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Performance Evaluation Of Solar Adsorption System With/Without Wing Using Methanol –Charcoal

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***Abstract*— Solar energy is freely and abundantly available on the surface of the Earth, solar adsorption refrigeration devices are very useful to meet the needs for cooling requirements in refrigeration, air-conditioning, ice-making and food preservation in isolated areas. 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 experimental investigation of the solar adsorption system for tropical wet and dry climatic zone of India. The objective of work is to understand the different parameters which may affect on the performance the solar adsorption refrigeration system and enhancement by taking proper parameters for the improvement of COP .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 consists of a flat plate collector having sorption bed, condenser and an evaporator. The working pair of fluid used is low grade charcoal and methanol and comparative analysis is done for tropical region.**

Keyword- *Solar adsorption, Adsorbent, Adsorbate, Refrigeration, Coefficient of Performance.*

I INTRODUCTION

The depletion of ozone layer got started when there were introduction of deleterious effects of CFCs and HCFCs as refrigerants on the ecological system came into picture which when released into atmosphere. The importance and demand of using of eco-friendly refrigerants and systems increased after that which eventually increased the call for 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 will be very effective tool of nature where the electricity is not enough like remote areas. However the solar refrigeration is highly dependent upon environmental factors such as cooling water temperatures, air temperature and solar radiation. Among all systems, Solar adsorption refrigeration system is one of the promising to technology adsorption refrigeration system is useful for requirements such as ice-making, air conditioning, medical and food reserve system in remote areas [2]. These 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. Compare to other systems , the heat transfer of solar adsorption system is poor. 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 selection of different composite adsorbent blocks would be the useful method to improve the cooling rates. Use of the refrigerating tube is promising method to solve the problem of solar adsorption system.

Abbreviations

A.C.: Activated charcoal
M : Methanol
M_m : mass of total methanol in system
Mma : mass of methanol at point A (in Kg)
Mmd : mass of methanol at point D
Q_T : total heat
$Q_{AB:}$ heat used to increase temperature of Activated Charcoal (A.C.) and Methanol (m)
$Q_{BD:}$ Progressive Heating for A.C. and m
Tbdes : Temperature before desorption (in °C)
Tades : Temperature after desorption
Ta : Temperature at point A
Tb : Temperature at point B
Td : Temperature at point D
Tcc : Temperature of condensate
Tee : Temperature of evaporate

II PROBLEM DEFINATION

Past research and experiences had indicated that different types of pairs for solar adsorption refrigeration system process, Study has been done for selection of pairs of adsorbent and adsorb ate. The Problem Definition is Performance Evaluation of Solar Adsorption System With/Without Wing Using Methanol –Charcoal.

Objective

The objective of work is:

1. To study solar adsorption refrigeration system.
2. To construct model for solar adsorption system with the help of flat plate collector with/without wing by using methanol and charcoal and investigation performance with different parameters.
3. To do systematic comparative investigation and present the way of improvements.

III METHODOLOGY

- Solar adsorption refrigeration process study.
- Literature Survey.
- Problem Definition.
- Selection of Dimensions.
- Manufacturing of Set up.
- Testing with different variables.
- Collection of solar data.
- Calculations and results.
- Conclusions and comparative remarks.
- Recommendations of parameters for future study.

