Performance Analysis of an Earth Tube Heat Exchanger for Winter Heating in Erbil

Sirwan A. Rasha*

Abstract— The aim of this study was to evaluate the performance of a specially designed earth tube heat exchanger that was installed in a loamy soil inside the campus of the college of Engineering, Salahaddin University at Erbil, Iraqi Kurdistan region for winter heating from November 2012 to February 2013. The system was composed of 23 pipes in form of two tiers buried at a depth increment of 3 – 4 m. Air was sucked from a testing room to the inlet pipe of the system by a ventilator which was powered by 70 W motor. The results indicated that the inside soil temperature differed significantly from the ground temperature recorded at a depth of 3.5 m. The coefficient of performance (COP) in heating mode ranged from as low as 1.97 during November to as high as 4.22 during January. Furthermore, it was also noticed that Cop values that were obtained during the night time were higher than those obtained during the daytime. It can also be inferred that the system alone is not sufficient to create thermal comfort with a limited length of 33 m, but provides a significant portion of the heating load. The system efficiency can be improved by expanding the pipe network and controlling heat dissipation.

Keywords— Building Environment, Earth tube heat tube exchanger, . Renewable energy, Winter heating

1. INTRODUCTION

EARTH tube heat exchanger (ETHE) is a device that enables transfer of heat from ambient air to deeper layers of soil and vice versa [14]. Since the early explanation of its use in cooling commercial buildings, there has been a considerable increase in its application [12]. For many years earth heat exchangers have been acknowledged to be useful tools for the climatization of buildings, both to decrease energy consumption and increase building comfort [5], [8] revealed that only a moderate climate having a large temperature difference between summer and winter is suited for earth tube heat exchangers. Different configurations of earth –to-air heat exchanger have been used in Central and Western Europe as heat suppliers during the cold season [16]. Their performance depends on the air flow rate, convective heat transfer at the tube surface, depth, dimensions and number of pipes and soil properties [6].

Since the soil transports heat slowly and has a high heat storage capacity, its temperature changes slowly depending on the depth of measurement [1]. As consequence of this low thermal conductivity, the soil can transfer some heat from the cooling season to the heating season. Heat absorbed by the earth during the summer effectively is used in the winter [10]. The U.S. Environmental Protection Agency (EPA) considered the ground heat exchange system as the most available environmentally clean, energy efficient and cost effective space conditioning systems [7]. An earth tube is a long underground metal or plastic pipe through which air is drawn as air travels through the pipe, it gives up or receives some of its heat to/ from the surrounding soil and enters the room as conditioned air during the cooling and heating period [9]. Earth tube heat exchanger usually consists of loops (s) of pipe buried in the ground horizontally or vertically. Vertical loops go deeper showed that [13]. Horizontal loops are usually buried at 1 to 4 m depth. Temperature regime at this depth and beyond is stable, with no diurnal fluctuation and with only a small seasonal or annual variation, it was observed that a single pass earth tube exchanger buried 3 m deep below the soil surface was able to warm up the cold ambient air by as much as 14 ^{o}C in the nights of January [14] . This means that earth tube heat exchanger holds considerable promise as a means to heat ambient air for a variety of applications such as the livestock buildings and greenhouses. Earth tube heat exchanger is based on a well-known fact that while ambient temperature are subject to daily fluctuations, temperature of the soil beyond a depth of, say, 2 meter remains virtually constant [15]. There was observed temperature differences of about 7 ^{o}C and 10 ^{o}C between ground surface and 4 m depth for alkry'at and Alsadr cities, north eastern side of Baghdad during winter times [2]. On the other hand, the measured soil temperature at two locations in Arbil city, Iraqi Kurdistan region during the period from November, 1st, 2012 to February, 28th, 2013 recorded positive differences at a depth of 3.5 m during the winter season from December to February ranged from 13.73 to 21.56 ^{o}C [11]. This suggests that it may serve for preheating systems during these times. On the other hand, It has been reported that, the electricity demand is increasing continuously in Iraqi Kurdistan Region. Albeit, the available electricity increased from 1,075,839 MWh to 6,806,489 MWh during the period from 2008 to 2012, it does not satisfy the consumer's needs [17].

Based on the above facts, it would be beneficial to investigate earth tube heat exchangers as auxiliary cooling and heating devices together with air conditioning. The

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current study aimed to study the possibility of using earth tube heat exchanger to heat buildings.

