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Computing model and Application of NH3-H2O Absorption Refrigeration System

Adel Akair
*[*1]Department of Mechanical Engineering,Higher Institute of Sciences and Technology-Garyan*

ABSTRACT
A theoretical investigation of an ammonia-water absorption refrigeration system has been performed. A mathematical model for a single stage ammonia-water absorption system has been set up. A sample calculation proves that the proposed model can be used to predict the performance of ammonia-water absorption refrigeration system. The application results show the computing model also can be used to analyse the effect of any changes of the parameters of the system to the Coefficient of Performance (COP) of the system.

KEYWORDS: *computer model,ammonia-water absorption refrigeration system*

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I. INTRODUCTION

Ammonia-water absorption refrigeration system was invented for nearly one and a half centuries. And since then, it has been widely used until 1960s. In the 1970s, the energy efficiency issues ruled this technology out, because of its low COP (< 0.8 for a single stage absorption system). Vapour compression refrigeration systems, which use chlorofluorocarbon (CFCs) as refrigerants, became dominant. However, another environmental issue has become very sensitive due to public awareness of the damaging effect of CFCs emission on the ozone layer, has recalled the interest in absorption refrigeration.

There are four advantages for ammonia absorption refrigeration system:

- It avoids the use of ozone-depletion refrigerants, which make it environmentally friendly;
- It can be powered by waste energy (e.g., waste heat from power station), which make it energy efficient;
- Hence, it reduces the emissions of green house gases;
- Compared with water-lithium bromide absorption cycle, it can produce lower temperature (below 0 °C), which make it suitable for refrigeration.

Some researches have been done on this area (Alizadeh et al in1979 [1]; Shiqiong Xu et al in 1984[2]; Elegido, E. et al in 1991[3]; Bulgan, Ahmet T. in 1995 and 1997[4], [5]; Sun, D.W, in 1997 and1998 [6], [7]). For the simulation of ammonia absorption refrigeration systems, the key factor is the property calculation of ammonia-water solution and its vapour at different points in the system. The property calculation has been done first by Ziegler, B.and Trepp, Ch. (1984) [8]; later by Bourseau, P. et al, 1986 [9]; and by Ibrahim, O. M.; Klein, S. A. [10]; and Patek, J. et al (1995) [11]. Mathematical models for computer-simulation of their performance have been devised. In all the above models, there are many similarities in that they simulate the cycle fairly reasonably, but there is one weak assumption, this being that the concentration of the vapour at the generator exit is assumed (99% or 100%). This is not precisely true, it should be able to be calculated.

1. Single-effect vapour absorption system and the mathematical model

The mathematical model for this study has been developed with the following assumptions:

- The heat losses and unintentional pressure drops in the pipelines and system components are negligible.
- There is neither sub-cooling nor super-heating at the condenser and the evaporator respectively. Consequently, the refrigerant is assumed to be at the saturated state when leaving both.
- The processes at all throttle valves are assumed to be adiabatic, resulting in constant enthalpy processes.
- Heat transfer to and from the surroundings to the system is negligible other than that specified at the components.
- Circulating pump is isentropic (ASHRAE, Fundamentals 1997[12].

Fig 1 illustrates a single-effect ammonia-water absorption refrigeration system. The strong solution is pumped to generator (the pressure is raised to high pressure P_G). The refrigerant in generator is boiled off, and the vapour goes to condenser. The remaining solution (weak solution) flows back to absorber through a throttle valve (the pressure reduces to P_A). The high-pressure liquid refrigerant from condenser passes into evaporator through an expansion valve that reduces the pressure of the refrigerant to the low pressure existing in evaporator (P_E). The liquid refrigerant vaporises in evaporator by absorbing heat from the material being cooled and the resulting low-pressure vapour passes to absorber, where it is absorbed by the weak solution coming from generator and forms the strong solution. Then, it completes the total cycle. Heat exchanger 2 (pre-heater) is used to pre-heat the fluid from absorber to generator; Heat exchanger 1 (pre-cooler) is used to pre-cool the fluid from Condenser to Evaporator, which raise the total efficiency of the system.