IV EXPERIEMENTAL SETUP

For solar adsorption refrigeration system, performance is affected greatly by the characteristics of adsorption bed of the system. In general way, the characteristics like good heat and mass transfer plays very important role. Recent research showed that the aluminium alloy have a stronger catalytic effect on the decomposition reaction under the solar adsorption refrigeration, therefore stainless steel is used as adsorbent heat transfer metal instead of aluminium alloy although stainless steel has poor heat transfer ability than that of aluminium alloy. The adsorbent bed is made of flat plate stainless steel box, having surface area 1 m^2 (ie.1m x 1m) also 18-19 kg adsorbent (activated carbon produced from coconut shell) will be charged and sealed inside the steel plate box, then selective coating is covered on top surface of the steel plate box. Finally the steel plate box is placed behind sheet of fiber plastic plates in a thermal insulated case. The permeability of the fiber plastic plate for solar radiation is about 0.88-0.92, which is higher than that of glass. To achieve the assurance better heat transfer between the front side and the adsorbent, many fins (also made of stainless steel) are placed inside the adsorbent bed box in contact with the front side and the activated carbon. The distance between these fins is approximately 0.115 m. The adsorbent layer is placed at bed which create the thickness about 0.04 m, the total weight of stainless steel metal is about 20 kg, and those parameters mentioned above are obtained according to both previous experimental results and optimized calculation. The false (0.01 m thick in the radial distance) bottom is created in the set up to improve the transfer of methanol vapor through the activated carbon layer which is situated in the rear side of the adsorbent bed as mentioned by Pons and Guillemiont [2,7]. As this ''false bottom'' is completely open to the circulation of vapors, it permits a uniform distribution of methanol in the adsorbent.

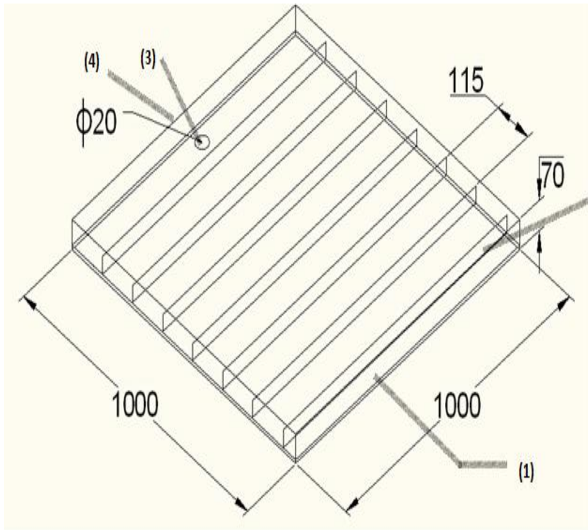

Figure 1. Construction of adsorption bed

(1) adsorbent bed, (2) supporting plate and fins, (3) hole for flow of methanol vapour, (4) extension for temperature measurement.

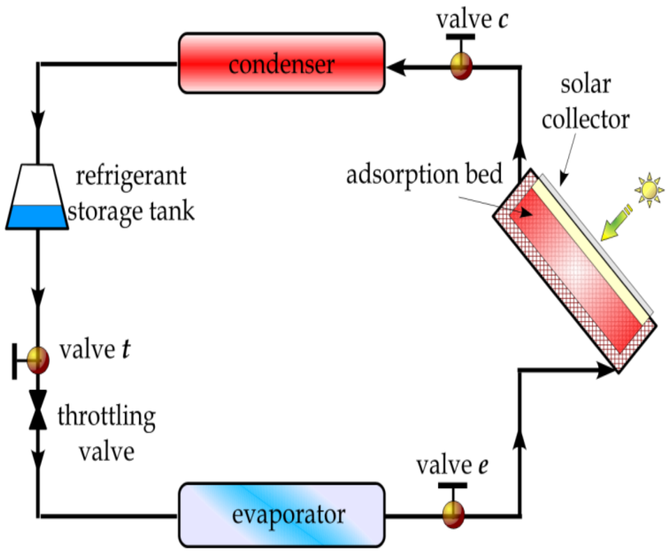

Figure 2 Schematic diagram of the solar adsorption cooling system

Processes Involved In The Cycle:

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.

Following are the processes of basic adsorption cycle

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

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

- Process I- Isosteric Heating Process 1-2

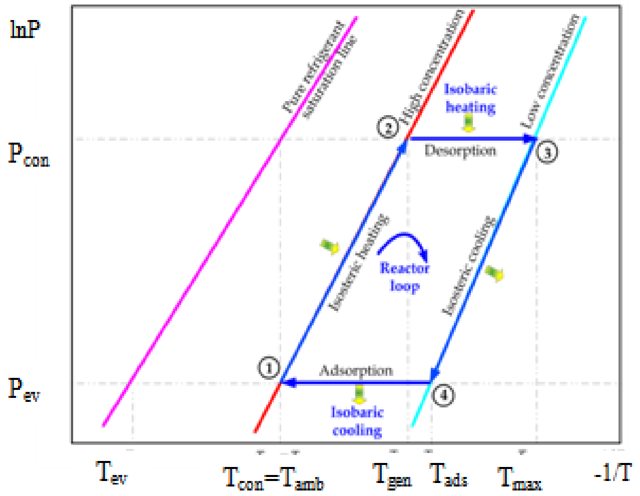


Figure 3Thermodynamic adsorption cooling cycle .

