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Investigation on Lithium-Bromide and Water (Li-Br-H_2O) Vapour Absorption Refrigeration System with Additive

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***Abstract*:- This paper evaluates the mixture of Li-Br and potassium formate (CHO_2K) as an alternative absorbents of vapour absorption system. The objective of this study is to investigate the performance improvement parameters of Li-Br vapour absorption refrigeration system by use of additive. To compare the performance of both the systems, thermal analysis of both the systems has been studied and influence of changing operating conditions has been analysed numerically and graphs has been plotted. Analysis of results has shown the efficiency of the system is increased by 16%. Hence, by use of potassium formate the heat requirement in the absorber and generator is dramatically decreased and therefore, an improvement in the efficiency of the system has been achieved.**

Keywords: Refrigeration system, Lithium bromide, Potassium formate, Absorption system

I. INTRODUCTION

At the early stages, vapour absorption refrigeration system was widely used for refrigeration but because of its low co-efficient of performance, vapour compression refrigeration cycle took its place. Nowadays, due to increasing global warming the environmental activist are focusing on developing an alternative of VCRS system with almost similar or more co-efficient of performance. A popular alternative is an absorption system. It can operate at low grade heat or the heat produces from turbine exhausts, solar plant, industrial process etc. It can be useful where there is no supply of electricity or electricity is very costly.

The absorption system mainly uses two mixture combination:

(1)Ammonia – water: Ammonia is used as a refrigerant in the system while water acts as an absorber. This system finds its application in commercial plants. This system is not useful in domestic air conditioning because of its toxicity.

(2) Li-Br and water: Water is used as a refrigerant and lithium bromide as an absorber. This system is widely used for air conditioning applications. The Li-Br system requirements are less than ammonia- water system which makes its system maintenance easy.

Potassium formate possess low vapour pressure which is helpful in working at lower temperature [1]. The crystallization temperature, density and viscosity are various properties of potassium formate which makes it's a prominent additive for selection [2]. Potassium formate easily gets absorbed at low temperature than lithium bromide [3]. A new absorbent mixture of Li-Br + CHO_2K is proposed [5]. The values of vapour pressure, density and viscosity are obtained experimentally [6]. The major drawbacks of using lithium bromide alone is that it crystallises at high concentrations and lower absorber temperature. Therefore, an anti-crystallization additive should be used to overcome this crystallization problem. Potassium formate as an additive is used in this paper because of its physical properties to overcome crystallization problem which eventually helps in increasing system's performance.

II. WORKING OF VARS CYCLE

The Li-Br refrigeration cycle is shown in fig.1
As we can see the liquid refrigerant coming from evaporator has low temperature as well as low pressure reaches absorber. Simultaneously, the strong solution from generator reaches absorber. In absorber mixing of liquid refrigerant and strong solution takes place and this is again pumped back to generator. Pump delivers high pressure weak solution to generator where the refrigerant drives off to condenser after receiving heat from the source. The Condenser condenses high pressure refrigerant into liquid and then it is allowed to enter into throttling valve. After getting throttle, the refrigerant enters evaporator where refrigerant changes its phase from liquid to vapour after absorbing heat load, thus producing refrigeration effect. The vapour refrigerant again enters absorber and cycle gets repeated.

