Design and Analysis of Solar Vapour Absorption Refrigeration System for 1 TR Capacity

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ABSTRACT:

This paper presents the design of vapor absorption refrigerating system of capacity 1 tonne based on the basic concepts of thermodynamic principles. In design the area of all the major components of the system is calculated on the basis of enthalpy parameters at different points in the system. The data is analyzed using the first and second laws of thermodynamics to determine the refrigerating effect, the net heat required to run the system and the coefficient of performance (COP). Refrigerant used in the system is Ammonia (R717) and water is used as Absorbent. Solar energy is utilized as heat input in absorber.

KEYWORDS Absorption, absorber, R717 (Ammonia), Coefficient of Performance.

INTRODUCTION

VARS belong to the class of vapour cycles similar to vapour compression refrigeration systems. However, unlike vapour 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.

This cycle is operated with help of heat supply from generator by thermal energy collected from the sun without the need to convert this energy into mechanical and for circulation of refrigerant and absorber solution a pump is needed which can be operated from battery or engine shaft and it requires much less work than compression work in vapor compression cycle so this cycle can be used.

Hourz et al.[1] performed a thermodynamic analyses for different working fluid pairs. A computer simulation model has been developed to predict the performance of solar absorption refrigeration system using different working fluid. Detailed thermodynamic properties for ammonia- water, ammonia-lithium nitrate and ammonia-sodium thiocyanate are expressed in polynomial equations and used in cycle simulation. The performances of these three cycles against various generator, evaporator, and condenser temperatures are compared. The results show that the ammonia-lithium nitrate and ammonia-sodium thiocyanate cycles give better performance than the ammonia-water cycle.

Hammad et al.[5] proposed a alternate designs for a 24-h operating solar powered absorption refrigeration technology. The development includes an in-depth review of the design and operation of the conventional and solar-assisted absorption refrigeration systems coming-up with new alternative designs, detailed thermodynamic analysis of some of the new alternative designs and selection of the most suitable alternative design. The analysis indicates that continuously operating solar-powered aqua-ammonia absorption system with refrigerant storage is the most suitable alternative design for an uninterrupted supply of cooling effect.

Mathematical Modeling of VAR system

Condenser & Evaporator Pressure:

For condensing ammonia vapors at 30 ºC, the corresponding pressure required can be noted from the refrigeration table of ammonia (R-717).

In this way, the condenser pressure is fixed at (p_c) = 10.34 bar.

The evaporator pressure is kept equal to the atmospheric pressure (1 bar), to ensure design economy.

From enthalpy table and pressure we can find enthalpies as below:

h_1 = 1609 kJ/kg, h_2 = 40 kJ/kg, h_3 = 40 kJ/kg, h_4 = 516 kJ/kg, h_5 = 516 kJ/kg, h_6 = 1626 kJ/kg, h_7 = 460 kJ/kg, h_8 = 460 kJ/kg

Concentration of the strong solution can be directly noted down from the Enthalpy-concentration diagram as x_2 = 0.55

Assume, degassing factor=0.11, concentration of the weak solution
x_5=0.55-.11=0.44. Cooling Capacity of the Refrigeration system is considered as 1 TR.

