Passive air-conditioning of domestic using a hybrid system of solar updraft tower and a geothermal in Tikrit city-Iraq

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Abstract. In constructing a hybrid solar updraft tower with an underground heat exchanger, this study provides a theoretical and experimental investigation. A valuable function that lowers energy consumption in the case of domestic buildings is the Underground Tube Heat Exchanger. The submerged underground heat exchanger tube for heating in winter season and cooling in summer and the air is to be supplied by the influence of solar updraft tower to the building. The findings show that at 3 m depth from the earth, which is called buried depth at a 152 mm outer diameter, the maximum efficiency of the underground heat exchanger system. In comparison, with rising velocity of air, the temperature of the outlet air from the ground heat exchanger increases, varying from (22.2–28 °C) and also increases with increasing pipe diameter and decreases with increasing tube length. The difference between the findings of the theoretical and the experimental tests was 1.8 %. The combined geothermal heat exchanger and solar updraft tower system is used as an air conditioning system and was satisfactory efficient for thermal building loads.

Keywords: Buried Heat Exchanger, Tube heat exchanger, Solar Updraft Tower, Geothermal

1. Introduction
In today’s consequence the life style has been improved from older days. There is strong interest in renewable energy sources since the energy crisis which occur in (1970), when the sun was chief source of energy in universe. Solar energy consists of two main components, the heat and radiant light that comes from the sun and has been attached and used by humans since ancient times using a combination of advanced technologies and solar energy in simplicity it is the energy produced directly from the sun collected elsewhere, usually the Earth Labs [1]. An underground air-conditioning system (underground tube) is that utilizes for multipurpose like pre-heating or pre-cooling air in winter and summer respectively. The underground temperature of soil is higher than in winter and lower than ambient air temperature in summer, this is due to a high soil thermal mass that store high fraction of the heat gain. The use of passive cooling (system has been setup that focuses on heat gain and heat dissipation control in a building in order to reduce the energy consumption for cooling and enhanced the indoor thermal comfort) combined system with low cooling load creates thermal summer comfort that saves energy consumption for cooling. Beside of the two interesting, the natural ventilation and underground pipes are promising passive air-conditioning techniques. Natural ventilation uses in spaces where a little variation in indoor climate and in a region with hot climate is passable. On the other hand, due to the availability of solar energy, the solar updraft tower is an alternative solution to
using natural ventilation in buildings. Hammadi and Mohammed [2] presented a study to use the variations of temperature between soil and air to pre-heat or pre-cool ventilation using an underground heat exchanger. For pre-cooling purposes in hot conditions, the buried tube is used to transfer the excess heat to the ground as a heat sink. Effect of tube radius, tube length, tube depth buried underground, air flow rate inside the tube, soil type and type of tube material are studied by researchers.

Yousef et al., [3] presented a theoretical study of the thermal properties and performance of ground heat exchangers in tropical climatic conditions in Malaysia. An aluminium pipe with a length of (25 m), a depth of (2 m), and diameters ranges (80, 100, 125 mm). The results indicated that the required length of the pipe ranged between (3.1-23 m) with a flow rate of (0.02 - 0.2 kg / s) and the incoming air temperature is (Tin = 35°C). This amount of heat removal is sufficient to cool (condition) small, local buildings. The results also showed that the temperature of the outgoing air is equal to (25.6°C) for a PVC floor heat exchanger with a length of (25 m) and a diameter of (100 mm) and the incoming air at a temperature of (35°C) with a flow rate equal to (0.02kg / s). Agrawal et al., [4], studied the effect of operational variables on the performance of ground heat exchangers. The researchers conducted a simulation using the ANSYS FLUENT program. The effect of length (30, 40, 50, 60 m), the diameter (0.1, 0.15, 0.2, 0.25 m), air velocity (2,3,4,5 m / s), and the temperature of the air entering the tube is (34.35) are studied. The results show that the statistical analysis of the pipe diameter is the most influential factor on the rate of heat transfer by (53.28%), followed by the temperature and velocity of the incoming air and length by (30.78%), (9.40%) and (6.45%) respectively.