- Process I- Isosteric Heating Process 1-2

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].

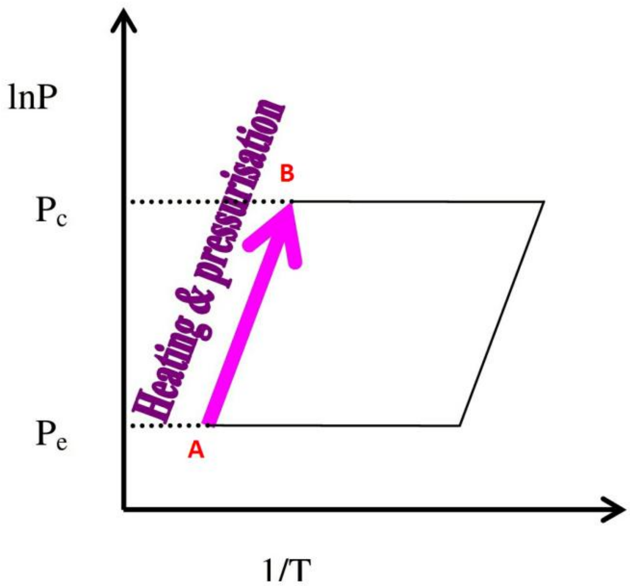


Figure 4 Heating and Pressurization process

- Process II- Isobaric Heating Process 2-3

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]

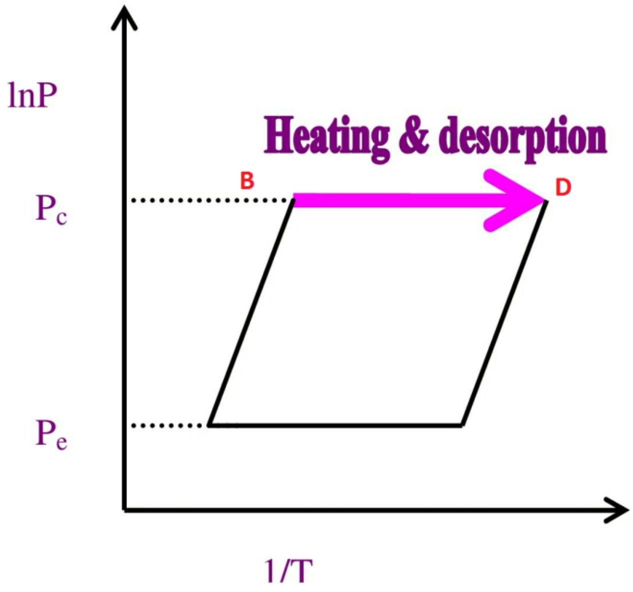


Figure 5 Heating and Desorption process

- Process III- Isosteric Cooling Process 3-4

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 [3-4]

