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"A Review On Solar Adsorption Refrigeration System"

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Abstract - The climate of the India comprises wide range of the weather across a vast geographic scale which can affect the coefficient performance of the solar adsorption refrigeration system. This paper primarily focuses on the performance and analysis of the solar adsorption system for tropical wet and dry climatic zone of India. The objective of this review is to understand the different parameters which may affect the solar adsorption refrigeration system .For that we have to consider certain factors which are relevant to the intensity of solar radiation such as local latitude, angle of inclination of the receiving surface, weather conditions etc. The system proposed consist of a glass tube having sorption bed, condenser and an evaporator. The working pair of fluid used is low grade charcoal and methanol .For the successful operation of this system the factors such as adsorbent-adsorbate pair, system design and arrangement of the subsystems have been chosen with great care.

Key Words: *Solar adsorption, Adsorbent, Adsorbate, Refrigeration, Coefficient of Performance*

I. INTRODUCTION

In 90's deleterious effects of CFCs and HCFCs as refrigerants on the ecological system came into picture which when released into atmosphere, deplete the ozone layer. The importance and demand of using of eco-friendly refrigerants and systems increased after that. Which ultimately increased the need of solar energy for refrigeration system as it is innocuous to environment, abundant, clean and easily available. The solar refrigeration system is based on the use of the solar energy for the production of desired refrigerating effect. Solar refrigeration can be very useful in the areas where electricity is insufficient. Which means solar refrigeration is highly dependent upon environmental factors such as cooling water temperatures, air temperature and solar radiation.

Solar adsorption refrigeration system is one of the promising solar thermal refrigeration system. Solar adsorption refrigeration system is useful for requirements such as ice-making, air conditioning, medical and food reserve system in remote areas [2]. This systems had been tested extensively; however it can't replace the existing system due to some problems encountered. One of them is the rate of heat transfer which is the most important aspect. The heat transfer of solar adsorption system is poor compare to other refrigeration system. Second and the most common problem encountered in every solar system is the environmental conditions in summer and winter. In summer we can get good amount of heat in the morning but limited amount of cooling in the night. In winter the problem is exactly opposite [1]. We can get great cooling effect after sunset but limited heating in the morning. The use of composite adsorbent blocks is useful method to improve the cooling rates. Use of the refrigerating tube is promising method to solve the problem of solar adsorption system.

Hence, this paper is composed of the solar adsorption refrigeration system made up of glass tube and reflectors along with pair of domestic charcoal and methanol for the analysis of the COP of the system for the most of the time of the year.

II. LITERATURE REVIEW

N.M. Khattab et al studied the operation of solar adsorption system with activated carbon as a adsorbent and methanol as adsorbate. Based on that, he designed adsorbent bed and evaporative system. He analyzed it for a year for different inclination of adsorbent bed with sun. The shape of adsorbent bed was circular having diameter 200mm and it is tested with four different types of bed reflector arrangements. The net COP achieved by him was 0.159 in June and 0.136 in November in Egyptian climatic conditions. According to his studies the COP achieved by domestic charcoal as adsorbent is greater than that of activated charcoal.

Mohand Berdja et al focused their work on cold production by solar adsorption refrigeration in Algeria's climate. In this they have analyzed their system using software e.g. ANSYS for temperature distribution over adsorption plate. They achieved COP of 0.127 at 15 ^{0}C. They also found that COP and specific cooling power increased with increase in heat source temperature and decreased with decreasing evaporative temperature. Different components of solar adsorption system like adsorption plate, evaporative chamber are analyzed with their different arrangements.

K. Sumathy et al has done significant work in theoretical review of solar adsorption systems proposed till date. They have reviewed all the parameters regarding adsorption and thermodynamic point of view is also considered for solar adsorption refrigeration cycle. There are two types of adsorption systems, intermittent adsorption system based on various adsorbent- adsorbate pairs are explained with thermodynamic point of view and second one is continuous adsorption system which is further divided on the basis of their working modules are explained. The experimental data regarding different working models and simulations from different climates are also compiled to have a broader approach towards adsorption system.

