 0.13417038) respectively, and after an hour of operation for the same flow rates, the percentage of The heat transmitted by conduction of thermocouples at a distance of (0.6 m) to the heat stored in the soil (0.34359258 , 0.21894348 , 0.14842537 , 0.17331427) and the heat saturation rate of the soil (0.937164262 , 0.903606075 , 0.880955221 , 0.803650763) respectively and after four and a half hours of continuous operation and for the same rates Flow The ratio of heat transmitted by conduction to thermocouples at a distance of (0.6 m) and heat stored in the soil (0.48495846 , 0.39857228 , 0.36333879 , 0.46992039) and soil heat saturation ratio (0.716809891 , 0.664745101 , 0.514910674 , 0.373506893) respectively, as the percentage of heat transmitted by conduction to heat stored in the soil by a certain amount increases with the passage of time depending on the percentage of soil saturation with heat.

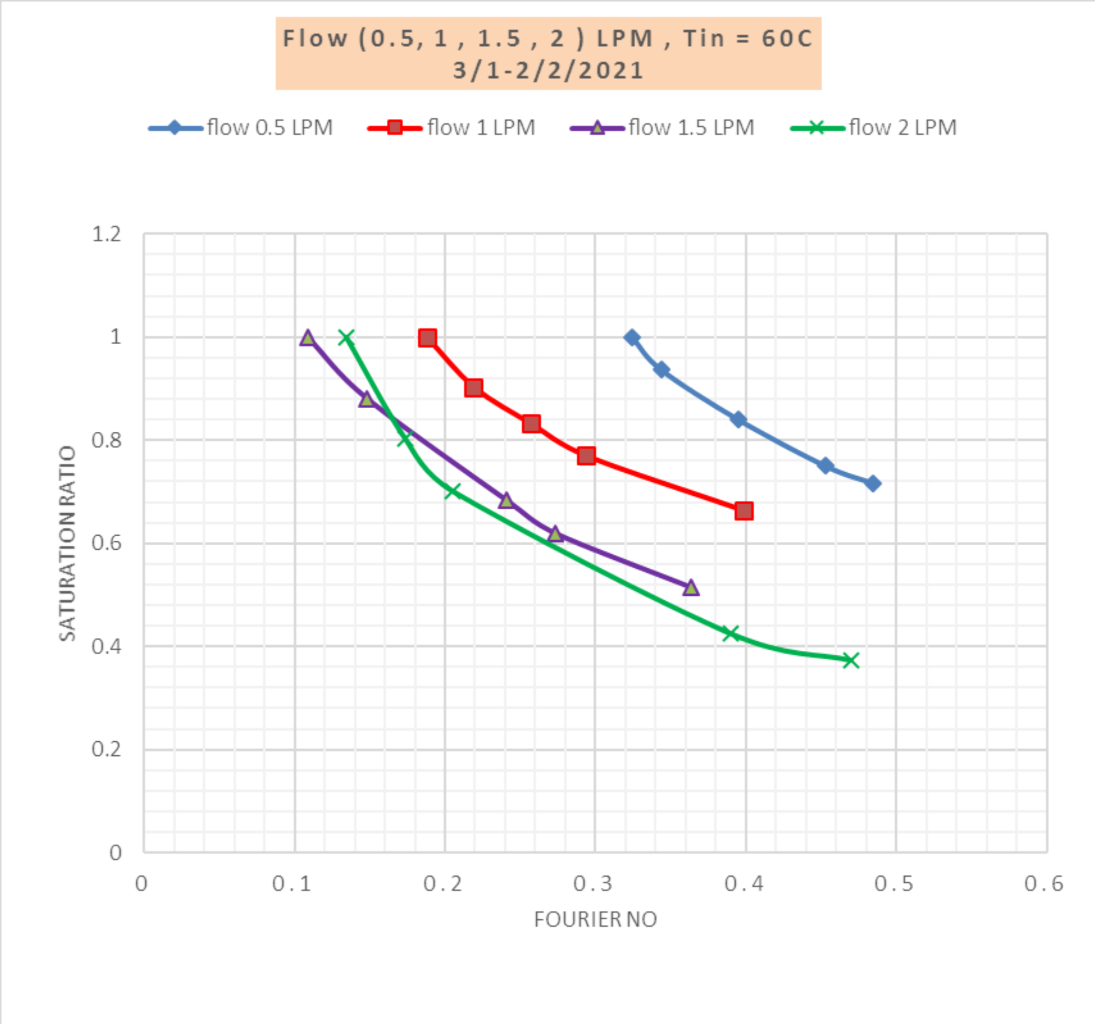

Figure (4.15) shows the relationship between Furrier Number and the heat saturation rate of the soil at temperature (60 °C) and flow rate (0.5-2LPM)

