Solar Powered Air-Conditioning Using Absorption Refrigeration Technique

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ABSTRACT

The present work includes design, construction and operates of a prototype solar absorption refrigeration system, using methanol as a refrigerant to avoid any refrigerant that cause global warming and greenhouse effect. Flat plate collector was used because it's easy, inexpensive and efficient.

Many test runs (more than 50) were carried out on the system from May to October, 2013; the main results were taken between the period of July 15, 2013 to August 15, 2013 to find the maximum C.O.P, cooling, temperature and pressure of the system. The system demonstrates a maximum generator temperature of 93.5 ^{o}C, on July 18, 2013 at 2:30 pm, and the average mean generator temperature T_{gavr} was 74.7 °C, for this period. The maximum pressure Pg obtained was 2.25 bar on July 19, 2013 at 2:00 pm. The current system shows cooling capacity of 0.15 ton with coefficient of performance of 0.48, and minimum evaporator temperature obtained was 14.2^{o}C.

A comparison of the present with previous works, showed that most of the previous work used ammonia as the main refrigerant, and even that used methanol it was as aqua methanol, or to be part of pair refrigerant, while the present work use the methanol as the main and the only refrigerant in the system. The results and the factors that provided by the current work, give a good understanding for using the methanol as a refrigerant with the solar absorption system. And the system can work in continuous operation cycle. This work gave fundamental understanding for designing solar refrigeration system, by using the results of present study to design air-conditioning unit, with one ton capacity, using the solar energy, and the methanol as a refrigerant.

Keyword: solar power, absorption refrigeration, methanol

منظومة تبريد هواء تعمل بالطاقة الشمسية بأستخدام تقنية التثليج بالامتصاص

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الخلاصة

البحث الحالي يشمل على تصميم وتصنيع نموذج اولي لنظام تبريد بتقنية الامتصاص يعمل بالطاقة الشمسية، ويستخدم الميثانول كمادة مبردة في المنظومة كونه لايحمل اثار سلبية تزيد من عملية الاحتباس الحراري ولا يسبب تلاشي طبقة الاوزون، حيث تم استخدام مولد شمسي من نوع اللوح السطحي كونه سهل التصنيع وقليل الكلفة وله كفاءة جيدة في عمل المنظومة.

اجريت العديد من التجارب على النموذج الاولي من شهر ايار الى تشرين الثاني 2013 ، وبصورة رئيسية في الفترة مابين 15 تموز الى 15 اب لعام 2013 للحصول على اقصى معامل اداء وطاقة وحرارة وضغط مطلوب لتشغيل المنظومة. واظهرت التجارب اقصى درجة حرارة ومقدارها 93.5 درجة مئوية بتاريخ 18 تموز 2013 الساعة 2:30 بعد الظهر، وكذلك معدل درجة للمولد مقدارها 74.7 درجة مئوية للفترة ذاتها، وكذلك اقصى ضغط تشغيلي مقداره 2.25 بار، بتاريخ 19 تموز 2013.
واعطت المنظومة الحالية قدرة تبريد مقدارها 0.15 طن ومعامل اداء مقداره 0.48 مع ادنى درجة تبريد في المبخر مقدارها 14.2 درجة مئوية.
الدراسة الحالية تضع المفاهيم الاولية والاساسية لعملية تصميم منظومة تبريد بالامتصاص تعمل بالطاقة الشمسية بالاعتماد على نتائج الدراسة الحالية، وتوضح الدراسة خطوات اساسية لتصميم منظومة تبريد هواء بالامتصاص تعمل بالطاقة الشمسية وبقدرة واحد طن بأستخدام الميثانول كوسط تبريد رئيسي.
كذلك تم اجراء مقارنة بين العمل الحالي والأعمال السابقة ، أظهرت أن معظم الطرق الاخرى تستخدم الأمونيا كغاز تبريد رئيسي.

الكلمات الرئيسية: طاقة شمسية، تثليج امتصاصي، ميثانول

1. INTRODUCTION

The concerns on energy price, the depleting of resources and the global climate changes are given more attention to environment-friendly and sustainable alternatives. The energy crisis in the seventies, and the unclear future of energy situation, increase the demand for exploiting alternative energy sources, the most important alternative source that inspiring people is the solar intensity energy.

The solar energy is collector area dependent, and is a diluted form of energy and is available for only a fraction of the day. Also, its availability depends on several factors such as latitude and sky clearness. At the same time, its system requires high initial cost. But on the other hand, it has some attractive features such as its system requiring minimum maintenance and operation cost, and it does not have negative effects on the environment. Another important feature of solar energy is its ability to satisfy rural areas where conventional energy systems might be not suitable or uneconomical, **Duffie & Beckman, 1980**.

The conventional refrigeration systems require mechanical energy as the driving source and are responsible for the emission of CO_2 and the other green house gases such as chlorofluorocarbon CFCs and hydro chlorofluorocarbon HFCs which are considered major cause for ozone layer depletion. From this context the absorption refrigeration system attains a considerable attention in 1970s due to the energy crisis and ecological problems related to the use of CFCs and HFCs. **Anyanwu, 2012.**

The Montreal Protocol (1987) controls the release and use of CFCs, and has set a time scale schedule for eliminating their production. This agreement is an historic step in the ongoing process of building consensus regarding environmental impacts of CFCs.