Khairul Habib et al has presented the theoretical analysis of the solar powered combined adsorption refrigeration cycles using evacuated tube solar collector. In combined adsorption cycle activated carbon-R507a was used for bottoming cycle and activated carcon-R134a used for topping cycle. The simulation has done to determine the performance parameters of the combined cycle. They have simulated same model for climatic conditions of Malaysia and Singapore. The net COP and chiller efficiency was 0.12 and 0.25 respectively for cycle time between 450 to 500 seconds.

M.S. Fernandes et al reviewed basic solar adsorption system working with different types of adsorbent-adsorbate combination like activated carbon-methanol, activated carbon-ammonia, Zeolite-water, silica gel- water and other unpopular working pairs. The experimental data of adsorption system around the world is compiled with respect to their working pair to have clear comparison between all the adsorbent-adsorbate pair. The selection criteria of adsorbent-adsorbate according to the application and operation is also explained. Combination of basic adsorption system with other systems i.e. hybrid systems are mentioned.

Mahmoud Salem Ahmed et al has done literature work on different types of adsorbent adsorbate pair which used in solar adsorption systems. This includes classification and comparison for the working pairs in order of their use. The comparison is done on the basis of the performance parameters of the pairs. This will help us to discover and invent future pairs of adsorbent-adsorbate for better COP. According to review, Silica gel and chlorides with water gives maximum COP whereas zeolite with water shows poor performance working under similar conditions.

E.E. Anyanwu et al has done the thermodynamic design procedure for solar adsorption refrigeration. Later performance analysis is done after application of thermodynamic approach to systems using different pairs of adsorbent-adsorbate pairs. Adsorbent-adsorbate pair considered are activated carbon-methanol, activated carbon-ammonia and zeolite-water.

III. BASIC PRINCIPLE OF SOLAR ADSORPTION SYSTEM

The process of adsorption involves separation of a substance from one phase accompanied by its accumulation at the surface of another. The adsorption phenomenon is the result from the interaction between a solid and a fluid (refrigerant) based on a physical or chemical reaction. Physical adsorption occurs when the molecules of refrigerant (adsorbate) fix themselves at the surface of a porous solid element (adsorbent) due to Van der Waals forces, thus leading to the accumulation of a substance on the surface of another [7].

3.1 Solar Adsorption Cycle

Solar adsorption system is similar to vapor compression system in which compressor is replaced by solar heat driven adsorption bed. The adsorption bed is integrated with a flat plate solar collector and contains a porous adsorbent medium (low grade charcoal). The adsorbed content of refrigerant varies cyclically, depending on the adsorbent temperature and system pressure, which varies between a maximum limit set by the condensation pressure and a minimum limit imposed by the evaporation pressure [7]. Refrigerant used is methanol as it has greater affinity towards charcoal.

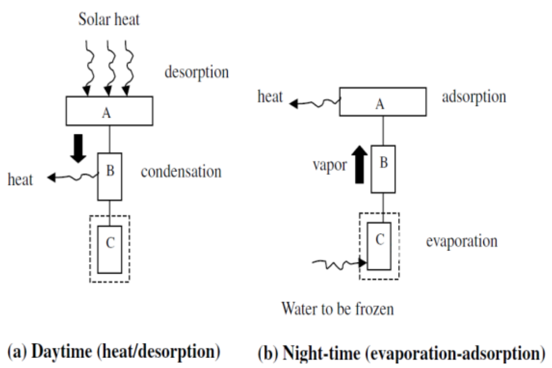

Fig -1: Operation principle of solid adsorption refrigeration system utilizing solar heat. A: Sorption bed (solar collector); B: condenser; C: evaporator [1].

This cycle consists of following two phases;
1. Daytime

During this phase, due to solar heat, adsorption bed gets heated and its pressure increases. The refrigerant present on the surface of bed gets evaporated at a constant pressure, this constant pressure heating is known as desorption. Vapor refrigerant is pass thorough condenser where gets condensed and its pressure is reduce to evaporator pressure. This condensed refrigerant is stored in refrigerant storage tank.

2. Night time

During this phase, cooled refrigerant enters the evaporator where it gains heat from the cold box and get vaporized thus giving the cooling effect. This vapor refrigerant get adsorbed in the adsorption bed. So the actual cooling effect is achieved during night time only.

