CONTRIBUTION TO IMPROVING THE PERFORMANCE COEFFICIENT OF A SOLAR ABSORPTION REFRIGERATION SYSTEM

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ABSTRACT
It is easy to notice lately, the significant growth that the energy market, which opens the doors to a race for new energy sources and new methods for obtaining the benefit of energy. It is in the same vein as some industrial and research laboratories with an interest environment increasingly growing development of absorption chillers that have many advantages.
The absorption refrigeration systems using ammonia-water couple now become a promising solution for cooling due to their many advantages. These systems use greener refrigerants to the environment. They also have the advantage of using a free source of heat and clean by coupling with a solar heat source.
The objective of this work is to study a refrigeration loop absorption using the ammonia-water pair purpose of determining its performance and suggest improvements. This improvement in the coefficient of performance "COP" is based on changes to the system to absorption itself. Our approach is to increase the number of boilers and absorbers (three boilers, condenser, evaporator and two absorbers). The modifications brought us the following advantages: the possibility of operating with temperatures vary around 70 °C panels that require less costly simple plans and elimination of the distillation column which is explained by the reduction in the overall cost of the facility with improved COP.

Keywords: *Absorption, Refrigeration, Solar, Improvement, COP.*

1. INTRODUCTION

Refrigerating absorption machines operate with the couple ammonia / water NH_3-H_2O are primarily designed for applications in industrial and commercial cold, with temperatures evaporation of up to -60 °C. This type of machine is used instead for operating temperatures below 0 °C **[1]**.

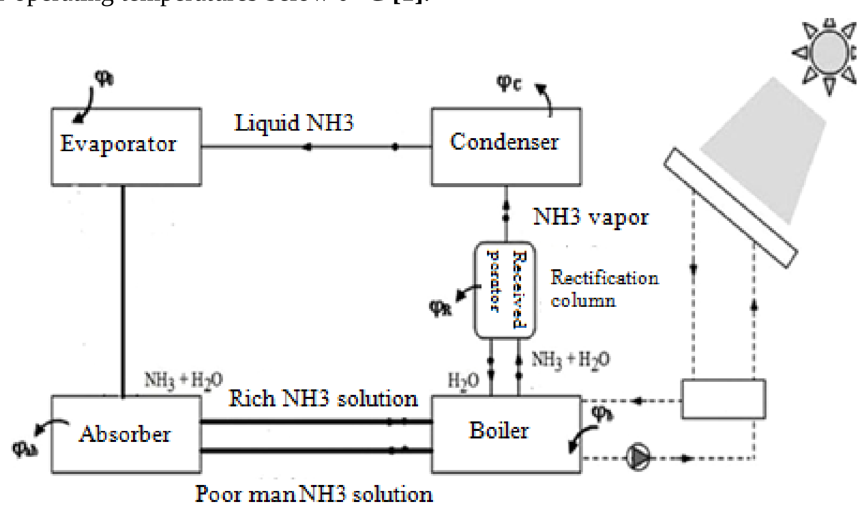

Figure 1: Schematic description of the absorption cycle NH_3-H_2O

The thermal energy required to operate these technologies comes from sunlight.
The solar thermal system converted solar light by means of a greenhouse effect and uptake by the capture member is called the solar irradiation.

Generally they are three necessary components: solar collector, energy storage system, absorption machine, [2].
The absorption machine is, for us, the heart of the entire system of solar cooling. It therefore seemed interesting to us to see how these machines are modeled. In this regard, there are generally two approaches [3].

- The first is based on a phenomenological description of each component of the machine. This approach is based on different energy balances to couple the four components of this product.
-The second (which is probably the most used) performance evaluation by an empirical model. This will usually curve fitting based on the manufacturer. Indeed, these are tests that establish a simple correlation customary for the COP and the cooling capacity of the machine. Correlations are thus valid for the range of tests and tested the machine model studied. So let's look at some approaches to modeling that formed the basis for the development of models of absorption machine.

2. PRESENTATION OF THE STUDIED INSTALLATION

Which aims to improve COP of solar absorption refrigeration, it was the geometric modifications to the system itself. It consists of three boilers, condenser, evaporator and two absorbers are as shown in Figure 2.

