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Performance of an Intermittent Absorption Cycle refrigerator Producing Continuous Cooling Effect.

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PERFORMANCE OF AN INTERMITTENT ABSORPTION CYCLE REFRIGERATOR PRODUCING CONTINUOUS COOLING EFFECT

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خلاصه – يستعرض البحث نتائج التجارب العمليه للاداء الحرارى لجهاز تبريد بالامتصاص لبخار الامونيا فى الماء ، يعمل بالطاقه الشمسيه على دائره الامتصاص المتقطعه ، ولكن يمكنه انتاج طاقه تبريد بصفه مستمره . والجهاز به اثنين من (مولد البخار – ممتص) يتبادلان العمل ليلا ونهارا بواسطه التحكم فى مجموعه من الصمامات لأداء هذا الغرض ، ويستمد الطاقه الحراريه اللازمه لتشغيله من مسطح ماص للطاقه الشمسيه مساحته ٢م٢ . وقد تم قياس درجات الحراره والضغط فى أماكن مختلفه من الجهاز ، كما قيست كثافه الاشعاع الشمسى الكلى ودرجات حراره الجو أثناء فتره التجارب . وقد أظهرت التجارب امكانية عمل الجهاز نهارا ، وهذه نتيجه هامه جدا حيث ان الأجهزه السابقه تقوم بالتبريد ليلا فقط ، وقد تراوحت قيم معامل الاداء الحرارى حول ١ر٠ عند مستوى اشعاع شمسى متوسط . أما درجات حراره المبخر فقد تراوحت بين –١ و ٢٥°م حيث وجد أنها تتأثر بشده بطريقه التحكم فى تشغيل الجهاز ودرجه حراره الجو .

ABSTRACT- In the present work, the performance of a solar powered intermittent absorption refrigerator, which can produce a continuous cooling effect is presented. The refrigerator employs a flat-plate solar collector of 2 m^2 area to supply the Ammonia-Water absorption cycle with required heat. For this purpose, an experimental set up with two generator-absorber vessels has been built. The continuous cooling effect can be obtained by a proper manual control of eight valves connecting the system components. The cycle pressures and the system temperatures at different locations are measured. Also the solar radiation data and ambient temperature are recorded during the experimental work. Results are given in graphical form. The system coefficient of performance COP ranges around 0.1 over the 24 hours, and the evaporator temperature is seen to be highly dependant on the valves adjustment and the ambient temprature .

1. INTRODUCTION

In 1959, trombe and Foex (1) have actually started the experimental attempts to test and operate the Ammonia-Water solar absorption refrigeration system. They have built an ice maker which was able to produce 5 kg of ice for each square meter of a solar reflector, during four hours heating. It is believed that, the first experimental results on the system were conducted in 1959 by Eisentadt et al (2). Their tests have demonstrated the system feasibility in the field of air conditioning.

On the other hand, the intermittent cycle has been described and studied by Chinnappa (3), concluding that subzero cooling can be achieved by using a flat-plate collector. In order to verify this fact experimentally, Chinnappa (4) has built a system with a well designed flat-plate collector. A generator temperature of 100 °C, corresponding to a solar insolation of 700 W/m^2 was measured. The system COP over 6 hours cooling, varied from 0.058 to 0.06, while the minimum evaporator temperature recorded was -9.7 °C. However, the change in the solution concentration was from 0.398 to 0.462 inside a water-cooled absorber. Another system (5) was able to produce 6 hours night cooling effect, with an evaporator temperature ranging from -7 to 0°C, while the ambient temperature was 8°C. Also an evaporator temperature as low as -12°C could be obtained with a similar design (6-8).In a better case, a minimum evaporator temperature of -17°C has been recorded, with a selective coated flat-plate collector (9). The cooling effect (from 6 to 10 a.m.) was performed in an ambient temperature of 10 °C, while the system COP varied from 0.09 to 0.152, corresponding to a maximum solar radiation of 700 W/m^2.

