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Experimental Study of Using Ethyl Ether-Acetaldehyde Solution in A Solar-Driven Absorption Chiller Integrated with A Parabolic Trough Solar Concentrator

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ABSTRACT: Absorption cooling systems due to having the capability of using renewable and waste energy sources and also working with environmentally friendly refrigerants have fascinated many researchers as potential alternatives to traditional vapor compression cooling systems. However, the performance of these systems still lower than those of traditional ones. The refrigerant mixture can play a crucial role in improving the performance of these systems. In this regard, for the first time, the effects of using ethyl ether-acetaldehyde as a working pair in a 0.5 kW solar-driven absorption refrigeration system integrated by a parabolic trough solar concentrator are experimentally examined. The experiments are conducted on certain days in October at Babylon University, Iraq. The performance of the proposed hybrid system using ethyl ether-acetaldehyde is compared with a similar one with a common pair of lithium bromide (LiBr-water). Moreover, the operating conditions of the main system components in terms of temperature and pressure are discussed. The results show that the ethyl ether-acetaldehyde solution can operate under a low hot water temperature of 78 °C supplied by the solar collector and produce chilled water with a temperature of 7 °C. While for a hot water temperature of 90°C produced by the solar collector, the system with LiBr-water pair can produce chilled water with the temperature of about 16 °C. Therefore, the ethyl ether-acetaldehyde solution can be suitable for areas with hot and moderate temperatures. Moreover, the coefficient of performance improves from 0.64 to 0.78 by using ethyl ether-acetaldehyde as working pair instead of LiBr-water.

KEYWORDS: The solar-driven an absorption refrigeration; a parabolic concentrator; the refrigerant mixture; Ethyl ether-acetaldehyde; Coefficient of the performance.

INTRODUCTION

In the Gulf region, air conditioning and refrigeration have been responsible for one of the highly energy consumption sectors. The traditional refrigeration systems, the vapor compression refrigeration, consume high grade of electricity to compress the refrigerant by a compressor. The required electricity generated by fossil fuel results in reducing the main irreplaceable energy source of each country and affecting negatively on the environment including global warming and ozone depletion. These negative impacts of using fossil fuel in the refrigeration systems made humans think about naturally available and environmentally friendly sources such as solar energy in these systems. Thus, the solar-driven refrigeration systems have attracted much attention due to providing a large proportion of required energy by solar energy, resulting in generating less pollution and conserving the environment [1], [2]. Generally, solar-driven refrigeration systems can be categorized into two different systems according to the solar system used, namely, photovoltaic based solar system and solar thermal system. The former uses solar energy to generate electricity, which powers the compressor of a conventional refrigerator. However, in the latter system, the solar thermal energy provides the energy used in a generator of an absorption refrigeration system which operates based on the principles of absorption cycle rather than the compression cycle [3]. Kim and Ferreira [4] compared these systems in terms of economic practicability and efficiency and found out the solar absorption refrigeration system was cheaper and more efficient than the solar electrical refrigeration system. Besides, using working fluid which is harmless to the environment in the solar absorption refrigeration system instead of chlorofluorocarbons (CFC's) helped preserve the ozone layer. In another study, Otanicar et al. [5] demonstrated that the percentage of incident radiation that could be used in solar absorption refrigeration was approximately three times higher than the solar electrical refrigeration system. Thus, due to the benefits of solar thermal systems, recently the focus of researchers is on them. In the absorption refrigeration, after absorbing the refrigerant in an absorbing material and pressurizing in the absorbent liquid phase, the mixture is undergone a heating process in the generator to regenerate refrigerant vapor with high pressure. Although this system requires less electrical energy to increase the pressure of refrigerant due to pressurizing in the liquid phase, it needs a heat input to reproduce the refrigerant vapor which could be provided by solar thermal collectors [6], [7]. For the first time, Trombe and Foex [8] fabricated solar absorption chillers with a pilot plant using aqua-ammonia as the working pair, which is followed by Chinnappa [9] who employed two different working fluids, ammonia-water and ammonia-lithium nitrate, with the highest temperature of 405 K. In another study, he built a simple refrigeration system that used flat plate collectors to heat the working pair and illustrated that the evaporator temperature of 101 °F (38.33 °C) was achievable on a clear day via flat plate collectors [10]. One of the significant parts affecting the performance of absorption chillers is refrigerant–absorbent working pair, which have been studied by researchers. Among the different types of refrigerant mixtures, ammonia-water and lithium bromide-water (LiBr-water) are more common. Brendel et al. [11] utilized ammonia-water in a solar-powered 10 kW absorption system. In their experimental setup, a helical coil heat exchanger inside a shell was used to convert ammonia-water to the ammonia vapor. The results showed that the COP varied between 0.58 and 0.74 for the generator temperature of 80 to 120 °C, respectively. Following that, Lostec et al. [12] tested a 10-kW absorption system working with aqua-ammonia. In this system, the ethylene glycol-water was employed inside the cooling circuit. They obtained a COP of 0.6 when the evaporator temperature was 16 °C. Furthermore, once the evaporator temperature decreased, the COP experienced a significant fall due to the overfeeding the evaporator. This phenomenon also reported by Albers and Ziegler [13] and Asdrubali and Grignaffini [14] when the generator temperature rose.