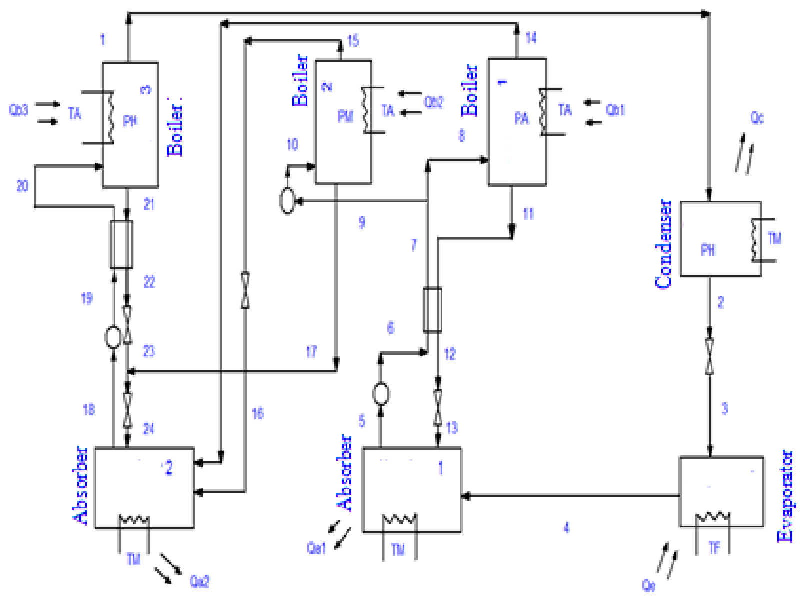

Figure 2: Diagram of an installation for solar absorption refrigeration running three boilers

3. THERMODYNAMIC STUDY

Knowledge of the climate and the geography of the region where our facility, is a very important factor in the study. These elements are variable, but we can estimate a monthly average, [4].
To establish the heat balance of any component and to size the heat transfer surfaces associated with him, it is necessary to know precisely enthalpies working fluids in the liquid and gaseous state depending on the temperature and concentration.
Among the existing models, we chose the one proposed by Mr. Feidt [5] which combines the method of Gibbs free energy for the thermal properties and the equations that calculate the bubble point and the dew points of the mixture. This method combines the advantages of both and eliminates the need for iterations in order to have conditions of equilibrium phases.
The simulation of this system leads to determinations of different mass and energy balances.

3.1. Mass balance

- **Boiler 1**

$$\dot{m}_8 = \dot{m}_{14} + \dot{m}_{11} \quad (1a)$$
$$\dot{m}_8 x_8 = \dot{m}_{14} x_{14} + \dot{m}_{11} x_{11} \quad (1b)$$

- **Boiler 2**

$$\dot{m}_{10} = \dot{m}_{15} + \dot{m}_{17} \quad (2a)$$
$$\dot{m}_{10} x_{10} = \dot{m}_{15} x_{15} + \dot{m}_{17} x_{17} \quad (2b)$$

- **Boiler 3**

$$\dot{m}_{20} = \dot{m}_1 + \dot{m}_{21} \quad (3a)$$
$$\dot{m}_{20} x_{20} = \dot{m}_1 x_1 + \dot{m}_{21} x_{21} \quad (3b)$$

- **Absorber 1**

$$\dot{m}_4 + \dot{m}_{13} = \dot{m}_5 \quad (4a)$$
$$\dot{m}_4 x_4 + \dot{m}_{13} x_{13} = \dot{m}_5 x_5 \quad (4b)$$

- **Absorber 2**

$$\dot{m}_{14} + \dot{m}_{16} + \dot{m}_{24} = \dot{m}_{18} \quad (5a)$$
$$\dot{m}_{14} x_{14} + \dot{m}_{16} x_{16} + \dot{m}_{24} x_{24} = \dot{m}_{18} x_{18} \quad (5b)$$

- **Evaporator**

$$\dot{m}_3 = \dot{m}_4 \quad (6a)$$
$$\dot{m}_3 x_3 = \dot{m}_4 x_4 \quad (6c)$$

- **Condenser**

$$\dot{m}_1 = \dot{m}_2 \quad (7a)$$
$$\dot{m}_1 x_1 = \dot{m}_2 x_2 \quad (7b)$$

- **Pump 1 :**

$$\dot{m}_5 = \dot{m}_6 \quad (8a)$$
$$\dot{m}_5 x_5 = \dot{m}_6 x_6 \quad (8b)$$

- **Pump 2 :**

$$\dot{m}_{18} = \dot{m}_{19} = \dot{m}_{20} \quad (9a)$$
$$\dot{m}_{18} x_{18} = \dot{m}_{19} x_{19} = \dot{m}_{20} x_{20} \quad (9b)$$

- **Pump 3 :**

$$\dot{m}_9 = \dot{m}_{10} \quad (10a)$$
$$\dot{m}_9 x_9 = \dot{m}_{10} x_{10} \quad (10b)$$

