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STUDIES ON PERFORMANCE OF SOLAR POWERED VAPOUR ABSORPTION REFRIGERATION

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ABSTRACT

Vapor absorption refrigeration belongs to the class of vapor cycles like vapor compression refrigeration cycle. Input for vapor absorption system is in the form of heat hence these systems are also called as thermal operated systems. Since the liquids are used to absorb the refrigerants, they also called as wet absorption system. So these system runs on low grade energy, they prepared when low grade energy such as, waste heat or solar energy is available. So from all the point of view such as, environmental friendly, cost and easily available energy. Work has been carried out to check the performance like Cop and Circulation ratio using solar based system to observe the variables like flow rate and composition.

Key words: Vapor Absorption Refrigeration Systems (VARS), pressure of the evaporator, pressure of the condenser, Solar

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1. INTRODUCTION

Vapor Absorption Refrigeration Systems (VARS) belong to the class of vapor cycles like vapor compression refrigeration systems. However, unlike vapor compression refrigeration systems, the required input to absorption systems is in the form of heat. Hence these systems are also called as heat operated or thermal energy driven systems. Since conventional absorption systems use liquids for absorption of refrigerant, these are also sometimes called as wet absorption systems.

Like vapor compression refrigeration systems, vapor absorption refrigeration systems have also been commercialized and are widely used in various refrigeration and air conditioning applications. Since these systems run on low-grade thermal energy, they are preferred when low-grade energy such as waste heat or solar energy is available. Since conventional absorption systems use natural refrigerants such as water or ammonia they are environment friendly.

Since the beginning of the last century, average global temperature has risen about 0.6 K per UN Intergovernmental panel on climate change. It is also warned that the temperature may further increase by 1.4-4.5 K until 2100. Having realized the seriousness of the situation, the world community decided to take the initiatives to stop the process. One of such effort is the Kyoto protocol, a legally binding agreement under which industrialized countries will reduce their collective emission of greenhouse gases by 5.2% compared to the year 1990. Especially regarding the reduction of carbon dioxide, being the inevitable by-product of industrial activities, industries should improve facilities and processes to achieve the goals. Refrigeration industry is one of those hardest hits by the effect of the protocol.

In Europe, use of HFC134a will be banned for the air conditioning units in new cars. Inspection and monitoring are required for all stationary HFC based refrigeration, air conditioning and heat pump units for the safe containment of HFCs. Reduction of energy consumption fo1r refrigeration, however, cannot be relied solely on the improvement of efficiency. Reduction in use of synthetic refrigerants and production of co2 provide a new opportunity for solar refrigeration. Considering cooling demand increases with intensity of solar radiation, solar refrigeration has been considered as a logical solution. In the 1970s-solar refrigeration received great interests when the world suffered from oil crisis. There were many projects for the development of solar refrigeration technologies and solar refrigeration continued to be an important issue.

A variety of solar refrigeration technologies have been developed and many of them are available in the market at much cheaper prices than ever.[1] Solar energy is very large inexhaustible source of energy. The power from the sun intercepted by the earth is approximately 1.8 ×1011 MW which is much larger than the present consumption rate on the earth of all commercial energy sources. Thus, solar energy could supply all the present and future energy needs of the world on the continuing basis.

Flat plate collectors

Flat plate collector is an insulated weather proofed box

Containing a dark absorber plate under one or more

Parts of a Flat Plate Collector:

Cover Plate: It is made up of glass tempered with a low iron

Content and 3.2-6.4 mm thick. The collector has 85%transmittance when this type of glass is used. *Absorber Plate:* It is made up of copper because of its high conductivity. Moreover, it is corrosion resistant. These copper plates 0.05 mm thick with 1.25 cm tubes. Tubes are Spaced 15 cm apart, the efficiency is 97 %. Moreover, black paint over copper plate is used which has Absorptance =0.85-0.9 and emittance=0.08-0.12.

Enclosure/Insulation: It is made up of steel, aluminum or fiber glass. Fiber glass is widely used.