2. EXPERIMENTAL SET-UP

2.1. Site Description

The study site is ca 400 m amsl and located at 36° 02′ N and 44° 23′ E. The system installation is on an open field inside the campus of the College of Engineering, Salahaddin University, Arbil, Iraqi Kurdistan Region. The soil at the site has a loamy texture to a depth of more than 4 m [11].

2.2. Building Description:

The building is composed of a testing room with external dimensions of 2 m length, 2 m width and 3 m height (Fig. 1). Walls are 25 cm thick made of concrete blocks. Roofing is 15cm RCC slab. The floor is covered with concrete. The inner walls were lined with gypsum, while the outer surfaces were lined with cement. The room has a single glass window, made of Polyvinyl chloride (PVC) with dimensions of 0.6 m x 0.8 m. On the other hand, the door has a span of 0.8 m and a height of 2.1 m, made of (PVC) too.

2.3. Description of the Heating System

The earth tube heat exchanger was made from a metal pipe that was 33 m long and 10 cm in diameter and 3mm wall thickness.

The system was composed of 23 pipe portions; each had a length of 1 m arranged in two tiers(Fig.1).

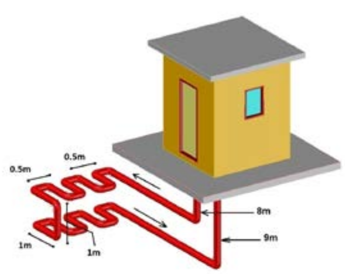

Fig.1. Layout of the ETHE system

The first tier had 6 pipes connected with 0.5m horizontally in series placed at a depth of 4 m below the soil surface. The second tier had also 6 pipes and placed 1 m above the first tier. The pipes within each tier were placed 0.5m apart. Each tier was forming a horizontal layer with a small angle of inclination to prevent condensation of water. It is worthy to mention that the whole network was made by bending one pipe which had a length of 33 m.(Fig. 1). A ventilator powered by a 70 W motor was connected to tube inlet inside the room via a specially fabricated duct to suck ambient air to the system. The conditioned air was let into the room through the pipe outlet, which was at a height of 1 m above the room floor.

The air velocity was measured with a portable anemometer Model Testo 405-V1.

2.4.Data Collection

The system was commissioned in November 2013 and its performance was tested during November, 2012 through February 2013. The system was turned on the dates indicated in Table 1 through 4 for about 6 hours per day . The recorded data encompassed the soil temperature at a depth of 3.5m; indoors and outdoors temperatures; the air temperature at the pipe outlet and equilibrium indoor temperature. Measurements were made at 3 am and 3 pm.

The air temperature was measured with a portable thermometer Model Testo Testo 925.

2.5.Performance Analysis

The coefficient of performance (COP) was calculated according to the formula proposed by (ASHRAE , 1989):

$$COP = Q_{out} / W_{in} \quad [1]$$

where

Q_{out} = The heat added by the air(w)

W_{in} = Energy input (w)

$$Q_{out} = m\,C_p\,(T_o - T_i) \quad [2]$$

M = mass flow rate (kg s^{-1})

C_p = specific heat capacity at constant pressure (kJ/ Kg °C).

$$m = V / v \quad [3]$$

V = volumetric flow rate ($m^3\,s^{-1}$)

v = air specific volume ($m^3\,kg^{-1}$)

The volumetric rate was calculated from:

$$V = vel\,(\pi d^2 / 4) \times 10^{-4} \quad [4]$$

Vel = Air velocity (ms^{-1})

d = pipe diameter (cm)

T_i = the inlet temperature(° C)

T_o = the outlet temperature (° C)

3. RESULT AND DISCUSSION

3.1. Soil temperature Regime

Prior to the design of the ETHE for the tested room, the soil temperature regime was studied up to a depth of 4 m [11]. It was found that the stratum between 3 to 4 m had stable temperature regime. It is evident from Table 1 that the monthly soil temperature at depth of 3.5 ranged from 25.42 to 27.16 °C at 3 pm and from 26.56 to 28.17 °C at 3 am. during the testing period. This will support the findings of Sharan and Jadhav[14], who found that under an arid

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climate the soil temperature below 2 m depth remained between 25 – 27 °C. With one exception, the coefficient of variation for this parameter is below 4% over the testing period. This implies that the amplitude of the diurnal variations diminished considerably. Similarly, it was observed that the amplitude at 3 m was just 2.8 °C around the mean of 27 °C. Thus, deeper layers of the study soil can be used as heat source in winter and as a heat sink in summer [14].

