# Design & Fabrication of Vapour Absorption Refrigeration System using Solar Parabolic Trough

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**Abstract:-**For past few decades, energy has played a prominent role in the development of technology and economy. Energy has now become inevitable factor for production as well. The objective of this project is to develop an environment friendly vapour absorption system. Vapour absorption system uses heat energy, instead of mechanical energy as in vapour compression system, in order to change the condition of refrigerant required for the operation of the cycle. R 717(NH3) and water are used as working fluids in this system. The basic idea of this project is derived from the solar heating panel to obtain heat energy, instead of using any conventional source of heat energy. In this project various observations are done by varying operating conditions related to heat source, condenser, absorber and evaporator temperatures. The drawback of this system is that, it remains idle in the cloudy weather conditions.

**Keyword: -** Absorber, Condenser, Capillary tube, Dc battery, Evaporator, Generator, Heat exchanger, Pump, Solar panel.



## 1. Introduction

Vapour Absorption Refrigeration Systems (VARS)works on the refrigerant absorption principle. It belongstothecategoryofvapourcyclessimilarto VapourCompression Refrigeration Systems (VCRS). However,unlike VCRS, heat is used as an input for the absorptionsystems.Hencethesesystemsarealsocalledheatoperatedorthermalenergy-drivensystems.

The most commonly used pair of refrigerants areAmmonia-WaterandLiBr-Water.ForInstance,V.KBajpai's work included a VARS system using $NH_3$asrefrigerantand$H_2O$asabsorbent.TheCOPofthesystemwasfoundbearound0.58,whenusedwithparabolic solar collector.In previous research it has been found thatthe system with LiBr solution performs better than thesystemusingammoniasolution.Thissystemhasbeendesigned as a single effect absorption system as opposedto a double effect system although double effect systemhasasignificantlyhighercoefficientofperformancebecause of the simplicity and cost-efficiency of a singleeffectsystem.

Therearevariouswaystoprovideheatenergyasinputinthesystem,themostcommonmethodsincaseofSolarEnergy are Flat Plate Solar Collector, Parabolic SolarCollector and Evacuated tube type Solar Collector.

## 2. WorkingPrinciple

VARShassimilarworkingcomponents,exceptgeneratorand absorber, like VCRS. Generator, absorber andpumpinVARSworkssimilarlytothecompressorpresentin VCRS. ItshouldbenotedthatinNH3solution,wateractasrefrigerantandNH3actastheabsorbent.Theroleofabsorbentistoenabletheflowofrefrigerantfromtheabsorbertothegeneratorbyabsorbingthevapoursofrefrigerantandformingasolutionthatcanbe easilypumped to the generator while consuming significantlylesselectricityusedbytheelectricVCRSsystemtocompresstherefrigerant. The input energy in the form of thermal energy isadded through hot steam and water from a solar waterheater/electricheater/gasburner.Thethermalenergyvaporisesthewaterin R717solutionpresentinthe generator to steam. The high-pressure steam flows tothecondenserleavingstrongNH3solutioninthegenerator. This pressurised steam then rejects heat to thesurroundingandcondensetopressurisedwater,whichis throttled through an expansion valve to low pressureand temperature liquid water. This low-temperature liquidwaterflowstotheevaporator,absorbstheheatfrom the load and evaporates to vapour state. These watervapours are then sucked in the absorber by the strong R717solution, which is throttled down from the generator, to form weak R717 solution and reject heat in theprocess. This weak R717 solution is then pumped back tothegeneratortocompletethecycle.

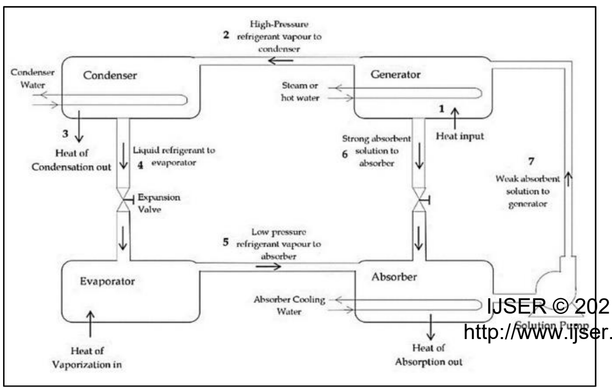



**Fig.2.1.**VapourAbsorption RefrigerationSystem

## 3. Design of VARS using solar parabolic trough:-

### 3.1 Parabolic Solar Collector

The collector designed here is parabolic solar trough collector. The geographical coordinates of the place forwhich it is designed are (Latitude: 22.6216º; Longitude:75.8034º).Themonthofoperationisassumedtobe May. Thus,calculatingdeclinationangleandhourangle