On the other hand, Ramadan (10), has built a similar system and studied the effect of some parameters on its thermal performance. He concluded that, for a given condenser temperature, the cooling effect increases and the evaporator temperature decreases by lowering the initial solution concentration. Another system (11) has been built in the National Research Centre (Cairo), to study the thermal requirements of the generation process. Two mathematical correlations linking the generator temperature and heat with the other system parameters are derived.

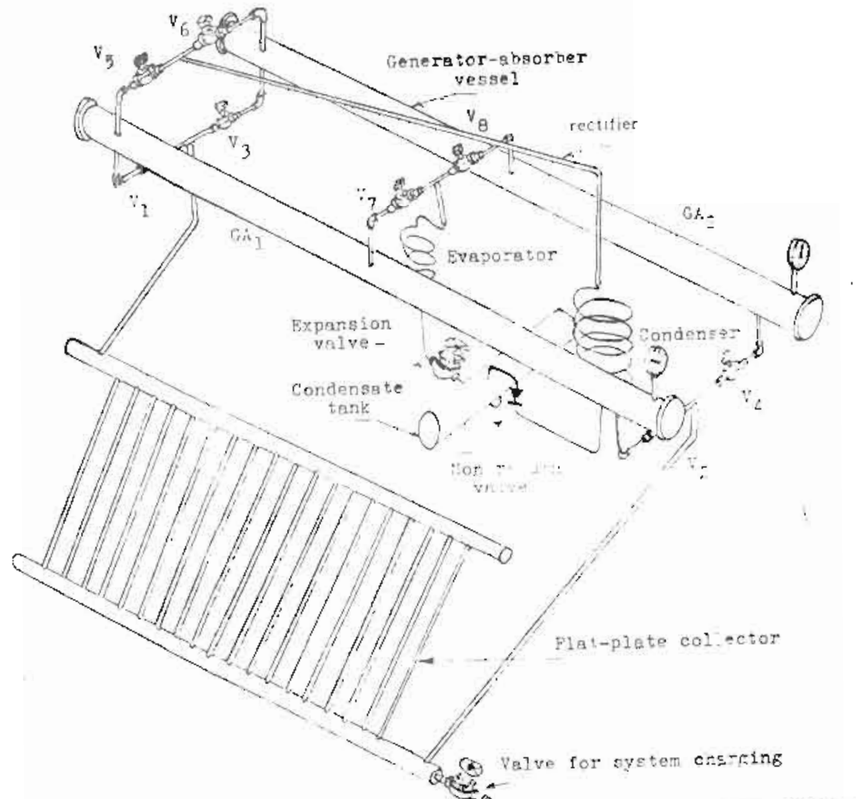
However, most of the above researchers reported on a bad absorption process, due to the close concentrations of the weak and rich solutions. This problem has been dealt with by Venkatesh and Mani (12). They have built a two stage system to improve the absorption process, and hence the cooling effect. A system COP of 0.235, corresponding to a generator temperature of 70°C has been obtained. On the other hand, the system should be modified to produce cooling effect at the sunshine period, which is essentially important, specially in tropical countries. This is the object of this work, and is carried out by using an additional generator-absorber vessel with some control valves.

2.EXPERIMENTAL SET UP

The experimental set up consists of solution and refrigerant circuits as shown schematically in Fig. 1. The flat-plate collector is connected with two generator-absorber vessels, forming the solution circuit. These two vessels exchange the generation and absorption processes in sequence. The components of the refrigerant circuit are, the rectifier, condenser, non-return valve, condensate tank, expansion device and the evaporator. In fact, the two circuits are linked by one of the generator-absorber vessels. The specifications of the system components are given below.