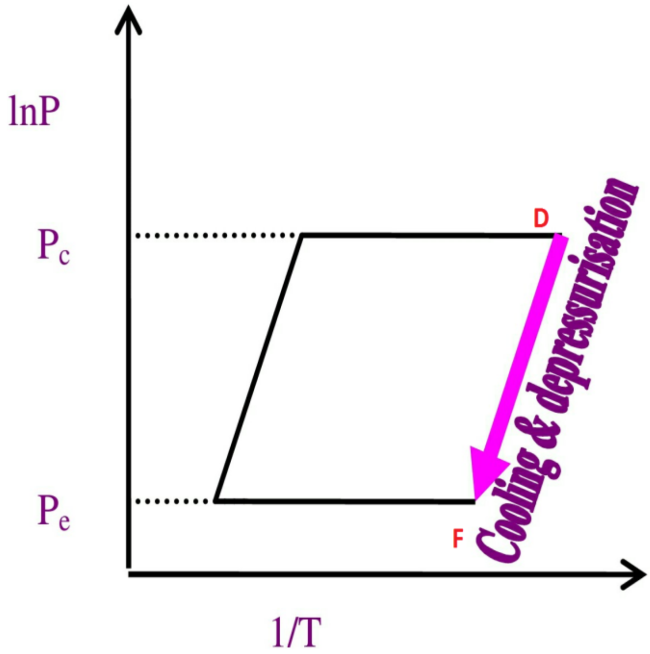


Figure 6 Cooling and Depressurization process .

- Process IV- Isobaric Cooling Process 4-1

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].

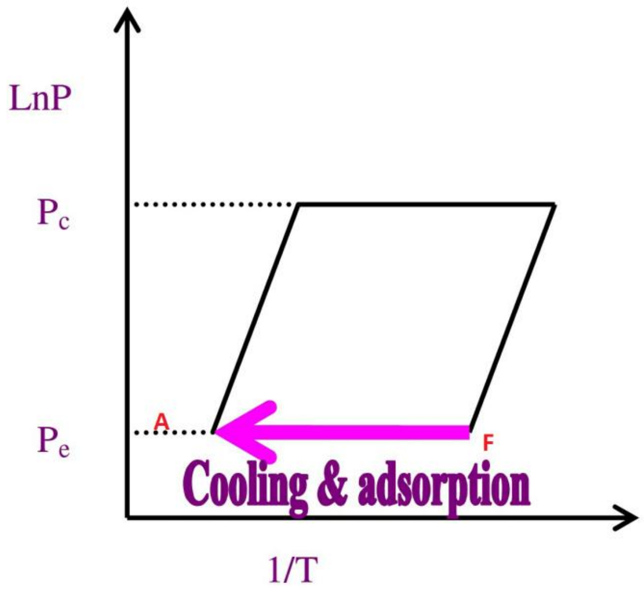


Figure 7 Cooling and Adsorption process.

V EXPERIMENTAL INVESTIGATION OF SYSTEM

In the system , Q_T represent the total heat gained by system while is the sum of Heat gained in Q_{AB} which used to increase temperature of Activated Charcoal (A.C.) and Methanol (m) and Q_{BD} is progressive heating used for A.C. and methanol.

Therefore,

$$Q_T = Q_{AB} + Q_{BD} \qquad (1)$$

While

$$Q_{AB} = (M_{A:C}\, Cp_{A:C} + Cp_m\, M_mA) \times (T_B - T_A) \qquad (2)$$

And

$$QBD = [M_{A:C}\, Cp_{A:C} + Cp_m \{ (M_mA + M_mD)/2 \}] (T_D - T_B) + (M_mA – M_mD) \times H. \qquad (3)$$

The gross heat released during the cooling period Q_{e1} will be the energy of vaporization of methanol.

$$Q_{e1} = (M_mA – M_mD) \times L \qquad (4)$$

But the net energy actually used to produce ice Qe will be

$$Q_e = Q_{e1} - Q_{e2} \qquad (5)$$

where Q_{e2} is the energy necessary for cooling the liquid adsorbate from the temperature at which it is condensed to the temperature at which it evaporates.

$$Q_{e2} = (M_mA – M_mD)\, Cp_m\, (T_c - T_e) \qquad (6)$$

Q_{ice1} is the energy required to cool water from T_A to 0 ºC and to produce ice

$$Q_{ice1} = M^* (L^* + Cp_{water} (T_A - 0)) \qquad (7)$$

where M* and L* are the mass and latent heat of fusion of ice and net cooling produced .

Table No.1 Steps involved in solar adsorption system.

