ISSN: 2278-4632
Vol-11 Issue-02 2021

# ANALYSIS OF TWO STAGE SOLAR VAPOUR ADSORPTION REFRIGERATION SYSTEM

**P K Das, Mir Naseer Hussain**
[1](Mechanical Engineering, Gandhi Engineering College,Bhubaneswar)
[2](Mechanical Engineering, Gandhi Engineering College, Bhubaneswar)

**ABSTRACT**

*Solar adsorption refrigeration devices are of great significance to meet the needs forcooling requirements of the modern world. They are environmental friendly, non- corrosive, noiseless, and do not require any electricity when compared to the VCRS. Various solar powered cooling systems have been tested extensively; however, these systems are not yet ready to compete with the commercially used vapour compression system. For these reasons, research activities in this sector are still increasing to solve the technical, economic and environmental problems. The objective of this project is to fabricate and analyse a two stage vapour adsorption refrigeration system using activated carbon-methanol pair and to compare the system performance for different evaporator loads. Based on the experiment, the two stage adsorption system is showing an increase in performance as the evaporative load increases, but the temperature difference in the evaporator is decreasing as the loadincreases.*

**Key words:** Adsorption, Vapour Adsorption Refrigeration System (VARS), Activated carbon-methanol pair, solar COP.

## I. INTRODUCTION

The use of solar energy for various purposes is receiving much attention as a result of the projected world energy shortage. Refrigeration is particularly attractive as a solar energy application because of the near coincidence of peak cooling loads with the available solar power [1][3]. It can also be effective in reducing the emission of CFCs and HFCs which are listed as a major source of ozone layer depletion [1].

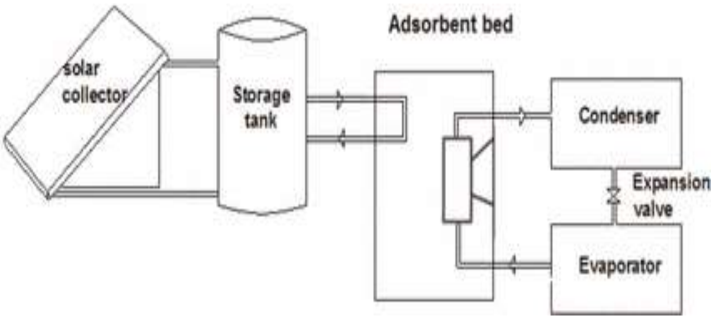
Solar refrigeration has the potential to improve the quality of life of people who live in areas with shortage of electricity. It is usually used for storage of agricultural products, food and medicines (e.g. vaccines) in remote areas [3]. The adsorption system is one of the promising solar thermal refrigeration methods, and it is environmental friendly along with low cost and low maintenance requirements. As the adsorption system utilises the heat energy, it can be deployed in effective waste heat recovery systems to make use of the heat content of the exhaust which is elsewasted.

Despite of a large potential market, existing solar refrigeration systems are not competitive with electricity-driven refrigeration systems because of their high capital costs [1]. Improvements such as reduced collector area, improved system performance, and reduced collector cost will lower the cost of solar components. Several solar refrigeration systems have been proposed and are under development, such as sorption systems including liquid/vapour, solid/vapour absorption, adsorption and photovoltaic-vapour/compression systems. Most of the above mentioned systems have not been economicallyjustified.

## II. SYSTEM DESCRIPTION

The adsorption refrigeration machine used in this experiment consists essentially of a solar collector receiver circuit and a refrigeration circuit [3]. The refrigeration circuit consist of an evaporator, an expansion device, a condenser and an adsorber containing a porous medium, (activated carbon) reacting by adsorption with methanol. The method of working is similar to that of a VCRS except for the thermal compressor, which doesn't require electric power to work [5]. The Solar collector receiver circuit consist of a parabolic trough solar collector and a storage tank. The parabolic trough heats up the water in the tank which is circulated through the pipe passing through the focus of parabolic trough using thermosyphon system. Valves are provided along the circuit to ensure proper flow of refrigerant (methanol) in the refrigeration circuit and hot water along the solar collector receiver circuit[4].

ISSN: 2278-4632
Vol-11 Issue-02 2021




136

**Figure 1** Solar based adsorption refrigeration system

The adsorption and desorption process is responsible for the flow of refrigerant through the system. Various processes of the cycle can be understood from the clapeyrondiagram

which is plotted between *ln* p and - [1] [2].

