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Performance Analysis Vapour Absorption Refrigeration Chiller Run by Solar Thermal Energy

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Abstract— *Over the past few decades, energy is the backbone of technology and economic development. In addition to men, machines and money, 'energy' is now the fourth factor of production. The objective of this paper is to design and study an environment friendly ammonia water vapour absorption refrigeration system of unit capacity using Ammonia (R717) as a refrigerant and water as a absorbent working fluids and run by exhaust water Solar Thermal Set Up. The system is designed and tested in Thermal Engineering lab of Agnos College of technology RKDF University Bhopal Madhya Pradesh for various operating conditions using hot water as heat source. In this paper, performance of the fabricated system is outlined with respect to various operating conditions related to heat source, condenser, absorber and evaporator temperatures. The solar heating unit remains idle in the summer months. Also the solar potential is at maximum in the summer other months of year.*

Keywords— Vapour Absorption Refrigeration, solar Thermal set up, environment Friendly.

I. INTRODUCTION

Solar energy is a very large, inexhaustible source of energy. The power from the sun intercepted by the earth is approximately 1.8 ×1011 MW which is much more larger than the present consumption rate on the earth of all commercial energy sources. Thus, in principle, solar energy could supply all the present and future energy needs of the world on the continuing basis. This makes it one of the most promising of the unconventional energy sources. In addition to its size, solar energy has two other factors in its favour. First unlike fossil fuels and nuclear power, it is an environmental clean source of energy. Second, it is free and available in adequate quantities in almost all parts of the world where people live. However, there are many problems associated with its use. The main problem is that it is a dilute source of energy. Even in the hottest regions on earth, the solar radiation flux rarely exceeds 1kWh/m ^{2} and the total radiation over a day is best about 6 kWh/m^2.These are low values from the point of view of technological utilization. Consequently, large collecting areas are required in many applications and this result in excessive costs. A second problem associated with the use of solar energy is that its availability varies widely with time. The variation in availability occurs daily because of the day-night cycle. In addition, variation occurs at a specific location because of local weather conditions. Consequently, the energy collected when the sun is shining must be stored for use during periods when it is not available. The need for significantly adds to the cost of the system. Thus, the real challenge in utilizing solar energy as an energy alternative is to address these challenges. One has to strive for the development of cheaper methods of collection and storage so that the large initial investments required at present in most applications are reduced. Flat plate collectors Flat plate collector is an insulated weather proofed box containing a dark absorber plate under one or more transparent or translucent covers.

II. LITERATURE SURVEY

Energy systems are complex as they involve the consideration of economic, technical and environmental factors. There is a dearth of thermally driven absorption refrigeration machines on the market which provide small-capacity cooling for domestic applications, as stressed upon by Velmurugan V et al. [1] this paper presents a description of a new solar refrigeration system using three fluid ammonia-hydrogen/water (NH_3-H_2/H_2O) vapour absorption systems. This technique uses solar energy to produce the desired cooling effect and without polluting the environment. According to Celina Maria Cunha Ribeiro et al.[2] the circulation of the working fluids is accomplished

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via a bubble pump, its action depends significantly on the mass transfer in the evaporator and the absorber. Also Joshua Folaranmi Leonardo [3] has described a new method for using a focusing collector, where heat from the sun is concentrated on a black absorber located at the focal point of the reflector where water is heated to a very high temperature. He also describes a solar tracking system by manual tilting of the bar at the support of the parabolic dish. The setup is mounted on a frame supported with a lever for tilting the parabolic dish reflector to different angles enabling capturing solar energy during different periods of the day The influence of operating conditions such as: ammonia fraction in inlet solution and tube diameter on the functioning of the bubble pump was presented and discussed by Ali benhmidene et al. [4]. It was found that, the liquid velocity and pumping ratio increase with increasing heat flux, and then it decreases. Optimal heat flux depends namely on tube diameter variations. Ali benhmidene et al. [5] found that the optimum heat flux can be correlated as a function of the mass flow rate and tube diameter, while the minimum heat flux required for pumping can be correlated as a function of tube diameter. The effects of hot water inlet temperatures on the coefficient of performance (COP) have been studied by V Mittal et al. [6]. S. Gabsi et al. [7] designed and simulated an absorption diffusion refrigerator using solar energy for domestic use. The climatic conditions and the cost due to technical constraints for various components such as the solar generator, the condenser, the absorber and the evaporator limits the system's application for small scale purposes. Mass and energy conservation equations showed that the new absorption cycle could produce viable amounts of cooling for domestic applications. [8]

