International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Special Issue - AMET-2018

Investigation on Vapor Absorption Refrigeration with Additives

Shriraj D. Gulbhile†, Swapnil D. Ambhore‡ and Mandar M. Lele†

†Department of Mechanical Engineering, MAEER's MITCOE, Pune 411038, Maharashtra, India
‡Department of Mechanical Engineering, MAEER's MITCOE, Pune 411038, Maharashtra, India
†Department of Mechanical Engineering, MAEER's MITCOE, Pune 411038, Maharashtra, India

Abstract

This paper reveals about the investigation on vapor absorption refrigeration with additives. There are various techniques to enhance the vapor absorption refrigeration cycle performance particularly by changing the property of absorbent.This is achieved by addition of organic salt into absorbent mixture. It was shown that the addition of organic salt(potassium formate,sodium.formate, sodium lactate,potassium acetate) into the LiBr-H2O solution with the mass fraction of 2:1 can improve the COP of LiBr-H2O cycle from 0.75 to 0.95 as well as heat required to absorbent generator is dramatically decreased from 374 k to 329 k.

Keywords: vapor absorption, LiBr-H_2O,VAC

1. Introduction

The most industrial operations use heat energy for producing work by combustion of fuels. After utilizing some part of this thermal energy, the unutilized thermal energy is rejected to surrounding as a heated waste such as hot water or waste vapor streams. This heated waste can be used for Refrigeration by using heat-operated refrigeration system, such as vapor absorption refrigeration cycle (VAC). The vapor absorption refrigeration cycle is one of the best alternatives to the traditional vapor compression refrigeration cycle. The absorption cycle is more beneficial to vapor compression cycle because this cycle uses a waste heat as the energy source to obtain cooling effect instead of expensive electric energy in the form compressor work thus reducing the work input as compared with traditional vapor compression cycle. The second most important difference between absorption cycle and compression cycle is the refrigerant fluid used. Many of the vapor compression systems commonly use chlorofluorocarbon refrigerants because of its thermos physical properties. CFC is unsafe to the environment. It causes depletion of the ozone layer that will make absorption systems more important due to low environmental effect.

In early days, The ice was produced by evaporation of pure water in the sealed evacuated chamber by using sulfuric acid in 1700's, (Herold KE *et al.* 1989). After few decades later, it was realized that ice could be produced from water in a vessel which is connected to another vessel containing H_2SO_4(Gosney WB *et al.* 1982). As the H_2SO_4 absorbed water vapor the partial pressure of water vapor dropped. It induced a reduction in temperature or cooling effect which formed the layers of ice on the surface of water. The early development of an absorption cycle, Ferdinand Carrehas invented the device using water and ammonia as the working fluid in 1859. A few decades later, a refrigeration cycle using lithium bromide and water as the working fluid was introduced for industrial applications.

2. Working Principle of VAC

The absorption refrigeration cycle uses the binary working fluid solution which contains refrigerant and absorbent. The mixture of the solution is connected to each other by two sealed evacuated vessels as shown in below figure.

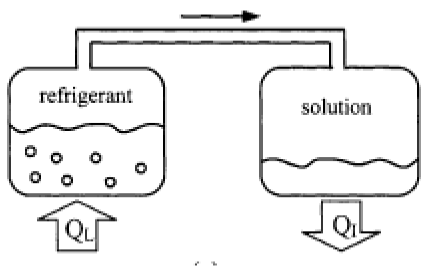

Fig.1 Absorption Process(PongsidSrikhirin*et al.* 2001)

The figure 1 shows that the two vessels which are in vacuum connected to each other. The left vessel contain a liquid refrigerant while right vessel contain mixture of refrigerant and absorbent. The absorbent at right vessel absorbs the liquid refrigerant vapors from left vessel. It causes the drop in partial pressure of left vessel. The left vessel gives cooling effect to the

ISSN : 2454-9150 Special Issue - AMET-2018

surrounding. The cooling effect occurs till binary solution reaches its saturation level. The binary solution of the right vessel cannot continue the absorption process due to saturation of the refrigerant. To continue the refrigeration cycle the refrigerant from right vessel should be separated. The separation of this diluted binary solution is done by providing heat. Heat is applied to the right vessel in order to dry the refrigerant from the binary solution. It is shown in figure 2.