Analysis of Two Stage Solar Vapour Adsorption Refrigeration System

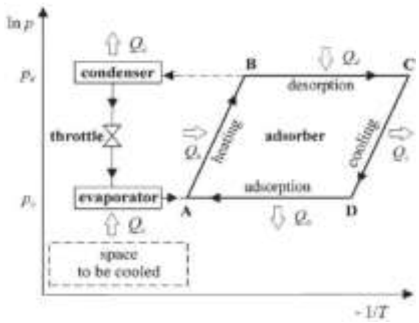



**Figure 2** Clapeyron diagram cycle for adsorption/desorption process

Since the refrigeration is intermittent, a system with two beds out of phase is necessary to realise the continuity [2]. But if a renewable source like solar energy is used as the power, then methods such as sensible heat storage is to be deployed to ensure continuous operation for a longer period of time. The sensible heat thus stored during the day time helps to use the second bed after sunset, thus effectively utilisation of maximum possible available energy can be achieved[4].

The connection of this two stage adsorption refrigeration system is being designed in such a way that by operating a pair of valves the flow through the beds A and bed B can be switched, thereby eliminating the need of separate condensers [2]. The two stage adsorption system is as shown below.

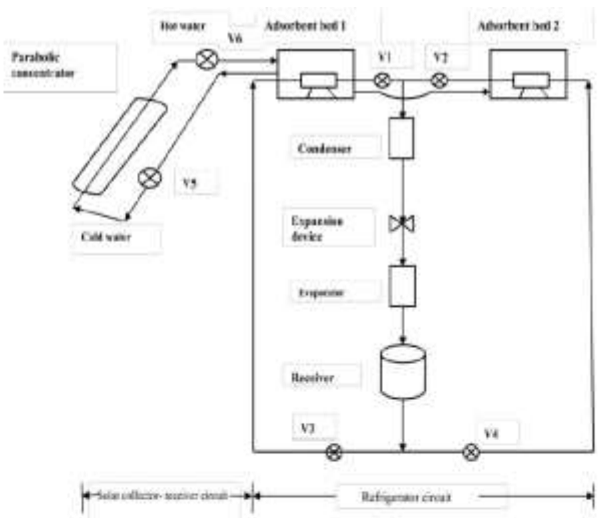



**Figure 3** Solar collector circuit and refrigeration circuit of a two stage solar adsorption system

After sunset, adsorber bed 1 acts as the adsorber and adsorber bed 2 as the desorber. In the evening adsorber bed 2 is cooled down and valve V4 is opened by keeping other valves V1, V2 and V3 closed. After the complete adsorption of refrigerant vapour, the hot water from tank 1 is transferred to tank 2, which acts as a heat source for adsorber bed 2. After the complete adsorption of methanol vapour by adsorption bed 2, the valve V2 is opened by keeping the valves V1 and V3 closed. The refrigerant passes through the condenser, expansion device and evaporator finally the refrigerant vapour is being stored in the accumulator. During this time the bed 1 acts as a adsorber which is cooled down by cooling water to the evaporator pressure so that it is ready for adsorbing the refrigerant stored in the accumulator[2][4].

## III. NOMENCLATURE

$m_{evap}$ - Mass of water in cabin(kg)

$C_p$ - Specific heat of water at constant pressure (kJ/kgK) $\Delta T$- Temperature difference(K)

$COP_{solar}$ - Solar coefficient ofperformance RE - Refrigeration effect(kJ)

CP - Cooling power(W)

$I_{avg}$ - Average solar irradiation during desorption phase (W/m$^2$) $A_{tot}$ - Total area of solar radiation(m$^2$)

$A_{col}$ - Area of collector (m$^2$) $A_{ad.box}$ - Area of adsorption box(m$^2$)

$\lambda$ - Reflectivity of stainless steel(=0.85)

$\varepsilon$ - Absorptivity of copper(=0.9)

$\Phi$ - Transmisivity of glass(=0.85)

## IV. PERFORMANCE PARAMETERS

Objective of a refrigeration machine is to reduce the cabin temperature and therefore, performance of a refrigeration system can be determined by measuring the ability to reduce cabin temperature. The most important parameters used to determine the performance of a refrigeration system is the net refrigeration effect and the COP of the adsorption machine.