III. EXPERIMENTATION SET UP

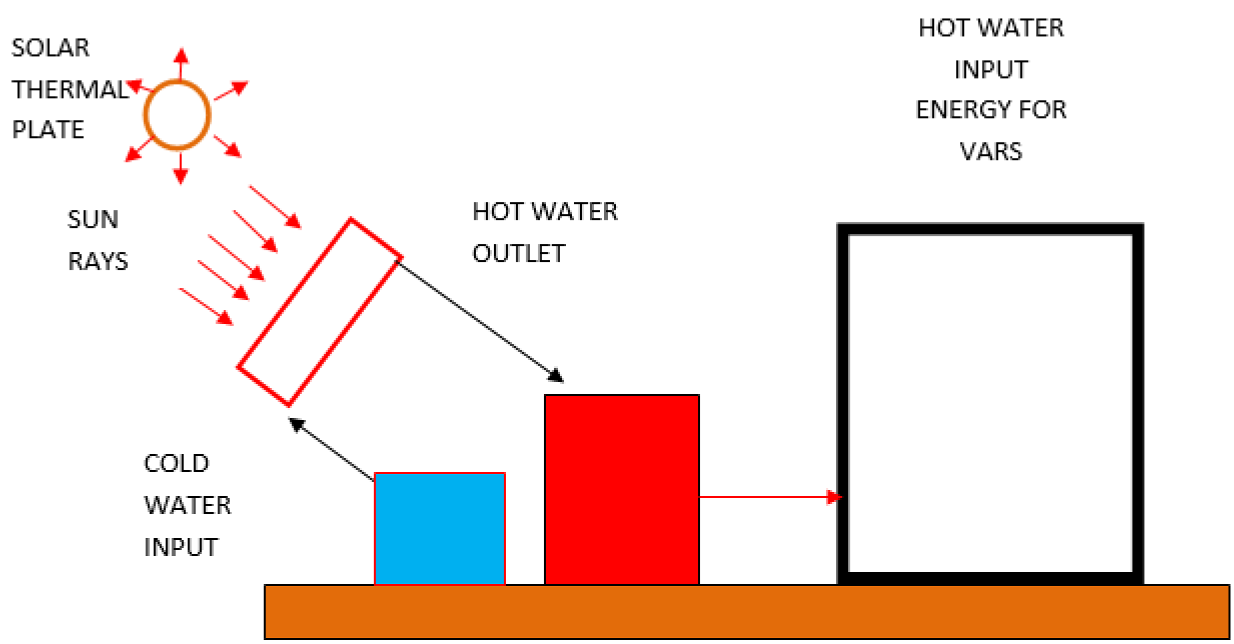

Fig.2: Solar water heater

IV. DESIGN OF PARABOLIC THROUGH COLLECTOR

Assume Maximum Temperature at T_g = 95 °c

Solar Constant I_{SC}=1388 W/m²,

Outer space radiation =1367w/m²

Geographical Location of the place where the solar collector is installed Bhopal Madhya Pradesh India.

Latitude Angle (Φ) =the latitude of a location on earth's surface is the angle made by radial line, joining the given location to the center of the earth, with its projection on the equator plan.

Latitude Angle (Φ) =23°

Longitude Angle (ϒ) = It is the angle between inclined plane surface , under the line due south and the horizontal projection of normal to the inclined plane surface **Longitude Angle(ϒ)**=77°

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Angle (Hour (Ꞷ) =the hour angle at any moment is the angle through which the earth must turn to bring the meridian of the observer directly in line with sun's rays. **Angle Hour (Ꞷ) =0**

Number of days for six months taken

n=183days

Declination Angle (δ) =It is define as the angular displacement of the sun from the plane of earth's equator. It is positive when measured above equatorial plane in the northern hemisphere.

