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Development of an Absorption Air – Conditioning System Using Aqua – Ammonia Solution

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Abstract: The price of basic commodities such as fuel and energy is continuously increasing nowadays, thus people are looking for alternative ways to provide the same amount of comfort and satisfaction while cutting down on their expenses. One area where energy and cost savings play a big role is in comfort cooling since a large amount of energy is spent for this. This study focused on the development of an absorption air – conditioning system utilizing aqua – ammonia solution as the refrigerant. Its objective is to design a laboratory set – up of an aqua – ammonia system making sure that there will be no leakage and to be able to attain the optimum coefficient of performance (COP). The components of the aqua – ammonia system were designed and fabricated to include the generator, rectifying column, absorber, condenser, evaporator, and heat exchangers. Most of the connections were arc –welded to make it seamless and prevent leaks. To simulate the performance of the system using waste heat, a Bunsen burner was used which was attached to a propane tank via a rubber hose with a regulator. One of the limitations of this study was the use of aqua ammonia solution with a concentration of only 28%. This is because high concentration of aqua ammonia solution is not readily accessible. The system was tested to determine its performance. Temperatures and pressures at various points in the system were measured while the cooling effect and the coefficient of performance were calculated. The maximum COP obtained by the system was 0.3685 while the maximum average COP was 0.078. Although these values were a bit low compared to the maximum attainable COP for an absorption refrigeration system, it proved its potential for air – conditioning application. The system did not have leakage during the entire testing. Further studies to improve the performance of this aqua – ammonia system were recommended.

Key Words: absorption refrigeration system; aqua – ammonia; coefficient of performance

1. INTRODUCTION

Absorption refrigeration is a process that generates a cooling effect by using two fluids and some quantity of heat input instead of electrical input. It is used primarily in large commercial and industrial applications. In these industries, the unit cost of heat would be low or there is thermal energy available that would otherwise be wasted. In other words, this type of refrigeration utilizes waste heat to provide the cooling effect needed. On the other hand, this system is more expensive and more complex, larger and less efficient than vapor-compression systems. The challenge for engineers today would be to increase the efficiency of an absorption refrigeration system while at the same time providing a much more compact and cost-efficient design.

An absorption refrigeration system is composed of the following major components: an evaporator, a condenser, a generator, an absorber and a pump. Figure 1 shows the schematic diagram of an absorption refrigeration system. This system is the same as the vapor compression system except that instead of a compressor, it is replaced by a generator, absorber and a pump while instead of mechanical and electrical energy, heat is utilized.

In the absorption system, the vapor is drawn from the evaporator by absorption into liquid with high affinity to the refrigerant. The refrigerant then is expelled from the solution in the generator by application of the heat and its temperature also increases. The refrigerant in the vapor phase passes through the condenser where heat is rejected and the refrigerant becomes liquefied. The liquefied refrigerant then flows back to the evaporator at a reduced pressure and the cycle is completed (Bangotra, 2012).

This study focused on the development of an absorption air-conditioning system utilizing aqua-ammonia solution as the refrigerant. Its objective is to design the aqua – ammonia absorption air – conditioner simulating a small – scale absorption cycle model making sure that there will be no leakage and be able to attain the optimum coefficient of performance (COP). Related studies would show that the maximum attainable coefficient of performance (COP) for this kind of system is 0.8. In the study of Bangotra, et al in 2012, the COP obtained from his design was 0.2079.