IV. SELECTION OF WORKING PAIR

The selection of working fluid of adsorbent-adsorbate plays an important role in the system operation. Different pairs of adsorbent-adsorbate gives different working temperatures and it affects the rate of heat transfer. The selection of any pair of adsorbent-adsorbate for refrigeration application depends on certain desirable characteristics of their constituents. These characteristics range from their thermodynamic and chemical properties to their physical properties and also their cost and availability [7].

4.1 Desirable properties of adsorbate

The properties of ideal adsorbate used in solar adsorption system are as follows [6]:

- Evaporation temperature below 0 ^{0}C (for refrigeration purposes it can be higher in the case of air-conditioning applications).
- Small molecular size so as to facilitate the adsorption effect.
- High latent heat of vaporization and low specific volume when in the liquid state.
- High thermal conductivity.
- Thermally stable with the adsorbent in the operating temperature range.
- Chemically stable in the operating temperature range.
- Low saturation pressures (slightly above atmospheric pressure) at normal operating temperature.

4.2 Desirable Properties of adsorbent

The properties of ideal adsorbent used in solar adsorption system are as follows [6]:

- Ability to adsorb a large amount of adsorbate when cooled to ambient temperature, to yield a high cooling effect.
- Desorption of most (ideally all) of the adsorbate when heated by the available heat source.
- Low specific heat.
- Good thermal conductivity, to shorten the cycle time.
- Non deterioration and adsorption capacity losses over time or with usage.
- Non-toxic and non-corrosive.
- Chemically and physically compatible with the chosen refrigerant.

4.3 Desirable properties of working fluid (methanol-charcoal)

Most commonly used working fluid is methanol-charcoal for solar adsorption system. Properties of methanol-charcoal are as follows [6]:

- It operates at low regeneration temperature.
- It has large cyclic adsorption cyclic capacity.
- Low adsorption heat.
- Low freezing point.
- Methanol has high evaporation latent heat.

V. PROCESSES

There are 4 processes involved in adsorption cycle out of which 2 are isosteric process and remaining 2 are isobaric process. The cycle is illustrated on Clapeyron diagram.

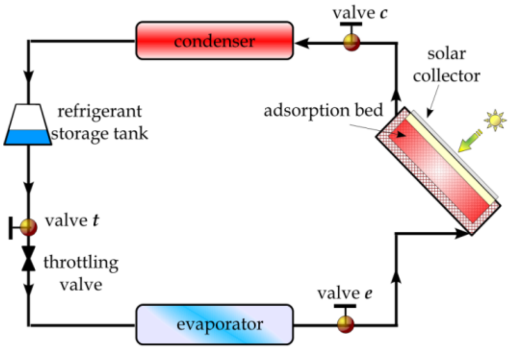

Fig -2: Schematic diagram of the solar adsorption cooling system. [8]

Following are the processes of basic adsorption cycle

1. Isosteric Heating (Process 1-2)
2. Isobaric Heating (Process 2-3)
3. Isosteric Cooling (Process 3-4)
4. Isobaric Cooling (Process 4-1)

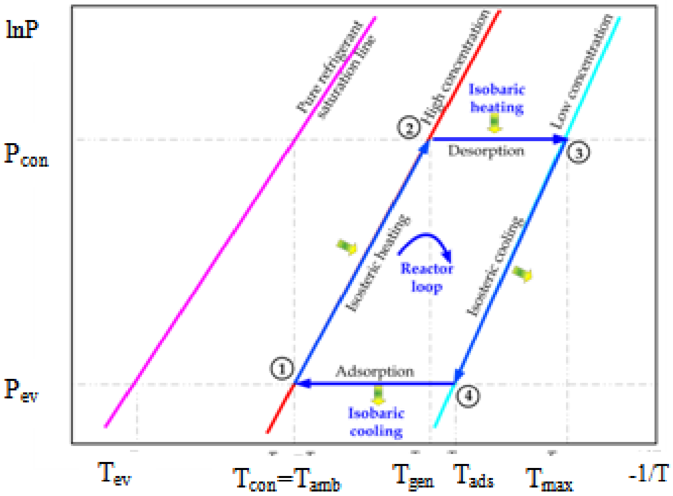

Fig -3: Thermodynamic adsorption cooling cycle [8].

