Statistical Analysis of Lithium Bromide-Water (LiBr- H_2O) Vapour AbsorptionRefrigeration System Using First Law of Thermodynamics

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Abstract

The first Law of Thermodynamics is connected to a single stage Lithium Bromide-Water Vapor Absorption Refrigeration framework and the execution examination of every part is determined through numerical model on MATLAB 7.0.1. First law of thermodynamics is additionally used to ascertain to assessment of mass flow rate and heat rate in every part of the framework. Estimated the thermodynamic properties and Energy transfer rate in every part of Vapor absorption refrigeration system, with the assistance of empirical relation. The goal of this paper is to show observational relations for finding the attributes and execution of a solitary stage Lithium bromide - water (LiBr-H_2O) vapor absorption refrigeration system. The fundamental heat and mass exchange conditions and suitable conditions depicting the thermodynamic properties of the working fluid at all thermodynamic states are assessed Mass stream rate and heat flow rate in every segment of the framework are classified. The coefficient of performance of the system is deciding for different temperatures ranges. It very well may be seen that when the temperature of inlet water expands, the required circulation ratio diminishes, and the system COP esteem increments. In the event that the temperature is underneath 58°C, the system COP will be near zero, the system does not work by any means and from 58°C to 83°C, the COP will increment in a slower pace, after 83°C of generator temperature the COP increment quickly.

Keywords — Absorption Refrigerator, Energy, Heat Rate, COP

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Introduction: Day by day the demand in power consumption is increases; we all are responsible to find the alternative source of power. The one of the major power consumption is refrigeration and air conditioning, one of the best choices is vapour absorption refrigeration system. Absorption systems can be driven by low grade thermal energy providing a means for converting waste heat into useful purposes as well as help in reducing peak summer electric demands.

Aside from this, ongoing examinations have demonstrated that the regular working liquids of vapor compression system are causing ozone layer consumption and green house impacts. In any case, ARS's innocuous cheap waste warmth, sun based biomass or geothermal energy sources for which the expense of supply is insignificant as a rule. Besides, the working liquids of this system are environment friendly [1-3]. The general execution of the retention cycle as far as refrigerating impact per unit of energy input commonly poor, in any case, squander warmth, for example, that rejected from a power can be utilized to accomplish better by and large energy use. Alkali/water (NH_3/H_2O) frameworks are generally utilized where bring down temperature is required. In any case, water/lithium bromide ($H_2O/LiBr$) system are likewise broadly utilized where moderate temperatures are required (for example cooling), and the last system is more proficient than the previous [4-6].

The target of this paper is to think about the First Law Thermodynamic Analysis of single stage Vapor Absorption Refrigeration System with the assistance of numerical model. This model is produced on MATLAB Software (Simulink Tool). Many authors choose various computer programming, but here selected MATLAB where we can easily and directly take part for simulation through the block diagram and formulation.

This paper is differs from the above literature studies in that availability analysis is carried out for each component of the system. Here utilizing water/lithium bromide as working liquid and water is utilized as a refrigerant. Heat exchange rate of every segment in the cycle, some execution parameters and Coefficient of Performance are determined from First Law Analysis. The consequence of this examination can be utilized either to measure another refrigeration cycle or rating a current framework.

Benefits of LiBr-H_2O over NH_3-H_2O

The NH_3-H_2O system is more complicated than the LiBr-H_2O vapour absorption refrigeration system, since it needs a rectifying column that assures that no water vapour enters the evaporator where it could freeze. The NH_3-H_2Osystem requires generator temperatures in the range of 125°C to170°C with air-cooled absorber and condenser and 80°C to 120°C when water-cooling is used. These temperatures cannot be obtained with flat-plate collectors. The coefficient of performance (COP), which is defined as the ratio of the cooling effect to the heat input, is between 0.6 to 0.7.In the LiBr-H_2O system water is used as a coolant in the absorber and condenser and has a higher COP than the NH_3-H_2Osystems. The COP of this system is between 0.6 and 0.8.