Grosso and Raimondo [5] found out an experimental application of a small building in Italy using tubes with a length of (48 m) and buried with a depth of (2.6 - 3.2 m). The results showed that the difference between the entrance and exit temperature of the tube in the summer was equal to (10°C). Wu et al., [6], designed and evaluated the capacity of geothermal heat exchangers to carry air-conditioning (cooling) in Quanzhou, southern China. Where a PVC pipe was buried, with a length of (60 m) and a radius of (0.2 m), and the tube was buried at a depth of (3.75 m), where the air velocity inside the tube was (2.2 m / s). CFD to perform a simulation of the heat exchanger. As it was found from the results that there is a decent agreement between the theoretical results and the experimental results with an error rate of (3.3%). The results of the study also showed that the daily cooling load capacity of the floor heat exchanger is (43.2 kW / h), while the degrees The temperature of the outside air ranges between (23.8-29.5°C) for the inside air at a temperature ranging between (37 -27.3°C).

Sayeed et al., [7], presented a study on measuring the distribution of ground temperatures at different depths and the main factors that affect the earth’s temperature in Tongyeong City (Korea). The annual temperature of the earth at a depth of (2 m) ranges between (15-25°C), while at a depth of more than (15 m), the earth temperature is constant around (22°C). The daily temperature of surface earth decreases with increasing the depth and the maximum value of the temperature was at a depth of (0.25 m). Patel and Mishra [8], conducted an analytical study of different types of heat exchangers, where the two researchers used (ANSYS FLUENT) With a total length (50 m) and an external diameter (0.08 m) and thickness (0.002). As an analysis was made for different types of velocity (1 to 5 m / s). Summer and winter were (8.01°C), and winter was (vertical), and the maximum temperature separation during the season was Summer and Winter were (22 °C), But in the case of burial of the tube diagonally, the maximum difference in temperature during the summer and winter seasons was (22°C), and the results showed that for the three cases, the outside air temperature increases with the increases of air velocity. Kamal et al, [9], studied the effect of moist soils on the thermal performance of geothermal exchangers used for heating purposes in India, as two types of geothermal heat exchangers were used, one without a humidification system and the other with a humidification system) Each system consists of three PVC pipes of different diameters (0.1, 0.05, 0.075 m), each tube length is (61.5m), both systems are buried under the ground with a depth of (3.7 m). For the purpose of dampening a PVC pipe was used. With a diameter of (0.025 m), it is equipped with small holes with a diameter of (0.003 m) along the length of the tube. The results of this study showed that geothermal exchangers equipped with a humidification system have a higher efficiency by (15.8-26.1%) than
geothermal exchangers without a humidification system, as well as when with the same length of tube, the temperature of the outgoing air in the dry system is lower than that of the wet system. One of the most important factors that can affect the performance of geothermal exchangers is the type of tube material. Menhoudj et al., [10], conducted a numerical and experimental study to perform the work of geothermal exchangers used in cooling buildings in Algeria. As two types of geothermal heat exchangers were used, the first is (EAHE-PVC), which represents the plastic tube connected to a room, and the second type is (EAHE-Zinc), which represents the zinc tube connected to a second room, where the diameter of each tube was (120 mm), and the length (20 m), the tubes were buried at a depth of (2 m), and each air duct was armed with a fan that pumps air into the room at a volume flow rate equivalent to (90 m³ / hr). The results showed that the rate of decrease in temperature is equal to 6.5°C for zinc tube and 6°C for PVC pipe. The energy provided by zinc tubes covers 35.41% of the room’s needs to carry the cooling, as for the energy provided by PVC pipes. It covers (58.42%) of the room’s needs to carry the cooling.

The main objective of the current research is to find out the best diameter and length of buried tube heat exchanger and the optimum design of solar updraft tower for that the hybrid system is used to save energy sources and reduce conventional air-conditioning load by reducing the cooling or heating load of any buildings or residential.

2. Methodology
2.1 Materials and Equipment's
The aluminium pipe specifications and the operating conditions are explained in the following sections. The air-conditioning system consists a test room, solar updraft tower, underground heat exchanger pipe, and trench ditch 16 m length, 3.25 m depth, 1 m width as shown in figure 1. The underground pipe which is made from aluminium of 15.2 cm diameter and 31 m length.

2.2 Experimental study
All the system data such as, design and work parameters recorded using three sensors: temperature, humidity sensors and solar meter. All the tests carried out in Tikrit City (34. 35°N, 43.37°E), where the climate is hot and dry, in summer season (April - June months) with different parameters. Thermocouples type (K) were used to measure and record the temperatures of ambient air, solar updraft tower, soil and test room. The temperatures of air which exits and enters from the tubular heat exchanger was also measured and recorded. The volumetric air flow rate was measured by using a normal anemometer (hot wire) type (PCE-423). The experiments were repeated four times to make sure of the reading of measurement and accuracy, as shown in figure 2.