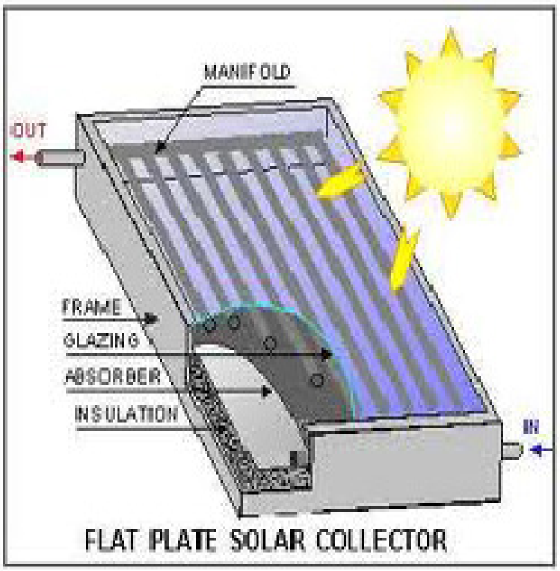
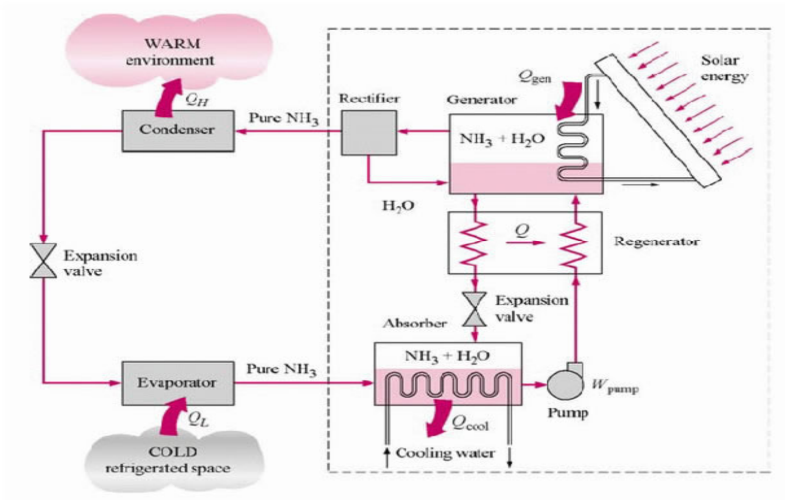


Figure 2 Flat plate collector parts

$$COP_R = \frac{\text{Desired output}}{\text{Required input}} = \frac{\text{Cooling effect}}{\text{Work input}} = \frac{Q_L}{Q_{gen} + W_{pump,in}} \cong \frac{Q_L}{Q_{gen}}$$



2. MATHEMATICAL MODELING

The operating pressures at which the system is working needs to be determined to carry on further calculations, using an enthalpy concentration chart. Once the pressure of the condenser (Pc) and the pressure of the evaporator (Pe) are determined the corresponding points can be fixed on the chart as shown in fig. 4. The various other points and condition lines for components like absorber, generator, heat exchangers etc can be subsequently fixed.

2.1. Condenser Pressure (Pc)

The pressure to be maintained in the condenser for changing the phase of ammonia vapors into ammonia liquid depends on type of condensing medium used and its Temperature.

In this system, water is used as a condensing medium. Water is available at a temperature of 25 0C. i.e. condensing temperature is Tc= 25 0C. For condensing ammonia vapors at 250C, the corresponding pressure required can be noted from the refrigeration table of ammonia (R-717).

2.2. Evaporator Pressure (Pe)

The evaporator pressure can be fixed per the minimum temperature required to be maintained in the evaporator chamber. The minimum temperature attained is not a designing criterion in this system, as we require to cool water only for drinking purposes. The pressure maintained in the evaporator should be as close to the atmospheric pressure as possible, because maintaining a higher pressure is a difficult and costly affair. Moreover, it also has leakage problems and the unit needs to be hermetically sealed. The evaporator pressure is kept equal to the atmospheric pressure (1 bar), to ensure design economy. The corresponding saturation temperature in the evaporator (ammonia vapors) becomes -33 0C.

2.3. Absorber

In absorber, the pure NH3 gas enters at condition 4 and Weak aqua solution enters at condition 10 and after mixing, strong aqua comes out at condition 5. The mixing occurring inside is underlined but aqua condition coming out is known. Join the points 10 and 4 and extend the vertical line passing through point 7 till it cuts at point 7". Now we can say that mixing taking place along the line 4-10 and at pressure Pe and resulting aqua is coming out at 5 after losing heat in the absorber. Joining the points 4 and 10 and marking point 7" is not necessary for solving the Problems or designing the system components.