Declination Angle (δ) =23.45 sin[$\frac{360}{365}$(284+n)]

δ =23.45 sin[$\frac{360}{365}$(284+183)]

δ =23.04°

Zenith Angle (Z)=It is the angle between sun's ray and perpendicular(normal) to the horizontal plane

Cos Z = sinΦ sinδ+cosΦ coS δ cos Ꞷ

CosZ = sin (23°) sin (23.04°) +cos (23°) cos (23.04°) cos0°

CosZ = 0.999

Z=2.562°

Available radiation intensity (I_z)

$I_z = I_{sc}\ e^{[-ce(secz)s]}$

C=0.357, S=0.678

$\boldsymbol{I_z}=1388\ e^{[-0.357(sec2.562°)0.678]}$

I_z= 1089.65 w/m²

The value of radiation on a horizontal surface (I_h)

$I_h = I_z$ **cosZ**

=1089.65cos (2.562°)

I_h =1088.56 W/m²

Total solar radiation intensity=200MW/m²

Reflected Intensity R_i=Reflectivity of material × Solar radiation intensity

Reflectivity of aluminum sheet=0.9

Thus R_i=0.9×200=180 MW/m²

Therefore; Heat required at collector

Q_i=mCp×ΔT

Q_i=4×4.178 (95-45)/3600

Q_i=0.2326KW

Area of parabolic through collector (A_d)

$A_d = =\frac{Heat\ required\ at\ collector}{Reflected\ intensity}$

$A_d = \frac{Q_i}{R_i}$

=232/180=1.288

A_d=1.288 m²

Depth of parabolic collector (h)

h=0.25m

Surface area of collector (A_s)

$A_s = \frac{\pi}{6}x[\frac{r}{h^2}]x\frac{r^2}{4h^2}x(\frac{1}{2-r^3})$

1.288=π/6×[r/0.25]×[(r²/4×0.25)/(2-r³)]

r = 0.4196=0.42---

Focal length (F)

(F) $= \frac{r^2}{4h}$

0.42²/4x0.25

F=0.1746m

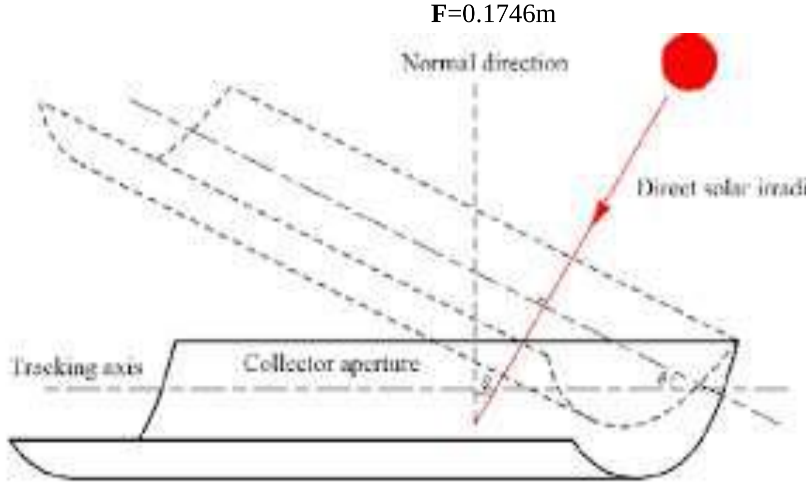

Fig.3: Parabolic trough collector

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DESIGN OF GENERATOR

Flow rate of refrigeration.

$Q=\frac{capacity}{time}$

$Q=\frac{4\ liter}{3600}$

$Q=\frac{4\ x10^{-2}}{3600}$=1.11×10⁻⁶m³/sec

Heat transfer rate at generator ;

(i)Length of coil attach on outer side of generator,

L=0.51m

(ii)Inner diameter of coil

D_i=0.016m

(iii)Outer diameter of coil

D_o=0.022m

Therefore

D_m= 0.022-0.016=0.006m

Assume;

Ambient temperature T_a=27.40°C

Collector fluid temperature T_g=90°C;

Bulk temperature T_f=(27.40+90)/2=58.7°C

Taking properties at

T_f=58.7°C

μ=0.4708 N sec/m ϑ=0.478x10⁻⁶ m²/sec

P_r=3.020 K=0.6513W/mK ƒ=985 kg/m³

Thus,

Reynolds Number (R_e)

$R_e= \frac{\mu x Dm}{\vartheta}$

$= \frac{0.4708x0.006}{0.478x10^{-6}}$ =5909.623

Since the flow is force convection ,therefore using monrad and peloton equation;