1. Process I- Isosteric Heating Process 1-2

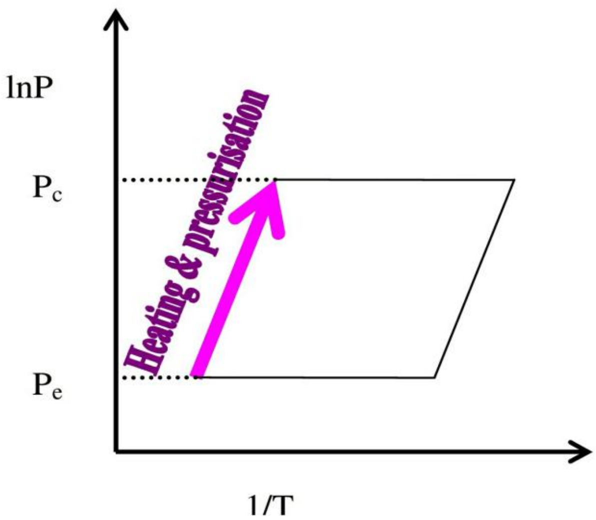

Fig -4: Heating and Pressurization process [8].

It is the Heating and Pressurization process. The process starts at point 1, when the adsorbent is at adsorption temperature) and at a low pressure (evaporation pressure), and adsorbate is at high concentration. The valve which isolates the condenser from the evaporator is closed and, as heat is applied to the adsorbent, both temperature and pressure increase along the isosteric line 1–2, while the mass of adsorbed refrigerant remains constant at the maximum value [7,8].

2. Process II- Isobaric Heating Process 2-3

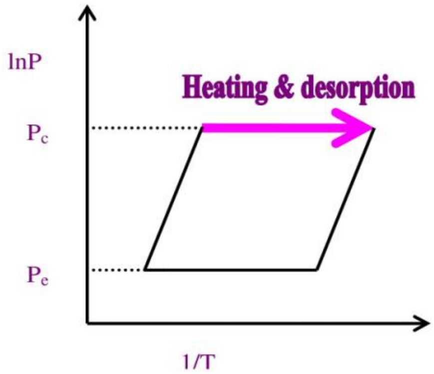

Fig -5: Heating and Desorption process [8].

At point 2 pressure reached is condenser pressure and desorption process starts. In this progressive temperature rise take place at constant pressure. The refrigerant vapor is released from the adsorbent and then liquified in condenser (releasing the condensation heat, at the condensation temperature and then collected in a receiver tank. This stage ends when the adsorbent reaches its maximum regeneration temperature, and the adsorbate concentration decreases to the minimum value [7,8].

3. Process III- Isosteric Cooling Process 3-4

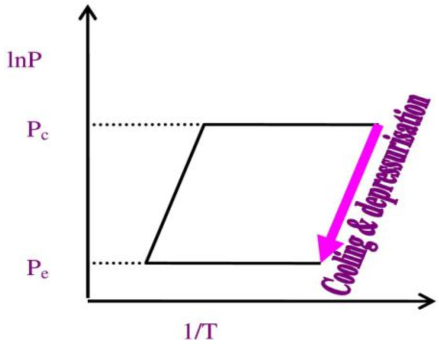

Fig -6: Cooling and Depressurization process [8].

In this process, the adsorbent cools down along the isosteric line 3–4, while the adsorbed refrigerant remains constant at the lowest concentration. During this phase, the valve is opened, allowing for the refrigerant to flow into the evaporator, and the system pressure decreases until it reaches the evaporator pressure [7,8].

4. Process IV- Isobaric Cooling Process 4-1

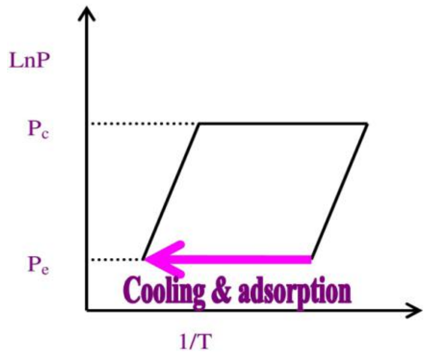

Fig -7: Cooling and Adsorption process [8].