The literature review reveals that in the majority of previous studies, two different working pairs of LiBr-water and ammonia-water have commonly been employed in solar-driven absorption refrigeration systems, which LiBr-water was showed better performance compared to the ammonia-water. Consequently, to fill the mentioned gap, using alternative working pairs to enhance the system COP and overcome the mentioned limitations of common working pairs like LiBr-water, for the first time, a novel solution of ethyl ether-acetaldehyde is introduced to use in these systems. To this end, a comparison between using a new mixture of ethyl ether-acetaldehyde and common pair of LiBr-water in a 0.5 kW solar-driven absorption refrigeration system is experimentally made. To provide the required hot water, a parabolic through solar collector is employed. The experiments are conducted during October at Babylon University, Iraq. Moreover, the operating conditions of the main system components in terms of temperature and pressure are discussed.

EXPERIMENTAL SETUP

Figure1 demonstrates the schematic of the closed cycle of the presented solar-powered absorption refrigeration system along with the positions of all used thermocouples. As can be seen, the absorption refrigeration cycle is a closed cycle, where the working fluid remains within the system, and only the heat and work are transferred to the surrounding. The working pair for the absorption cooling system consists of two fluids, namely, refrigerant and absorbent, which have a strong chemical affinity for each other. The heat from a high-grade temperature source increases the temperature of solution in the generator, and as a result, the refrigerant gradually evaporates from the boiling solution (Point 7), which becomes stronger in absorbent concentration. Vapor refrigerant by losing heat condensed in the condenser (Point 8), and the liquid refrigerant after passing the expansion valve enters the evaporator (Point 9). Evaporation of the refrigerant liquid takes place in the evaporator. The evaporated refrigerant leaves the evaporator (Point 10) and enters the generator to mix with the strong solution in the absorber, which comes from the generator and after passing the heat exchanger and expansion valve (Points 1, 2, and 3). Since this process is exothermic, heat must be removed from the absorber to maintain solution temperature at an identical low value in order to ensure a high chemical affinity between the refrigerant and absorbent. Then the produced liquid solution is pumped into the heat exchanger and finally generator (Points 4, 5, and 6). The heat exchanger is placed between the generator and absorber to minimize the sensible heat losses. It should be mentioned that, in the absorption cooling cycle, a pressure transducer is used to measure the small pressure difference between the high-pressure side of the system (generator and condenser) and the low-pressure side (evaporator and absorber). As shown in Figure 1, the hybrid system consists of different components, including a parabolic solar collector, condenser, evaporator, generator, heat exchanger, absorber, storage tank, and two pumps. The storage tank is used to store the hot water in the collector loop. The diameter and length of the storage tank are 35 and 50 cm, respectively, with the capacity of 48 liters. Tank is fabricated from steel, which can withstand a pressure up to 4 bar and corrosion. Water is selected as the working fluid in the closed cycle of the solar collector, and two different working pairs, including ethyl ether-acetaldehyde and LiBr-water are used through the absorption cycle. Cycle commences by transferring heat from the water, which its temperature is risen by receiving the solar energy through the parabolic solar collector and then pumped into the generator, to the solution. As a result, the acetaldehyde/water evaporates at its boiling point and separates from the ethyl ether/LiBr. Next, inside the heat exchanger, the strong solution from absorber was used to preheat the weak solution before entering the absorber to reduce the heat loss and decline the temperature of the strong solution to be ready for the chemical reaction in the absorber. In the next stage, the acetaldehyde/water vapor is transferred to the condenser to convert into the liquid in the constant pressure process. After passing the refrigerant from the expansion valve and decreasing its pressure and temperature, the acetaldehyde/water liquid evaporates in an evaporator under constant pressure and get the required heat from the chilled water and covert to refrigerant vapor, and decline the chilled water temperature. Then, the refrigerant vapor is mixed with the ethyl ether/ LiBr in the cooling water tank through the isotherms process. Ultimately, the liquid solution is pumped into the generator and the cycle starts again. To record the pressure and temperature, pressure was logged every minute, while the temperature was recorded every 10 min

