Development and Fabrication of Solar Vapour Absorption Refrigeration System using Parabolic Solar Trough

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ABSTRACT

As the saying goes, "There is no energy crisis, only a crisis of ignorance". With the minds of research along with scientific investigation, a pathway has led to deep dive into renewable energy sources. In the era of energy crisis renewable energy is seen as a farsighted option with great capability and endurance. This paper deals with application of solar thermal energy with vapor absorption system. In vapor absorption, system heat energy is taken as source of input energy unlike mechanical energy in vapour compression refrigeration system. The performance characteristics and evaluation depends on heat energy supplied and pump work used in the refrigeration system .Hence, here idea of experimental setup developed from this thought that if the heat energy required for the process is extracted from the solar energy and supplied to the generator then energy requirement to the generator can be reduced. Hence, our project novelty is based on the running a vapour absorption refrigeration system using the heat energy extracted from solar energy by using a parabolic solar heat collector. This heat is used to supply the heat required in the generator for the system. Hence, our result of experiment would aim for generation where the input work of electrical energy is given only through pump and other sources of input work are removed. Air-conditioner and refrigerator uses 70% of domestic energy utilized. This work provides a solution for this high energy consuming machines. We hope to take a small step in this direction for future development and establishment of new advancements in this regard.

Keywords:-Renewable energy, vapour absorption, heat energy, parabolic solar heat collector, solar thermal energy, pump work*

INTRODUCTION

Development of a country depends on the per capita energy consumption of the people of that country. It is deemed that more the energy consumption more prosperous the nation is. In the present scenario, the same case is applicable but with a small change of utilizing clean energy which is environmental friendly. As rightly said by Martin Rees "We do not fully understand the consequences of rising population and increasing energy consumption on the interwoven fabric of atmosphere, water, land and life." There has been ever increased need for utilizing clean energy and specially dealing with the refrigerants causing the depletion of ozone layer. Hence the need of hour comes with the utilization of renewable sources of energy so to find a solution in this path few literature surveys was made like Sorawit Kaewpradub et al[1] found a way to utilize waste heat of engine exhaust from automobiles in generating refrigerating effect. Piyush Mahendru et al[2] in their paper studied about the analysis of Lithium bromide, water vapor absorption refrigeration system using the mole concentration concept. Pongsid Srikhirin et al[3] studied about the various vapor absorption refrigeration systems present and the working fluids which may be used to get various outputs. Arturo González Gilstudied [4] about solar air cooling on single & double effect Lithium Bromide vapor absorption refrigeration system. Benjamin Bronsema [5] identified the problems faced in hybrid ventilation systems and provided certain solutions to them. T. O. Ahmadu[6] studied about a lithium bromide chiller, which gave a Arakerimath [7] studied about solar vapour absorption cooling system utilizing parabolic solar dish collector where the C.O.P was obtained to be 0.72 for the cycle. Joydeep Chakraborty et al [8] studied about lithium bromide vapor absorption system using solar energy. Anan Pongtornkulpanich [9] studied about a new pair of absorbent and refrigerant in vapour absorption system using activated carbon and methanol providing the required heat through solar energy. Soteris Kalogirou [10] studied about designing a lithium bromide vapor absorption refrigerator providing the design conditions necessary for the heat exchangers. Shekhar D. Thakre et al [11] presented about the cooling system in truck by using vapor absorption system taking source from the waste heat of automobiles. Salem M. Osta-Omar et al[12] studied about the concentration of absorbent and refrigerant required in a vapor absorption system. The concentration of aqueous solution of lithium bromide was found using electrical conductivity and temperature measurements. K.Balaji et al[13] studied about vapor absorption system using waste heat source from sugar industry and designed a hypothetical model for the Li Br, water refrigeration system. Jaspalsinh B Dabhi et al[14] studied about various pairs for adsorption cooling systemsand their outputs. The various pairs included silica gel -water, activated carbon -ammonia, zeolite –water, metal organic framework materials. Makena Harish et al[15] studied about design of vapour absorption refrigeration system of 5.25 Kw capacity using solar water heaters. Rotchana Prapainop et al [16] studied about properties of refrigerant & how different refrigerant properties affects the performance of the system. Joyeep chakraborty et al [17] described about the lithium bromide refrigeration system using solar energy as the heat source. Shabari Girish K.V.S. et al[18] studied about a detailed case study for a lithium bromide refrigeration system. Abhishek Ghodeshwar [19] and team studied Comparison and analysis of vapor compression and absorption refrigeration system. Prashant Sharma et al[20] studied about thermal analysis of vapor absorption refrigeration system using solar energy.