The International Institute of Refrigeration in Paris (IIF/IIR) has estimated that approximately 15% of all the electricity produced in the whole world is employed for refrigeration and air-conditioning processes of various kinds, and the energy consumption for air-conditioning systems has recently been estimated to 45% of the whole households and commercial buildings, **Santamouris**, **1994**.

Due to the international attempt to find alternative energies, absorption refrigeration has become a prime system for many cooling application. Where thermal energy is available the absorption refrigerator can very well substitute the vapour compression system, **Epstein**, **1992**.

Researchers have proved that the absorption refrigeration technology has a promising potential for competing with the conventional vapour compression refrigeration systems. In comparison with the vapour compression refrigeration systems absorption refrigeration systems have the benefits of energy savings if powered by waste heat or solar energy, simpler control, absence of vibration and low operation cost. **Anyanwu, 2012.**

More interests have been paid to the solar thermal-driven refrigeration technologies, especially solar sorption (absorption and adsorption) systems, due to the low efficiency of the solar photovoltaic collectors of (10–15%) contrary to that of the solar thermal collectors, and the electrically driven systems are characterized by the limited useful power that can be achieved by solar means, and also by their fairly high initial cost, **Papadopoulos** ,**2003**, and **Dind**, **2004**.

One of the most common solar air conditioning alternatives is a solar powered absorption system. The solar absorption system is similar in certain aspect to the conventional vapor compression air conditioning system in that the electrical compressor; is replaced with a solar-powered generator and absorber. **Fig.1** shows a commercial flat-plate solar-powered single-effect absorption cooling system. The most standard pairs of chemical fluids used include lithium bromide-water solution ($LiBr$-H_2O), where water vapor is the refrigerant and lithium bromide is the absorbent, and ammonia-water solution (NH_3-H_2O) with ammonia as the refrigerant and water the absorbent, **ASHRAE, 1997**.

The aim of the present work is to study the performance of solar absorption refrigeration using methanol. For this study a solar absorption refrigeration unit was constructed. The system was operated mainly during the months of May to October (2013) for a period of 8 hours per day (8 am to 4 pm).

2.EXPERIMENTAL WORK

The system consists of a generator, condenser, absorber and evaporator, all were connected using copper pipes of 3/8" or 9.5 mm, and the heat exchanger is used with the system between the evaporator and the absorber, some of the connections made by welding and others by copper fittings. **Fig. 1** shows the schematic diagram for the system and **Fig.2** shows the absorption refrigeration system a.

The generator was assembled using 11 copper pipes of 12.7 mm and 1 m long, the two ends of the pipes were connected to two main pipes at the top and bottom, each of these pipes was a copper pipe; 1.25 m in length and 28.58 mm, in diameter, all the pipes were of thickness of 1mm. Painted black to improve its solar absorbing capabilities. The generator is rectangular in shape with the dimensions of (125 cm x 125cm x 10 cm) and at 20° incline angle, and with a total volume of 3 liters, without the header. The generator total area is 0.66 m^2, **Fig. 3** below shows the generator.

The absorber consists of main vessel that contains the refrigerant. It is a steel container of thickness of 0.8 mm, and 13 l in capacity. The absorber has 4 openings; one for inlet pipe coming from the heat exchanger followed by the evaporator, the second is used as outlet, connected to the generator, the third is used as the filling point of refrigerant, and the forth is used as drain.

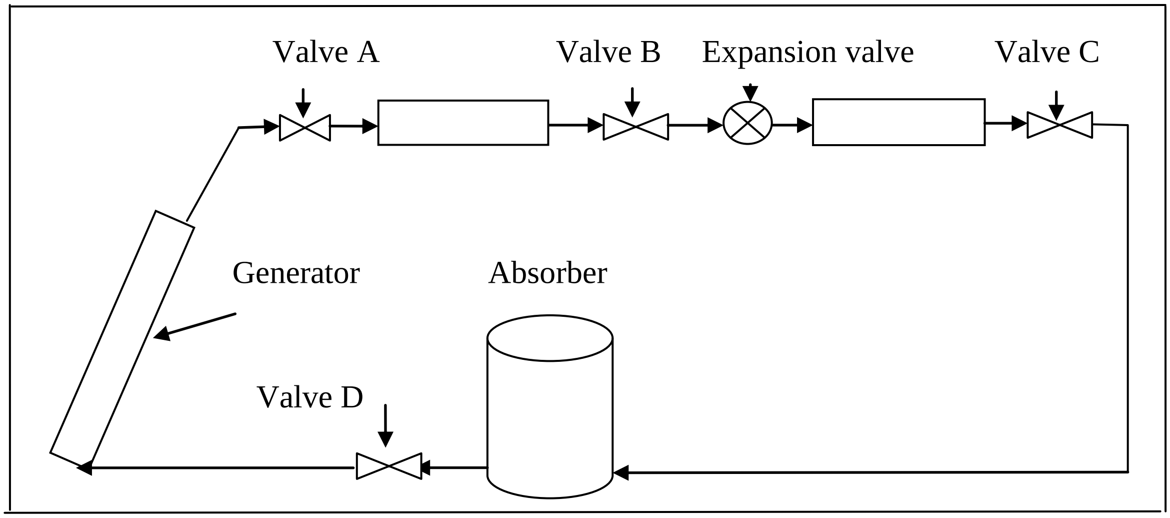

Figure 1. Schematic diagram of the solar absorption refrigeration system.