Flat-Plate Collector :

The flat-plate solar collector consists of a finned-tube flat absorber cased in a wooden box, and coverd with a double glass cover. The solar absorber is fabricated with 19 steel tubes of 100 cm length, and 3/4 inch inner diameter, fitted at 10 cm centre to centre distance, with two tubular headers of 220 cm length and 2 inch diameters. Strips of G.I. sheets (1 mm thick) are welded between tubes to form the solar absorber, which is painted with blackboard paint and fixed in a wooden box. The back and sides are insulated with 10 cm glass wool layer. The double glass cover which consists of two ordinary window glass layers (3 mm thick), 2 cm apart, is fixed at a distance of 5 cm from the solar absorber. The collector is tilted 27° facing the south direction.



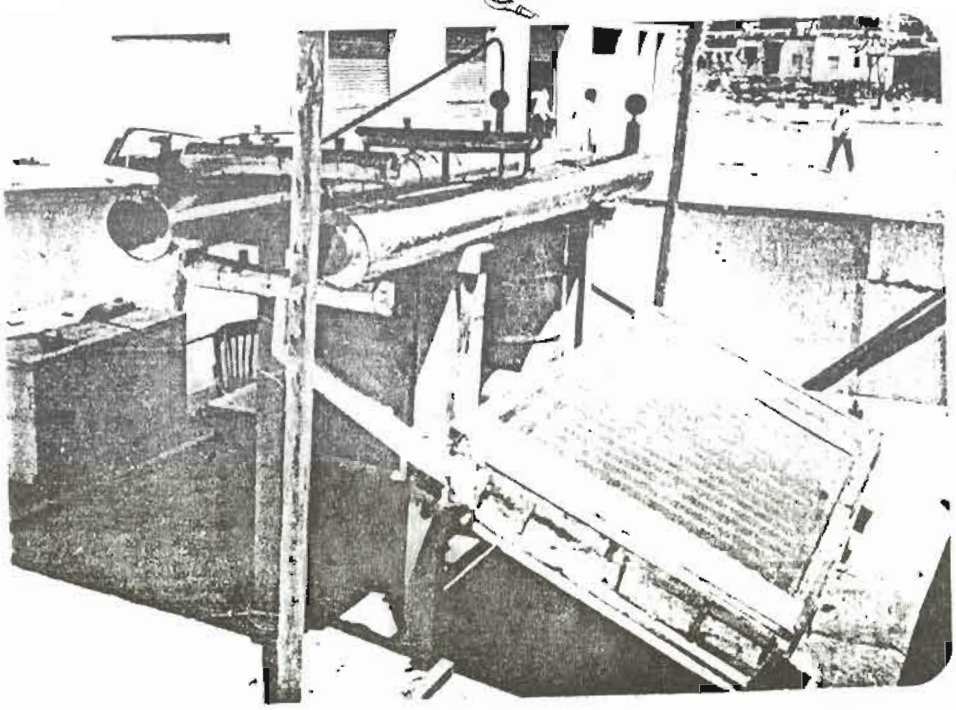


Fig. 1. Schematic diagram and photograph of the experimental set up.

Generator-Absorber Vessels :

Each of the generator-absorber vessels is a 4 inch diameter steel pipe of 3 m length, closed at both ends by steel discs, and insulated with a 6 cm glass wool layer which can be easily removed. The two pipes are supported horizontally at a vertical distance of 70 cm from the collector upper header and fitted with two pressure gauges. The insulation is removed when the vessel works as an absorber.

Rectifier :

The rectifier is simply an inclined 1/2 inch diameter steel tube, connecting the generator outlet to the condenser coil inlet points. The length of the rectifier is 175 cm and tilted about 20° to the horizontal.

Condenser :

The condenser consists of a coil placed in a stagnant water tank. A steel tube of 8 mm I.D. and 5 m length is used to form the coil. The tank which has a 60 cm diameter and a 80 cm height, is filled with water to a level of 75 cm, and fixed under the generator-absorber vessels.

Condensate Tank :

The condensate tank is a peice of the 4 inch pipe with a length of 80 cm, insulated with a 6 cm glass wool layer and fixed horizontally beside the condenser tank.

