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DESIGN OF SOLAR POWER VAPOUR ABSORPTION REFRIGERATION SYSTEM

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Abstract: *Refrigeration demand is rapidly increasing in many parts of the world, especially in moderate climates. Air conditioners and refrigerators consume more electricity about 70% for domestic uses. This results in a dramatic increase in electricity demand on hot summer days, which causes an increase in the use of fossil fuel and electric energy. Vapour compression system leads to global warming and air pollution. This paper describes the usage of vapor absorption refrigeration system using solar thermal energy. In this system an electric generator is replaced by solar thermal collector for heating the refrigerant called ammonia-Water. Cylindrical parabolic concentrating collector used to gain highest temperature. During the study of 2.5liter vapor absorption system an atmospheric temperature, fluid temperature at the collector, temperature of condenser and evaporator were measured to find out the COP of the system. The main objective of this study is to reduce the electricity consumption by introducing solar thermal energy*.

Keywords: Solar Cooling, vapor absorption cycle, Ammonia-water solution.

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1. INTRODUCTION

Vapor absorption refrigeration system differs from vapor compression refrigeration system due to utilization of thermal energy source instead of electric energy. Now a day's availability of electric energy is limited. To save electric energy wherever possible another option is to use solar energy which available everywhere and free of cost. Vapor absorption system very much useful in rural area where supply of electricity limited or not available. In vapor absorption refrigeration system two working fluids are used: a refrigerant and an absorbent. Among the most applied working fluids are the pair ammonia refrigerant water absorbent (NH3–H2O) and water refrigerant–lithium bromide absorbent (H2O–LiBr). Ammonia-water pair can produce cooling upto -5˚C and therefore it is suitable for refrigeration too. Cylindrical parabolic concentrating collector used to increase temperature so that aqua ammonia solution can heat up at 120˚C which is required temperature of aqua-ammonia solution. Solar water heating utilizing thermo-siphon is attractive, because it eliminates the need for a circulating pump.

II. DESIGN

Fig. Experimental Setup of solar power vapor absorption system

The working fluid for the system is solution of ammonia (refrigerant) and water (absorbent). Solar energy in the form of heat is supplied to this solution in the generator. As a result refrigerant is vaporized leaving behind a weak solution. This weak solution sent back to absorber through pressure reducing valve. Vapor containing pure refrigerant at the exit of generator passed through condenser where it is liquefied. The liquid refrigerant at high pressure passed through expansion valve from which low pressure liquid flows through evaporator where cooling is achieved by continuous vaporization of the refrigerant resulting low temperatures. The vaporized refrigerant is then absorbed in weak solution present in absorbers which in turns form strong solution. In this way cycle repeated.

1. DESIGN OF PARABOLIC TROUGH COLLECTOR

Assuming Maximum Temperature at generator T_g = 90 °C

Solar Constant I_{Sc} = 1367 W/m^2, Extraterrestrial radiation =1449.87W/m^2

Geographical location of the place where the solar collector was placed: Amaravati

Latitude Angle $\emptyset = 20.93°$, Longitude Angle $\gamma = 77.77°$

Number of days for month 18may

n=138days

Declination angle

$$\delta = 23.45\sin\left[\frac{360}{365}(284+n)\right]$$

$$= 23.45\sin\left[\frac{360}{365}(284+138)\right]$$

$$= 19.49°$$

Zenith angle Z;

$$\cos Z = \sin\emptyset \sin\delta + \cos\emptyset \cos\delta \cos\omega$$

$$\cos Z = \sin(20.93°)\sin(19.49°) + \cos(20.93°)\cos(19.49°)\cos(0)$$

$$\cos Z = 0.99$$

$$Z = 8.10°$$

Available radiation intensity

$$I_Z = I_{Sc} e^{[-c(\sec Z)s]}$$

C=0.357, s=0.678

$$I_Z = 1367 e^{[-0.357(\sec 8.10)0.678]}$$

Fig. parabolic trough collector

I_Z = 1070.53W/m^2

The value of radiation on a horizontal surface I_h is;