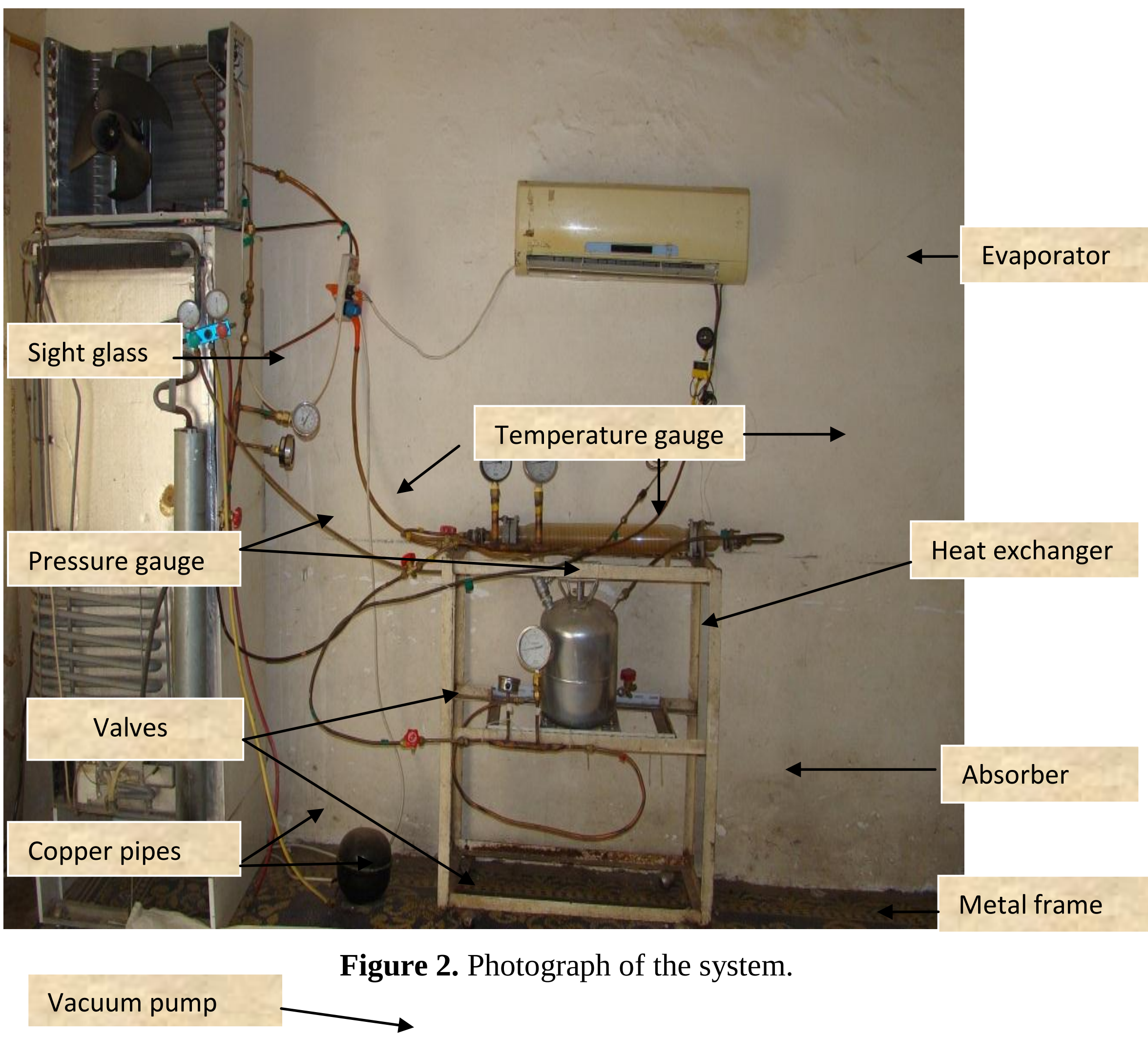

Figure 2. Photograph of the system.