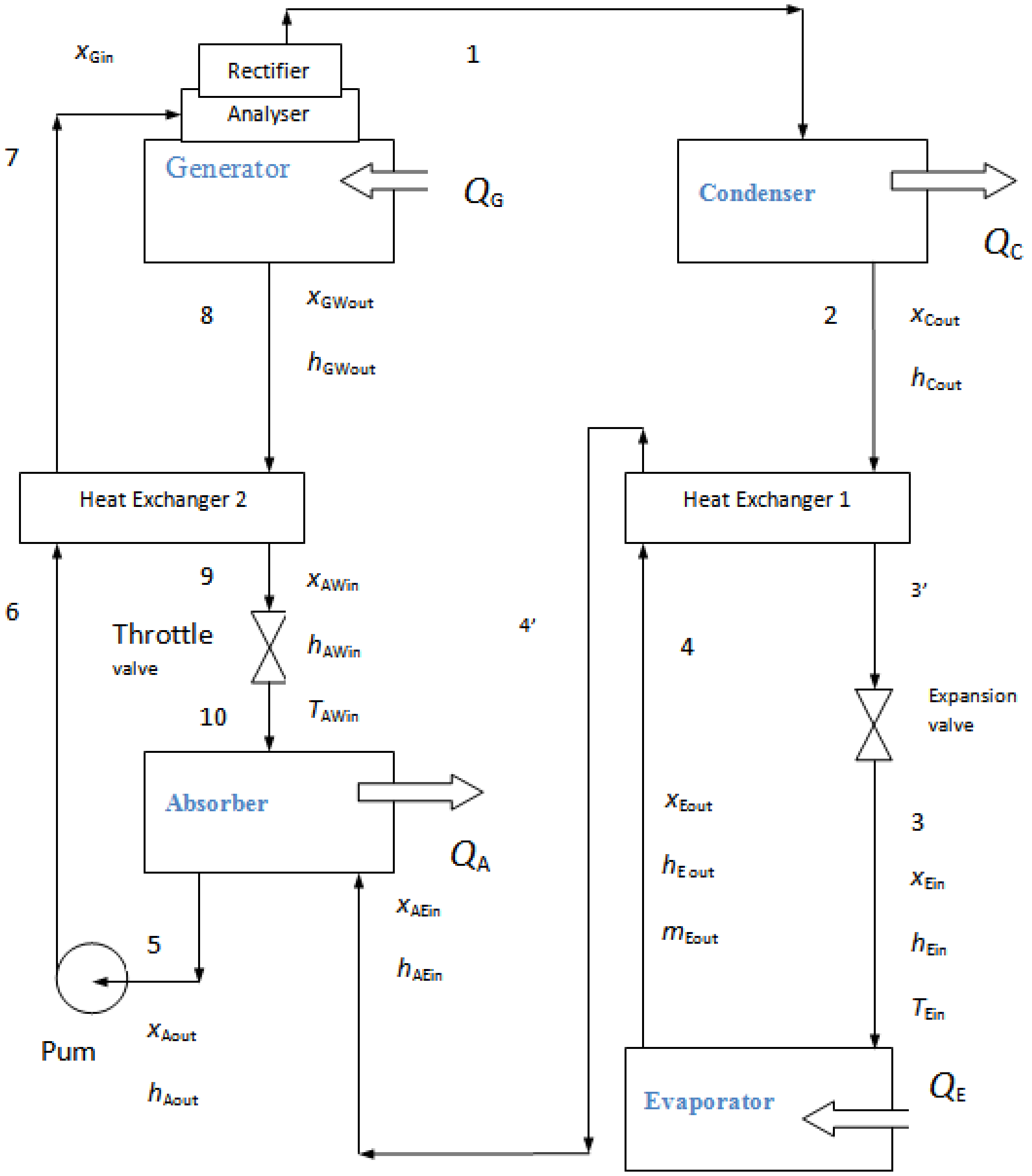

Fig 1 The single-effect ammonia-water absorption refrigeration system

The mathematical model for absorption cycle is based on the mass continuity, material continuity, and energy conservation principle. These are linked with equations giving the chemical and thermodynamic properties of ammonia-water solution and vapour, as shown in the following three equations which can be applied to any part of the system.

(1) Mass balance: $\Sigma m = 0$ (1)

(2) Material balance (or partial mass balance): $\Sigma m x = 0$ (2)

(3) Energy balance $\Sigma Q + \Sigma m h = 0$ (3)

Applying equations (1) – (3) to the individual components of the system, lead to the following equations (see Fig 1):

- **For mass balance:**

If the mass handled by the pump is m_{Aout} and the refrigerant vapour distilled is m_{GVout}, then by mass balance, the weak solution returning to the absorber is (m_{Aout} - m_{GVout}).

$$m_{GWout} = m_{Aout} - m_{GVout} \quad (1.1)$$

where, m_{Aout} --- mass flow rate of Strong Solution from Absorber to Generator (kg/min), m_{GVout} --- mass flow rate of refrigerant vapour from Generator to Condenser(kg/min), m_{GWout} --- mass flow rate of weak solution from Generator to Absorber(kg/min).