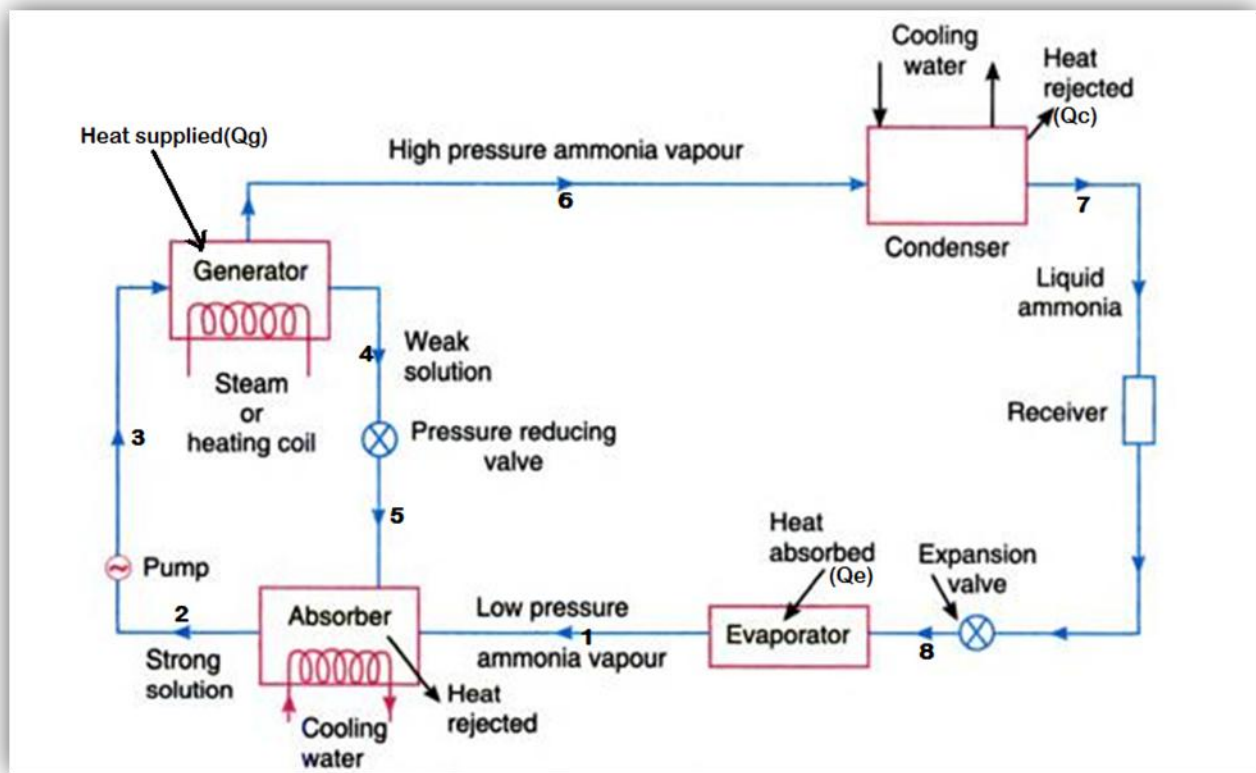

Fig 1. Block diagram of NH_3-H_2O VAR system

By applying mass balance and energy balance equation to each components following quantities can be indentified:

Energy balance equation for evaporator:

$Q_e = m_1 (h_1 - h_8) = 210$ kJ/kg = 1 TR

m_1 = mass flow rate of refrigerant = 0.1828 kg/min

m5 = mass flow rate of week solution = 0.8226 kg/min

m2 = mass flow rate of strong solution = 1.0054 kg/min

From Energy balance equation for Absorber:

$m_1h_1 + m_5h_5 = Q_A + m_2h_2$

Q_A = Heat required to carry out by cooling water = 678.3708 kJ/min

By applying energy balance equation to condenser:

$Q_C = m_1 (h_1 – h_8)$

Q_C = 214 kJ/min

Energy balance equation for Generator:

$Q_G = m_6h_6 + m_4h_4 – m_3h_3$

Q_G = 681.47 kJ/kg

Design of Components:

Design of Absorber:

Consider the volume of absorber tank is 15 litters.

Best suited dimensions for absorber is 0.28 m (Φ) × 0.243 m (l)

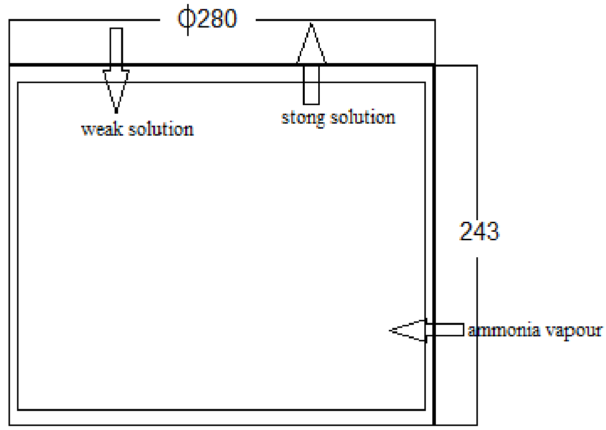

Fig 2. Design of absorber

Design of Condenser:

For design of condenser coil we can take in consideration heat transfer equations as below.
$Q_C = U \times A \times \Delta T$
(U=340-400 W/m2 K for copper and water combination)

From above equation, standard diameter condenser available in market is 1.2cm, 1.4cm, 1.8cm, 2.0cm and 2.4cm. In this experiment following dimensions are considered for condenser coil.
d = 0.012 m
l = 4.73 m

Design of Evaporator:

For design of evaporator coil, same design consideration like condenser coil is used.
$Q_E = U \times A \times \Delta T$, d = 0.012 m, l = 4.6 m

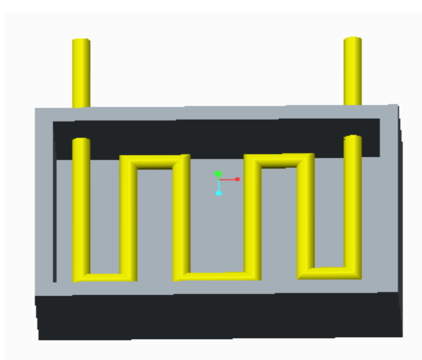

Fig 3. Design of Evaporator

Design of Generator:

Solar energy is used as heat input in generator so, flat plate collector with 6 mirrors is considered for concentration of solar energy in generator tube.