GAPS IDENTIFIED FROM LITERATURE SURVEY

Although Vapor absorption refrigeration outstands vapor compression system in many aspects like using non-harmful refrigerants, using clean energy and reducing carbon emissions indirectly most of the literature work has been done on lithium bromide refrigeration system. Very little work is done in the recent times on ammonia water vapour absorption system. Since ammonia’s freezing point (-77C) is very less compared to lithium bromide which is a better option considering the application in the field of refrigeration. Hence based on the literature survey it is decided to conduct an experimental analysis on ammonia water based vapor absorption refrigeration system aiming for obtaining better results compared to lithium bromide refrigeration system. The novelty of this paper is in the utilization of solar thermal (heat) energy applications for producing refrigerating effect using ammonia water as the working pair. In Vapour absorption system, we require heat energy for the separation of refrigerant and absorbent. The heat source required for this is supplied with the help of solar heat supplied from a parabolic solar collector. Once the connections are made, coefficient of performance is calculated and the results are analyzed.

Solution to energy consumption and energy saving for future is eminently visible from the source of renewable energy. Idea of setting an interlink for obtaining refrigerating effect with solar heat generated from parabolic solar trough not only overcomes the deficiency of energy consumption but also deals with overcoming the high end solution for ozone layer depletion which is a gigantic problem nowadays.

WORKING PRINCIPLE OF ABSORPTION SYSTEM:

In a vapor absorption system two fluids are used which are the absorbent and refrigerant. Absorbent is a substance which absorbs the refrigerant causing the pressure to reduce. As the refrigerant vapor gets absorbed the temperature of the refrigerant gets reduced due to vaporization of the refrigerant. This basic process causes the refrigerating effect. As this occurs the absorbent becomes more and more diluted due to refrigerant getting absorbed into it and hence to separate this again heating is used to bring the absorber back to its normal state. Hence, by the process of supplying heat energy the refrigerating effect is produced in a cyclic process as shown in Figure 1.

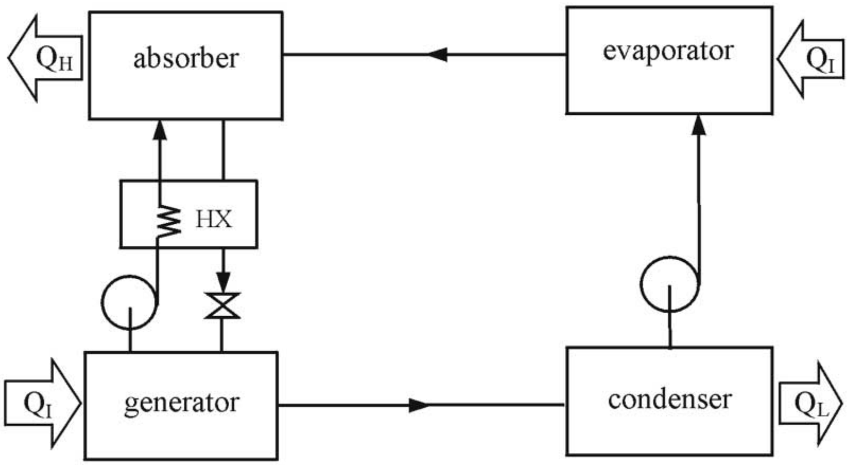

Fig.1:-*Working Process of Vapor Absorption System*

VAPOR ABSORPTION COOLING SYSTEM EQUIPMENTS

Condenser: The condenser converts the refrigerant vapor into liquid refrigerant .Here an Air-cooled Fin type Condenser is used for getting the required heat transfer in the process. The refrigerant used here (Ammonia) enters as vapor and exits at the outlet as liquid refrigerant.