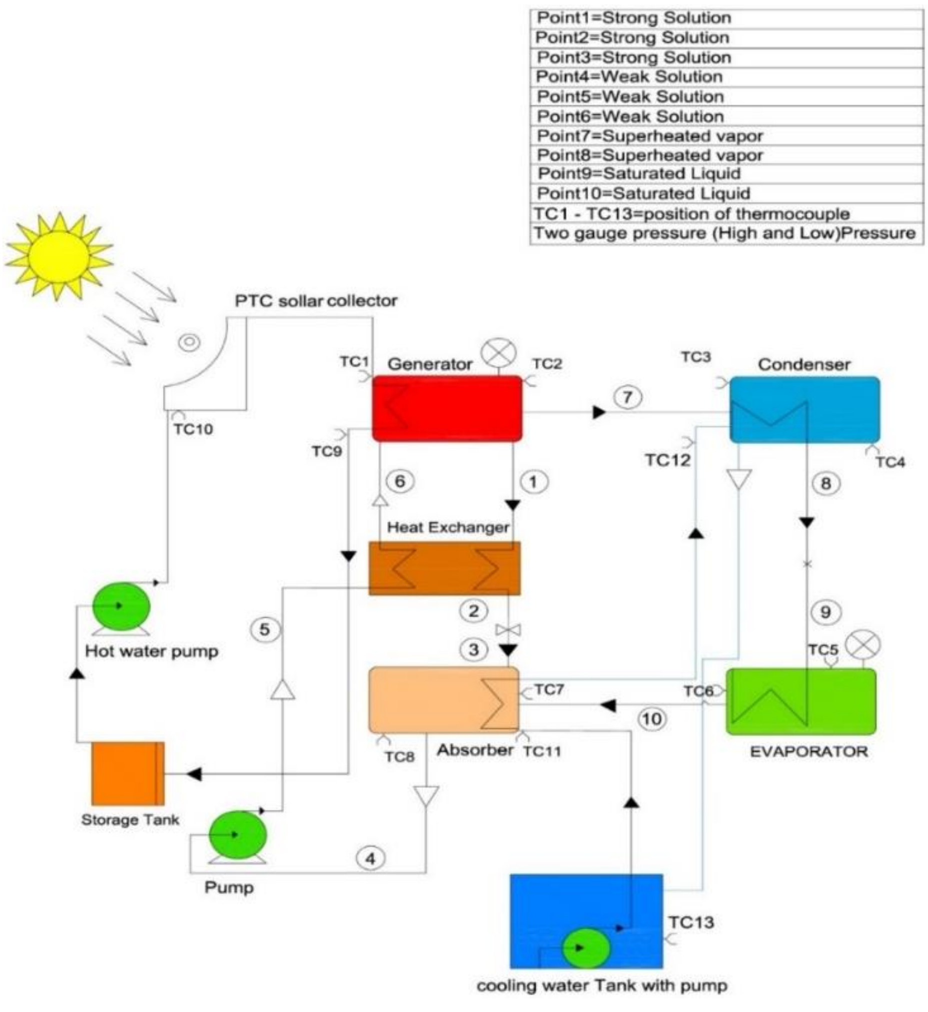

Figure 1. Schematic diagram of a Solar-Driven absorption cooling system.

DESCRIPTION OF USED GENERATOR, CONDENSER, EVAPORATOR, AND ABSORBER

A shell and a coil heat exchanger due to the high heat transfer rate, low maintenance costs, and compact design were used as the generator, in which circular layers of helical corrugated tubes were set inside a shell. The hot water was from parabolic collector flowed through coils and the fluid from absorber flows over the coils (through the shell), shown in Figure. 2(a). By using this design, not only the heat transfer surfaces rise significantly, which results in enhancement of heat transfer in the generator, but also by creating a disturbance in the flow field, the heat transfer coefficient increases. Like the generator, shell and coil heat exchanger were employed for the condenser, evaporator, and absorber. The details of the inlet and outlet flow of each component are illustrated in Figure. 2(a) and the employed generator and capillary tube are shown in Figures. 2(b) and (c), respectively.

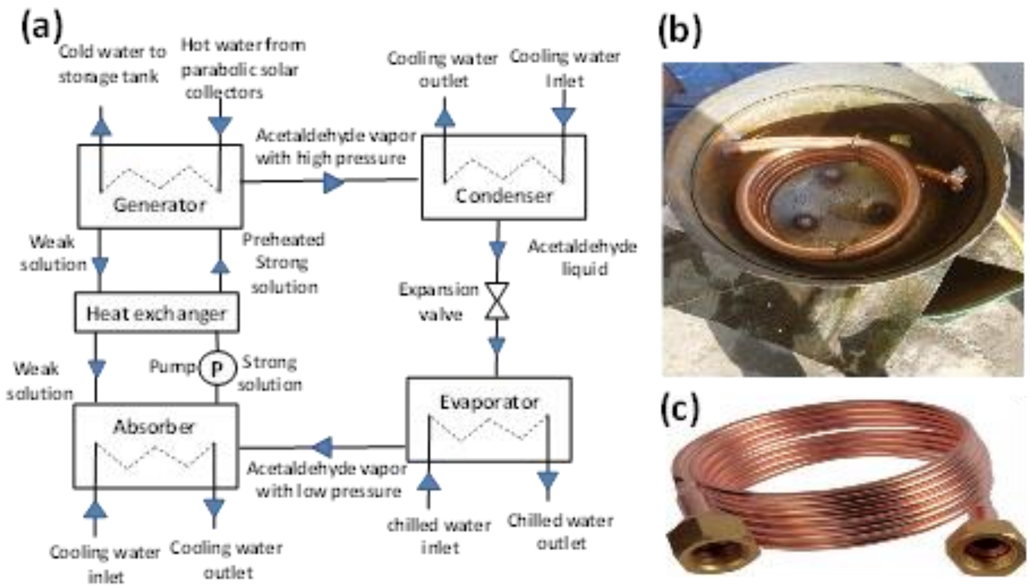

Figure 2. (a) schematic of inlet and outlet details of each component in the system; (b) the employed generator; and (c) the capillary tube.

The geometrical specifications of the shell and helical tube heat exchangers used as generator, condenser, evaporator, and absorber are shown in Table 1.