Heat input at the collector = Solar constant * area

Solar constant is considered as 250 W/m2

Hence, Area of the collector is 7.57188 m2

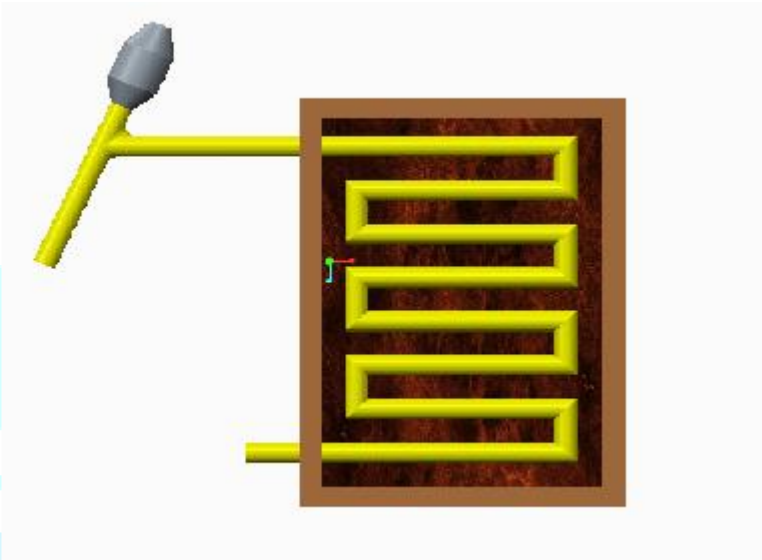

Fig 4. Design of Generator

Experimental Setup

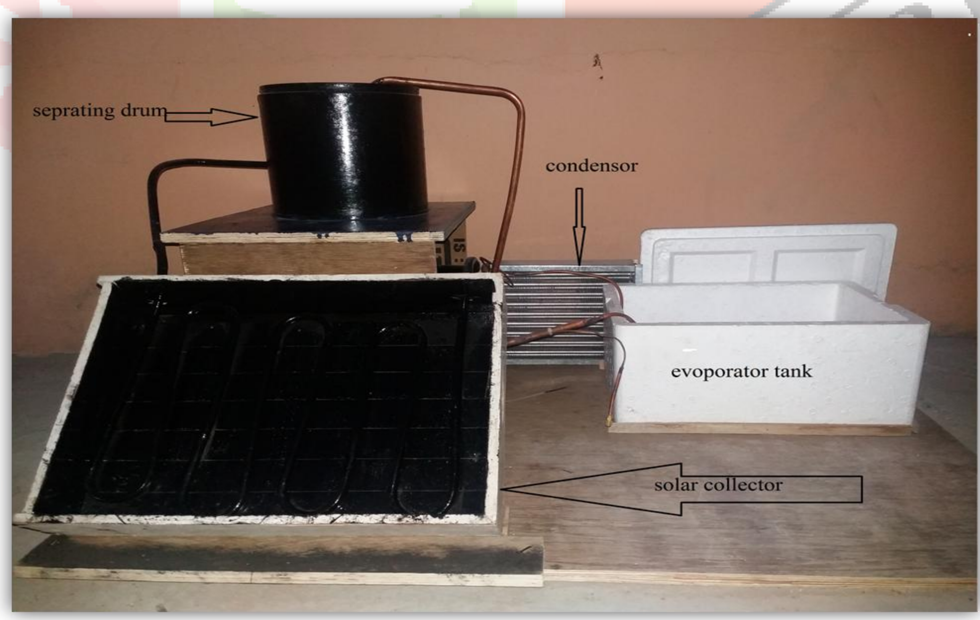

Fig 5. Experimental Set-up

As per the dimensions derive in design procedure, components are manufactured and assembled as shown in figure. For the circulation of strong solution, pump having 16 W capacity is used. Evaporator tank consist of water with 3 litter volume which is required to be cooled below atmospheric temperature. Temperature gun is used to measure temperature of refrigerant in generator, evaporator, and condenser.

Result and discussion:

Effect of provision of mirror:

From the chart, we can see that with increase in number of mirrors, there is significan rise in generator temperature.