- **The exchanger 1:**

$$T_7 = T_{12}.\mathrm{eff} + T_6(1 - \mathrm{eff}) \quad (11)$$

- **The exchanger 2 :**

$$T_{20} = T_{22}.\mathrm{eff} + T_{19}(1 - \mathrm{eff}) \quad (12)$$

- **As was given :**

$$\dot{m}_1 = \dot{m}_2 = \dot{m}_3 = \dot{m}_4 \quad (13a)$$
$$\dot{m}_5 = \dot{m}_6 = \dot{m}_7 = \dot{m}_8 + \dot{m}_9 \quad \text{with} \quad \dot{m}_8 = \dot{m}_9$$

Therefore

$$\dot{m}_5 = \dot{m}_6 = \dot{m}_7 = 2\dot{m}_8 = 2\dot{m}_9 \quad (13b)$$

$$\dot{m}_9 = \dot{m}_{10} \quad (13c)$$
$$\dot{m}_{11} = \dot{m}_{12} = \dot{m}_{13} \quad (13d)$$
$$\dot{m}_{15} = \dot{m}_{16} \quad (13e)$$
$$\dot{m}_{20} = \dot{m}_{18} = \dot{m}_{19} \quad (13f)$$
$$\dot{m}_{21} = \dot{m}_{22} = \dot{m}_{23} \quad (13g)$$
$$\dot{m}_{24} = \dot{m}_{17} + \dot{m}_{23} \quad (13h)$$

- **We also:**

$$x_1 = x_2 = x_3 = x_4 \quad (14a)$$
$$x_5 = x_6 = x_7 = 2x_8 = 2x_9 \quad (14b)$$
$$x_9 = x_{10} \quad (14c)$$

$$x_{11} = x_{12} = x_{13} \quad (14d)$$
$$x_{15} = x_{16} \quad (14e)$$
$$x_{20} = x_{19} = x_{18} \quad (14f)$$
$$x_{21} = x_{22} = x_{23} \quad (14g)$$
$$x_{24} = x_{17} + x_{23} \quad (14h)$$

3.2. Energy balance

- **Boiler 1** :

$$\dot{Q} = \dot{m}_{11}h_{11} + \dot{m}_{14}h_{14} - \dot{m}_8h_8 \quad (15)$$

- **Boiler 2 :**

$$\dot{Q} = \dot{m}_{15}h_{15} + \dot{m}_{17}h_{17} - \dot{m}_{10}h_{10} \quad (16)$$

- **Boiler 3 :**

$$\dot{Q} = \dot{m}_1h_1 + \dot{m}_{21}h_{21} - \dot{m}_{20}h_{20} \quad (17)$$

- **Absorber 1 :**

$$\dot{Q} = \dot{m}_5h_5 - \dot{m}_4h_4 - \dot{m}_{13}h_{13} \quad (18)$$

- **Absorber 2 :**

$$\dot{Q} = \dot{m}_{18}h_{18} - \dot{m}_{14}h_{14} - \dot{m}_{16}h_{16} - \dot{m}_{24}h_{24} \quad (19)$$

- **Evaporator :**

$$\dot{Q} = \dot{m}_4h_4 - \dot{m}_3h_3 \quad (20)$$

- **Condenser :**

$$\dot{Q} = \dot{m}_2h_2 - \dot{m}_1h_1 \quad (21)$$

- Some calculations:

- **Boiler 1:**

$$\dot{m}_8 = \dot{m}_{14} + \dot{m}_{11} \quad (22a)$$
$$\dot{m}_8x_8 = \dot{m}_{14}x_{14} + \dot{m}_{11}x_{11} \quad (22b)$$
$$(\dot{m}_{14} + \dot{m}_{11})x_8 = \dot{m}_{14}x_{14} + \dot{m}_{11}x_{11} \quad (22c)$$
$$\dot{m}_{14}x_8 + \dot{m}_{11}x_8 = \dot{m}_{14}x_{14} + \dot{m}_{11}x_{11} \quad (22d)$$
$$\dot{m}_{14}(x_8 - x_{14}) = \dot{m}_{11}(x_{11} - x_8) \quad (22e)$$
$$\dot{m}_{11} = \dot{m}_{14}\left(\frac{x_8 - x_{14}}{x_{11} - x_8}\right) = \dot{m}_{12} = \dot{m}_{13} \quad (22f)$$