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

Chapter five

Conclusions and Recommendations

5.1 Conclusions

5.1.1 General

1. Geothermal potential in Iraq offers a good exploitation of horizontal ground source heat exchanger system.

2. At a sufficient depth, the experimental ground temperature shows that it is relatively stable, less than the ambient air temperature in the summer and higher in the winter season.

5.1.2 Testing the Thermal Parameters of Vertical Geothermal Heat Exchanger as an heat source

1- The total amount of heat transferred to the soil (Q total) decreases with the passage of operating time due to the saturation of the earth with heat and its rejection of the residual heat.

2- The heat transferred by reaching thermocouples (Q 0.6m) increases with the increase in the inlet temperature and the rate of flow of the fluid.

3- The heat stored in the soil (Q stored) decreases as the temperature and flow rate of the liquid increase.

4- The ratio of heat transferred by conduction to heat stored in the soil (furrier number) decreases as the entrance temperature increases.

5- The heat saturation rate of the soil decreases after every hour of operation due to the soil's rejection of heat transfer (Q total) to reach the state of heat saturation.

6- The best total heat transferred to the soil after four and a half hours of continuous operation was at inlet temperature (60°C) and flow rate (2LPM) and its value (192.44W), and the best conductive heat transfer (Q0.6m) was at inlet temperature (60°C) and flow rate (2LPM) and its value (61.522W) and better Soil stored heat (Q stored) was at inlet temperature (60°C) and flow rate (2LPM) and its value (168.78W)

The best soil heat saturation ratio was at the inlet temperature (60°C), flow rate (0.5LPM) and its value (0.7168).

7- At the inlet temperature (50°C) the value of the heat stored in the soil (Q stored) was very low due to the high moisture content of the soil due to precipitation during the test period.

5.3 Recommendations

1- The present work can be developed by fulfilling the design requirements of the heat pump system associated with the geothermal heat exchanger

2- Installing a humidification system in the zero house area around the geothermal heat exchanger because moisture is important in increasing the rate of heat transfer and thermal conductivity of the soil

3- The research may extend to include mixing metals with a high thermal conductivity coefficient with the soil to get rid of heat accumulation around geothermal heat exchangers.

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Appendixes A

Calibration

Appendix A
Calibration

A- Calibration

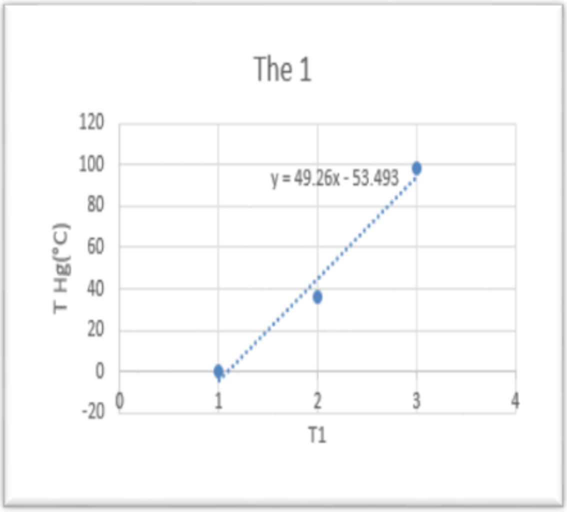
Calibration of the measuring system The relationship between the input values of the system and the output values of the system is determined, then the volumetric flow rates and temperatures of the soil and the outside air and the temperature of the working fluid in GHE are measured at the inlet and outlet where the flowmeter was used to measure the volumetric flow rates of the fluid and the thermometer was used to measure the temperature For soil at a certain depth, a data logger was used to measure the temperature of the working fluid and the outside air by means of installed thermocouples, and these devices are easy to use and have appropriate measurement accuracy.

