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Design and Fabrication of Vapour Absorption Refrigeration System [Libr-H_20]

Mohd Aziz Ur Rahaman[1], Md. Abdul Raheem Junaidi[2], Naveed Ahmed[3], Mohd. Rizwan[4]

[1,2,3,4]*(Mechanical Engineering Department, Osmania University, India)*

Abstract: *Most of the energies are utilized by the industries due to depletion of fossil fuels and increasing the fuel price to exploit the maximum presented energy from the waste heat source. The industry which utilizes steam turbine exhaust carries a considerable amount of thermal energy. This energy can be set in to positive use as a heat source for vapour absorption system to serves as cooling system. This paper illustrates the thermal and fiscal advantages of using single effect lithium bromide water absorption by means of waste heat. The objective of this work is to hypothetical design of lithium bromide water absorption Refrigeration system using waste heat from any industry steam turbine exhaust. The various parts of the vapour absorption system are absorber, solution heat exchanger, evaporator, condenser and generator. Energy consumption and energy savings in terms of energy and fuels are calculated. The Overall heat transfer coefficient, effectiveness and COP of the heat exchanger are measured. The energy and global warming crises have drawn rehabilitated benefit to thermally driven cooling systems from the air conditioning and process cooling fraternities. The lithium bromide-water absorption refrigerator is one of the favorites due to the following specific reasons it can be thermally driven by gas, solar energy, and geothermal energy as well as waste heat, which help to substantially reduce Carbon dioxide emission its use of water as a refrigerant it is quiet, durable and cheap to maintain, being nearly void of high speed moving parts its vacuumed operation renders it amenable to scale up applications. LiBr-H_2O absorption refrigerator enjoy cooling capacities ranging from small residential to large scale commercial or even industrial cooling needs. The coefficient of performance (COP) varies to a small extent (0.65-0.75) with the heat source and the cooling water temperatures.*

Keywords: *Fabrication, Vapour absorption, Refrigeration, LiBr-H_2O absorption refrigerator, waste heat.*

I. INTRODUCTION

The working fluid in an absorption refrigeration system is a binary solution con- sisting of refrigerant and absorbent. In Fig. 1(a), two evacuated vessels are connected to each other. The left vessel contains liquid refrigerant while the right vessel con- tains a binary solution of absorbent/refrigerant. The solution in the right vessel will absorb refrigerant vapor from the left vessel causing pressure to reduce. While the refrigerant vapor is being absorbed, the temperature of the remaining refrigerant will reduce as a result of its vaporization. This causes a refrigeration effect to occur inside the left vessel. At the same time, solution inside the right vessel becomes more dilute because of the higher content of refrigerant absorbed. This is called the "absorption process". Normally, the absorption process is an exothermic process, therefore, it must reject heat out to the surrounding in order to maintain its absorption capability.

Whenever the solution cannot continue with the absorption process because of saturation of the refrigerant, the refrigerant must be separated out from the diluted solution. Heat is normally the key for this separation process. It is applied to the right vessel in order to dry the refrigerant from the solution as shown in Fig. 1(b). The refrigerant vapor will be condensed by transferring heat to the surroundings. With these processes, the refrigeration effect can be produced by using heat energy. However, the cooling effect cannot be produced continuously as the process cannot be done simultaneously. Therefore, an absorption refrigeration cycle is a combination.

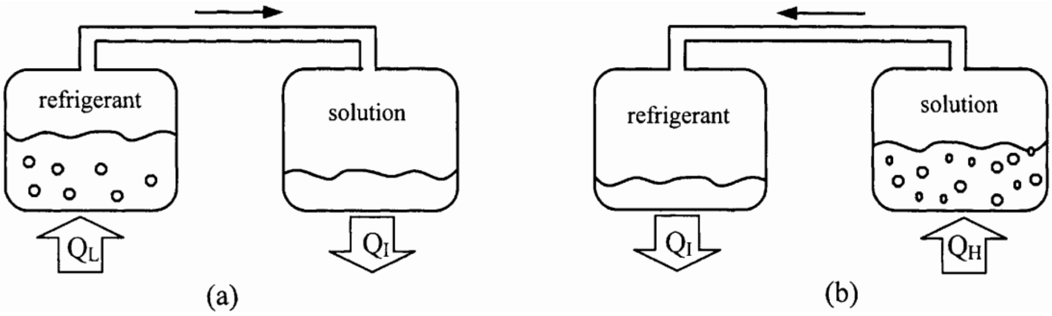

Fig. 1(a): Absorption process occurs in right vessel causing cooling effect in the other;

