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Design a solar collector for VAR system with 1TR capacity at its maximum COP

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Abstract

Now a day's industrialization, globalization, human comfort increases use of energy drastically. It leads to deficiency of energy as well as increase in its cost. Alternate source of energy which is available at low cost and abundant in nature is the prime focus for the researcher. This paper is prepared with aim to drive a vapor absorption refrigeration (VAR) system of a unit capacity through solar energy. VAR system can be drive through waste heat or solar energy. For VAR system R717 (Ammonia) is used as a refrigerant. In this paper we had inscribed the calculation of COP for the system at different temperature of absorber and generator. Effectiveness of heat exchanger and generator temperature are the most affecting parameter to the COP of the system. And at the optimum value of COP required size of the collector is calculated. On the basis of series of numerous iteration carried out by changing generator temperature and effectiveness of heat exchanger (HE), it is concluded that with the increasing generator temperature, COP of the system increase up to some limit and after that it decreases. With increasing in effectiveness of heat exchanger COP increases.

Keywords- *Vapor absorption refrigeration system, solar collector, solar system,Aqua-Ammonia,COP*

I. INTRODUCTION

In today's situation energy consumption is increasing drastically because of industrialization, globalization and human mentality find comfortable lifestyle and environment. But earth has limited resources of conventional fuel which are going to be vanished within few decades. So researchers are trying to find an alternate for this energy scarcity. Sun is an inexhaustible source of energy which continuously supplies the energy to earth. In this paper attempt was made to identify optimum parameter for the maximum COP of VAR system and collector area required for such system which is sufficient to supply heat in the generator to drive complete system. Generator temperature and simple heat exchanger effectiveness are the limiting parameters for the maximum COP calculation. Optimum value of these parameters are obtained and based on these optimum value required area of the solar collector is calculated.

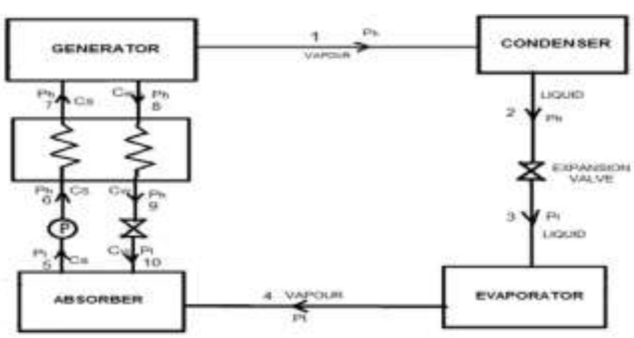

Figure 1 Aqua ammonia VAR system

VAR system replaces compressor through generator and absorber. In VAR system lithium-bromide and aqua-ammonia is commonly used pair of refrigerant absorber. As water serves the purpose of refrigerant in lithium-bromide, practical limitation is faced to lower the temperature below 4°C as below this temperature value water starts to freeze. In case of aqua-ammonia pair, ammonia serves the purpose of refrigerant and water is used as absorber. This pair provides wide range of temperature below the 0°C also. This is the reason to select aqua-ammonia as a refrigerant absorber pair for this paper as it can lower temperature up to -77°C.

II. CALCULATION FOR MAXIMUM COP

2.1. Identify Optimum parameter

Condenser and evaporator works as heat transfer surface. Vapor ammonia transfer heat to the surrounding cooling media when passing through condenser. Whichever cooling media is used in condenser i.e., air or water, inlet condition is always at atmospheric temperature. So condenser temperature is considered at normal atmospheric temperature.

Condenser temperature (T_a) = 35°C

Evaporator temperature is decided according to the application. Here in this paper we have considered that this system is used for the preservation purpose which involves negative temperature.

Evaporator temperature (T_e) = -10°C

From the refrigeration property Table of ammonia (R717)

Condenser pressure (P_c) = 12 bar

Evaporator pressure (P_e) = 3 bar.

