Designing of Solar Powered Vapor Absorption Refrigeration (VAR) System

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ABSTRACT

The project deals with, Designing of solar powered vapor absorption refrigeration system. The prices of electric power have been increasing exponentially worldwide. Industrial refrigeration is one of the most energy consuming sector. If we can fabricate a refrigeration system which uses no electric power or minimal amount of energy, it'll be breakthrough. We dealt with direct solar energy which used as its heat source in vapor absorption refrigerator in which we used refrigerant as solution of ammonia and water.

The solution for energy demand problem in refrigeration lies in absorption refrigeration system. By making an absorption refrigeration system, we are not only cutting down the energy costs but also preserving our environment. This refrigeration system doesn't use any of the CFCs so our ozone layer is safe. It is anticipated that the production of refrigerator-freezers will substantially increase in the near future as a result of the increased demand, especially in the developing countries.

The invention can improve refrigerating unit, raise coefficient of performance, reduce energy cost of refrigerating unit and has notably social and economic benefit. Compared with the existing compressor refrigeration system, our system realizes simplified structure, low energy consumption and reduction of 'discharge and environmental pollution by hazardous substance'.

Keywords:

Solar, Refrigerator, Vapor Absorption refrigeration system, Flat Plate Collector.

I. INTRODUCTION

REFRIGERATION is a process of removing the heat from matter which may be a solid, or liquid, or a gas.

Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature. One of the most important applications of refrigeration has been the preservation of perishable food products by storing them at low temperatures.

Refrigeration systems are also used extensively for providing thermal comfort to human beings by means of air conditioning. Air Conditioning refers to the treatment of air so as to simultaneously control its temperature, moisture content, cleanliness, odour and circulation, as required by occupants, a process, or products in the space.

The subject of refrigeration and air conditioning has evolved out of human need for food and comfort, and its history dates back to centuries. The history of refrigeration is very interesting since every aspect of it, the availability of refrigerants, the prime moversand the developments in compressorsand the methods of refrigeration all are a part of it.

Refrigeration is divided into two types:

1. Vapor compression system.
2. Vapor absorption system.

By means of absorption, expansion, condensation, and evaporation, and a cooling medium, such as air or water. The refrigerant (Ammonia) removes heat from a substance and transfers it to the cooling medium.

2. PROCEDURE

REFRIGERATION CYCLE:

Inrefrigeration cycle, heat is transported from a colder location to a hotter area. As heat would naturally flow in the opposite direction, work is required to achieve area. A refrigerator is an example of such a system, as it transports the heat out of the interior and into its environment. the refrigerant is used as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere.

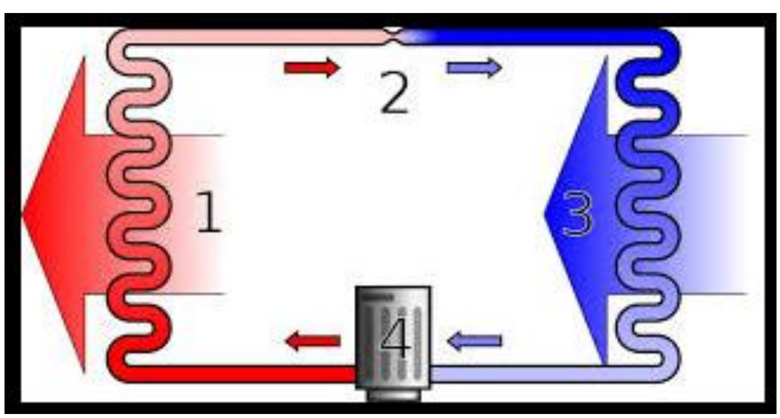

Figure1: A simple stylized diagram of the refrigeration cycle: 1) condensing coil, 2) expansion valve, 3) evaporator coil, 4) compressor

Circulating refrigerant vapour enters the compressors, where its pressure and temperature are increased. The hot, compressed refrigerant vapour is now at a temperature and pressure at which it can be condensed and is routed through a condenser. Here it is cooled by air flowing across the condenser coils and condensed into a liquid. Thus, the circulating refrigerant removes heat from the system and the heat is carried away by the air. The removal of this heat can be greatly augmented by pouring water over the condenser coils, making it much cooler when it hits the expansion valve. at the expansion valve it removes the heat and cools that place and then the liquid is converted into vapour again the process is continued.

