STUDY ON THE OPTIMIZATION OF SOLAR ASSISTED VAPOUR ABSORPTION REFRIGERATION SYSTEM

Dr.R.Rameshkumar
Department of Automobile Engineering, K.S.R College of Engineering, Tiruchengode, TN, India

Abstract: Solar assisted vapour absorption system has been proposed for simulation and analysis. The dynamic simulation and the computer modelling procedure of one of the system in vapour absorption refrigeration lithium bromide/water absorption refrigeration system is described as the analytical expression that fit for LiBr concentration. Refrigerant temperature in the range of interest from 0.45 to 0.65 kg LiBr/kg is chosen for simulation due to restriction of crystallization in solution liquid to liquid heat exchanger. This will save considerable computing time and effort required for evaluation of system performance. The mathematical modelling for the vapour absorption system with lithium bromide /water pair devised and well established software MATLAB 7.8 is being used as a simulation tool. The result from simulation describes the variation in coefficient of performance with respect to the generator temperature. For a constant efficiency at the heat exchanger, there is an optimum temperature to be used at the generator, while a higher temperature will decrease the system COP.

1. INTRODUCTION

In recent years, the lithium bromide/water absorption system has become prominent in refrigeration air conditioning. It possesses several advantages over the other types of absorption system, such as:

- It has the highest coefficient of performance (COP) compared to other single-stage absorption units at the same cycle temperatures
- It is compared to simplifier components since it can work efficiently without the need of rectification columns. A basic generator is sufficient due to the nonvolatility of the absorbent (LiBr), allowing only water vapour to be driven off the generator.
- Less pump work is needed compared to other units due to operation at vacuum pressures.
- On the other hand, the lithium bromide/water absorption system has some drawbacks such as:
- It is limited to relatively high evaporating temperature since the refrigerant is water .This means that evaporation temperature above 0^0C must generally be satisfied to prevent the flow of freezing.
- Crystallization of LiBr salt at moderate concentrations (>0.65 kg LiBr/kg solution) will tip of the cycle range of operation.
- The systems have to be designed in hermetically sealed units since they operate at vacuum pressures. Improper operation would result if leakage of air into the system occurred.

Irrespective of its drawbacks, the LiBr/water unit is still considered as the most economical for this kind of refrigeration technique. This article describes and analyzes the computer modeling of such units. The modeling procedure is generalized to enable those concerned with use or evaluation of cycles employing this material to save considerable time and effort required for calculations. India, being a warm tropical country, most of the refrigeration and HVAC applications involves cooling of air, water, other fluids or products. Heating is used only for a very small period in winter in the northern parts of the country and in places at high altitudes.

Refrigeration and Air-conditioning accounts for a significant portion of the energy consumption in many manufacturing industries (like chemicals, pharmaceuticals, dairy, food etc.), agricultural & horticultural sectors (mainly cold stores) and commercial buildings (like hotels, hospitals, offices, airport, theatres, auditoria, multiplexes, data processing centers, telecom switching exchanges, etc.)

Refrigeration and air conditioning and air conditioning system cover a wide variety of cooling applications, using both standard and custom- made equipment’s. Some commonly used applications are process cooling by chilled water or brine ,ice plants, cold stores, freeze drying, air conditioning systems etc.

Comfort air-conditioning generally implies cooling of room air to about 24^0C and relative humidity in the range of 50% to 60%. Industrial process air conditioning and precision air conditioning may require temperatures ranging from 18^{0}C to 24^{0}C with relative humidity values ranging from 10% to 60%.

This manual highlights some issues related to energy efficiency and energy conservation in refrigeration and air conditioning, along with some emerging innovative techniques to eliminate or minimize conventional refrigeration and air conditioning.

Refrigeration is the process of removing heat from an enclosed space, or from a substance, and moving it to a place where it is an unobjectionable. Primary purpose of refrigeration is lowering the temperature after enclosed space or substance and then maintaining that lower temperature. The term cooling refers generally to any natural or artificial process by which heat is dissipated. The process of artificially producing extreme cold temperatures is referred to as cryogenics.