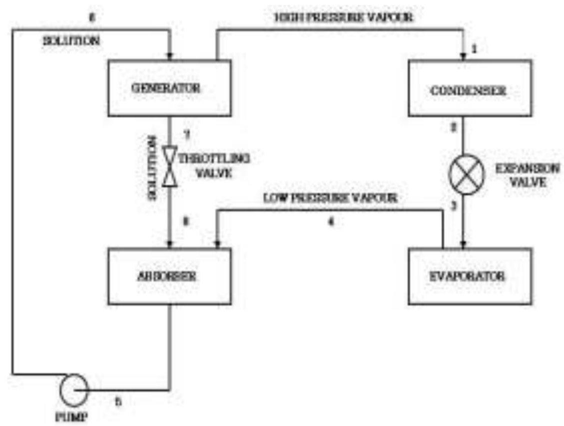


Figure1: Schematic diagram of an Absorption refrigeration system

2. METHODOLOGY

The aqua ammonia absorption system was designed based on the maximum attainable COP of 0.8. This maximum COP could be attained based on the calculated concentration of aqua ammonia solution which is 60%, however due to unavailability of the high concentration of the solution, the group utilized 28% aqua – ammonia solution.

Since ammonia reacts with numerous kinds of metals, the group made use of stainless steel and aluminium steel for the system. Table 1 gives the summary of the materials used for the design. Most of the connections were arc – welded on the components so as to make it seamless and prevent leaks. Pipe fittings were treaded on to each other.

As for the burner assembly, the group used a Bunsen burner attached to a propane tank via a rubber hose with regulator. The regulator served as the main control for the amount of gas flowing while for the flame temperature would be at the Bunsen burner itself.

This aqua – ammonia air-conditioning unit has a heat exchanger put in between the generator and the absorber. On the other hand, the fluid coming in from the absorber being pumped to the rectifying column is being pre-heated as it passes through the heat exchanger. This is to improve the performance of the system.

Table 1: Materials Used for components and Piping

Component	Materials Used
Generator	Stainless Steel
Rectifying Column	Stainless Steel
Absorber	Stainless Steel
Condenser	Aluminum Steel
Evaporator	Aluminum Steel
Solution Heat Exchanger	Stainless Steel
Refrigerant Heat Exchanger	Stainless Steel
Refrigerant Receiver	Stainless Steel

Based on the maximum attainable COP of the system, the components were designed using the general equation defining the maximum heat transfer through a heat exchanger:

$$Q = U \times A \times LMTD$$

where: Q = heat transfer, kw
U = overall heat transfer coefficient, KW/m^2-K
LMTD = logarithmic mean temperature difference, K

The fabricated components were then assembled and subjected to leak testing by using pressurized air after which the aqua – ammonia solution was charged to the system. The system was then tested using varying temperatures and the COP of the system was computed using the following equation:

$$COP = Qe / Qgen$$
$$Qe = m_1(h_{12} - h_{11})$$
$$Qgen = m_6h_6 + m_{15}h_{15} - m_5h_5$$

where: COP = coefficient of performance
Qe = heat transferred at the evaporator
Qgen = heat transferred at the generator
m = mass flow rate
h_{12} = enthalpy of the refrigerant leaving the evaporator
h_{11} = enthalpy of the refrigerant entering the evaporator
h_6 = enthalpy of the refrigerant vapor leaving the generator
h_5 = enthalpy of the refrigerant entering the evaporator
h_{15} = enthalpy of the refrigerant leaving the generator

3. RESULTS AND DISCUSSION

Based on the maximum COP attainable for the system, the calculated dimensions for the different components are shown in Table2.

Table 2: Dimensions of Components

Component	Diameter (m)	Length (m)
Generator	0167	0.25
Rectifying Column	0.15	0.525
Evaporator	0.24	0.36
Condenser	0.267	0.4
Solution Heat Exchanger	0.21	0.27
Refrigerant Heat Exchanger	0.178	0.265
Absorber	0.135	0.54
Refrigerant Receiver	0.147	0.221

Figure 2 shows the schematic diagram of the system with labels on it. The flow of the refrigerant can be traced using the arrows. The mass and energy calculations corresponding to this can be seen in Table 3.