$I_h = I_Z \cos Z$

$I_h = 1070.53 \cos(8.10^{\circ})$

$I_h = 1059.85 W/m^2$

total solar radiation intensity= 529.92 W/m^2

Reflected intensity R_i = Reflectivity of material × solar radiation intensity

Reflectivity of aluminium sheet = 0.9

Thus; $R_i = 0.9 \times 530 = 477\ W/m^2$

Therefore; Heat required at collector

$Q_i = m \times C_p \times \Delta T$

$Q_i = \frac{3 \times 4.187 \times (90°C - 40°C)}{3600}$

$Q_i = 0.174 KW$

Area of parabolic trough collector

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

$A_d = \frac{174}{477}$

$A_d = 0.364\ m^2$

Depth 0f parabolic collector

h= 0.25m

Surface area of collector

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

$0.364 = \frac{\pi}{6} \times [\frac{r}{(0.25)^2}] \times [\frac{(\frac{r^2}{4 \times (0.25)^2})}{2-(r)^3}$

r = 0.39m

Focal length = $\frac{r^2}{4h}$

$F = \frac{(0.39)^2}{4 \times 0.25}$

F = 0.152m

2. DESIGN OF GENERATOR

Fig. generator with heating copper coil

Flow rate of refrigerant;

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

$Q = \frac{3liter}{3600}$

$Q = \frac{3\times10^{-3}}{3600}$

$Q = 8.34 \times 10^{-7}\ m^3/sec$

Heat transfer rate at generator;

Length of coil attach on outer side of generator,

L= 0.41m

Inner diameter of coil

D_i= 0.015m,

Outer diameter of coil

D_o= 0.019m

Therefore;

$D_m = D_o - D_i$

D_m = 0.019-0.015

D_m = 0.004m

Assume;

Ambient temperature T_a = 30 °C

Collector fluid temperature T_g = 90 °C

Therefore;

Bulk temperature $T_f = \frac{30+90}{2}$ = 60 °C

Taking properties at $T_f = 60°C$

μ = 0.4708 $Nsec/m$, ϑ = 0.478× $10^{-6}\ m^2/sec$, P_r = 3.020, K = 0.6513 W/mK

ρ = 985 Kg/m^3

Thus,

Reynolds number;

$$R_e = \frac{\mu \times D_m}{\vartheta}$$

$$= \frac{0.470 \times 0.004}{0.478 \times 10^{-6}}$$

= 3933.05

Since the flow is forced convection, therefore using monrad and pelton equation;

$$N_u = 0.02(R_e)^{0.8} \times (P_r)^{0.33} \times [\frac{D_o}{D_i}]^{0.53}$$

$$= 0.02(3933.05)^{0.8} \times (3.020)^{0.33} \times [\frac{0.019}{0.015}]^{0.53}$$

= 24.52

Thus, heat transfer coefficient;

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

$$= \frac{24.52 \times 0.6513}{0.004}$$

= 3992.47 W/m^2K

Thus, Heat load at generator

$$Q_g = h\ A\ (T_g - T_s)$$

Where,

T_s = surface temperature

$$Q_g = 3992.47 \times \pi \times 0.004 \times 0.41 \times (90°C - 85°C)$$

=102.85 Watt.

4. DESIGN OF EVAPORATOR

Fig. Shell and tube type evaporator

Mass flow rate of refrigerant from condenser = 0.01051 Kg/min.

= 1.75 $\times 10^{-4}\ Kg/Sec$.

Ambient temperature T_a = 40 °C,

Cooling unit temperature Te= 10 °C

Heat load at Evaporator $Q_e = m_R(h_a - h_e)$

As aqua- ammonia flow throughout system, take enthalpies at above temperature

From refrigeration table

At 40 °C, $h_a = 390.587\ KJ/Kg$

At 10 °C, h_e = 246.531 KJ/Kg

Hence, by putting above value, we get heat load on evaporator

Q_e = 1.75 $\times 10^{-4}$ (390.587-246.53) $\times 10^3$

Q_e = 25.21Watt.

Coefficient of performance of the system;

COP = $\frac{Q_e}{Q_g}$

= $\frac{25.21}{102.85}$

COP = 0.2451

III. RESULT AND DISCUSSION

After the total assembly and calculations were complete the setup was tested. The testing was performed from 9:00 am to 6:00 pm and the reading was noted. Every half an hour the parabolic dish was adjusted manually to track the movement of the sun. From the testing done it was noted that the lowest temperature achieved was 10°C. It was noted that the cabin temperature increased for a certain period and then dropped. The C.O.P of the system was obtained from the calculations as 0.2451. The mass flow rate of the refrigerant obtained was 0.01051Kg/min.

IV. CONCLUSION

Experimental data shows that during 9.00am to 3.00pm generator temperature increase with increase in ambient temperature, cop increase to 0.85 but after 3.00pm cop decreases to 0.144 with decrease in ambient temperature of 41 °C. Thus this analysis provides that the operating temperatures of condenser and absorber has to be maintained less than 40 °C, evaporator temperature has to be more than 10 °C and the generator temperature not exceeding 85 °C, so as to run the absorption system efficiently during the utilization of heat from sun and provide cooling effect.

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