3.2. Fluctuation of Outdoor and indoor temperatures

Figs. 2 and 3 depict the time series for the ambient (outdoor) and indoor temperatures over the testing period at 3 pm and 3 am respectively. The average daily fluctuation was also presented in Fig. 4. It can be observed from the figures below that the amplitude of indoor temperature is

TABLE 1.
Average temperatures and their variations recorded during the tested period from November 2012 to February 2013

Month	Time of the day											
	03:00 pm						03:00am					
	Soil Temperature At a depth of 3.5 m (°C)		Equilibrium air temperature inside the tested room (°C)		Air temperature outside the tested room (°C)		Soil Temperature At a depth of 3.5 m (°C)		Equilibrium air temperature inside the tested room (°C)		Air temperature outside the tested room (°C)	
	Average	CV	Average	CV	Average	CV	Average	CV	Average	CV	Average	CV
Nov	25.42	1.97	23.45	9.65	21.46	16.27	26.56	3.75	22.02	12.2	16.86	23.46
Dec	25.74	1.19	17.24	31	12.44	5.32	27.96	3.39	15.43	10.39	7.01	27.18
Jan	25.69	2.48	16.49	2.48	9.04	35.3	28.17	3.32	15.63	2.98	5.53	59.28
Feb	27.16	4.16	16.01	4.1	10.51	12.23	27.25	3.37	15.09	5.10	7.65	17.92

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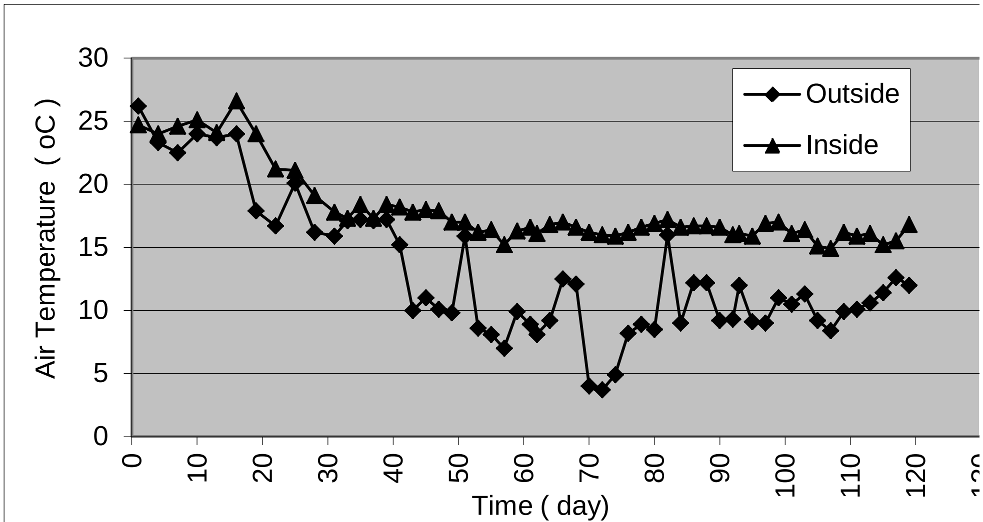

Fig.2. Fluctuation of outdoor and indoor temperatures at 3 a.m. over the period of the study

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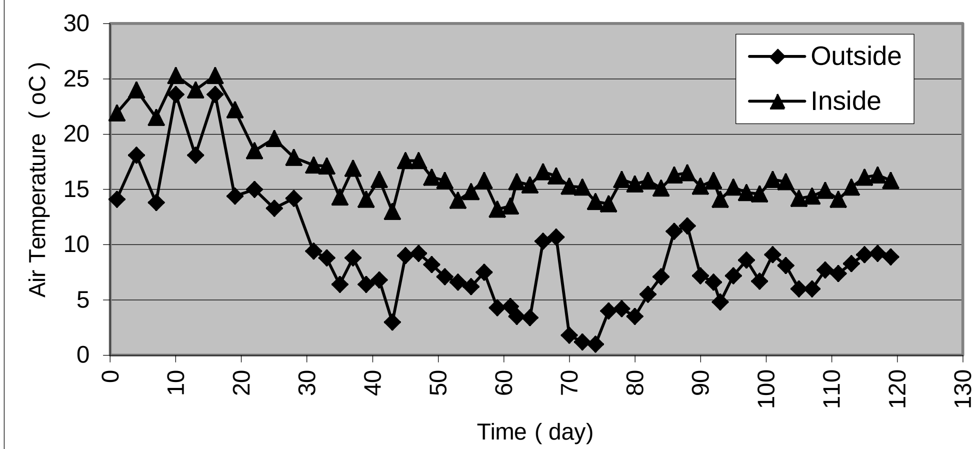