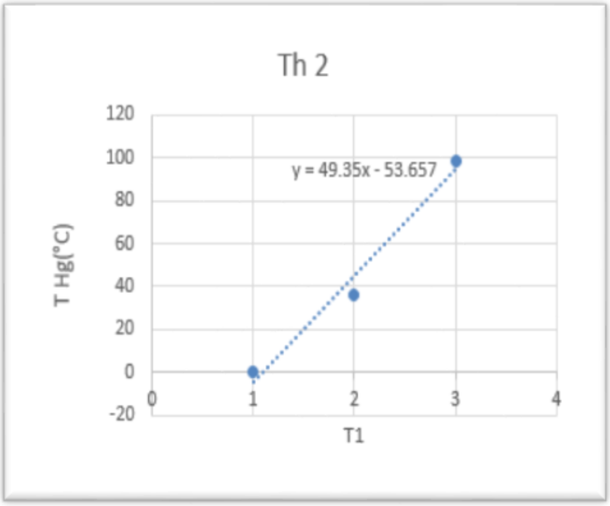
A-1 Thermocouples Calibration

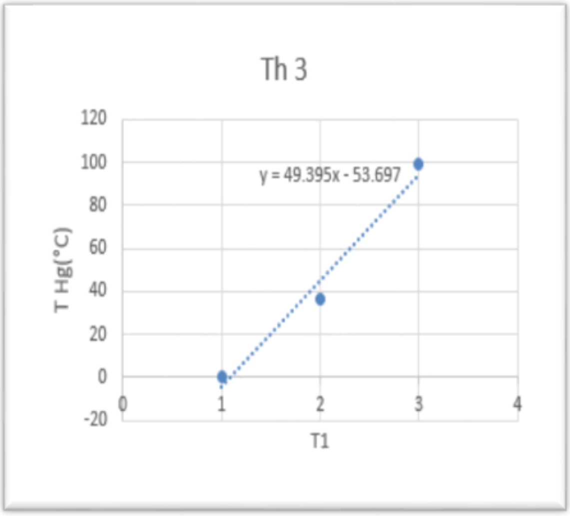
Thermocouples are a type that is widely used as temperature sensors by connecting them to a multimeter or data logger. It is more used in tests and therefore during the subsection it will be spent and explain its main function and what precautions must be taken to ensure the accuracy of the experiments that are conducted where the thermocouple was used K type in the experiments carried out due to the suitability of the temperature range and the best accuracy among the different types of thermocouples used. The calibration of the thermocouples consists of a standard temperature scale (Hg) and a data logger, both of which are in a constant temperature bath with the thermocouples insulated with fiberglass All thermocouples were calibrated together.. Table (A.1) and figure (A.1) show the A-2 relation between the results of the thermometer and the standard mercury thermometer.

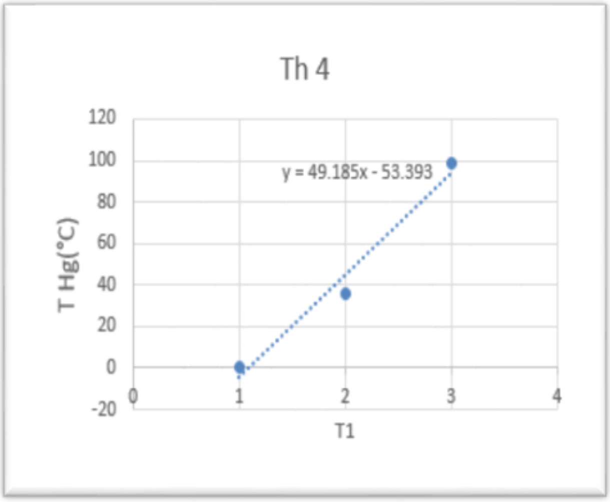
Table A.1: Calibration of Thermocouple used to measure the working fluid temperature