Table 1. The variables and their value of PTC

	Generator	Condenser	Evaporator	Absorber
The inner diameter of helical tube (mm)	13.56	13.56	13.56	13.56
The thickness of helical tubes (mm)	0.7	0.7	0.7	0.7
Number of revolution	6	5	6	4.5
The total length of helical tube (m)	2.9	2.76	3	2

HEAT EXCHANGER AND CAPILLARY TUBE

The double-pipe heat exchanger has constructed of copper was used for preheating the working fluid before entering the generator, flowing inside the outer pipe as well as cooling the returning strong solution from the generator, flowing inside the inner pipe. The diameter of inner and outer tube was 15.88 and 28.58 mm, respectively, and the length of the heat exchanger was 944 mm. The mass flow rate of weak solution (outer fluid) and a strong solution (inner fluid) was 0.0052 and 0.0054 kg/s. Due to the low cost of the capillary tube and lack of any moving parts in this device, it was used as a simple expansion valve between the condenser and evaporator to reduce the pressure and the corresponding saturation temperature of refrigerant from condenser to the evaporator condition. By passing through such small and long tubes, a drop in the pressure happens as a result of frictional resistance created by tube walls followed by the flash vaporization due to the drop of internal energy and hence enthalpy. The decrement of pressure intensifies with decreasing the diameter and increasing the length of the capillary tube. In this study, the capillary tube was helical with inner diameter, outer diameter, length, and the number of revolutions of 1 mm, 1.7 mm, 1.26 m, and 7, respectively. Figure 2(c) illustrates the employed capillary tube in this study.

PUMPS

Two different pumps were used in the solar-powered absorption system to circulate the fluid inside two close loops, including the solar collector and the absorption cooling, as shown in the figure.1. A water pump set on the storage tank, which is responsible for transferring the hot water from the solar collector to the generator, and the flow meter is located after the pump to record the flow rate of hot water entering the generator.
A chemical pump was employed in the absorption cooling loop to pump the weak solution from the absorber to the generator. In the addition, in the condenser and evaporator units, for circulating the cooling and chilled water, another pump was used with the power of 25W, the flow rate of 100L/h, and the maximum suction of 1.8 m.

PARABOLIC TROUGH SOLAR COLLECTOR

The parabolic solar collector has two main components, namely, a reflector which is a curved parabolic mirror focusing the solar radiation on the absorber tube, and a receiver collecting solar energy and transferring the heat to the fluid. The reflector made of stainless steel with parabolas shape contained the support structure for providing a strong base against the air below and other disturbances as illustrated in the figure. 3(a). The absorber tube and concentric transparent cover were two principal components of the receiver, shown in the figure. 3(b). The absorber tubes made of copper, due to its high thermal conductivity, and coated with heat-resistant black paint was located at the focal axis and surrounded with the concentric glass cover, through which the liquid to be heated flows. To enhance the solar collector performance, absorber tubes were coated with selective surfaces, and the space between the tube and glass cover was evacuated. Furthermore, the existence of the concentric glass cover declined the radiation and convection losses. The absorber plate was fixed with the reflector via the welding technique. Figure. 3(c) demonstrates the schematic of the three-dimensional and right view of the parabolic solar collector with defining each component.

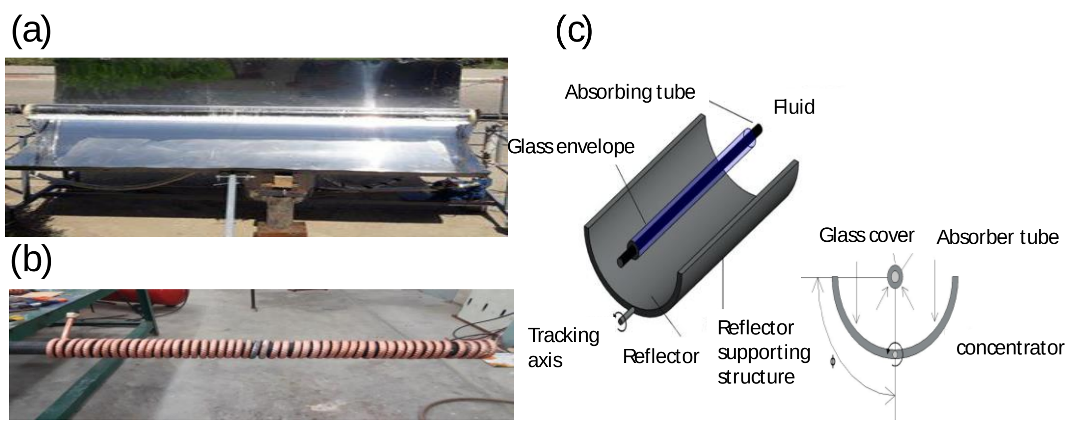

Figure 3. (a) the reflector; (b) receiver; and (c) schematic of the employed solar collector.

The geometrical specifications of the parabolic solar collector are listed in the table 2. In general, the incidence angle is not zero and the distance of reflected the light is greater. This means that the receiving tube should have a slightly larger dimension to maintain high interceptors also in cases where the angle of incidence is large, so the diameter of the receiver is assumed 12.7 mm. In the addition, the length of the receiver tube is 19.10 m, and the number of turns is equal to 95 turns. The diameter of the receiver base is chosen 38mm to easily turns the receiver tube on it. The welding technique and the screws are used to fix the absorber plate with a reflector. To keep the aperture area constant, the top distance between the two reflectors is kept constant by riveting these reflectors to the frame. The copper metal was selected for the receiver designing due to its high thermal conductivity. A copper tube was procured from the market of O.D 12.7mm and the thickness 1mm for testing purposes.

Table 2. The variables and their value of PTC collectors.

