REVIEW OF DESIGN OF SINGLE EFFECT SOLAR POWERED VAPOUR ABSORPTION AIR CONDITIONING SYSTEM

Mr. S. S. Mali[1] , Prof.M.M.Wagh[2], Prof. N. N. Shinde[3]

[1]M. Tech Scholar, Department Of Energy Technology, Shivaji University Kolhapur (INDIA).
[2]H.O.D. Department of Energy Technology, Shivaji University, Kolhapur (INDIA).
[3]Prof. Department of Energy Technology, Shivaji University, Kolhapur (INDIA)

ABSTRACT

The solar powered absorption refrigeration technologies are attractive alternatives that not only can serve the needs for air-conditioning, refrigeration, ice making and coagulation purposes, but also can meet demand for energy conservation and environment protection. However, a lot of research work still needs to be done for large-scale applications in industry and for the replacement of conventional refrigeration machines. An air-conditioning system utilizing solar energy would generally be more efficient, cost wise, if it was used to provide both heating and cooling requirements in the building it serves.

This research work is a review of the research state of art of the solar absorption refrigeration technologies. After an introduction of basic principles, the development history and recent progress in solar absorption refrigeration technologies are reported. The application areas of these technologies are categorized by cooling temperature demand, and are further elaborated with fundamental knowledge on absorption systems, and a detailed review on the past efforts in the field of solar absorption cooling systems with the absorption pair of Ammonia and water. This knowledge will help them to start the parametric study in order to investigate the influence of key parameters on the overall system performance.

Keywords:* *Solar Absorption Refrigeration, Energy Conservation, Economical, Ammonia & Water.

I INTRDUCTION

Refrigeration technologies play a vital role in many industrial applications. Notably in the food field where reduction of post-harvest losses, improved food safety and hygiene, promotion of international trade and improved food supply to the cities are considered as top-priority objectives. Air-conditioning is the dominant energy consuming service in buildings in many countries. Conventional cooling technologies used for refrigeration and air-conditioning cause high electricity peak loads because of their concurrent operation during periods of high ambient temperature. Not only that but also the refrigerants generally used in conventional cooling systems are adding significantly to climatic change and ozone depletion.

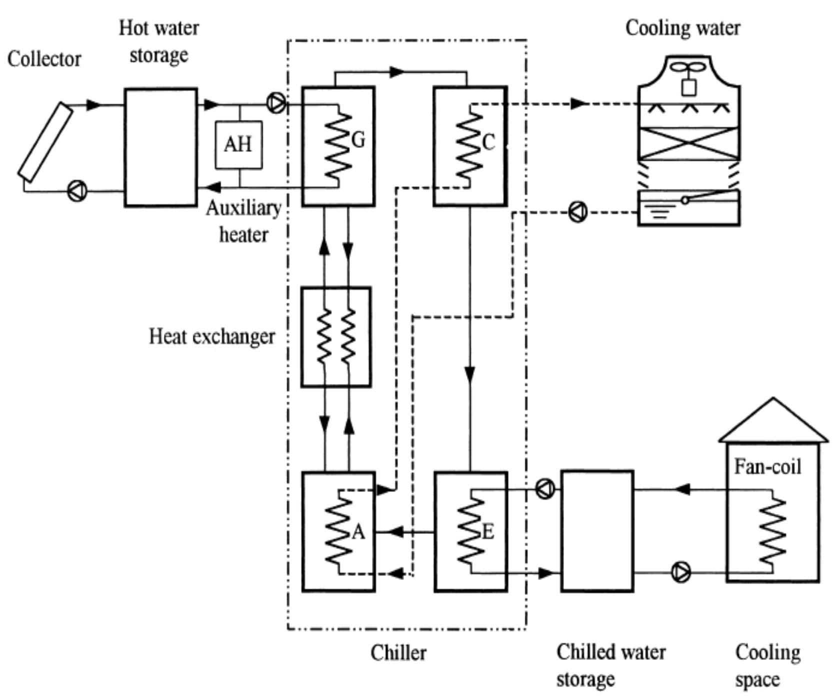
II SINGLE EFFECT SOLAR VAPOR ABSORPTION AIR-CONDITIONING SYSTEM

Fig. Shows the schematic diagram of a single-effect solar absorption system;[2] this system has been the basis of most of the experience to date with solar air- conditioning.

