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An Environmentally Friendly Idea for Cooling of Water in Water-Cooled Chillers in Urban Areas

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Abstract: *It is known that wet cooling towers in the air-conditioning systems are the considerable pollutants in urban environments. In addition, they consume significant amount energy in buildings due to large-scale axial or radial fan operation and also pumping systems for circulating the water between the chillers and cooling towers which are normally installed at high elevations. This paper presents a new idea for reducing the initial and ongoing costs along with the clean production of the cooling water requirement in the condensers of the air-conditioning systems. Considerations are restricted for chillers with an actual capacity of less than 50 tons of refrigeration (TR). The idea is the construction of a ground source heat exchanger (GSHE) under the building foundation and integrating the constructed GSHE with a water cooled chiller. For this purpose, conventional polyethylene and also heavy grade galvanized pipes are assessed for GSHE. On the other hand, computations are performed for three various soils such as clay, sandy clay, and siltstone having the thermal conductivities of 0.8, 1.9, and 3.2 W/mK, respectively. It is found that using this new method, the wet cooling tower can be eliminated from the air- conditioning systems and the replaced GSHE can handle safely the cooling water needs.*

Keywords: *Air-conditioning system, Ground source heat exchanger (GSHE), Wet cooling tower, Building foundation, clean technology*

1. INTRODUCTION

Cooling towers are the necessary parts of the not only water cooled compression chillers but also the absorption types for dissipating the waste heat from the air-conditioning and refrigeration systems. Without a cooling tower, a water-cooled air-conditioning system cannot be operated. Although, to date, several attempts have been performed on the improvement of the wet cooling towers performance, however, it is known that they are still one of the major players in the energy consumption issue. They are usually made of two general types; galvanized frame and structure with one or multi-radial fans, and fiberglass frame and structure with a single axial fan. Due to need to a high amount of airflow in both types, naturally, they consume a significant value of the electricity. On the other hand, they are usually installed on the roof of the building with the significant lengths of supply and return water risers as illustrated in figure 1. Therefore, in order to circle the water between the chiller and cooling tower, an additional amount of electricity should be consumed for the corresponding pumping system. Hence, the initial and ongoing costs of the air-conditioning systems equipped with wet cooling towers are significantly higher for owners. Even if the cooling tower has been installed out of the building on the earth, a considerable distance is recommended between the building and the cooling tower. In addition to the initial and ongoing costs, they have the other disadvantages. The wet cooling tower is one of the air and water polluters since it uses the ambient air directly in the water cooling process. In all urban environments in general and in the metropolises, in particular, the air is polluted due to significant carbon emission generated by the industrial plants, public and private transportation systems, and the other fossil fuel consumer resources. Therefore, the polluted air is usually used for water cooling process in wet cooling towers. Moreover, the wet cooling towers are famous devices in water losing almost due to evaporating a considerable amount of water. Imagining the hundreds of such cooling towers with the aforementioned disadvantages in urban environments indicates that besides the initial and ongoing costs, additional costs should be taken into account for their water usage and environmental considerations. This paper is an attempt for replacing an environmentally friendly system instead of the wet cooling tower. The idea is cooling of the water needed for water-cooled condensers of an air-conditioning system using the GSHE. In this regard, the ground under the building foundation is used for the construction of a GSHE to dissipate the waste heat of the circulating water into the ground. Considerations have been restricted on the chillers with actual capacities less than 50 TR in the present study.

Figure1. *A sample of the wet cooling towers on the highest location of a building*

In the past decade, several studies have been performed on the wet cooling towers ranging from the large scale to small-scale ones. Llano-Restrepo and Monsalve-Reyes (2017) developed a mathematical equation for prediction of the volumetric mass transfer in counter-flow wet cooling towers. Their model was formulated for both saturated and supersaturated air. In the experimental work of Rahmati et al. (2016), the effects of packing stages on a wet cooling tower performance were investigated. They found that for a specific air mass flow rate, increasing the packing stage number enhances the coefficient of efficiency. In the other research, Alavi and Rahmati (2016) used an external wind creator and assessed the natural draft wet cooling tower performance under this situation. It was demonstrated that the crosswind speed of 0.48 m/s is a critical value. That is, for crosswind speeds less than the critical value, both temperature range and cooling efficiency reduce, however, beyond the critical value, the aforementioned parameters improve with respect to the windless condition. Shahali et al. (2016) focused on the rib number of packing on the wet cooling tower performance. They showed that both water temperature range and cooling efficiency enhance with increasing the parking rib number. Lyu et al. (2017) suggested a new idea for improving the wet cooling tower performance. They implemented the water collecting devices in the cooling tower and revealed that using the non-uniform fill layout, the cooling performance enhances in both windless and crosswind conditions. In a different study, Askari et al. (2016) used multi-walled carbon nanotubes and nanoporous graphene nanofluids in order to conserve the energy and water in wet cooling towers. They indicated that using the nanofluids, efficiency, temperature range, and tower characteristics are enhanced in comparison to the water. Zheng et al. (2012) analyzed a closed cooling tower under unsaturated and supersaturated conditions, analytically. It was shown that under supersaturate condition of the outlet air, the difference between the unsaturated and supersaturated conditions was little. Effects of non-uniform layout fillings on the wet cooling towers performance were investigated by Gao et al. (2016). They demonstrated that under optimum layout pattern, the cooling performance enhances up to 30%. Imani-Mofrad et al. (2016) investigated the fill beds effects on the thermal performance of a wet cooling tower using the ZnO/water nanofluids. In their study, six different filled beds and several nanoparticle concentrations were examined. They confirmed that compared with the water, nanofluids improve the tower performance.

