IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 1 Ver. IV (Jan- Feb. 2015), PP 20-24
www.iosrjournals.org

Air Conditioning System with Ground Source Heat Exchanger

S.V. Kota Reddy [1], S. Anil Babu [2], Clifton Arokiyaraj[3], Gaurav Naik[4], Soham Shukla [5], Barath Masamsetty [6], Kevin Alexander [7]

1 Academic President, Manipal University Dubai campus, Dubai International Academic City, Dubai, UAE.
2 Assistant Professor, School of Engineering & IT, Manipal University Dubai campus, Dubai International Academic City, Dubai, UAE.
3, 4, 5, 6,& 7, Undergraduate Students, School of Engineering & IT, Manipal University Dubai campus, Dubai International Academic City, Dubai, UAE

Abstract: *The weather of the United Arab Emirates region poses a considerable challenge in terms of the extreme summers where average ambient temperature exceeds 45 ºC. The extreme summers result in greater power consumption by the air conditioning systems widely used in the region, the continual increase in energy demand and greenhouse gas emissions decree for efficient use of renewable energy resources. Thus there a is growing necessity to improve the geo-thermal techniques in order to cut-down on power consumption for refrigeration and air conditioning applications. The Vertical Looping Method was employed in the implementation of direct exchange ground source heat exchanger. This paper presents the experimental results on the performance of the system with medium as still air, water and sand. The experimental result shows that the highest coefficient of performance of 3.72 achieved when the bore hole is filled with water.*

Keywords: *Ground Source, Heat Exchanger, Vertical Looping, Condenser, Air Conditioner.*

I. Introduction

Air source heat exchangers utilize the outside air as a heat sink to supply cooling to a building. One of the largest geothermal systems in Europe that provided heating and cooling by geothermal energy storage to a building area of close to 200.000 m² in Nydalen was proposed by R. Curtis et al. [1]. In many areas, the air temperature fluctuates fundamentally during the time prompting a lessening in framework effectiveness, the proficiency of a heat exchanger diminishes as the distinction between the indoor and outside temperatures expands. On the other hand, at a moderately shallow profundity, the ground temperature basically stays consistent at a moderate temperature (e.g., 15-25 °C) as the year progresses. Maeir Zalman Olfman et al. [2] proposed an experiment the depth dependence of the ground temperature response to heating by a deep vertical borehole ground heat exchanger by comparing experimental results to various models of ground heat exchange.

The ground can give reliably high effectiveness when it is utilized as the heat source or sink for a ground source heat exchanger (GSHE). Huajun Wang et al. [3] proposed direct-expansion ground source heat pump (GSHP) system in typical clay soils for space heating of a building in Jinzhou, China. It uses R-22 as the refrigerant, consisting of four single U-shaped copper ground heat exchangers with a uniform depth of 20 m. A special circular bend is designed on the copper tube to enhance the lubricant oil return of the scroll compressor.

Leslie Johns et al. [4] explained a GSHP shallow system of cooling capacity 6000 Ton at Tulane University. A 2000 Ton capacity chiller was required extracting humidity from the building. The GSHP system capital cost was $ 32 million. Tulane would save at least $ 400 K or 33% of the previous heating, ventilating, and air conditioning (HVAC) maintenance costs, reduced energy consumption by 2700 million kWh, reduced energy expenditures by $ 189.5 million, and reduced emission by 26 % or 14,175 metric ton/year.

The performance of the GSHE with horizontal configuration was analysed experimentally and analytically by Nabiha Naili et al. [5] at the research and technology center of energy (CRTE), in northern Tunisia. The results showed that the utilization of the ground source heat pump is appropriated for cooling building in Tunisia, which is characterized by a hot climate.

This paper presents the design, development and testing of an air conditioning system with ground source heat exchanger (ACSWGSHE). The effective heat exchanger design will play important role in improving the overall coefficient of performance (COP) of the system. The performance of ACSWGSHE with conventional split air conditioner system was compared.

