Solar Operated Water Cooler Using Vapour Absorption Cycle

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ABSTRACT

In the current trends globally, the excessive utilization of the energy and overconsumption of fuel has resulted in the global warming and environmental pollution. The Absorption cooling offers the possibility of using heat to provide cooling. For cooling purpose the required heat input is obtained from the excessive heat of the boiler or from non-conventional power sources like solar energy. NH3-H2O system ammonia used as a refrigerant and water is used as an absorbent, these two liquids served as standard and a refrigerant cycle is produced. The system VARS environment friendly and does not deplete the atmosphere. Thus it is essential to create awareness in the world for this system for it is an alternative system which is more environmental friendly. The objective of this paper is to present empirical relations for evaluating of the performance of a single stage vapour absorption system.

Keywords*: Refrigeration, COP, VARS, Ammonia-Water.*

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1. INTRODUCTION

In recent trends of shortage of energy production and fast increasing non-reusable energy consumption, there is a need to minimize the overall energy consumption. Recovering the lost heat energy from various heat production units like generators, boiler and thermal plants and then utilizing the waste heat energy from the system is rapidly becoming a common scientific ideology and industrial practice in recent times. The present energy crisis has forced the scientists all over the world to adopt new methods of energy conservation in various sectors of industries areas. But the sudden reduction of the different types of power and energy like electrical, thermal, and chemical are unavoidable in the competitive industrial growth throughout the world. Refrigeration systems form a vital component for the industrial growth. Therefore, it is desirable to provide a solution for the conservation of energy by adopting the Vapor Absorption System Refrigeration System.The Refrigeration System which operates nowadays is VCRS which requires high grade energy for their operation. Apart from this, the analysis and the studies have shown that the conventional working fluids of vapor compression system are causing ozone layer depletion and green house effects.However, the VARS is operational by harnessing the harmless inexpensive waste heat, solar, biomass or geothermal energy sources for which the cost is negligible. Moreover, the working fluids of these systems are envoi mentally friendly. The overall performance of the absorption cycle in terms of refrigerating effect per unit of energy input generally poor, however, waste heat such as that rejected from a power can be used to achieve better overall energy utilization. Ammonia/water (NH3/H20) systems are widely used where lower temperature is required.

2. DETAILED SYSTEM DESCRIPTION

The Vapor absorption refrigeration systems use a heat source instead of electricity to provide the energy needed to produce cooling. The most basic components of a vapor absorption cycle are the evaporator, absorber, pump(s), generator (or desorber).a condenser and throttle valves.

In this system the NH3 is used as a refrigerant and the water is used as an absorbent. In two working fluid system the ammonia vapor is produced in the generator at high pressure from the heating of the strong aqua-ammonia solution by an external source. The ammonia vapors flow to a condenser, where heat is rejected and condensed to a high-pressure liquid form. The liquid is then throttled though an expansion valve to the lower pressure in the evaporator where it evaporates by absorbing heat and provides useful cooling. The remaining liquid absorbent, in the generator passes through a valve, where its pressure is reduced, and then is recombined with the low-pressure refrigerant vapors returning from the evaporator, so the cycle gets completed and can be repeated.

Whereas in three working fluid the expansion valve is removed and a third fluid is introduced Hydrogen gas which has the properties including lightness, high reactiveness and low partial pressure. So when the ammonia vapors comes in contact with hydrogen gas which has low partial pressure the pressure of the complete system comes down rapidly causing flash evaporation which causes cooling.

The cycle can be broken into different flows, one comprising of the ammonia-water mixture and the other comprising of the ammonia vapor alone. Points are the cycle of the ammonium hydroxide solution, and the rest of the points constitute the ammonia vapor cycle. The solution rich in refrigerant at point is pumped to higher pressure through the solution heat exchanger into the generator where heat is added and an ammonia-water vapor mixture is sent to the rectifier, and the solution poor refrigerant is sent back through the solution heat exchanger to the absorber.

