

EXERGoeconomic COMPARASION BETWEEN A SINGLE EFFECT LITHIUM BROMID-WATER AND WATER-AMMONIA ABSORPTION REFRIGERATION SYSTEMS

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Abstract. *This work presents the exergoeconomic comparison between a single-effect absorption refrigeration system using lithium bromide-water and ammonia-water pairs, operating with the direct combustion of natural gas. The method combines exergetic and economic analysis and this study was done after the energetic analysis of all system's components. The exergoeconomic evaluation of the thermodynamic flows, which go through these cycles, was performed for operational conditions aimed at a refrigerating capacity from 5 to 15 TR. It was applied to the present systems to reveal which component in the cycle would be wasting energy. This method was also based on the incidence matrix that represents the physical structure of the above-mentioned systems. The exergoeconomic method combines the exergetic and economic analysis, and was applied to each system to reveal which one is thermoeconomically more efficient*

Keywords: *Absorption system, exergoeconomy, thermoeconomy.*

1. INTRODUCTION

Today, the absorption cooling systems have received a lot of attention, both from the perspective of thermal analysis and the use of different energetic sources. Its use in cogeneration systems has been seen as the best appropriate and the most energetically and economically thrifty.

More recently, thermal systems analyses have been followed by an economic consideration. These analyses have been followed by a simultaneous approach from the thermodynamic and the economic perspectives. The exergetic analysis has been used to evaluate thermal systems so as to include the energy quality concept in the thermodynamic analysis, which otherwise is not attained when only the first law of thermodynamics or the energetic analysis is applied. The exergetic analysis has already become an essential parameter for the equipments' and thermal systems' optimization by reducing the detected irreversibilities (Bejan *et al.*, 1996).

Several important methodologies for the exergetic analysis can be found in the literature (Kotas, 1985; Szargut, 1988 and Tsatsaronis, 1993). Aphornratana and Eames (1995) have shown the influence of the flow rate in the irreversibility of a single-effect absorption cooling system. Moreira (2004) presented the exergetic study for a single and double-effect LiBr-water unit under way with local technology, with capacities varying between 5 and 15 tons of cooling. Berlitz *et al.* (1999) presented economic studies related to the thermodynamic model for double effect LiBr-water absorption refrigerators.

The ammonia-water absorption system is composing by a natural gas engine an absorption refrigeration unit using GAX cycle that was made for ROBUR-SERVER model ACF-60. In this study, the exergy of a stream is decomposed into thermal and mechanical exergy flow, the efficiencies based on thermodynamic second law for each subsystem is identified, as well where and why the losses and irreversibilities occur (Santos, 2005).

The thermoeconomic analysis, also known as exergoeconomic, has followed two ways: the first can be described as a costs calculating method, i.e., a method that uses the mean cost as basis to evaluate the rational price. This method includes the mean cost approach introduced by Hernandez *et al.* (2003). They have proposed the mean cost approach to the thermoeconomic optimization of the heat supplied to the generator of the single-effect absorption cooling system, using both water-lithium bromide and water-ammonia pairs. That paper offers a detailed energetic analysis followed by the mean cost calculation for each exergy unity, for all the cogeneration plant flows.

The second comprises a method that uses the marginal costs so as to minimize the components or the products costs. These methods include the functional thermoeconomic analysis as presented by Erlach *et al.* (1999). Those researchers introduce a structural theory as a reference and a mathematical formulation common to all methodologies, using thermoeconomic models that can be described by linear equations. The pros and cons in each method can be found in each one of the above mentioned method.

The present paper shows the exergetic cost theory applied to a serial single absorption cooling systems using water-lithium bromide and ammonia-water, operating between 5 and 15 tons of cooling. The systems are formed by generator, absorber, condenser, evaporator, pump, expansion valves, heat exchanger for each systems and an intercooler for the NH₃-H₂O system. For this application it is necessary to suppress the flows after the expansion valves, because these are isenthalpic processes. Thus, for our analysis, each valve will be part of the corresponding subsequent equipment, as schematically described in Fig. 1.