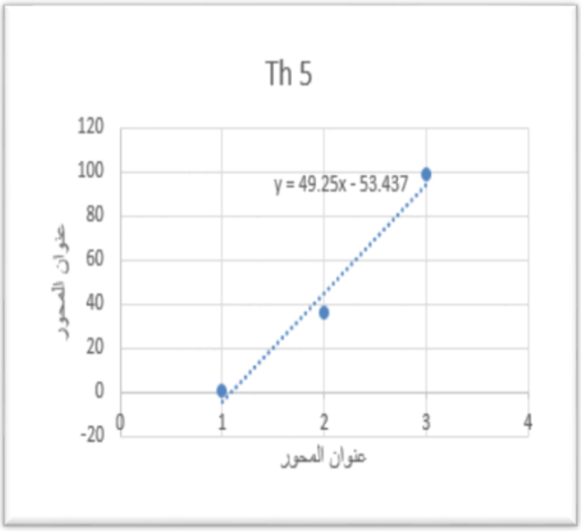
device type	freezing temperature (0°C)	human body temperature (37 °C)	boiling temperature (100 °C)
mercury thermometer	0	36.08	100
Thermo couple 1	0.18	36.2	98.7
Thermo couple 2	0.14	36.15	98.84
Thermo couple 3	0.12	36.25	98.91
Thermo couple 4	0.17	36.22	98.54
Thermo couple 5	0.19	36.31	98.69
Thermo couple 6	0.2	36.28	98.62
Thermo couple 7	0.18	36.22	98.67
Thermo couple 8	0.13	36.45	98.84
Thermo couple 9	0.17	36.1	98.57
Thermo couple 10	0.17	36.21	98.55
Thermo couple 11	0.19	36.52	98.64
Thermo couple 12	0.15	36.34	98.61