Parameter	**Value**
Aperture width	1.025 m
Length	2.02 m
Depth	0.335 m
Concentrator aperture area	2 m^2
Focal length	0.23 m
Rim angle	97°
Receiver diameter	5 mm
Receiver length	2
Optical Concentration ratio	68
The diameter of receiver base	38 mm
Number of revolutions of helical coil receiver	95

PHYSICAL PROPERTIES OF THE WORKING PAIRS

As mentioned earlier, the new working pair, ethyl ether-acetaldehyde, is compared with the common one, LiBr-water, in this study. 10 liters of both solutions were used in this study, where the ethyl ether-acetaldehyde solution was employed with a ratio of 3:2. The physical properties of these materials are provided in the table 3. The new solution has some superiorities over the LiBr-water one that is mentioned here. For example, the system with LiBr-water pair requires being vacuum, while the system with ethyl ether-acetaldehyde does not need to operate under vacuum pressure due to evaporation at lower temperature. Lower boiling point of this solution is another superiority over the LiBr-water one. In contrast to the system with LiBr-water, the system was working with ethyl ether-acetaldehyde can work without any series or parallel auxiliary cooling system. Furthermore, no oxidation occurs in copper tubes when ethyl ether-acetaldehyde solution is used, and the system does not need to be discharged because the proposed fluid evaporates at low temperatures.

Table 3. Physical properties of the ethyl ether, acetaldehyde, water, and lithium bromide.

Properties	**Ethyl ether**	**Acetaldehyde**	**Lithium bromide**	**Water**
Chemical formula	$C_4H_{10}O$	CH_3CHO	LiBr	H_2O
Molecular weight (g/mol)	74.122	44.05	86.845	18.015
Boiling point (°C)	35	20.20	1265	100
Density (g/cm³)	0.706	0.79	3.464	0.997
Melting point (°C)	-116	-123.50	552	0
Flashpoint (°C)	-45	-38	1265	Non-flammable
Vapor pressure	538 mmHg at 25 °C	740 mmHg at 20 °C	powder	23.76 mmHg at 25 °C
Entropy (J/mol. K)	253.5	250	66.9	69.95
Viscosity (mPa.s)	0.24 at 25 °C	0.21 at 20 °C	powder	0.890
Enthalpy (kJ/mol)	271.2	-166	-350	44.6

MEASUREMENT INSTRUMENTS

Table. 4 provides the details of the measurement instruments along with their accuracy. Pressure transducers (PM-9107-gauge pressure made in China) were used to measure the pressure difference between high-pressure points (i.e., generator and condenser) and low-pressure points (i.e., evaporator and absorbent). To transform the voltage signal of pressure sensors from analog to digital in order to be readable by the software program (DaLi08), an interface was used. A universal data logger (UDL100) with high accuracy and resolution, a sampling period of 750 ms, and channels isolation voltage of 400 V were used. Analog pressure gauges and pressure transmitters (QP-83A) with a working range of up to 10 bar and having high corrosion resistance were employed for measuring the pressure and transferring to the pressure data logger due to their straightforward calibration and monitoring. This measuring instrument was set to measure the generator and absorber pressures.

To measure the temperature of different parts of the system, K-type thermocouple and BTM-4208SD data logger were used. Moreover, to determine the flow rate, a rotameter PT878 was employed. The measurement and reading processes of each parameter were repeated several times throughout the experiments to ensure the accuracy of the measured results. All the measurement instruments were calibrated in the laboratories of Babylon University in Iraq. All the k-type thermocouples used in this study are calibrated with a standard thermometer and an accuracy of ±0.5 °C in a temperature range from 0 to 100 °C.

Table 4. The used equipment for measurement and their accuracy.

Equipment	Measurement	Accuracy
PM-9107-gauge pressure	Gauge pressure	±2% F. S
K-type thermocouple	Temperature	±0.5 ˚C
BTM-4208SD data logger	Temperature	±(0.4%+0.5 ˚C)
Rotameter PT878	Flow rate	±(0.06-0.6) m^3/h

RESULTS AND DISCUSSION

To evaluate the impacts of using new working pair in the solar-driven absorption chiller, firstly, the climate conditions and performance of the parabolic solar collector are discussed. Next, the hybrid system performance with both ethyl ether-acetaldehyde and LiBr-water is examined and compared in terms of temperature and pressure of different parts as well as the system efficiency.

The experiments were conducted in the course of October between 8 a.m. to 2 p.m. on selected days. Furthermore, the tests were performed at Babylon city, Iraq, which is located in 32.39 N latitudes and 44.39 E longitudes. Noted that the parabolic solar collector performance entirely depends on weather conditions; therefore, to overcome this drawback, the average daily solar irradiation and ambient temperature are considered to calculate the solar collector performance as shown in Figure. 4. As can be seen, the radiation intensity is low during morning hours and the maximum solar flux is obtained at almost 12 p.m. with an amount of 716 W/m^2; however, the ambient temperature reached a maximum of 38.4 °C at 2 p.m.

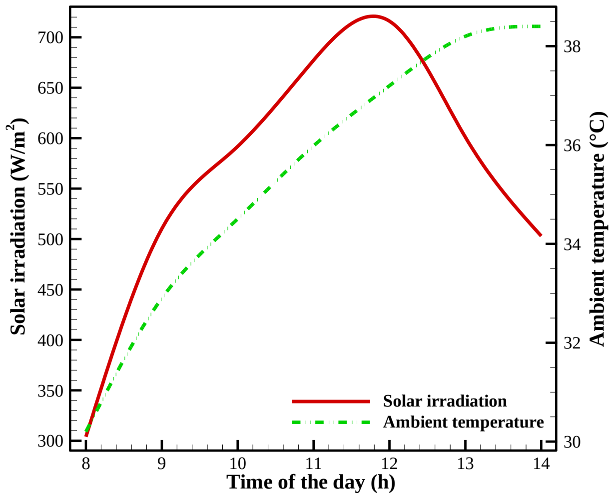

Figure. 4 Average daily variations of solar irradiation and ambient temperature during the tests period in October.