Further examination of the previous works on the wet cooling towers indicates that most of them have been focused on the tower performance improvement. In other words, to date, no alternative method has been developed for the cooling water supply in water-cooled chillers. Therefore, most likely, this study is the first attempt in this way in which the wet cooling tower of an air-conditioning system will be replaced with a GSHE. The GSHEs are now known to researchers, but due to the other applications such as ground source heat pumps. They constructed mostly with polyethylene pipes in two general forms, namely horizontal and vertical GSHEs. Although both of these forms have advantages and disadvantages with respect to each other, however, this paper focused on the horizontal type due to a simple design and cost-effective reasons. Numerous investigations have been done for horizontal GSHEs in the past decade. A significant number of the previous works (Kim et al., 2016; Congedo et al., 2012; Dasare and Saha, 2015; Seung et al., 2015; Wu et al., 2010) in this regard is on the effects of the horizontal GSHE layout in the heat transfer process. Almost, a considerable number of previous researchers indicate that soil conductivity is the major player in such heat exchangers, whereas, pipe diameter and installation depth have not an effective role in the GSHEs performance. It was hoped that the obtained results in the present study arouse interest among the air-conditioning engineers.

2. PROBLEM DESCRIPTION AND ANALYSIS METHOD

This paper presents a new method for providing the cooling water needs of a water-cooled chiller in various buildings based on the GSHE as a clean technology. Figure 2(a) shows a conventional system of the chiller-cooling tower circuit. In this system, the water circulates between the chiller and cooling tower via one or a number of the pumps. In general, depending on the building condition, the distance between the chiller and cooling tower is considerable and hence, a large amount of pumping power needs to handle the water between the chiller and cooling tower. In order to better control of coolant temperature, a bypass line is normally constructed between the supply and return lines near the cooling tower as illustrated schematically in figure 2(a). The constructed bypass line is equipped with a control valve which is operated manually or with an automatic system. In the new idea which is suggested in this paper, the water after passing the condenser is collected in a supply header and after that, the collected water is divided into the several buried pipes embedded under the building foundation. The water during the flowing from the buried pipes dissipates the waste heat from the condenser to the ground and collected into a return header, which is located on the ground level similar to the supply header. Finally, the cooled water is transferred to the condenser via a supply line as demonstrated in figure 2(b). Therefore, it is easy imagining the wet cooling tower elimination from the circuit and instead, the coolant is cooled in a closed circuit called the GSHE. It is worth mentioning that the GSHE may be constructed in several rows and columns depending on the required thermal capacity and building area. The biggest advantage of this new method is an indirect heat transfer mechanism of the coolant in comparison the conventional case. As a result, the water loss from this system is zero and environmental effects of such cooling system are minimized. On the other hand, the wet bulb temperature of the local environment has not any effect on the heat transfer process. However, compared with a conventional cooling tower, some new parameters have effective roles on the heat transfer mechanism. In agreeing with previous researchers (Kim et al., 2016; Congedo et al., 2012; Dasare and Saha, 2015; Seung et al., 2015; Wu et al., 2010) the soil type is one of the important parameters in this regard. Hence, three different soil types of clay, sandy clay, and siltstone having the thermal conductivities of 0.8, 1.9, and 3.2 W/mK(Cui et al., 2015) have been carried out in order to demonstrate the soil characteristic effects on the heat transfer process in the GSHE. Table 1 indicates the three different soil properties under consideration in detail. It is assumed that the soil moisture around the GSHE is constant (Chong et al., 2013). The other parameter which has an influence on the designed GSHE is the applied pipe type. In this regard, for comparison purposes, two different materials such as conventional polyethylene and heavy grade stainless steel pipes are examined. The details of the applied materials are presented in table 2. In addition, the properties of the working fluid are demonstrated in table 3.