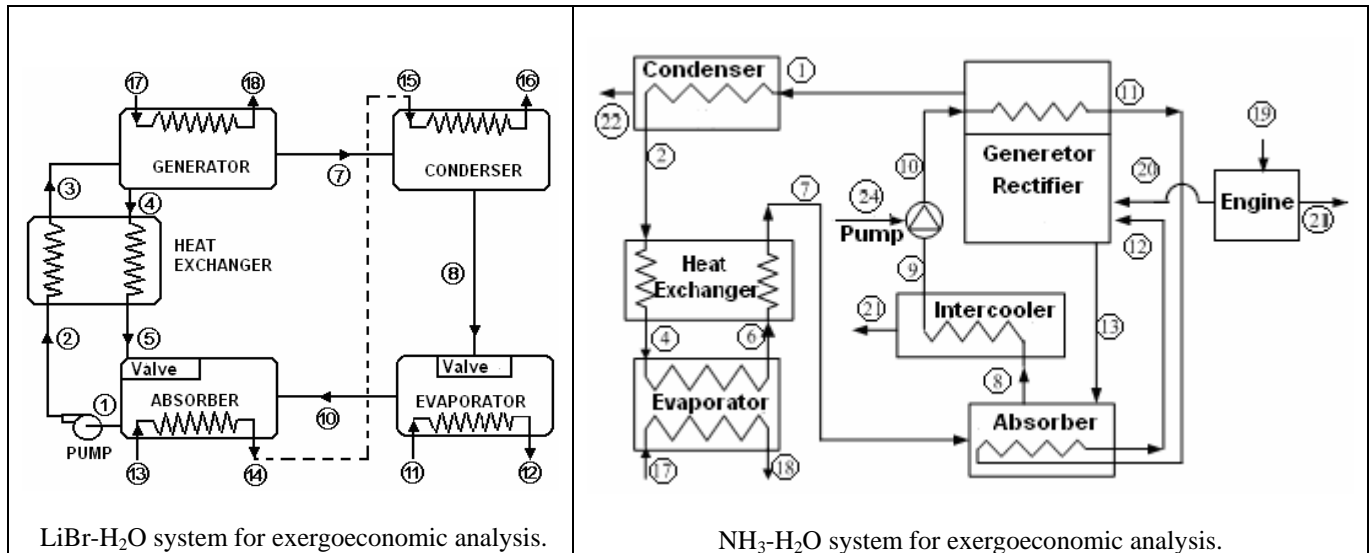


Figure 1 – Representation of LiBr-H₂O and NH₃-H₂O systems for exergoeconomic analysis.

2. METODOLOGY OF THE EXERGOECONOMIC ANALYSIS

The exergoeconomic analysis have as a meaning objective, among others, determine the exergetics and monetary costs of all system components; allowing the knowledge and the comprehension of the forming process of these costs; promoting the optimization not only of the specific variables of each system component, but of the whole system.

This detailed analysis was obtained with the contribution of the Thermodynamics Second Law in conjunction with exergetic analysis, in which, according to Tsatsaronis (1993), would permit a better measurement to evaluate the magnitude of lost energy in relation to the amount of supplied energy under the form of energetic resource; it would also permit a better measurement of quality or loss from a thermodynamic point of view, thus becoming a good variable to define the reasonable efficiency for the energetic system.

2.1. The Exergoeconomic Analysis Formulation of the Systems

For analysis the following simplifying hypotheses were made:

- The both cycle solutions, in the generator and the absorber, are presumed to be in balance as regards to corresponding temperatures and pressures;
- The work to pump the solution in the recirculation is negligible;
- The working fluid is in a saturation state at the condenser's and the evaporator's outputs;
- The concentrated solution at the generator's output, and the diluted solution at the absorber's output, is considered saturated;
- The temperatures are uniform in the mean components (generator, condenser, evaporator, and absorber).

The exergoeconomic analysis is preceded by the energetic and exergetic analyses and have the input data used as a basis indicated in Table 1. The thermophysical properties of the solution and the cooling liquid, to the exception of the entropy, are obtained from the Engineering Equation Solver [EES] software. The energetic and exergetic analysis details are given by Moreira (2004) and Santos (2005) for LiBr-H₂O and NH₃-H₂O systems respectively, who uses the solution properties' equations supplied by Kaita (2001) and Sun (1997).

To calculate the exergetic cost, the exergy of each physical flow must be known. After the operational conditions were defined, all the thermodynamic properties necessary to calculate the exergies were estimated. Table 3 shows these properties as well as each flow's exergy specification.