$N_u=0.02(R_e)^{0.8}$ x $(P_r)^{0.33}$x$[D_o/D_i]^{0.53}$

$N_u=0.02(5909.62)^{0.8}$ x $(3.020)^{0.33}$x$[0.022/0.016]^{0.53}$

N_u=35.47

Thus**, Heat transfer coefficient (h);**

$h =\frac{N_u \times K}{D_m}$

h=3.47 x0.6513/0.006

h =3850.26W/m²K

Thus heat load generator (Q_g)

Qg=hA (Tg-Ts)

Where,

T_s=Surface temperature

Q_g =3850.26xπx0.006x0.51x (95-92)

Q_g= 111.04 watt.

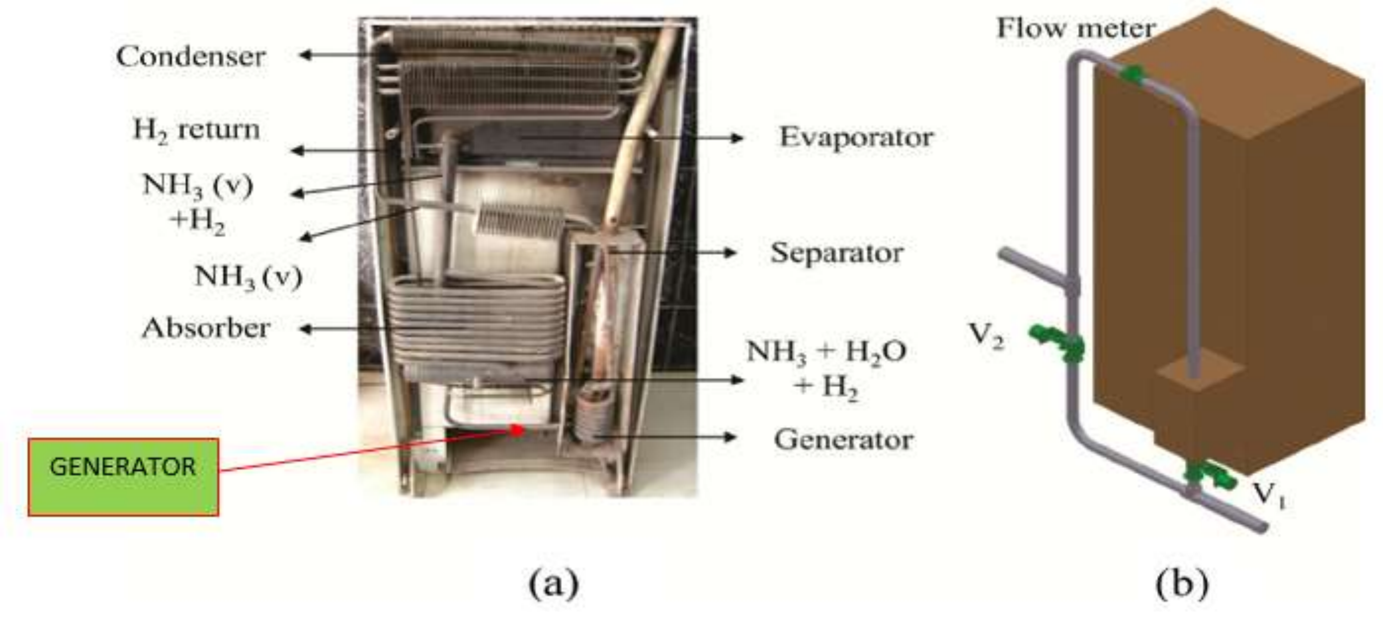

Fig.5: Generator with heating coil

DESIGN OF EVAPORATOR

Mass flow rate of refrigerant from condenser =17.5x10⁻³kg/sec

Ambient temperature T_a= 45°C

Cooling unit temperature T_e=15°C

Heat load at evaporator Q_e=m_r (h_a-h_e)

As aqua-ammonia flow through out system enthalpy at above temperature

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From refrigerant table
At 45°C, h_a= 396.81kj/kg
At 15°C, T_e= 251.44 kj/kg

Hence by putting above values, we get
Heat load on evaporator
Q_e= 17.5x10⁻³ x (396.81-251.44)
Q_e= 2.543Watt
COP $= \frac{Q_e}{Q_g}$ =2.543/111.04=0.0229
COP =0.0229