Expansion Valve: The high pressure liquid refrigerant leaving the condenser enters the expansion valve and reduces the pressure as it leaves out of the system .A capillary tube is used here as an expansion valve which brings the down the pressure in the system.

Evaporator: This low-pressure low temperature liquid refrigerant enters the Evaporator whose function is to absorb the heat in the refrigerated space and produce the required refrigerating effect of the system. The refrigerant enters as liquid condition in evaporator and leaves as vapor or superheated vapor from the evaporator.

Absorber: The function of an absorber is to gulp the refrigerant formed in the evaporator. It absorbs the vapor refrigerant coming out of the evaporator and forms a solution in the absorber system. Here, Liquid water is used as an absorbent as water has great affinity towards Ammonia vapors as shown in Figure 3.

Generator: The generator is used to separate this solution formed in the absorber into their original forms of refrigerant and absorbent. The generator takes heat as the source, and separates the solution into refrigerant and absorbent and helps it to flow back into the condenser and completes the cycle.

EXPERIMENTAL SET-UP

Solar Parabolic Trough Collector

It consists of a solar collector shaped in a parabola for obtaining maximum concentration of solar radiation. Here, the parabolic solar trough collector fabricated using aluminum plates with plywood was used. Initially plywood is setup, on which aluminum sheets pasted. A pipe situated at the focus of the parabola so that the solar radiation on the collector will be concentrated on it and the refrigerant flowing inside the pipe gets heated. Here, this works as a generator for separating the refrigerant and absorbent as shown in Figure2.

Fig.2:-*Fabrication of solar parabolic trough collector*

Fig.3:-*Condenser, evaporator and absorber unit*

Table.1:-*Details of components used in the experiment*

S. No.	Component	Material	Specification	Size	Units
1	Parabolic Collector	Aluminum	1 tube	1	Metre
2	Condenser	Copper	16 windings	0.4	Metre
3	Expansion Valve	Copper	40 windings	1.5	Metre
4	Absorber	Iron	1	0.15 x 0 .20	Metre^2
5	Pump	Plastic	1	4	Watt
6	Thermocouples	Digital	4		Celsius, Kelvin

The experiment was conducted based on the data provided in Table 1. All the equipment stated above were purchased and connected in a cyclic manner stated in the working principle. Once the equipment were ready, the refrigerant was filled in the condenser under the supervision of local refrigerant technician. The experimental set up was ready and it was connected to the parabolic collector fabricated earlier. Once this entire set up was ready, we started with the experiment and took the values of temperatures by using digital thermocouples at various required connections of Condenser, Generator & Evaporator. Based on these values of temperature readings we found the coefficient of performance at various timings of the day as per the availability of solar energy in the day. On completion of it we collected the values of temperatures for a week and the average instantaneous Coefficient of performance was found.

The experiment was made on the following assumptions:

- The flow is considered as steady and reversible.
- Pure refrigerant is flowing in the condenser, expansion valve and evaporator.
- There is no pressure loss in the system.
- Changes in kinetic and potential energy are negligible in the system.

