Simulation of the heat exchange processes of an absorber and a generator with NH3/LiNO3

Simulação dos processos de troca de calor de um absorvedor e de um gerador com NH3/LiNO3

Simulación de los procesos de intercambio de calor de un absorbedor y un generador con NH3/LiNO3

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ABSTRACT  
A mathematical model is the representation, through equations, of the phenomenon that you want to model. In the context of control systems, models are used to analyze and design control systems. A system is dynamic when its variables change depending on another variable, which is generally time. In this article, an absorption refrigeration system is considered, a model and simulation of it is carried out and the results are
compared with the available experimental data, where the existence and uniqueness of the solution in a certain space of finite smoothness is demonstrated, and the certain properties of the solution to the problem.

**Keywords:** Simulation, Heat Exchange, Absorber, Generator, Refrigeration.

RESUMO
Um modelo matemático é a representação, através de equações, do fenômeno que se deseja modelar. No contexto dos sistemas de controle, modelos são usados para analisar e projetar sistemas de controle. Um sistema é dinâmico quando suas variáveis mudam dependendo de outra variável, que geralmente é tempo. Neste artigo, considera-se um sistema de refrigeração por absorção, realiza-se um modelo e simulação deste e comparam-se os resultados com os dados experimentais disponíveis, onde se demonstra a existência e singularidade da solução em um determinado espaço de suavidade finita, e as certas propriedades da solução do problema.

**Keywords:** Simulação, Troca de calor, Absorvente, Gerador, Refrigeração.

RESUMEN
Un modelo matemático es la representación, a través de ecuaciones, del fenómeno que se desea modelar. En el contexto de los sistemas de control, se utilizan modelos para analizar y diseñar sistemas de control. Un sistema es dinámico cuando sus variables cambian dependiendo de otra variable, que generalmente es el tiempo. En este artículo se considera un sistema de refrigeración por absorción, se realiza un modelo y simulación del mismo y se comparan los resultados con los datos experimentales disponibles, donde se demuestra la existencia y singularidad de la solución en un cierto espacio de suavidad finita, y las ciertas propiedades de la solución al problema.

**Palabras clave:** Simulación, Intercambio de Calor, Absorbedor, Generador, Refrigeración.

1 INTRODUCTION

The technological advancement in absorption chillers powered by renewable sources has aroused significant interest in the scientific community in recent years, due to the increase in primary energy consumption, which causes problems such as greenhouse gases and air pollution, among others. These machines are classified as an interesting alternative for the use of residual energy (cogeneration and/or industrial processes) and/or renewable energy (solar). This technology is used in sectors that require
a wide variety of cooling and/or air conditioning conditions. However, the low efficiency of these machines compared to conventional systems makes it necessary to make improvements to the heat and mass transfer processes of the critical components, mainly the absorber, in order to reduce their large size, above these disadvantages these systems are promoted in the current world energy market, although with high prices, which is related to the complexity of the system and the size of the heat exchangers[1].

The absorber is usually the largest element of absorption machines, due to its low heat and mass transfer coefficients, this fact influences the final design of the entire system.[2], For this reason, the development of a numerical tool that includes physical construction characteristics becomes interesting for the design and optimization of absorption chillers.

2 DESORBER MODEL

For heat transfer between the solution rich in ammonia-lithium nitrate refrigerant and the activation water during the desorption process of the absorption chiller, a welded plate heat exchanger has been used, where 2 processes occur in its channels, in the first one the solution is heated by the hot activation water, so that the liquid solution entering the desorber goes from subcooling to saturation state, this region will be called subcooling zone 1 (SUB); Subsequently, this liquid solution at the saturation point continues to be heated and the forced boiling process occurs where the ammonia is separated from the ammonia-lithium nitrate solution, generating ammonia vapor that passes in saturation equilibrium conditions with the solution of lower concentration in refrigerant resulting from this boiling process, this region has been called zone 2 boiling by forced circulation (EBULL).
as a result of the division of the desorber into zones. In Table 1, the data of the heat exchanger used for the desorber are presented.

![Figure 1. Desorber zones](source)

Table 1. Desorber data

<table>
<thead>
<tr>
<th>Description</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presión de trabajo</td>
<td>$P_{abs}$</td>
<td>1555</td>
<td>[kPa]</td>
</tr>
<tr>
<td>Fluido de trabajo</td>
<td>$\text{NH}_3$-$\text{LiNO}_3$</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ebullición forzada</td>
<td>EBF</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cambio de líquido a vapor</td>
<td>L-V</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fabricante</td>
<td>SWEP</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Intercambiador de placas</td>
<td>B25TH</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Área lateral de cada placa</td>
<td>$A_p$</td>
<td>1.44</td>
<td>m$^2$</td>
</tr>
<tr>
<td>Distancia entre cada placa</td>
<td>$b$</td>
<td>0.002</td>
<td>m</td>
</tr>
<tr>
<td>Espesor de cada placa</td>
<td>$e$</td>
<td>0.004</td>
<td>m</td>
</tr>
<tr>
<td>Ancho de cada placa</td>
<td>$W$</td>
<td>0.116</td>
<td>m</td>
</tr>
<tr>
<td>Ancho interno de la placa</td>
<td>$l_c$</td>
<td>0.072</td>
<td>m</td>
</tr>
</tbody>
</table>