The incidence matrix for the plant on Figure 1 is presented by the $n \times m$ order **A** matrix, where **n** is the equipments number, and **m** are the flows for each system. Each line in the matrix represents an equipment, and each column is a flow. Their elements a_{ij} are +1 if the flow **j** enters the equipment **i**; and -1 if the flow leaves the equipment, or zero, if the flow is not related to the equipment. Table 2 shows the dimensions (6 × 15) of the resultant incidence matrix for cycle absorption LiBr-H₂O system and Table 3 show the (7 × 15) of the resultant incidence matrix for NH₃-H₂O system.

The economic rating of the thermodynamic flows that perform one cycle will be set up for the operational conditions later defined, always focusing the utilization of the available exergy from burning process of single and double effect absorption refrigeration systems. The exergoeconomic method combines the exergetic and economic analysis, and was applied to each system to reveal which one is thermoeconomically more efficient.

Table 1. Input data for simulation of energetic and exergetic analyses of the cooling systems.

	LiBr-H ₂ O system	NH ₃ -H ₂ O system
Available heat at the Generator	21,1 kW	21,1 kW
Condenser temperature	37°C	37°C
Evaporator temperature	5°C	5°C
Strong solution concentration	64%	52,05%
Wake solution concentration	48%	37,05%
Combustion gas temperature in the generator input	678°C	678°C
Combustion gas temperature in the generator output	300°C	300°C
Cold water temperature in the evaporator input	12°C	12°C
Cold water temperature in the evaporator output	7°C	7°C
Cooling water temperature in the absorber input	29,5°C	37°C
Cooling water temperature in the absorber output	35°C	64°C

Table 2. Input data for simulation and energetic and exergetic analyses of the LiBr-H₂O system.

Flows →	1	2	3	4	5	7	8	10	11	12	13	15	16	17	18
Equipment↓															
Generator	0	0	+1	-1	0	-1	0	0	0	0	0	0	0	+1	-1
Condenser	0	0	0	0	0	+1	-1	0	0	0	0	+1	-1	0	0
Evaporator	0	0	0	0	0	0	+1	-1	+1	-1	0	0	0	0	0
Absorber	-1	0	0	0	+1	0	0	+1	0	0	+1	-1	0	0	0
Heat Exchanger	0	+1	-1	+1	-1	0	0	0	0	0	0	0	0	0	0
Pump	+1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3. Input data for simulation and energetic and exergetic analyses of the NH₃-H₂O system.

Flows →	1	2	4	6	7	8	9	10	11	12	13	17	18	20	22
Equipment↓															
Generator	-1	0	0	0	0	0	0	+1	-1	+1	-1	0	0	1	0
Condenser	+1	-1	0	0	0	0	0	0	0	0	0	0	0	0	-1
Evaporator	0	0	+1	-1	0	0	0	0	0	0	0	+1	-1	0	0
Absorber	0	0	0	0	+1	-1	0	0	+1	-1	+1	0	0	0	0
Heat Exchanger	0	+1	-1	+1	-1	0	0	0	0	0	0	0	0	0	0
Pump	0	0	0	0	0	0	+1	-1	0	0	0	0	0	0	0
Intercooler	0	0	0	0	0	+1	-1	0	0	0	0	0	0	0	0

The exergy balance can be expressed more explicitly as:

$$\sum_{entrance} B_i^* - \sum_{exit} B_j^* = D \tag{1}$$

It is possible to express this balance by means of the incidence matrix **A** and the vector **B** through:

$$[A] \times [B] = [D] \tag{2}$$

where **D** is the dimension vector (**n** x 1) that determines the exergetic destruction; each one of its **n** elements represents one specific equipment.

The exergy balance supplies the exergy destruction value for each equipment in the system, and this destruction is the difference between the input exergy and the output exergy in each component. This happens because in every real process there will always be destructions and losses, which cause a higher exergy in the process input related to the product exergy. By definition, the exergetic cost of a product is the exergy amount necessary to obtain it (**B***).