- **For Material balance:**

Applying material balance to the generator-analyser-Rectifier, taking the refrigerant ammonia as the material under consideration, the flow rates of the strong solution and weak solution can be determined:
In which X_{Aout} represents the refrigerant concentration of rich (strong) solution, X_{Gwout} represents the refrigerant concentration of poor (weak) solution , X_{GVout} represents the refrigerant concentration of vapour.

$$m_{Aout} = \frac{X_{GVout} - X_{Aout}}{X_{Aout} - X_{GWout}} m_{GVout} \quad (2.1)$$

$$f = \frac{m_{Aout}}{m_{GVout}} \quad (2.2)$$

From equation (1.1) and (2.1), the circulation ratio of the system can be derived as:

- **For energy balance:**

Absorber: Heat removed from absorber

$$Q_A = m_{Ein} h_{Ein} + m_{AWin} h_{AWin} - m_{Aout} h_{Aout} \quad (3.1)$$

Generator: Heat input to generator

$$Q_G = m_{GVout} h_{GVout} + m_{Gwout} h_{GWout} - m_{Gin} h_{Gin} \quad (3.2)$$

Liquid-liquid heat exchanger (preheater): The energy balance for the solution heat exchanger (preheater) is as follows:

$$Q_{ph} = m_{Aout} (h_{Gin} - h_6) = - \varepsilon_{ph} m_{GWout}(h_{AWin} - h_{GWout}) \quad (3.3)$$

$$h_6 = h_5 + W_{me} \quad (3.3a)$$

$$h_{Gin} = h_6 + \frac{m_{GWout}}{m_{Aout}} (h_{GWout} - h_{AWin}) \quad (3.3b)$$

Similarly,

$$T_9 = \varepsilon_{ph} T_A + (1 - \varepsilon_{ph}) T_G \quad (3.3c)$$

Pump: The pump work is given by

$$W_{me} = m_{Aout} v_{Gin} (P_G - P_A) / \eta_p \quad (3.4)$$

Whereη_p is the pump efficiency (here , assume $\eta_p = 1$), and v_{Gin}--- is the specific volume to generator (m^3/kg)

Condenser: Heat removed from condenser

$$Q_C = m_{GVout}\,(h_{Cout} - h_{GVout}) \qquad (3.5)$$

Liquid-vapour heat exchanger (precooler):

$$Q_{pc} = m_{Eout}(h_{AEin} - h_{Eout}) = - m_{GVout}\,(h_{Ein} - h_{Cout}) \qquad (3.6)$$

Evaporator:

$$T_{AEin} = T_E + \varepsilon_{pC}\,(T_C - T_E) \qquad (3.6a)$$

$$h_{Ein} = h_{Cout} + (h_{Eout} - h_{AEin}) \qquad (3.6.b)$$

$$Q_E = m_{Ein}\,(h_{Eout} - h_{Ein}) \qquad (3.7)$$

The overall energy balance gives

$$Q_G + Q_E + W_{me} = Q_C + Q_A (3.8)$$

$$COP = \frac{Q_e}{Q_g + W_{me}} \qquad (3.9)$$

The system performance: **Coefficient of performance(COP)**

II. THE CALCULATION OF PROPERTIES OF AMMONIA-WATER MIXTURE

2.1 Pressure, concentration and Temperature

The equilibrium calculations of the properties: Empirical relations obtained by regression analysis of the thermodynamic data of the ammonia system are used. The relation among saturation pressure P (atm), temperature T (K), and concentration
X(decimal) (Bourseau, P. et al, 1986), is given by equation (4):

Which can be re-written as:

The constants A and B are functions of the liquid phase composition.

A = 7.44 – 1.767X + 0.9823X2 + 0.3627X3 (4.3)

B = 2013.8 – 2155.7X + 1540.9X2 – 194.7X3 (4.4)

2.1.1 Given T (K), X(decimal), P(atm.) can be calculated by equation (4.1)

2.1.2 Given P (atm.), X(decimal), T (K) can be calculated by equation (4.2)

2.1.3 Given P(atm.), T (K), X(decimal) can be calculated by equation (4.5)

From equation (4), (4.3), (4.4),

X3 + a X2 + b X + c = 0 (4.5)

Where a = (0.9823 – 1540.9 / T) / (0.3627 + 194.7/T)

b = (- 1.767 + 2155.7 / T) / (0.3627 + 194.7/T)

c = (7.44 – log10 P – 2013.8 / T) / (0.3627 + 194.7/T)

Let

X = y – a / 3

Then

y3 + py + q = 0

If

Δ = (q/2)2 + (p/3)3 > 0

There will be a real root for equation y3 + py + q = 0.