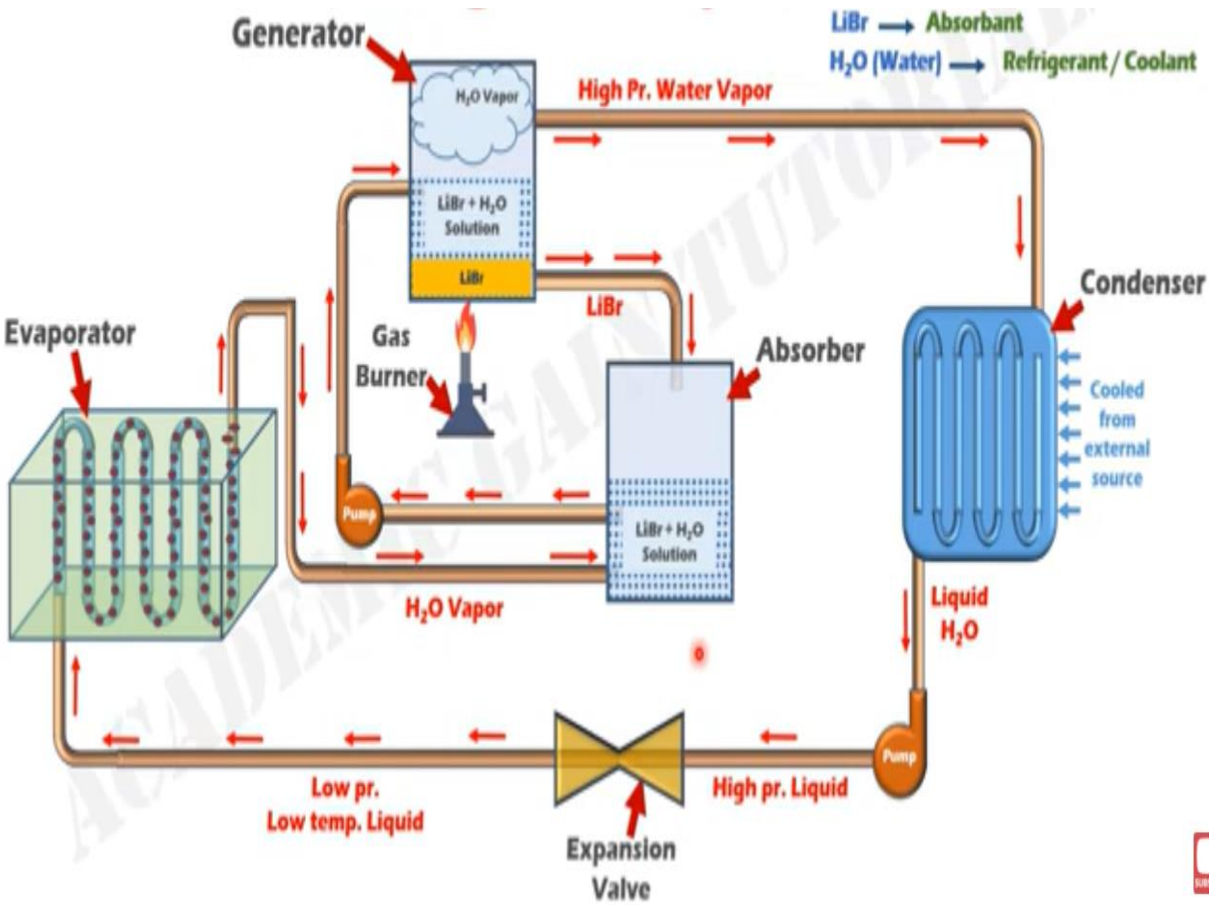

Fig. 1: Diagram of Lithium-Bromide Absorption System.

III. ANALYSIS

Following are the design considerations for the system under operation:

Table 1: Operating conditions of Li-Br system

Sr. No.	Components	Operating Range
1	Evaporator	5ºC
2	Condenser	20 to 50ºC
3	Absorber	5 to 50ºC
4	Generator	60 to 120ºC
5	Refrigeration Capacity	5.25 kW
6	Effectiveness of Heat Exchanger	0.65
7	Refrigeration Solution	(1) Li-Br (2) Li-Br + CHO_2K

Thermal analysis of both the systems is carried through following procedure:

(1) Concentration of strong solution,

$$X_{SS} \text{ OR } X_1 = \frac{49.05+1.125T_A-T_E}{134.65+0.47\,T_A} \quad (1)$$