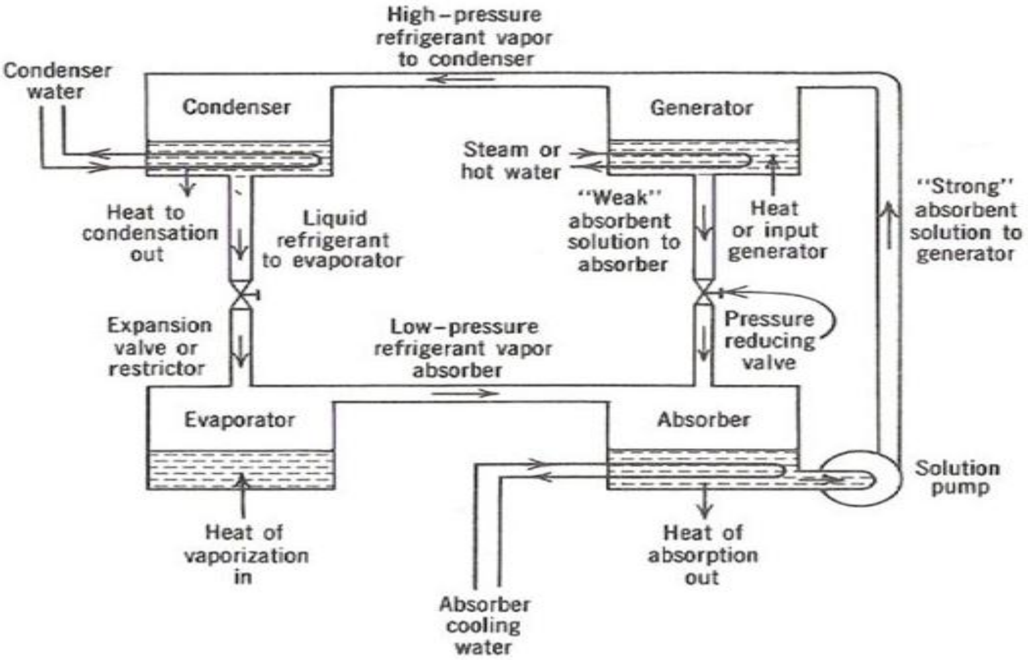

Fig. 1(b): Refrigerant. Fig. 2: Schematic diagram of absorption refrigeration system

Separation process occurs in the right vessel as a result of additional heat from outside heat source. of these two processes as shown in Figure As the separation process occurs at a higher pressure than the absorption process, a circulation pump is required to circu- late the solution. The work input for the pump is negligible relative to the heat input at the generator, therefore, the pump work is often neglected for the purposes of analysis.

II. METHODOLOGY

To design a single stage vapour absorption refrigeration system based on H20-LiBr has a refrigeration capacity of 175 (0.05)watts. The system operates at an evaporator temperature of 5 degree centigrade (Psat=8.72mbar) and a condensing temperature of 30 degree centigrade (Psat=32.3 mbar). The concentration of solution at the exit of absorber and generator are 0.35 and 0.45, respectively. Assume 100 percent effectiveness for the solution pump, exit condition of refrigerant at evaporator and condenser to be saturated and the condition of the solution at the exit of absorber and generator to be at equilibrium. Enthalpy of strong solution at the inlet to the absorber may be obtained from the equilibrium solution data.