3. OVER VIEW AND ANALYSIS OF VAR SYSTEM

VAPOR ABSORPTION REFRIGERATION SYSTEM:

The objective of this paper is to design and study an environment friendly vapour absorption refrigeration system of unit capacity using R 717 (NH3) and water as the working fluids. In this project, performance of the fabricated system is outlined with respect to various operating conditions related to heat source, condenser, absorber and evaporator temperatures. But the irony is that, this solar heating unit remains idle in the summer monthsalso the solar potential is at maximum in the summer.

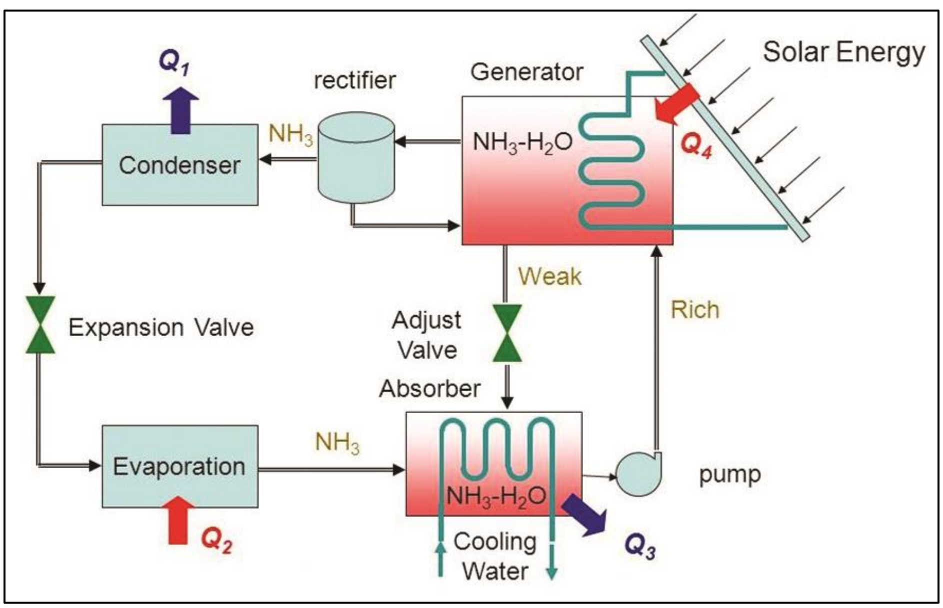

Figure2: Block diagram of the Solar Powered VAR System

The Solar Powered Vapour Absorption Refrigeration System consists of some parts are following shown below:

1) Condenser
2) Evaporator

3) Generator
4) Absorber
5) Expansion valve
6) Heat exchanger
7) Pump

4. DETAILED PARTS LIST OF VAR SYSTEM

The Solar Powered Vapour Absorption Refrigeration System consists of some parts are following shown below:

EVAPORATOR:

It is in the evaporator where the refrigerant pure ammonia (NH3) in liquid state produces the cooling effect. It absorbs the heat from the substance to be cooled and gets evaporated. From here, the ammonia passes to the absorber in the gaseous state.