(2) Concentration of weak solution,

$$X_{WS} \text{ OR } X_4 = \frac{49.04+1.125T_G-T_C}{134.65+0.47\,T_G} \quad (2)$$

(3) Enthalpy of sat. Liquid leaving condenser,

$$H_8 = (T_E - 25) \times 4.184 \quad (3)$$

(4) Enthalpy of sat. Water vapour,

$$H_{10} = (572.8 + 0.417\,T_E) \times 4.184 \quad (4)$$

(5) Refrigerant mass flow rate,

$$M_R = \frac{Q_E}{H_{10}-H_8} \quad (5)$$

(6) Strong solution mass flow rate,

$$M_s = \frac{M_R * X_4}{(X_4-X_1)} \quad (6)$$

(7) Weak solution mass flow rate,

$$M_w = \frac{M_R * X_1}{(X_4-X_1)} \quad (7)$$

(8) Temperature at state 5,

$$T_5 = T_G - E_{SHX}\,(T_G - T_A) \quad (8)$$

(9) Specific heat of strong solution,

$$C_{X1} = [1.01 - 1.23\,X_1 + 0.48\,(X_1)^2] \times 4.184 \quad (9)$$

(10) Specific heat of weak solution,

$C_{X4} = [1.01 - 1.23 X_4 + 0.48 (X_4)^2] \times 4.184$ (10)

(11) Temperature at state 3,

$T_3 = T_3 + [E_{SHX} \times \frac{X_1}{X_4} \times \frac{C_{X4}}{C_{X4}} \times (T_G - T_A)]$ (11)

(12) Enthalpy at state 1,

$H_1 = [42.81 – 425.92 X_1 + 404.67 (X_1)^2] + [1.01 - 1.23 X_2 + 0.48 (X_2)^2] \times (T_A)$ (12)

(13) Enthalpy at state 5,

$H_5 = [42.81 – 425.92 X_4 + 404.67 (X_4)^2] + [1.01 - 1.23 X_4 + 0.48 (X_4)^2] \times (T_5)$ (13)

(14) Enthalpy at state 7,

$H_7 = (572.8 + 0.417 T_G - 0.043 T_E) * 4.184$ (14)

(15) Heat capacity of condenser,

The pressure of evaporator and condenser is calculated by the equation given by Lasing [7].

(22) Condenser pressure, P_{COND} = antilog $[7.855 - \frac{1555}{(T_C - 273.15)} - \frac{11.2414 * 10^4}{(T_C + 273.15)^2}$

$Q_C = M_R (H_7 – H_G)$ (15)

(16) Heat capacity of generator,

$Q_G = (M_W H_5 + M_R H_7 – M_G H_1)$ (16)

(17) Heat capacity of absorber,

$Q_A = (M_W H_5 + M_R H_{10} – M_8 H_1)$ (17)

(18) Co-efficient of performance,

$COP = \frac{Q_E}{Q_G}$ (18)

(19) Maximum COP,

$(COP)_{MAX} = \frac{(T_E + 273.15) (T_G - T_A)}{T_G + 273.15) (T_C - T_E)}$ (19)

(20) Relative performance ratio,

$= \frac{COP}{COP_{MAX}}$ (20)

(21) Evaporator pressure, P_{EVA}=antilog $[7.855 - \frac{1555}{(T_E - 273.15)} - \frac{11.2414 * 10^4}{(T_E + 273.15)^2}]$

IV. RESULTS AND DISCUSSION

The new absorbent mixture of Li-Br + CHO_2K absorption system is compared with lithium bromide absorption system under identical conditions. Co-efficient of performance of both the systems is compared by generator temperature, absorber temperature, condenser temperature at varied operating conditions were carried out and an increase of 16% in the efficiency of the system has been achieved with the new absorbent mixture.