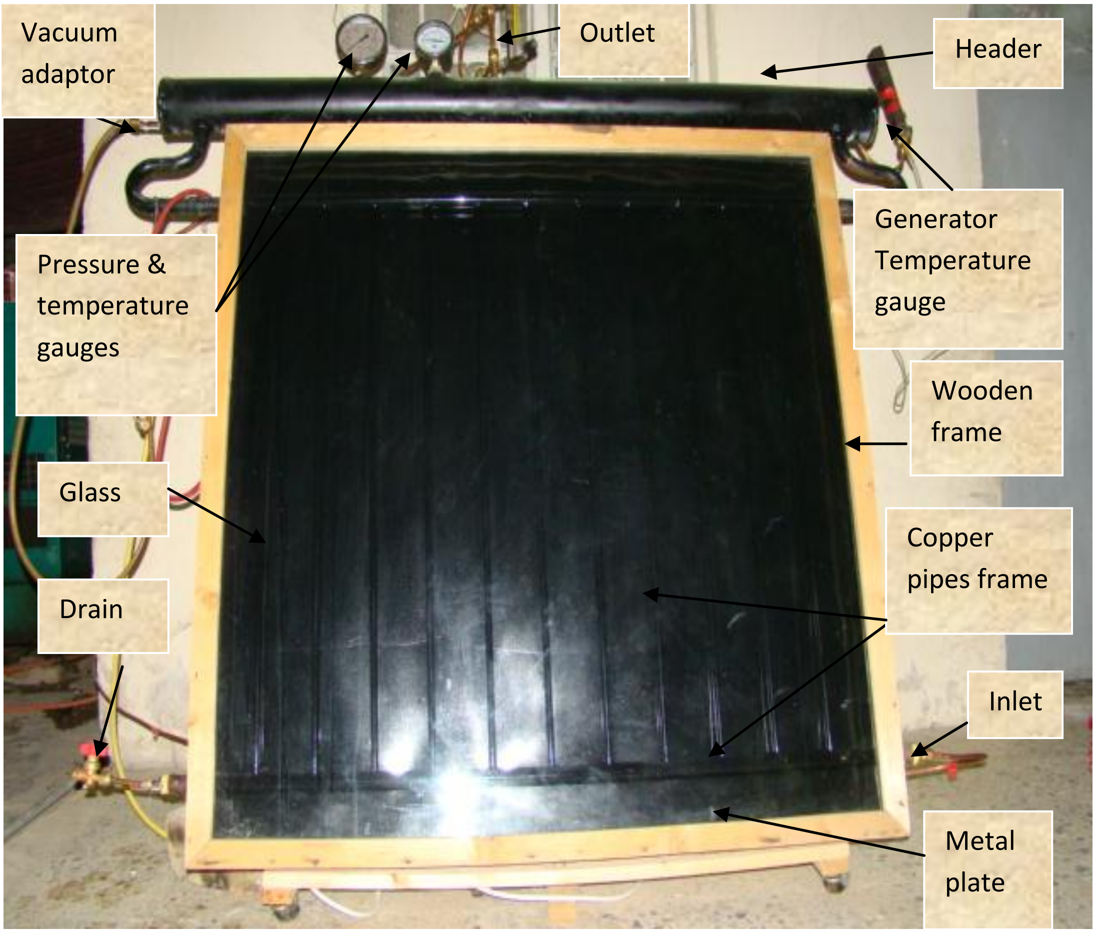

Figure 3. A photograph of the generator.

3.EXPERIMENTAL PROCEDURES

At the start of the generation process valve A is opened and valves B, C, D are closed. The generator kept in a position facing the sun at the angle of 20^{o} to start solar absorption to heat the generator and the liquid inside. Methanol starts to evaporate and the vapour accumulates in the header producing vapour at high pressure, then methanol vapour pass to the condenser which is cooled by forced air. Readings were taken each 15 minutes; these records include ambient temperature, generator metal temperature and the vapour temperature and pressure at the header.

At the maximum pressure produced in the generator, refrigeration process starts. To start the refrigeration process valves B and C are opened and valve D is closed, the condensate refrigerant pass to the evaporator under the pressure produced in the generator, and refrigeration occurs due to the passing of the refrigerant inside the expansion valve, which causes boiling of the refrigerant and a decrease in the pressure inside the evaporator, which leads to absorb the heat from the surrounding of the evaporator. Readings were taken each 5 minutes for the temperature and the pressure of the evaporator. Then the vapour passes to the heat exchanger which is cooled by passing cold water with normal flow to condense the refrigerant that accumulates at the absorber tank, which will refill the generator again.

4.RESULTS AND DISCUSSIONS

Many test runs were made on the solar absorption refrigeration system, using methanol as a refrigerant in these experiments, the system demonstrated interesting results. The main results were taken between the period of July 15, 2013 to August 15, 2013 to find the maximum energy, temperature and pressure that the system can reach. There were many test runs obtained along the period of October 2012 to October 2013, to find the operation of the system in different seasons. There were about 50 tests have been carried out for the generator, and 10 tests to find the optimum operating pressure of the methanol refrigerant in the evaporator.

VARIATION OF GENERATOR AND SOLUTION TEMPERATURE AND GENERATOR PRESSURE WITH TIME.

Fig. 4 to 7. show that the generator temperature (T_g), is higher than refrigerant vapour temperature (T_s), and the maximum temperature obtained was 93.5 ^oC, in July 18, 2013 at 2:30 pm. And the average mean generator temperature (T_{gav}) was (74.7 °C).The maximum pressure (Pg) obtained was 2.25 bar on July 19, 2013 at 2:00 Pm.