Time Duration	Process of cycle	Pressure	Remarks of Processes involved in system
8.00 a.m. To 10.00a.m.	A to B	Pe=Ps(Te)	Isosteric Heating of the adsorbent.
10.00 am To 5.00 pm	B To D	Pc=Ps(Tc)	Heating of the adsorbent. Desorption and condensation of the refrigerant
5.00 To 8.00 p.m.	D to F	Pc=Ps(Tc)	Isosteric cooling of the adsorbent. Depressurisation of the system
8.00 pm to 8.00 a.m.	F to A	Pe=Ps(Te	Cooling of the adsorbent Evaporation and adsorption of the refrigerant

VI OBSERVATIONS

To evaluate the performance of the system, parameters are note down days wise in the month of March, April and May 2017.

Reading of system in March is as follows;

Table No. 2 Temperature of System in March 2017

Sr No	Temp in ° C ----- Dates	T bds	Tads	T a	T b	Td	T cc	T ee
1	1	28.5	47.5	28.5	38.5	49.5	14.5	13
2	5	29	48	28.5	38.5	50	15	14
3	9	29	47.5	29	39	50.5	14.5	12
4	13	29.5	48	29	40	52	14	13
5	17	30	49	28	40.5	51	14	12.5
6	21	31	49.5	30	41	51	13	12

The same process repeated in April and May 2017.

Table No 3. Temperature of System in April 2017

Sr No	Temp in ° C ----- Dates	T bds	Tads	T a	T b	Td	T cc	T ee
1	1	29	48	29.5	37	51	14	13
2	5	30.5	48.5	29	38	51.5	14	12.5
3	9	31.5	48.5	29	39	51.5	14	12
4	13	31.5	49	28	39.5	52	14	12
5	17	30.5	49	28.5	39.5	52	13	11.5
6	21	32	49.5	28	40	52	13	11.5

Table No. 4 Temperature of system in May 2017.

Sr No	Temp in ° C ----- Dates	T bds	Tads	T a	T b	Td	T cc	T ee
1	1	29	49	28.5	37.5	49.5	14.5	13
2	5	29	49.5	28.5	38	50	15	14
3	9	29	49	29	39.5	50.5	14.5	12
4	13	29.5	48	29	41	52	14	13
5	17	30	50	28	42	51	14	12.5
6	21	31	49.5	30	41	51	13	12

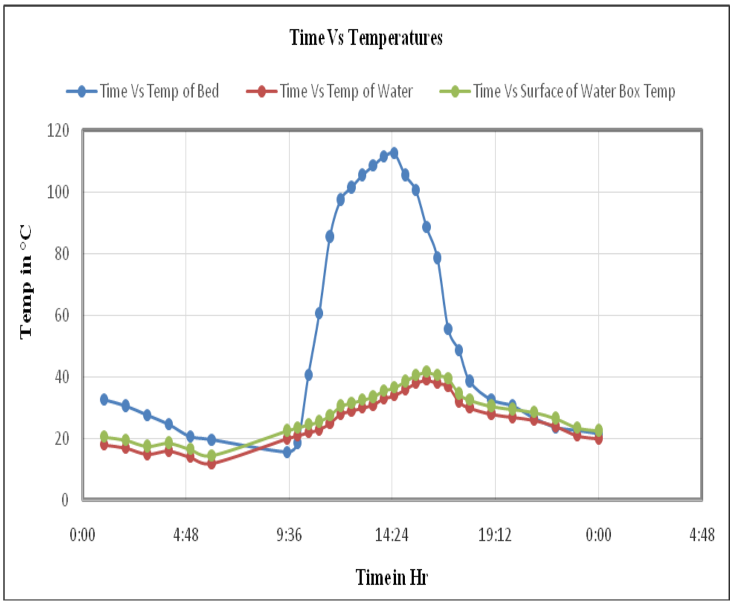
Table No 5. Diffused radiation in KW/m^2 month wise.