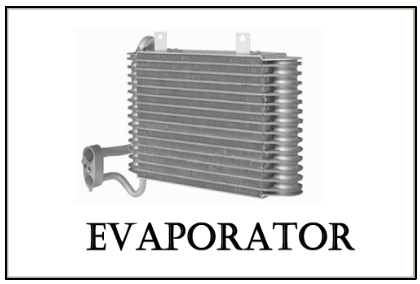

Fig3: Evaporator

ABSORBER:

In the absorber the weak solution of ammonia-water is already present. The water, used as the absorbent in the solution, is unsaturated and it has the capacity to absorb more ammonia gas. As the ammonia from evaporator enters the absorber, it is readily absorbed by water and the strong solution of ammonia-water is formed. During the process of absorption heat is liberated which can reduce the ammonia absorption capacity of water; hence the absorber is cooled by the cooling water. Due to absorption of ammonia, strong solution of ammonia-water is formed in the absorber.

Figure4: Absorber

PUMP:

The strong solution of ammonia and water is pumped by the pump at high pressure to the generator.

Fig5: Pump

GENERATOR:

The strong solution of ammonia refrigerant and water absorbent are heated by the external source of heat such as steam or hot water. It can also be heated by other sources like natural gas, electric heater, waste exhaust heat etc. Due to heating the refrigerant ammonia gets vaporized and it leaves the generator. However, since water has strong affinity for ammonia and its vaporization point is quite low some water particles also get carried away with ammonia refrigerant, so it is important to pass this refrigerant through analyzer.

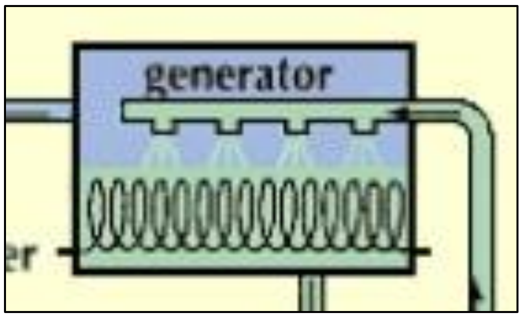

Fig6: Generator

CONDENSER:

Just like in the traditional condenser of the vapor compression cycle, therefrigerant enters the condenser at high pressure and temperature and gets condensed. the condenser is of water cooled type.

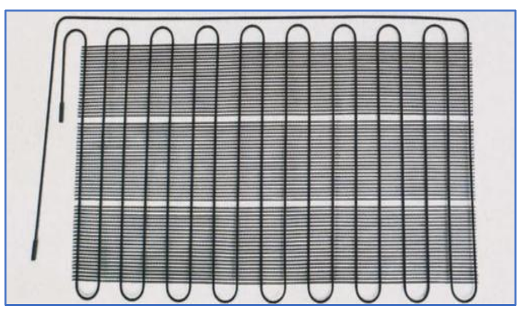

Fig7: condenser

EXPANSION VALVE:

When the refrigerant passes through the expansion valve, itspressure and temperature reduce suddenly. This refrigerant (ammonia in this case) then enters the evaporator.

Fig8: Expansion valve

WORKIGN MODEL OF VAPOUR ABSORPTION REFRIGERATION SYSTEM

Fig9: Back side photo of a domestic absorption refrigerator.

1. Hydrogen enters the pipe with liquid ammonia.
2. Ammonia and hydrogen enter the inner compartment of the refrigerator. An increase in volume causes a decrease in the partial pressure of the liquid ammonia. The ammonia evaporates, taking heat from the liquid ammonia (ΔH_{Vap}) and thus lowering its temperature. Heat flows from the hotter interior of the refrigerator to the colder liquid, promoting further evaporation.
3. Ammonia and hydrogen return from the inner compartment, ammonia returns to absorber and dissolves in water. Hydrogen is free to rise upwards.
4. Ammonia gas condensation (passive cooling).
5. Hot ammonia (gas).
6. Heat insulation and distillation of ammonia gas from water.
7. Heat source (electric)
8. Absorber vessel (water and ammonia solution).