Table1. *Properties of the various soils under consideration (Cui et al., 2015)*

Soil No.	Soil	ρ (kg/m^3)	C$_p$ (j/kg.k)	k (W/m.k)
I	Clay	1285	1200	0.8
II	Sandy clay	1750	1000	1.9
III	Siltstone	2570	1556	3.2

Table2. *Details of the applied materials in the present study*

Material	Thickness (m)	Inner diameter (m)	ρ (kg/m^3)	C_p (j/kg.k)	k (W/m.k)
Concrete	1	---	2200	920	1.2
Polyethylene	0.005	0.04	946	1920	0.35
Stainless Steel (20%,Ni)	0.00287	0.04	8000	480	16

Table3. *Thermophysical properties of the water (computed at T=35˚C)*

Fluid	ρ (kg/m^3)	C_p (j/kg.k)	k (W/m.k)	μ (kg/m.s)
water	994	4179.5	0.6218	0.00072545

In order to analyze the problem, a single pipe with 10 m length is studied in this investigation. A computational domain according to figure 3 is defined for the problem. This domain has dimensions of 0.75 cm×4 m×10 m in x, y, and z directions, respectively. In the computational domain, a concrete slab with 1m thickness is provided as the building foundation just under the ground surface. The pipe inner diameter is constant and equal to0.04 m and the center to center distance between the two neighboring pipes is fixed to 0.75 m. The coordinate's origin is set at the center of the pipe at the inlet section. The diameter and thickness of the applied pipes are presented in table 2. The water mass flow rate is 164 kg/hr and the corresponding Reynolds number is 2000 based on the pipe diameter. The water flows into the GSHE with a constant temperature of 35 ˚C which is a common outlet temperature of a water-cooled condenser in the air conditioning system. It is worth mentioning that the temperature drop in a conventional wet cooling tower is considered 5 ˚C in most air-conditioning systems.

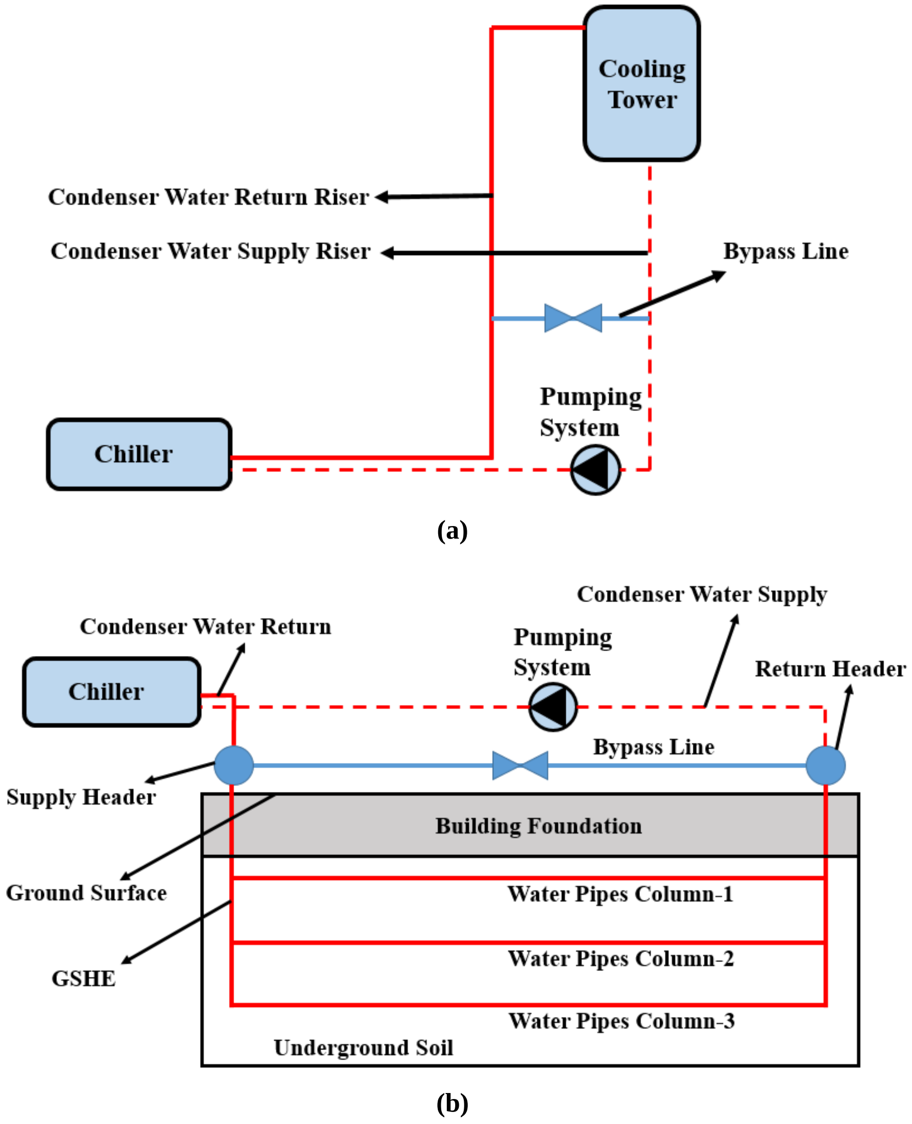

Figure2. *Schematics of the chiller-cooling tower circuit; a) conventional method; b) the present new idea*

The governing equations of the problem under consideration are as follows;

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \qquad (1)$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\upsilon(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}) \qquad (2)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial y}+\upsilon(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}) \qquad (3)$$

$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial z}+\upsilon(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}) \qquad (4)$$

$$\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}=\alpha(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}) \qquad (5)$$