Fig.3. Fluctuation of outdoor and indoor temperatures at 3 p.m. over the period of the study

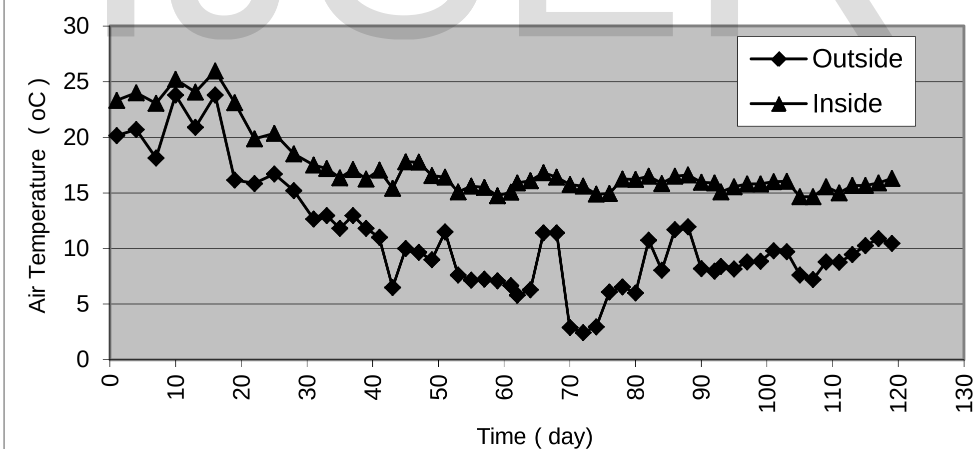

Fig.4. Fluctuation of average daily outdoor and indoor temperatures over the period of the study

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damped compared to the ambient temperature. The coefficients of variation for the equilibrium indoor temperatures support this fact (Table 1). The results also indicated that the indoor temperature exhibited the highest fluctuation during November compared to the other months, but remained much smaller than that of the ambient. Fig.5 illustrates that there is a steady decrease in average indoor and outdoor temperatures with elapsed time over the testing period from November 2012 to February 2013.

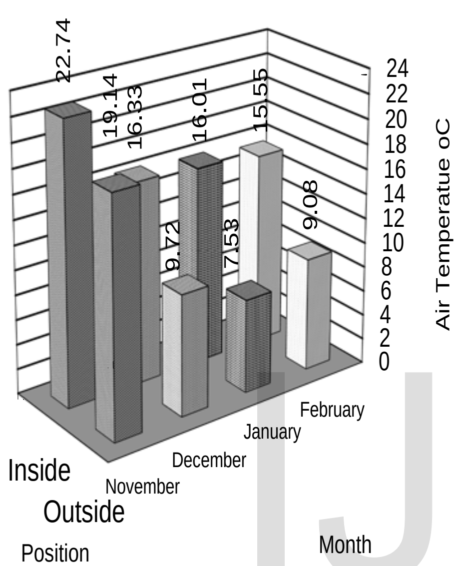

Fig.5. Average monthy air temperaturer at indoor and outdoor during the period of the study

Moreover the results presented in Fig 6 indicated that there is a positive difference between indoor and outdoor temperatures over the testing period. The differences vary from a minimum of 3.6 ^oC to a maximum of 8.48 ^oC during the month of January. This means that the system was able to warm up the ambient air in the coldest month from 7.53 to 16.01 ^oC. On the other hand, it can be noticed from Table 1 that the equilibrium was much lower that the soil temperature at a depth of 3.5 m particularly

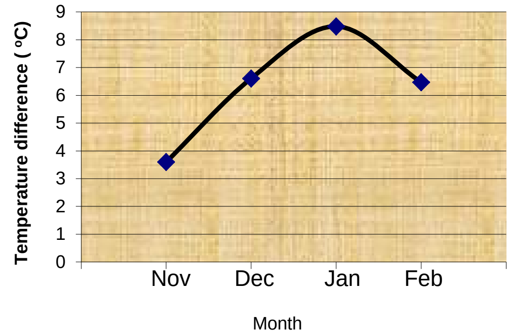

Fig .6. Monthly average difference between indoor and outdoor air temperature during the period of the study.

during December, January and February, suggesting that the system was exchanging heat inefficiently. Contrarily, it was shown that the outlet temperature of a single pass earth tube heat exchanger was just above the basic soil temperature (26.6^{o}C) at 3 m depth, suggesting that the tube was exchanging heat quite effectively [14]. Before operating the system Higher temperature differences were expected. One plausible explanation for this contradiction is the limited length of the employed pipe. The huge dissipation of heat from the walls, roof and other components of the tested room may be another factor because the tested room was not isolated building without secondary roof. Additionally, the system was operated for a long period(6 hours for each run).