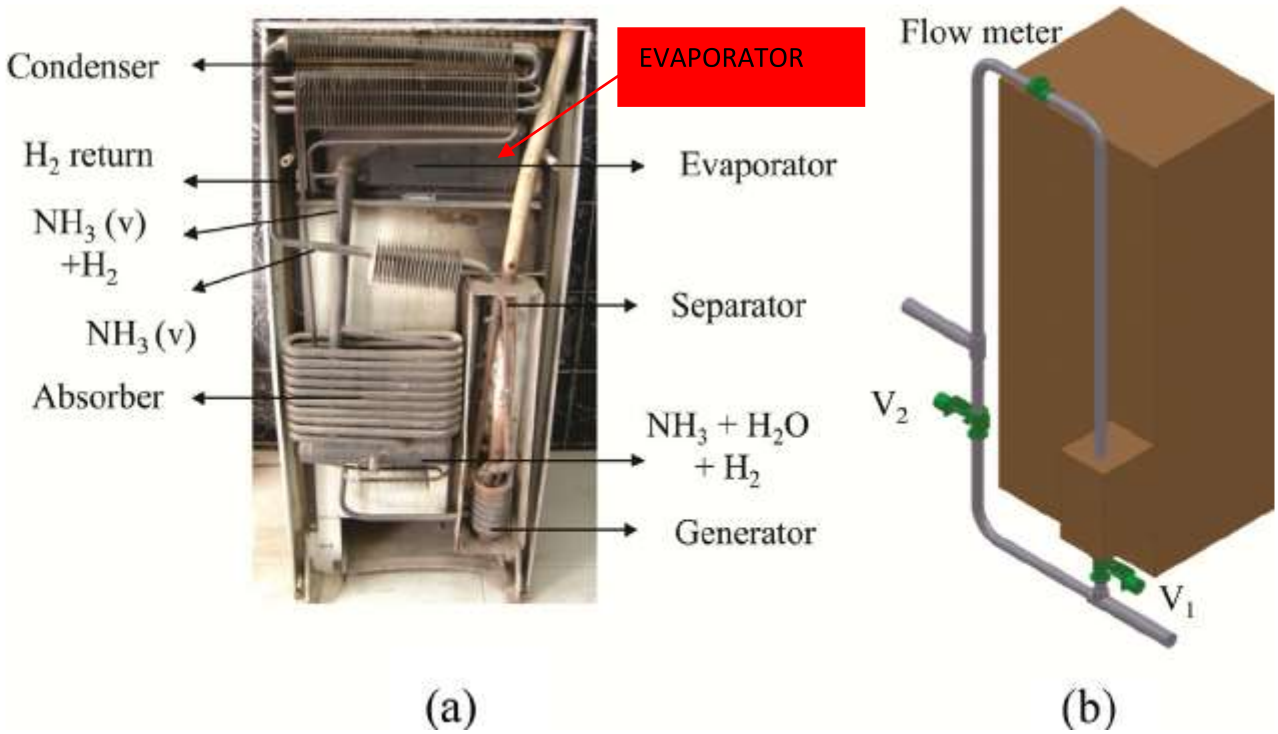

Fig.6: Shell and tube type evaporator

V. EXPRIMENTAL CIRCUITS

In this system there are the circuit which are describe one by one

5.1 HOT WATER CIRCUIT

First the available cold water is filled in the entire circuit of collecting tank, solar panel's riser pipes, header pipes & generator coils. Then the entire system is placed in open atmosphere to receive solar radiation. The radiation received by the absorber plate is transferred to the water in the riser pipes. As a result the water gets heated and the density decreases. As the hot water is less dense than cold water it automatically rises up and enters the collecting tank. The relatively cold water from collecting tank replaces the hot water in the riser pipes and the procedure repeats. The collected hot water then circulates in the coil placed in the generator where the hot water gives off its heat to the refrigerant. So in the hot water circuit the water receives heat in the solar panel and gives off the heat in the generator.