II. Design & Fabrication Of ACSWGSHE

A 1.5 Ton split air conditioner (AC) has been considered for development of ACSWGSHE. The condenser of conventional split AC has been modified to act as GSHE. The heat exchanger was placed in a bore hole of diameter 0.2 m and 15 m depth in the ground as shown in the Fig. 1. The diameter of tube is 10 mm and material used was copper. The heat exchanger is in the form of helical coil. The refrigerant used was R-22.

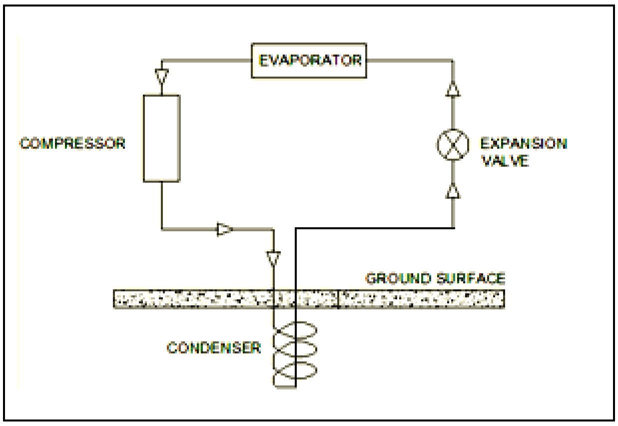

Fig.1. Schematic diagram of ACSWGSHE system

2.1 Calculation of condenser length

The following equations are used to determine the heat transfer coefficient on refrigerant and water side from Thirumaleshwar M. [6]:

To determine heat transfer coefficient for Refrigerant R-22

$Nu_h = 0.023 \times Re^{0.8} \times Pr^{0.3}$ (1)

$Re_h = (u \times D) / \upsilon$ (2)

$\upsilon = \mu \times v$ (3)

$Pr_h = (C_p \times \mu) / K$ (4)

$Nu = (hi \times D) / K$ (5)

To determine heat transfer coefficient for water

$\beta = 1 / T_f$ (6)

$Gr_D = (D^3 \times g \times \beta \times d_T) / \upsilon^2$ (7)

$Pr = (\mu \times Cp) / K$ (8)

$Nu = 0.53 \times (Gr_D \times Pr^2)0.25$ (9)

$Nu = (ho \times D) / K$ (10)

$U = (hi \times ho) / (hi + ho)$ (11)

$Q_k = U \times A \times d_T$ (12)

By using above equation the effective length of the ACSWGSHE condenser is 35 m.

Fig. 2 shows the photograph of condenser coil, fabricated using copper tube of diameter 10mm. The tube is bent in the form of helical shape and to maintain the gap between consecutive coils, spacers are bronzed as shown in Fig. 2.

Fig. 2. Photograph of ACSWGSHE condenser coil

1.2 Material Testing

In the UAE, the ground water constitutes of considerable amounts of salts which are corrosive in nature [7]. The salinity levels are found maximum and it will reach up to 15740 Ls at sabkha by the beach areas. Thus, it was necessary to study the reaction of copper with samples of ground water of different salinity levels. It was found that the copper tube was reacted with 5% saline water solution. Therefore, it is necessary to have nickel coating on copper tube to avoid corrosion in the bore hole. The nickel coating was preferred as it will offer low thermal resistance for heat transfer and also cheaper than other coatings.

2.3 Testing of ACSWGSHE

The various parameters like condenser, evaporator, indoor and outdoor air temperate measured by using dry bulb and wet bulb thermometers. Pressure at suction and discharge side of the compressor was measured using compound pressure gauges. The power consumption was measured using energy meter. The underground temperature was measured using thermocouple at a depth of 15 m below ground level.

2.4 Testing of conventional split air conditioning system

Before modification the conventional split air conditioning system was tested for 50 hours. The various test readings are shown in Table 1. The readings are for test cycle of 2 hours.