By considering the effectiveness of HE in the range of 0.7 to 0.8 with an interval of 0.5 and obtain optimum generator temperature by considering temperature range of 90°C to 140 °C with an interval of 10°C. Results are obtained through mathematical iteration. Variation of COP with different values of generator temperature and effectiveness of heat exchanger are tabulated as below:

Table 1 COP VS T_g

Generator Temperature	COP of different Effectiveness		
	ε =0.7	ε =0.75	ε=0.80
90	0.4411	0.4574	0.4911
100	0.5052	0.5563	0.5698
110	0.5404	0.5689	0.5941
120	0.5524	0.569	0.5866
125	0.5552	0.5674	0.5791
130	0.5507	0.5659	0.5781
140	0.5478	0.558	0.5772

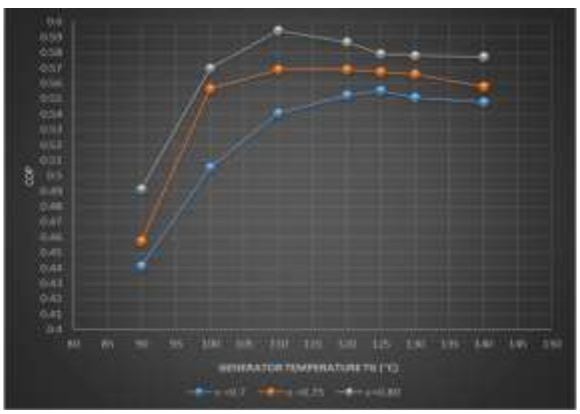

Figure 2 COP VS T_g

Let's considering the effectiveness of heat exchanger as 0.75. For this value of effectiveness maximum COP of the system can be obtained at generator temperature of 120°C.

2.2. Calculate Maximum COP and Heat required in the generator

At these optimum values of effectiveness and generator temperature we can plot different points on enthalpy concentration chart of aqua-ammonia and can obtain enthalpy values at those points.

Following are the enthalpy values obtained at different points from h-c chart:

h_1 = 1675 KJ/kg

h_2 = 492 KJ/kg

h_3 = 492 KJ/kg

h_4 = 1640 KJ/kg

h_5 = 50 KJ/kg

h_6 = 50 KJ/kg

h_7 = 281 KJ/kg

h_8=435 KJ/kg

h_9=131 KJ/kg

h_{10}=131 KJ/kg

h_{11}= 1800 KJ/kg

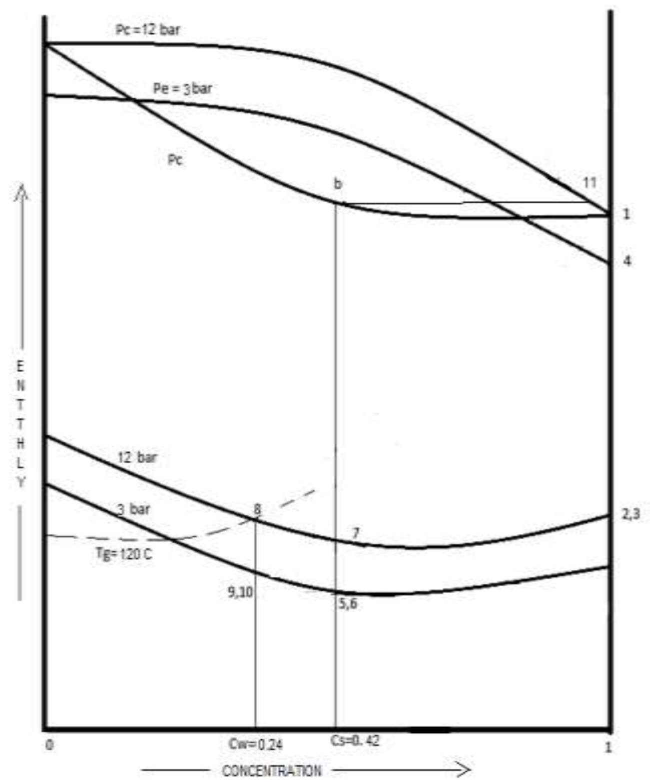

Figure 3 h-c chart at ε =0.75 and Tg =120°C

Absorber temperature (T_a) = Condenser temperature (T_c)

Plotting evaporator pressure 3 bar and absorber temperature 35°C on h-c chart we get point5

$h_5 = h_6$ = 50 KJ/kg, $T_6 = T_c$

Aqua-ammonia concentration of rich solution C_r = 0.420

By considering generator temperature at maximum COP, T_g = 120°C

From condenser pressure and generator temperature h_8 = 435 KJ/kg, $T_8 = T_g$

Aqua ammonia concentration of weak solution C_w = 0.24

Now, specific rich solution circulation (f):

$$f = \frac{1 - Cw}{Cr - Cw} = 4.2$$

Now specific weak solution circulation (f') f' = f - 1 = 3.2

Refrigerating effect Q_e = 1TR = 210 KJ/min.