Nomenclature –

S.No.	Symbol	Description	Units	Subscripts	Description
1	m	Mass flow rate	kg/s	o	Atmospheric

2	T	Temperature	°C	A	Absorber
3	P	Pressure	kPa	G	Generator
4	h	Enthalpy	kJ/kg	C	Condenser
5	X	Percentage of Solution	Dimensionless	E	Evaporator
6	Q	Heat Transfer	kJ	W	Weak Solution
7	COP	Coefficient of Performance	Dimensionless	S	Strong Solution
8	C_{pw}	Specific heat of water	kJ/kg K	In/out	Inlet/outlet to or from the System

Details and Methodology-

Figure 1 demonstrates the schematic square graph of finish Vapor Absorption Refrigeration System. Figure 1 shows the schematic block diagram of complete Vapour Absorption Refrigeration System. Low pressure refrigerant vapour from the evaporator is absorbed by the liquid strong solution from the absorber.

In figure 1 the pump receives low pressure liquid weak solution from the absorber, increase the pressure of the weak solution and the send itto the generator. By the weak solutions, it is meant that the ability of the solution to absorb the refrigerant vapour is weak. In the generator, heat from a high temperature source drives off the refrigerant vapour in the weak solution. In the solution heat exchanger heats the cool solution from the absorber on its way to the generator and cools the solution returning from the generator the absorber. Thus, the heat load decreases in the generator and the COP increases. The high pressure refrigerant vapour condenses into liquid in the condenser and enters the evaporator through a throttling valve, maintaining the pressure difference between condenser and the evaporator.

The cycle performance is measured by the coefficient of performance (COP) which is defined as the refrigeration rate over the rate of heat addition at the generator plus the work input to the pump.

$$\mathrm{COP} = \frac{Q_E}{Q_G + W_P}$$

It should be noted that the refrigerant in the LiBr-H_2O system is water and the LiBr acts as the absorbent, which absorbs the water, vapour, thus making pumping from the absorber to the generator easier and economical.

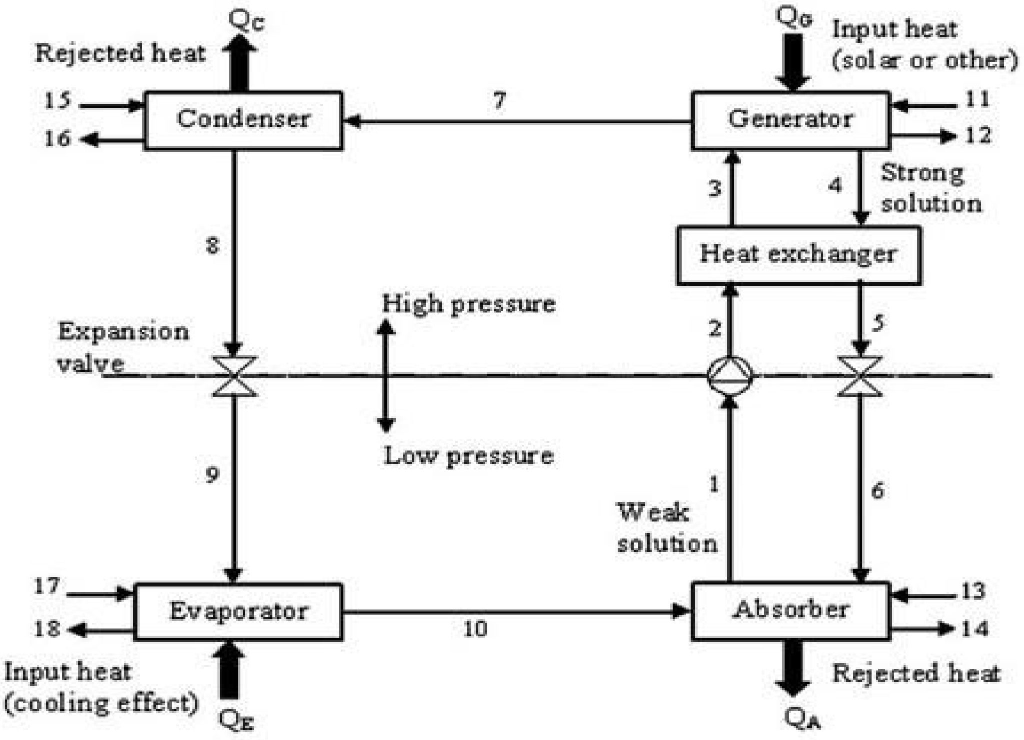


Figure 1 Schematic Diagram of Simple Vapour Absorption Refrigeration System

THERMODYNAMIC ANALYSIS

Assumptions: -

Following are the assumption made for carrying out the Energy analysis of (LiBr-H2O) Vapour Absorption Refrigeration System.