5.2 REFRIGERANT CIRCUIT

The refrigerant gets separated from the aqua ammonia solution in the generator by absorbing the heat from the hot water in the generator coil. The ammonia after getting vaporized flows through the circuit and enters the condenser. In the condenser the refrigerant Vapour gives off its heat to the surrounding air and gets converted into liquid ammonia. So the refrigerant gives off its latent heat in the condenser. The liquid refrigerant then enters the capillary tube where the pressure drops to the evaporator pressure. The low pressure low temperature liquid refrigerant then enters the evaporator receives heat and produces the refrigerating effecting in the evaporator cabinet. The refrigerant gets converted into Vapour after receiving the heat. The Vapour refrigerant is absorbed by the water present in the absorber. This is due to the chemical affinity of the water towards ammonia. This is the motive force for the refrigerant. In the absorber the ammonia Vapour mixes

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with water and results in aqua ammonia solution. This solution is pumped to the generator pressure by a fractional HP pump. In the generator the ammonia gets vaporizes and separates from the solution. If any amount of ammonia remains in the solution it is sent back to the absorber through capillary tube. Thus the cycle repeats.

After the system is reached to steady state the following readings are taken

1. Collecting tank water outlet temperature
2. Temperature of the refrigerant before evaporator
3. Temperature of the refrigerant after evaporator

VI. RESULTS AND DISCUSSION

The experiment test trails are conduct about five hours per day for 183 days. The temperatures are noted at particular intervals of time. The temperature variations are shown in Fig 7..As the temperature of hot water supplied to the generator from the single flat plate solar collector increases, the evaporator temperatures at inlet and outlet are decrease. It is also observed from the Fig.8 the difference between evaporator temperatures at inlet and outlet marginally increases as the time of operation increases. The temperature drop is found that in the range of 7 to 80C. Almost after two hours of operation there is no further drop is observed and it may be due to there is no change in supply water temperature to the generator. The maximum COP is in the range of 3 to 3.5 and actual COP is found in the range of 0.75 to 0.79

Table.1: Collector Fluid Temperature with Local Time Temperature in Bhopal

SNo.	Local Time(inHrs)	Ambient Temperature(ºC)	Collector Fluid Temperature(ºC)
1	9:00	26.40	40
2	10:00	28.60	70
3	11:00	31.20	100
4	12:00	31.90	120
5	13:00	33.70	126
6	14:00	34.50	123
7	15:00	34.80	115
8	16:00	32.00	110

Every one an hour the parabolic dish was adjusted manually to path the movement of the sun. From the testing done it was noted that the lowest temperature achieve was 25ºC. It was noted that the cabin temperature increased for a definite period and then drop

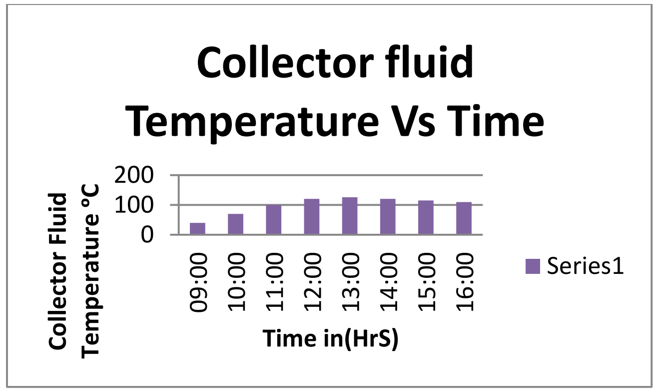

Fig.7: Variance of Collector fluid temperature with local time in Bhopal

The C.O.P of the system was obtain from the calculations as 0.0229 The result was noted that the collector fluid temperature increased with time but only up to a certain period. It can also be noted that the fluid temperature increases till 13:00 to a temperature of 120ºC nd then starts reducing. Now a second set of data is analyze. Here cabin temperature variance is consider with respect to time. A digital thermometer was used for the purpose. It was noted that the cabin temperature reduces up to 13:00 hrs and then

Table.2: Cabin temperature with local time temperature in Bhopal

SNo.	Local Time (inHr)	Cabin Temperature (ºC)
1	9:00	27.50
2	10:00	26.20
3	11:00	25.10
4	12:00	24.30
5	13:00	23.50
6	14:00	23.70
7	15:00	24.60
8	16:00	26.00