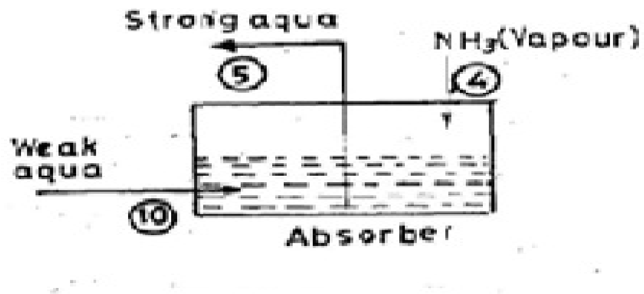
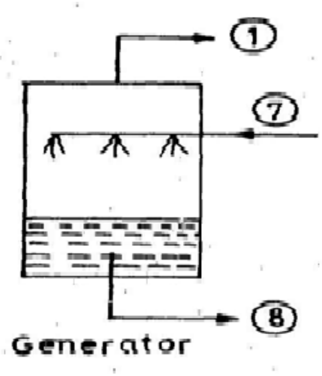


Figure 5 Absorber

2.4. Generator

In generator, strong aqua is heated by supplying heat Qg, for the generation of High NH3 vapours



2.5. Design Procedures

A. Nomenclature

τ =Transmittance of glass cover

αη= Absorptance of absorber surface

M =Mass of water (kg)

C =Average heat capacity of receiver tube (J/kg K)
ΔT =Change in mass temperature (T)
At =Change in time period (sec)
I =Solar radiation (W/m2)
A =Area of receiver tube exposed to radiation (m2)
η =Efficiency

B. Collector Area Design

The collector area A can be determined from the following eqn. 1,[1]

$$\tau\alpha = MC\frac{\Delta T}{\Delta t} * \frac{1}{IA} \qquad (1)$$

C. Number of Tubes

The determination of number of tubes depends on the size of each tube available commercially. It is given by eqn.2,

$$Number\ of\ tubes = \frac{Collector\ Area\ Required}{Projected\ area\ of\ standard\ tubes} \qquad (2)$$

Efficiency

The efficiency is calculated using empirical relation [2] as follows:

$$\eta = 0.527 - \frac{0.1736\Delta T}{I} \qquad (3)$$

Month	Radiation (kWhr/m2/Day)
January	5.46
February	5.94
March	6.39
April	5.93
May	5.35
June	3.87
July	3.71
August	4.08
September	4.83
October	4.54
November	4.65
December	4.99

TABLE III

Material	Borosilicate Glass
Selective coating materials	AL/SS/CU
Absorption coefficient(α)	0.93
Emission coefficient	0.065
Transmission coefficient (τ)	0.890

3. CALCULATIONS

f. Calculations of solar water heater.

Useful energy (energy absorbed by the collector plate) is given by

$Qu = K \times S \times A$

Where,

K=efficiency of collector plate (assume k=0.85)

S=average solar heat falling on earth's surface

=6 kwhr/m2/day= 250 W/m2

A=Area of collector plates

Now

Heat req. in the generator, Qg = 304.2 KJ/min

= 304.2 × 1000 / 60 J/s

= 5070 W

Hence approximate area of the collector plates required

For providing this much amount of energy = 5070 / (250 × K)

= 5070 / (250 × .85)

= 24 square meters (approx.)

Total Area of collector plates

A= 24sq m

Therefore, we can use 4 collector plates of having Dimensions of 3 X 2 sq m.

Thus, Qu=0.85 × 250 × 24 = 5070 W= 5070 J/s

The energy absorbed by the collector helps in heating Of the water flowing in the tubes of the collector Plates.

$U = m \times Cp \times (To-Ti)$

Let rate of water flowing through the tubes,

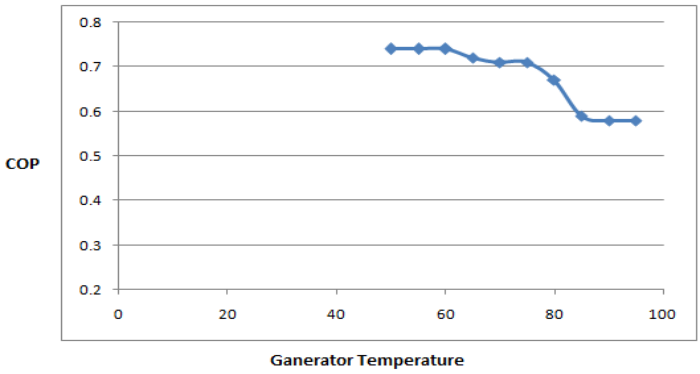
m = 1.2 kg/min = 0.02 kg/s, (typical example)

The work done by the pump for raising the pressure is Negligible and hence neglected.