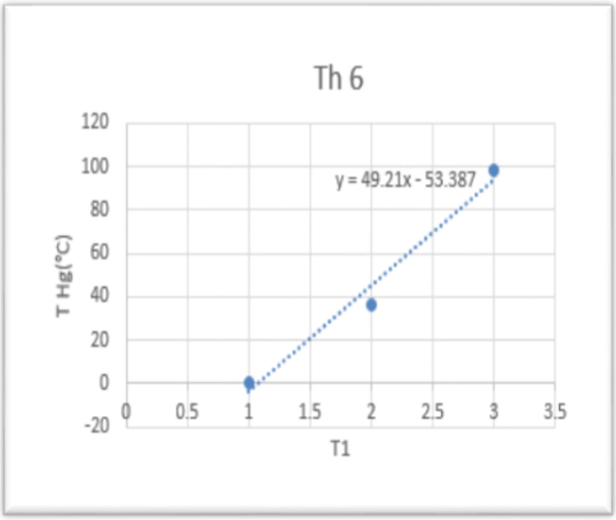

The 1
y = 49.26x - 53.493
T Hg(°C)
T1


Th 2
y = 49.35x - 53.657
T Hg(°C)
T1


Th 3
y = 49.395x - 53.697
T Hg(°C)
T1


Th 4
y = 49.185x - 53.393
T Hg(°C)
T1


Th 5
y = 49.25x - 53.437
عنوان المحور
عنوان المحور


Th 6
y = 49.21x - 53.387
T Hg(°C)
T1

A-3

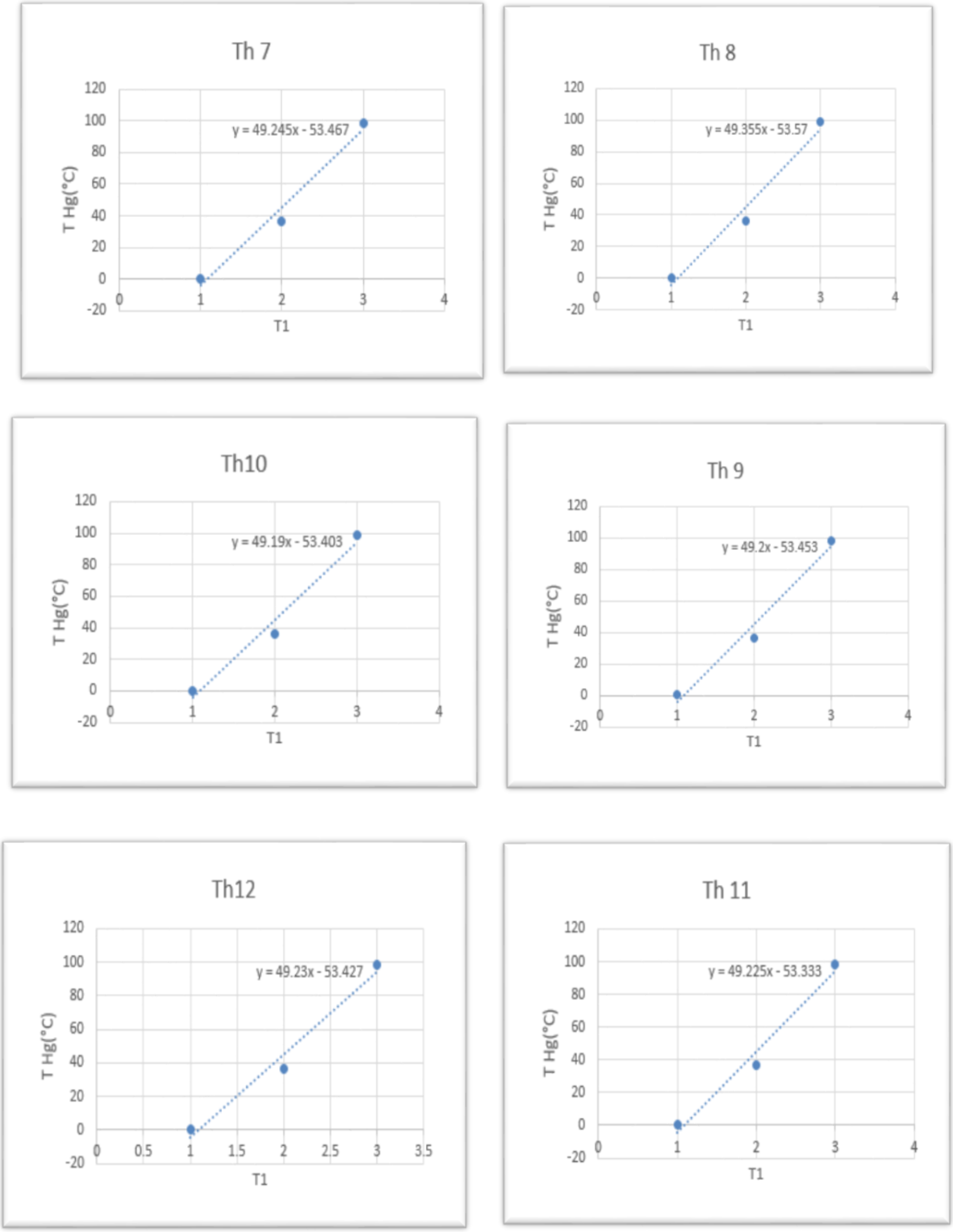


Fig.A.1: Calibration of thermocouples for measuring soil temperature

A-2 Flowmeter calibration

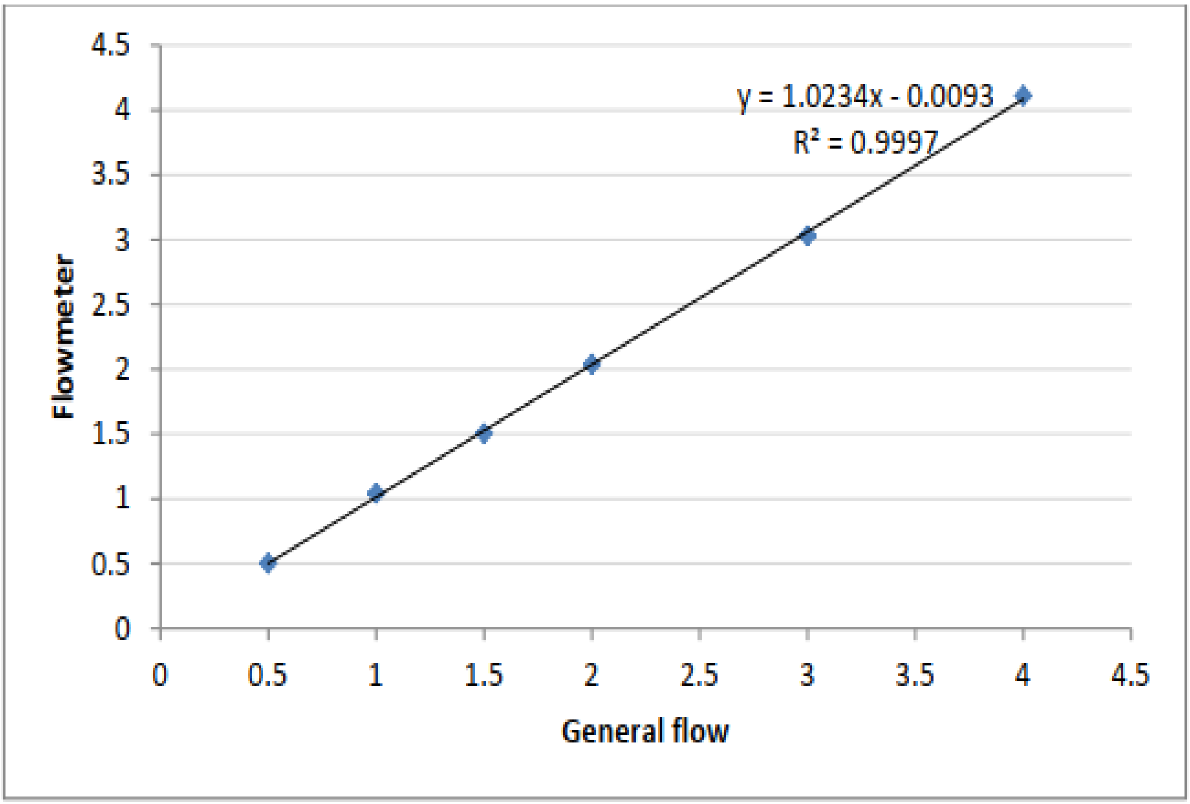


Fig. A.3: Calibration of the water flow meter

A-3 Calculations for the best inlet temperature and fluid flow

at Tin= 60 °C , flow rate = 2LPM																	
time	mass flow rate	Tin °C	Tou °C	Tave °C	Ts °C	Tth8 °C	Cp (J/kg.k)	ΔTw	ΔTs	L (m)	K(W/m.k)	ln(ro/rin)	Q0.6(W)	Q total(W)	Qstored(W)	Fourier No	saturation ratio
08:30	0.033333	60	56.1	46	54	16.65	3963.39	3.9	37.35	2	0.29	2.232	60.9515	515.235	454.284	0.13417	1
09:30	0.033333	60	56.8	54.2	54.2	16.72	3881.94	3.2	37.48	2	0.29	2.232	61.1636	414.069	352.906	0.17331	0.80365076
10:30	0.033333	60	57.2	55.1	54.7	17.01	3872.21	2.8	37.69	2	0.29	2.232	61.5063	361.403	299.897	0.20509	0.70143282
11:30	0.033333	60	58.3	56	55.1	17.46	3862.33	1.7	37.64	2	0.29	2.232	61.4247	218.863	157.439	0.39015	0.42478327
12:30	0.033333	60	58.5	57.2	55.8	18.1	3848.92	1.5	37.7	2	0.29	2.232	61.5226	192.444	130.921	0.46992	0.37350689

Tin = Inlet temperature (°C)