Required:

a) The mass flow rates of refrigerant, weak and strong solutions
b) Heat transfer rates at the absorber, evaporator, condenser, generator and solution pump.
c) System COP and second law efficiency, and
d) Solution pump work (density of solution = 1200 kg/m^3).

In order to proceed with the design, firstly we need to calculate the composition with the help of stiochiometric formulae.The composition of water-lithium bromide solutions can be expressed either in mass fraction (ξ) or mole fraction (x). For water-lithium bromide solutions, the mass fraction ξ is defined as the ratio of mass of anhydrous lithium bromide to the total mass of solution, i.e.,

$$\text{Concentration}(\xi) = \frac{\text{mass of anhydrous lithium bromide}}{\text{mass of total solution}}$$

The composition can also be expressed in terms of mole fraction of lithium bromide as:

$$\text{No of moles}(X) = \frac{\text{number of moles of anhydrous lithium bromide}}{\text{number of moles of total solution}}$$

where M_L (= 86.8 kg/kmol) and M_W (= 18.0 kg/kmol) are the molecular weights of anhydrous lithium bromide and water respectively.

Specification of the system:

Size of the evaporator tank	: 15*30 cm.
Capacity of the evaporator(cooling Effect)	: 0.05 Tr (tonnage of refrigeration).
Size and capacity of the condenser	: 5 metres and 189.924 kW.
Size and capacity of the generator	: 3 litres and 221.54 kW.
Size and capacity of the absorber	: 3 litres and 206.75 kW.
Mass flow of refrigerant across the System	: 0.076 g/s.

Now after obtaining all the required parameters calculating its cefficient of performance.
The COP of the system is given by:

$$COP = \frac{Q_e}{Q_g + W_P} \approx \frac{Q_e}{Q_g}$$

In order to find the steady-state performance of the system from the above set of equations, one needs to know the operating temperatures, weak and strong solution concentrations, effectiveness of solution heat exchanger and the refrigeration capacity. It is generally assumed that the solution at the exit of absorber and generator is at equilibrium so that the equilibrium P-T-ξ and h-T-ξ charts can be used for evaluating solution property data. The effectiveness of solution heat exchanger, $^{\varepsilon}HX$ is given by:

$$^{\varepsilon}HX = \frac{(T_7 - T_6)}{(T_8 - T_6)}$$

From the above equation the temperature of the weak solution entering the generator (T_7) can be obtained since T_6 is almost equal to T_5 and T_8 is equal to the generator temperature T_g. The temperature of superheated water vapour at state 1 may be assumed to be equal to the strong solution temperature T_8.

Coefficient of performance:-

System COP (neglecting pump work) = $\mathbf{Q_e/Q_g = 0.789}$

Second law efficiency = COP/COP_{Carnot}

$COP_{Carnot} = [T_e/(T_c-T_e)][(T_g-T_a)/T_g]$ = **1.129.**

∴ Second law efficiency = 0.6983 * 100 = 69.83 %.

III. FABRICATION

The primary components of the refrigeration system are:

1. Generator

According to the requirements specified in the design segment, we purchased a 3 litre, mild steel cylinder (it is usually used to carry refrigerants). this cylinder was purchased from gobind refrigerator &air conditioning equipments,balnagar.

Operations performed:

Drilling : Drilling of four holes of dia 1.5cm at the specifies spots for the inlet and outlets and one hole of dia 2.5 cms for the connection of thermocouple was performed on a vertical drilling machine.

Welding: Arc welding was done to weld four 1.5cms and one 2.5 cms mild steel, internally threaded nuts which get mated with the bronze adapters for inlet and outlet connections and one for the thermocouple.

2. Absorber

Another 3 litre, mild steel cylinder similar to the generator is used for the purpose of absorber. It was purchased along with the generator.

Operations performed:

Drilling: Drilling of three holes of dia 1.5cm at the specifies spots for the inlet and outles was performed on a vertical drilling machine.