2.1 The main processes taking place are as follows:

1) The weak solution from the absorber at point is pumped through the heat exchanger to the generator. During this process, the concentration of the weak solution is held constant.
2) The sensible heating of the weak solution in the generator takes place. In this process the boiling of ammonia vapor from the solution at the constant condensing pressure. During this process, the weak solution becomes strong solution.
3) The strong solution passing to the absorber through the heat exchanger, in which it preheats the weak solution owing from the absorber to the generator. During this process, the concentration of the strong solution is constant.
4) The absorption of ammonia vapor from the evaporator by the strong solution in the absorber. The condensation of ammonia vapor in the condenser by the cooling water from the cooling tower, at constant condensing pressure.
5) The condensed ammonia flows from the condenser to the evaporator.
6) The evaporation of the aq. ammonia in the evaporator takes place due to the prevailing low pressure. Also the ammonia absorbs the heat from the space to be cooled. The ammonia vapor from the evaporator is in turn absorbed by the strong solution in the absorber, thus completing the cycle of refrigeration.

2.2 Review of Solar Technologies: In the solar powered absorption air-conditioning system, it is very much essential to have hot water storage [3]. It serves as a buffer reservoir to have nearly constant heat input. Also, it has been suggested that the nominal storage amounts for cooling purposes range from 80 kg/m2 of collector area to 200 kg/m2. A critical problem with the hot water storage tank is its heat loss to the surrounding area. Sometimes, the heat loss from the hot water storage tank could be equivalent to 2 h of operation per day of the solar air-conditioning system [4]. Similar to the hot water storage tank, a chilled water storage tank is often used in the solar powered air-conditioning system. While the hot water storage tank experiences considerable heat loss, the chilled water storage tank has a lower rate of heat gain because of the small temperature difference between the chilled water tank and its surroundings. Furthermore, if the chilled water storage tank is installed near the air-conditioned area, its heat gain could assist in cooling. Generally, a parallel auxiliary-heater arrangement is preferred to the series one. Since the chiller has the best performance at high temperatures, it is better to use the auxiliary heater directly to drive the chiller when the temperature in the hot water storage tank is lower than the required level. If the auxiliary heater is connected in series between the hot water storage tank and the chiller, water is often returned to storage hotter than it is taken out, which raises the storage temperature and decreases the collector efficiency. However, if the storage temperature is below the needed energizing temperature but above the return temperature from the generator, then, a series connection can be considered, since only a portion of energy need be supplied by the auxiliary heater to reach the energizing temperature.[5] This method may be suitable in installations needing auxiliary energy only during short periods. In the heating season, the hot water is directly provided from the hot water storage to the fan-coil of the air-conditioned space, or/and to places where the heat is used for bathing or other domestic applications. The main parameter that governs the performance of the chiller is the chilled Water temperature. This is because, as the chilled water temperature decreases, the evaporator temperature decreases, thereby decreasing the pressure in the evaporator, all of which finally results in an increased concentration of the solution. This results in the possibility of crystallization of the solution. Also, with the decrease in evaporating temperature, the coefficient of performance (COP) of the chiller would decrease. [6]



A – absorber; G – generator; C – condenser; E – evaporator

III MATHEMETICAL MODELING

The operating pressures at which the system is working needs to be determined to carry on further calculations, using an enthalpy concentration chart. Once the pressure of the condenser (Pc) and the pressure of the evaporator (Pe) are determined the corresponding points can be fixed on the chart. The various other points and condition lines for components like absorber, generator, heat exchangers etc can be subsequently fixed.

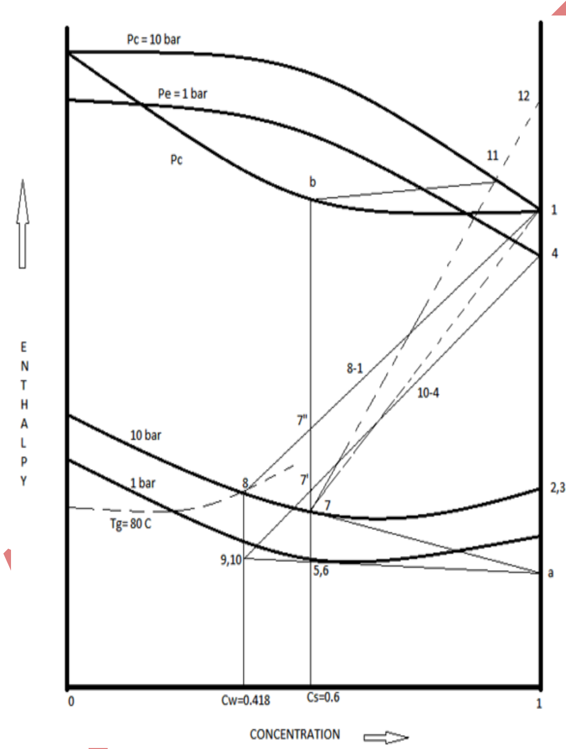
3.1 Condenser Pressure (Pc)

The pressure to be maintained in the condenser for changing the phase of ammonia vapors into ammonia liquid depends on type of condensing medium used and its temperature.