The addition of potassium formate in the mixture dramatically decreased the heat requirement in the generator section and provides lower crystallization temperature. The impact of varying operating conditions of different components on the efficiency of both the system has been shown below:

A. Co-efficient of Performance (Cop) v/s Generator Temperature

Fig 2. Shows the variation of performance of Li-Br system with respect to generator temperature. The maximum COP = 0.789 is obtained when the Generator temperature is kept 85 ^{O}C (Keeping all other system parameters as constant). Further increasing the generator temperature COP tends to decrease because of increasing weak solution concentration, which initiates crystallization.

The variation of performance of the Li-Br + CHO_2K system with respect to generator temperature is shown in fig.2 The maximum COP = 0.915 is obtained when the Generator temperature is kept at 65^{O}C without crystallization problem.

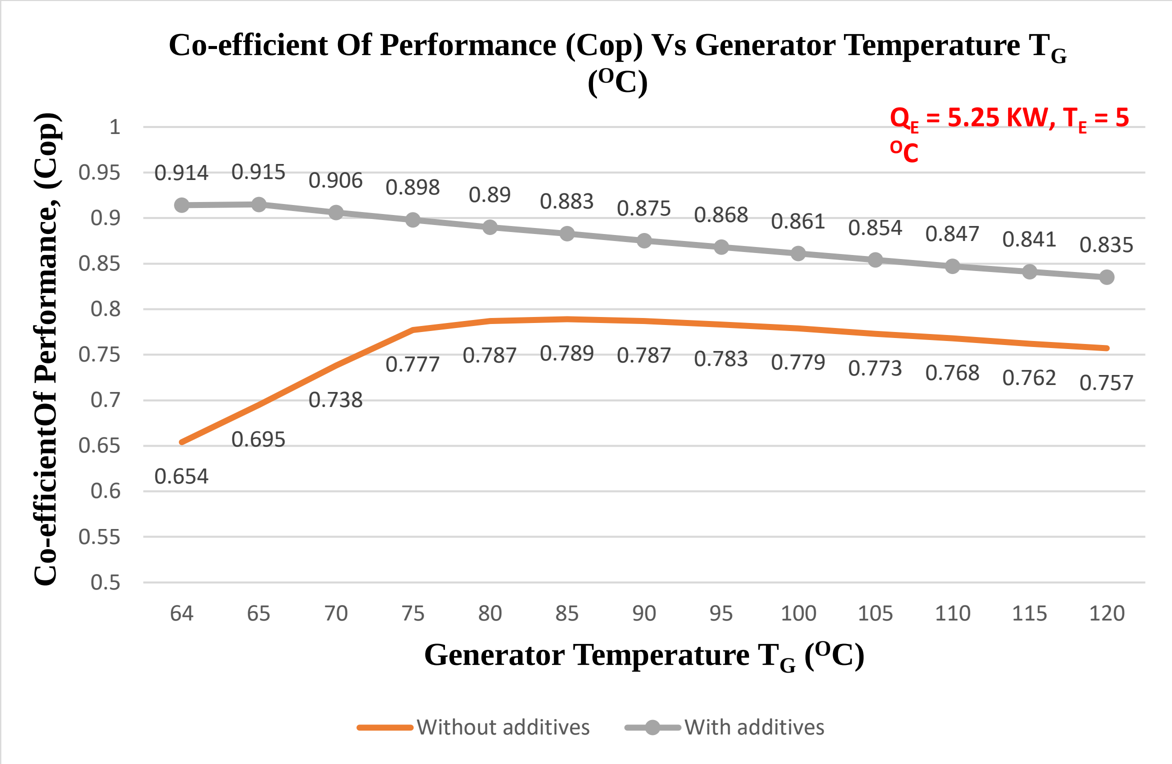

Fig. 2: Graph of Co-efficient of Performance (Cop) V/s Generator Temperature T_G (^OC) of Li-Br System.