Before examining the hybrid system, it is beneficial to investigate the performance of the parabolic through solar collector. As shown in Figure.1, the closed loop of supplied hot water consists of a collector and a storage tank. The storage tank is employed to storage heat during the day to use the energy at the time with lower sun radiation. Figure. 5 demonstrates the solar collector inlet and outlet temperatures of the working fluid during the test time as well as the storage tank temperature. As can be seen, all mentioned temperatures increase during the test time and reach the highest amount of 78 °C at the end of the day. The thermal efficiency of the parabolic solar collector is determined by.:

$$\eta_{th} = \frac{\dot{m}_{collector} C_p (T_{w,out} - T_{w,in})}{I \, A_{collector}} \quad (1)$$

in which, $\dot{m}_{collector}$, Cp, $T_{w,out}$, and $T_{w,in}$ are the water mass flow rate, specific heat capacity, outlet and inlet temperatures, respectively. The mass flow rate of water was constant and equal to 0.0277 kg/s during the experiments. $A_{collector}$ and I represent the aperture area of concentrator (given in Table 2) and beam radiation (see Figure. 4), respectively. The variations of the thermal efficiency of the solar collector with time is presented in Figure. 5. According to the Figure, a similar trend to the solar irradiation can be observed for the thermal efficiency. On the other words, the thermal efficiency increases by rising the solar irradiation, while by decreasing the solar irradiation, the difference between the inlet and outlet temperatures significantly reduces and as a result, the thermal efficiency falls down. The optimal efficiency is achieved once the collector received the most amount of solar flux at noon and its value is equal to 0.64. However, the maximum supplied hot water temperature of 78 °C is achieved once the efficiency is 0.49.

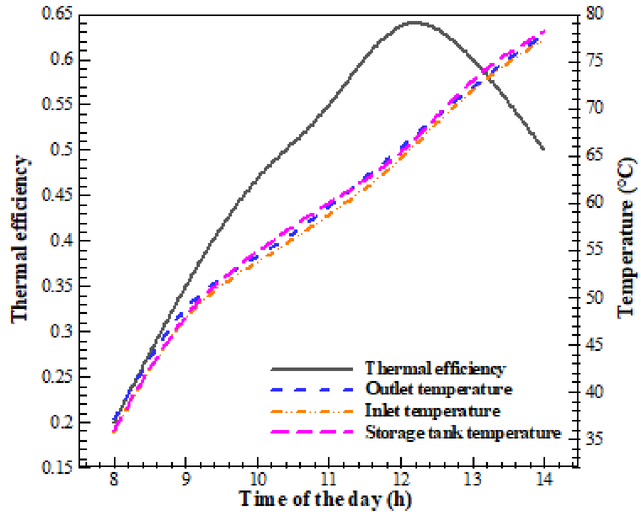

Figure 5. Thermal efficiency of the parabolic through solar collector along with the working fluid outlet and inlet temperatures and storage tank temperature during the tests.

Two main operating parameters, including pressure and the temperature, are examined in this section for two major components of the system: the generator and the evaporator. Firstly, the pressure and the temperature of the generator using ethyl ether-acetaldehyde and LiBr-water solutions are compared in the figure. 6. As can be seen, the generator temperature of the system with LiBr-water solution is higher than the system with ethyl ether-acetaldehyde one due to the higher boiling point of water. Except the initial time, which the temperature of the system with ethyl ether-acetaldehyde is higher than another one, the changing phase occurs in ethyl ether-acetaldehyde mixture sooner and the latent heat of fusion of acetaldehyde consumes the heat dissipated by the hot working fluid. Consequently, higher temperature of generator of the system with LiBr-water solution leads to an increase in the pressure through the generator as illustrated in Figure. 6, where the pressure of generator with LiBr-water mixture is higher than the other one in whole the test time. The pressure rises to the condenser pressure, and then, the evaporation continues under the constant condenser pressure.

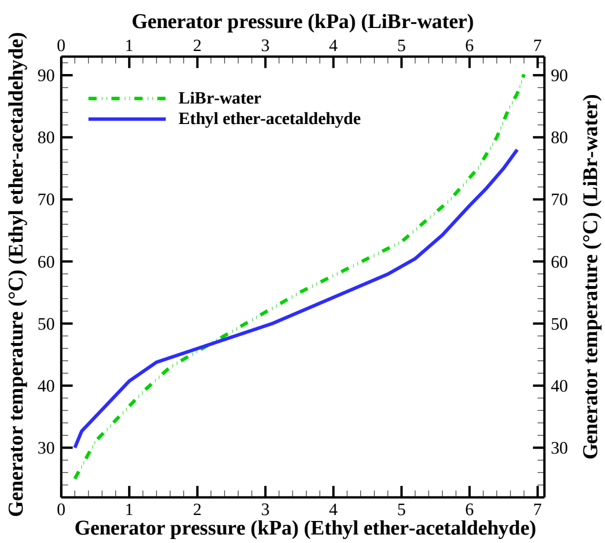

Figure 6. Comparison of the generator (a) temperature and (b) pressure using two different solutions of ethyl ether-acetaldehyde and LiBr-water.