The ammonia-water vapor is purified in the rectifier by condensing the water vapor in the mixture into liquid. The pure ammonia vapor is sent to the condenser and the water liquid is sent back to the generator. The ammonia vapor loses heat to the surrounding by convection as it goes through the condenser and is cooled into liquid ammonia. The ammonia liquid is passed through the refrigerant heat exchanger for further cooling, and then passed through a flow restrictor where it experiences a sudden drop in pressure and evaporates because this new pressure is less than its saturation pressure.

The ammonia is now a saturated vapor at a temperature that corresponds to this new pressure. This temperature is always lower than the desired compartment temperature. The saturated ammonia vapor is sent to the evaporator where heat from the refrigerator is absorbed. The ammonia vapor goes through the heat exchanger once again, but this time to absorb heat, before returning to the absorber where it is absorbed into the water and the process repeats again.

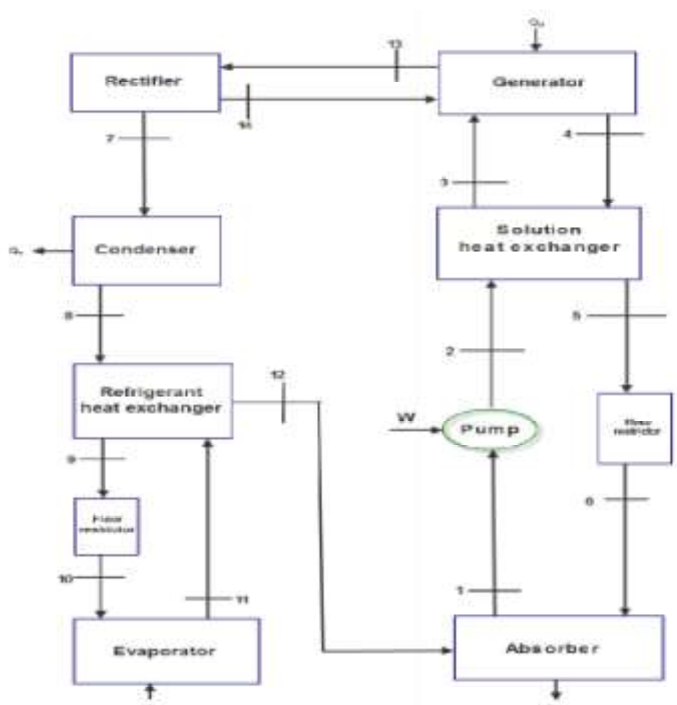

Fig - 1 Ammonia-water absorption refrigeration system flow diagram

2.1 Generator

The generator delivers the refrigerant vapour to the rest of the system by separating refrigerant from the solution. The generator provides sensible heat and latent heat to the weak solution of aqua-ammonia. The sensible heat raises the inlet stream temperature up to the saturation temperature. The heat of Vaporization consists of the heat of vaporization of pure water and the latent heat of mixing of the liquid solution. The solution absorbs heat from the warmer steam or water, causing the refrigerant to boil (vaporize) and separate from the absorbent solution. As the refrigerant is boiled away, the concentration of the absorbent solution becomes more. The concentrated absorbent solution further returns back to the absorber and the refrigerant vapour moves to the condenser. Considering the heat and mass balance across generator, the generator characteristics were found out.

2.2 Condenser

The purpose of condenser is to condense the refrigerant vapours. In the condenser, heat is extracted from a refrigerant at constant pressure. The phase of the refrigerant changes from vapor to liquid state and the temperature of the refrigerant changes from 90 to 31^{o}C. As heat transfers from the refrigerant vapor to the water, refrigerant condenses on the tube surfaces. The condensed liquid refrigerant is collected at the bottom of the condenser before proceeding to the expansion device.

2.3 Evaporator

The evaporator containing a bundle of tubes carry the system of circulating water to be cooled. At a lower pressure in the evaporator, the refrigerant gets evaporated by absorbing heat from the circulating water and the refrigerant vapours thus formed tend to increase the pressure in the vessel. With increase in pressure, the boiling temperature increases and the desired cooling effect is not obtained. Therefore the refrigerant vapours are removed from the vessel into the lower pressure absorber. Most commonly the evaporator and absorber are contained inside the same shell, allowing refrigerant vapours generated in the evaporator to move continuously to the absorber. In the evaporator, phase change of refrigerant takes place at a constant pressure. In order to facilitate the heating the evaporator extracts heat from the space or substance to be cooled.