The product's obtaining will be more efficient the smaller the relation between **B*** and **B**. Thus, the unitary exergetic cost (**k**) is defined as the exergy necessary to obtain the exergy unit of the product:

Applying the proposition of the Valero et al (1986), of the subsystem that compound the plant, determinate the system of (**m** - **n**) equations that will calculate the cost that the referred flux of the plant will have form the Eq. (3) form where **A** is incidence matrix, **α** is production matrix and **ω** is a vector of exergy values.

$$\begin{pmatrix} A \\ \alpha \end{pmatrix} \times B^* = \begin{pmatrix} 0 \\ \omega \end{pmatrix} \quad (3)$$

Valero *et al.* (1986) has formulated an endowment proceeding of exergetic costs, based only in thermodynamics precepts, such as:

- The exergetic cost of a flow (B^*), resource (F^*), or product (P^*) is the real quantity of exergy needed to produce it;
- A detailed analysis of the global nature of the process and of the function of each subsystem in progressive formation of the final products, is the only requirement needed to solve the endowment problem of exergetic costs;
- The exergetic costs in the entrance of an equipment or component of the system should be rated with the flow that outcomes from it.

Based on these postulates, a collection of proposition has been created and the systematic application on the equipments will permit us value the exergetic costs of the flows. These propositions will be set up in a general way, and afterwards will be applied in the systems to be considered.

- Proposition 1 – The exergetic cost is a conservative property

$$\sum_{entrance} B_i^* - \sum_{exit} B_j^* = 0 \quad (4)$$

- Proposition 2 – for a system or control volume with more than one energetic resource, the exit unitary exergetic costs must be equal to the entrance ones (resource rules)

For a general system example as shown on Fig. 2, we have:

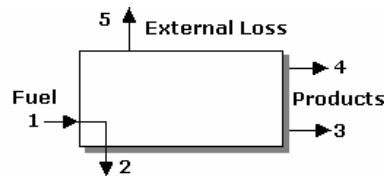


Figure 2. General System Example (Torres, 1999)

$$\frac{B_1^*}{B_1} = \frac{B_2^*}{B_2} \quad (5)$$

- Proposition 3 – if a system has a product formed by various flows, the exergetic cost will be the same for each one of them (product rule). In the Fig. 2 example we have:

$$\frac{B_3^*}{B_3} = \frac{B_4^*}{B_4} \quad (6)$$

- Proposition 4 – in the absence of value of an external loss flow, we shall admit a null exergetic cost. In this example we have:

$$\frac{B_5^*}{B_5} = 0 \quad (7)$$

- Proposition 5 – in the absence of external value, the exergetic cost of the entrance flows in the system is equal to its exergy. In this example we have:

$$B_1^* = B_1 \quad (8)$$

The methodology to value the monetary costs is an application of a cost balance to a subsystem or equipment as shown on Fig. 3.

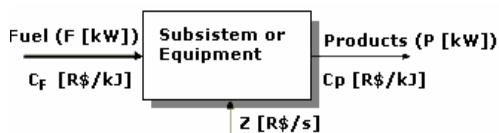


Figure 3. Balance of Monetary Costs.

The balance shown on Fig. 3 can be mathematically represented as follows:

$$C_P \cdot B_P = C_F \cdot B_F + Z \quad (9)$$

Where C_F and C_P represent the costs in monetary unit per exergy unit for the resource and the product respectively; in the same way B_F and B_P represent the amount of exergy for the resource and the product, and Z is the invested capital. In the particular case of a plant in operation and already paid, we can take Z as a null value, although that's not the case, because the capital invested in each internal combustion engine is an important economic parameter for comparison. To determine Z , we shall consider:

$$Z_{(i)} = \frac{3600 \cdot (A/P)}{t_{op}} \cdot F_i \quad (10)$$

Where t_{op} represents the useful life time (in seconds); F_i represents the investment for each equipment or subsystem; (A/P) represents the capital recovering factor and will be calculated by Eq. (6), considering I the interest rate (varying from zero to 1); and N represents the reimbursement period (in years).

$$\left(\frac{A}{P}\right) = \frac{I \cdot (1+I)^N}{(1+I)^N - 1} \quad (11)$$

3. RESULTS AND DISCUSSION

The results obtained from computer simulation for the LiBr-H₂O and NH₃-H₂O systems are shown in Tab. 4 and Tab. 5 respectively. They were based on the thermodynamics model carried out by Moreira (2005), having as initial parameters those indicated in Tab.1, and are: temperature values (T), pressure (p), solution concentration (X), flow rate (m), enthalpy (h), entropy (s), and exergy (B), referring to the points as represented in Fig. 1.

