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# Analysis of Valve Operated Absorption Refrigeration Using Ammonia & Water Working Fluid

M.Mohammad Basid<sup>1</sup>, L.Ranjith Kumar<sup>1</sup>, M.Reuben William<sup>1</sup>, J.Pramoth Manuel<sup>1</sup>, Mr.S.Ashokraj<sup>2</sup>  
U.G. Student, Department of Mechanical Engineering, Francis Xavier Engineering College, Vannarpet, Tirunelveli,  
Tamil Nadu, India<sup>1</sup>

Associate Professor, Department of Mechanical Engineering, Francis Xavier Engineering College, Vannarpet,  
Tirunelveli, Tamil Nadu, India<sup>2</sup>

**ABSTRACT:** This paper presents a pump-less AMMONIA /WATER absorption cycle refrigerator that does not use a mechanical pump for solution circulation. In this refrigerator, the solution circulation is achieved by making use of pressure in the generator.

To achieve this, the generator is designed to carry out two functions namely desorption and circulation alternatively, which is served by two operational valves. A mathematic model for the solution circulation is developed to predict the refrigerator's performance.

### I. INTRODUCTION

This paper describes and evaluates a pump-less AMMONIA /WATER absorption cycle refrigerator. In conventional absorption refrigeration systems, a mechanical pump is usually used to circulate the working fluids. Although the power consumption on the pump is only a small portion of total energy input, the use of electricity for a heat-powered system is not so convenient in cases where electricity supply is not available. For a heat-powered system, it is desirable to use heat for the circulation to keep the supply source simple. The idea utilizing heat to circulate working fluids in absorption refrigeration cycle is not new. Around 1920, a diffusion-absorption refrigeration cycle was pioneered. In this cycle, a bubble pump is used to circulate the working fluid. This cycle has been investigated extensively since its invention. The diffusion-absorption refrigeration cycle typically uses a mixture of ammonia-water-hydrogen as its working fluid. The roles of ammonia and water are familiar from conventional absorption cycle experience. Hydrogen is added to equalize the pressure throughout the cycle and so permit the use of a bubble pump to circulate the working fluids. However, the presence of hydrogen increases the resistance for the mass transfer and therefore the COP of this system tends to be significantly lower than a conventional water-lithium bromide absorption cycle. Recently, a two-fluid bubble pump system was investigated by Pfaff et al. Based on a water-lithium bromide vapour absorption refrigerator, their system used a bubble-pump to transfer the refrigerant-poor solution between the absorber and generator. The rising refrigerant vapour bubbles push the solution into the generator in slug flow pattern. Saravana and Maiya [6] also reported the influence of the working fluids and the effect of component pressure drops on a similar two-fluid bubble pump refrigerator and reported a transfer-tank operated vapour absorption refrigeration systems. Their system used three valves to control pumping stages and part of the refrigerant, which was used to pump the solution, was directly discharged to the absorber after pumping period. Obviously, a reduction in COP is inevitable as a result of such an arrangement.

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## II. RELATED WORK

### THERMODYNAMIC ANALYSIS

The properties of liquid mixture of AMMONIA -WATER solution and AMMONIA vapour are calculated from the available correlations and methods of calculation available in the literature. Some of the thermo-physical properties of both AMMONIA and WATER are presented in Table.1.

S. NO	THERMOPHYSICAL PROPERTIES	REFRIGERANT (AMMONIA) NH <sub>3</sub>	ABSORBENT (WATER) H <sub>2</sub> O
1.	Molecular weight (Mw)	102.03 gmol <sup>-1</sup>	87.12 gmol <sup>-1</sup>
2.	Boiling point (Tb)	-26.6oC	166oC
3.	Critical pressure (Pc)	40.59 bar	40.18 bar
4.	Critical temperature (Tc)	101.06oC	385oC
5.	Critical volume (Vc)	0.1989 m <sup>3</sup> kmol <sup>-1</sup>	0.310 m <sup>3</sup> kmol <sup>-1</sup>
6.	Freezing point (Tf)	-103.3oC	-20oC