Evaporator :

The coil of the evaporator, which is made from a 7 mm I.D. and 500 cm steel tube, is placed in a water tank (25 cm diameter and 30 cm height) to measure the cooling effect. A glass wool insulation is backed in the space between this tank and an outer wooden box which has dimensions of 40x40x70 cm. The evaporator is supported beside the condensate tank.

Expansion Device :

An ordinary 1/8 inch gate valve is used as an expansion device, which is manually controlled.

Control Valves :

All the eight control valves (3/4 inch), as well as the non-return valve, have no copper parts, since it highly reacts with Ammonia. The function of these valves is to keep one of generator-absorber vessels working as a generator (with the flat-plate collector), while the other performing the absorption process (with the cooling circuit).

The set up is suitably instrumented to measure the temperature at various locations on its components. Also, total solar radiation on the collector tilted surface, and ambient air temperature are measured.

Charging The System :

The system is checked for any leakage by compressed water, and evacuated to an extremely low pressure for charging the Ammonia-Water solution and Ammonia liquid. According to the system size and design calculations (13), the amounts of Ammonia-Water solution (with a concentration of 0.2) and Ammonia liquid to be charged are estimated by 20 and 21 Kg respectively. During the charging process, the apparatus is cooled by spraying cold water to prevent temperature rise due to the heat released by the absorption of Ammonia in the weak solution.

3. RESULTS AND DISCUSSION

The system is subjected to some preliminary tests to overcome any technical problems facing its operation. The short term performance of this system is described here, through the data collected from three different experiments. The system is allowed to operate for a long time before each experiment, to attain its steady cyclic variations during the measurements.

Fig. 2 shows the results of the first experiment, obtainend over 24 hours (starting from midnight) at a clear sky condition and a moderate solar radiation intensity. The vessel GA_1 which was working as an absorber before 4.50 a.m., exchanges its function with GA_2, by closing the valve V_7 and opening V_8 at this time. Generation process is started at 6 a.m. by opening the valves V_1 and V_2, conneting the vessel GA_1 with the flat-plate collector, and continued to 6 p.m. The opening condition for each valve is represented by a horizontal line, corresponding to its opening duration as shown in the figure. However, the results of this experiment are not satisfactory, since the evaporator temperature (surface temperature of the evaporator coil at exit) is not very low compared to the ambient temperature. It is believed that this is because of the following reasons :

a- The absorption process is not efficient, because the direct solar radiation hits the absorber surface, raising its temperature and hence decelerating the absorption rate. Therefore, the absorber should be shaded to improve the absorption during sunshine periods.

b- The time of exchanging duties between vessels GA_1 and GA_2 (4.50 a.m.) is not properly fixed. It can be shifted to any other time, with the resulting drop in evaporator temperature, to maintain it always at a lower level compared to that of the ambient.

c- It is believed also that the expansion valve is not properly adjusted.

However, minimum evaporator temperatures of 5°C at 5 a.m., and 4°C at 9 p.m. are obtained as shown in Fig. 2. The variations in the evaporator temperature are seen to follow that of ambient temperature, while the generator pressure increases with the solar radiation intensity. The absorber pressure increases with increasing the absorption rate.

In the second experiment, the absorber is partially shaded and the expansion valve is slightly tightened. The time of exchanging duties between GA_1 and GA_2 is also shifted to 10.30 a.m. as shown in Fig. 3. Therefore, results are improved showing a lower evaporator temperature during the day time, compared to that of ambient. A minimum evaporator temperature of -1°C is recorded at 10.30 a.m. The water inside the evaporator is heated to 30°C at 9.15 a.m. to measure its temperature drop during a certain period, and hence calculate the cooling effect and the system COP. The heat losses to surroundings can be ignored, since the evaporator water temperature is changed around that of ambient. Therefore, the approximate value of the system COP during this period is estimated by 0.12.