Table 4 - Thermodynamics analysis results of the LiBr-H₂O system.

Points	T (°C)	p (kPa)	X (%)	\dot{m} (kg/s)	h (kJ/kg)	s (kJ/kg.K)	b (kJ/kg)	B (kW)
1	34,44	0,87	54,9	0,050	83,4	0,2211	22,22	1,116
2	34,44	6,275	54,9	0,050	83,41	0,2211	22,22	1,116
3	63,6	6,275	54,9	0,050	143,2	0,4053	27,09	1,360
4	91,13	6,275	64	0,043	231,2	0,4864	90,89	3,914
5	52,13	6,275	64	0,043	161,5	0,2827	81,92	3,528
6	52,13	0,87	64	0,043	161,5	0,2827	81,92	3,528
7	80,59	6,275	0	0,007	2654	8,56	94,34	0,673
8	37	6,275	0	0,007	154,9	0,5319	1,06	0,007
9	5	0,87	0	0,007	154,9	0,5577	6,633	0,046
10	5	0,87	0	0,007	2510	9,025	176,3	1,251
11	12	-	-	0,804	50,24	0,1804	1,176	0,946
12	7	-	-	0,804	29,31	0,1063	2,337	1,880
13	29,5	-	-	1,673	123,5	0,4296	0,1513	0,253
14	32,45	-	-	1,673	135,9	0,4702	0,4041	0,676
15	32,45	-	-	1,673	135,9	0,4702	0,4041	0,676
16	35	-	-	1,673	146,5	0,505	0,7173	1,200
17	678	-	-	0,196	290,6	7,642	305,5	52,75
18	300	-	-	0,196	183,3	7,422	263,9	51,87

Table 5 - Thermodynamics analysis results of the NH₃-H₂O system.

Points	T (°C)	p (bar)	X (%)	ṁ (kg/s)	h (kJ/kg)	s(kJ/kg.K)	b(kJ/kg)	B (kW)
1	54,27	14,28	0,9986	0,07347	1340	4,348	607,6	44,64
2	37	14,28	0,998	0,07347	174,7	0,6129	563,7	41,42
3	33,14	12,78	0,998	0,07347	174,7	0,614	563,4	41,39
4	6,57	4,878	0,998	0,07347	29,33	0,121	566	41,58
5	3,51	4,878	0,998	0,07356	29,33	0,125	564,7	41,54
6	5	4,878	0,998	0,07356	1276	4,604	467,1	34,34
7	30,45	4,878	0,998	0,07356	1340	4,826	464,9	34,20
8	64,14	4,878	0,5205	0,3115	416,3	1,905	649,9	264,74
9	37	4,878	0,5205	0,3115	-73,59	0,394	813,6	253,44
10	37,17	14,28	0,5205	0,3114	-72,05	0,395	814,7	253,70
11	42,8	14,28	0,5205	0,3114	-46,69	0,476	815,8	254,04
12	63,12	14,28	0,5205	0,3114	45,7	0,759	823,1	256,31
13	105,15	14,28	0,3705	0,238	251,6	1,319	861	204,92
14	74,65	4,878	0,3705	0,238	251,6	1,343	853,8	203,20
15	76,15	14,28	0,9899	0,07496	1420	4,588	1448	78,56
16	76,15	14,28	0,5198	0,001489	106,5	0,937	526,5	0,78
17	12	-	-	4,371	50,51	0,181	1,618	7,07
18	7	-	-	4,371	29,53	0,106	2,918	12,75
19	27	-	-	0,009199	-	-	-	-
20	677,9	-	-	0,1827	-	-	822,5	150,27

From the Eq. (2) determine the exergy balance for each component in both the systems. Thus, like the destruction exergetic to the respective components. The matricidal form for the LiBr-H₂O system is shown in the Eq. (12) e for the NH₃-H₂O system having Eq. (13).