## CORRELATIONS:

### Pressure at liquid-vapour equilibrium:

The pressure at vapour-liquid equilibrium with respect to the temperature and concentration of AMMONIA in the solution

### Density of AMMONIA & WATER:

The density of the liquid refrigerant and absorbent with respect to the temperature

### Density of AMMONIA & WATER Solution:

The density of AMMONIA - WATER solution with respect to temperature and concentration at saturation condition

### Enthalpy of AMMONIA - WATER solution:

Enthalpy of mixture, AMMONIA - WATER solution with respect to the enthalpies of individual component and excess enthalpy of solution

### Enthalpy of AMMONIA (hr) :

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The enthalpy of AMMONIA with respect to temperature at saturated condition

### Enthalpy of WATER (hd):

The enthalpy of WATER with respect to temperature at saturated condition

### Excess Enthalpy of AMMONIA - WATER Solution (hE):

The excess enthalpy of solution with respect to temperature and mole fraction of AMMONIA at equilibrium condition

### PUMPING PHASE :

At the end of the desorption phase, we assume the solution levels are L0 in the generator and L1 the transfer pipe, or riser. At the beginning of the pumping phase, valves V0 and V1 are closed and this causes the solution level in the riser to increase whilst that in the generator falls, if heat continues to be added. Because the change in volume occupied by the solution in the generator must equal that in the riser

### DESORPTION PHASE:

After the pumping phase, both valves are again opened. Once this occurs the generator pressure will fall back to equal the condenser pressure and the level in the riser will fall to L1. Once the pressure in the generator equals that in the condenser then the weak solution will begin to flow under gravity from the absorber to the generator. This phase will last until the solution level in the generator rises to height of L0.

### COP OF THE SYSTEM:

The total heat input to the system during the pumping and desorption phases equals the sum of their equations

### 1. PRESSURE PHASE

#### FIND OUT PL2

$$L1=1.5;$$

$$S=0.0314$$

$$; SP=5.024 \times 10^{-5};$$

$$L=2;$$

$$L2=2;$$

$$Gama=1.627;$$

$$PA=4.3897; \text{ \% absorber pressure in bar}$$

$$P_{L2}=Gama \cdot L1 \cdot \left( \frac{L}{L1} + \left( \frac{SP}{S} \right) \cdot \left( \frac{L}{L1} - 1 \right) \right) + PA \quad \text{ans}=7.6450 \text{ bar}$$

#### TO FIND W\_L1\_L2

$$L2=2;$$

$$L1=1.5;$$

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$$S_P=5.0240 \times 10^{-5};$$

$$P_{L2}=764.5; \text{ \% IN KPa}$$

$$W_{L1L2}=P_{L2} \times S_P \times (L2-L1) \quad \text{ans}=0.0192 \text{Kj}$$

### TO FIND OUT $M_p$ AND $M_g$

%To raise the solution from L1 to L2, the minimum generator pressure required

$$P=442.1781;$$

$$\text{\% in kpa } V_P=0.0235;$$

$$\text{\% volume of inside pipe } T_P=302.728;$$

$$\text{\% Temp in kelvin } R=0.08149;$$

$$\text{\% From data table } m_p=(P \times V_P)/(T_P \times R) \quad \text{ans}=0.4212 \text{kg}$$

$$V_G=0.0052; \text{ \% IN } M^3$$

$$P_G=767.0134; \text{ \% IN KPa}$$

$$T_G=60; \text{ \% IN } ^\circ\text{C}$$

$$T_G=T_G+273$$

$$m_g=(P_G \times V_G)/(T_G \times R) \quad \text{ans}=0.147 \text{kg}$$

### TO FIND OUT $Q_{L1L2}$

$$m_p=0.4212; \text{ \% in kg}$$

$$h_{vTp}=414.664;$$

$$m_s=0.34;$$

$$m_g=0.147;$$

$$h_{sTp}=241.3;$$

$$h_{sTg}=287.5;$$

$$h_{vTg}=426.6;$$

$$Q_{L1L2}=(m_p \times h_{vTp}) + ((m_s - m_p + m_g) \times h_{sTp}) - (m_s \times h_{sTg}) - (m_g \times h_{vTg}) \quad \text{ans}=30.0738 \text{ kJ}$$