Then the solution is:

$$y_1 = (-q/2 + ((q/2)^2 + (p/3)^3)^{1/2})^{1/3} + (-q/2 - ((q/2)^2 + (p/3)^3)^{1/2})^{1/3}$$

Where, $p = - a^2/3 + b$

$q = 2 a^3 / 27 – b a/3 + c$

Then,

$X = y_1 – a / 3$

2.1.4 The calculation of temperature of ammonia solution (liquid phase)

The temperature of ammonia-water solution (liquid phase), also can be calculated by the following equation (Patek, J. et at, 1995):

Where *T* is the temperature of ammonia-water solution, P is the pressure at the point of the system (kPa), and *x'*

$$T\,(p,x') = T_0 \sum_i a_i\,(1-x')^{m_i}\,[\ln(\frac{p_0}{p})]^{n_i} \qquad (5)$$

is the ammonia mole fraction in the liquid phase, P_0 is the reference pressure (P_0 = 2000kPa), T_0 is the reference temperature (T_0 =100 K), a_i, m_i, n_i are the coefficients of the equation, the values a_i, m_i, n_i are stated in table 1.

Table 1 Exponents and coefficients of Equation (5)

i	m_i	n_i	a_i	i	m_i	n_i	a_i
1	0	0	3.22302E+00	8	1	2	1.06154E-02
2	0	1	-3.84206E-01	9	2	3	-5.33589E-04
3	0	2	4.60965E-02	10	4	0	7.85041E+00
4	0	3	-3.78945E-03	11	5	0	-1.15941E+01
5	0	4	1.35610E-04	12	5	1	-5.23150E-02
6	1	0	4.87755E-01	13	6	0	4.89596E+00
7	1	1	-1.20108E-01	14	13	1	4.21059E-02

2.1.5 The calculation of temperature of ammonia solution (gas or vapour phase)

The temperature of ammonia-water solution (gas phase), also can be calculated by the following equation (Patek, J. et at, 1995):

$$T\,(p,x'') = T_0 \sum_i a_i\,(1-x'')^{m_i/4}[\ln(\frac{p_0}{p})]^{n_i} \qquad (6)$$

Where *T* is the temperature of ammonia-water solution (gas phase), P is the pressure at the point of the system (kPa), and *x''* is the ammonia mole fraction in the gas phase, P_0 is the reference pressure (P_0 = 2000kPa), T_0 is the reference temperature (T_0 =100 K), a_i, m_i, n_i are the coefficients of the equation, the values a_i, m_i, n_i are stated in table 2.

Table 2 Exponents and coefficients of Equation (6)

i	m_i	n_i	a_i	i	m_i	n_i	a_i
1	0	0	3.24004E+00	10	3	0	-2.01780E+01
2	0	1	-3.95920E-01	11	3	1	1.10834E+00
3	0	2	4.35624E-02	12	4	0	1.45399E+01
4	0	3	2.18943E-03	13	4	2	6.44312E-01

5	1	0	-1.43526E+00	14	5	0	-2.21246E+00
6	1	1	1.05256E+00	15	5	2	-7.56266E-01
7	1	2	-7.19281E-02	16	6	0	-1.35529E+00
8	2	0	1.22362E+01	17	7	2	1.83541E-01
9	2	1	-2.24368E+00				

2.1.6 The concentration (mole fraction)of ammonia in gas phase

The concentration (mole fraction)of ammonia in gas phase is obtained by using the equation proposed by J.Patek and J.Klomfar (Patek, J. et at, 1995), as shown in equation (7):

$$x''(p,x') = 1-\exp\left[\ln(1-x')\sum_i a_i\left(\frac{p}{p_0}\right)^{m_i} x'^{\,n_i/3}\right] \tag{7}$$

Where x'' is the concentration (mole fraction)of ammonia in gas phase, P is the pressure at the points of the system (kPa), and x' is the ammonia mole fraction in the liquid phase, P_0 is the reference pressure (P_0 = 2000kPa), a_i, m_i, n_i are the coefficients of the equation, the values a_i, m_i, n_i are stated in table 3.