$$\begin{pmatrix}
 0 & 0 & 1 & -1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 \\
 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 1 & -1 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 1 & -1 & 0 & 0 & 0 & 0 \\
 -1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & -1 & 0 & 0 \\
 0 & 1 & -1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
 \end{pmatrix} \times \begin{pmatrix}
 B_1 \\
 B_2 \\
 B_3 \\
 B_4 \\
 B_5 \\
 B_7 \\
 B_8 \\
 B_{10} \\
 B_{11} \\
 B_{12} \\
 B_{13} \\
 B_{15} \\
 B_{16} \\
 B_{17} \\
 B_{18}
 \end{pmatrix} = \begin{pmatrix}
 D_g \\
 D_c \\
 D_{ev} \\
 D_{ab} \\
 D_{tc} \\
 D_b
 \end{pmatrix} \tag{12}$$

$$\begin{pmatrix} -1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 1 & -1 & 0 & 0 & 1 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\ 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 1 & -1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \times \begin{pmatrix} B_1 \\ B_2 \\ B_4 \\ B_6 \\ B_7 \\ B_8 \\ B_9 \\ B_{10} \\ B_{11} \\ B_{12} \\ B_{13} \\ B_{17} \\ B_{18} \\ B_{20} \\ B_{22} \end{pmatrix} = \begin{pmatrix} D_g \\ D_c \\ D_{ev} \\ D_{ab} \\ D_{tc} \\ D_b \\ D_{it} \end{pmatrix} \tag{13}$$

To the LiBrH₂O system of the component that revealed having the more destruction exergetic was the generator followed of absorber like showing Fig. 4:

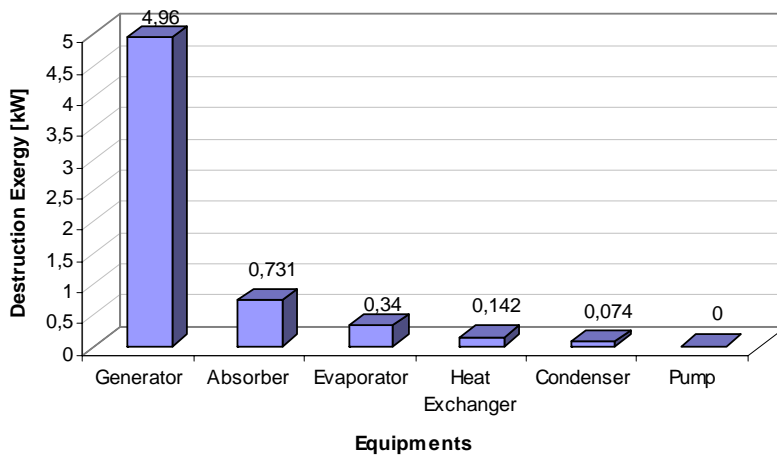


Figure 4. Exergetic destruction of the LiBr-H₂O system components.

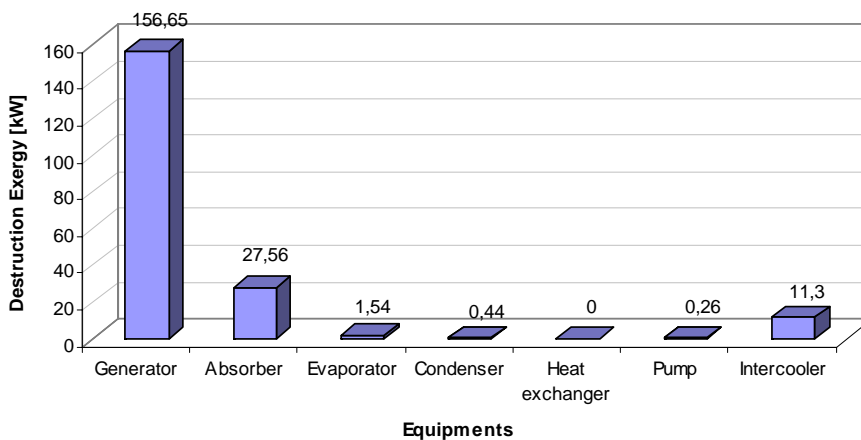


Figure 5. Exergetic destruction of the NH₃-H₂O system components.

The NH₃-H₂O system developed the same behavior with the destruction exergetic of generator being the more, followed of absorber, as shown in Fig. 5.