In the present study, the governing equations are solved numerically by means of the finite volume approach. For this goal, the convection and diffusion terms in momentum and energy equations are discretized using the second order upwind and central difference schemes, respectively, whereas, a second order accurate discretizationis carried out for all temporal derivatives. The discretized equations have been computed implicitly with an iterative approach on the fully unstructured grids using the following boundary and initial conditions;

- At tube inlet

$$u(x,y,0,t)=u_{in} \qquad (6)$$

$$T(x,y,0,t)=T_{in}=35^\circ C \qquad (7)$$

- At tube outlet

$$\frac{\partial p}{\partial z}(x,y,10,t)=0$$

- At front and rear surfaces ofy-z plane

$$\frac{\partial T}{\partial z}(x,y,0,t)=0 \qquad (8)$$

$$\frac{\partial T}{\partial z}(x,y,10,t)=0 \qquad (9)$$

- At sides ofx-yplane

$$\frac{\partial T}{\partial x}(0.375,y,z,t)=0 \qquad (10)$$

$$\frac{\partial T}{\partial x}(-0.375,y,z,t)=0 \qquad (11)$$

- At ground upper boundary

$$T(x,1.2,z,t)=20^\circ C \qquad (12)$$

- At ground bottom boundary

$$T(x,-2.8,z,t)=15^\circ C \qquad (13)$$

- Initial condition

The ground bottom boundary condition is assumed as the initial condition for the whole of the domain. That is

$$T(x,y,z,0)=15^\circ C \qquad (14)$$

The convergence of the 3D solutions is established by controlling the residuals of all flow variables which are set less than 10^{-8}.

3. GRID SIZE INDEPENDENCE STUDY AND VALIDATION

In order to ensure that the applied grid has sufficient resolution to achieve independent data to the grid number, three different grid numbers with various resolutions have been examined. The first grid (Grid-1), second grid (Grid-2), and the third grid (Grid-3) have 1927952, 1966224, and 2188680 control volumes, respectively. The grid size independence study showed that the obtained results are not sensitive to the grid resolution at least among three grid systems under consideration. Therefore, the first grid system (Grid-1) was applied for all simulations. Table 4 compares the obtained results for outlet water from the GSHE at different chiller operation periods. On the other hand, the applied computer code was validated against a previous work presented by Wu et al. (2010). As seen in figure 4 the obtained results of the specific heat per polyethylene pipe length of the validation case have good agreement with the previous aforementioned study.

Table4. *Grid size independence study for water outlet temperature (°C)*

Elapsed time (hr)	Grid-1	Grid-2	Grid-3
1	31.827	31.828	31.829
2	32.204	32.205	32.205
5	32.578	32.579	32.579
10	32.802	32.803	32.803
15	32.914	32.915	32.915
20	32.988	32.989	32.989
24	33.034	33.035	33.035

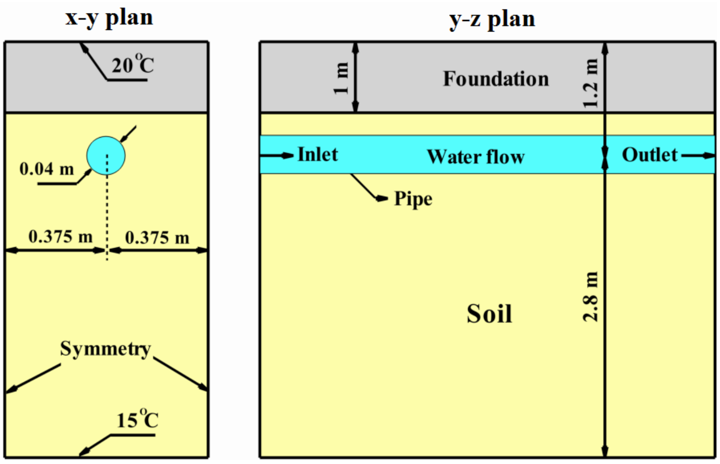

Figure3. *The computational domain in the present study*

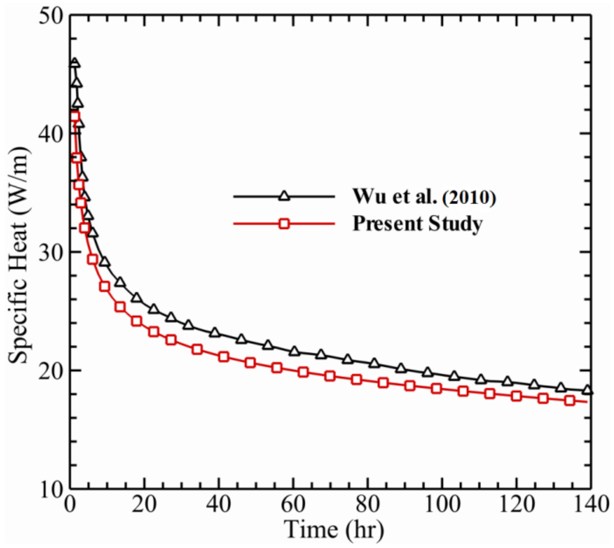

Figure4. *Validation of applied computer code with previous study [14]*

4. ADDITIONAL RELATIONS

Figure 5(Moran et al., 2011) reflects a refrigeration cycle with four main components, which forms the fundamental principles of a compression chiller. Heat is absorbed by evaporator from the conditioned air and is rejected to the ambient with the condenser. In a water cooled chiller, a wet cooling tower is necessary to provide cooling water for the condenser. The challenge of this procedure is rejecting enough waste heat from the condenser (total heat rejection) by cooling water provided with one or series of cooling towers. The total heat rejection in the condenser is determined using the following equation (Stanford, 2012);