B. **Co-efficient of Performance (Cop) v/s Absorber Temperature**

Fig 3. Shows the impact on performance of Li-Br system with respect to absorber temperature. The maximum COP = 0.808 is obtained at 19.95^{O}C absorber temperature. We can see from the graph that higher absorber temperature is not suitable for the system.

The impact on performance of the Li-Br + CHO_2K system with respect to absorber temperature is shown in fig 3. The maximum COP = 0.854 is obtained at 15^{O}C absorber temperature. Increasing the absorber temperature COP tends to decrease because the concentration of strong solution increases.

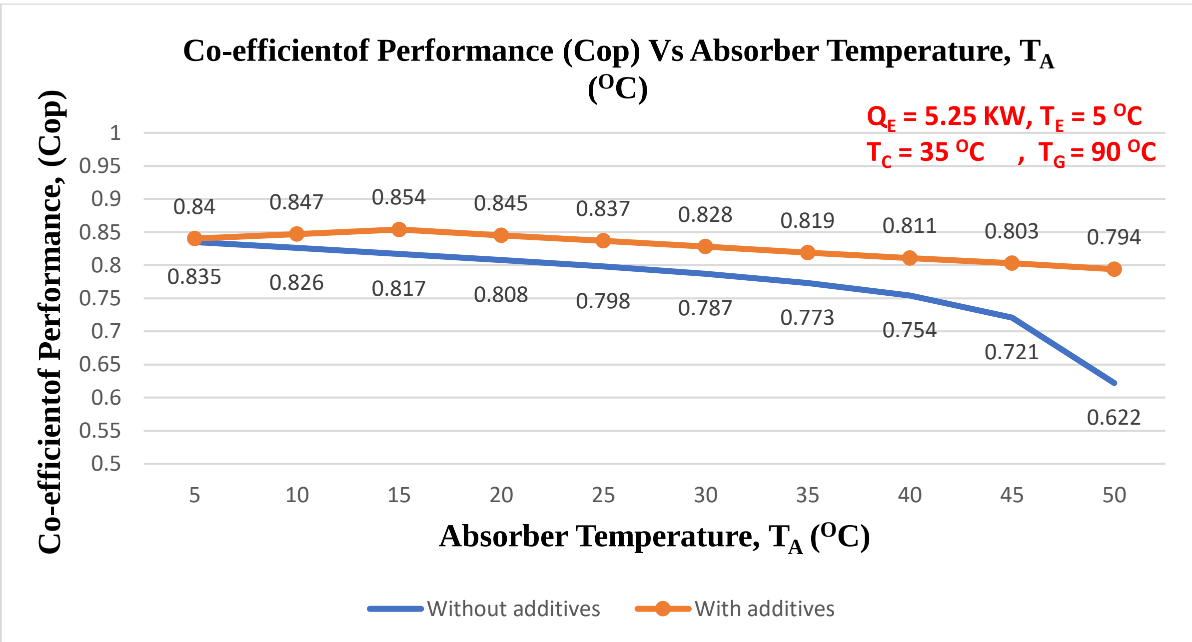

Fig. 3: Graph of Co-efficient of Performance (Cop) V/s Absorber Temperature T_A (^OC) of Li-Br System

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C. **Co-efficient of Performance (Cop) v/s Condenser Temperature**

Fig 4. Shows the impact of condenser temperature on performance of Li-Br system. The maximum COP = 0.805 is obtained when the condenser temperature is kept 20 ^{O}C. Increasing the condenser temperature, concentration of weak solution increases which results in the decline of the system performance.

The impact of condenser temperature on performance of the Li-Br + CHO_2K system is shown in fig 4. The maximum COP = 0.885 is obtained when the condenser temperature is kept 20 ^{O}C.