Applying the preposition of Valero *et al* (1986) to the system of LiBr-H₂O having:

$$\begin{pmatrix}
 0 & 0 & 1 & -1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 \\
 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 \\
 -1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & -1 & 0 & 0 & 0 \\
 0 & 1 & -1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{B_8} & \frac{-1}{B_{10}} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & \frac{1}{B_4} & \frac{-1}{B_5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 \frac{-1}{B_1} & 0 & 0 & 0 & \frac{1}{B_5+B_{10}} & 0 & 0 & \frac{1}{B_5+B_{10}} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & \frac{-1}{B_3} & \frac{1}{B_4+B_7} & 0 & \frac{1}{B_4+B_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & \frac{1}{B_4} & 0 & \frac{-1}{B_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
 \end{pmatrix}
 \times
 \begin{pmatrix}
 B_1^* \\
 B_2^* \\
 B_3^* \\
 B_4^* \\
 B_5^* \\
 B_7^* \\
 B_8^* \\
 B_{10}^* \\
 B_{11}^* \\
 B_{12}^* \\
 B_{13}^* \\
 B_{15}^* \\
 B_{16}^* \\
 B_{17}^* \\
 B_{18}^*
 \end{pmatrix}
 =
 \begin{pmatrix}
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0
 \end{pmatrix}
 \tag{14}$$

For the NH₃-H₂O system having:

$$\begin{pmatrix}
 -1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 1 & -1 & 0 & 0 & 1 & 0 \\
 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\
 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 \\
 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 1 & -1 & 1 & 0 & 0 & 0 & 0 \\
 0 & 1 & -1 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & \frac{1}{B_6} & \frac{-1}{B_7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 \frac{1}{B_1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{-1}{B_{13}} & 0 & 0 & 0 & 0 \\
 \frac{1}{B_1+B_{13}} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{-1}{B_{12}} & \frac{1}{B_1+B_{13}} & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & \frac{1}{B_7+B_{13}} & \frac{-1}{B_8} & 0 & 0 & 0 & 0 & \frac{1}{B_7+B_{13}} & 0 & 0 & 0 & 0 \\
 0 & \frac{1}{B_2} & \frac{-1}{B_4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{B_{10}} & \frac{-1}{B_{11}} & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
 \end{pmatrix}
 \times
 \begin{pmatrix}
 B_1^* \\
 B_2^* \\
 B_4^* \\
 B_6^* \\
 B_7^* \\
 B_8^* \\
 B_9^* \\
 B_{10}^* \\
 B_{11}^* \\
 B_{12}^* \\
 B_{13}^* \\
 B_{17}^* \\
 B_{18}^* \\
 B_{20}^* \\
 B_{22}^*
 \end{pmatrix}
 =
 \begin{pmatrix}
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0
 \end{pmatrix}
 \tag{15}$$

The results obtained the behavior at cost exergetic (B*) of each flux to the systems of LiBr-H₂O and NH₃-H₂O in the Fig. 6 and 7 respectively.

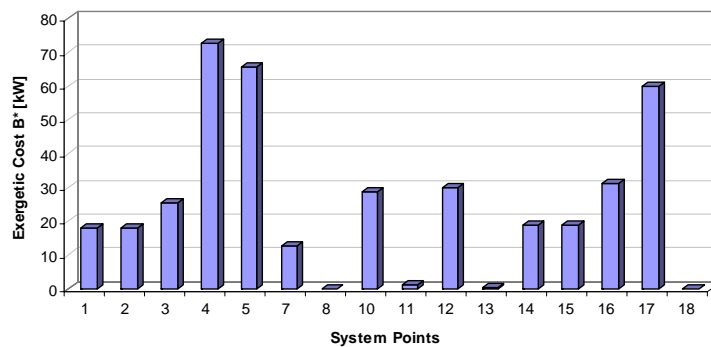


Figure 6. LiBr-H₂O system exergetic cost.

The flux 4 (exit of concentrated solution of the generator) shows more onerous for the system of LiBr-H₂O, because this flux is enthalpic end transports itself a big part of heat changed with the gas of combustion (source of energy primary).