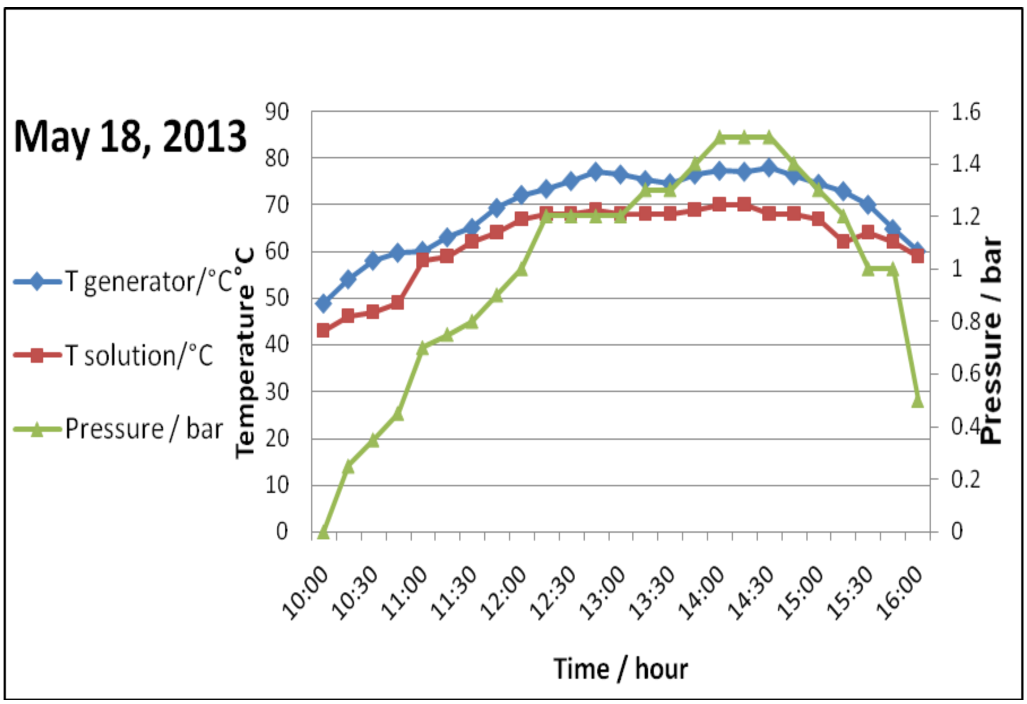

Figure 4. Variation of generator and solution temperature and generator pressure with time.

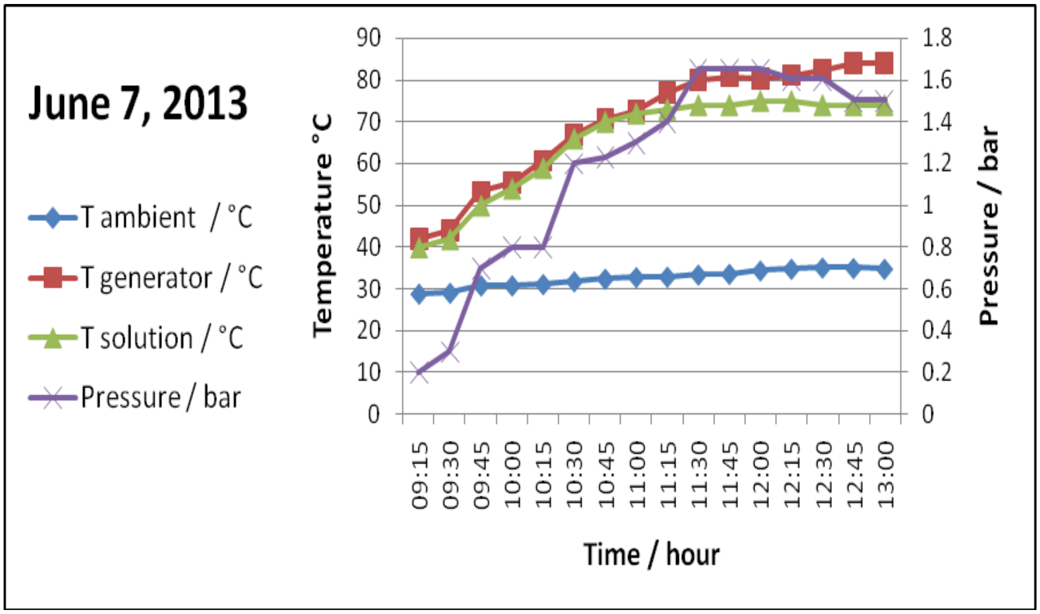

Figure 5. Variation of generator and solution temperature and generator pressure with time**.**

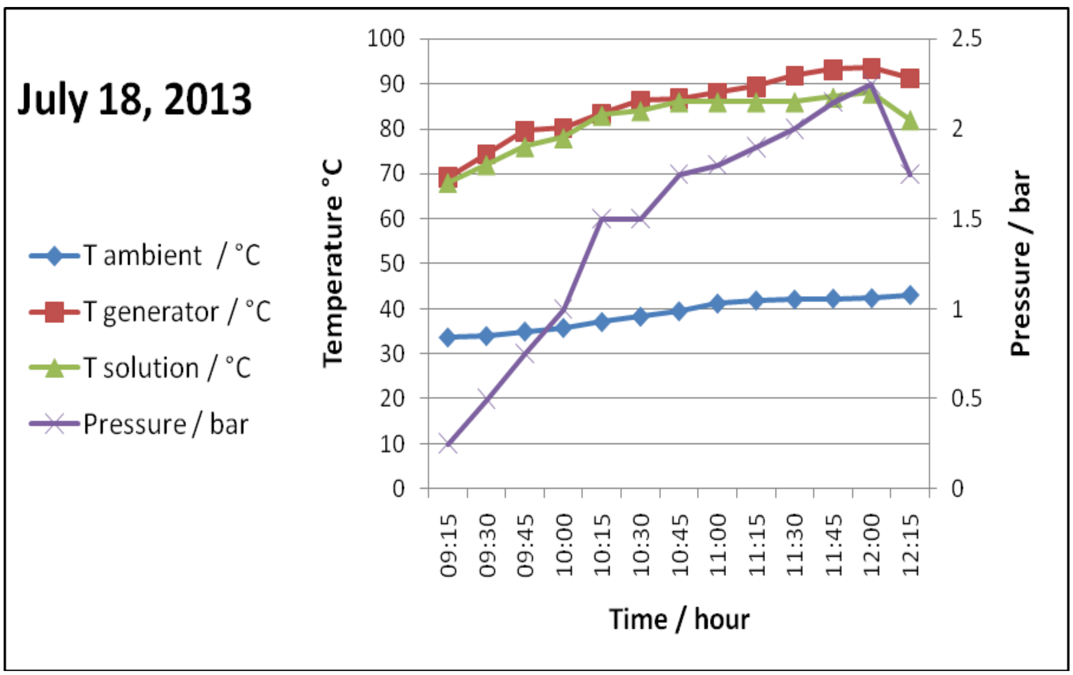

Figure 6. Variation of generator and solution temperature and generator pressure with time**.**