Welding: Arc welding was done to weld four 1.5cms mild steel, internally threaded nuts which get mated with the bronze adapters for inlet and outlet connections and

3. Condensor

As specified in the design segment, assuming the natural convection coefficient (h) to be 10W/mK and theoretical mass flow rate(m) to be 8*10^-5 kg/sec, the calculated length for a 1/4th inch mild steel was five meters. The pipe was bent at into several turns with the help of 180degrees bending tool to make it compact and also to enhance the drop in pressure which eliminates the requirements of any throttling device such as a capillary tube.

4. Evapourator

A 6mm thick glass container (24x15x6 cms) was ordered n purchased from a glass works shop at r.no 3 BANJARA HILLS. This container is used as an evaporator cabin which is filled with water and the water is expected to be cooled to 10 degrees centigrade as a result of the refrigeration cycle.

The same 1/4th inch mild steel tube is wounded in the form of a coil and sent through this evaporator cabin.

5. Pump

A special purpose 20w dc pump used in air-conditioning equipment is used in this cycle. The purpose of this device is to pump the solution (strong in water) from the absorber to the generator. This is the only mechanical device being used in the whole system. An adaptor is provided along with this pump to convert the 220v AC power input to 24V DC supply to the pump.

6. Frame

All the components are attached to a frame made of 18mm thick plywood frame shown below.

The generator is clamped by two 6inch mild steel strips with the help of 1 inch screws firmly.

The absorber is also clamped with a single similar 6 inch mild steel strip which is screwed to the frame and a support at the bottom.

The condenser is similarly fixed to frame and the frame is cut behind the condenser to enhance the convection heat transfer from the condenser.

The evaporator is supported at its base with a wooden frame.

The pump is screwed to the frame with two small screws.

The heating coil is fixed to the frame below the generator.

7. Pipes

The pipe used through out the system is ¼ th inch, mild steel pipe. The length of total pipe used for the refrigeration system was 10 mts. The piping was done with assistance from the technician at NATIONAL PIPE WORKS, AFZAL GUNJ.

8. Valves, guages and connecting adapters

One stainless steal steam valve is used at the outlet of generator to control the mass flow rate of steam coming out of the generator. Three ball valves, one each for the three outlets of generators is used. Out of these three, one is used to control the flow of weak solution(weak in water) from the generator to the absorber, second one is to control the flow of solution coming from the pump and the third one is used for initial filling of water-lithium bromide solution into the generator.

Two gauges, on pressure guage(range 760mm of Hg vacuum to 0mm of Hg) and one temperature guage (thermocouple range 0-200 degree centigrade) are mounted on the generator to check the state of steam before allowing it to flow through the system.

All the connections are made with the help of bronze connecting adapters of ¼ th inch dia and provided with brass washers on both sides. All these connections are sealed using Teflon and to ensure it remains leak proof.

All of these valves, gauges and connectors were purchased from UNIQUE CONTROL SYSTEMS, RANIGUNJ.

Fig. 3: Schematic arrangement of refrigeration system

IV. DESIGN IMPROVEMENT

a). Design of energy supplying network to the generator

The prime motive behind this project was to utilize low grade thermal energy which is released by many industries and manufacturing units that go unused. This energy should be tapped and supplied to the generator. A proper system should be designed for this purpose.

Also the solar energy should be properly supplied as an input to the generator to provide refrigeration and air conditioning for domestic purposes.

b). Design Of Solution Heat Exchanger

The efficiency of the system is greatly affected by the enthalpy of solution entering the generator and temperature of the solution entering the absorber. Thus a proper heat exchanger is necessary for enhancement of this refrigeration system.

c). Design Of A Water Cooled Condenser

A properly designed water cooled condenser will reduce the size of the refrigeration system and make it compact, easy to transport and efficient.

d). Design of Generator and Absorber

Since the system is operating under low pressure, the cylinders for generator and absorber can be peoperly selected so that mass of the system is greatly reduced and making the system cost effective.

V. CONCLUSION

A simple vapor absorption system was designed and fabricated to analyze the performance of the system. The system is tested with heat input from an electric heating element of 500 watts capacity for a pressure of 32.5 mbar. The COP is found to be 0.698 and the increase from the designed value is because of higher generator temperature. A more efficient thermal system should have higher COP and lower total entropy generation.