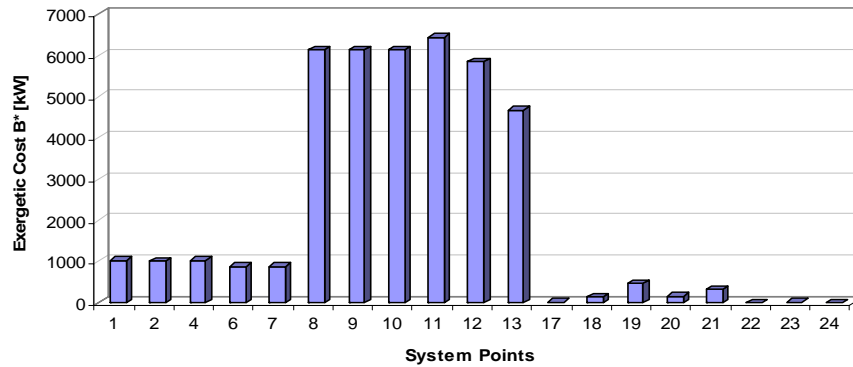


Figure 7. Exergetic Cost of the various fluxes of the NH₃-H₂O system.

The behavior of the exergetic cost to the NH₃-H₂O system shown that the flux 11 (exit of generator) is the current that absorbs as the heat exchanged by gases of combustion (flux 20).

The capital invested in each component is determined by the equation 11, considering the initial investments to be shown individually in Tab. 5 for each subsystem, in real (R\$).

Table 5 - Initial investment of each subsystem.

Subsystems	Investment (F _i) - (R\$)	
	LiBr-H ₂ O system	NH ₃ -H ₂ O system
Generator	4.882,40	24.320,00
Condenser	4.164,40	11.670,00
Evaporator	5.054,72	24.432,00
Absorber	5.973,76	11.670,00
Heat Exchanger	2.326,32	11.670,00
Pumps	1.306,80	1.946,00
Intercooler	–	11.670,00

Applying the rocking of costs according to Eq. (4), to get the results of the monetary costs:

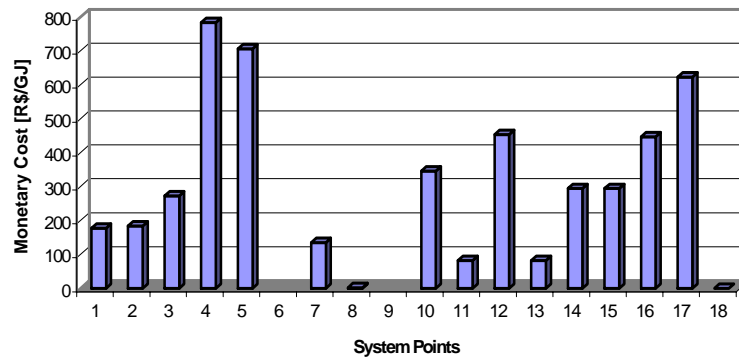


Figure 8. Monetary costs of the LiBr-H₂O system.

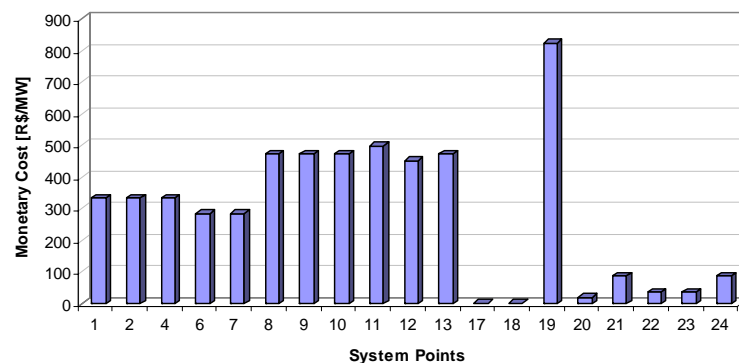


Figure 9. Monetary costs of the NH₃-H₂O system.

Chain the high cost of the flows 19 that is energetic entrance, 11, 12 and 13 a consequence of them to be an attribution of high reasons of mass of the system, based on these specifications and invoking simple balance mass at the generator, beyond this chain respectively to receive heat in the cooling from the absorber.

4. CONCLUSIONS

The simulation has demonstrated that, although LiBr-H₂O system have revealed a higher thermal performance than NH₃-H₂O system, the flows of exergetic and monetary costs of the performance in this second system are more expensive than LiBr-H₂O ones; this is due to the fact of the equipment at ammonia cycle is greater and initial capital of investment – NH₃-H₂O system – is lower than in LiBr-H₂O system. Whereas the NH₃-H₂O system demands special design consideration because both ammonia and water are volatile (albeit to highly differing degree).

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