THERMAL IMAGE OF SOLAR POWERED VAR SSYSTEM

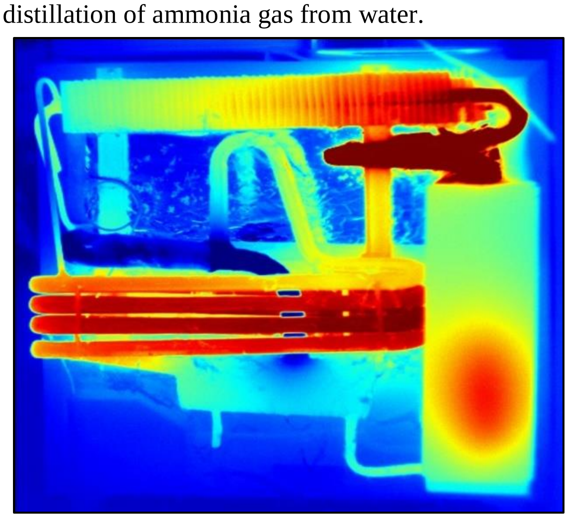

Fig10: Thermal image of domestic refrigerator

Thermal image of a domestic absorption refrigerator of a comparable type to the one in the labelled image above. Colour indicates relative temperature: blue=cold, red is hottest. The heat source (7) is contained entirely within the insulation section (6).

5. ANALYSIS OF AQUA-AMMONIA REFRIGERATION SYSTEM

For the analysis and design of aqua-ammonia refrigeration system, it is necessary to represent the process and condition of aqua on C-h (concentration-ethalpy) chart passing through different components of the system. This is most easy way to find out the enthalpies of aqua at different components. The input and output of the system being in the form of heat (enthalpy)only, the system performance can be calculated once the enthalpies at different points are known.

In the design of this system, once the temperature at condenser and evaporator are known and the load to be taken by the system is known, then we can decide the circulation of aqua as well as pure NH3 to be used in the system. After this, we can design the sizes and arrangements of the different components of the system.

System consist of water cooled condenser, generator, flat plate collector, evaporator, liquid receiver, two valves, non-return valve. System uses ammonia-water as working pair, in which ammonia used as refrigerant and water as absorbent. Ammonia in the generator is heated by hot water in the collector which is due to the solar energy absorbed from sun dut to heating high pressure ammonia vapour is produced. During the process both the valve is closed. Ammonia vapor is then condensed into condenser which surrounded with water to keep it cool and pressure is uniform. During this valve A closed and valve B is opened to collect liquid ammonia into receiver. Liquid ammonia is then passed to the evaporator at low pressure which is maintained through expansion valve. Refrigeration effect obtained in evaporator by absorbing heat from surrounding. Refrigeration effect obtained till all ammonia liquid completely vaporize.