$Q_e = M_r * (h_4 - h_3)$.

By solving this equation mass flow rate can be obtained

M_r= 0.183 kg/ min

From the research paper considering effectiveness of heat exchanger = 0.75

Effectiveness (ε) $= \frac{T_8 - T_9}{T_8 - T_6}$

By solving above equation

T_9 = 56.25°C

By plotting T_9 on refrigerant concentration of poor solution line we get

$h_9 = h_{10}$ = 131.25 KJ/kg

h_{11} = 1800 KJ/kg

To find out h_7 = enthalpy of rich solution entering to generator

$f' * (h_8 - h_9) = f * (h_7 - h_6)$

By solving this equation

h_7 = 281.42KJ/kg

Now, calculate heat required in generator

$q_g' = h_{11} - ((1-f) * h_8) - (f * h_7)$

= 2010.036 KJ/kg

$q_g = M_r * q_g'$

= 367.836 KJ/min.

Now, Calculating pump work Q_p

At the inlet temperature of pump

From property table specific volume of ammonia $V_{NH3} = V_f$ = 1.704 * 10^{-3} m^3/kg

From steam table specific volume $V_{H2O} = V_g$ = 1.006 * 10^{-3} m^3/kg

Specific volume of refrigerant (V) solution transferred by pump

$V = C_r * V_{NH3} + (1-C_r) * V_{H2O}$

= 3.93* 10^{-4} m^3/kg

Pump work $Q_p = f * V * (P_c - P_e)$

= 1.485KJ/kg of ammonia

For calculating COP:

$$COP = \frac{\text{Refrigerating effect}}{Q_p + Q_g}$$

$$= \frac{h_4 - h_3}{Q_p + Q_g}$$

= **0.6166**

By considering different values of affecting parameters to the COP. Out of these results which we have calculated, we have considered effectiveness of heat exchanger 0.75 and generator temperature at 120°C. From these calculations we are taking maximum COP for the VAR system as 0.6166.

III. REQUIRED SOLAR COLLECTOR AREA

3.1 Calculation of required area of solar collector:

Required heat = 367.836 KJ/min

Sun light falls on solar collector which is being used to heat the water. Let's consider heat absorbing capacity of insulating material as 93%.This heated water is stored in hot water tank. Its efficiency mainly depends on insulating material and its thickness. It has efficiency of 85%.

Required heat to be collected through the solar collector = {(367.836)/0.93*0.85}

= 465.320 KJ/min

Standard size available in the market for the evacuated tube is 2m in length and 0.058m in diameter. So area of the tube is 0.116 m^2

Now value of solar constant is

Required area of collector = (465.320/15)

= 31.021 m^2

No of tubes required = (31.021/0.116)

= 268

Heat input at the collector = Solar constant * area

= 250 W/m^2 * 31.021 m^2

= 7755.25 W

= 465.315 KJ/min

So overall COP of the system including solar collector and VAR system

$$COP = \frac{\text{Net refrigerating effect}}{\text{Heat input to the collector}}$$

= (210/465.315)

= 0.451

IV. CONCLUSION

The aim behind developing energy effective refrigeration and air conditioning system is to cut out dependency on conventional fuel and use waste heat sources and solar energy.

Performing numerous iteration to find the effect of effectiveness and generator temperature on COP value we can conclude that-

(1) COP increases with increase in effectiveness of heat exchanger
(2) COP increases with increase in generator temperature and reach to peak value and from that point it starts to decrease

Heat required for driving the VAR system with 1TR capacity is 388.2153 KJ/min. Collector area required to trap these much amount of heat is 25.606 m^2. This system can be used even to lower the temperature in negative scale in all the season. So large collector area can also be justified.

Initial cost to drive these system through solar is too much high. So this is not widely accepted. Largest Manufacturer country of ETC pipe is China. So import of this pipes makes its cost too high around Rs. 600 per pipe. But if it manufactured in India then cost reduced to Rs. 200 per pipe. That is the main reason not to installed solar system abundantly. Second reason is additional battery pack requires to drive solar assisted system in night. It increases cost up to an extent.

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