Comparison between actual and calculated values shows that heat loss from the generator greatly affects the system performance. The cooling capacity is limited because of limitations temperature and need of rectification which is absent in the current system. Further analysis to this system should involve the entropy generation to identify and quantify performance degradation of the system. The COP can be increased further by using a heat exchanger between the absorber and generator as well as between the condenser and pressure reducing valve. The various components of 0.05TR H20-LiBr vapour absorption system were fabricated using mild steel due to the corrosive nature of water on copper, brass etc.

The thermodynamic analysis of absorption system using LiBr-H2O as working fluid has been presented. The irreversibility rate in generator is found to be the highest while it is found to be the lowest in the condenser and absorber. It is found that the irreversibility rate in the generator is more because of increase rate of heat transfer in the generator, also the exergy losses are more in generator because of heat of mixing in the solution, which is not present in pure refrigerant/fluids.

Results show that as expected the COP of the system increases minutely as the generator temperature is increased but the exergy efficiency of the system drops with the increase in generator temperature. It is also found that the COP of the system increases with increase in evaporator temperature this largely depends on the enthalpy difference between the chilled water at inlet and outlet of evaporator. However, it is reverse in case of exergy efficiency. The results with respect to exergy losses in each component and exergy efficiency are very important for the optimization of absorption system. These results are helpful for designers to bring changes in the actual system for optimum performance and less wastage of energy.

REFERENCES

[1]. Ziegler, F., Recent developments and future prospects of sorption heat pump system. International Journal of Thermal Science, Vol. 38, (1999),pp.191-208.

[2]. J.D Killon,; S.Garimella.(2001): A critical review of models coupled heat and mass transfer in falling film absorption, 24, pp.755-797.

[3]. G.A. Florides,; S.A. Kalogiroua,; S.A. Tassoub,; L.C. Wrobelb. (2003):Design and construction of a LiBr–water absorption machine, 44(15),pp.2483-2508.

[4]. D.A. Kouremenos, K.A. Antonopoulos and E. Rogdakis, 'Hour Simulation of Solar H2O-LiBr Absorption Heat Transformers in Athens', Solar and Wind Technology, Vol. 7, N°2/3, pp. 111-118, 19, 1990.

[5]. Eisa, M. A. R., Devotta, S., and Holland, F. A. Thermodynamic design data for absorption heat pump systems operating on water lithium bromide: Part I: cooling. Applied Energy, 1986, 24, 287–301.

[6]. Mr. S. S. Mali , Prof.M.M.Wagh, Prof. N. N. Shinde, " Review Of Design Of Single Ef ect Solar Powered Vapour Absorption Air Conditioning System " International Journal Of Advance Research In Science And Engine ring, Vol. No.2, Is ue No.7, July, 2013, Pp 4 -52.

[7]. G. Ali Manso ri And Vinod Patel, "Thermodynamic Basis For The Choice Of Working Fluids For Solar Absorption Co ling Systems " Solar Energy, Volume 2 , Is ue 6, 1979, Pp. 483-491.

[8]. Mical ef,D. And Mical ef, C, "Mathematical Model Of Vapour Absorption Refrigeration Unit" Int.J Simul Model 9, 2 , 2010, Pp 86-97.

[9]. Anil Sharma, Bimal Kumar Mishra, Abhinav Dinesh, Ashok Misra, "Configuration Of A 2 Kw Capacity Absorption Refrigeration System Driven By Low Grade Energy Source" International Journal Of Metal urgical & Materials Science And Engine ring (Ijmmse) Vol. 2 Is ue 4 Dec - 2012 1-10, Pp 1-9.

[10]. Desai AD, Bannur PV. Design, fabrication and testing of heat recovery system from diesel engine exhaust. J Inst Engrs 2001; 82:111–8.

[11]. ASHARE, 'Handbook of Fundamentals', 1985.