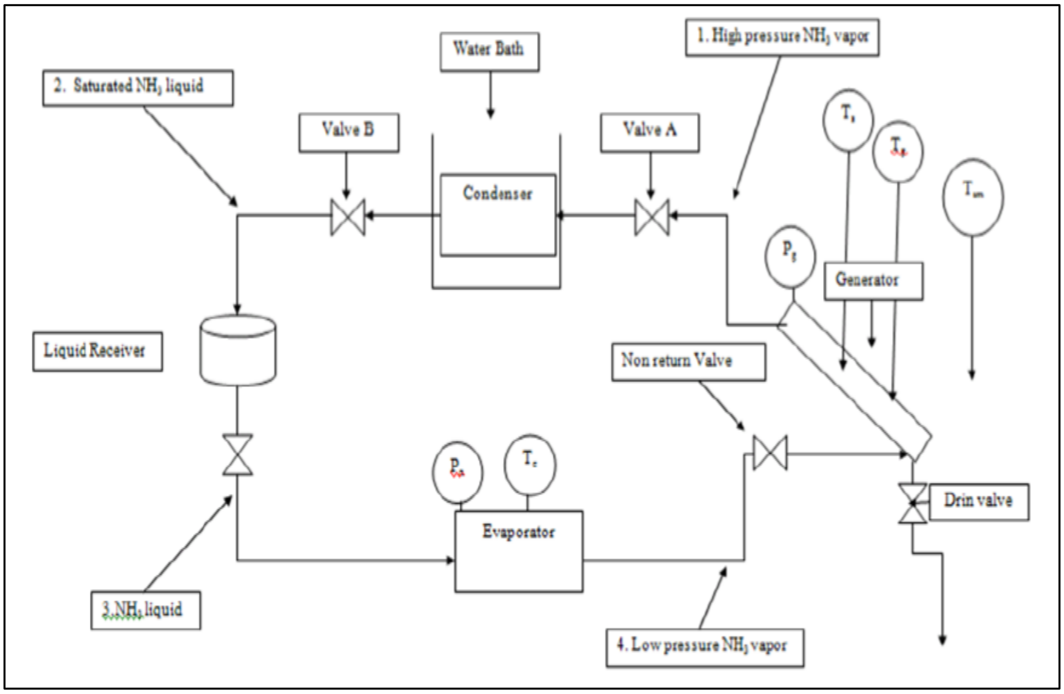

Figure11: The Use of Direct Solar Energy in Absorption Refrigerator.

SOLAR FLAT PLATE COLLECTOR

The following materials required for fabricating a flat plate solar collector Aluminum tray as base, copper plate as absorber plate, black paint, copper tubes, tempered glass. The schematic diagram is shown below.

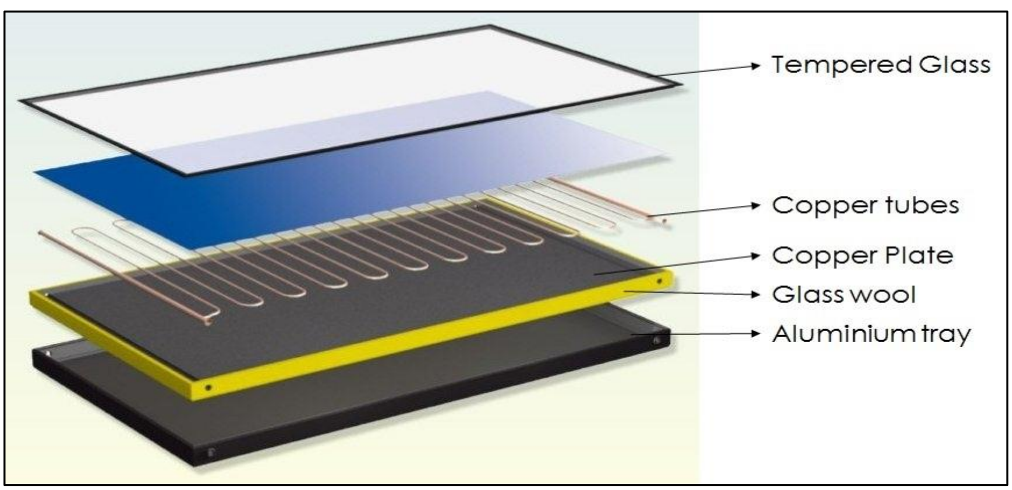

Fig12: Schematic view of Flat plate solar collector

Aluminum Tray: Aluminum tray made in rectangle box shape to use as base.

Insulation Material (Fiber Glass Wool): It is made up of steel, aluminum or fiber glass. Fiber glass is widely used as insulation.

Copper Plate:

It is made up of copper because of its high conductivity. It is also known as absorber plate. Moreover, it is corrosion resistant. These copper plates 0.05 mm thick with 1.25 cm tubes. Tubes are spaced 15 cm apart; the efficiency is 97 %. Moreover, black paint over copper plate is used which has absorptance=0.85-0.9 and emittance=0.08-0.12.

Copper tubes:

The copper tubes are used for inlet and outlet of hot water. Here the inlet will be cold water and out let will be hot water. Tubes should be spaced 15 cm apart for the efficiency of 97%.Diameter – 1.25 cm, Length – 4 meters. The tubes will be in the form of Serpentine. Copper tubes soldered to make better thermal energy transfer between copper plate to water in tubes.