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3.3. Coefficient of Performance for heating tests.

Tables 2 through 5 exhibit the calculations of coefficient of performance (COP) of the earth tube for heating during the entire period of the test. It was considered as one of the measures of heat exchanger efficiency. The calculation was based on initial indoor temperature and soil temperature at the tube outlet within the first fifteen minutes. It is worthy to mention that the outlet temperature after this period was close to the equilibrium air temperature of the tested room. Heating tests were of 6 hours continuous duration during day and night.

It is apparent from the above tables that the COP values ranged from as low as 0.24 during the first day of November 2012 to as high as 6.39 during 13th January 2013 .

It is also evident that the COP values during the nighttime were superior to those during the daytime (Fig.7). The results presented in Fig. 7 also elucidated that the system

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achieved the highest performance during January. The mean monthly COP values for November through February were 1.97, 3.18 ,4.22 and 3.11 respectively. In a similar study, Baxter (1992) observed that COP for heating mode during January ranged from 3.2 to 10.3[4].

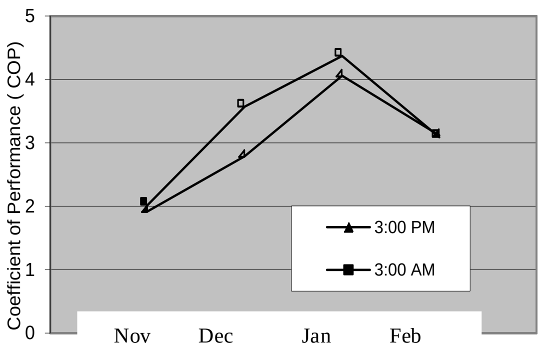

Fig.7. Overall Coefficient of Performance of the earth
tube heat exchanger during the tested period

It commendable to mention that the system is capable of improvement to be used on a commercial scale through expanding the pipe network and controlling heat dissipation.

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4.CONCLUSION

Based on the obtained results, it can be stated that the earth tube heat exchange holds considerable promise as means to heat ambient air for a variety of applications such as office buildings. It can also be concluded that that the System alone is not sufficient to create thermal comfort with limited length of 33, but can provide significant portion of heating load.

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TABLE 2.
Calculation of coefficient of performance of the earth tube for heating during the month of November 2012.

Date	Ti (^oC)	To(^oC)	□(m^3/kg)	V (m^3/s)	m (kg /s)	Cp (J/kg. ^oC)	Q_{out}(w)	Q_{in} (w)	COP
03:00pm									
1	24.2	24.7	0.8	0.027	0.033	1007.00	16.81	70.00	0.24
4	21.3	24	0.8	0.027	0.033	1007.00	90.79	70.00	1.30
7	20.5	24.6	0.8	0.027	0.033	1007.00	137.87	70.00	1.97
10	22	25.1	0.8	0.027	0.033	1007.00	104.24	70.00	1.49
13	21.7	24.1	0.8	0.027	0.033	1007.00	80.70	70.00	1.15
16	22	26.6	0.8	0.027	0.033	1007.00	154.68	70.00	2.21
19	15.9	24	0.8	0.027	0.033	1007.00	272.38	70.00	3.89
22	14.7	21.2	0.8	0.027	0.033	1007.00	218.57	70.00	3.12
25	18.1	21.1	0.8	0.027	0.033	1007.00	100.88	70.00	1.44
28	14.2	19.1	0.8	0.027	0.033	1007.00	164.77	70.00	2.35
03:00am									
1	15.1	21.9	0.8	0.027	0.033	1007.00	228.66	70.00	3.27
4	19.1	24	0.8	0.027	0.033	1007.00	164.77	70.00	2.35
7	14.8	21.5	0.8	0.027	0.033	1007.00	225.30	70.00	3.22
10	24.6	25.3	0.8	0.027	0.033	1007.00	23.54	70.00	0.34
13	19.1	24	0.8	0.027	0.033	1007.00	164.77	70.00	2.35
16	24.6	25.3	0.8	0.027	0.033	1007.00	23.54	70.00	0.34
19	15.4	22.2	0.8	0.027	0.033	1007.00	228.66	70.00	3.27
22	16	18.5	0.8	0.027	0.033	1007.00	84.07	70.00	1.20
25	14.3	19.6	0.8	0.027	0.033	1007.00	178.22	70.00	2.55
28	15.2	17.9	0.8	0.027	0.033	1007.00	90.79	70.00	1.30

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Table 3.
Calculation of coefficient of performance of
the earth tube for heating during the month of December 2012.