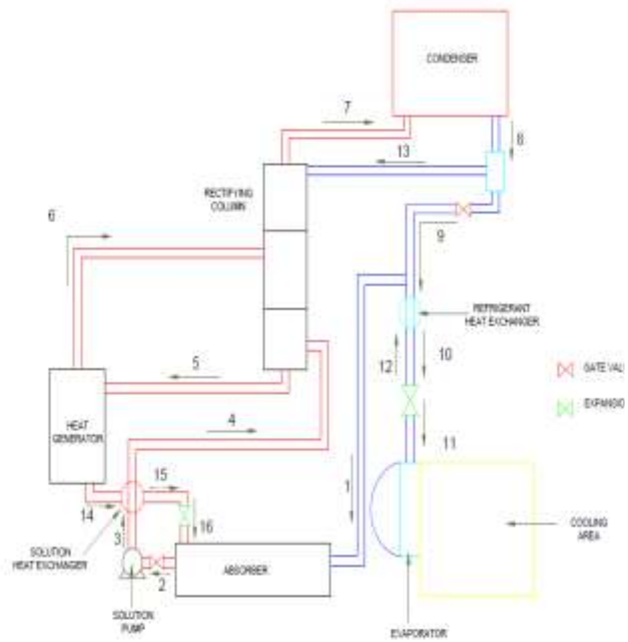


Figure 2: Schematic diagram with state points

During the actual testing the temperature and pressure were measured at various points in the system at a certain time interval between 20 to 30 minutes, while the enthalpies were read from the chart and tables. The heat transferred through the evaporator and the generator and the COP of the system were then calculated.

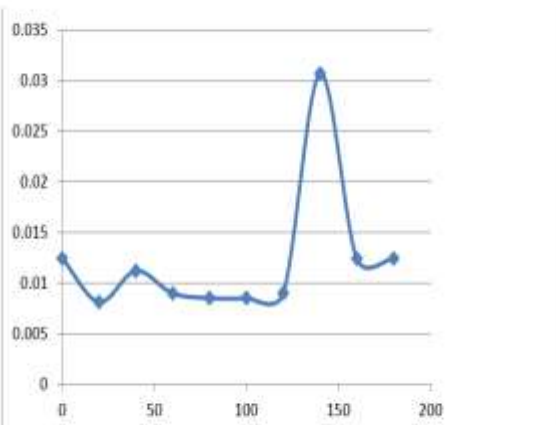
Table 3: Mass and Energy Calculation Equation

Component	**Mass Balance**	**Energy Balance**
Evaporator	$m_1 = m_{11} = m_{12} = m_9 = m_{10}$	$Q_E = m_1(h_{12} - h_{11})$
Condenser	$m_7 = m_8$	$Q_C = m_7 (h_7 - h_8)$
Refrigerant Receiver	$m_7 = m_{13} + m_9$	
Refrigerant Heat Exchanger	$m_1 = m_{11} = m_{12} = m_9 = m_{10}$	$Q_{RHX} = m_1 (h_{12} + h_9 - h_{10} - h_1)$
Absorber	$m_2x_2 = m_{16}x_{16} + m_1x_1$	$Q_{abs} = m_1h_1 + m_{16}h_{16} - m_2h_2$
Solution Heat Exchanger	$m_4 = m_{15}$; $m_3 = m_{14}$	$Q_{SHX} = m_4h_4 + m_{15}h_{15} - m_3h_3 - m_{14}h_{14}$
Generator	$m_5x_5 = m_6x_6 + m_{14}x_{14}$	$Q_{Gen} = m_6h_6 + m_{15}h_{15} - m_5h_5$
Rectifying Column	$m_6 = m_7 + m_{h2o}$; $m_5 = m_{13} + m_4 + m_{h2o}$	