2.3 Site of Test
The sunshine period of Iraq is around 3200 h/year with a minimum of 171 h/month in December and a maximum of 370 h/month in July [11]. The solar radiation intensity mostly is about 5.0 kWh/m² day, which is sufficient to deliver suitable energy for solar thermal requests. The total increasing of this is around 1800 kWh/m² per year. The diverse climate of Tikrit city (34. 35°N, 43.37°E), hot and dry in summer and spring (April - June), and the maximum air temperature is up to 45°C with annual average ambient temperature of 33 °C. The other metrological data (solar intensity, minimum and maximum temperature and sunshine period) are measured and obtainable in table 1.
3. Experimental set up

The study was carried out on a test room (240 x 240 x 120) cm$^3$ made of a compressed wood material. The test room connected with the tubes of the Underground heat exchanger pipe and solar updraft tower.

3.1 Requirement System Setup of Buried Tube Heat Exchanger

The underground heat exchanger pipe was made of aluminium material U-shaped with dimensions (length of 31 m and 15.2 cm diameter), 0.6 m the distance between two line as shown in Figure 1. The pipe of Aluminium is available in local markets, low cost, high conductivity, corrosion resistance, and good physical properties as shown in Table 2. The tests were conducted during April to June months in the research area of Tikrit / Iraq and recorded readings per hour. The sensors were used to record and measure the temperature inside the test room, solar updraft tower and soil. The relative humidity sensor fixed inside and outside the test room.

3.2 Design of Solar updraft tower

The solar updraft tower system used consists of a solar Collector, installed above the test room, where the Solar radiation falling on the solar collector heats the air under the glass, and since the cold air is heavier than hot air, thus leads to the gangway of the hot air through the updraft tower, due to the pressure difference, and the properties of the solar updraft tower are exposed in table 3.

| Month | Mean sunshine period (hours) | Mean solar intensity (W/m$^2$) | Mean temp. (Max) °C | Mean temp. (Min) °C |
|-------|-----------------------------|-------------------------------|---------------------|---------------------|
| April | 8.5                         | 685                           | 29                  | 18                  |
| May   | 9.6                         | 715                           | 33                  | 23                  |
| June  | 11.5                        | 760                           | 42                  | 29                  |

Table 2. Physical properties of aluminium.

| Tensile resistance (Kg/mm$^2$) | Thermal conductivity (W/cm) | Flexibility factor (Kg/mm$^2$) | Density at 20 °C (g/cm$^3$) | Fusion point (°C) |
|-------------------------------|-----------------------------|--------------------------------|-----------------------------|-------------------|
| 6.3                           | 2.18                        | 7250                           | 2.7                         | 660.1             |

Table 1. Data that measured for Tikrit.
Table 3. Physical possessions of solar updraft tower.

| Item                                      | Value         | Item                                      | Value         |
|-------------------------------------------|---------------|-------------------------------------------|---------------|
| **Physical properties of Solar updraft tower** |               | **Chimney Tower [12]**                     |               |
| Chimney height                            | 6 cm          | Chimney Tower absorption ($\alpha_{ch}$)  | 0.82          |
| diameter of the chimney tower             | 20 cm         | Chimney Tower Reflective ($\rho_{ch}$)    | 0.18          |
| length of the side solar Collector (square shape) | 240 cm       | Chimney Tower Emission ($\varepsilon_{ch}$) | 0.56          |
| Solar updraft tower collector angle       | $\Theta=35^\circ$ |                                           |               |
| **Glass cover of the solar Collector (4 mm) [12]** |               | **Surface of the absorbent collector**    |               |
| Glass cover absorption ($\alpha_{r}$)     | 0.1           | Glass wool (Thickness)                    | 1.5 cm        |
| Glass cover Permeability ($\tau_{r}$)     | 0.82          | Cork insulation                           | 1.5 cm        |
| Glass cover Emission ($\varepsilon_{r}$)  | 0.9           | Compressed wood                           | 1.5 cm        |
| Glass cover Reflective ($\rho_{r}$)       | 0.08          |                                           |               |

3.2.1. **Solar updraft tower manufacturing materials.** The solar updraft tower consists of several elements: the floor layer which is called thermal reflector consists of compressed wood, cork and glass wool, glass panel which is represent the roof of the solar collector, and chimney tower

3.2.2 **Solar Collector.** The structure of the solar collector is in the form of a square with a length 240 cm, and area 5.76 m$^2$ as shown in figure 3 (a, b and c), and it is function to absorb and collect the solar radiation.