CALCULATIONS

T_g: Temperature in the generator T_c: Temperature in the condenser
T_e: Temperature in the evaporator

Day 1: 02/03/2019

S.No.	Time	T_g	T_c	T_e	C.O.P
1	9: 00 AM	345	327	285	0.354
2	2:00 PM	353	335	287	0.305
3	6:00 PM	339	323	285	0.353
					0.337

Day 2: 03/03/2019

S.No.	Time	T_g	T_c	T_e	C.O.P
1	9: 00 AM	342	330	286	0.228
2	2:00 PM	360	342	284	0.356
3	6:00 PM	335	325	285	0.212
					0.265

Day 3: 04/03/2019

S.No.	Time	T_g	T_c	T_e	C.O.P
1	9: 00 AM	349	330	286	0.228
2	2:00 PM	362	342	284	0.356
3	6:00 PM	348	325	285	0.212
					0.297

Day 4: 05/03/2019

S.No.	Time	T_g	T_c	T_e	C.O.P
1	9: 00 AM	357	333	285	0.400
2	2:00 PM	361	331	287	0.542
3	6:00 PM	346	329	285	0.318
					0.419

Day 5: 06/03/2019

S.No.	Time	T_g	T_c	T_e	C.O.P
1	9: 00 AM	362	340	284	0.308
2	2:00 PM	358	336	286	0.351
3	6:00 PM	348	338	288	0.165
					0.275

Day 6: 07/03/2019

S. No.	Time	T_g	T_c	T_e	C.O.P
1	9: 00 AM	340	326	283	0.271
2	2:00 PM	356	338	286	0.278
3	6:00 PM	360	328	288	0.640
					0.396

Day 7: 08/03/2019

S.No.	Time	T_g	T_c	T_e	C.O.P
1	9: 00 AM	360	342	288	0.266
2	2:00 PM	362	346	286	0.211
3	6:00 PM	358	340	288	0.278
					0.252

$$\textbf{Coefficient of performance} = \left[\frac{\text{Refrigerating effect in the evaporator}}{\text{Heat supplied in the generator}}\right]$$

$$\textbf{C.O.P} = \left[\frac{T_g - T_c}{T_g}\right] * \left[\frac{T_e}{T_c - T_e}\right]$$

Day 1

$$\textbf{C.O.P 1} = \left[\frac{345-327}{345}\right] * \left[\frac{285}{327-285}\right] = \textbf{0.354}$$

C.O.P 2 = $\left[\frac{353-335}{353}\right] * \left[\frac{287}{335-287}\right]$ **= 0.305**

C.O.P 3 = $\left[\frac{339-323}{339}\right] * \left[\frac{285}{323-285}\right]$ **= 0.353**

Average C. O. P Day 1 = $\left[\frac{COP1+COP2+COP3}{3}\right]$

$= \left[\frac{0.354+0.305+0.353}{3}\right] = 0.337$

Day 2

C.O.P 1 = $\left[\frac{342-330}{342}\right] * \left[\frac{286}{330-286}\right]$ **= 0.228**

C.O.P 2 = $\left[\frac{360-342}{360}\right] * \left[\frac{284}{342-284}\right]$ **= 0.356**

C.O.P 3 = $\left[\frac{335-325}{335}\right] * \left[\frac{285}{325-285}\right]$ **= 0.212**

Average C. O. P Day 2 = $\left[\frac{COP1+COP2+COP3}{3}\right]$

$= \left[\frac{0.228+0.356+0.212}{3}\right] = 0.265$

Day 3

C.O.P 1 = $\left[\frac{349-330}{349}\right] * \left[\frac{287}{330-287}\right]$ **= 0.363**

C.O.P 2 = $\left[\frac{362-344}{362}\right] * \left[\frac{288}{344-288}\right]$ **= 0.256**

C.O.P 3 = $\left[\frac{348-332}{348}\right] * \left[\frac{284}{332-284}\right]$ **= 0.272**

Average C. O. P Day 3 = $\left[\frac{COP1+COP2+COP3}{3}\right]$

$= \left[\frac{0.363+0.256+0.272}{3}\right] = 0.297$

Day 4

C.O.P 1 = $\left[\frac{357-333}{357}\right] * \left[\frac{285}{333-285}\right]$ **=0.399**

C.O.P 2 = $\left[\frac{361-331}{361}\right] * \left[\frac{287}{331-287}\right]$ **= 0.542**

C.O.P 3 = $\left[\frac{346-329}{346}\right] * \left[\frac{285}{329-285}\right]$ **= 0.318**