- **Boiler 2:**

$$\dot{m}_{10} = \dot{m}_{15} + \dot{m}_{17} \quad (23a)$$
$$\dot{m}_{17} = \dot{m}_{10} - \dot{m}_{15} \quad (23b)$$
$$\dot{m}_{17}x_{17} = \dot{m}_{10}x_{10} - \dot{m}_{15}x_{15} \quad (23c)$$
$$(\dot{m}_{10} - \dot{m}_{15})x_{17} = \dot{m}_{10}x_{10} - \dot{m}_{15}x_{15} \quad (23d)$$
$$\dot{m}_{10}(x_{17} - x_{10}) = \dot{m}_{15}(x_{17} - x_{15}) \quad (23e)$$
$$\dot{m}_{15} = \dot{m}_{10}\left(\frac{x_{17} - x_{10}}{x_{17} - x_{15}}\right) \quad (23f)$$
$$\dot{m}_{15} = \frac{\dot{m}_{14}}{2}\left(\frac{x_8 - x_{14}}{x_{11} - x_8}\right)\left(\frac{x_4 - x_{13}}{x_4 - x_5}\right)\left(\frac{x_{17} - x_{10}}{x_{17} - x_{15}}\right) = \dot{m}_{16} \quad (23g)$$
$$\dot{m}_{17} = \dot{m}_{15}\left(\frac{x_{10} - x_{15}}{x_{17} - x_{10}}\right) \quad (23h)$$
$$\dot{m}_{17} = \frac{\dot{m}_{14}}{2}\left(\frac{x_8 - x_{14}}{x_{11} - x_8}\right)\left(\frac{x_4 - x_{13}}{x_4 - x_5}\right)\left(\frac{x_{17} - x_{10}}{x_{17} - x_{15}}\right)\left(\frac{x_{10} - x_{15}}{x_{17} - x_{10}}\right) \quad (23i)$$

- **Boiler 3:**

$$\dot{m}_{20} = \dot{m}_1 + \dot{m}_{21} \quad (24a)$$
$$\dot{m}_{20}x_{20} = \dot{m}_1x_1 + \dot{m}_{21}x_{21} \quad (24b)$$
$$(\dot{m}_1 + \dot{m}_{21})x_{20} = \dot{m}_1x_1 + \dot{m}_{21}x_{21} \quad (24c)$$
$$\dot{m}_1x_{20} + \dot{m}_{21}x_{20} = \dot{m}_1x_1 + \dot{m}_{21}x_{21} \quad (24d)$$
$$\dot{m}_1(x_{20} - x_1) = \dot{m}_{21}(x_{21} - x_{20}) \quad (24e)$$
$$\dot{m}_{21} = \dot{m}_1\left(\frac{x_{20} - x_1}{x_{21} - x_{20}}\right) \quad (24f)$$

$$\dot{m}_{21} = \dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right) = \dot{m}_{22} = \dot{m}_{23} \quad (24g)$$

- **Absorber 1:**

$$\dot{m}_4 x_4 + \dot{m}_{13} x_{13} = \dot{m}_5 x_5 \quad (25a)$$
$$(\dot{m}_4 + \dot{m}_{13}) x_5 = \dot{m}_4 x_4 + \dot{m}_{13} x_{13} \quad (25b)$$
$$\dot{m}_4 x_5 + \dot{m}_4 + \dot{m}_{13} = \dot{m}_5 \quad (25c)$$
$$\dot{m}_{13} x_5 = \dot{m}_4 x_4 + \dot{m}_{13} x_{13} \quad (25d)$$
$$\dot{m}_4 (x_5 - x_4) = \dot{m}_{13}(x_{13} - x_5) \quad (25e)$$
$$\dot{m}_4 = \dot{m}_{13}\left(\frac{x_{13}-x_5}{x_5-x_4}\right) \quad (25f)$$
$$\dot{m}_4 = \dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right) = \dot{m}_1 = \dot{m}_2 = \dot{m}_3 \quad (25g)$$

$$\dot{m}_4 = \dot{m}_5 - \dot{m}_{13} \quad (25h)$$
$$\dot{m}_4 x_4 = \dot{m}_5 x_5 - \dot{m}_{13} x_{13} \quad (25i)$$
$$(\dot{m}_5 - \dot{m}_{13}) x_4 = \dot{m}_5 x_5 - \dot{m}_{13} x_{13} \quad (25j)$$
$$\dot{m}_5 x_4 - \dot{m}_{13} x_4 = \dot{m}_5 x_5 - \dot{m}_{13} x_{13} \quad (25k)$$
$$\dot{m}_5 (x_4 - x_5) = \dot{m}_{13}(x_4 - x_{13}) \quad (25l)$$
$$\dot{m}_5 = \dot{m}_{13}\left(\frac{x_4-x_{13}}{x_4-x_5}\right) \quad (25m)$$
$$\dot{m}_5 = \dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right) = \dot{m}_6 = \dot{m}_7 = 2\dot{m}_8 = 2\dot{m}_9 \quad (25n)$$
$$\dot{m}_{10} = \frac{\dot{m}_{14}}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right) = \dot{m}_9 \quad (25o)$$