2. NEED FOR EFFICIENT VAPOUR ABSORPSTION SYSTEM

Use of nature–assisted cooling techniques and minimal use of energy guzzling refrigeration equipment's is the key energy conservation. There is an urgent need to promote and commercialize all proved techniques that use natural processes to eliminate or minimize the use of conventional refrigeration and air conditioning. Basic design of industrial processes and also architectural space should strive to minimize the demand for conventional refrigeration and air conditioning. A strategy focusing on both refrigeration load reduction and energy efficiency improvement for conventional refrigeration is necessary to limit the unmitigated growth of conventional refrigeration.

Vapour absorption is being used where waste heat is available such as solar energy or geothermal energy or of any source. Here in this project solar energy is used as generator input source for vapour absorption system, vapour absorption system particularly (LiBr-H20) pair have been usefully provide for air conditioning use of long run . Running cost of vapour absorption system is cheap and economical.

3. REFRIGERATION & AIRCONDITIONING SYSTEMS

3.1REFRIGERATIONSYSTEM EFFICIENCY

The cooling effect of refrigeration systems is generally quantified in tons of refrigeration. The unit is derived from the cooling rate available per hour from 1 ton of ice, with melts over a period of 24 hours. British measuring units are still popularly used by refrigeration and air conditioning engineers; hence it is necessary to know the energy equivalents.

1 Ton of Refrigeration (TR)

TR = 3023kcal/h = 3.51kw$_{thermal}$ = 12000Btu/hr

The commonly used figures of merit for comparison of refrigeration system are coefficient of performance (COP), Energy efficiency ratio (EER) .These are defined as follows:

If both refrigeration effect and work done by the compressor are taken in the same units, the ratio is COP=Refrigeration effect/work done

If the refrigeration effect is quantified in Btu/hr and work done is in watts, the ratio is EER=Refrigeration Effect /Work done

Higher COP or EER indicates better efficiency.

3.2 COP AFFECTING PARAMETERS

COP is affected by the evaporator temperature and the condenser temperature and the condenser temperature. Higher the evaporator temperature and lower the condenser temperature, better is the COP.

1^{0}C higher temperature of refrigerant in the evaporator or 1^{0}C lower in the condenser improves the COP 2% to 4%.

The evaporator temperature can be increased by:

- Changing process temperature settings.
- Installing an evaporator of higher rating i.e. more heat transfer area.
- Keeping the heat transfer surface clean i.e. avoiding fouling, defrosting as per requirement etc.

The condenser temperature can be decrease by:

- Installing a condenser of higher rating i.e. more heat transfer area.
- The condenser temperature is allowed to float down with ambient temperature.
- Water cooled or evaporative cooled condensers are used instead of air cooled condensers.

COP is also affected by:

- The efficiency of the type of compressor used.
- The amount of refrigerant charged in the system. Systems with refrigerant leaks consume more power.

- The physical properties of refrigerant used.

1. PROPOSED SYSTEM

4.1 Practical Absorption System

The simple absorption system discussed above can function and provide refrigeration but its operating efficiency will be very low. In order to make it more practical it is fitted with a heat exchanger, an analyzer and a rectifier. These accessories which help to improve the performance and working of the plant are described below.

- **Heat Exchanger:** The location of the heat exchanger between the generator and absorbers is ideal. The strong solution pumped from the absorber to the generator must be heated and the weak solution form the generator to the absorber must e cold. The heat exchanger between the two streams therefore reduces both the cost of heating the generator and the cost of cooling absorber.
- **Analyzer:** The analyzer is in direct contact with heat exchanger consisting of series of tray mounted above the generator. Its function is to remove partly some of the unwanted water particle associated with ammonia vapour going to the condenser.
- The water vapour if allowed to enter to condenser may enter the expansion valve where they will freeze and choke the pipe line.
- **Rectifier:** The final reduction of the percentage of water vapour occurs in the rectifier, water cooled heat exchanger which condenses water vapour and returns it to the generator. The net refrigerating effect of such a machine is the heat extracted in the evapourator. The total energy supplied for operating the machine is the sum of the work done by the liquid pump and the heat supplied in the generator.
- Absorptive refrigeration uses a source of heat to provide the energy needed to drive the cooling process.
- **Evaporation**: A liquid refrigerant evaporates in a low partial pressure environment, thus extracting heat from its surroundings – the refrigerator.
- **Absorption**: The gaseous refrigerant is absorbed – dissolved into another liquid - reducing its partial pressure in the evaporator and allowing more liquid to evaporate.
- **Regeneration**: The refrigerant-laden liquid is heated, causing the refrigerant to evaporate out. It is then condensed through a heat exchanger to replenish the supply of liquid refrigerant in the evapourator.