Table 3 Exponents and coefficients of Equation (7)

i	m_i	n_i	a_i	i	m_i	n_i	a_i
1	0	0	1.98022017E+01	8	3	2	-3.42198402E+03
2	0	1	-1.18092669E+01	9	4	3	1.19403127E+04
3	0	6	2.77479980E+01	10	5	4	-2.45413777E+04
4	0	7	-2.88634277E+01	11	6	5	2.91591865E+04
5	1	0	-5.91616608E+01	12	7	6	-1.84782290E+04
6	2	1	5.78091305E+02	13	7	7	2.34819434E+01
7	2	2	-6.21736743E+00	14	8	7	4.80310617E+03

2.1.7 The relations between ammonia mole fraction (x') and mass fraction (x).

The relations between ammonia mole fraction and mass fraction in the ammonia-water mixture are given as follows:

$$x' = \frac{x/17.03}{x/17.03+(1-x)/18.015} \tag{8}$$

Where

x' ---ammonia mole fraction

x --- ammonia mass fraction

17.03 --- ammonia molecular mass

18.015 --- water molecular mass

And

$$x = \frac{17.03x'}{17.03x'+18.015(1-x')} \tag{9}$$

2.2 Enthalpies:

In order to perform thermal calculations on the ammonia absorption cycle, the enthalpy data must be available for the working pair at all crucial points in the cycle.

2.2.1 The specific enthalpy values of the liquid phase of Ammonia-Water Solution

The enthalpies of the binary solution at different points of the system are obtained in (kJ/kg) by using the equations proposed by J.Patek and J.Klomfar (Patek, J. et at, 1995), as shown in equation (10):

Where h_l is the specific enthalpy of the ammonia-water solution (kJ/kg), T is the temperature of solution (K),

$$h_l\ (T, x') = h_0 \sum_i a_i \left(\frac{T}{T_0} - 1\right)^{m_i} x'^{n_i} \tag{10}$$

and x' is the ammonia mole fraction in the liquid phase,
T_0 is the reference temperature (T_0 = 273.16 K), h_0 is the reference enthalpy (h_0 = 100 kJ/kg), a_i, m_i, n_i are the coefficients of the equation, the values a_i, m_i, n_i are stated in table 4.

Table 4 Exponents and coefficients of Equation (10)

i	mi	ni	ai	i	mi	ni	ai
1	0	1	-7.61080E+00	9	2	1	2.84179E+00
2	0	4	2.56905E+01	10	3	3	7.41609E+00
3	0	8	-2.47092E+02	11	5	3	8.91844E+02
4	0	9	3.25952E+02	12	5	4	-1.61309E+03
5	0	12	-1.58854E+02	13	5	5	6.22106E+02
6	0	14	6.19084E+01	14	6	2	-2.07588E+02
7	1	0	1.14314E+01	15	6	4	-6.87393E+00
8	1	1	1.18157E+00	16	8	0	3.50716E+00

2.2.2 The specific enthalpy values of the gas phase of Ammonia-Water vapour

The enthalpies of the gas phase of Ammonia-Water vapour are also obtained in (kJ/kg) by using the equation proposed by J.Patek and J.Klomfar (Patek, J. et at, 1995), as shown in equation (11):

$$h_g\ (T, x'') = h_0 \sum_i a_i \left(1 - \frac{T}{T_0}\right)^{m_i} (1 - x'')^{n_i} \tag{11}$$

Where h_g is the specific enthalpy of the ammonia-water vapour (kJ/kg), T is the temperature of vapour (K), and x'' is the ammonia mole fraction in the vapour phase,
T_0 is the reference temperature (T_0 = 324K), h_0 is the reference enthalpy (h_0 = 1000 kJ/kg), a_i, m_i, n_i are the coefficients of the equation, the values a_i, m_i, n_i are stated in table 5.