- The Refrigerant is pure water.
- There are no pressure changes except through the flow pump.
- In above figure 1at point1, 4 and 8, there is only saturated liquid.
- In above figure 1 at point10, there is only saturated vapour.
- In pump the Pumping process is isentropic.

- I assuming that the weak solution contain more percentage of refrigerant and less percentage of absorbent and strong solution contain more percentage of absorbent and less percentage of refrigerant.
- I assume that the Percentage of weak solution at state 1, 2 and 3 and Percentage of strong solution at state 4, 5 and 6 will remain same.
- In above figure 1, The Temperatures at state 11,12,13,14,15,16,17 and 18 are the external circuit for water which is use to input heat for the components of system.
- in figure 1,We have divided our system into two pressure limits, one is high pressure limit and other is low pressure limit, in the following system we are taking high pressure from the table corresponds to generator temperature (T_7) and low pressure corresponds to evaporator temperature (T_{10}).

P1=P6=P9=P10= Low pressure

P2=P3=P4=P5=P7=P8= High pressure

Input Parameters:-

Following are the input parameters for carrying out the Energy analysis of (LiBr- H2O).

Table1. Input Design parameters for Vapour Absorption Refrigeration system [7]

S. No	**Input Parameters**	**Values**
1	Mass flow rate of Refrigerant (mr=m7=m8=m9=m10)	0.005 kg/s
2	Effectiveness of heat exchanger(ε)	0.7
3	Generator Temperature $=T_G=T_4=T_7$	80°C
4	Condenser Temperature$=T_C=T_8$	30°C
5	Absorber Temperature$=T_A=T_1=T_2$	30°C
6	Evaporator Temperature$=T_E=T_{10}=T_9$	5°C
7	Percentage of weak solution $Xw=X_1=X_2=X_3$	55.3
8	Percentage of strong solution $X_s=X_4=X_5=X_6$	56
9	The Temperature of water when it comes out from the Generator$=T_{11}$	90°C
10	The Temperature of water when it enters in to the Generator$= T_{12}$	100°C
11	The Temperature of water when it enters in to the Absorber$= T_{13}$	20°C
12	The Temperature of water when it comes out from the Absorber$= T_{14}$	24°C
13	The Temperature of water when it enters in to the Condenser$= T_{15}$	20°C
14	The Temperature of water when it comes out from the condenser$= T_{16}$	24°C
15	The Temperature of water when it enters in to the Evaporator $= T_{17}$	12°C
16	The Temperature of water when it comes out from the Evaporator$= T_{18}$	20°C

Energy analysis of Generator:-

On balancing the energy across the generator, one can say;

$$Q_G+Q_3=Q_4+Q_7 \tag{1.1}$$

Now:

$$Q_3= m_3.h_3 \tag{1.2}$$

$$Q_4=m_4.h_4 \tag{1.3}$$

$$Q_7= m_7.h_7 \tag{1.4}$$

Balancing the concentration across the generator, one can say;

$$m_3.X_3=m_4.X_4 \tag{1.5}$$

Since;

$m_1=m_3$

$X_3=X_w$

$X_4=X_s$

Putting the value of m_3, X_3 and X_4 in equation 1.5, we will get

$$m_1=\frac{m_4 \cdot X_s}{X_w} \tag{1.6}$$

Where,

$m_1= m_2=m_3=$ mass flow rate of weak solution (LiBr-H_2O)

From the following relation, we know;

$$m_6 = \frac{-m_{10}}{1 - \frac{X_6}{X_1}} \tag{1.7}$$

Where,

m_{10} = mass flow rate of refrigerant= 0.005 kg/s

$m_6 = m_4 = m_5$=mass flow rate of strong solution (LiBr-H_2O)