Refrigeration effect is the net effect of refrigeration produced in evaporator of the adsorption machine [2] and is given by

$$RE = m_{evap} \times C_p \times \Delta T$$

Since the adsorption system used for this experiment is solar powered, the solar coefficient of performance is to be determined, unlike the simple coefficient of performance as in the case of conventional vapour compressionsystems.

$$COP_{solar} = \frac{€P}{\text{Input Solar Power}}$$

$$CP = \frac{RE}{\text{time for cooling}}$$

$$\text{Input Solar Power} = I_{avg} \times A_{tot} \quad A_{tot} = (A_{col} \times \lambda \times \varepsilon) + (A_{ad.box} \times \Phi)$$

## V. EXPERIMENT

The Solar vapour adsorption refrigeration system was designed, fabricated and tested in the atmospheric conditions of Govt. Model Engineering College, Thrikkakara, Kochi. The testing of the apparatus is done by operating the valves on the suction side and thereby allowing the adsorbent to adsorb the refrigerant. After the sufficient quantity of refrigerant being adsorbed,

the valve on the suction side is closed. Manual tracking is done to achieve maximum input energy to the system. When the temperature increases, the water in the adsorber box get heated up with the help of solar concentrator, and thus increase the temperature of adsorber bed. As the temperature increases, activated carbon desorbs the adsorbed refrigerant and as it rises beyond the boiling point of the refrigerant, the refrigerant is boiled and this increases the pressure inside the thermal compressor. The valves on delivery side are subsequently opened so that the flow of refrigerant from adsorber bed to compressor is possible. The condenser condenses the refrigerant and takes away the heat. It is then passed through the expansion device, capillary tube so that the pressure of the refrigerant is reduced.

The low pressure refrigerant takes in heat from the evaporator coil when passed to the evaporator. This produces refrigeration effect in the evaporator. After taking up the heat from the evaporator, the refrigerant flows back to the sump due to gravity and thus the cycle iscompleted.

After the sunset, the hot water in the day box is being transferred to the night box, which has a bed already adsorbed with the refrigerant. The temperature of water increases the bed temperature and the processes are repeated to establish more output times compared to a single bed adsorptionsystem.

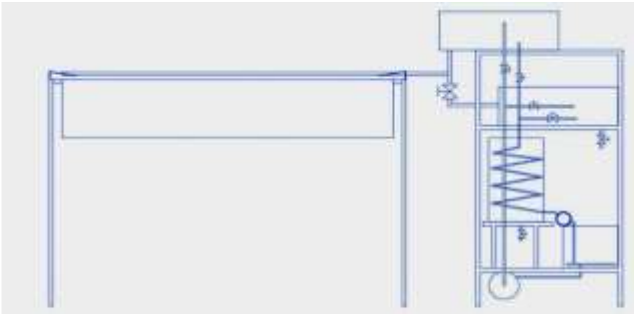


**Figure 4** Circuit diagram of the fabricated adsorption test machine

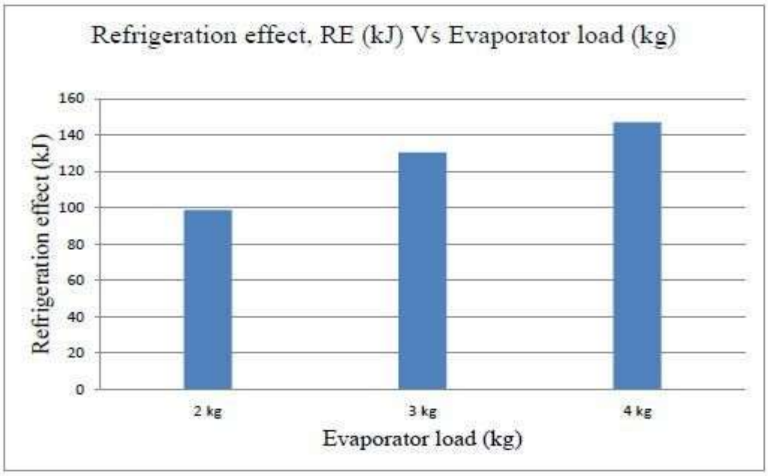
For the purpose of analysis the fabricated system is tested for different evaporative loads and the temperature of the adsorber bed and the cooling cabin is obtained along with the ambient temperature and solar insolation. The variation of these parameters on varying the evaporator load is being tested and plotted. The refrigeration effect and solar COP of the system for various evaporative loads is also obtained and analysed in this project.

## VI. RESULTS AND DISCUSSIONS

Temperature points of adsorber bed and cabin water was obtained and was plotted for various evaporator loads along with variation of solar insolation and ambient temperature of the day on which the experiment was conducted.