Tou = outlet temperature (°C)

Tave = average temperature (°C)

Ts = heat exchanger surface temperature (°C)

Tth8 = Average temperature of the thermocouples installed around the exchanger (°C)

m'=mass flow rate (L/sec)

L = 2 m

ro = 0.6725 m

ri =0.145m

Qtotal= m' * Cp* (Tin-Tou)

Q0.6m= 2*3.14*L*Ks*(Ts-Tth8) / ln(ro/ri)

Qstored= Qtotal- Q0.6m

Furrier no= Q0.6m / Q stored

saturation ratio=Q per hour / Qtotal

Cp =-0.00000003136*Tave^5+0.00001113*Tave^4-0.00149*Tave^3+0.1025-3.323*Tave+4217.8

الخلاصة

تهدف الدراسة الحالية الى دراسة المعاملات الحرارية للمبادل الحراري العمودي. تم اختيار المبادل الحراري العمودي كمصدر للحرارة والذي تم تنفيذه على ارض الكلية التقنية الهندسية في النجف / جامعة الفرات الاوسط التقنية يتكون المبادل الحراري من انبوب بطول (2m) وقطر خارجي وداخلي (14.5 ,14.2cm) على التوالي يحتوي على انبوبين داخلين من البولي أثيلين لدخول وخروج السائل بقطر (2.5cm) لكلا الانبوبين .

تم اختبار وضع التشغيل المستمر (وقت قصير) بواقع اربع ساعات ونصف يومياً من الساعة (8:30 am – 12:30 pm) ولفترة ثلاثة اشهر ونصف (تشرين الثاني ، كانون الأول ، كانون الثاني ، شباط) عند درجة حرارة المدخل (°C 60, 50, 40) ومعدلات تدفق حجمي للسائل (0.5 ,1 , 1.5 , 2 LPM) للتربة الجافة.

حيث تم حساب الحرارة الكلية المنتقلة للتربة والحرارة المنتقلة بالتوصيل الى المزدوجات الحرارية على بعد (0.6m) والحرارة المخزونة بالتربة وكذلك حساب فورير نمبر ونسبة التشبع الحراري للتربة.