Let,

$Y=aX^2$ …………(Equation of Parabola)

$Y=0.041667X^2$….. (In Inches)

Focal point (f)=$1/4a$=1/(4*0.041667)=6

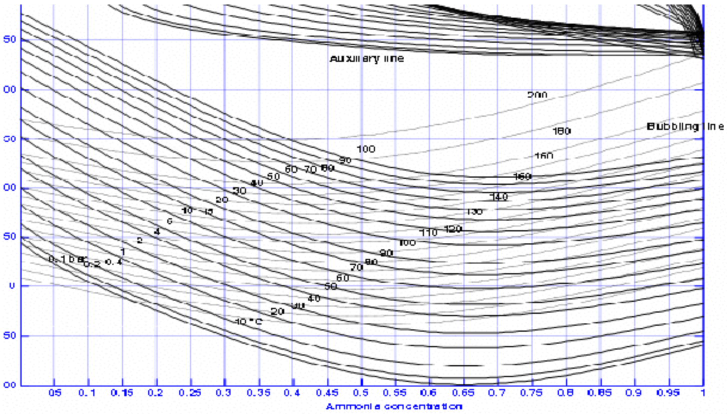
Length of parabola from 'X1' to 'X2' is "S"

S={[(p*q)/t] +t*ln[(p+q)/t]}

But q= $\sqrt{t2+p2}$& p=12

So, S= 27.55 inch= 0.698m

Number of solar trough required are




5.

FROM GRAPH OBTAINED DATA

**3.2Calculation for Pump:-**

State 1- Saturated vapour state at

$P_C$=14 bar, C=1$T_1$ =90°C, $h_1$=1700 kj/kg.

State 2- Saturated liquid at

$P_C$=14 bar, C=1$T_2$ =37°C, $h_2$=500kj/kg.

State 3- Isenthalpic processat

C=1,$P_E$=5bar $T_3$=4°C, $h_3$=$h_4$=500 kj/kg.

State 4- saturated vapour at

$P_E$=5 bar, C=1 $h_4$=1660 kj/kg.

State 5- From absorber (strong solution) at

P=5bar $T_5$=37°C, C=0.53, $h_5$=70 kj/kg.

State 6- After pump, negligible enthalpy change Therefore $h_6$=$h_5$ .

State 7-after heat exchanger $h_7$=200kj/kg.

State 8-P=14 bar, $h_8$=305 kj/kg.

State 9- $h_9$=150 kj/kg.

State 10-$h_{10}$=$h_9$=150 kj/kg

ha=-190 kj/kg

$h_b$=1790 kj/kg

$C_w$(Weak) = 0.42

$C_5$ (Strong) = 0.53

Concentration:-

$C_1$=$C_2$=$C_3$=$C_4$=0.98

$C_8$=$C_9$=$C_{10}$=0.42

$C_5$=$C_6$=$C_7$=0.53

Pressure:-

$P_1$=$P_2$=$P_6$=$P_8$=$P_9$=$P_{10}$=14Bar (Condenser pressure)

$P_3$=$P_4$=$P_5$=$P_{10}$=5 Bar (Evaporator pressure)

Mass flow rate:-

$M_1$=$M_2$=$M_3$=M4=0.0271 kg/min.

$M_8$=$M_9$=$M_{10}$=0.110 kg/min.

$M_5$=$M_6$=$M_7$=0.137 kg/min.

CALCULATIONS

Refrigerant: - $NH_3$ (Ammonia)

Boiling point = -33°C

Melting point = -77.7°C

Specific gravity= 0.91

Solubility in $H_2O$ = 47% at 0°C,31% at 25°C,18% at 50°C

Absorbent: - $H_2O$ (water)

Boiling point = 100°C

Density = 1000kg/m³

**3.3Calculation of heat**

Assume capacity=0.15TR

Heat extracted by Evaporator:-

$\dot{m}_r$= 0.0271 kg/min.

$Q_E$=$\dot{m}_r$($h_4$-$h_a$ ) = 0.15x210 = 31.5 kj/min.

Heat removed by condenser:-

$Q_c$=$\dot{m}_r$($h_1$-$h_2$) =32.52 kj/min.

Heat removed on absorber:-

$Q_A$=$\dot{m}_r$($h_4$-$h_a$) =50.135 kj/min.