**Table 1** Tabulation of Refrigeration effect and solar COP for different evaporator load

| Evaporatorload(kg) | RefrigerationEffect(kJ) | Solar COP |
|---|---|---|
| 2 | 98.65 | 0.069 |
| 3 | 130.416 | 0.087 |
| 4 | 147.136 | 0.096 |



ISSN: 2278-4632
Vol-11 Issue-02 2021

**Figure 6** Variation of refrigeration effect (kJ) for different evaporator loads

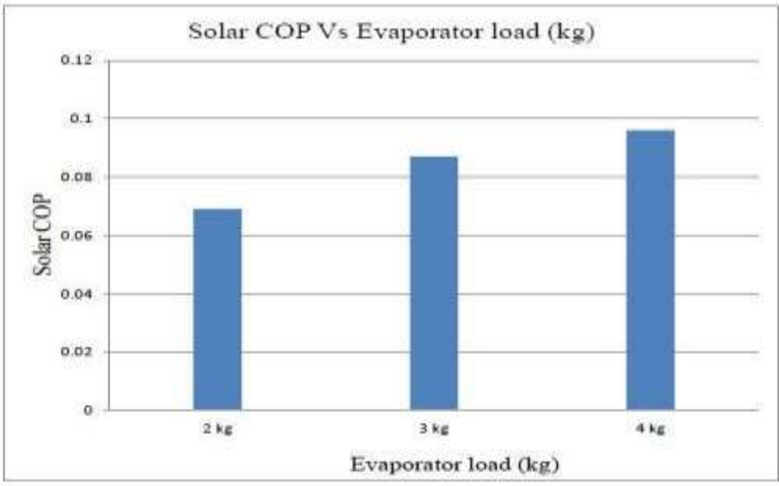



**Figure 7** Variation of Solar COP for different evaporator loads

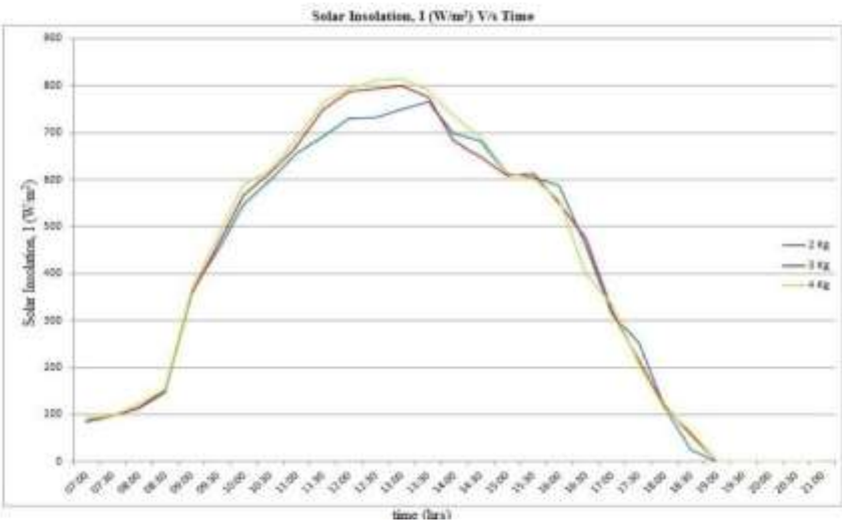
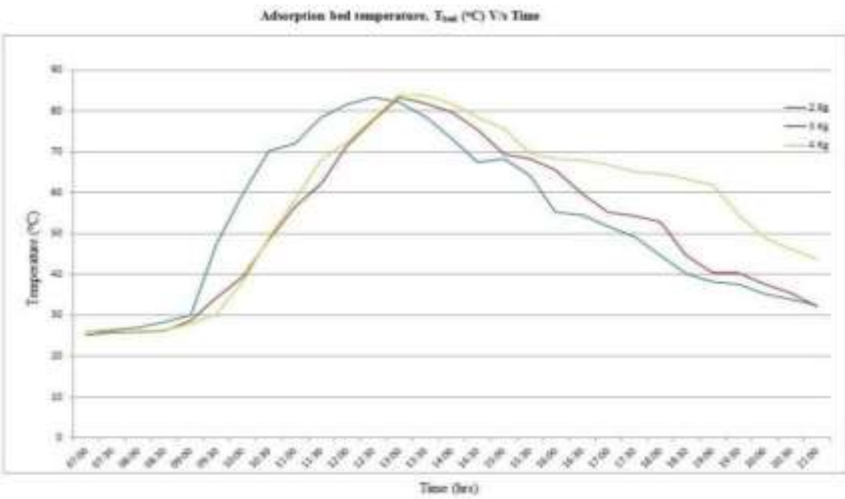