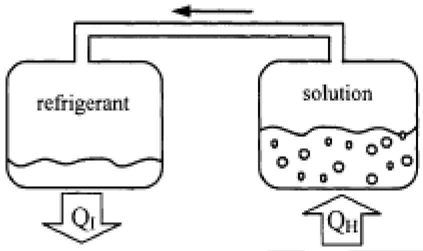

Fig.2 Separation Process[PongsidSrikhirin*et al.*2001]

The processes that are explained earlier are separate processes. The cooling effect cannot be produced continuously as the process cannot be done simultaneously. Those processes are combined in vapor absorption cycle as shown in figure. The vapor absorption cycle mainly contains an evaporator, absorber, generator and condenser.

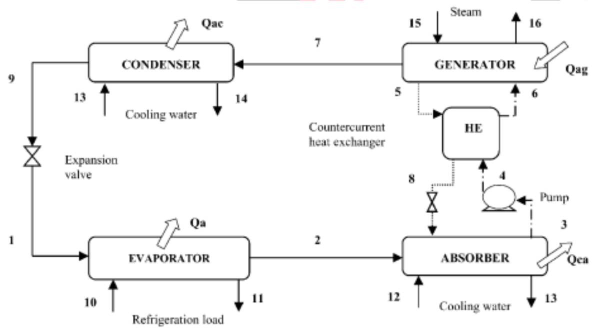

Fig.3 Schematic of an absorption refrigeration cycle [Antonio De Lucas*et al.*2004]

The COP of the whole cycle can be estimated by the taking the ratio cooling capacity obtained at evaporator to the heat input for the generator where pump work is neglected

$$COP_R = (evaporator\ work) / (heat\ input\ to\ genrator + pump\ work)$$

3. Working Fluids for VAC

Performance of an absorption cycle is mainly dependent on the thermodynamic and chemical properties of the working fluid (Perez-Blanco H et al. 1984).

Refrigerant absorbent mixture should satisfy the following conditions.

1. The mixture should permit high difference between the boiling point of the pure refrigerant and the binary solution at the same pressure.
2. Transport properties that effects on heat and mass transfer should be favorable such as viscosity, thermal conductivity, and diffusion coefficient.
3. The refrigerant absorbent mixture should also be chemically stable, non-toxic, non-explosive, environmental friendly and easily available.

There are many refrigerant and absorbent compound is suggested in a literature. Absorption fluid data survey by Marcriss (Marcriss RA *et al*. 1988) shows that 40 refrigerant compounds and 200 absorbent compounds available, However, the most common working fluids are Water-NH3 and LiBr-water. But Water-NH3 compound requires a rectifier to strip away water which evaporated with ammonia. The second disadvantage of ammonia is its ability to corrosion. It is corrosive to copper and its alloy. The properties of Water-NH_3 is obtain from literature (Park YM et al. 1990). The use of LiBr-water for absorption cycle began from 1930 due to its two characteristics those are non-volatility absorbent (rectifier is eliminated) and high heat of vaporization. However, at high concentration the refrigerant and absorbent mixture is susceptible to crystallization. The thermodynamic properties of LiBr-water are shown in literature (Lee RJ *et al.* 1990). LiBr-water is also corrosive to some metal and it can be avoided by adding some additives shown in (Iyoki S *et al.* 1978).
Many working fluids are suggested in literature. A survey of absorption fluids provided by Marcriss suggests that, there are some 40 refrigerant compounds and 200 absorbent compounds available.

4. Performance Enhancement of VAC by additives.

The vapor absorption cycle is generally used in industrial application where large heat source is available. The vapor absorption cycle units are big industrial devices. It implies that large absorbent mixture has to be moving inside the machine it means large surface area is required and consequently the volume of this cycle is large. By increasing the efficiency of absorbent could make possible to reduce the size of unit. A variety of mechanical and physicochemical methods have been adopted for the improvement of absorber performance. This article is focuses on addition of salts into LiBr-H_2O solution.

A binary compound LiBr-water is the most successful working for an absorption refrigeration system. However, at high concentration such as at high temperature, the solution is susceptible to crystallization. It was found that the addition of a second salt as in a ternary mixture can improve the solubility of the solution.