The variations of the evaporator pressure with produced chilled water temperature are measured during the experiments and plotted in Figure. 7, for both ethyl ether-acetaldehyde and LiBr-water. Due to the difference between the physical properties of two mixtures, the evaporator works under the different conditions. Increasing the temperature in evaporator leads to an increase in its pressure, which is sharper for the case with LiBr-water. Moreover, it is interesting to mention that in the same conditions, hot water temperature of 78 °C, the absorption cooling system with ethyl ether-acetaldehyde solution produces the chilled water with a temperature of 7 °C, which is approximately half of the temperature produced by the system with LiBr-water (16 °C). Therefore, the chiller with ethyl ether-acetaldehyde solution produces the desired result at lower inlet temperature in comparison with the chiller working with LiBr-water pair. The latter needs to a higher inlet water temperature of above 90 °C to produce colder chilled water in evaporator.

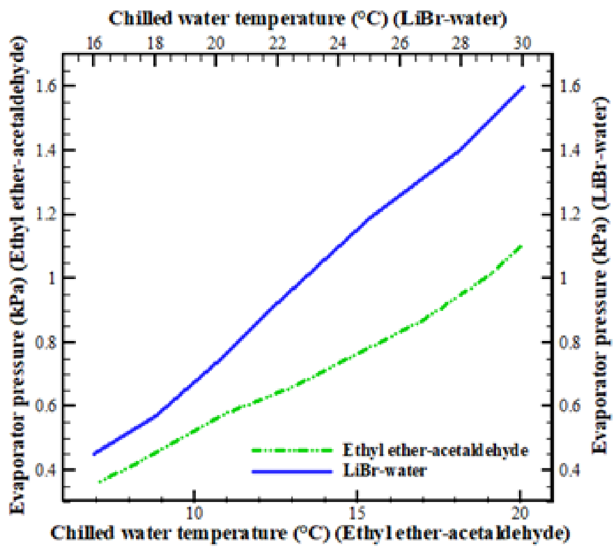

Figure 7. Comparison between the evaporator pressure-chilled water temperature response of the chiller with ethyl ether-acetaldehyde and LiBr-water solutions

The figure. 8 shows the temporal variations of the amount of the mass for the solution in generator and the entered mass of refrigerant into the condenser for ethyl ether-acetaldehyde solution as an example. As can be seen, initially, the mass of the solution in generator sharply decreases due to the process of evaporation within the generator; however, by passing time, the rate of evaporation declines. Consequently, in contrast, the refrigerant mass in condenser increases. Moreover, the evaporated mass is equal to the condensed mass in condenser.

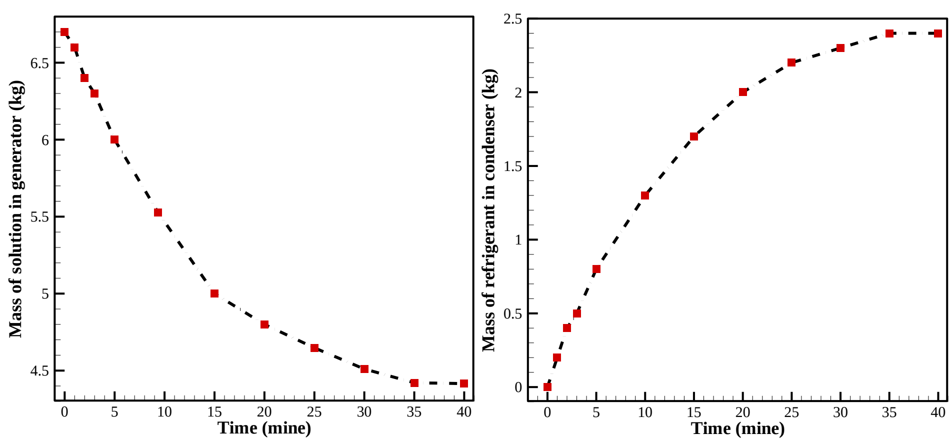

Figure 8. Variations of solution mass in generator and refrigerant in condenser.

To evaluate the performance of an absorption cooling system, the coefficient of performance (COP) is introduced as follows:

$$COP = \frac{Q_{evaporator}}{Q_{supplied}} \quad (2)$$

where, the $Q_{evaporator}$ is the cooling energy produced by the evaporator and $Q_{supplied}$ represents the supplied heat by the solar collector to generator. It should be noted that work done by pump is negligible; therefore, it is neglected in this study.

The variations of the COP with condenser temperatures are illustrated in Figure. 9. The COP of this system depends on the amount and state of the collected refrigerant. The high concentration of refrigerant and pressure difference between the evaporator and condenser lead to release more refrigerant vapor, since in any refrigeration system, the COP improves with increasing the pressure difference between the evaporator, condenser and generator. As can be seen in Figure. 9, the COP declines by increasing the condenser temperature, which this reduction is more pronounced for ethyl ether-acetaldehyde solution due to the mentioned reasons in this section. Moreover, the COP of the hybrid system with LiBr-water ranks first once the condenser temperature is higher than about 29 °C. It is outstripped by the system using ethyl ether-acetaldehyde solution, which experiences a dramatic rise with the reduction in condenser temperature because of the sharp increase in the evaporation rate of acetaldehyde in the generator unit. The COP of the LiBr-water system increases from 0.31 to 0.64, when the condenser temperature decreases from 36 to 20 °C. This variation is more pronounced for the cooling cycle with ethyl ether-acetaldehyde, where the COP increases from 0-0.78 for such condenser temperature change. Consequently, for low-temperature of condenser, lower than 29 °C, employing ethyl ether-acetaldehyde and for the higher condenser temperature using LiBr-water solution are recommended. It should be noted that the proposed system with ethyl ether-acetaldehyde could be worked at low-temperature range of 50-80 °C with relatively good COP, which it is suitable for areas with hot and moderate temperatures.