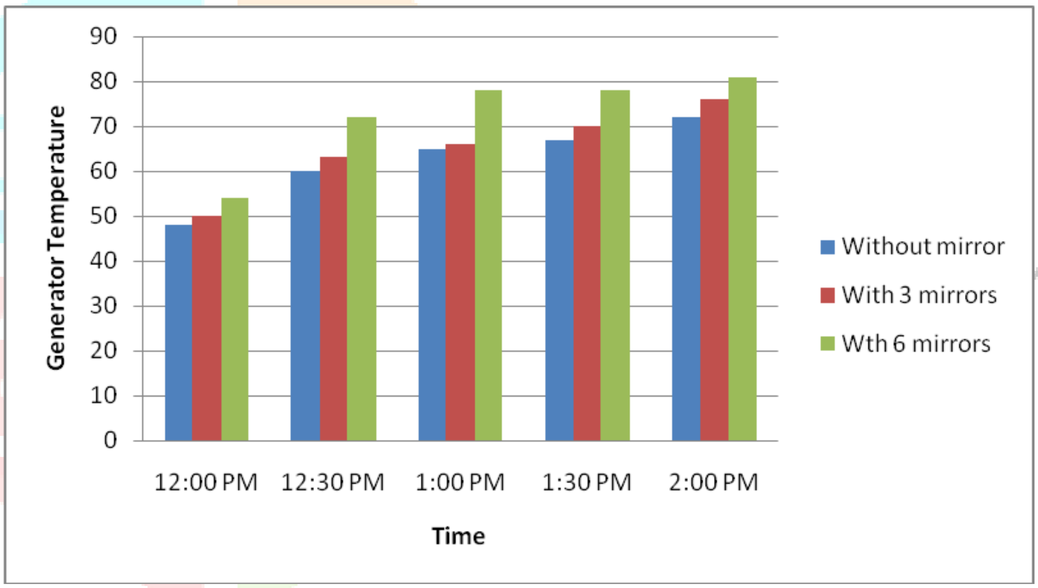

Fig 6 Effect of mirror on performance of generator

Generator temperature vs. COP:

Fig 7 shows the variation in COP with generator temperature and condenser temperature. With rise in generator temperature, COP decrease and with rise in condenser temperature, COP decreases. The evaporator temperature is 10° C and absorber temperature is 30 ° C

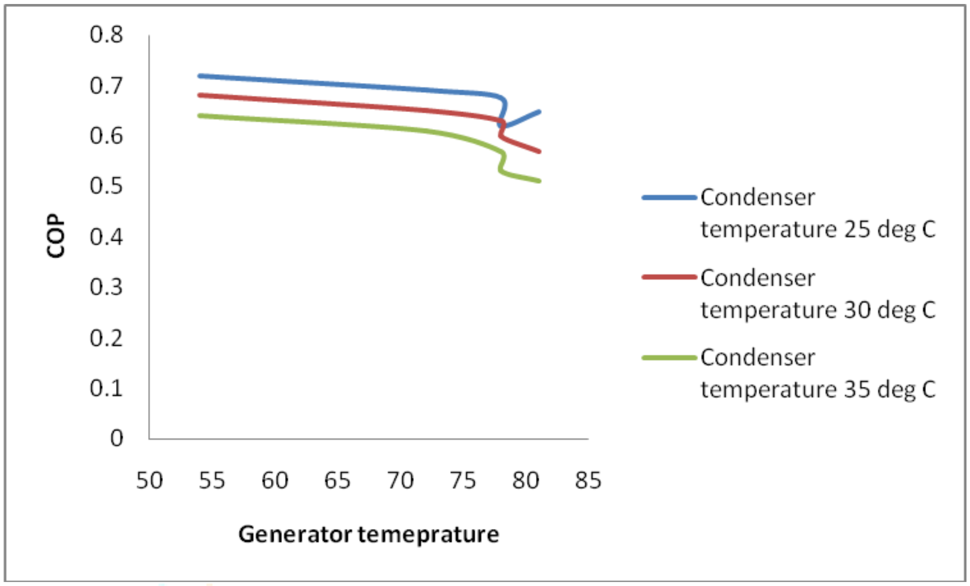

Fig 7. Effect of generator and condenser temperature on COP

Conclusion:

This paper includer design of different componenets of NH_3-H_2O VAR system for 1TR Cooling capacity. In experimental investigation it is cleared that with the provision of mirror, there is rise in generator temperature but contradication to this is the rise in generator temperature causes the decrease in COP of the system as the heat rejected in condenser is restricted to certain limit.

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