3.2.3. **Chimney Tower.** It is a vertical tube with Thickness 1.6 mm, diameter 20 cm and length 6 m that allows the passage of hot air currents in the solar collector into space, resulting in the creation of a kinetic momentum force, called buoyancy force as shown in figure 4.

3.2.4. **Absorber Floor.** The solar collector floor was isolated by three layers (wood, cork and glass wool), all sides are painted black, so that as much solar radiation as possible is reversed, as shown in figure 5.

3.2.5. **Test Room.** The test room was designed and manufactured of compressed wood with thickness 1.5 cm and an iron structure with thickness 3×3 cm$^2$, dimensions 2.4 × 2.4 m$^2$ and the room contains a door in dimensions 120× 80 cm$^2$ and contains two windows in dimensions 20×20 cm$^2$, as shown in figure 6.
4. Mathematical Model

The Computational Fluid Dynamics (CFD) is required for the comparison between simulation data and experimental data by using MATLAB to simulate and to visualize the flow behaviour.

4.1 Analytical modelling of UGP Using MATLAB

The sub-surface annual temperature prediction was developed by Kusuda and Achenbach [13]. The same prediction applied in this study and presented as shown in figure 7. The boundary conditions considered in the present simulation as the wall of the chimney is considered as adiabatic wall. Furthermore, constant temperature conditions are applied to ground. All the side faces of energy storage layers are considered to be adiabatic, at the collector inlet is inlet pressure and outlet air temperature from exit underground pipe.

\[
T(t, z) = T_{ms} + \alpha_z \ast e^{-z \sqrt{\frac{\pi}{365 \alpha_s}}} \ast \cos\left(\frac{2\pi}{365} (t - t_0 - \frac{z}{2} \sqrt{\frac{365}{\alpha_s}})\right)
\]  

(1)

Kusuda equation used to predict soil temperature at different depths and times. [13]

Soil resistance, thermal resistances of each material, total resistance, total conductance and convection resistance is calculated by the following formula:
\[ R_C = \frac{1}{2\pi r_1 h} \]  

(2)

The thermal pipe wall resistance by conduction is:

\[ R_P = \frac{1}{2\pi k_n} \ln \left( \frac{r_1 + r_2}{r_1} \right) \]  

(3)

Thermal soil resistance of heat transfers by conduction the surrounding soil to the outer surface of the pipe

\[ R_S = \frac{1}{2\pi k_S} \ln \left( \frac{r_1 + r_2 + r_3}{r_1 + r_2} \right) \]  

(4)

Total Resistance and conduction

\[ R_t = R_C + R_P + R_S \]

The overall heat transfer coefficient of air heat exchanger and solar updraft tower.

\[ U_t = \frac{1}{R_t} \]  

(5)

The internal heat transfer coefficient of air which passes through the tube is written as:

\[ h = \frac{Nu^* k_{air}}{d} \]  

(6)

Nusselt Nu, Reynolds Re and Prandtl Pr number are define as:

\[ Nu = 0.023 \; Re^{0.8} \; Pr^{0.3} \]  

for cool purpose  

(7)

\[ Nu = 0.023 \; Re^{0.8} \; Pr^{0.4} \]  

for heat purpose  

(8)

\[ Re = \frac{\rho a v s D}{\mu a} \]  

(9)

\[ Pr = \frac{c_a \mu a}{k_a} \]  

(10)

The mass flow rate of air is calculated in the subsequent equation:

\[ \dot{m} = \rho_a \cdot v \cdot A_p \]  

(11)

Heat can be calculated by total travel air, which flow through the tube as shown in [14]:

\[ Q = \dot{m} c_a (T_i - T_0) = \frac{\dot{m} \Delta T_m}{R_T} \]  

(12)

To calculate the value of outlet air temperature:

\[ T_{out} = T_s - (T_s - T_i) \exp \left( \frac{-k A_S}{\dot{m} C_a} \right) \]  

(13)

In order to simplify and solve the system of energy equations in the solar updraft tower, and to simplify the mathematical model, some assumptions were considered:

1. Flow is steady and laminar.
2. Inlet air temperature of the solar updraft tower is the same as the room temperature.
3. The energy transfer between the room wall and surrounding is neglected. [15].

\[ \alpha_g A_g + h r_{abs, g} A_{abs} (T_{abs} - T_G) = h_g A_g (T_G - T_{ch}) + U_{g,a} A_g (T_G - T_a) \]  

(14)