Tempered Glass:

It is made up of glass tempered with a low iron content and 5 mm thick andL X B = 72 X 52 cm. The collector has 85% transmittance when this type of glass is used.

Cooler pump:

The cooler pump used to transfer water into inlet of flat plate collector in the speed of 10 m/sec. It'll immerse in water storage tank and circulate water in solar collector

The total setup was made into a perfect flat plate solar collector as shown below.

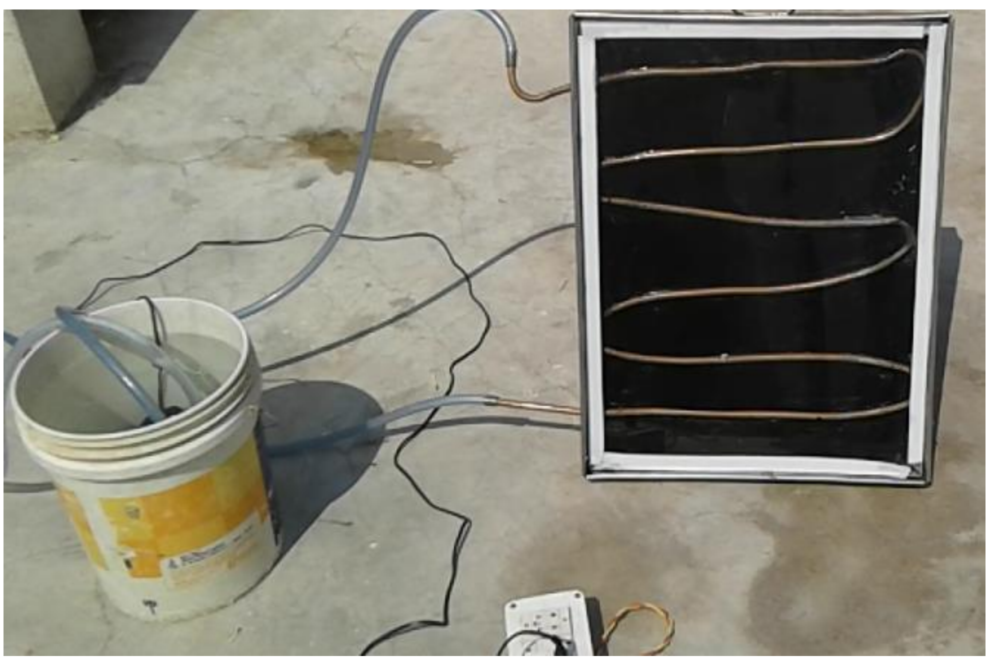

Fig13: A view of Flat plate solar collector

6. OBJECTIVE

The main objective of this project is to design an energy efficient, by fabricating solar powered vapor absorption refrigeration system. By making this, we are not only cutting down the energy costs but also preserving our environment. This refrigeration system doesn't use any of the CFCs so our ozone layer is safe and also the maintenance cost is low. This project provides information for equipment selection and system design. This project provides a procedure for preparing a manual calculation for co-efficient of performance. A number of published methods, research papers provide a good source of design information and criteria in the preparation of the solar vapour absorption refrigeration system.

The domestic refrigerator-freezers operating on alternative refrigerants such as HFC-134a, contribute indirectly to global warming by the amount of carbon dioxide produced by the power plant in generating electricity to operate over a unit over its lifetime. This contribution is nearly 100 times greater than the direct contribution of the refrigerant alone.

The invention can improve refrigerating unit, raise coefficient of performance, reduce energy cost of refrigerating unit and has notably social and economic benefit. Compared with the existing compressor refrigeration system, the system realizes simplified structure, low energy consumption and reduction of 'discharge and environmental pollution by hazardous substance'.

The current project can result in development of a system which can be a decisive step in bringing refrigeration to the far off rural areas. In urban areas a huge chunk of households consumes more refrigeration energy than is required due to inefficient usage. This project also holds promise to reduce if not eliminate this huge portion of energy consumption pie.