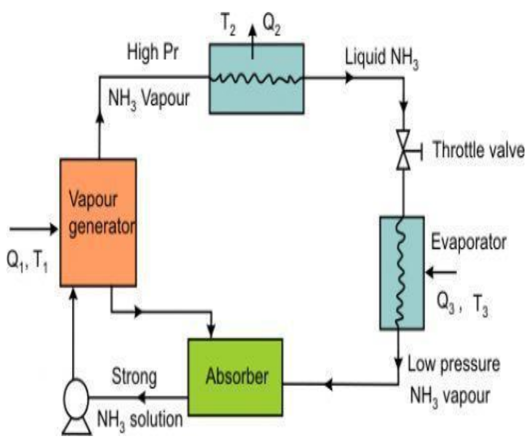
4.2 Principle of Working

The demand for energy for refrigeration and air-conditioning to control temperature and humidity and for fresh air has increased continuously throughout the last decades, especially in developing countries like India. This increase is caused amongst other reasons, by increased thermal loads, occupant comfort demands, and architectural trends. This has been responsible for the escalation of electricity demand and especially for the high peak loads due to the use of electrically driven vapor compression machines. Moreover, the consumption of primary energy and the emission of greenhouse gases associated with electricity generation from fossil fuels lead to considerable environmental consequences and monitory costs. Conventional energy will not be enough to meet the continuously increasing need for energy in the future. In this case, renewable energy sources will become important. An alternative solution for this problem is solar energy, which is available plentiful in most areas, which also represents a good source of thermal energy. Of the various solar air-conditioning alternatives, the absorption system appears to be one of the most promising methods.

The absorption cycle is similar in certain respects to the electrically driven vapor compression machines. Of the various solar absorption air-conditioning systems, LiBr- H_2O and H_2O–NH_3 are the major working pairs available. It is reported that LiBr-H_2O pair has higher COP than any other pair of the working fluids. The LiBr-H_2O system operates at a generator temperature in the range of 70–95°C with water used as a coolant in the absorber and condenser. The COP of the system is between 0.6 and 0.8. The major components in the LiBr-H_2O solar absorption cooling systems are chillers and solar collectors. Many researchers have developed solar-assisted absorption refrigeration systems. Most of them have been produced as experimental units. Computer codes have also been written to simulate the systems. Some of these designs are presented here.

The solar energy is gained through the collector and is accumulated in the storage tank. Then, the hot water in the storage tank is supplied to the generator to boil off water vapor from a solution of lithium bromide + water. The water vapor is cooled down in the condenser and then passed on to the evaporator where it is again evaporated at low pressure, thereby providing cooling to the required space. Meanwhile, the strong solution leaving the generator to the absorber passes through a heat exchanger to preheat the weak solution entering the generator. In the absorber, the strong solution absorbs the water vapor leaving the evaporator. Cooling water from the cooling tower removes the heat by mixing and condensation. Since the temperature of the absorber has a higher influence on the efficiency of the system than the condensing temperature, the heat rejection (cooling water) fluid is allowed to flow through the absorber first and then to the condenser. An auxiliary energy source is provided so that hot water is supplied to generator when solar energy is not sufficient to heat the water to the required temperature level needed by the generator.

The mathematical modelling of complete solar-assisted absorption cooling system requires the modelling of absorption system as well as that of solar collector system separately



2. PROPOSED MATHEMATICALMODELLING

Let w_1 be the mass flow rate of the pump = 0.4 kg/s. The pump pumps both the Li-Br and H_2o solution. Let w_2 be the mass flow rate ofLi-Br with concentration x_2. Let w_3 be the mass flow rate of H_2O with concentrationx_3.

Mass flow rate of Li-Br solution = w_2.

Mass flow rate of H_2O (vapour) = w_3

$w_1= w_2+w_3$.