We have:

$$\dot{m}_{24} = \dot{m}_{17} + \dot{m}_{23} \quad (25p)$$

$$\dot{m}_{24} = \frac{\dot{m}_{14}}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)\left(\frac{x_{10}-x_{15}}{x_{17}-x_{10}}\right) + \dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right) \quad (25q)$$

$$\dot{m}_{24} = \frac{\dot{m}_{14}}{2}\left[\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)\left(\frac{x_{10}-x_{15}}{x_{17}-x_{10}}\right) + 2\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right)\right] \quad (25r)$$

- **Absorber 2:**

$$\dot{m}_{18} = \dot{m}_{14} + \dot{m}_{16} + \dot{m}_{24} \quad (26a)$$

$$\dot{m}_{18} = \dot{m}_{14} + \frac{\dot{m}_{14}}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right) + \frac{\dot{m}_{14}}{2}\left[\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)\left(\frac{x_{10}-x_{15}}{x_{17}-x_{10}}\right) + 2\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right)\right] \quad (26b)$$

$$\dot{m}_{18} = \dot{m}_{14}\left[1 + \frac{1}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right) + \frac{1}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)\left(\frac{x_{10}-x_{15}}{x_{17}-x_{10}}\right) + \left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right)\right] = \dot{m}_{19} = \dot{m}_{20} \quad (26c)$$

- **Evaporator :**

$$\dot{m}_3 = \dot{m}_4 \quad (27a)$$
$$\dot{m}_3 x_3 = \dot{m}_4 x_4 \quad (27b)$$

- **Condenser :**

$$\dot{m}_1 = \dot{m}_2 \quad (28a)$$
$$\dot{m}_1 x_1 = \dot{m}_2 x_2 \quad (28b)$$

Table.1: Determination of parameters (h and x) for some values of T and P.

Elements of the installation	T	P	h	x	$\dot{m}$
1	70	20	1370	1	$\dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)$
2	50	20	220	1	$\dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)$
3	50	2	10	1	$\dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)$
4	-20	2	1240	1	$\dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)$
5	25	2	100	0.24	$\dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)$
6	25	20	140	0.24	$\dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)$
7	32.5	20	230	0.24	$\dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)$
8	32.5	10	0	0.12	$\frac{\dot{m}_{14}}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)$
9	32.5	10	0	0.12	$\frac{\dot{m}_{14}}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)$
10	32.5	15	50	0.12	$\frac{\dot{m}_{14}}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)$
11	80	10	120	0.41	$\dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)$
12	40	10	-10	0.41	$\dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)$
13	40	2	-30	0.41	$\dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)$
14	70	10	1440	0.98	$\dot{m}_{14}$
15	70	15	1400	0.55	$\frac{\dot{m}_{14}}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)$
16	70	10		0.55	$\frac{\dot{m}_{14}}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)$
17	80	15	150	0.45	$\frac{\dot{m}_{14}}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)\left(\frac{x_{10}-x_{15}}{x_{17}-x_{10}}\right)$
18	65	10	50	0.49	$\dot{m}_{14}\left[1+\frac{1}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)+\frac{1}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)\left(\frac{x_{10}-x_{15}}{x_{17}-x_{10}}\right)+\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right)\right]$

19	**65**	**20**	**110**	**0.49**	$\dot{m}_{14}\left[1+\frac{1}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)+\frac{1}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)\left(\frac{x_{10}-x_{15}}{x_{17}-x_{10}}\right)+\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right)\right]$
20	**52.5**	**20**	**190**	**0.49**	$\dot{m}_{14}\left[1+\frac{1}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)+\frac{1}{2}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)\left(\frac{x_{10}-x_{15}}{x_{17}-x_{10}}\right)+\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right)\right]$
21	**80**	**20**	**180**	**0.58**	$\dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right)$
22	**40**	**20**	**220**	**0.58**	$\dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right)$
23	**40**	**15**	**40**	**0.58**	$\dot{m}_{14}\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right)$
24	**60**	**10**	**50**	**0.53**	$\frac{\dot{m}_{14}}{2}\left[\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)\left(\frac{x_{10}-x_{15}}{x_{17}-x_{10}}\right)+2\left(\frac{x_8-x_{14}}{x_{11}-x_8}\right)\left(\frac{x_{13}-x_5}{x_5-x_4}\right)\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right)\right]$