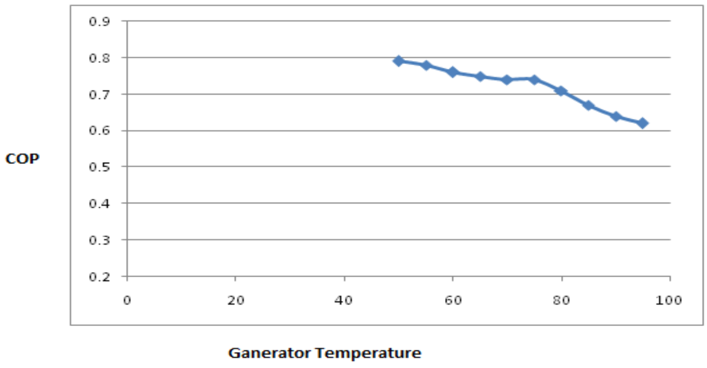
Designed solar collector

Phase one assembly of the system

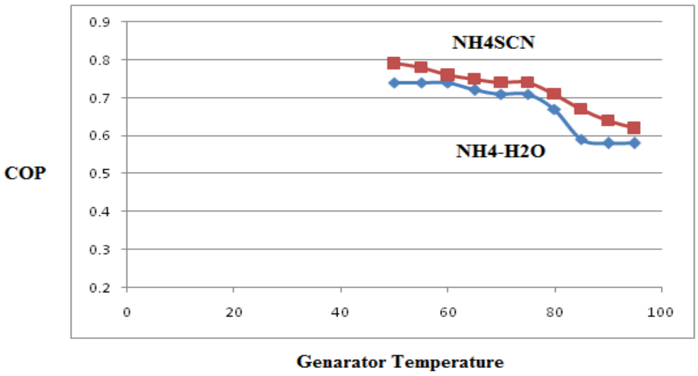
4. RESULTS AND DISCUSSIONS



Above graph showing the variation of COP value with different temperatures at the heat generating unit of Ammonia water as a refrigerant.



Above graph showing the variation of COP value with different temperatures at the heat generating unit of Ammonium thiocyanate as a refrigerant and this will give you the best COP value compared to the aqua ammonia solution.



This is the graph showing you the comparison between Ammonia water and ammonium thiocyanate as a working pair and Conclude that improvement in the COP value is obtained ammonium thiocyanate as a working fluid.

4.1. Justification

In this project ammonia-water and ammonium Thiocyanate are employed as working pair to check the performance of the refrigerator and outside of these two-pair associated with working fluids Ammonium Thiocyanate to be a working fluid to receive best COP value on the system. So

Improvement in the COP value is given as,

Average COP value for Ammonia Water is = 0.67

Average COP value for Ammonium Thiocyanate is = 0.72

So % age Improvement of COP value is given as

$$(COP)_{\%\ age\ Improved} = \frac{(COP)\ Ammonium\ thiocycnate - (COP) Ammonia\ water}{(COP) Ammonia\ Water} X\ 100$$

$$= \frac{(0.72)-(0.67)}{(0.67)} X\ 100$$

$(COP)_{\%\ age\ Improved} = 7.4\%$

So, % age improvement in the COP value for the system is about 7.4% and it can be concluding that Ammonium Thiocyanate can be used as a working pair for the system to obtain better COP value.

Sr No	Particulars	Existing System	Current System	Improvement in the system
1	Electric heater	Yes	Replaces by solar water heater and heater driven by solar power	Due to solar power electrical energy can be saved
2	Pump	Yes	No pump since the system is running due to gravity force	Due to no pump action cost of the pump and electricity can be saved
3	Ammonia water working fluid	Yes	Here the working fluid is replaced by Ammonium Thiocyanate	Cop value of the system is increased by 7.4%

5. FUTURE SCOPE

Now each day Study on performance of absorption system is taking very good scope to improve the coefficient of Performance with the system. So, in future study is usually continued instead of Aqua ammonia and ammonium Thiocyanate as working fluids they will use Dimethylene-Activated carbon, Ammonia-Lithium Nitroxide as working fluids. With addition towards study of different working pairs, simulation study of the inlet and outlet temperature variations from the generator and simulations may be accomplished for the circulation of refrigerant during the entire system

6. CONCLUSION

In this project, solar panel technology is used as a primary source to generate the heat energy to run the actual vapor absorption refrigeration system to uncover the refrigeration effect. So, from the cost and environmental point of view and the availability of the low-grade energy mindset I can conclude that,

- Electrical energy is replaced by the solar energy, due to this overall 31.8% of improvement in the evaporator temperature can obtained.
- Ammonia water working fluid is replaced by Ammonium Thiocyanate and the improvement in COP value of about 7.4% is achieved.
- In general absorption system use of pumping action is necessary and in this system work has been carried out with the gravity force. So, reduction in the cost of pump and electricity.
- Finally, it is very much necessary to take care of the overall maintenance and cost effectiveness of the system.

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