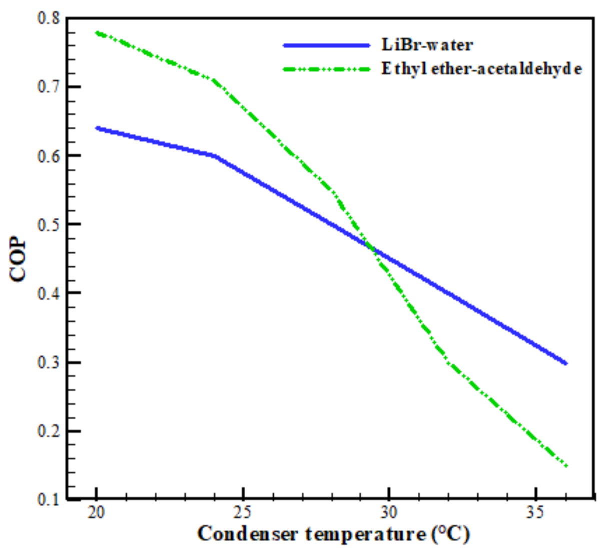

Figure 9. COP-condenser temperature response for the systems working with ethyl ether-acetaldehyde and LiBr-water.

The temporal variations of COP for a small interval of 300 sec once the operation of refrigerant reduces in generator for the systems with ethyl ether-acetaldehyde and LiBr-water are presented in Figure. 10. As can be seen, generally, the COP decreases due to the reduction in cooling energy produced by the evaporator for both cases, while this reduction is more pronounced for ethyl ether-acetaldehyde pair. However, the value of COP is higher for the ethyl ether-acetaldehyde compared to the other one in whole considered time.

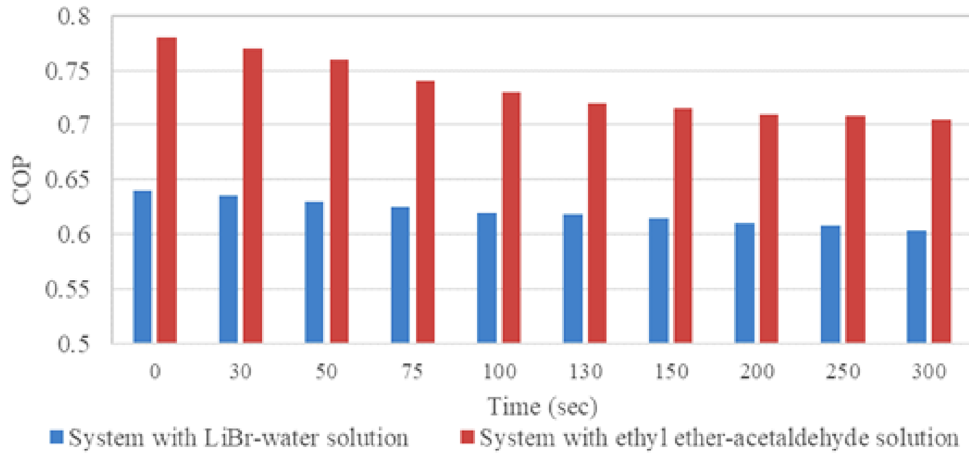

Figure 10. Variations of COP with time using two different solutions of ethyl ether-acetaldehyde and LiBr-water.

CONCLUSIONS

This experimental work focuses on proposing solar-driven the absorption cooling system with a new solution and comparing the new refrigerant mixture with a common one in the literature. In this context, an absorption cooling system integrated with a parabolic through solar collector working with two different working pairs, namely, LiBr-water and ethyl ether-acetaldehyde has been presented. The pressure and temperature of different components along with the COP of the system are discussed. Through practical experiments that were conducted, the following points can be concluded

1.The proposed hybrid system with ethyl ether-acetaldehyde as a solution could work at a low-temperature range of 50-80 °C with relatively good COP. Therefore, the use of this solution was recommended for areas with hot and moderate temperatures.

2.The recommended solution could work under mild pressure and low-temperature heat source.

3.The absorption system worked efficiently at generator temperatures of 40 to 78°C.

4.The new pair (ethyl ether-acetaldehyde) could provide chilled water at evaporator with a temperature of 7 °C, while this temperature was higher for the common solution of LiBr-water, which was 16 °C.

5.The highest value of COP equal to 0.78 was achieved when the ethyl ether-acetaldehyde mixture had been used, while the maximum amount of COP was 0.64 when LiBr-water was employed. Nevertheless, when the generator temperature was lower than nearly 57 °C, the LiBr-water performed well.

6.The novel working pair showed a significant enhancement in COP in comparison with LiBr-water, thus this working pair could be a feasible alternative solution in solar-driven absorption refrigeration systems.

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