4. COEFFICIENT OF PERFORMANCE: COP

The coefficient of performance is the ratio of the energy capacity of the evaporator on energy powers of the boilers:

$$COP=\frac{\dot{Q}_e}{\dot{Q}_{b1}+\dot{Q}_{b2}+\dot{Q}_{b3}} \tag{29a}$$

$$COP=\frac{\dot{m}_4(h_4-h_3)}{(\dot{m}_{11}h_{11-\dot{m}_8h_81}+\dot{m}_{14}h_{14})+(\dot{m}_{15}h_{15}+\dot{m}_{17}h_{17}-\dot{m}_{10}h_{10})+(\dot{m}_1h_1+\dot{m}_{21}h_{21}-\dot{m}_{20}h_{20})} \tag{29b}$$

$$COP=\frac{h_4-h_3}{Ah_{11}+Bh_{14}-\frac{1}{2}Ch_8+\frac{1}{2}Dh_{15}+\frac{1}{2}Eh_{17}-\frac{1}{2}h_{10}+h_1+Fh_{21}-Gh_{20}} \tag{29c}$$

With:

$A=\left(\frac{x_5-x_4}{x_{13}-x_5}\right)$

$B=\left(\frac{x_5-x_4}{x_{13}-x_5}\right)\left(\frac{x_{11}-x_8}{x_8-x_{14}}\right)$

$C=\left(\frac{x_5-x_4}{x_{13}-x_5}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)$

$D=\left(\frac{x_5-x_4}{x_{13}-x_5}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)$

$$E=\left(\frac{x_5-x_4}{x_{13}-x_5}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)\left(\frac{x_{10}-x_{15}}{x_{17}-x_{10}}\right)$$

$$F=\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right)$$

$$G=1+\frac{1}{2}\left[\left(\frac{x_5-x_4}{x_{13}-x_5}\right)\left(\frac{x_4-x_{13}}{x_4-x_5}\right)\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)\right]+\frac{1}{2}\left[\left(\frac{x_{17}-x_{10}}{x_{17}-x_{15}}\right)\left(\frac{x_{10}-x_{15}}{x_{17}-x_{10}}\right)\left(\frac{x_4-x_{13}}{x_{17}-x_{15}}\right)\left(\frac{x_5-x_4}{x_{13}-x_5}\right)\right]+\left(\frac{x_{20}-x_1}{x_{21}-x_{20}}\right)$$

In applying the principles of thermodynamics on a real cycle, conditions and assumptions used following bases:

1 Temperatures in the elements of the system (boiler, condenser, absorber and evaporator) are assumed uniform throughout the volume in question.

2. Solution rich refrigerant at the outlet of the absorber is a saturated temperature and the concentration in the absorber liquid. Likewise, the weak solution leaving the refrigerant generator is connected by a balance of pressure and temperature relationship builder concentration.

3. Coolant leaving the boiler is taken as saturated vapor at the temperature and corresponding pressure.

4. Coolant leaving the condenser is taken as the saturated liquid at the same temperature and pressure.

The refrigerant in the evaporator outlet is in the form of saturated steam at the temperature and low pressure of the evaporator. The isenthalpic expansions are assumed.

Heat exchange with the environment and losses are assumed negligible.

Calculations are based on the determination of the respective enthalpies of the liquid phase and vapor phase from the analytical expressions of the Gibbs free energy of [6], knowing the pressure, the temperature and the content of the solution. Also, one has to determine the quantities of vapor-liquid equilibrium of the binary pair ammonia water from the Peng-Robinson equation [7] and the interaction coefficient K_{ij} characterizing torque mixture.
There are two methods for the determination of various thermodynamic parameters (h, x), either from existing relationships or correlations [8],[9]et[10] , or from diagrams of (Merkel) and (Oldhame) [11] which is our case.

5. SIMULATION

- For our work, a pressure range is selected between 2 and 20 bars.
- The choice of a high pressure leads us to a title goes to one (1).

- **Boiler 1**

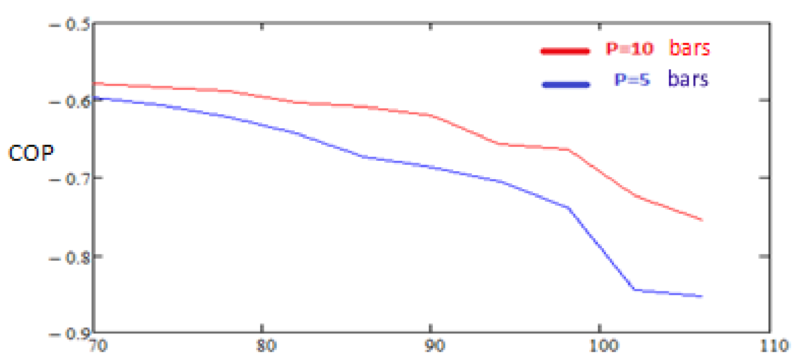

Figure 3: Variation of COP as a function of the first boiler temperature Tb1.