2.4 Absorber

Inside the absorber of a vapour absorption system, the refrigerant vapour is absorbed by the solution. As the refrigerant vapour is absorbed, it condenses from a vapour to a liquid so that the heat it acquired in the evaporator is being released. The cooling water circulating through the absorber tube bundle carries away the heat released from the condensation of refrigerant vapours by their absorption in the solution. The weak absorbent solution is further pumped to the generator to drive off the refrigerant by supply of heat. The refrigerant vapours formed in the generator migrate to the condenser. In the absorber strong solution of aqua –ammonia absorbs the vapors from the evaporator turning it into a weak solution. The cooling water flows through the absorber in order to extract heat from it.

3. SELECTION OF REFRIGERANT

The Refrigerant is the most important part of the refrigeration system. The refrigerant in the system defines the working and the cycle of the refrigeration system. The working further lists out the components in the system. The components which are being used finally define the system if it is VARS or VCRS.

Aside from the afore mentioned requirements, the refrigerant must also meet standard refrigerant characteristics listed below. These characteristics are defined in other to maintain the surrounding conditions so that the refrigeration while operating should damage the atmosphere and the environment. A refrigerant must be or have the following properties –

-ozone and environmentally friendly
-low boiling temperature
-vaporization pressure lower than atmospheric
-high heat of vaporization
-nonflammable and non-explosive

In the recent times, commonly most of the manufacturers use ammonia as a refrigerant because it has a greater heat of vaporization, a lower vaporization pressure, a higher auto-ignition temperature, and is to the 100th time more soluble in water than other refrigerants. Also that ammonia (chemical formula NH_3) had all the desired properties of the refrigerant mentioned above and thus was chosen as the refrigerant for this project.

The selection of the refrigerant in turn results in the calculation which are to be determined. The total system pressure can now be obtained because it is dependent on the type of the refrigerant used. Before entering the evaporator, pure ammonia refrigerant leaves the condenser in a liquid phase at the eminent temperature of 0^oC. Here the saturation pressure of ammonia is at approximate temperature and thus the overall system pressure at the temperature of 0^oC, the saturation pressure of ammonia is 9.00 bar; but to ensure that the refrigerator works for a range of temperatures it was decided to have the operating pressure at 0 bar instead the 3 bar pressure. T his would allow the ammonia to circulate. After the flash vaporization of liquid ammonia, it was arbitrarily chosen that the difference in temperature between the cabinet compartment and the ammonia fluid that would facilitate heat transfer to the refrigerate in this case ammonia. This means that since the cabinet has a temperature of 3^oC, the vaporized ammonia gas should have a pressure that corresponds to a temperature of -5^oC. At this temperature, the saturation pressure of ammonia is approximately 3.5 bar. In order to drop the ammonia pressure to 3.5 bar, and to facilitate vaporization, the third fluid is used in a mixture with the ammonia or simply pressure valves are used to regulate the pressure in the system. Using Dalton's Law of partial pressure which states that the overall pressure of a mixture is the sum of the partial pressure of each of the gases in the mixture.[9] The desired pressure can be obtained in the system.

Physical Properties of Ammonia which is used as a refrigerant are as following -

- Ammonia is a colorless gas.
- It has a pungent odor with and an alkaline or soapy taste. When inhaled suddenly, it brings tears into the eyes.
- It is lighter than air and is therefore collected by the downward displacement of air.
- It is highly soluble in water: One volume of water dissolves about 1300 volumes of ammonia gas. It is due to its high solubility in water that the gas cannot be collected over water.
- It can be easily liquefied at room temperature by applying a pressure of about 8-10 atmosphere.
- Liquid ammonia boils at 239.6 K (- 33.5°C) under one atmosphere pressure. It has a high latent heat of vaporization (1370 J per gram) and is therefore used in refrigeration plants of ice making machines.
- Liquid ammonia freezes at 195.3 K (-77.8°C) to give a white crystalline solid.