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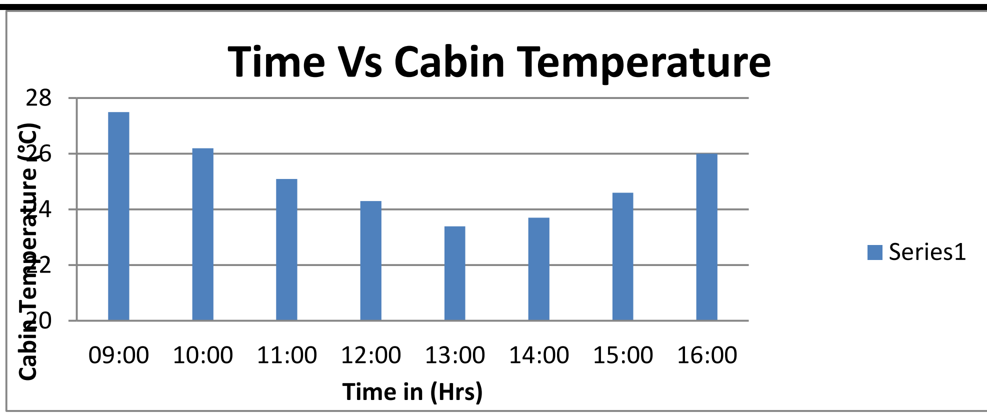

Fig.8: Variance Cabin temperature with local time in Bhopal

Table.3: Collector Fluid Temperature with Local time temp. in Bhopal

SNo.	Local time(inHrs)	Atmospheric Temperature(°C)	Collector Water Temperature(°C)
1	9:00	27.50	27.50
2	10:00	29.40	41.00
3	11:00	34.30	59.00
4	12:00	35.60	78.00
5	13:00	36.20	89.00
6	14:00	38.70	80.00
7	15:00	37.10	91.00
8	16:00	35.50	82.00

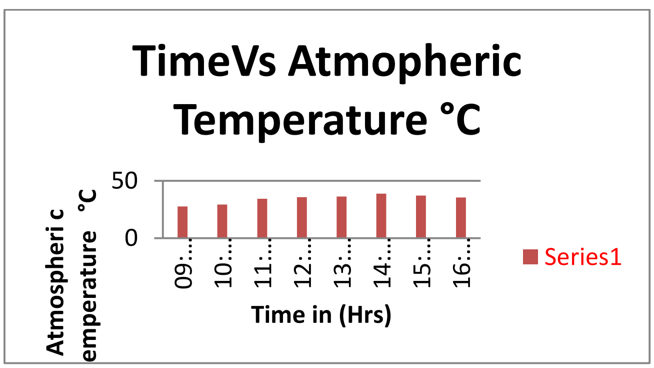

Fig.9: Atmospheric temperature with local time in Bhopal

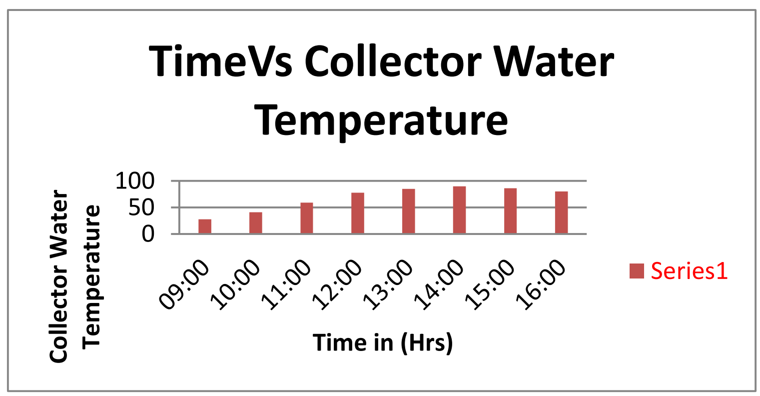

Fig.10: Collector water temperature with local time in Bhopal

VII. CONCLUSION

The following conclusions can be made from the present investigation

1. The Solar flat plate collector Water Heater (SWH) can be effectively used in summer to produce refrigeration effect using Vapour absorption refrigeration cycle.
2. The amount of refrigeration effect is based on the temperature of the hot water supplied to the generator.

3. The maximum drop in the temperature at the evaporator in the present work is estimated to be 7 to 80C.
4. The COP (Coefficient of Performance) of the system is about 0.78 against the maximum COP of the system
5. The additional cost of the refrigeration cycle is very low.

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