Table 5 Exponents and coefficients of Equation (11)

i	m_i	n_i	a_i	i	m_i	n_i	a_i
1	0	0	1.28827E+00	10	1	3	1.64508E+01
2	1	0	1.25247E-01	11	2	3	-9.36849E+00
3	2	0	-2.08748E+00	12	0	4	8.42254E+00
4	3	0	2.17696E+00	13	1	4	-8.58807E+00
5	0	2	2.35687E+00	14	0	5	-2.77049E+00
6	1	2	-8.86987E+00	15	4	6	-9.61248E-01
7	2	2	1.02635E+01	16	2	7	9.88009E-01
8	3	2	-2.37440E+00	17	1	10	3.08482E-01
9	0	3	-6.70515E+00				

2.3Specific volume

The relation between the specific volume v (m^3/kg), temperature T (K) and concentration X (decimal) of saturated ammonia-water solution is fitted by Da-Wen
Sun (Sun, Da-Wen, 1997) with the source data taken from ASHRAE handbook [12], and given as follows (the coefficients are listed in table 6):

Table 6 Exponents and coefficients of Equation (12)*

i	j	a_{ij}	i	j	a_{ij}
0	0	9.9842E-04	0	2	-1.2006E-04
1	0	-7.8161E-08	1	2	-1.0567E-05
2	0	8.7601E-09	2	2	2.4056E-07
3	0	-3.9076E-11	3	2	-1.9851E-09
0	1	3.5489E-04	0	3	3.2426E-04
1	1	5.2261E-06	1	3	9.8890E-06
2	1	-8.4137E-08	2	3	-1.8715E-07
3	1	6.4816E-10	3	3	1.7727E-09

* Standard error = 4.058×10^{-6}, mean deviation $=2.195\times10^{-3}$

$$v(T,X)=\sum_{j=0}^{3}\sum_{i=0}^{3}a_{ij}(T-273.15)^{i}X^{j} \qquad (12)$$

III. COMPUTING SIMULATION AND RESULTS

The main investigation parameters are: heat removed from absorber $Q_{A;}$ heat input to generator $Q_{G;}$ heat removed from condenser Q_C; refrigerating effect Q_E; the coefficient of performance of the ammonia absorption system (COP). The equations (1.1) – (12) shown above compose the mathematical model for the ammonia-water absorption system. The simulation was performed on a well-designed software. The flow chart for the simulation program of ammonia absorption system is shown in Fig 2.

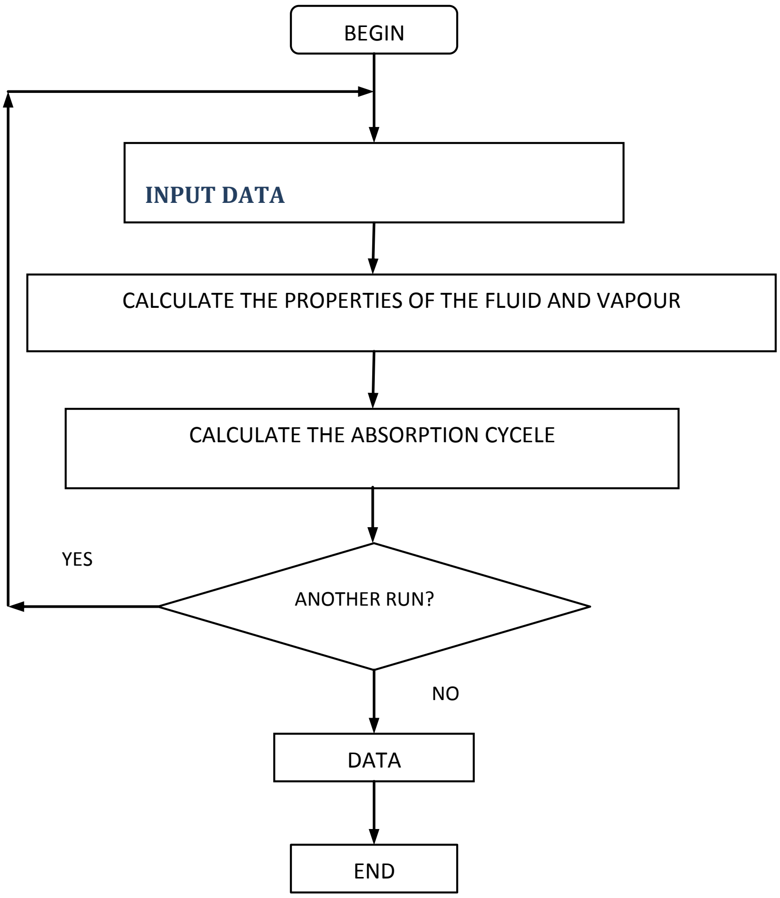

Fig2 the flow chart for the calculation program

Table 7 presents the state points data at different components for the single-effect ammonia-water absorption refrigeration system from the simulation [7]. The inputs are::

- Absorber temperature T_A = 25 °C
- Generator temperature T_G = 100 °C
- Condenser temperature T_C = 30 °C
- Evaporator temperature T_E = -5 °C
- Effectiveness of the heat exchanger
  pre-heater $\varepsilon_{ph} = 0.80$

pre-cooler $\varepsilon_{pc} = 0.00$

- The pressures of the system
  high pressure $P_G = P_C = 1166.92$ kPa
  low pressure $P_E = P_A = 354.42$ kPa
- The refrigerant mass flow rate: m_1 = 1 kg/min (= $m_{\mathrm{GVout}} = m_{\mathrm{Cout}} = m_{\mathrm{Eout}}$).