The third experiment is carried out with a complete shading to the absorber. Valve V_8 is also partially opened to restrict the expansion of Ammonia in order to decrease the rate of absorption during the day time. This is becaues the cooling of absorber by ambient air was seen to be insufficient during the day time. Figure 4 shows the system performance over the 24 hours (starting from noon time). The evaporator temperature recorded a minimum value of 5°C at 10 p.m.

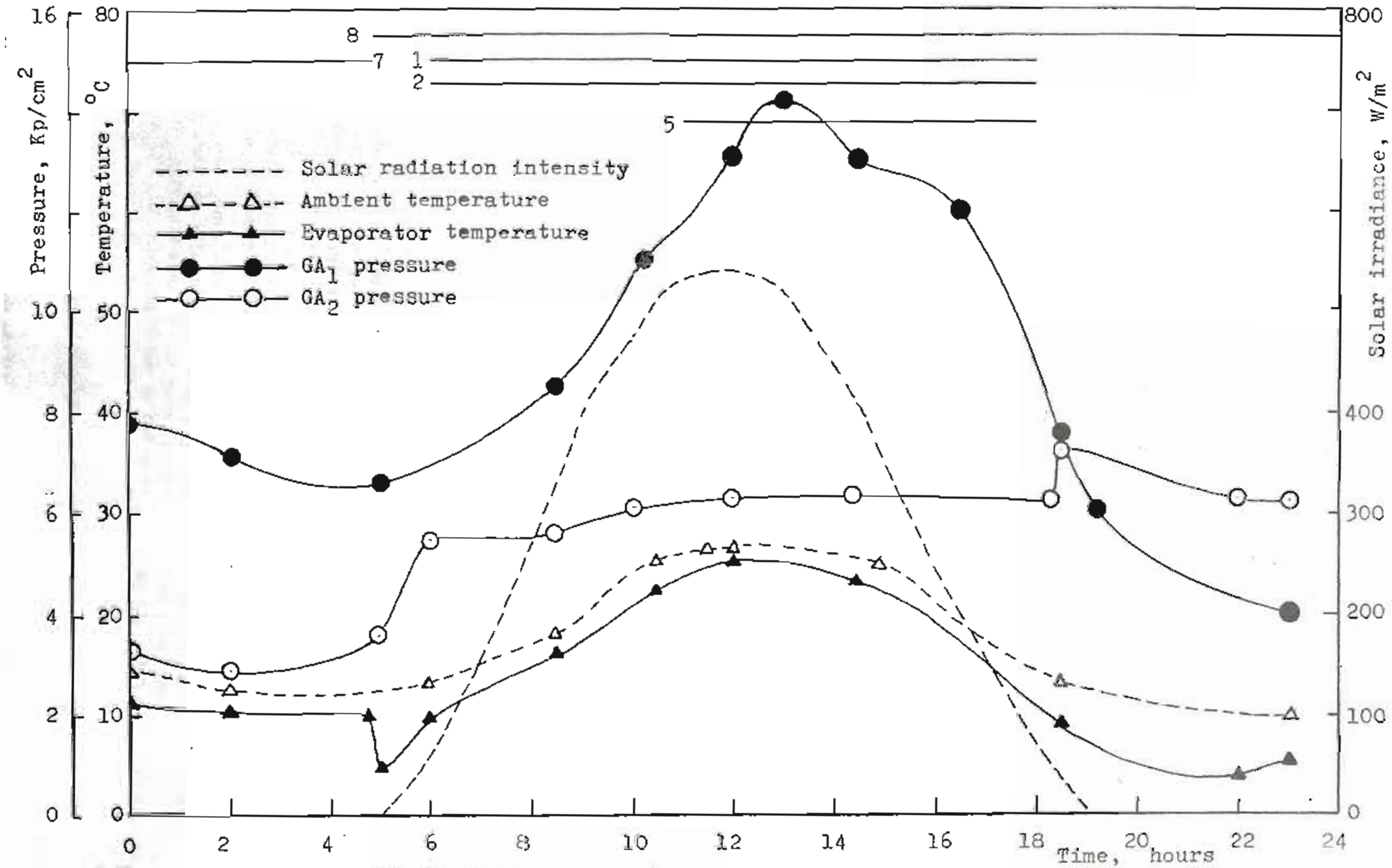


Fig. 2. Results of the first experiment (Date: 16 April, 1987).