Heat given in Generator:-

$$Q_G=\dot{m}_r(h_b-h_a) = 53.658 \text{ kj/min.}$$

Again,

$$Q_G=894.3 \text{ watt}$$

Heater of 894.3 watt is required for generator.

Coefficient of performance:-

Actual COP: -

$$COP_{act}=(Q_E/Q_G)=0.587$$

Theoretical COP: -

$$COP_{Th}=[(TG-TC)TE]/[(TC-TE)TG]=1.53$$

At absorber

By using equations

$$m_4+m_{10}=m_5$$

Or,

$$m_4=m_5-m_{10}$$

&

$$m_4c_4=m_5c_5-m_{10}c_{10}$$

Then,

$$0.0271=m_5-m_{10} \text{ -----eq. (1)}$$

&

$$0.0265=0.53m_5-0.42_{m10} \text{ --------eq. (2)}$$

From eq. (1) & eq. (2)

We get,

$$m_5=0.137 \text{ kg/min. } m_{10}=0.110 \text{ kg/min.}$$

For $h_6$ :-

By using formula

$$h_6=h_5+[(p_6-p_5)V_5]/1000$$

&

$$V_5=(1-C_5)V_{H20}+0.85C_5V_{NH3}$$

From the refrigeration table

$$V_{H20} \text{ At 5 bar}= 0.001096$$

$$V_{NH3} \text{ At 5 bar} = 0.00158$$

$$V_5=0.00127 \text{ m}^3\text{/kg}$$

$$h_6= 70+\{[(14-5)x105x0.00127]/1000\}= 71.104 \text{ kj/kg}$$

Power consumed by pump:-

$$P = m5(h6-h5)$$

$$\text{Then, } P =\left(\frac{0.137}{60}\right)= 0.0025 \text{ kW}$$

$$P=2.52 \text{ watt}$$

Assume efficiency =0.7

ThenPower required to pump =3.6 watt

**3.4Tube design:-Capillary**

**a)For capillary 1**

Diameter of capillary tube, D = 0.914 mm

Area of cross section, A = 0.000000486

From the refrigeration table

**AT 14 BAR**

Viscosity of ammonia

$$\mu_0=116\text{x } 10^{-3} \text{ Ns/m}^2$$

Specific volume of ammonia

$$V_O=1.71\text{x}10^{-3} \text{ m}^3\text{/kg}$$

Mass flow rate of ammonia

$$\dot{m}=0.0271\text{kg/min.} = 0.0004516\text{kg/sec.}$$

$$G =\frac{\dot{m}}{A}= 927.88\text{m}^2$$

Then,

velocity at entrance of capillary tube

$$u_O=G\text{x}V_O =1.585 \text{ m/sec.}$$

Now, Reynold number

$$R_e=\frac{DG}{\mu\mathbf{0}}=6295.18 \text{ ....eq (i)}$$

Then, friction factor

$$f_o=Re\left(\frac{0.32}{0.25}\right) =0.036 \text{ ....eq (ii)}$$

Enthalpy at entrance of the capillary tube

$h_0$=357.25kj/kg

**AT 5 BAR**

From refrigeration table

Various parameters of ammonia at liquid and vapour states

$V_f$=0.00156m$^3$/kg

$V_g$=0.317 m$^3$/kg

$h_f$= 171.63 kj/kg

$hf_g$= 1269.45 kj/kg

$\mu_f$= 0.174 Ns/m$^2$

$\mu_g$= 0.00916 Ns/m$^2$

Now,

$h_1$=$h_0$= $h_{fx}$X$hf_g$…..eq (a)

Dryness fraction X= 0.146

Now,at exit of capillary tube

Similarly by using formula as eq (a)

Specific volume

$V_1$=0.0476

Velocity at exit

$u_1$=44.18 m/sec

Viscosity:-

Similarly by using formula as eq (a)

$u_1$=0.15*10$^{-3}$Ns/m$^2$

And friction factor

By using equation (i) and (ii)

$f_1$=0.038

Now, Change in pressure

$\Delta P = P_0 - P_1 = 9x10^5$Ns/m$^2$

Change in velocity

$\Delta U = u_1 - u_0$ =42.6 m/s

Average velocity u=$\frac{u1+u0}{2}$=22.88 m/sec.