Table 1 Test cycle of conventional split air conditioning system

Sl.No.	Time (hours)	Temperatures(^{0}C)						Power consumption
		Room		Ambient		Evaporator exit		
		DBT	WBT	DBT	WBT	DBT	WBT	(kWh)
1	12.15	21.5	18.4	28.9	24.4	12.3	11.2	5.3
2	12.30	21.1	18.3	27.5	23.7	11.5	10.6	
3	12.45	20.5	17.7	33.8	25.2	10.9	10.1	
4	13.00	11.3	10.3	32.9	25.2	11.3	10.3	
5	13.15	20.6	17.5	33.2	25	11.6	10.3	
6	13.30	20.8	17.2	35.4	25.9	11.5	10.9	
7	13.45	21	17.3	35.8	25.2	11.7	10.6	
8	14.00	21.1	17.4	34.6	25.5	11.3	10.4	
9	14.15	21.1	17.5	33.5	25.9	11	10.3	

2.5 COP Calculation for conventional split air conditioning system by using tested data

$$m = \rho \times A \times v \qquad (13)$$

$$Q_0 = m \times Cp \times dT \qquad (14)$$

$$COP = Q_0/Power \qquad (15)$$

By using equations (13), (14) and (15) COP = 2.11, thus the COP of the system was found to be 2.11.

2.6 Testing Of ACSWGSHE with Still Air

After integrating the heat exchanger in place of condenser which was kept under the ground at 15 m depth, the system was tested for its performance. It was observed that there was no ground water at the depth of 15 m at the location of Manipal University Dubai campus, G04, Dubai International Academic City, UAE. Initially this system was tested with still air present in the bore hole.

The condenser temperature increased abruptly due to poor convection heat transfer between copper tube and the ground as medium was still air. After few minutes, the compressor was stopped due to excess heating of the condenser.

2.7 Testing of ACSWGSHE system bore well filled with water

The bore well is filled with water and tests were conducted. The various readings of the system are as given in Table 2.The readings are for test cycle of 2 hours.

Table 2 Test cycle of ACSWGSHE system bore well filled with water

Sl.No.	Time (hours)	Suction pressure (psi)	Discharge pressure (psi)	Temperatures(^{0}C)						Power consumption
				Room		Ambient		Evaporator exit		
				DBT	WBT	DBT	WBT	DBT	WBT	(kWh)
1	09.15	50	150	22.8	17.7	30.5	23.5	16	14.7	3.2
2	09.30	50	160	22	17.4	31	22.5	14.8	13.3	
3	09.45	50	165	21.8	17	32	22.4	13.5	12.6	
4	10.00	50	170	21.9	17.1	32.7	22.2	13.3	12.5	
5	10.15	50	175	22	17.3	33.3	23.1	13	12.4	
6	10.30	50	175	22.3	17.3	33.9	23.1	12.1	12.6	
7	10.45	50	175	22.4	17.1	34	22.1	12.4	12.8	
8	11.00	50	177	22.1	17.1	34.1	22.4	12.2	12.8	
9	11.15	50	180	22.2	17.2	34.5	21.8	12.3	12.2	

2.8 COP Calculation for ACSWGSHE bore well filled with water by using tested data from table 2

By using equations (13), (14) and (15), thus the COP of the system was found to be 3.72

2.9 Testing of ACSWGSHE system bore well filled with sand

The bore well is filled with sand and tests were conducted. The various readings of the system are as given in Table 3.The readings are for test cycle of 2 hours.

Table 3 Test cycle of ACSWGSHE system bore well filled with sand

Sl.No.	Time (hours)	Suction pressure (psi)	Discharge pressure (psi)	Temperatures(^{0}C)						Power consumption
				Room		Ambient		Evaporator exit		
				DBT	WBT	DBT	WBT	DBT	WBT	(kWh)
1	10.30	32	155	25.1	21.6	37	29.2	22.1	20.1	4.5
2	10.45	40	170	25.1	21.8	37	29	21.7	20.1	
3	11.00	40	180	25.1	21.6	37.2	29.1	21.7	20.1	
4	11.15	40	180	24.8	21	37.4	28.9	19.9	21.3	
5	11.30	45	190	24.8	21	38.2	28.6	21.2	19.7	
6	11.45	50	200	25	21.5	37.6	28.3	21.4	20.2	
7	12.00	50	220	23.7	20.2	38.4	28.4	20.2	18.8	
8	12.15	50	230	23.6	19.9	38	27.8	20	17.9	
9	12.30	55	230	23.5	19.8	38.1	28.2	17.4	17.4	