- **Boiler 2**

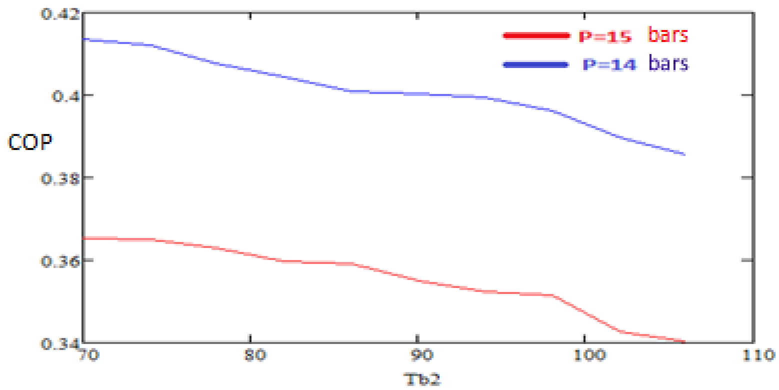

Figure 4: Variation of COP as a function of the second boiler temperature Tb2.

- **Boiler 3**

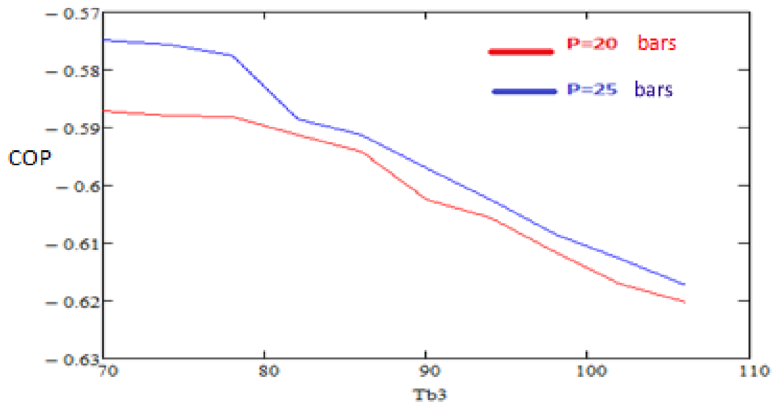

Figure 5: Variation of COP as a function of the third boiler temperature Tb3.

- **Evaporator**

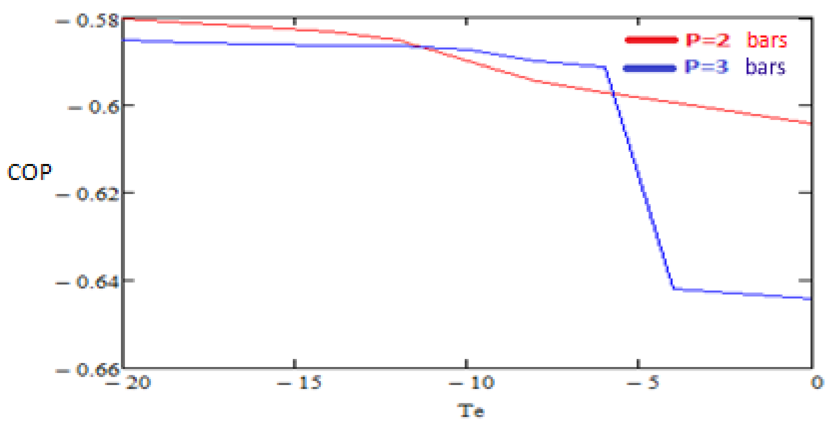

Figure 6: Variation of COP as a function of the evaporator temperature Te.

- **Absorber 2**

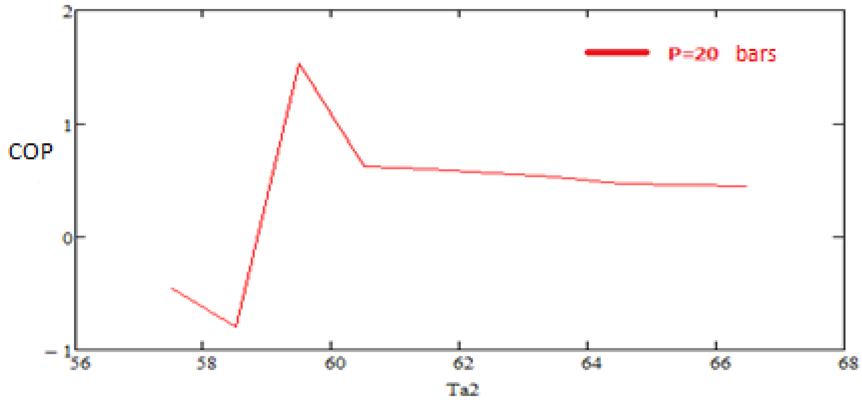

Figure 7: Variation of COP as a function of the second absorber temperature Ta2.