The coefficient of heat transfer by the absorber plate is [16]:

\[ U_{abs,r} = \left[ \frac{1}{h_r} + \frac{t_{ins}}{h_{ins}} \right]^{-0.5} \]  

(15)
The overall heat transfer coefficient between glass cover and ambient air \( (U_{g,a}) \) in the form as:

\[
U_{g,a} = h_a + h_r g_a - k_g a \tag{16}
\]

The average mass flow rate of air at the solar updraft tower and underground pipe is the same:

\[
m = \rho A u \tag{17}
\]

The velocity of air in the solar updraft tower can be obtained as:

\[
V_{ch} = \left( \frac{\text{Buoyancy terms}}{\text{Friction terms}} \right) \tag{18}
\]

\[
V_{ch} = \sqrt{\frac{2gH (\rho_a - \rho_r)}{\rho_a}} \tag{19}
\]

5. Result and discussion

Experimental tests were directed under weather conditions of the city of Tikrit, which is located at (34.35°N, 43.37°E). Tests were conducted during April, May and June. From the literatures of the climate conditions of the current site the global solar radiation measurements on horizontal surfaces show that have, while the minimum values were in December, also, the lower in December and January and the maximum temperature has higher values in July using direct measurement [16]. The effects of the operative weather conditions were discussed in the following sections.

5.1 Soil temperature

The yearly sub-surface soil temperature based on heat conduction theory is expected. The results show that the profile of annual sub-surface soil temperature exhibits a sinusoidal pattern due to the annual temperature fluctuation above. The measured and prediction soil temperatures at depths 1, 2 and 3 m are presented in figure 8. It has been shown that the appropriate depth for the installation of the air to earth heat exchanger system is 3 m. At this depth, the predicted sub soil temperatures ranged from 24.4°C to 25°C.

5.2 Pipe length

As it can be seen from figure 9 that the temperature of the outside of the tube starts between (30.8 - 33°C) at the length of the exchanger (10 m). As for the length of the exchanger (20 m), the temperature of the outgoing air from the tube varies between (30-27.4 °C) while the temperature of the air out of the tube is between (28-25 °C) at the length of the exchanger. (30 m) as for the length of the heat exchanger. The temperature of the air exiting the tube ranged between (40 m). (27.2-24.5 ºC). It is clear that the air temperature at the exit tube decreases with increases the tube length. This is due to there is an efficient time to exchange the heat transfer between the soil and pipe wall. So, the buried tube with a length of (40 m) provides more cooling than a shorter pipe length.

5.3 The tube’s diameter

As the temperature of the air was exiting the tube, as shown in figure 10, ranged between (31-33 °C) at the diameter 10 inches, while at the diameter 8 inches, the temperature of the air was coming out of the tube ranged between (28-30 °C). When it reached the lowest value (26-23 °C) at the diameter 4 inches as it becomes clear that the temperature of the air coming out of the tube is inversely proportional to the diameter of the tube, where the temperature of the air leaving the tube increases with the increase in the diameter of the tube and decreases with the decrease of the diameter of the tube because it is in the state of diameter. The small tube, the air remains in the center of the tube and close to the surrounding soil, and the thermal energy transfer becomes rapidly, which allows more heat transfer to the soil, and thus the air temperature approaches the surrounding soil temperature.
Figure 11 shows the difference between the experimental and theoretical results of the air temperature coming out of the tube for the month of May at different air speeds starting from (9:00) in the morning until the end of the last reading at (18:00) in the evening. The difference between the experimental and theoretical results of the air temperature coming out of the tube for the day (16th June 2020), it ranged from (0.3 °C) to (2.5 °C) from the start of the test at (9:00) in the morning at an air flow rate of (Q=91.73 m³/hr) until the end of the test in the hour (18:00) in the evening when the rate of air flow (Q=87.36 m³/hr), while the rate of difference between them was (1.2%) and the maximum difference between the experimental and theoretical results was (2.4%) per hour. (13:00) at a constant flow rate (Q=162.24 m³/hr). While the results for (18th June 2020) showed that from the beginning of the air flow (hr / 92.35 m³ = Q) in the hour (9:00) in the morning to the end of the test in the hour (18:00) in the evening at an air flow rate (Q=88.61m³/hr) The difference between the theoretical and experimental results of the temperature of the air exiting the tube was from (0.1 ºC) to (1.3 ºC), while the average difference between them was (0.56%), and the maximum difference between experimental and theoretical results was (1.4%) per hour. (13:00) at a flow rate of (Q=165.36 m³/hr). The reason for the difference in the experimental and theoretical results is due to the neglect of the thermal losses implemented by the MATLAB program.