4. ENERGY ANALYSIS AND ENERGY ANALYSIS

4.1ENERGY ANALYSIS

For the thermodynamic analysis of vapour absorption refrigeration system, the energy and mass balance equations of the various components are given below:

1. **Evaporator**
The energy balance in evaporator is given by
Qe = m19 (h19 – h20)
Where,
Qe = Cooling load in evaporator in kW.
m19 = Mass flow rate of chilled water to evaporator in kg/s.
h19 = Specific enthalpy of inlet chilled water in evaporator in kJ/kg.
h20 = Specific enthalpy of outlet chilled water in evaporator in kJ/kg.

2. **Condenser**
The energy balance in condenser is given by
Qc = m17 (h18 – h17)
Where,
Qc = Heat rejected in condenser in kW.
m17 = Mass flow rate of cooling water entering condenser in kg/s.
h18 = Specific enthalpy of cooling water leaving condenser in kJ/kg.
h17 = Specific enthalpy of cooling water entering condenser in kJ/kg.

3. **Generator**
The energy balance for generator is
Qg1 = m15 (h15 – h16)
Where,
Qg1 = Heat load in generator 1 in kW.
m15 = Mass flow rate of hot water entering generator coils in kg/s.
h15 = Specific enthalpy of hot water entering generator in kJ/kg.
h16 = Specific enthalpy of hot water leaving generator in kg/s

4. **Pump**
Work supplied to the pump is given by
Wp= m1 (Pg - Pa) / ρ
Where, Wp = Power consumption of pump in kW.
Pg = Pressure in generator in kPa.
Pa = Pressure in absorber in kPa.
ρ= Density of Water/aqua-ammonia solution

5. **COP**
Coefficient of performance of the system is given as
COP = Qe / (Qg + Wp)
Where
COP = Coefficient of Performance
Qe = Cooling load in evaporator in kW
Qg1 = Heat load in generator 1 in kW.
Qg2 = Heat load in generator 2 in kW.
Wp = Power consumption of pump in Kw

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5.RESULTS AND DISCUSSION

The major outcome of this work is the investigation of the variation of COP of the system corresponding to variation in absorber and generator temperature.The general trend from these figures indicates that the COP decreases as absorber temperature decreases. This can be attributed to the fact that the concentration of most of the solution, falls as temperature increases which satisfies the Raoult's law. The more is the concentration of weak solution the more is the refrigerant evaporated giving more cooling thus more COP. But the nature of curve also tells another story. The COP attains a maximum. Going by these curves one can predict that after certain temperature of absorber the COP won't show considerable increase. The optimum point lies close to 40^{o}C. The Figure 2 showing relation between COP and generator temperature clearly shows that the COP attains a maximum after the optimum point, after which there is no considerable increase in COP. The point lies close to 90^{o}C. Clearly the absorber temperature being close to 40^{o}C and simultaneously generator temperature being close to 90^{o}C may give a maximum value of COP. A further increase in generator temperature and decrease in absorber temperature won't increase the COP considerably.