Major problems outlined in refrigeration were as follows:

- Low co-efficient of performance.
- Large Size & huge weight.
- High cost

OBJECTIVE:

1. **COP:** We aim to improve the COP of the adsorption/absorption refrigerator to make it more attractive for usage.

2. **Size:** We aim to reduce the size of the assembly by making it more compact.

3. **Weight:** The absorption/adsorption refrigeration system is too bulky. Its weight reduction is also one of the aims. It can be reduced by using polymers.

4. **Cost:** Cost is the biggest barrier in implementation of Adsorption/absorption refrigeration. We aim to minimize it as far as possible.

5. **Extended Usability:** Till date absorption refrigeration is limited for industrial purposes. We aim to make it available for mass rural use as stated above in small capacities by using solar adsorption/absorption.

Advantages

- No moving parts, so operation is really quiet.
- Ammonia is used as refrigerant which is easily and cheaply available.
- Load variations doesn't affect performance of system.
- Maintenance cost is low.
- Refrigerant doesn't produce the greenhouse effect, because it doesn't produce chloro-flouro carbons.

Dis-Advantages

- Initial cost is high.
- Corrosive in nature.

Applications

- Food storage in recreational vehicles.
- Cold storage houses.
- Small domestic refrigerators.

7.CALCULATIONS

FORMULAE:

Heat absorbed in evaporator =Mr (h6-h5)

Heat generated in generator =Mr (h3-h2)

Heat rejected from condenser= Mr (h4-h3)

COP: heat absorbed in evaporator /work done by pump+ heat supplied in generator.

a) Mass flow rate of ammonia as refrigerant

Mr = 0.18 Kg/min

b) Heat removed in the evaporator= refrigeration effect

= Mr. × (h4 – h3)

= 1 TR = 210 KJ/min

If cold water flow rate is Mw then Mw Cp ΔT= 210 Kj/min, if ΔT=17 0C, then Mw= 3.0 Kg/min

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

Qc = (h4-h3) per kg of ammonia

i.e. Qc = Mr × (h2 – h1)

= 0.18 × (1630 - 460)

Therefore, heat removed

$$Qc = 211.6\ KJ/min$$

d) Heat removed from absorber. When the NH3 vapour at point 4 and aqua at 10 are mixed, the resulting condition of the mixture in the absorber is represented by 7" and after losing the heat in the absorber (as it is cooled), the aqua comes out at condition 5. Therefore, the heat removed in the absorber is given by

$$Qa = (h7'' – h5)\ \text{per Kg of aqua.}$$

Extend the triangle 10-7"-5 towards right till 10-7" cuts at 4 and 10-5 cuts at point 'a' on x axis. Therefore, heat removed per kg of NH3 is given by

$$Qa = (h4 - ha)\ \text{per kg of ammonia}$$

$$Qa = Mr \times (h4 - ha)$$

$$= 0.18 \times (1550 - 70)$$

$$= 266.4\ KJ/ min$$

$$\text{Thus } Qa = 266.4\ KJ/min$$

Now the resultant aqua is at condition 7", which loses heat up to condition 5. Temp at 7" = i.e. T7" = 82 0C (from C-h chart) Say, water gets heated to a temp of 82 C from 25 0C while removing heat from the absorber.

If Mw = mass of cooling water required

Then

$$Mw \times Cp \times (Ti – T0) = 266.4$$

$$Mw \times 4.18 \times (82 - 25) = 266.4$$

$$Mw = 1.12\ Kg/min$$

That is, the mass of cooling water required in absorber is 1.12 kg/min.

e) Heat given in the generator Say Qg is the heat supplied in the generator and Qd is the heatremoved from water vapour then the net heatremoved per kg of aqua is given by

$$qg – qd = (h7' – h7)\ \text{per kg of aqua}$$

as the aqua goes out in at condition 7 and comes out at condition 8 and 1, which can be considered as a combined condition 7'. By extending the triangle 8-7-7' towards right till 8-7'cuts at 1 and 8-7 cuts at a on y axis, then the heat removed per kg of NH3 is given by Q g - Qd

= (h1 – ha) per kg of ammonia Now for finding out Qd separately, extend the vertical line 7-7' till it cuts the auxiliary line Pc and mark point 'b' as shown. Then draw a horizontal line through b which cuts Pc line in vapour region at point 11. Then join the points 7 and 11 and extend the line till it cuts y axis at 12.