Average C. O. P Day 4 = $\left[\frac{COP1+COP2+COP3}{3}\right]$

$= \left[\frac{0.399+0.542+0.318}{3}\right] = 0.419$

Day 5

C.O.P 1 = $\left[\frac{362-340}{362}\right] * \left[\frac{284}{340-284}\right]$ **=0.308**

C.O.P 2 = $\left[\frac{358-336}{358}\right] * \left[\frac{286}{336-286}\right]$ **= 0.3515**

C.O.P 3 = $\left[\frac{348-338}{348}\right] * \left[\frac{288}{338-288}\right]$ **= 0.1655**

Average C. O. P Day 5 = $\left[\frac{COP1+COP2+COP3}{3}\right]$

$= \left[\frac{0.308+0.3515+0.1655}{3}\right]= 0.275$

Day 6

C.O.P 1 = $\left[\frac{340-326}{340}\right] * \left[\frac{283}{326-283}\right]$ **=0.271**

C.O.P 2 = $\left[\frac{356-338}{356}\right] * \left[\frac{286}{338-286}\right]$ **= 0.278**

C.O.P 3 = $\left[\frac{360-328}{360}\right] * \left[\frac{288}{328-288}\right]$ **= 0.640**

Average C. O. P Day 6 = $\left[\frac{COP1+COP2+COP3}{3}\right]$

$= \left[\frac{0.271+0.278+0.640}{3}\right] = \mathbf{0.396}$

Day 7

C.O.P 1 = $\left[\frac{360-342}{360}\right] * \left[\frac{288}{342-288}\right]$ **=0.266**

C.O.P 2 = $\left[\frac{362-346}{362}\right] * \left[\frac{286}{346-286}\right]$ **= 0.211**

C.O.P 3 = $\left[\frac{358-340}{358}\right] * \left[\frac{288}{340-288}\right]$ **= 0.278**

Average C. O. P Day 7 = $\left[\frac{COP1+COP2+COP3}{3}\right]$

$= \left[\frac{0.266+0.211+0.278}{3}\right] = \mathbf{0.252}$

Overall Average Instantaneous C.O.P

$= \left[\frac{AVG\ COP\ DAY1+AVG\ COP\ DAY2+AVG\ COP\ DAY3+AVG\ COP\ DAY4+AVG\ COP\ DAY5+AVG\ COP\ DAY6+AVG\ COP\ DAY7}{7}\right]$

$=\left[\frac{0.337+0.265+0.297+0.419+0.275+0.396+0.252}{7}\right] = \mathbf{0.3201}$

So, overall average C.O.P. obtained as 0.3201 for this system

CONCLUSION

In the present generation, the motto for development is "First & Fast" rather than "slow& steady". Therefore, here we used solar heat energy for heat required in the generator. Harnessing solar energy into panels is a technological stuff giving an overall output of maximum 8 % only but when we use solar heat from collectors, we could generate a great cause and effect in producing refrigeration effect .Although the temperature difference obtained here is of low range (8 to 13) degrees maximum. An improvisation in this temperature difference can be obtained by changing the concentration levels of absorbent and refrigerant pairs or by considering other design factors of evaporators, condensers, length between the evaporator and parabolic solar trough etc. Hence, this may be a pathway for the future scope of development in this direction.

Furthermore utilizing this device in the application of air conditioning has futuristic approach rather than refrigeration .Hence with the present generation facing the crisis of energy generation, consumption and utilization this method forms a pathway in finding a small step towards a mighty development in the field of energy saving design of appliances. Reconsidering the designs in a proper way would lead to utilization in every domestic household refrigeration and air conditioning appliance connected through solar energy, which is safe, clean & simple technology. As the saying goes "Nature satisfies everyone's need not greed" so this a definite and promising solution for overcoming the problems of ozone depletion , high energy consumption & global warming by utilizing nature's greatest brightest and everlasting source "THE SUN".

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