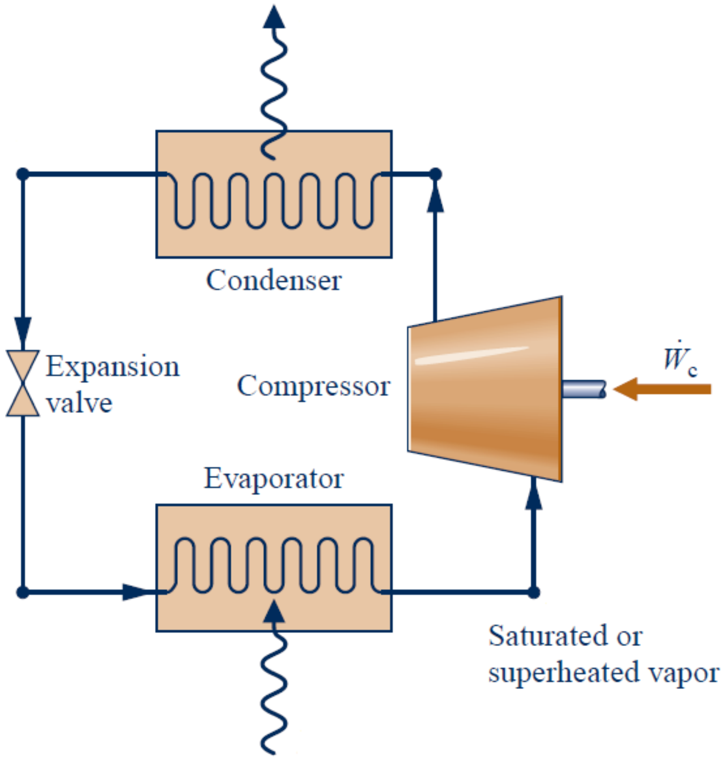

Figure5. *A schematic of the refrigeration cycle (Moran et al., 2011)*

$$THR(kW) = q_{load}(kW) + W_{\dot{C}omp}(kW) \tag{15}$$

In general, the compressor inlet power (kW) per chiller actual cooling capacity (TR) varies between the 0.4 and 0.8 (Stanford, 2012). Applying a constant factor of 0.6, the variation between the THR and chiller capacity will be as figure 6.

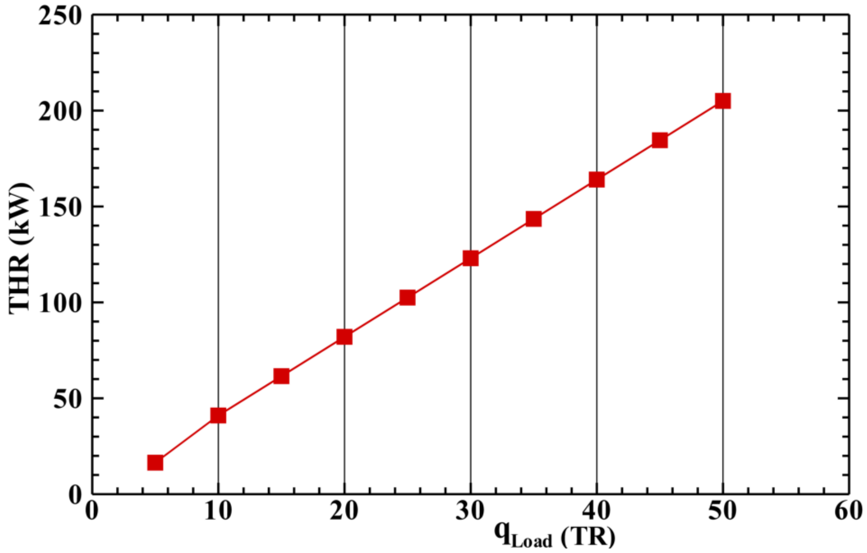

Figure6. *Variation of the condenser total THR with chiller actual cooling load*

The number of required pipes in the suggested method is assessed using the following equation;

$$n = \frac{q_{load}}{q_{pipe}} \times \beta \tag{16}$$

in which the correction factor of β is 1.00, 0.33, and 0.20 once the each individual pipe length in GSHE is 10 m, 30 m, and 50 m, respectively.