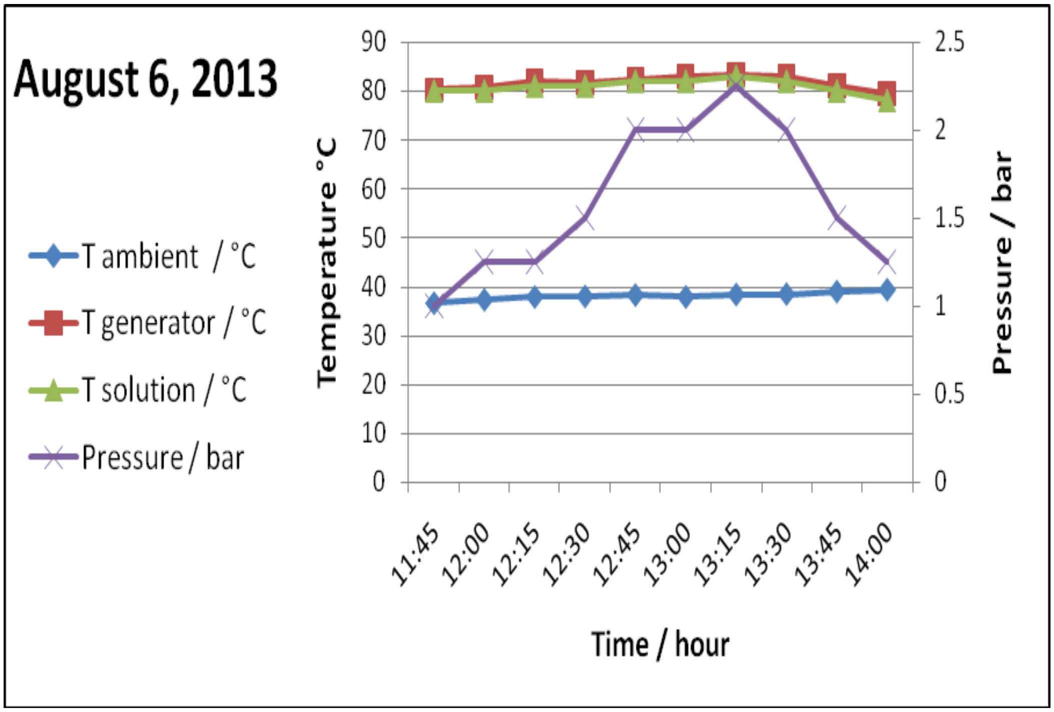

Figure 7. Variation of generator and solution temperature and generator pressure with time**.**

REFRIGERATION CYCLE AND VARIATION OF TEMPERATURES AND PRESSURE WITH TIME.

The indoor cycle or refrigerating cycle occurred when the liquid methanol passes through the evaporator by the expansion valve, with the operating pressure that produced by the generator, then the methanol evaporates at the evaporator, absorbing the heat in the surrounding making the evaporator cool**. Fig. 8** and **Fig. 9** show the refrigeration process results of the system, and the variation between evaporator temperature (T_e), absorber temperature (T_a), and the evaporator pressure (P_e), absorber pressure (P_a) with refrigeration time.

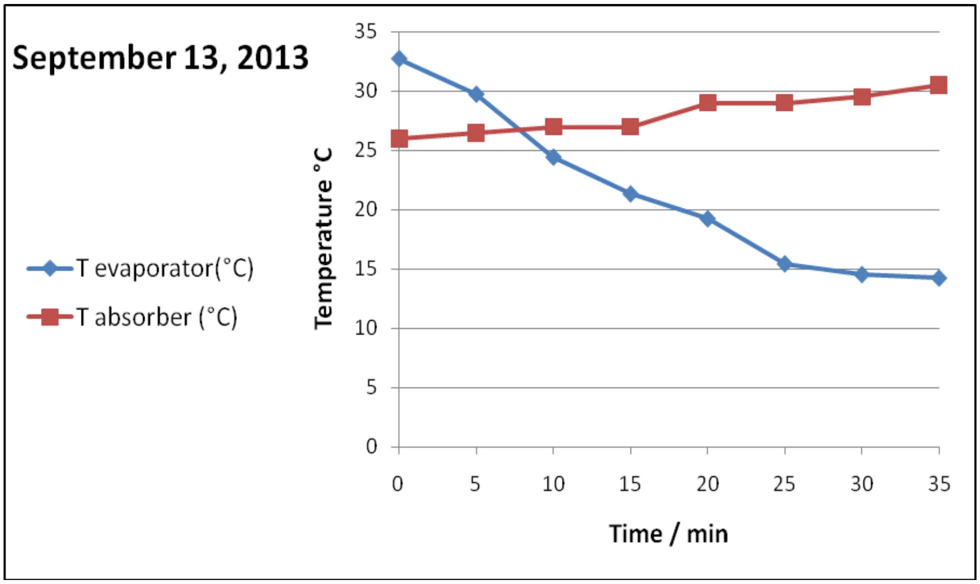

Figure 8. Variation of the temperature and pressure in the evaporator and the absorber with time.