Date	Ti (^oC)	To(^oC)	□(m^3/kg)	V (m^3/s)	m (kg /s)	Cp (J/kg. ^oC)	Q_{out}(w)	Q_{in} (w)	COP
03:00pm									
1	14.9	17.8	0.8	0.027	0.033	1007.00	97.52	70.00	1.39
3	16.1	17.3	0.8	0.027	0.033	1007.00	40.35	70.00	0.58
5	16.2	18.4	0.8	0.027	0.033	1007.00	73.98	70.00	1.06
7	16.1	17.3	0.8	0.027	0.033	1007.00	40.35	70.00	0.58
9	16.2	18.4	0.8	0.027	0.033	1007.00	73.98	70.00	1.06
11	14.2	18.2	0.8	0.027	0.033	1007.00	134.51	70.00	1.92
13	9	17.8	0.8	0.027	0.033	1007.00	295.91	70.00	4.23
15	10	18	0.8	0.027	0.033	1007.00	269.01	70.00	3.84
17	9.1	17.9	0.8	0.027	0.033	1007.00	295.91	70.00	4.23
19	8.8	17	0.8	0.027	0.033	1007.00	275.74	70.00	3.94
21	14.9	17	0.8	0.027	0.033	1007.00	70.62	70.00	1.01
23	7.6	16.2	0.8	0.027	0.033	1007.00	289.19	70.00	4.13
25	7.1	16.4	0.8	0.027	0.033	1007.00	312.73	70.00	4.47
27	6	15.2	0.8	0.027	0.033	1007.00	309.36	70.00	4.42
29	8.9	16.3	0.8	0.027	0.033	1007.00	248.84	70.00	3.55
31	7.9	16.6	0.8	0.027	0.033	1007.00	292.55	70.00	4.18
03:00am									
1	10.4	17.2	0.8	0.027	0.033	1007.00	228.66	70.00	3.27
3	9.8	17.1	0.8	0.027	0.033	1007.00	245.47	70.00	3.51
5	7.4	14.3	0.8	0.027	0.033	1007.00	232.02	70.00	3.31
7	9.8	16.9	0.8	0.027	0.033	1007.00	238.75	70.00	3.41
9	7.4	14.1	0.8	0.027	0.033	1007.00	225.30	70.00	3.22
11	7.8	15.9	0.8	0.027	0.033	1007.00	272.38	70.00	3.89
13	4	13	0.8	0.027	0.033	1007.00	302.64	70.00	4.32
15	10	17.6	0.8	0.027	0.033	1007.00	255.56	70.00	3.65
17	10.2	17.6	0.8	0.027	0.033	1007.00	248.84	70.00	3.55
19	9.2	16.1	0.8	0.027	0.033	1007.00	232.02	70.00	3.31
21	8.1	15.8	0.8	0.027	0.033	1007.00	258.92	70.00	3.70
23	7.6	14	0.8	0.027	0.033	1007.00	215.21	70.00	3.07
25	7.2	14.8	0.8	0.027	0.033	1007.00	255.56	70.00	3.65
27	8.5	15.8	0.8	0.027	0.033	1007.00	245.47	70.00	3.51
29	5.3	13.2	0.8	0.027	0.033	1007.00	265.65	70.00	3.80
31	5.4	13.5	0.8	0.027	0.033	1007.00	272.38	70.00	3.89

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Table 4.
Calculation of coefficient of performance of
the earth tube for heating during the month of January 2013.