From equation 1.7, we will put value of m_6 ($m_6 = m_4$) in equation 1.6

Then we will get value of m_1, and we know that $m_1 = m_2 = m_3$

Now we have to find Enthalpy at state 3, 4 and 7

Hence we will get h_3, by using equation 1.8

$$h_3 = \frac{m_2 h_2 + m_4 h_4 - m_5 h_5}{m_3} \tag{1.8}$$

Since,

$h_2 = h_1$

We will find h_2, corresponds to absorber temperature and X_w and h_5 corresponds to temperature at state 5 (T_5) now T_5 will be find out from empirical relation as shown by equation 1.5

Now, h_4 we will find with the help of table at $T_4 = T_G$

Now, h_7 we will find out from empirical relation as shown by equation 1.9

$$h_7 = (-0.0012539 \times T_7^2 + (1.88060937 \times T_7) + (2500.559) \quad (1.9)$$

We know that, again from equation 1.2, 1.3, 1.4, after putting values of m_3, m_4, m_7, h_3, h_4, h_7 in the following equations then we will get the value of Q_3, Q_4, Q_7

Then, we will put the value of Q_3, Q_4, and Q_7 in equation 3.1 from equation 1.2, 1.3, 1.4

Then, we will get Q_G

$$Q_G = (m_7 \times h_7) + (m_4 \times h_4) - (m_3 \times h_3) \quad (1.10)$$

We also know that heat supplied to the generator is,

$$Q_G = m_{11} \times 4.2 \times (T_{12} - T_{11}) \quad (1.11)$$

Where

$m_{11} = m_{12}$= mass flow rate of water, at the inlet and outlet of Generator.

T_{11}= Temperature of water when it enters in to the Generator

T_{12}= Temperature of water when it comes out from the Generator

We have taken the value of $T_{11,}$ T_{12} from input parameter

Compare equation (1.10) with equation (1.11)

Then we will get the value of m_{11}

$$m_{11} = \frac{(m_7 \times h_7) + (m_4 \times h_4) - (m_3 \times h_3)}{4.2 \times (T_{11} - T_{12})} \quad (1.12)$$

Energy analysis of Condenser:-

On balancing the energy across the condenser, one can say;

$$Q_C + Q_8 = Q_7 \quad (1.15)$$

Now

$$Q_8 = m_8 . h_8 \quad (1.16)$$

$$Q_7 = m_7 . h_7 \quad (1.17)$$

Where,

h_7=Enthalpy at state 7

We got Enthalpy at state 7 from the equation (3.9)

h_8 =Enthalpy at state 8

We will find out enthalpy at state 8, by using the following relation

$$h_8 = 4.2 \times T_8 \tag{1.18}$$

Where,

T_8= Temperature at state 8, and taken from the input parameter

C_{pw} = Specific heat of water = 4.2 kJ/kg K

We know that, again from equation 1.16, 1.17, after putting values of m_7, m_8, h_7, h_8 in the following equations then we will get the value of Q_7, Q_8

Then, we will put the value of Q_7, Q_8 in equation 1.15 from equations 1.16, 1.17

Then, we will get Q_C

$$Q_C = (m_7 \times h_7) - (m_8 \times h_8) \tag{1.19}$$

We also know that heat transfer from the condenser is,

$$Q_C = m_{16} \times 4.2 \times (T_{16} - T_{15}) \tag{1.20}$$

Compare equation (1.19) with equation (1.20)

Then we will find out the value of m_{15}

$$m_{15} = \frac{(m_7 \times h_7) - (m_8 \times h_8)}{4.2 \times (T_{16} - T_{15})} \tag{1.21}$$

Where,

$m_{15}=m_{16}$= mass flow rate of water, when it enters and comes out from the condenser

T_{15}= Temperature of water when it enters in to the Condenser

T_{16}= Temperature of water when it comes out from the Condenser

We have taken the value of T_{15}, T_{16} from input parameter

Energy analysis of Evaporator:-

On balancing the energy across the evaporator, one can say;

$$Q_E+Q_9=Q_{10} \tag{1.22}$$

Now

$$Q_{10}=m_{10}.h_{10} \tag{1.23}$$

$$Q_9=m_9.h_9 \tag{1.24}$$

Where,

h_{10}=Enthalpy at state 10

We will find out Enthalpy at state 10 from the empirical relation shown by equation 1.25

$$h_{10}=(-0.00125397\times T_{10}^2)+(1.88060937\times T_{10})+(2500.559) \tag{1.25}$$