5.1. Interpretations

- Figure 3 shows that the variation of COP is inversely proportional with boiler1 temperature (T_{14}) and decreases with increasing temperature in the range 70 °C< T_{14} <106 °C with mean pressures P=10 bars and P=5 bars.
- Figures 4 (and 5) show also that the variation of COP is inversely proportional with boilers 2 (and 3) temperature T_{15} (and T_1) and decreases with increasing temperature in the range 70°C < T_{15} <106°C. Increasing the pressure at these temperatures T_{15} (and T_1), at P=15 bars (and P=25 bars), keeping the same boiler gives us COP smaller relative to the pressure P=14 bars (and P=20 bars).
- In the evaporator, Figure 6, the variation of COP is inversely proportional to the temperature of the evaporator T_e. for a low pressure, P = 2 bars, it is noted that the COP is important.
- In the absorber 2, Figure 7, we can that the COP has a very important value in the temperatures ranging around 60 °C for a pressure P = 20 bars.
- From these curves, we see that the pressure is a major factor in improving COP.

6. CONCLUSION

This work has been subject to the dynamics of a solar cooling simulation. The primary objective of this work is to make improvements to the facilities has refrigeration's absorption works with the binary pair (NH_3 / H_2O) aims to have interesting COP.

The ammonia-water mixture was the principal binary couple in the absorption refrigerating machines for many years [12]. Many studies were done on vapour-liquid balance and the thermodynamics and transport properties of this mixture.

- The development of a simulation tool is based on a multidisciplinary approach.
  Based on a literature review, two important points were highlighted:
- The first concerns the modeling and validation of the various elements of the solar absorption refrigeration installation. The changes to the system and the results of different simulations show good prospects to continue in this field of research.
- The second point concerns the simulation of a facility to global solar absorption, with the difficulty of making a real coupling between the refrigeration requirements and the associated production of solar cooling.

The study of this solar engine with three boilers shows that it has the ability to operate from a high temperature to the boilers (70 °C) with interesting performance, the ability to use ordinary solar collectors (less expensive) which may affect the overall cost of the installation.

7. REFERENCES

[1] - Mr. Sharia *, A. and M. Bouidida Pilatte + *; "Machine refrigeration / absorption (water-ammonia) Sensor operated planes on the site of Rabat"; + * University Mohammed V, BP 1014 Rabat, Morocco; + Service Thermodynamics, Faculty + Polytechnique de Mons, Boulevard Dolez 31, B-700; Mons, Belgium; Rev. Int. Cold. 1991 Vo1. September 14

[2] J. Castaing-lasvignottes2001; http://jc.castaing.free.fr/jc.castaing@free.fr.

[3] J. Ph. Praene. Integration and dynamic modeling of components of a solar cooling system in absorption coupled with the building. PhD Thesis, University of La Reunion, France, 2007.

[4] D. Lafri, A. Hamid, M. Belhamel, D. Semmar. Study of the thermal behavior of a cure solar storage exchanger Heat. Revue of renewable energy: thermal Days.2001.

[5] M. Feidt, A. H. Taleb, O. Lottin. Thermodynamic properties of ammonia water mixtures. International Congress of Refrigeration, 2003, Washington, ICR 0113.

[6] B. Ziegler. C. Trepp. Equation of state for ammonia-water mixtures. Int. J. Refrig. (1984) 7 101-106.

[7] S.A. Akam, Z. Ouchiha, N. Said, B. Bellal. Experimenting with a loop Absorption NH3-H2O. Rev. Energ. Ren. : Valorisation (1999) 17-22-17.

[8] ENICK,R.M, DONAHEY, G.P,HOLINSGER modeling the high- pressure ammonia-water system wit WATAM and the Peng-Robinson Equation of state for kalina cycle studies.Ind.Eng.Chem.Res.vol.37.p. 1644-1650,-1998- ;

[9] WEBER, L.AEstimating the virial coefficient of the ammonia+water mixture. Fluide Phase Equilbia.vol.192.no.1-2.p.31-49-1999

[10] RUKES, B DOOLEY, R.B Guidline on the IAPWS formulation 2001 for the thermodynamic properties of ammonia-water mixtures, IAPWS (The International Association for the properties of Water and Steam) 2001.Maryland-USA;

[11] PIERRE RAPIN form the cold. 10th Edition, DUNOD;

[12] Andy Pearson (2008) Refrigeration with ammonia, International Journal of Refrigeration 31 (4) : 545-551.