Month ------- Dates	Feb	March	April	May
1	17280	15552	20995.2	24192
3	18144	18144	16243.2	25488
5	22032	12096	18835.2	20736
7	13824	12528	14860.8	15984
9	17280	12700.8	20476.8	18144
11	14688	13737.6	15638.4	18144
13	18144	13219.2	21254.4	38016
15	16416	17884.8	21168	31104
17	15552	16416	20217.6	20736
19	10800	15552	20390.4	15379.2
21	11145.6	15984	19440	18144
23	13824	18835.2	18144	22464

VII PERFORMANCE EVALUATION OF SYSTEM

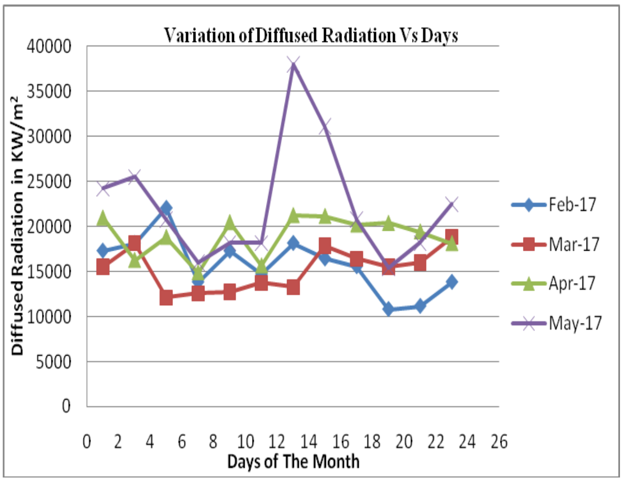
A. Variation of temperature of Water in Ice-box with respect. to Time.

From the graph 1, it is clear that solar radiations varies with respect to time henceforth the temperature of bed-adsorbent surface changes with time in unsteady manner. It is found that effective solar radiations are available during period of 10.30 am to 5.30 pm thus the temperature in bed during this period reaches to 100 ℃ to 120 ℃. After 3.30 pm the temperature in bed gets lower and lower. Desorption starts after 6 pm and temperature near about to be constant at around 11.00 p.m. From midnight methanol vapours absorbed by adsorbent bed.



Graph No 1. Variation of temperatures with respect to Time in Hrs.

These all parameters are related to solar radiation as well as surrounding air temp and relative humidity as well. Most effectively diffused radiation decides the temperature of adsorbent bed at morning and evening. The variation of diffused radiation month wise is shown in Graph no 2 as below.

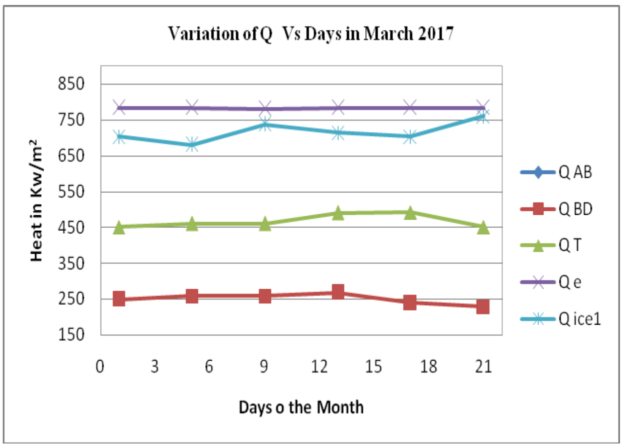


Graph No. 2 Variation of Diffused Radiation Month Wise.

Considering all environmental conditions and observations, results are prepared as below.

Table No 6. Results of Solar adsorption refrigeration system of March 2017

Dates	Q_{in}	Q_{AB}	Q_{BD}	Q_T	Q_e	Q_{ice1}
1	16280	202.2	248.4	450.5	782.6	702.9
5	15552	202	258	460	783	680
9	18144	202	258	460	781	737
13	12096	222	268	490	783	714
17	12528	253	239	491	783	703
21	12701	222	229	451	783	760



Graph No 3. Variation of Heat in March 2017.