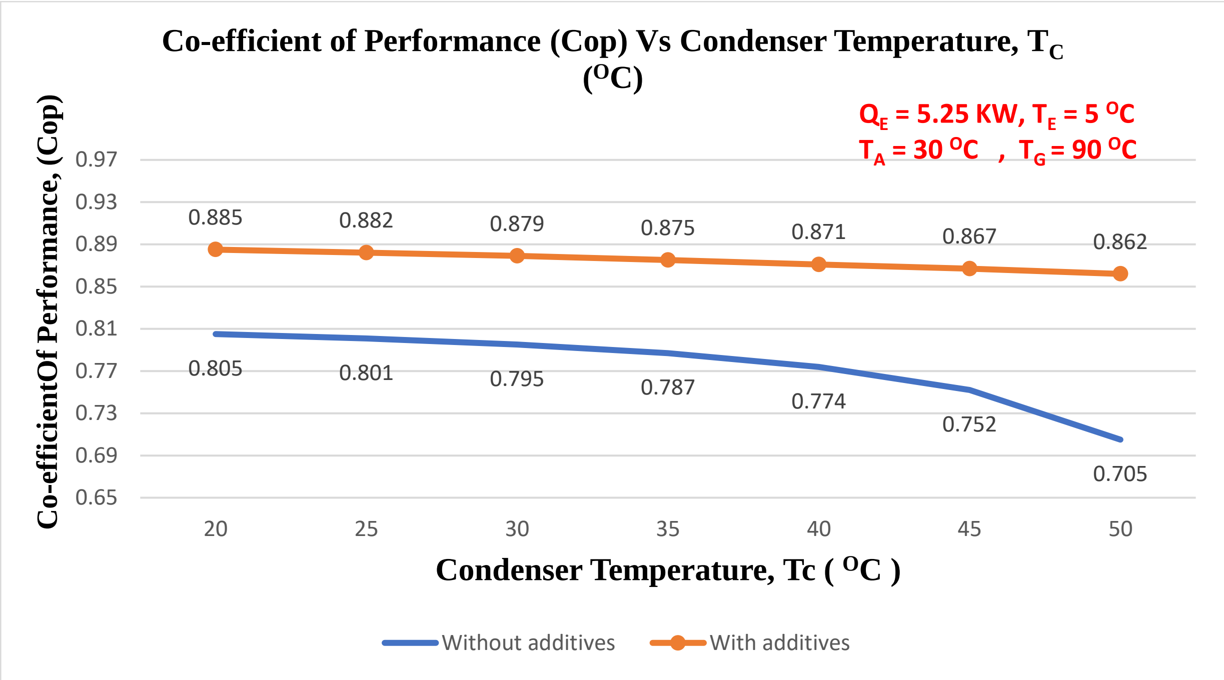

Fig. 4: Graph of Co-efficient of Performance (Cop) V/s Condenser Temperature T_C (^{O}C) Of Li-Br System

V. CONCLUSION

A new working absorbent pair of Li-Br and CHO_2K has been presented in this paper and its performance has been compared with the Li-Br system under identical conditions. The analysis of results shows that, the efficiency of the system is increased by 16%.

Lower absorber temperature up-to 5^{O}C is obtained without crystallization problem. The heat requirement in the generator section is decreased drastically and the maximum COP=0.915 is obtained at lower generator temperature of 65 ^{O}C.

Potassium formate being less expensive and less corrosive to metals forms the best pair with lithium bromide to be used as an absorbent mixtures.

Nomenclature

Li-Br	Lithium Bromide
M	Mass flow rate (kg/s)
RE	Refrigeration effect(kW)
T	Temperature (ºC)
X	Li-Br mass fraction in Li-Br/Water solution (%)
ε	Effectiveness of solution heat exchanger
P	Pressure of the system (kPa)
W	Work done
ν	Kinematic viscosity (m^2/s)
H	Enthalpy at state point (kJ/kg)

Subscripts

A:	Absorber
R:	Refrigerant
X1:	strong solution
X2:	weak solution
G:	Generator
In:	entering
Out:	exiting
1–10:	Mentioned Position
E:	Evaporator
C:	Condenser

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