5. RESULTS AND DISCUSSION

5.1. Thermal Interaction

In the first part of this section, the interaction between the pipe and the ground will be discussed briefly. Considerations are restricted to a single buried pipe since the obtained results can extend to a set of pipes with the symmetric condition concept. Figure 7 illustrates the thermal interaction between the polyethylene pipe and ground in soil II after operation periods of 10hr and 20hr. Examination of the side-view and top-view images reveals that the waste heat of the water dissipates from the pipe outer surface to the ground. Therefore, the temperature around the pipe is relatively high and by moving away from the pipe, temperature magnitudes diminish gradually. On the other hand, it is observable that within the soil, the rate of thermal diffusion enhances as a function of elapsed time. Further consideration of the temperature field in the ground indicates that an asymmetry temperature distribution is developed in the soil. This is due to this fact that the flow in the pipe experiences higher heat exchange rate with the pipe surface since the flow is developing near the inlet section. It is known the heat transfer rate at entrance region is higher than that of the developed region. Therefore, it is predictable that the thermal diffusion from the pipe to the ground becomes a little higher at primary sections of the pipe in comparison to the other sections. However, our considerations are on the mean value of the total heat transfer per pipe length.

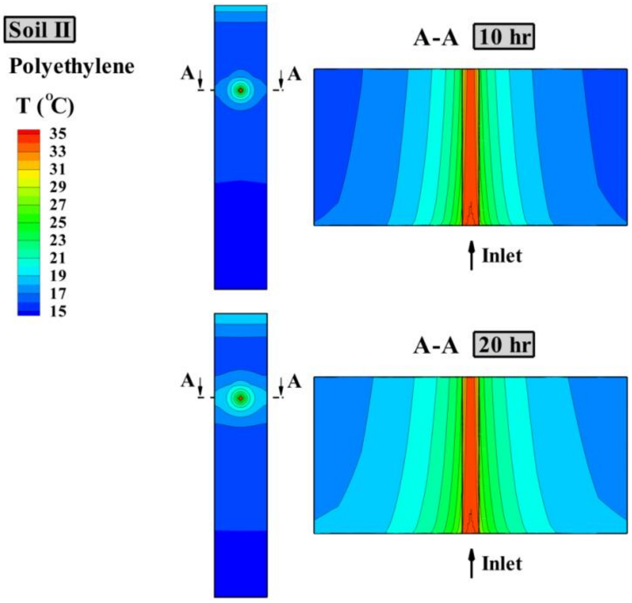

Figure7. *Temperature field within the ground for polyethylene pipe in soil II after 10hr and 20hr operation time of the chiller*

5.2. Effects of Soil Type

Most of the previous researchers (Kim et al., 2016; Congedo et al., 2012; Dasare and Saha, 2015; Seung et al., 2015; Wu et al., 2010) have demonstrated that the type of soil is an important player in GSHEs performance since this parameter changes the thermal diffusion rate in the ground. Figure 8 shows the time history of the heat dissipation rate of the 10 m steel pipe in three soil types such as soil I, soil II, and soil III. As seen, the difference between the heat dissipation rates becomes evident at the start of the system. With the passage of time, the differences between the soil types are revealed more and more. For a 24hr of the continuous chiller operation period of the chiller, it seems the rate of heat transfer between the GSHE and ground is higher in soil with the highest thermal conductivity in comparison to the others. In other words, the rate of heat dissipation changes as a function of soil thermal conductivity. According to the obtained results in figure 8, the rate of heat dissipation of the steel GSHE in soil III is 42.61% and 147.95% more than that of in soil II and soil I, respectively after the 10hr of operation time. These differences reach 45.68% and 152.48% after an elapsed time of 24hr.

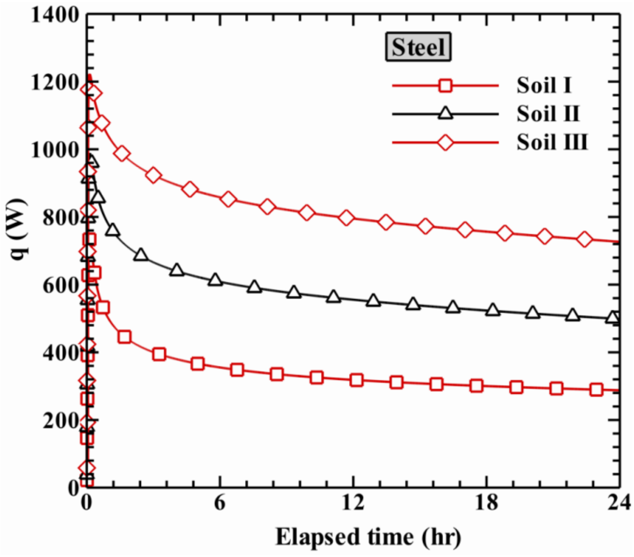

Figure8. *Heat dissipation of 10 msteel pipe along the time in various soils such as soil I, soil II, and soil III*

5.3. Effects of Pipe Material

Figure 9 compares the time histories of water outlet temperature from the GSHE for both polyethylene and stainless steel pipes in the soil I and soil III. It is expressible that for low conductivity soils such as soil I, effects of the pipe material is not considerable. Therefore, in the regions with improper soils such as soil I, selection between the polyethylene and steel pipes for GSHE design has not a considerable effect. The difference between the two pipe materials after 24hr of operation time is only 0.88%. However, in high potential soils such as soil III, it seems the pipe material effects are considerable. In other words, after the 24hr continuous operation time of the chiller, a 5.13% difference is observed between the polyethylene and steel pipes. As a result, pipe material has significant and insignificant effects in high and low conductivity soils, respectively.