Average fiction factor f= $\frac{f0+f1}{2}$=0.037

Now, Length of capillary tube

By using formula,

L=1.72m. L = 5.6 ft

**b)For capillary 2**

ṁ=0.11kg/min= 0.00183kg/sec. G = 3771.6 kg/m2s

From refrigeration table At 60$^0$c :-

Specific volume $V_0$=0.00121 m$^3$/kg

Then velocity at entrance

$u_0 = GV_0$ =4.5 m/sec

Viscosity,

$\mu_{H2O}$ = 0.45*10$^{-3}$Ns/m$^2$ , $\mu_{NH3}$=0.098*10$^{-3}$ Ns/m$^2$

At concentration 0.42

$\mu_0$=0.42 ($\mu_{NH3}$ ) +0.58 ($\mu_{H2O}$ ) = 0.302*10$^{-3}$ Ns/m$^2$

And,

friction factor By using equation i and ii

$f_o$=0.032

At 4 bar & at concentration 0.42

From refrigeration table

Specific volume

$V_{NH3}$ = 0.00158 m$^3$/kg $V_{H2O}$ = 0.001 m$^3$/kg

0.42 ($V_{NH3}$ ) +0.58 ($V_{H2O}$ ) = 0.0012436

Then velocity at exit

$u_1$= G $V_1$ = 4.7 m/sec

Viscosity $\mu_{H2O}$= 0.153*10$^{-3}$Ns/m$^2$, $\mu_{NH3}$=1*10$^{-3}$Ns/m$^2$

Then, by using above equation

$u_1$= 0.644*10$^{-3}$Ns/m$^2$

And

friction factor By using eqi and ii

$f_o$= 0.038 Now,

Change in pressure P0-P1 =9bar

Change in velocity

ΔU=0.2 m/s

Average velocity

$u=\frac{u1+u0}{2}$ =4.6 m/sec

Average friction factor

f = 0.035

Then Length of capillary tube By using formula

$L = \frac{\Delta P - G\Delta u}{\frac{G}{2D}*(fu)}$ =2.3m. =7.5ft

**3.5Design of heat exchanger:-**

From our design data

Temp of hot fluid at inlet $T_{h1}=90^0c$

Temp of hot fluid at exit $T_{h2}=60^0c$

Temp of cold fluid at exit $T_{c1}=70^0c$

Temp of cold fluid at inlet $T_{c2}=37^0c$

Now,

$Q_1= T_{h1}-T_{c1}$

$Q_2= T_{h2}-T_{c2}$

For calculation of LMTD

By using equation

$Q_m = (Q_1- Q_2)/\ln Q_1/Q_2$

Then

$Q_m$=294.5 k

Heat transferred in heat exchanger,

By using formula

$Q = \dot{m}r(h9 - h8)$ =300 watt

Taking Overall heat transfer coefficient of ammonia solution

U = 80 w/m2.degree

Then,

$Q = UAQ_m$

300 = 80*π*0.004*L*294.5

Length of pipe inside heat exchanger l=1.6 m.

## 4. Advantages:-

- As there is no moving part in the entire system, the operation is essentially quite and subjected to a very little wear.
- The load variations does not effect the performance of a vapour absorption system.
- Absorption system may be designed to use any readily available source of thermal energy such as process steam ,hot exhaust from furnaces and solar energy, therefore they can be used in places where electric power is hard to obtain or is very expensive.
- In here pump is used for pumping refrigerant absorbant solution, which consumes less power.
- Maintenance cost is low as because of absence of moving part.
- In the absorption refrigeration system no refrigerant produces the greenhouse effect, so their use won't be stopped in future

## 5. Disadvantages:-

- Set up is too large as it consists of three more equipment those are absorber, generator ,and pump.

- Initial cost is high.
- Corrosive in nature.
- Low working pressure.
- Due to low working pressure the cop of vapour refrigerationis low, it is about 1.1
- High heat rejection system is required, as heat is being rejected from condenser, analyzer, rectifier and absorber.

## 6. Application

- Household and Commercial indoor cooling purpose
- Refrigeration in off-grid rural areas for preserving food and vaccine
- Use in cold storage system to preserve rotten-prone food
- Use to make ice cream and other related products
- Cooling purpose for Transportation vehicle

## 7. Conclusion

The temperatures, pressures and concentration ratio at different points were calculated. Further the generation and absorbertemperature were varied to determine the optimum temperatures.The generation, solution, condenser and evaporation heatexchangers were designed. The solar collector area required to power such a vapor absorption system was also calculated.Thus the

results indicate that a suitable solar vapour absorption refrigeration system can be designed keeping in view the climatic condition of a particular location. Keeping in view the climatic conditions of t a particular location,methodology described inthis work can be adopted to design and develop a suitable system that can be most effectively and efficiently used maximum utilization of the solar power.

## 8. Referances

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