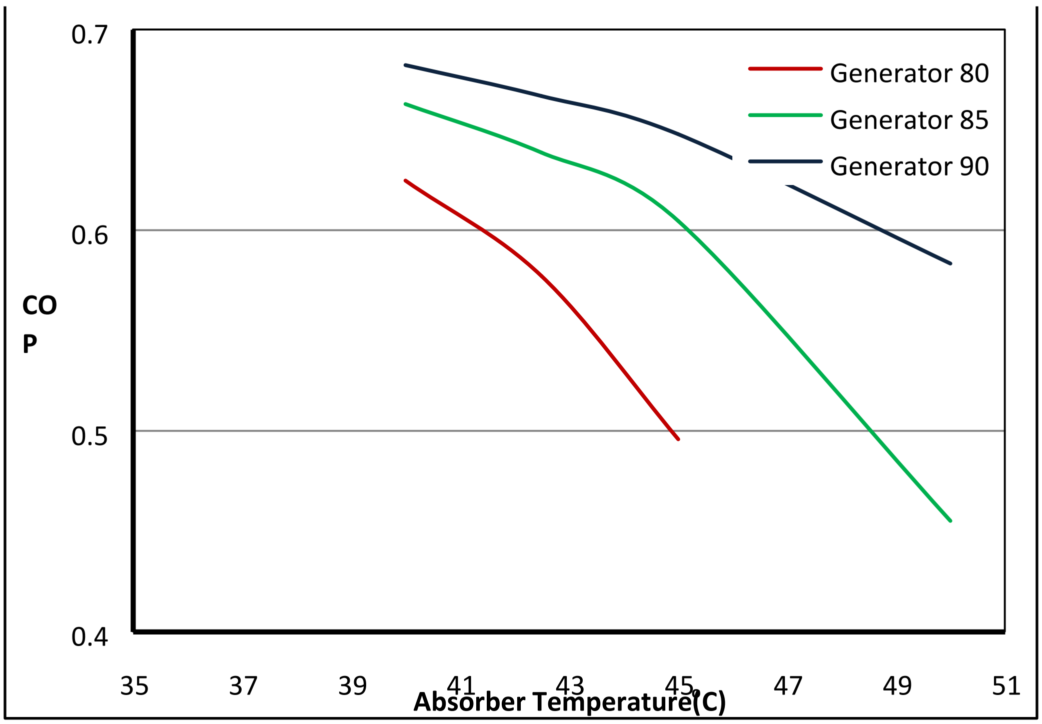

Figure 1 - The variation of COP with respect to absorber temperature

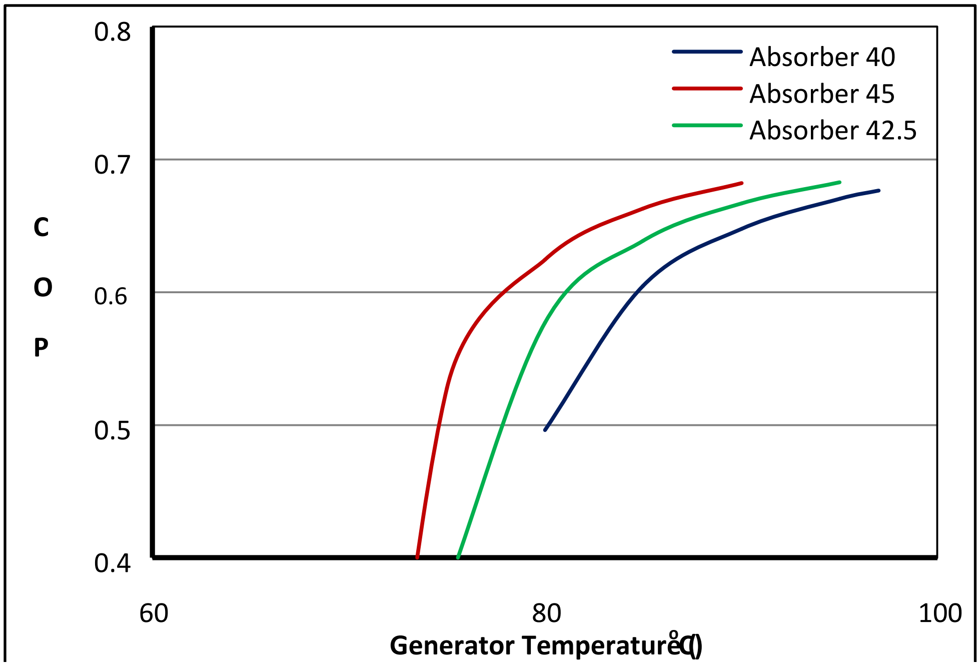

Figure 2 - The variation of COP with respect to generator temperature

6. CONCLUSION

COP of the system is greatly influenced upon the system temperatures. The effect of parameters like Condenser, Generator, Absorber and Evaporator temperature on system COP have been studied. Particularly, the model is based on a number of fundamental assumptions. These are used to enable a closed system of equations and maintaining enough simplicity to be able to extend the program for an analysis of a more complicated system.

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