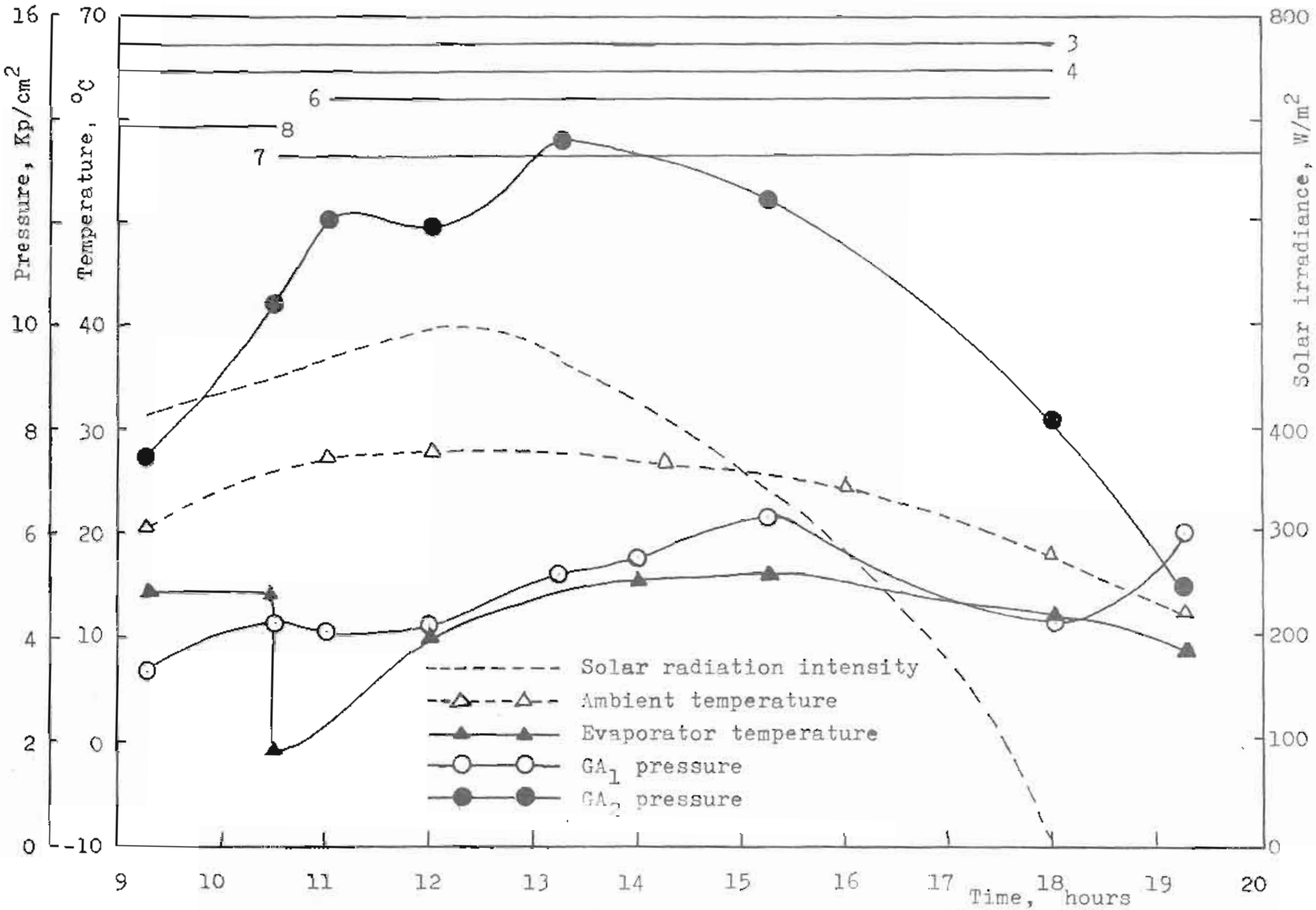


Fig. 3. Results of the second experiment (Date: 19 April, 1987).