Date	Ti (^oC)	To(^oC)	n (m^3/kg)	V (m^3/s)	m (kg /s)	Cp (J/kg. ^oC)	Q_{out}(w)	Q_{in} (w)	COP
03:00pm									
1	7.1	16.1	0.8	0.027	0.033	1007.00	302.64	70.00	4.32
3	8.2	16.8	0.8	0.027	0.033	1007.00	289.19	70.00	4.13
5	11.5	17	0.8	0.027	0.033	1007.00	184.95	70.00	2.64
7	11.1	16.9	0.8	0.027	0.033	1007.00	195.03	70.00	2.79
9	3	16.2	0.8	0.027	0.033	1007.00	443.87	70.00	6.34
11	2.7	16	0.8	0.027	0.033	1007.00	447.23	70.00	6.39
13	3.9	15.9	0.8	0.027	0.033	1007.00	403.52	70.00	5.76
15	7.2	16.2	0.8	0.027	0.033	1007.00	302.64	70.00	4.32
17	7.9	16.6	0.8	0.027	0.033	1007.00	292.55	70.00	4.18
19	7.5	16.9	0.8	0.027	0.033	1007.00	316.09	70.00	4.52
21	15	17.2	0.8	0.027	0.033	1007.00	73.98	70.00	1.06
23	8	16.6	0.8	0.027	0.033	1007.00	289.19	70.00	4.13
25	11.2	16.7	0.8	0.027	0.033	1007.00	184.95	70.00	2.64
27	8.2	16.6	0.8	0.027	0.033	1007.00	282.46	70.00	4.04
29	7.9	16.2	0.8	0.027	0.033	1007.00	279.10	70.00	3.99
31	8.3	16	0.8	0.027	0.033	1007.00	258.92	70.00	3.70
03:00am									
1	4.5	15.7	0.8	0.027	0.033	1007.00	376.62	70.00	5.38
3	4.4	15.4	0.8	0.027	0.033	1007.00	369.89	70.00	5.28
5	11.3	16.6	0.8	0.027	0.033	1007.00	178.22	70.00	2.55
7	11.7	16.2	0.8	0.027	0.033	1007.00	151.32	70.00	2.16
9	2.8	15.3	0.8	0.027	0.033	1007.00	420.33	70.00	6.00
11	2.2	15.2	0.8	0.027	0.033	1007.00	437.15	70.00	6.24
13	2	14.9	0.8	0.027	0.033	1007.00	433.78	70.00	6.20
15	5	15.7	0.8	0.027	0.033	1007.00	359.80	70.00	5.14
17	5.2	15.9	0.8	0.027	0.033	1007.00	359.80	70.00	5.14
19	4.5	15.5	0.8	0.027	0.033	1007.00	369.89	70.00	5.28
21	6.5	15.8	0.8	0.027	0.033	1007.00	312.73	70.00	4.47
23	8.1	15.1	0.8	0.027	0.033	1007.00	235.39	70.00	3.36
25	12.2	16.3	0.8	0.027	0.033	1007.00	137.87	70.00	1.97
27	8.2	15.3	0.8	0.027	0.033	1007.00	238.75	70.00	3.41
29	8.2	15.3	0.8	0.027	0.033	1007.00	238.75	70.00	3.41
31	7.6	15.8	0.8	0.027	0.033	1007.00	275.74	70.00	3.94

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Table 5.
Calculation of coefficient of performance of the earth tube for heating during the month of February 2013.

Date	Ti (oC)	To(oC)	□ (m3/kg)	V (m3/s)	m (kg /s)	Cp (J/kg. oC)	Qout(w)	Qin (w)	COP
03:00pm									
1	11	16.1	0.8	0.027	0.033	1007.00	171.50	70.00	2.45
3	8.1	15.9	0.8	0.027	0.033	1007.00	262.29	70.00	3.75
5	8	16.9	0.8	0.027	0.033	1007.00	299.28	70.00	4.28
7	10	17	0.8	0.027	0.033	1007.00	235.39	70.00	3.36
9	9.5	16.1	0.8	0.027	0.033	1007.00	221.94	70.00	3.17
11	10.3	16.4	0.8	0.027	0.033	1007.00	205.12	70.00	2.93
13	8.2	15.1	0.8	0.027	0.033	1007.00	232.02	70.00	3.31
15	7.4	14.9	0.8	0.027	0.033	1007.00	252.20	70.00	3.60
17	8.9	16.2	0.8	0.027	0.033	1007.00	245.47	70.00	3.51
19	9.1	15.9	0.8	0.027	0.033	1007.00	228.66	70.00	3.27
21	9.6	16.1	0.8	0.027	0.033	1007.00	218.57	70.00	3.12
23	10.4	15.2	0.8	0.027	0.033	1007.00	161.41	70.00	2.31
25	11.6	15.5	0.8	0.027	0.033	1007.00	131.14	70.00	1.87
27	11	16.8	0.8	0.027	0.033	1007.00	195.03	70.00	2.79
03:00am									
1	5.8	14.1	0.8	0.027	0.033	1007.00	279.10	70.00	3.99
3	8.2	15.2	0.8	0.027	0.033	1007.00	235.39	70.00	3.36
5	9.6	14.7	0.8	0.027	0.033	1007.00	171.50	70.00	2.45
7	7.7	14.6	0.8	0.027	0.033	1007.00	232.02	70.00	3.31
9	10.1	15.9	0.8	0.027	0.033	1007.00	195.03	70.00	2.79
11	9.1	15.7	0.8	0.027	0.033	1007.00	221.94	70.00	3.17
13	7	14.2	0.8	0.027	0.033	1007.00	242.11	70.00	3.46
15	7	14.4	0.8	0.027	0.033	1007.00	248.84	70.00	3.55
17	8.7	14.9	0.8	0.027	0.033	1007.00	208.48	70.00	2.98
19	8.4	14.1	0.8	0.027	0.033	1007.00	191.67	70.00	2.74
21	9.3	15.2	0.8	0.027	0.033	1007.00	198.40	70.00	2.83
23	10.1	16.1	0.8	0.027	0.033	1007.00	201.76	70.00	2.88
25	10.2	16.3	0.8	0.027	0.033	1007.00	205.12	70.00	2.93
27	9.9	15.8	0.8	0.027	0.033	1007.00	198.40	70.00	2.83