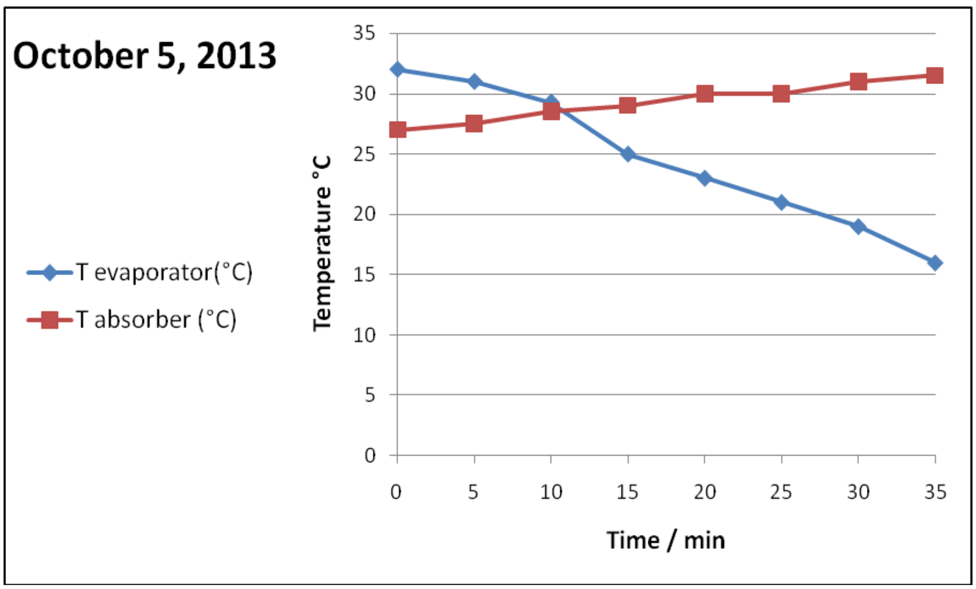

Figure 9. Variation of the temperature and pressure in the evaporator and the absorber with time.

EFFECT OF MAXIMUM TEMPERATURE ON C.O.P

Fig. 10. shows the distribution of coefficient of performance plotted with generator temperature and pressure. The C.O.P increases with the increasing of the generator temperature and pressure; this increase is due to the increasing quantity of the methanol evaporated from the generator.

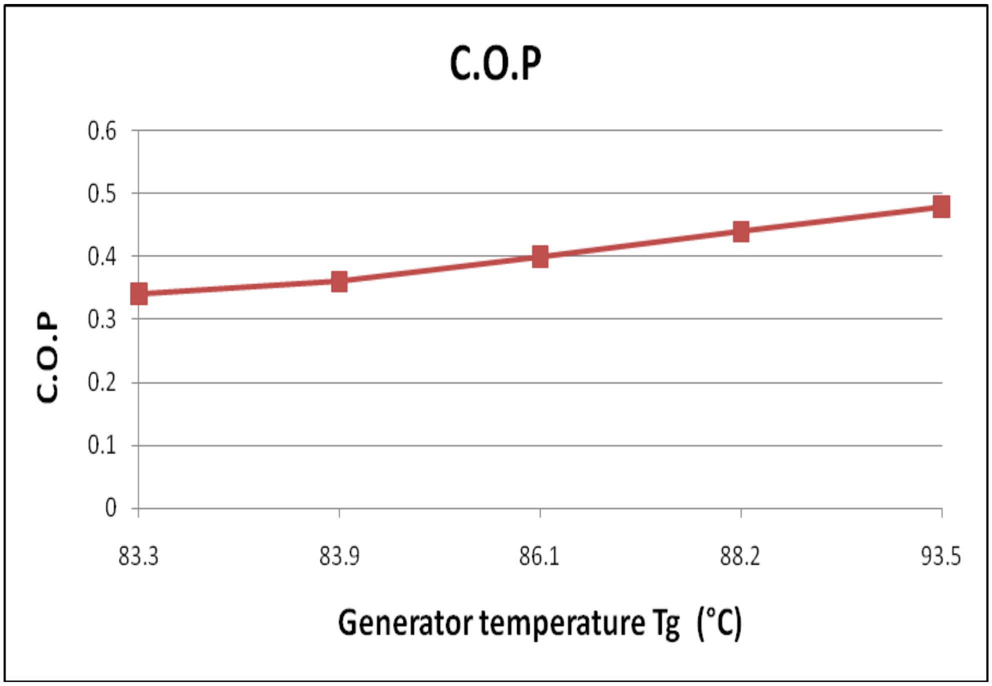

Figure 10. Effect of maximum generator temperature on C.O.P.

EFFECT OF MAXIMUM GENERATION TEMPERATURE ON COOLING LOAD

Fig. 11 shows that the cooling load of the system increases with the increase of the generator temperature. This increase in cooling load is due to the increase of the evaporated methanol and the pressure of the system.