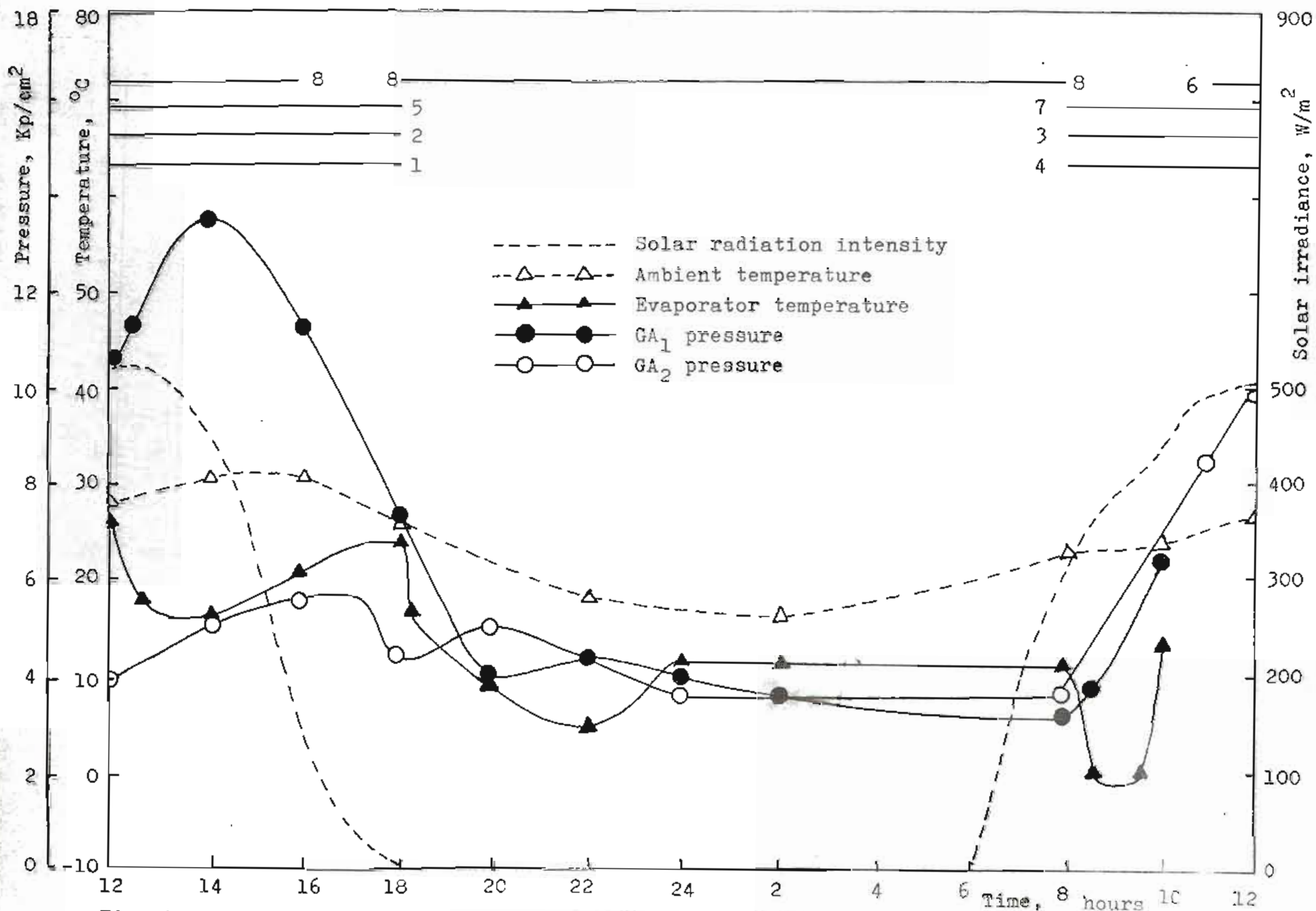


Fig. 4. Results of the third experiment (Date: 28, 29 April, 1987).