Table 7 Thermodynamic properties at various state in ammonia-water system

Fluid state		t (C)	P (kPa)	X	m(kg/min)	h(kJ/kg)
Generator	ref exit (1)	100	1166.92	98.93%	1.00	1214.02
	sol inlet(7)		1166.92	52.62%	3.42	59.46
	sol exit (8)	100	1166.92	33.51%	2.42	223.58
Condenser	ref exit (2)	30	1166.92	98.93%	1.00	130.51
Evaporator	ref exit (4)	-5	354.42	98.93%	1.00	1259.09
Absorber	sol exit (5)	25	354.42	52.62%	1.00	-140.7
	sol inlet(10)	40	354.42	33.51%	2.42	-54.29

Table 7 also shows the results of enthalpy at different points from the calculation.
Table 8 presents the simulation results of the energy flow and COP of the ammonia-water absorption system.

Table 8 Energy flow for each component and the energy balance

Q_G(kW)	Q_C (kW)	Q_E (kW)	Q_A (kW)	W_{me}(kW)	Q_{ph}(kW)	COP
25.87	18.06	18.81	26.82	0.057	11.23	0.7254

IV. THE APPLICATION OF THE MODEL TO EVALUATE THE INFLUENCE OF THE SYSTEM PARAMETERS TO ITS COP

The model may be applied to evaluate the influence of the system parameters to its performance. The following results are the separate investigations of the effect of different parameters to the system COP by applying the computing model. The following discussions are all based on the sample above. When a parameter is analysed, the other parameters are treated as fixed constants.

Fig 3 shows the influence of the effectiveness $\boldsymbol{\varepsilon_{ph}}$ (Preheater) to the system COP. It can be seen that the COP of the system increases while the $\boldsymbol{\varepsilon_{ph}}$ increases. The increases are from 0.50 to 0.81 while the $\boldsymbol{\varepsilon_{ph}}$ increases from 0.00 to 1.00. the difference is 0.31, the increase rate reaches to 37.4%.

Fig 4 presents the effect of generator temperature to the system COP.From the figure, it may see that the influence of generator temperature (t_G) to COP is quite obvious, when t_G increases, COP also increases, especially when t_G is higher than 150 ºC. At the temperature of 70 ºC the COP is 0.6462, but while the temperature reaches 180 ºC, the COP increases to 0.9121. The difference is 0.2101; the relative difference gets to 23.0%.

Fig 5 shows the influence of the effectiveness of pre-cooler to the system COP.There is a little influence for the ε_{pc} to the COP. From $\varepsilon_{pc} = 0.00$ to 1.00, the COP increases from 0.7254 to 0.7442. The increase is very limited, only 2.5%.