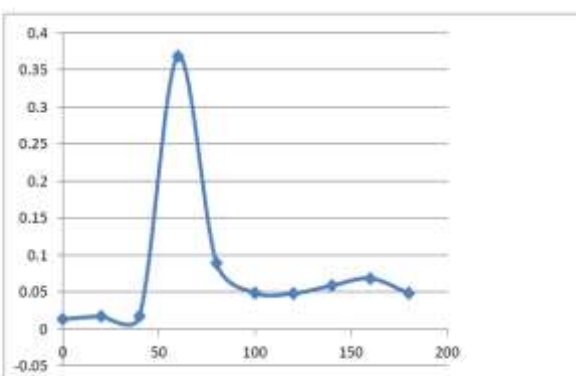
Table 4 shows the average COP and the highest COP attained on a per day basis. Figures 3, 4, 5 and 6 show the graphical representation of the COPs attained for the 4 – day testing period. The results show that the COP obtained varies from a minimum value of 0.007 in day 3 to a maximum value of 0.3685 in day 2. The average value of COP, however, varies from a minimum value of 0.010281 to a maximum value of 0.078. These values are a bit low compared to the maximum attainable value of 0.8. The low values of COP could be attributed to the low concentration of ammonia used. However, the result of the testing showed that the evaporator was able to produce a cool air of 28^0C during day 2 which means that this system has potential of producing cooling effect for use in an air – conditioning system. It was also observed that during the entire testing, there were no refrigerant leaks in the system.

Table 4: Average COP and Highest COP attained

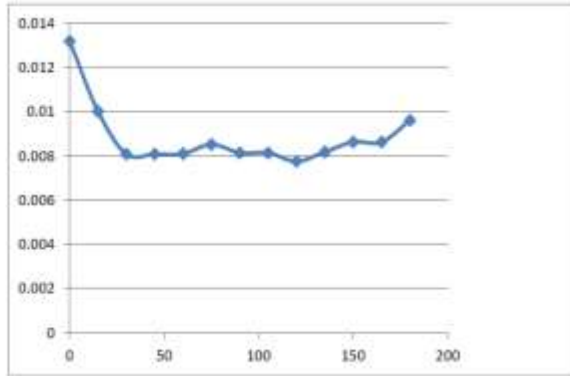
Day	Average COP attained	Highest COP attained
1	0.012235	0.030652
2	0.078007	0.368505
3	0.008848	0.010012
4	0.010281	0.012596



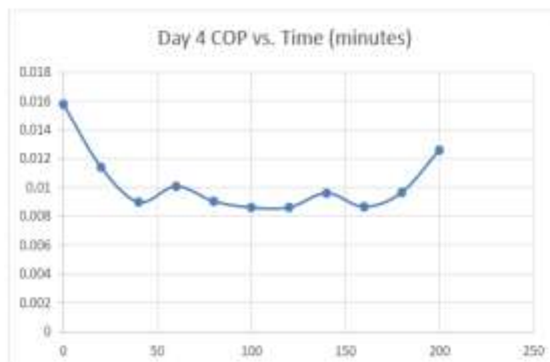
time (minutes)
Figure 3: Day 1 - COP with respect to time



time (minutes)
Figure 4: Day 2 - COP with respect to time



time (minutes)
Figure 5: Day 3 - COP with respect to time



time (minutes)
Figure 6: Day 4 - COP with respect to time

The final prototype of the small – scale model of the designed system can be seen in Figure 7.

Fig. 7 – Final prototype of the designed aqua – ammonia system

CONCLUSIONS

The small – scale model of the absorption air – conditioning system using aqua – ammonia solution designed for instructional laboratory proved to have potential for air – conditioning application. With a maximum COP of 0.3685 and a maximum average COP of 0.078 obtained during the actual testing, although a bit low compared to the maximum attainable value, would show that it produced cooling effect. In fact, cool air with a temperature of 28^0C was produce during the actual operation of the system. There were no leakages observed during the entire testing.

In order to improve the performance of the system it is suggested to use high concentration of aqua ammonia solution, taking into consideration the safety of handling. It is also suggested to consider the placement of the burner in the generator in such a way that the heat transfer to the refrigerant will be optimized. Further studies on this kind of system may use actual waste heat from exhaust gases.

6. REFERENCES

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