4.1 Effect of addition $KHCO_2$ into the LiBr-H_2O

The potassium formate is used as additive in the mixture of LiBr-water because its physical and thermal properties. Potassium formate has lower crystallization temperature, lower density and lower viscosity than LiBr, the latent heat of absorption is lower than LiBr. less toxic and is biodegradable (Antonio De Lucas et al. 2004) and it has good affinity with other additives. As a result, it was supposed that LiBr-$KHCO_2$could show optimal properties such as low vapor pressure (by LiBr) and less crystallization temperature (by$KHCO_2$).

Table 1 Comparison between LiBrVs LiBr+$KHCO_2$ [Antonio De Lucase et al. 2004]

Section	LiBr		LiBr+$KHCO_2$	
	Q(kw)	T(K)	Q(kw)	T(K)
Evaporator	1580.4	278.65	1580.04	278.65
Absorber	2039.14	313.15	1734.79	288.15
Generator	2084.67	374.85	1850.21	329.15
Condenser	1635.28	319.25	1577.16	319.25
COP	0.75		0.85	

The above table shows that addition of $KHCO_2$ in LiBr salt reduced boiling point of absorbent at generator from 374.85 K to 329.15 K. The table also indicates that COP is improved from 0.75 to 0.85With addition of $KHCO_2$. Physical properties are also benefited such as less corrosive, less expensive, lower density and viscosity with the addition of 35% potassium formate.

4.2 Effect of additionsodium formate into the LiBr-H_2O

The experiment was conducted with different mass fractions of $NaHCO_2$ into the LiBr-H_2O solution by M. Donate (Marina Donate et al. 2006). The following table shows that the lowest partial pressure is obtain at the mass fraction of 2:1.

Table 2 Experimental procedure parameters [Marina Donate et al. 2006]

S. No	Mass ratio (LiBr:$NaHCO_2$)	P (KPa)
1	1:0	103.
2	1:1	110
3	2:1	90
4	5:1	102
5	0:1	116

Table 3 Comparison between LiBrVs LiBr+$NaHCO_2$[Marina Donate et al. 2006]

Section	LiBr		LiBr+$NaHCO_2$	
	Q(kw)	T(K)	Q(kw)	T(K)
Evaporator	1580.4	278.65	1579.91	278.65
Absorber	2039.14	313.15	1709.84	284.15
Generator	2084.67	374.85	1672.38	329.15
Condenser	1635.28	319.25	1577.03	319.25
COP	0.75		0.94	

The table 3 shows the addition of sodium formate with mass fraction of 2:1 can improve the COP of VAC from 0.75 to 0.94 as well as the boiling of point of absorbent at generator reduces from 374.85 k to 329.15 k

4.3 Effect of addition potassium acetate into the LiBr-H_2O

The Effect of addition potassium acetate into the lithium bromide water absorbent is shown in table 4

Table 4 Comparison between LiBrVs LiBr+CH_3CO_2K [Marina Donate et al. 2006]

Section	LiBr		LiBr+ CH_3CO_2K	
	Q(kw)	T(K)	Q(kw)	T(K)
Evaporator	1580.4	278.65	1579.91	278.65
Absorber	2039.14	313.15	1700.97	285.15
Generator	2084.67	374.85	1672.38	329.15
Condenser	1635.28	319.25	1577.03	319.25
COP	0.75		0.94	

There were various salt has been tested by their thermophysical and chemical properties with addition of different mass fraction (Marina Donate et al. 2006). The table 4 shows the comparison between LiBr and LiBr with potassium acetate it not only improves the COP but also reduces corrosiveness of LiBr solution with the optimal mass fraction of LiBr:salt is 2:1

4.4 Effect of addition sodium lactate into the LiBr-H_2O

.