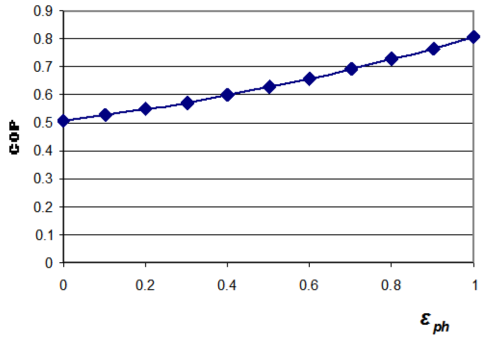

Fig 3 The influence of ε_{ph} to COP

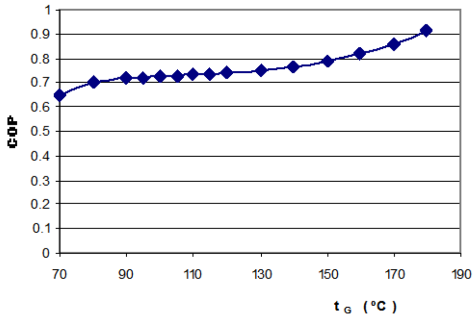

Fig 4 The influence of generator temperature to COP

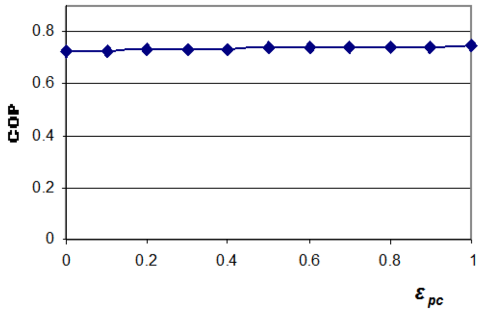

Fig 5 The influence of pre-cooler effectiveness to COP

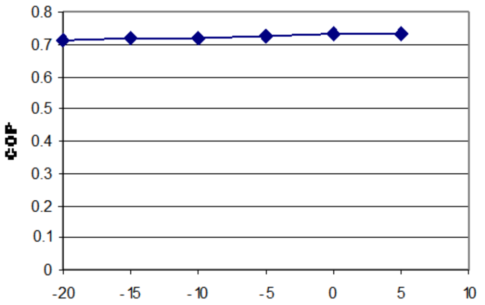

Fig 6 The influence of evaporator temperature

Fig 6 shows the influence of evaporator temperature to the system COP. Along with the increase of the temperature t_E, COP also increases, from 0.7123 at the temperature of -20 ºC to 0.7327 at the temperature of 5 ºC. This proves that the fact that the lower of the evaporator temperature, the lower to the system COP. The difference is 2.8%.

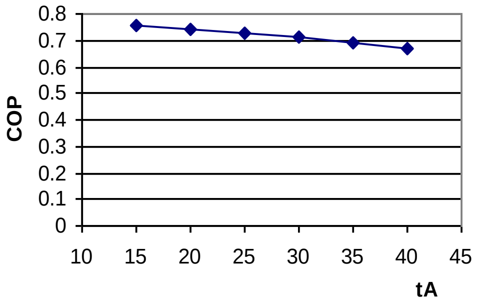

Fig 7 The influence of absorber temperature to COP

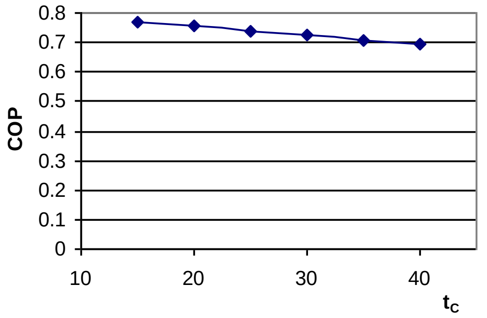

Fig 8 The influence of Condenser temperature to COP

Fig 7 presents the figure of the influence of absorber temperature to the system COP. The figure shows that the COP of the system will drop as the absorber temperature increases, the COP from 0.7577 at 15 ºC of the absorber temperature descends to 0.6712 at 40 ºC of the absorber temperature. The value of COP between the maximum and the minimum is 0.0865; the relative difference is 11.4%.

Fig 8 represents the influence of condenser temperature to the system COP. There is a trend similar to that of Fig 7. The COP drops along with the increase of the condenser temperature. The value of COP descends from

0.7719 at the condenser temperature 15 ºC to 0.6936 at the temperature 40 ºC. The difference of COP between the maximum and the minimum is 0.0783; the relative difference is 10.1%.

From the results above, it can be seen that any changes of any one of the system parameters, will cause the change of the performance of the system.

- The effectiveness of pre-heater is a factor of the largest effect to the COP. The higher is the ε_{ph}, the higher is the COP.
- The temperature of generator comes to the second large effect to the COP. The same trend as the case of ε_{ph}, the higher is the t_G and, the higher the COP is.
- As for the effectiveness of pre-cooler ε_{pc}, the effect to COP is very little, the difference of maximum COP and the minimum COP is only 2.5%, so the influence is negligible.
- The influence of evaporator temperature to the COP is also small, which is only 2.8% difference.
- The influence of absorber temperature and condenser temperature to the COP are nearly the same, the relative difference is 11.4% and 10.1% respectively.

V. CONCLUSION

A theoretical investigation of a single stage ammonia-water absorption refrigeration system has been carried out. A computational model is set up to calculate the performance of the system. A sample calculation is presented. The results show that the model is capable of calculating the parameters of a single stage ammonia-water absorption refrigeration system, which can be used to predict the performance of the system. An application of the model to evaluate the influence of the system parameters to its COP is also offered. The results from the application prove that the model can also be used to analyse the effect of any changes of the parameters of the system to the Coefficient of Performance (COP) of the total system.

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