2.10 COP Calculation for ACSWGSHE system bore well filled with sand by using tested data table 3

By using equation (13), (14) and (15), thus the COP of the system was found to be 1.07

III. Results And Discussion

The various tests were conducted on conventional split air conditioner and ACSWGSHE. The power consumption and COP are compared for 6 hours of test run as shown in Fig. 3 and Fig. 4 respectively. The power consumption and COP of conventional split air conditioner, ACSWGSHE bore well filled with water and ACSWGSHE bore well filled with sand were compared.

The power consumption of 29 % lower than conventional split air conditioner when ACSWGSHE bore well filled with water. Similarly COP of 43 % higher ACSWGSHE bore well filled with water than conventional split air conditioner.

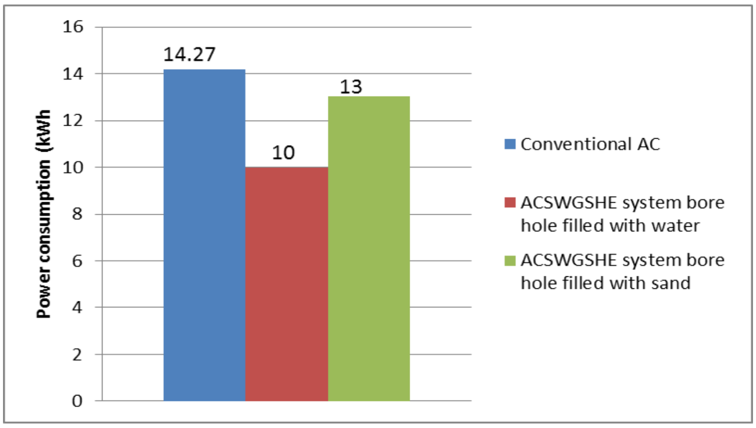

Fig. 3. The comparison of Power consumption of Convention Air condition system, ACSWGSHE filled with water and ACSWGSHE filled with sand.

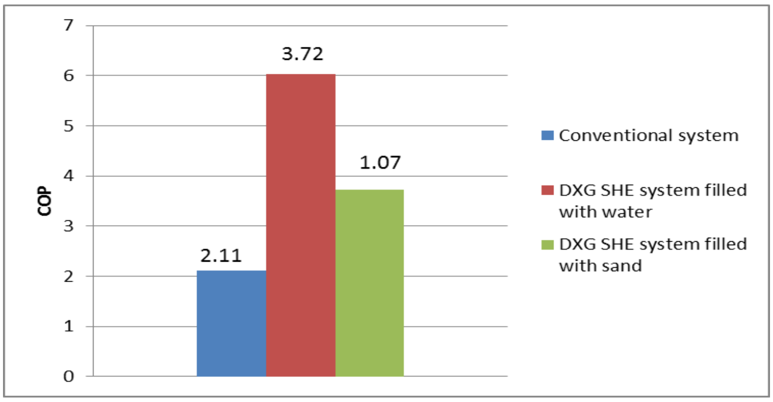

Fig. 4. The comparison of COP of Convention Air condition system, ACSWGSHE filled with water and ACSWGSHE filled with sand.

Fig. 5 shows the variation of underground temperature readings are for test cycle of 3 hours. In ACSWGSHE system bore well filled with sand, the condenser coil temperature was increased gradually from 26.9 °C to 71 °C due to improper heat exchange between condenser and ground.