Table No. 7 COP of cycle month wise

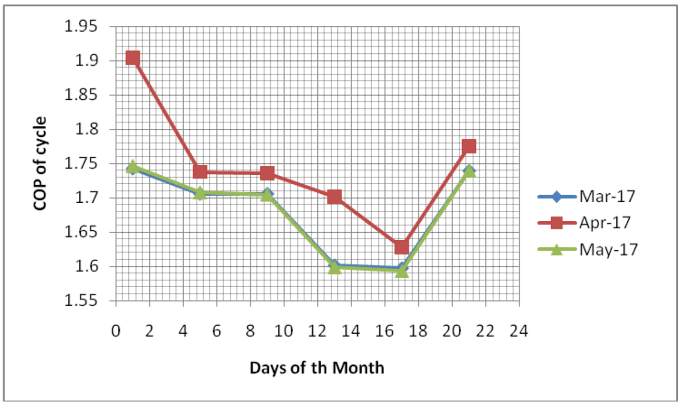
	COP of cycle		
Days	March	April	May
1	1.7427394	1.9038164	1.7460243
5	1.7060694	1.7374117	1.707642
9	1.7060694	1.7357839	1.7044998
13	1.6019935	1.7018204	1.5992278
17	1.5978485	1.6276587	1.5937249
21	1.7394669	1.7745235	1.7394669

Table No. 8 COP of solar system month wise.

	COP of solar system		
Days	**March**	**April**	**May**
1	0.048073	0.0372766	0.0323507
5	0.0503779	0.0482341	0.030739
9	0.0430409	0.0414614	0.0376608
13	0.0647716	0.052721	0.0490163
17	0.0624704	0.0382203	0.0431343
21	0.0616872	0.0500995	0.043181

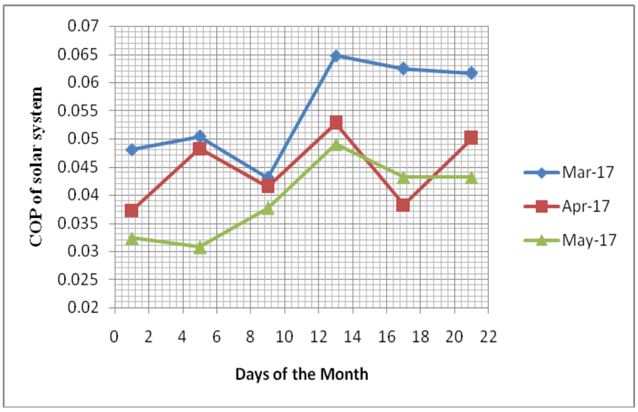
VIII RESULT AND DISCUSSION

The investigation is done on the basis of data which was recorded in last three months and COP is compared as following.



Graph No.4 Variation of COP of cycle month wise.

From graph no 4, it is cleared that maximum diffused radiation anticipated in April and temp of surrounding at night lower compared to afternoon temperature. Due to these parameters system has maximum COP of cycle compared to March and May 2017.



Graph No.5 Variation of COP of solar system month wise.

From the graph no 5, it is observed that COP of solar refrigeration system will be more when Radiation is optimum and the temp of air at midnight is lower. Not only diffused radiation is responsible to have more COP of system but also surround temperature, relative humidity and dew point temperature .etc are also making the effect on performance.

IX CONCLUSION

It is one of the best solution to avoid the depletion of ozone layer as well as utilization of solar energy in remote areas where enough solar radiation is available. Performance of the solar adsorption s refrigeration system is depend on the different parameters other than radiation like surrounding temp, Although it is driven by free solar energy but there should be a lot of scope in reduction in manufacturing cost, appropriate selection of adsorbent – adsorbate pairs, having greater capacity of heat transfer. Performance is affected by condensation temperature , relative humidity in a day, global and diffused radiation and adsorption bed. However for a research, one should take care of following points.

1. The condenser and evaporator must necessarily be close to each other and to the collector since the system operates at low pressure, thus they are located directly under the collector to have natural flow of refrigerant by means of gravity.
2. To execute the successfully operations of the system one must be checked Vaccum initially for the system and it should be sealed tightly.
3. To have the better performance, one can apply the wings to system which will increase solar radiation henceforth increase in temperature of the bed of adsorbent.

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