By mass balance; for Li-Br solution;

$w_2x_2=w_1x_1$

X_1=0.54 kg/s,X_2 = kg/s.

w_2 (0.70) =0.4 (0.54)

w_1 =0.4 kg/s.

w_2=0.308 kg/s.

w_3= 0.092 kg/s.

h_1 = -180 kJ/kg,h_2 = -50 kJ/kg.

Water leaving generator to condenser is in the form of saturated vapour as temperature in generator is 105^{o}C.

h_3 = -2676.0 kJ/kg. (For T=105^{o}C, h_g)

Water leaving condenser is in saturated liquid form, h_4= 146.7 kJ/kg. (For T=35^{o}C, h_f) Water leaving evaporator is in saturated vapour form

h_5=2510.6 kJ/kg (for T=5^{o}C, h_g)

Rate of heat: Heat transfer by generator (Qg)

Qg = $[(w_3*h_3) + (w_2*h_2)-(w_1*h_1)]$

(Q_g)= 0.092(2676)+0.308(-50)-0.4(-180)

(Q_g)= 302.792 KW.

Heat transfer by condenser (Qc)

Qc= $[(w_3*h_3)-(w_4*h_4)]$

Qc= [(0.092*2676)-(0.092*146.7)]

Qc =232.7468 KW

Heat transfer by absorber (Qa)

Qa =$[(w_2*h_2)+(w_5*h_5)-(w_1*h_1)]$

Qa =[0.308*(-50)+(0.092)*(2510.6)-(0.4*(-180)] Qa=287.575 KW

Heat transfer by evaporator (Qe)

Qe = $[(w_5*h_5)-(w_4*h_4)]$

Qe = [(0.092*2510.6)-(0.092*146.7)]

Qe = 217.478 kW.

Coefficient of Performance (COP)

COP=Qe/Qg

COP=217.478/302.792

COP=0.718

6. PROPOSED ALGORITHM

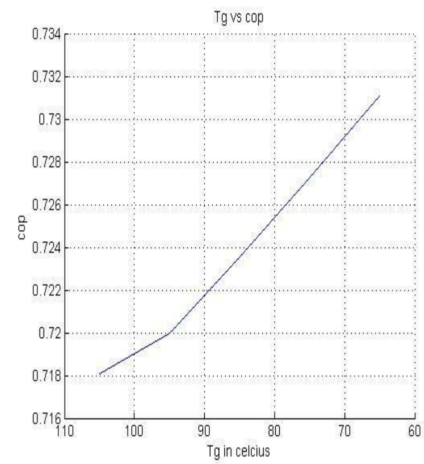
6.1 CODING FORCALCULATING COP

For calculating the co-efficient of the performance of the vapour absorption system (LiBr-H_2o) pair mathematical model is fed in the well developed software, MATLAB 7.8 and the required COP for varying condition of the four heat exchanger i.e. absorber, generator, evaporator and condenser heat input and temperature in addition to liquid-liquid heat exchanger in between absorber and generator line, the temperature input is feed by using MATLAB and the co-efficient of performance of model assumed is developed. M-file coding for calculating the COP and plotting the graph between generator temperature and COP is shown below, which is successfully executed and plots are obtained as shown below.

6.2 CODE FOR COP GENERATION

```
Tg=input('enter  the value of Tg');
T1=(Tg:-10:65);
T2=30;
T3=35;
m1= 0.4;
m2= 0.308;
m3= 0.092;
m4= 0.092;
m5= 0.092;
h1=-180;
h2=-50;
h3=[2676.6 2668.1 2651.9 2635.3 2618.2];
T4=5;
h4=146.743;
h5=2510.6;
Qg=(m3*h3)+(m2*h2)-(m1*h1);
display(Qg);
Qg1=Qg(1,1);
Qg2=Qg(1,2);
Qg3=Qg(1,3);
Qg4=Qg(1,4);
Qg5=Qg(1,5);
Qc=(m3*h3)-(m4*h4);
Qa=(m2*h2)+(m5*h5)-(m1*h1);
Qe=(m5*h5)-(m4*h4);
COP1=Qe/Qg1;
COP2=Qe/Qg2;
COP3=Qe/Qg3;
COP4=Qe/Qg4;
COP5=Qe/Qg5;
COP=[COP1 COP2 COP3 COP4 COP5];
display(Qc);
display(Qa);
display(Qe);
display(COP1);
display(COP2);
display(COP3);
display(COP4);
display(COP5);
display(COP);
display(T1);
figure1  = figure('Paper  Size',[20.98 29.68]);
axes1 =
axes('Parent',figure1,'YGrid','on','XGrid','on','XDir','reverse',...
'Font Name','Palatino');
xlim(axes1,[Tg-45  Tg+5]);
ylim(axes1,[0.716  0.734]);
hold(axes1,'all');
title('T1  vs COP');
X=[T1(1,1),T1(1,2),T1(1,3),T1(1,4),T1(1,5)];
Y=COP;
plot(X,Y);
xlabel('Tg in celcius');
ylabel('COP')
```