In this system, water is used as a condensing medium. Water is available at a temperature of 25^{O} C. i.e. condensing temperature is Tc= 25^{O} C. For condensing ammonia vapors at 25^{O} C.the corresponding pressure required can be noted from the refrigeration table of ammonia (R-717). In this way, the condenser pressure is fixed at Pc=10 bar.

3.2 Evaporator pressure (Pe)

The evaporator pressure can be fixed according to the minimum temperature required to be maintained in the evaporator chamber. The pressure maintained in the evaporator should be as close to the atmospheric pressure as possible, because maintaining a higher pressure is a difficult and costly affair. Moreover it also has leakage problems and the unit needs to be hermetically sealed. The evaporator pressure is kept equal to the atmospheric pressure(1 bar), to ensure design economy. The corresponding saturation temperature in the evaporator (ammonia vapors) becomes -33^{0}C.



Point 1 represents pure NH_3 saturated vapor at condenser pressure Pc and concentration C=1

Point 2 represents pure NH_3 saturated liquid at Pc and C=1. This point is marked in liquid region.

Point 3 represents the condition of pure NH_3 (wet) but at pressure Pe and C=1. Point 2 coincides with point 3 as 2-3 is a throttling process in which enthalpy remains constant.

Point 4 represents the condition of pure NH_3 at pressure Pe these are saturated vapors which absorbs heat in evaporator and converts from wet vapor to saturated vapor. This point is marked in vapor region.

The enthalpies at points 1, 2, 3 and 4 can be noted from the chart.

h1= 1630 KJ/Kg

h2= h3= 460 KJ/Kg

h4= 1530 KJ/Kg

The literature values for the design of the Aqua Ammonia vapour absorption system are

Temperature of the evaporator, Te = 10℃

Generator or condenser pressure, Pc = 10 bar

Evaporator pressure, Pe = 1 bar

Temperature of the Condenser, Tc = 25℃

Temperature of the Absorber, Ta = 25℃

Temperature of the Generator, Tg = 80℃

IV DESIGNS OF GENERATOR, CONDENSER, EVAPORATOR, AND ABSORBER

4.1 Design of Generator

The generator acts like the discharge of the compressor—it delivers the refrigerant vapor to the rest of the system.

Heat supplied in the generator

Now using equation Qg – Qd = (h1 - ha)

We can find the Qg

Length = 1M. Tube dia. = 0.01M"

Qgen = UG x AG x TG

From above equation we can find out AG

Area of tube = πDL

$$\text{No. of tubes} = \frac{\text{Area of generator}}{\text{Area of tube}}$$

Cross-sectional area of tube = $\pi /4 \times d^2$

Total cross-sectional area = n×a

Total cross-sectional area including space between the tubes = 2×Total cross sectional area

ie,cross-sectional area of generator = Now, $\pi/4 \times D^2$

From above we can find out diameter of generator

4.2 Design of Condenser

The function of the condenser is to remove the heat of the hot vapour refrigerant.

Heat removed in condenser

Heat removed in the condenser by the circulated cooling water is given by the equation:

Qc = Mr × (h2 – h1)

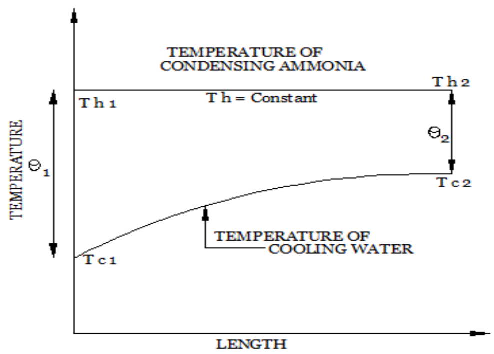
The cooling medium used is water

Inlet temperature of water is (tc1)

Exit temperature of cooling water (tc2)