In this process, adsorption–evaporation phase 4–1 occurs, producing the cooling effect in the evaporator, at evaporation temperature. At this stage, the vaporized refrigerant in the evaporator flows to the adsorbent bed where it is adsorbed until the maximum concentration is reached, at point 1. During this phase, the adsorbent is cooled down until it reaches the adsorption temperature, by rejecting the sensible heat and the heat of adsorption. At the end of this phase, the valve is closed (to prevent condensation to occur later on in the evaporator) and the cycle restarts [7,8].

VI. SYSTEM LAYOUT

The proposed system can be used in application where continuous cooling or higher cooling capacity is not required. The adsorption refrigeration system shown in figure consists of

1. Cover plate
2. Adsorbent Bed
3. Insulation Material
4. Frame
5. Condenser
6. Connecting Pipe
7. Evaporator
8. Water Tank
9. Insulation Box

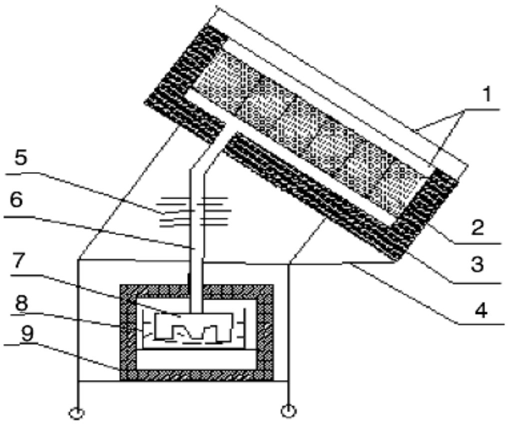

Fig -8: Schematic layout of solar adsorption refrigeration system without valve [3].

VII. CONCLUSION

The development of adsorption system for refrigeration is promising. An overall thermodynamic based comparison of adsorption system shows that the performance of system depends highly on both the adsorption pairs and processes. The technology continues to develop and the cost of producing power with solar adsorption refrigeration is falling.

This paper presents an overall review on fundamental understanding of desirable properties of adsorbent-adsorbate pairs and processes involved in adsorption refrigeration cycle.

VIII. FUTURE SCOPE

Though many novel adsorption system have been patented their claims of higher efficiency can't be verified some of these innovative system show promise and they should be studied so that the flaws that prevent them from working can be corrected reducing the cost of the system by inventing low cost adsorption material. New heat and mass recovery approaches and high performance adsorbent bed are still important research area.

Domestic charcoal with its low price when is used as adsorbent realize good performance as compared with another type of activated carbon. However using activated carbon must be studied from economical point of view.

IX. REFERENCES

[1] N.M. Khattab, "A novel solar-powered adsorption refrigeration module", Applied Thermal Engineering 24 (2004) 2747–2760.

[2] K. Sumathy, K.H. Yeung, Li Yong, "Technology development in the solar adsorption refrigeration systems", Progress in Energy and Combustion Science 29 (2003) 301–327.

[3] R.Z. Wang, R.G. Oliveira, "Adsorption refrigeration-An efficient way to make good use of waste heat and solar energy", Progress in Energy and Combustion Science 32 (2006) 424–458.
[4] Mohand Berdjaa et al, "Design and realization of a solar adsorption refrigeration machine powered by solar energy", International Conference on Solar Heating and Cooling for Buildings and Industry, Energy Procedia 48 (2014) 1226 – 1235.
[5] E.E. Anyanwu, N.V. Ogueke, "Thermodynamic design procedure for solid adsorption solar refrigerator", Elsevier, Renewable Energy 30 (2005) 81–96.
[6] Mahmoud Salem Ahmed et al, "A Review: Future of the adsorption working pairs in cooling", Sohag University (2010).
[7] M.S. Fernandes, "Review and future trends of solar adsorption refrigeration systems", Reviewable and Sustanable Energy Reviews 39(2014) 102-123.
[8] Sneha Patil, S. G. Dambhare, "Review on Study of Solar Powered Adsorption Refrigeration System", International Journal of Innovative and Emerging Research in Engineering, vol. 2, 2394 – 5494 (2015).
[9] G Halder, S.C. Sarkar, "The cooling effect by an adsorption-desorption refrigeration cycle", Journal of Energy in Southern Africa, Vol 18 No 2, 2007.
[10] Kai Wang et al, "New opportunities for solar adsorption refrigeration", ASHRAE, September 2007.