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REFERENCES

[1] Alghannam, A. O. (2012). Investigations of performance of earth tube heat exchanger of sandy soil in hot arid climate. Journal of Applied Sciences Research, 8(6): 344 3052.

[2] Al-Maliky, S. J. Bash. (2011). Investigation of the readiness of ground soils for installation of ground heat exchange systems in Baghdad city. Journal of Geology and Geography. Vol 3., No.1: 200 – 2006.

[3] ASHRAE (1985). Handbook of application. Atlanta Ga. American Society of Heating Refrigerating and Air Conditioning engineers Inc.

[4] Baxter, D.O. (1992). Energy exchange and related temperature of an earth tube heat exchanger in heating mode. Trans ASAE, 35(1): 275 – 285.

[5] Benkert, St., F.D. Heidt and D. Scholer. 1997. Calculation tool for earth tube heat exchangers GAEA. Department of Physics, University of Siegen, D-57068 Siegen, Germany.

[6] De Paepe, M. and A.Janssens, (2003). Thermohydraulic design of earth –air heat exchangers. Energy and Buildings, 35:389-397.

[7] Green Gas Technology Center (GGTC). (2005). Test and Quality Assurance Plan. Southern Research Institute, NC, USA.

[8] Jenssens, A., M. Steeman, J.Desmedt, H. Hose and M. De Paepe. (2005). Energy performance of earth-air heat exchanger in a Belgian office building. AIVC 26th conference-Brussels, Belgium, pp: 15 -20.

[9] Lee, K. H. and R.K.Strand. (2007). Implementation of an earth tube system into energyplus program. University of Illinois at Urbana-Champaign, Champaign, IL.

[10] Natural Resources Canada's Renewable and Electrical Energy Division (NRCan). (2004). Heating and cooling with a heat pump. Cat. No. M144-51/2004E TH 7638.H52 1994 697 C94-980265-4E. Ministery of Natural Resources Canadas, Ottawa, ON, Canada, 33 pages.

[11] S.A.Rasha. and T.H. Karim. (2014). Soil temperature profile at Arbil city -Iraqi Kurdistan Region. Forthcoming

[12] Scott, N.R., R.A. Parsons and T.A. Kochler (1965). Analysis and performance of an earth tube heat exchanger. ASAE paper no.65-840. St. Joseph, Michigan, ASAE.

[13] Sharan, G. (2004). Development and some applications of earth tube heat exchanger in Gujarat. Nanubhai Amin Memorial lecture at Electrical Research and Development Association, Vadodara as part of Technology Day.

[14] Sharan, G. and R. Jadhav. (2004) Performance of single pass earth-tube heat exchanger: An experimental study. Indian Institute of Management. Ahmedabad.

[15] Sharan, G. and R.K. Sahu and R. Jadhav. (2013). Air-cooling and heating system for tiger in zoo using earth tube heat exchanger. Center for Management in Agriculture, Indian Institute of Management. Ahmedabad, 380015.

[16] Tudor, A. and V. Badescu. (2013).The influence of several parameters on the performance of earth to air heat exchangers into south-eastern European climates. U.P.B. Sci., Series D, vol. 75 Iss.3, 2013.

[17] The Ministry of Energy (ME), (2012). The Annual report on energy in Kurdistan region, Iraq

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