Where,

$T_{10}=T_9=T_E=5^oC$

Since;

$h_9 = h_8$

We know that, again from equation 1.23, 1.24, after putting values of m_9, m_{10}, h_9, h_{10} in the following equations then we will get the value of Q_9, Q_{10}

Then, we will put the value of Q_9, Q_{10} in equation 3.22 from equations 1.23, 1.24

Then, we will get Q_E

$$Q_E = (m_{10} \times h_{10}) - (m_9 \times h_9) \tag{1.26}$$

We also know that heat extracted from the evaporator is,

$$Q_E = m_{17} \times 4.2 \times (T_{18} - T_{17}) \tag{1.27}$$

Compare equation (1.26) with equation (1.27)

Then we will find out the value of m_{17}

$$m_{17} = \frac{(m_{10} \times h_{10}) - (m_9 \times h_9)}{4.2 \times (T_{18} - T_{17})} \tag{1.28}$$

Where,

$m_{17} = m_{18}$ = mass flow rate of water, when it enters and comes out from the evaporator

T_{17} = Temperature of water when it enters in to the evaporator

T_{18} = Temperature of water when it comes out from the evaporator

We have taken the value of T_{17}, T_{18} from input parameter

Energy analysis of Absorber:-

On balancing the energy across the absorber, one can say;

$$Q_A+Q_1=Q_6+Q_{10} \qquad (1.29)$$

Now

$$Q_1= m_1.h_1 \qquad (1.30)$$

$$Q_6=m_6.h_6 \qquad (1.31)$$

$$Q_{10}= m_{10}.h_{10} \qquad (1.32)$$

we have found out m_1, m_6 from equation 3.6 and 3.7 and m_{10} from input parameter

Now we have to find enthalpy at state 1, 6 and 10,

Where,

h_1= Enthalpy at state 1

h_1 will find out from the table at X_w and T_A

h_6=Enthalpy at state 6

Since;

$h_5= h_6$

h_5 will find out from the table at T_5

T_5 will be calculated by the following relation

$$T_5 = -\varepsilon - \frac{T_4}{T_4 - T_2} \times (T_4 - T_2). \qquad (1.33)$$

Where,

Here we will get T_4 and T_2 from the input parameter, we know that

$T_4=T_G$ and $T_2=T_1=T_A$

ε = Effectiveness of heat exchanger, again it should be taken from input parameters

h_{10}=Enthalpy at state 10

We will calculate h_{10} from the following empirical relation, shown by equation 1.36

$$h_{10} = (-0.00125397 \times T_{10}^{2}) + (1.88060937 \times T_{10}) + (2500.559) \tag{1.37}$$

We know that, again from equation 1.30, 1.31, 1.32, after putting values of m_1, m_6, m_{10}, h_1, h_6, h_{10} in the following equations then we will get the value of Q_1, Q_6, Q_{10}

Then, we will put the value of Q_1, Q_6, Q_{10} in equation 3.29 from equation 1.30, 1.31, 1.32

Then, we will get Q_A

$$Q_A = (m_6 \times h_6) + (m_{10} \times h_{10}) - (m_1 \times h_1) \tag{1.35}$$

We also know that heat transfer the absorber is,

$$Q_A = m_{13} \times 4.2 \times (T_{14} - T_{13}) \tag{1.36}$$

Compare equation (1.37) with equation (1.38)

Then we will get the value of m_{13}

$$m_{13} = \frac{(m_6 \times h_6) + (m_{10} \times h_{10}) - (m_1 \times h_1)}{4.2 \times (T_{14} - T_{13})} \tag{1.37}$$

Where

$m_{13} = m_{14}$ = mass flow rate of water, at the inlet and outlet of absorber.

T_{13} = Temperature of water when it enters in to the absorber

T_{14} = Temperature of water when it comes out from the absorber

We have taken the value of T_{13}, T_{14} from input parameter

So we have found Q_G, Q_E, Q_C, Q_A, in this way we can calculate Coefficient of Performance of Vapour Absorption Refrigeration System. We know that it is defined by the ratio of heat extracted from the evaporator (cooling effect) to the summation of heat supplied to the generator and work done on the pump but here we are neglecting, work done on the pump.