### TO FIND OUT $P_H$

$$L2=2; \text{ \% Level of solution in the riser pipe L2}$$

$$L1=0.5; \text{ \% Level of solution in the riser pipe L1}$$

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$$S=0.0314;$$

$$Sp=5.024 \times 10^{-5};$$

$$GAMA=1.6291;$$

$$H=0.25; P_A=438.97 \quad P_h=GAMA \cdot L1 \cdot ((L2/L1) + ((Sp/S) \cdot (L2/L1))) + P_A + (GAMA \cdot H) \quad \text{ans} = 442.6407 \text{kJ}$$

### TO FIND OUT W\_H

$$H=0.25;$$

$$S=0.0314;$$

$$P_h=442.64;$$

$$W_H=P_h \cdot S \cdot H \quad \text{ans} = 0.0192 \text{ kJ}$$

### TO FIND OUT M\_PH, V\_PH

$$\text{row} = 21.568; \quad \% \text{ FROM DATA TABLE BY } P_H \text{ VALUE}$$

$$S=0.0314; \quad \% \text{ AREA OF GENERATOR}$$

$$H=0.25; \quad \% \text{ LEVEL OF SOLUTION}$$

$$m_{ph} = \text{row} \cdot S \cdot H \quad \text{ans} = 0.3386 \text{ kg}$$

$$v_{ph} = m_{ph} / \text{row} \quad \text{ans} = 0.0157 \text{ m}^3$$

### DESORPTION PHASE

#### TO FIND OUT M\_s\_gen, Ms\_i, Mr

$$ms=0.34;$$

$$mg=0.1470;$$

$$m=0.34+0.1470$$

$$X_w = ms/m \quad \text{ans} = 0.698$$

$$2 X_s = mg/m \quad \text{ans} = 0.3018$$

$$V=0.0157;$$

$$VPH=0.0078;$$

$$\text{row} = 32.38; \quad \% \text{ FROM DATA BOOK BY } P_H$$

$$m_{s\_gen} = \text{row} \cdot (V - VPH) \quad \text{ans} = 0.2558 \text{ kg}$$

$$S=0.0314;$$

$$H=0.25;$$

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$$ms_i=(X_s/X_w)*row*S*H \text{ ans}=0.1099\text{kg}$$

$$mr=(1-(X_s/X_w)) \text{ ans}=0.5676\text{kg}$$

## TO FIND OUT Qin

$$Q_{L1\_L2}=30.0738;$$

$$Q_H=85.3648;$$

$$W_{L1\_L2}=0.0192;$$

$$W_H=3.4747;$$

$$Q_{de}=101.8231;$$

$$Q_{in} = (Q_{L1\_L2}) + (Q_H) + (W_{L1\_L2}) + (W_H) + Q_{de} \text{ ans}=102.8149 \text{ kJ}$$

## TO FIND OUT COP

$$Q_{in}=220.7556;$$

$$Q_e=102.8149;$$

$$COP = (Q_e/Q_{in}) \text{ ans}=0.4657$$

## III. CONCLUSION

A valve operated pump free absorption refrigerator using AMMONIA& WATER as working fluid has been described and evaluated. This refrigerator has the advantages of being simple in construction and easy to operate. A mathematical model was described and the calculation results from this model shows that COP of this system is 0.4657 when  $L2/L1 = 1.33$  and  $d/D = 0.04$  are used. In order to achieve it, the valve-operated system requires higher generator temperature to establish enough pumping pressure. The temperature of the generator increases with the hydraulic head ratio  $L2/L1$  and cross-sectional area ratio  $d/D$ . Automatic valve operating system is required to make the system practically useful. This could be either electrical or mechanical one as long as they meet operation requirements. A mechanical valve control system will enable the refrigerator to run without electricity. A small PV panel may be sufficient to supply electricity to an electronic control device for the refrigerator. Therefore, it could be used in the cases that electricity supply is not viable and is possibly worthwhile for further investigation.

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