$\theta 1 = Tg - tc1$

$\theta 2 = Tg - tc2$



LMTD$\theta m = \theta 1 - \theta 2 / \ln(\theta 1/\theta 2)$

Qc= FUA θm

From above we can find out Area of the Condenser Ac

Length of each tube (L) = 100 cm =1m

Diameter of Condenser tube (D) = to be calculated

The effective area of Condenser (Ac) = $n \times \pi \times D \times L$

Area of tube = πDL

Cross-sectional area of tube = $\pi /4 \times d2$

Total cross-sectional area = $n \times a$

Total cross-sectional area including space between the tubes = 2× Total cross-sectional area

ie,cross-sectional area of condenser = Now, $\pi/4 \times D2$

From above we can find out diameter of the condenser

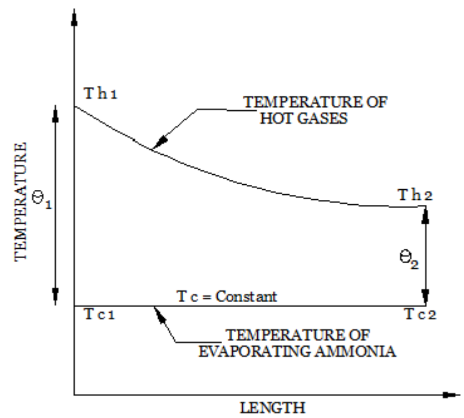
4.3 Design of Evaporator

Evaporator is an equipment in which refrigerant vaporizes to generate the desired refrigeration. It is also known as chiller. Considering the evaporator made of tubes and air cooled.

Let air inlet temperature to evaporator Th1 . Air outlet temp; Th2

$\theta 1 = Th1 - Te$

$\theta 2 = Th1 - Te$



$$[LMTD] = \Theta_m = \frac{\Delta\theta_1 - \Delta\theta_2}{ln\,(\Delta\theta_1/\Delta\theta_2)}$$

Heat removed in the evaporator

Qe = FUA θm

From above equation we can find out Area of the evaporator . Considering the number of evaporator tubes (n)

Length of each tube (L) = 1m .

Diameter of evaporator tube (D) = to be calculated.

The effective area of evaporator

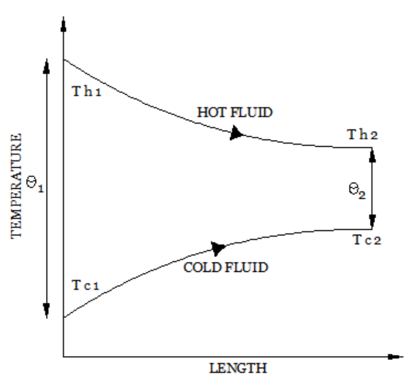
(Ae)=n × π × D × L

Area of tube = πDL

From above we can find out diameter of the evaporator

4.4 Design of Absorber

Considering the absorber to be direct contact heat exchanger in which the weak solution from the generator mixes with the ammonia gas from the evaporator and due to the direct mixing the heat is rejected. Air is used as cooling medium.



Heat removed from absorber.

QA = UA x AA x TA

From above equation we can find out Area of the absorber

Area of tube = πDL

$$\text{No. of tubes} = \frac{\text{Area of generator}}{\text{Area of tube}}$$

Cross-sectional area of tube = π /4 × d2

Total cross-sectional area = n×a =

Total cross-sectional area including space between the tubes = 2× Total cross-sectional area

ie , cross-sectional area of generator = Now, π/4 ×D2

4.4.1 Calculations of solar water heater:

Energy absorbed by the collector plate is given by Qu= K × S × A

Where,

K=efficiency of collector plate (assume k=0.70)

S=average solar heat falling on earth's surface=6 kwhr/ m2/day= 250 W/m2

A=Area of collector plates

COP of the system (For flat plate collector system)

The cop of the refrigerating unit can be calculated by using the equation:

COP = …Refrigerant Effect / Heat input in the generator

Now the COP of the system as a whole (system including solar water heater) can be calculated as

COP = Net refergerent effect produced / Heat input at the solar collecter

V CONCLUSION

From the discussion, one may conclude that solar-powered absorption refrigeration technologies could be used for producing a wide range of temperatures of cold. They are attractive technologies that not only can serve the needs for refrigeration, air-conditioning applications and ice making, but also can meet demand for energy conservation and environment protection. Comparatively, absorption systems are more suitable for air-conditioning while adsorption systems are more employed for low temperature purpose. In light of the above results, the feasibility of the solar powered vapour refrigeration system has been reasonably proved.

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