RESULT AND DISCUSSION

The summary of the Research paper these are the thermodynamic properties at the various thermodynamic states, energy flows at the various components of the system, COP of the system by using the input parameters of Table 1 are being calculated in the Table 2 and 3 are respectively, through the mathematical model on MATLAB, and I have obtained all the results by simulation technique.

STATES	P (kPa)	h (kJ/kg)	T (°C)	X% LiBr	m (kg/s)
1	0.8728	74.1	30	55.3	0.4
2	47.39	74.1	30	55.3	0.4
3	47.39	145.6	64.7	55.3	0.4
4	47.39	178.6	80	56	0.395
5	47.39	105.4	45	56	0.395
6	0.8728	105.4	45	56	0.395
7	47.39	2643	80	0	0.005
8	47.39	126	30	0	0.005
9	0.8728	126	5	0	0.005
10	0.8728	2510	5	0	0.005
11	-	378	90	0	0.6071
12	-	420	100	0	0.6071
13	-	84	20	0	1.462
14	-	100.8	24	0	1.462
15	-	84	20	0	0.7491

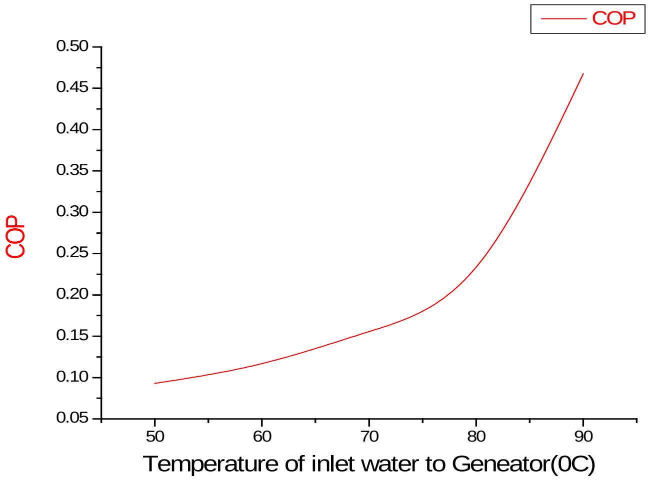
Table 3- Heat load at various Thermodynamic state of the System.

S.No.	Description	Notations	Calculated Value (k J/s)
1	The Heat load Rate in Evaporator	Q_E	11.92
2	The Heat load Rate in Condenser	Q_C	12.58
3	The Heat load Rate in Absorber	Q_A	24.56

4	The Heat load Rate in Generator	Q_G	25.5
5	The Coefficient of Performance of the system	COP	0.4675 (Dimensionless)

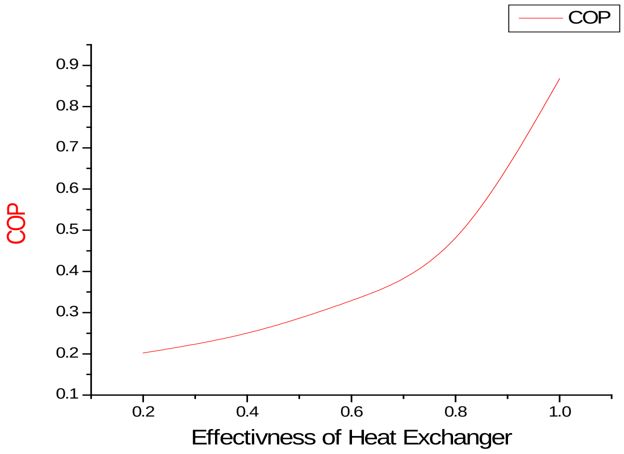
Variations in COP of the System with Temperature of inlet water to Generator

Figure shows the influence of inlet water temperature to generator (T_{11}) on the system performance. It can be observed that when the T_{11} increases, the required circulation ratio decreases, and the system COP value increases. If the T_{11} is below 58°C, the COP of the system will be close to zero, the system does not work at all, and from 58°C to 83°C, the COP will increase in a slower pace, after 83°C of T_{11}, the COP increase rapidly.