Then,

Qd is given by Qd = (h12 – h1) per kg of ammonia

$$Qd = 0.18 \times (1760 - 630)$$

$$Qd = 23.4 \text{ KJ/min.}$$

now using equation

$$Qg – Qd = (h1 - ha)$$

we have

$$Qg - 23.4 = 0.18 \times (1630 - 70)$$

T therefore,

$$Qg = 304.2 \text{ KJ/min}$$

Thus, the amount of heat required in the generator for running this unit is Now this amount of heat is provided by the hot water coming out of solar flat plate water heater. The temp of hot water coming out of solar water heater is about 84 0C. We can reasonably assume that the heating in generator is produced at about 80 0C, considering losses of heat.

f. Calculations of solar water heater. Useful energy (energy absorbed by the collector plate) is given by

$$Qu= K \times S \times A$$

Where,K=efficiency of collector plate (assume k=0.85)

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

A=Area of collector plates

NowHeat req. in the generator,

$$Qg = 304.2 \text{ KJ/min}$$

$$= 304.2 \times 1000 / 60 \text{ J/s}$$

$$= 5070 \text{ W}$$

Hence approximate area of the collector plates required for providing this much amount ofenergy = 5070 / (250× K)

$$= 5070 / (250 \times .85)$$

$$= 24 \text{ square meters (approx.)}$$

Total Area of collector plates:

$$A=24 \text{ sq. m.}$$

Therefore, we can use 4 collector plates of having dimensions of 3 X 2 sq. m.

Thus,

$$Qu=0.85 \times 250 \times 24 = 5070 \text{ W}= 5070 \text{ J/s}$$

The energy absorbed by the collector helps in heating of the water flowing in the tubes of thecollector plates.

$$U = m \times Cp \times (To-Ti)$$

Let rate of water flowing through the tubes, m = 1.2 kg/min = 0.02 kg/s, (typical example) Specificheat of water, Cp=4200 J/kg/k To=Outlet temp. of water in the collector plate Ti=Inlet temp. ofwater in collector plate=25 0C

Therefore, $$Qu = 0.02 \times 4200 \times (To-25)$$

$$\text{i.e. } 0.02 \times 4200 \times (To - 25) = 5070$$

$$\text{It gives, } To = 84\ 0C$$

The temperature (To) should be the inlet temp. of generator, but assuming water loses heat while flowing through the tubes. Also, there is certain effectiveness of the generator as a heat exchanger, less than 100 %. Hence net heating in the generator can be assumed to be taking place at 80 0C. Temperature at generator=80 0C This is the net heat input to the system, which is running as a refrigeration unit of 1 TR capacity. The work done by the pump for raising the pressure is negligible and hence neglected.

g. COP of the system

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

$$COP: \frac{\text{Refrigeration Effect}}{\text{Heat Input in Generator}}$$

Neglecting pump work

Therefore, COP = 210 / 304.2

= 0.69

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

$$COP = \frac{\text{Net Refrigeration effect produced}}{\text{Heat input at the solar collector}}$$

$$COP = \frac{210\ Kj/min}{360\ Kj/min} = 0.58$$

Hence theoretical COP of the whole system comes out to be 0.58.

8. CONCLUSION

- Using solar energy as the power source of the system proved to be feasible.
- Solar energy being a renewable source of energy proved to be efficient as compared to using electrical energy or steam at the same place.
- With the flow of ammonia through the system, we were able to use it as an refrigerator and that too with the help of renewable and non-polluting source of energy, I.e., solar energy.

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