**Figure 8** Solar radiation Vs Time graph



ISSN: 2278-4632
Vol-11 Issue-02 2021

**Figure 9** Adsorption bed temperature Vs Time graph

140

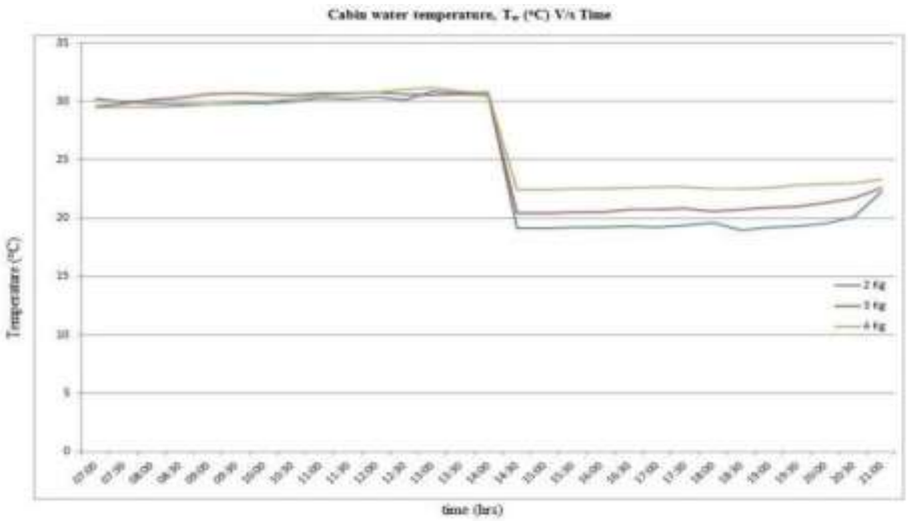



**Figure 10** Cabin water temperature Vs Time graph

## VII. CONCLUSION

A two stage solar vapour adsorption refrigeration system was fabricated and analysed in the atmospheric conditions of Solar Engineering laboratory of Govt. Model Engineering College, Thrikkakara. The principle of adsorption refrigeration and use of multiple bed adsorption system was studied using this project.

The temperature variations of the adsorber bed and cabin water was analysed by conducting experiment with different evaporative loads and its performance characteristics was studied. The solar COP of the system and refrigeration effect was calculated and the variation of these parameters for different evaporator loads was plotted.

The Maximum $COP_{solar}$ of 0.096 was observed to be achieved while the evaporator load was 4kg. The corresponding refrigeration effect obtained was about 147.14kJ. Even though, there was an increase in performance parameters, the temperature difference of the evaporator during the cooling process show a declining trend as the evaporator load increases.

## REFERENCES

[1] B. B. Saha, A. Akisawa, T. Kashiwagi; Solar/waste heat driven two-stage adsorption chiller: the prototype. *Renewable energy* 23 (2001):93-101.

[2] Baiju V, Muraleedharan C; Performance study of a two stage solar adsorption refrigeration system; *International journal of Engineering Science and Technology*, Vol. 3 No.7, July 2011.

[3] K Sumathy, Li Zhongfu; Experiments with solar-powered adsorptionice-maker;*Renewable Energy* 16 (1999) 704-707

[4] Baiju V, Muraleedharan C; Performance study and experiment cycles of two stage solar hybrid adsorption refrigeration system; *International Journal of Research in Education Methodology*, Vol. 3 No. 1, June2013

[5] M. Schicktanz, P. Hu genell, S.K. Henninger; Evaluation of methanol/activated carbons for thermally driven chillers, part II: The energy balance model; *International Journal of Refrigeration* 35 (2012), 554-561,Elsevier.

[6] Mr.Anirban Sur, Dr.Randip.K.Das, Review on Solar Adsorption Refrigeration Cycle. *International Journal of Mechanical Engineering and Technology*, 1(1), 2010, pp. 190– 226.

*[7]* B. Sandhya Rani, Dr. A. Ramesh, Dr. A.S. Shiva Shak are Gowda and A. Hareesh. Recent Design and Analysis of the Effect of Nozzle at the Outlet of Condenser on Vapour Compression Refrigeration System, *International Journal of*

[8] *Mechanical Engineering and Technology*, 7(6), 2016, pp.642–659.