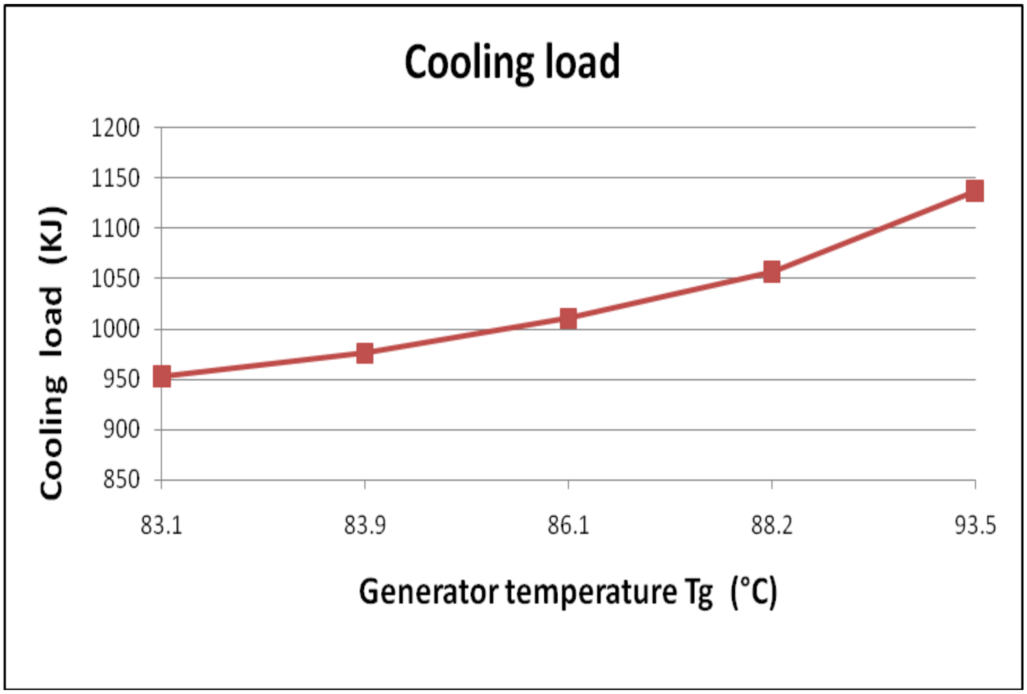

Figure 11. Effect of maximum generator temperature on cooling load**.**

MINIMUM EVAPORATOR TEMPERATURE

The increase in generator temperature leads to an increase in the cooling capacity of the system, which means lowering the evaporator temperature to the minimum temperature. That means the minimum evaporator temperature decreases with the increase of the maximum generator temperature. **Fig. 12** shows that the temperature of the evaporator decreases with the increase of the generator temperature, this is due to the fact of increasing the quantity of the methanol evaporated and the increase of the pressure, which causes circulation of the refrigerant.

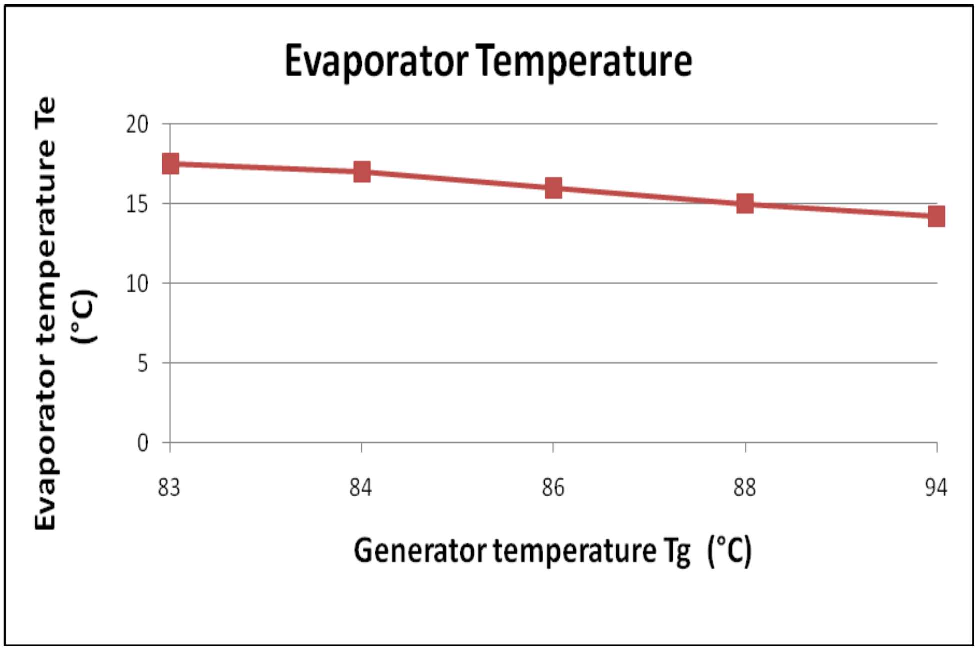

Figure 12. Effect of maximum generator temperature on the evaporator temperature**.**

CONCLUSIONS

1- The operation of this type of system is environmentally efficient, because it uses refrigerant that doesn't affect the Ozone layer, and uses a renewable energy that reduce the source depletion of the energy sources, also the system use clean energy that produce no waste gas that affect or increase the global warming, which demonstrate the sustainable development requirement for the future projects and researches.

2- The generator type and specification used in this work showed that the Maximum temperature that can be reached is 93 °C, and this can be achieved during July and August.

3- The system used with the design criteria and the condition that related to the experiments produced cooling capacity of 0.15 ton, and the C.O.P (0.35-0.48).

4- The employed operating pressure produced minimum evaporator temperature of (14.2°C -17°C).

5- The cooling ratio or C.O.P increases with the increase of the generator temperature.

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