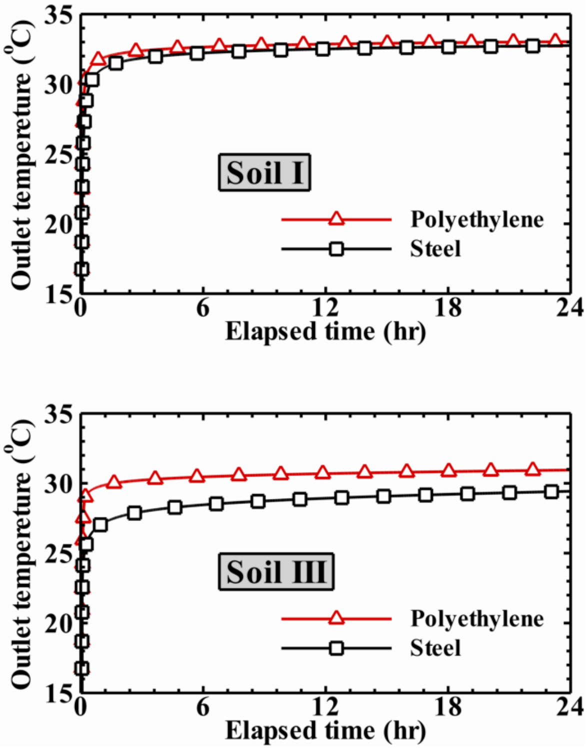

Figure9. *Variations of the water outlet temperature along the operation time for the polyethylene and steel pipes in soil I and soil III*

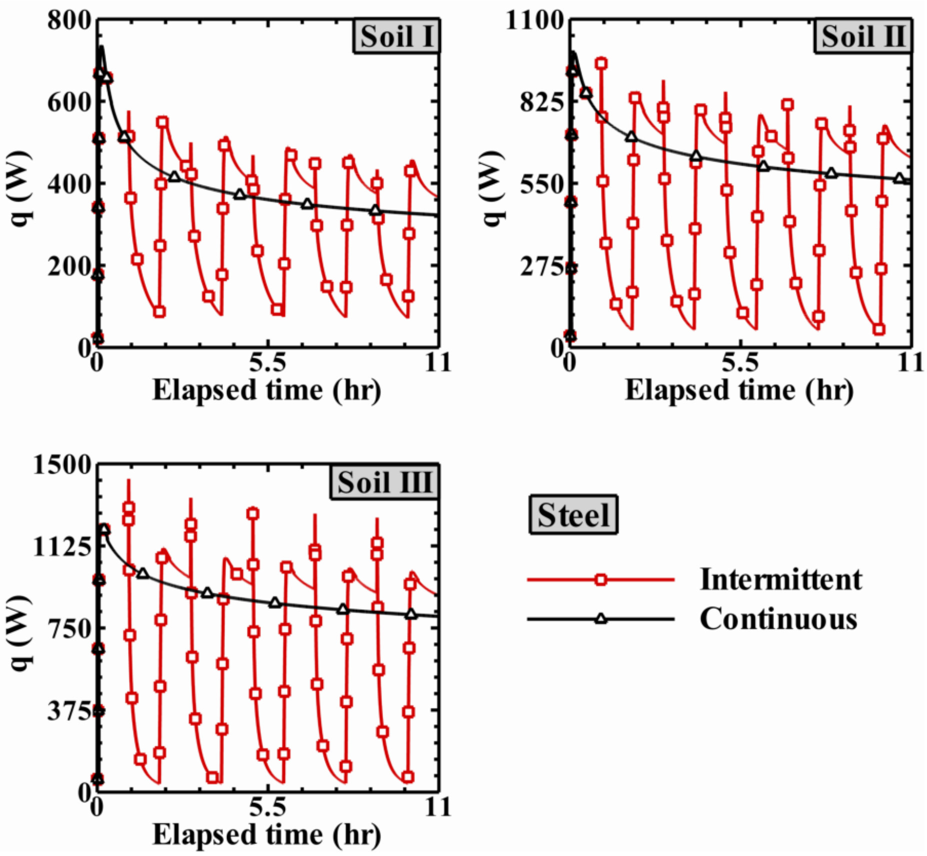

Figure10. *Comparison of the GSHE performance along the operation time in continuous and intermittent modes for a 10 msteel pipe*

5.4. Continuous Versus Intermittent Chiller Operation Effects

Chiller and cooling towers are devices in which intermittent operation has normally occurred. In the present study for comparison purposes, the continuous and intermittent operations of the GSHE are compared with each other. Figure 10 compares the continuous and intermittent operations of the GSHE along the chiller operation period for 10 m steel pipe under various soils. 1hr-on (cooling operation) and 1hr-off (recovering operation) are considered in the present study. As seen, regardless of the soil type, the performance of the GSHE is higher for intermittent operation in comparison to the continuous mode. Examination of the obtained results reveals that intermittent operation has higher heat dissipation rate in comparison to the continuous mode. On the other hand, a higher thermal conductivity of the soil leads to a better performance of the GSHE in intermittent mode. In addition, the intermittent operation of the GSHE reaches to a cyclic mode after enough operation period of the chiller. The heat dissipation rates for the intermittent mode in cyclic condition are found40.19%, 31.41%, and 24.58% higher than that of the continuous mode in soil I, soil II, and soil III, respectively. Similar results have been reported by Chong et al. (2013).