5.5 Cooling load
Figure 12 shows the change in the cooling load during the day and night hours. It is found that the cooling load increases during the summer months, when the temperature is very high. The maximum value of the cooling load accorded two hours after middle of the day. The highest value of the cooling load is 1750 W during the month of June at 3 pm, while the lowest value in the month of June 230 W at four o’clock in the morning, and approached to zero at the first morning hours.

5.6 Air velocity
Figure 13 shows the effect of solar radiation on the change in air velocity inside the solar updraft tower during daylight hours. The results show that the value of the air flow velocity at the entrance of the solar updraft tower is 0.95 m / s in the 30th April 2020 at 9:00 Am, then gradually increases with the increase in the solar radiation intensity, until it reaches its maximum value of 1.85 m / s at the peak time of 13:00 pm. Then, decreases with the decrease in solar radiation intensity until it reaches 0.9 m / s at 18:00 pm. also, the results show that the speed follows the same behaviour of the solar radiation variations. This behaviour also applied for the other time, and the flow velocity will change depends on the value of solar intensity

5.7 Solar updraft tower Temperature
Figure 14 shows that the air temperature entering the solar updraft tower starts from (49 ° C) at the start of the test at (9:00) in the morning and then increases gradually with increasing the solar radiation intensity until its value reaches (55 ° C) at (13:00) in the evening after that, it begins to decrease slightly until it reaches (46 ° C) at the end of the test at (18:00) in the evening. As for the temperature of the glass, it starts from (43 ° C) at the first reading at (9:00) in the morning, and then begins to rise with the increase in solar radiation intensity until it reaches (66 ° C) at (13:00) in the evening, after that it begins to decrease slowly until it reaches (42 ° C) at the end of the test time at (18:00) PM. As for the average temperature of the reflective surface of the solar updraft tower, it started at the first reading (43 ° C) at (9:00) in the morning, and then begins to increase with the rise in solar radiation intensity until it reaches (78 ° C) at (13:00) in the evening. Then it begins to decline slowly until it reaches (64 ° C) at the end of the test time at (18:00) in the evening.

5.8 Underground Soil Temperature
Figure 15 Shows the change in the earth’s temperature with the days of the year and the depth that was theoretically calculated from equation (2.3), as we note that the temperature on the surface of the earth is variable during the year, in the summer it reaches about (42 °C) and in the winter season to about (2
°C) due to the influence of the Earth's surface with weather conditions such as solar radiation, air temperature and other climatic conditions, while we notice that the change in the earth’s temperature at depths (1.2 m) gradually decreases because the effect of the earth’s weather conditions such as air temperature and solar radiation is lower due to greater depth. As the maximum temperature is obtained during the summer at a depth of (1 m) approximately (28 °C), and at a depth of (2 m) about (25 °C), while at a depth of (3 m), the earth's temperature will be approximately constant about (22 °C). and this corresponds to the results of the researchers [17].

**Figure 8.** Shows the effect of the tube depth on the temperature of the air exiting the tube.

**Figure 9.** Shows the effect of the geothermal heat exchanger length on the temperature of the outlet air.

**Figure 10.** Diameter effect of the heat exchanger tube on the outlet air temperature.

**Figure 11.** Comparison between theoretical and experimental results.
6. Conclusions
Due to the high demand for air conditioner in dry and hot regions and the solar is not certified to cover the demand for air conditioning in the summer months. The hybrid technology allows passive air-conditioning to be used with an underground heat exchanger in a dry and hot environment. Passive air-conditioning and solar updraft tower represent an effective alternative technique in air-conditioning technology. The proposed hybrids systems appropriate for summer and winter seasons. The inferences drawn from the present research are abridged as follows: the temperature and air velocity inside the solar updraft tower increases with the increase in solar light falling on the tower wall, maximum drop in air temperature is approximately (18 °C). The daily fluctuations of the earth's temperature are noticeable to a depth of (0.25 m), and that the earth's temperature decreases with an increase in depth and is constant throughout the year and is approximately equal to (21 °C) at the depth (3 m). The cooling efficiency of the geothermal heat exchanger is inversely proportional to the airflow velocity, reaching its maximum value (98.6%) when the air flow is \((Q = 31.3 \text{ m}^3/\text{hr})\), The temperature of the air exiting the tube is inversely proportional to the length of the tube and the depth of the tube, and in direct proportion to the velocity of the air flow and the diameter of the tube, and the average air temperature decrease is (12-18 °C).

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