and -1°C at 9 a.m. The state of all valves is shown in the figure. The system COP is estimated by 0.08 during this period. However, according to the system design calculations (13), a predicted value of 0.146 for the system COP, under the same conditions can be obtained.

4. CONCLUSION

The simple solar-powered intermittent-cycle refrigeration system is modefied by introducing an additional generator-absorber vessel, in order to produce continuous cooling effect. The performance of a modefied system with a flat-plate collector of 2 m^2 area is experimentally tested. An evaporator temperature as low as -1°C is recorded, but it was found to be highly dependant on the ambient air temperature and the valves control and adjustment. However, cooling of the absorber during the day time by the ambient air is not sufficient. Results have shown that the system is able to produce cooling effect at any time of the day if the valves are carefully controlled. The improvement of the absorption process and control procedure, and testing the long term performance of the system with computer simulation, are proposed for future study.

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5. REFERENCES

1- T. Trombe and M. Foex "The production of cold by Means of Solar Radiation", Solar Energy, Vol. 1, 1, pp.51, 1957.

2- M.M. Eisentadt, F.M. Flanigan and E.A. Farber, "Solar Air Conditioning With an Ammonia-Water Absorption Refrigeration System", Paper No. 59-A-276, ASME (1959).

3- J.C.V. Chinnappa, "Experimental Study of the Intermittent Absorption Refrigeration Cycle Employing the Refrigerant-Absorbent Systems of Ammonia-Water and Ammonia Lithium Nitrate", Solar Energy,Vol. 5, pp. 1-18, 1961.

4- J.C.V. Chinnappa, "Performance of an Intermittent Refrigerator Operated by a Flat-Plate Collector", Solar Energy, 7, 187 (1962).

5- R.K. Swartman, "A Combined Solar Heating/Cooling System", Presented in the International Solar Energy Congress And Exposition (1975).

6- R. Alward, "Solar Powered Absorption Refrigerator", M.E.Sc. Thesis, The University of Western Ontario, Canada, 1968.

7- R.K. Swartman and C. Swaminathan, "Solar Powered Refrigerator", Mechanical Engineering, P. 22., June 1971.

8- R.K. Swartman and C. Swaminathan, "Further Studies on Solar Powered Intermittent Absorption Refrigeration", Paper No. 6/114, ISES Conference, Mulbourne, Australia, 1970.

9- M.D.Staicvoici, "An Autonomous Solar Ammonia-Water Refrigeration System", Solar Energy Vol. 36, No.2, pp, 115-124, 1986.

10- Ramadan A.Ramadan, "An Investigation Into Solar Refrigeration", Ph.D. Thesis, Department of Mechanical Engineering, Alazhar University, Cairo, 1986.

11- W.H. Tadros, "Thermal Requirement of the Generator of Solar Intermittent Ammonia-Water Absorption Refrigeration System", Ph.D. Thesis, Department of Mechonical Power Engineering, Cairo University, Cairo, 1986.

12- A. Venkatesh and A Mani, "Description and Performance Prediction of a Two Stage Intermittent Solar Refrigeration System", International Symposium on Thermal Applications of Solar Energy, Japan, 1985.

13- H.E. Gad and A.M. Hamed, "Continuous Operating-Intermittent Basis Solar Absorption Refrigeration System", Bulletin Of the Faculty of Engineering, El-Mansoura University, Vol. 11, No.2, pp.M. 133-M.140, December 1986.