5.5. Total Pipe Number in GSHE

The total pipe length in the GSHE is computed based on the presented data in figure 6. Table 5 demonstrates the obtained results for required pipe length for chillers having the cooling capacities in the range of 5-50 TR. All the previous effective parameters such as the soil type and pipe material are included in table 5. It should be said that the presented results are based on the24hr continuous operation of the chiller. Based on the building area, different scenarios are included in table 5 for each individual pipe length such as the 10 m, 30 m, and 50 m. Selection ofeach pipe length is depended to the building floor area. The required pipe number is less once the steel pipes are selected for the GSHE construction in comparison to the conventional polyethylene pipe. As a result, it is expressible that with the reasonable pipe number, the GSHE can be replaced instead of the conventional wet cooling tower.

Table5. *Total pipe numbers as a function of the soil type and pipe material for each specific chiller cooling capacity after the 24hr continuous operation*

q_{load} (TR)	Pipe length (m)	Numbers of pipes					
Soil Type		**Soil I**		**Soil II**		**Soil III**	
Pipe Material		**Polyethylene**	**Steel**	**Polyethylene**	**Steel**	**Polyethylene**	**Steel**
5	10	82.4	71.3	52.2	41.2	39.4	28.2
	30	27.2	23.5	17.2	13.6	13.0	9.3
	50	16.5	14.3	10.4	8.2	7.9	5.6
10	10	164.7	142.6	104.5	82.3	78.8	56.5
	30	54.4	47.1	34.5	27.2	26.0	18.6
	50	32.9	28.5	20.9	16.5	15.8	11.3
15	10	247.1	214.0	156.7	123.5	118.3	84.7
	30	81.5	70.6	51.7	40.7	39.0	28.0
	50	49.4	42.8	31.3	24.7	23.7	16.9
20	10	329.4	285.3	209.0	164.6	157.7	113.0
	30	108.7	94.1	69.0	54.3	52.0	37.3
	50	65.9	57.1	41.8	32.9	31.5	22.6
25	10	411.8	356.6	261.2	205.8	197.1	141.2
	30	135.9	117.7	86.2	69.7	65.0	46.6
	50	82.4	71.3	52.2	41.2	39.4	28.2
30	10	494.1	427.9	313.4	246.9	236.5	169.5
	30	163.1	141.2	103.4	81.5	78.1	55.9
	50	98.8	85.6	62.7	49.4	47.3	33.9
35	10	576.5	499.3	365.7	288.1	276.0	197.7
	30	190.2	164.8	120.7	95.1	91.1	65.2
	50	115.3	99.9	73.1	57.6	55.2	39.5
40	10	658.8	570.6	417.9	329.2	315.4	225.9
	30	217.4	188.3	137.9	108.6	104.1	74.6
	50	131.8	114.1	83.6	65.8	63.1	45.2
45	10	741.2	641.9	470.2	370.2	354.8	254.2
	30	244.6	211.8	155.2	122.2	117.1	83.9
	50	148.2	128.4	94.0	74.1	71.0	50.8
50	10	823.5	713.2	522.4	411.5	394.2	282.4
	30	271.8	235.4	172.4	135.8	130.1	93.2
	50	164.7	142.6	104.5	82.3	78.8	56.5

6. CONCLUSION

A new idea was developed for replacing the wet cooling towers in air-conditioning systems with GSHEs having the cooling capacities in the range of 5-50 TR. In the first part of the results section, the parameters such as soil type and pipe material which have considerable influences in the GSHE design were studied in detail. It was found that soil type is one of the major parameters on the GSHE performance in the air-conditioning application. On the other hand, it was revealed that the pipe material effects increase with increasing the soil thermal conductivity. The maximum difference of heat dissipation per pipe length between the polyethylene and steel pipes was determined 39.57% in soil III. Based on the predicted numerical results, the total pipe number as the functions of the soil type, pipe material, and required cooling load was obtained based on each individual pipe length of 10 m, 30 m, and 50 m. Using the suggested system and data indicated in table 5, it is possible, providing the cooling water for water-cooled chillers without a wet cooling tower. According to this new idea, the energy consumption will reduce and water losses become zero in comparison to the conventional wet cooling towers. Therefore, it is expectable a considerable reduction in the initial and ongoing costs of the air-conditioning systems. As a near future work, the authors have planned to investigate the initial and ongoing costs of the proposed idea in the present study along with a comparison to the conventional wet cooling towers.

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