أفضل حرارة كلية تم نقلها إلى التربة بعد أربع ساعات ونصف من التشغيل المستمر كانت عند درجة حرارة الداخل (60°C) ومعدل التدفق للسائل (2LPM) وقيمتها (192.44W) ،

أفضل حرارة منتقلة بالتوصيل (Q0.6m) كانت عند درجة حرارة المدخل (60°C) ومعدل التدفق للسائل (2LPM) وقيمتها (61.522W).

أفضل حرارة مخزونة في التربة (Qstored) كانت عند درجة حرارة المدخل (60C°) ومعدل التدفق للسائل (2LPM) وقيمتها (168.78W).

أفضل نسبة تشبع حراري للتربة كانت عند درجة حرارة الداخل (60°C) ومعدل التدفق للسائل (0.5 LPM) وقيمتها (0.7168).

عند درجة حرارة المدخل (50°C) ، كانت قيمة الحرارة المخزونة في التربة (Qstored) منخفضة للغاية بسبب المحتوى الرطوبي العالي للتربة بسبب هطول الأمطار خلال فترة الاختبار.

Ministry of Higher Education
and Scientific Research
UNIVERSITY OF
KUFA
Faculty of Engineering

Nanotechnology and Advanced
Materials Research Unit

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Date:

وزارة التعليم العالي
والبحث العلمي
جامعة الكوفة
كلية الهندسة

وحدة ابحاث النانوتكنولوجي والمواد المتقدمة

العدد: ١

التاريخ: ٢٦/١/٢٠٢٢

Certification

Name: Waleed AbdulHamza

Thermal Conductivity Measurement , Volumertric Specific Heat

No. of sample	Thermal conductivity (W/m.k)	Specific Heat ($MJ/m^3.k$)	Error	Temperature (°C)
1	0.2761	1.365	0.0015	20.32
2	0.304	1.454	0.0016	20.73
3	0.305	1.431	0.0024	22.46
4	0.29	1.455	0.0019	21.64

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Dear Authors:

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Analysis of thermal conductivity, thermal diffusion and heat capacity using a vertical heat exchanger in Najaf soil

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STUDY OF THE EFFECT OF MOISTURE CONTENT ON THE THERMAL PROPERTIES OF SOIL IN THE TECHNICAL COLLEGE / NAJAF

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ABSTRACT

In the face of changing known conditions such as global warming, thermal diffusivity is a physical property represented by the thermal characteristics of the soil.

The heat transfer and temperature change in the surface layers of the soil at a depth of 2 m were investigated using a vertical heat exchanger in the sandy mixed soil in Najaf and according to location.

For one day at a temperature of 40 degrees Celsius and a flow of 0.5 liters per minute, the best thermal diffusivity was obtained, ranging 0.006251554 to 0.006625955 m^2/sec.

At a temperature of 40 degrees Celsius and a flow rate of 1 liter per minute, the best thermal performance coefficient was achieved.

Keywords: *soil temperature, thermal diffusivity, Thermal conductivity of soil*

INTRODUCTION

The thermal diffusivity of a soil is an important soil attribute that is employed in a variety of applications such as agriculture, climatology, and engineering. It has a big impact on the soil temperature profile, which controls the earth's heat and mass transmission, and it's a key parameter in energy balance applications including land surface modeling, numerical weather forecasting, and climate prediction[1] .

In both residential and commercial buildings, ground-source heat pump (GSHP) systems are frequently utilized for space heating and cooling. A ground heat exchanger (GHE) is used to exchange heat with the earth in this manner. The vertical kind of GHE is often used in GSHP systems because it has better thermal performance than the horizontal type. The GHE's thermal performance is an important factor to consider when constructing a GSHP system. The utilization of renewable energies has recently become increasingly significant in order to reduce energy consumption in general and fuel use in particular, as solar energy may be used to generate electricity. [2].

Summer in Iraq is distinguished by high air temperature and low relative humidity because it is the longest season of the year in comparison to other countries. As a result, reducing the air temperature inside the area is a significant challenge.

COMMITTEE REPORT

We certify that we have read this thisis titled " **Study of Thermal Parameters of Vertical Geothermal Heat Exchanger in Engineering Technical College Najaf** " which is being submitted by **Waleed Abdulhamza Asker** and as Examining Committee, examined the student in its contents . In our opinion , the thisis is adequate for the a ward of the degree of Master of Techniques in Thermal Engineering.

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