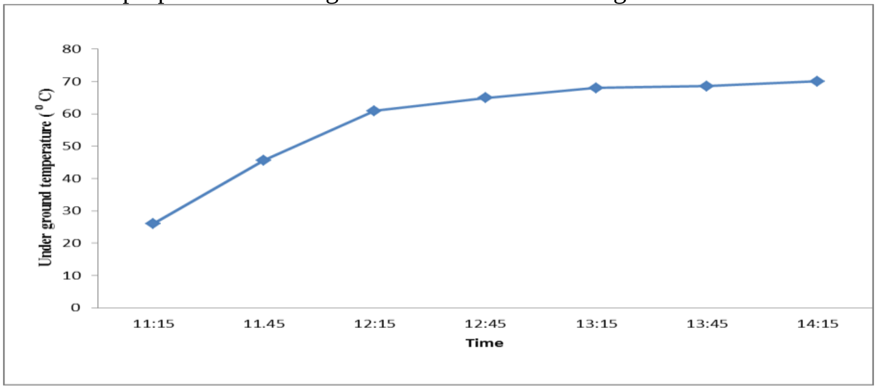

Fig. 5. Time Vs Underground temperature.

IV. Conclusions

The ACSWGSHE system was tested in an open hole 15 m deep and 0.2m diameter. It was initially tested with still air. The next test was conducted with water at ambient temperature filled in the hole. Finally it was tested by filling up the hole with sand. The COP of the system increased from 2.11 to 3.72 when bore hole was filled with water. But, when the ACSWGSHE system was tested after filling with sand, the COP reduced considerably due to lack of heat transfer from the condenser coil to the ground. The power consumption of the air conditioning system reduced by 29% when the air cooled condenser of conventional air conditioning system was replaced by ACSWGSHE when it was tested with water in bore hole. The initial cost for the ACSWGSHE system is considerably higher as compared to the conventional system. However over a longer period of time, the energy conservation and in effect, the savings are significant. Thus it can be concluded that the ACSWGSHE system when incorporated into centralized air conditioning systems will effectively reduce the consumption of energy when the condenser is placed at depths where there is sufficient presence of water in the bore hole.

Acknowledgement

We express our sincere thanks to American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE) for giving financial assistance to carry out this project at Manipal University Dubai Campus, Dubai International Academic City (DIAC), Dubai, UAE.

Nomenclature

Nuh	Nusselt number	
Reh	Reynold's number	
u	velocity of Refrigerant R-22	m/s
Cp	Specific heat	KJ/kg K
μ	Dynamic viscosity	N s/m^2
K	Thermal conductivity	W/(mK)
Prh	Prandtl number	
Tf	Fluid temperature	°C
B	volumetric thermal expansion coefficient	1/k
U	Overall heat transfer coefficient	W/m^2 K

References

[1]. R. Curtis, J. Lund, B. Sanner, L. Rybach,G. Hellström, Ground Source Heat Pumps- Geothermal Energy For Anyone, Anywhere: Current Worldwide Activity, Proc. World Geothermal Congress, Antalya, Turkey, 24-29 April 2005.
[2]. Maeirzalmanolfman, Allan D. Woodbury, Jonathan Bartley, Effects Of Depth And Material Property Variations On The Ground Temperature Response To Heating By A Deep Vertical Ground Heat Exchanger In Purely Conductive Media, Geothermic, Volume 51, July 2014, Pages 9-30.
[3]. Huajun Wang, Qian Zhao, Juntao Wu, Bin Yang, Zhihao Chen, Experimental Investigation On The Operation Performance Of A Direct Expansion Ground Source Heat Pump System For Space Heating, Energy And Buildings, Volume 61, June 2013, Pages 349-355.
[4]. Leslie Johns,Katiela Corte, Jonas, Serensen, Geo-Thermal Tulane's Better Energy Alternatives, Tulane University, Mgmt 7150-21,March 3,2010.
[5]. Nabihanaili, Issam Attar, Majdihazami, Abdelhamidfarhat, Performance Analysis Of Ground Source Cooling System With Horizontal Ground Heat Exchanger In Tunisia, Energy, Volume 61, 1 November 2013, Pages 319-331.
[6]. M.Thirumaleshwar, Fundamentals Of Heat And Mass Transfer, Published By Dorling Kindersley (India) Pvt.Ltd., 2006,Pages 578-595.
[7]. S. J. Bates, A Critical Evaluation Of Salt Weathering Impacts On Building Materials At Jazirat Al Hamra, Uae., Geoverse, Oxford Brookes University, 1-17, 2010.