Table 5 Comparison between LiBrVsLiBr+$C_3H_5NaO_3$[Marina Donate et al. 2006]

Section	LiBr		LiBr+ $C_3H_5NaO_3$	
	Q(kw)	T(K)	Q(kw)	T(K)
Evaporator	1580.4	278.65	1579.91	278.65
Absorber	2039.14	313.15	1700.97	285.15
Generator	2084.67	374.85	1692.91	333.15
Condenser	1635.28	319.25	1582.12	319.25
COP	0.75		0.93	

The sodium lactate salt had been added to into the solution of LiBr-H_2O refrigerant with the mass fraction 2:1. It improves the COP as well as anticorrosive property of absorbent. The table 5 (Marina Donate et al. 2006) shows the addition of additives improve the cop of VAC from 0.75 to 0.93 with respect to conventional LiBr-H_2O VAC

5. Conclusions

The main conclusions are:

1. The best ratio of new absorbent and additives mixture is2:1, because it presents the advantages of a low value of heat of dilution and the vapour pressures are also maintained lower than in the case of using LiBr individually. These low values of the heat of dilutions imply that the requirements of heat in the generator and refrigeration in the absorber with the new absorbent mixtures are lower than using lithium bromide.
2. The heating requirements in the generator section can be dramatically decreased using this kind of mixtures, being enough using a industrial waste stream with only a little more than 334.15 K to reach the boiling point of the diluted absorbent mixture. This fact allows to use condensate water, or any other residual stream of the industrial process, under 373.15 K, to get the evaporation of the absorbent mixture, not necessarily overheated water or steam. This fact provides an important economic advantage and improves the efficiency of absorption refrigeration cycle.
3. An improve in the COP of the absorption cycle is reached using the new absorbents.
4. Potassium and $NaHCO_2$seems to be promising alternatives to LiBr because the heating requirements in the generator section are lower.

References

PongsidSrikhirin , SathaAphornratana, SupachartChungpaibulpatana(2001), A review of absorption refrigeration technologies, Renewable and Sustainable Energy Reviews,5,343–372

Herold KE, RadermacherL(1989). Absorption heat pump, Mech. Eng,68–73.

GosneyWB(1982). Principle of refrigeration,Cambridge Uni. Press

Perez-Blanco H,(1984) Absorption heat pump performance for different types of solution. *IntJ*(2):115–22.

Antonio De Lucas, Marina Donate, Carolina Molero, Jose

Marcriss RA, Gutraj JM, Zawacki TS.(1988) Absorption fluid data survey: final report on worldwidedata, ORLN/sub/8447989/3, Inst. Gas Tech.

Park YM, Sonntag RE,(1990) Thermodynamic properties of ammonia-water mixtures: a generalized equation- of-state approach. *ASHRAE Trans*,96,150–159.

Berestneff AA.(1984) Absorption refrigeration. *MechEng ,72,*16–20.

Lee RJ, DiGuilio RM, Jeteter SM, Teja AS.,(1990) Properties of lithium bromide-water solutions at hightemperatures and concentrations-part II: density and viscosity. *ASHRAE Trans,96*,709–714.

Jeter SM, Moran JP, Teja AS.(1992) Properties of lithium bromide-water solutions at high temperatures and concentrations-part III: specific heat. *ASHRAE Trans* ,137–49.

Lenard JLY, Jeter SM, Teja AS. (1992)Properties of lithium bromide-water solutions at high temperaturesand concentrations-part IV: vapor pressure. *ASHRAE Trans,*98,167–172.

Modahl RJ, Lynch PJ.,(1971) Arsenic trioxide corrosion inhibitor for absorption refrigeration system, *USPatent No. 3609086*,

Iyoki S, Uemura T.,(1978) Studies on corrosion inhibitor in water-lithium bromide absorption refrigerating machine. *Reito,*53,1101–5.

Wen TC, Lin SM.(1992) Corrosion inhibitors the absorption system,*J Chin InstChem Eng;*22,311–316.

Verma SK, Mekhjian MS, Sandor GR, Nakada N.,(1999) Corrosion inhibitor in lithium bromide absorptionfluid for advanced and current absorption cycle machines.*ASHRAE Trans* ,105(1),813–5.

Albertson CE, Krueger RH.,(1971), Heat transfer additives for absorbent solution, *US Patent No.3580759*

Antonio De Lucas, Marina Donate, Juan F. Rodrı´guez,(2008), Applying surfactants to improve the absorption capacity ofmixtures of lithium bromide and formates in absorptionrefrigeration coolers, *International Journal of Refrigeration,*31,1073 – 1080

Marina Donate, Luis Rodriguez, Antonio De Lucas, Juan F. Rodrıguez,(2006),Thermodynamic evaluation of new absorbent mixtures of lithiumbromide and organic salts for absorption refrigeration machines, *International Journal of* Refrigeration ,29, 30–35