6.3 RESULTS AND DISCUSSION



7. CONCLUSION

The simulation study of lithium bromide absorption refrigeration water using solar as a source of energy had been studied. The co-efficient of performance of lithium bromide water as working fluid at various temperatures also had been studied. When the generator temperature is low, the best COP is obtained by using MATLAB. In future the co-efficient of performance of lithium bromide water for generator temperature range of 60-90^{0}c and varying Li-Br concentration in refrigerant (water) of range 0.5 to 0.7% of working range is choose and varying condenser, generator, absorber temperature in the feasible range is chosen and maximum COP achievable will be simulated and further optimization of the system will be analyzed in future.

REFRENCES

[1] .P. J. Wilbur, and C. E. Mitchell, Solar absorption air-conditioning alternatives, *Solar Energy*, **17**, 193–199(1975).

[2] V. Mittal, K. S. Kasana, and N. S. Thakur, Harnessing solar energy for absorption air-conditioning system**,** *Proc. Int. Congress on Renewable Energy Resources*, Allied Publishers, Pune, pp. 115–127 (2005).

[3] M. A. Hammad, and M. S Audi, Performance of a solar LiBr–water absorption refrigeration system, *Renew. Energy* **2**, 275–282 (1992).

[4] I. Haim, G. Grossman, and A. Shavit, Simulation and analysis of open cycle absorption systems for solar cooling, *Solar Energy*, **49**, 515–534 (1992).

[5] M. N. A. Hawlader, K. S. Novak, and B. D. Wood, Unglazed collector/regenerator performance for a solar assisted open cycle absorption cooling system, *Solar Energy*, **50**, 59– (1993).

[6] T. A. Ameel, K. G. Gee, and B. D. Wood, performance predictions of alternative, low cost absorbents for open cycle absorption solar cooling, *Solar Energy*, **54**, 65–73 (1995).

[7] Z. F. Li, and K. Sumathy, Simulation of a solar absorption airconditioning system, *Energy Conversion Mgmt*, **42**, 313–327 (2001).

[8] G. A. Florides , S. A. Kalogirou, S. A. Tassou, and L. C. Wrobel, Modelling and simulation of an absorption solar cooling system for Cyprus, *Solar Energy*, **72**, 43–51 (2002).

[9] N. K. Ghaddar, M. Shihab, and F. Bdeir, Modelling and simulation of solar absorption system performance in Beirut, *Renewable Energy*, **10**, 539–558 (1997).

[10] F. Assilzadeha, S. A. Kalogiroub, Y. Alia, and K. Sopiana, Simulation and optimization of a LiBr solar absorption cooling system with evacuated tube collectors, *Renewable Energy*, **30**, 1143–1159 (2005).

[11] P. T. Tsilingiris, Theortical modelling of a solar airconditioning system for domestic applications, *Energy Conversion Mgmt*, **34**, 523–531 (1993).

[12] Z. F. Li, and K. Sumathy, A computational study on the performance of a solar airconditioning system with a partitioned storage tank, *Energy*, **28**, 1683–1686 (2003).

[13] Y. L. Liu, and R. Z. Wang, Performance prediction of a solar/gas driving double effect LiBr-H2O absorption system, *Renewable Energy*, **29**, 1677–1695 (2004).

[14] Krieth E. Herold, Reinhard Radermacher and Sanford A. Klein, *Absorption chiller and pump*, CRC Press (1994).

[15] W. F. Stoeker, *Refrigeration and air conditioning*, International edn, McGraw-Hill (1987).