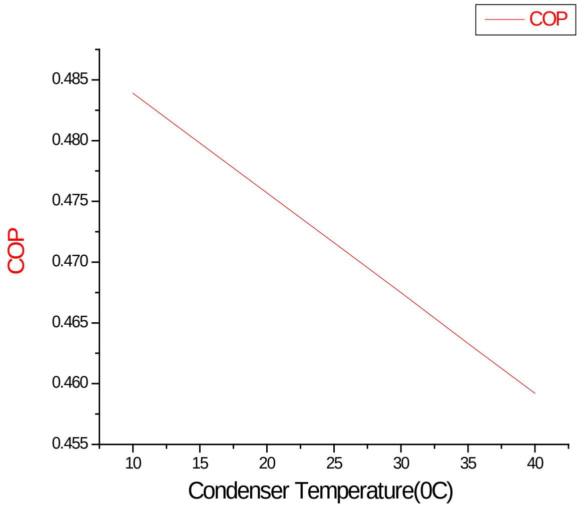
Variations in COP of the System with Effectiveness of Heat Exchanger

Figure shows the influence of Effectiveness of Heat Exchanger on the system performance. It can be observed that when the effectiveness of Heat Exchanger increases, than the value of COP of the system is also increases.



Variations in COP of the System with Condenser Temperature

Figure shows the influence of condenser temperature on the system performance. The system COP decreases with the condenser temperature increase, at the same time, circulation ratio will increase. The influence of absorber temperature is almost the same as the influence of condenser temperature.



CONCLUSIONS

A feasibility study is usually conducted in order to determine the appropriateness and suitability of the selected fluid pair. This is done before the expensive hardware development. In this Paper the first Law of Thermodynamics are applied to a single stage LiBr-Water absorption system, the performance analysis of each component are calculated through mathematical model on MATLAB 7.0.1.

In this study, studies related to ARS's are complied, and apart from the other studies, the effects of all performance parameters are investigated. From the above study, the following results can be drawn

- Empirical expressions to evaluate the thermodynamic properties at all the thermodynamic states and performance of a single stage LiBr-Water absorption system were presented, and the necessary heat and mass transfer equations for carrying out the components heat loads were specified.
- The energy analysis of all the thermodynamic components of Vapour Absorption System was determined by using empirical expressions. Moreover, the two pressures (Higher and Lower) were also derived. Finally, the value of Coefficient of performance was determined.
- The variations show that greater the difference between the absorber LiBr inlet and exit percentage ratios, more will be the coefficient of performance of the system. Moreover, coefficient of performance of the system goes on increasing with the rise in generator temperature.
- The thermal loads of the absorber and generator decrease, as generator and evaporator temperatures increases. The decrease of the generator thermal load increases the COP value.

Results shows that,

1. The Coefficient of Performance the system increases with increasing inlet water temperature to generator (T_{11}) and evaporator temperatures (T_{10}).
2. As the generator temperature is increases than COP of the system decreases.
3. As we increase condenser and absorber temperatures than Coefficient of Performance of the system decreases.
4. As the effectiveness of Heat exchanger increases than COP of the system is also increases.

Finally, the results of the energy analysis presented in Paper it can be applied as a useful tool for evaluation and improvement of the absorption system, it provides a simple and effective method to identify how losses at different devices are interdependent and where a given design should be modified for the best performance. In this Paper I have developed mathematical model of Vapour Absorption Refrigeration system (LiBr-Water) on MATLAB 7.0.1 and obtained all results through the simulation technique. Hence one can say that this model becomes versatile. After changing any parameter in input box, all results will be changed. We have analyzed this system by varying input parameters and found out optimal Coefficient of Performance of system.

In this Paper I have done energy analysis of Vapour Absorption Refrigeration system by generating empirical relations through curve fitting tool of MathCAD, and inserted these empirical relations in to the MATLAB. As for as my knowledge is concern no one has carried out energy analysis of Vapour Absorption System by generating empirical relations and developing mathematical model of system on MATLAB. Such types of mathematical model can be used as a tool in refrigeration and air conditioning in industries for inspect, and increase the performance of the system by change only the parameters.

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