Source: Authors

At the exchanger outlet there is a separation tank into which the saturated ammonia-poor solution falls, which passes to the solution exchanger, as well as the ammonia vapor that goes to the condenser; This tank does not have a flash effect and in its function as a separator and accumulator of the solution it guarantees that all the liquid ammonia mixed with the salt does not reach the condenser. In Error! Fonte de referência não encontrada., the diagram of the absorber with the separator tank is observed. In Error! Fonte de referência não encontrada., the initial scheme of the desorber is shown, in which the blue lines represent the NH3-LiNO3 solution, identified as the cold fluid that removes heat from the hot water, represented with the red lines, later the Diagram of the
2 desorber zones separated into “sub-exchangers”. The properties of each fluid according to the zones and working conditions are presented in Table.
Figure 2. Desorber diagram

Figure 3. Diagram of the desorber

Table 2. Desorber Fluid Properties

<table>
<thead>
<tr>
<th>Estado del fluido</th>
<th>Calor específico $C_p$ [kJ/kg·K]</th>
<th>Conductividad $k$ [W/m·K]</th>
<th>Viscosidad $\mu$ [kg/m·s]</th>
<th>Densidad $\rho$ [kg/m$^3$]</th>
<th>Concentración $\rho_{NH_3}$ [kg/m³] de amoníaco</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agua de activación</td>
<td>4,212</td>
<td>0,6638</td>
<td>0,0002937</td>
<td>961,1</td>
<td>-</td>
</tr>
<tr>
<td>NH₃/LNO₃ líquido saturado</td>
<td>3,131</td>
<td>0,3163</td>
<td>1,954</td>
<td>1013</td>
<td>0,4668</td>
</tr>
<tr>
<td>NH₃/LNO₃ líquido subenfriado</td>
<td>3,314</td>
<td>0,3405</td>
<td>1,553</td>
<td>963,1</td>
<td>0,5207</td>
</tr>
</tbody>
</table>

Source: Authors
2.1 ZONA DE SUBENFRIAMIENTO

The film convection coefficient for the water in zone 1, is calculated through the Nusselt single-phase convective heat transfer correlation from Table 2-2, for the liquid ammonia/lithium nitrate solution, the correlation is used. of single phase proposed by Zacarias in 2010. For this zone the heat transferred \((Q_d)\), \(Re\), \(Pr\), \(Dh\), \(\Delta P\), \(f\), \(U\), LMTD, he number of channels and plates is calculated, continuing with the methodology of the previous zones. Selected for providing better performance according to the comparison.

\[ Nu_0 = 11.7 \times 10^4 Pr^{0.21} Pr^{-1.19} Bo^{1.21} Ja^{-0.75} \]  
\[ (1) \]

2.2 BOILING ZONE

The forced boiling heat transfer coefficient for mixtures for the selected solution in zone 2 is the one presented by Taboas in 2009 taken from Table 2-5. For water, continue to use the Nusselt single-phase convective heat transfer correlation from Table 2-2.

For this area, the coefficient of friction and pressure loss is calculated by the expression of equation (2) and (3) respectively, taken from the reference [13].

\[ \Delta P = \Delta P_{t} - \Delta P_{st} - \Delta P_{mon} - \Delta P_{man} \]  
\[ (2) \]

\[ f = \frac{\Delta P_{Dh} \cdot \rho}{2G^2 \cdot L} \]  
\[ (3) \]

Donde \(\Delta P_{st}, \Delta P_{mon}, \Delta P_{man}\) this is given by the equations (4), (5) y (6).

\[ \Delta P_{st} = g \cdot \rho \cdot L \]  
\[ (4) \]
\[
\Delta P_{\text{mon}} = G^2 \cdot \left( \frac{1}{\rho \cdot \varphi} - \frac{1}{\rho \cdot L} \right) \cdot \Delta x
\]

(5)

\[
\Delta P_{\text{man}} = 1.5 \cdot \left( \frac{G^2}{2 \cdot p} \right)
\]

(6)

With the Boiling number (Bo) and the Martinelli parameter (Xtt) from reference [14], it is possible to indicate within the forced boiling zone which convective coefficient is dominant (nucleated or convective), applying the conditional:

Bo \cdot X_{tt} > 0.15 \cdot 10^{-3} \rightarrow \text{Nucleated boiling}

Bo \cdot X_{tt} < 0.15 \cdot 10^{-3} \rightarrow \text{Convective boiling}

The critical heat flux is calculated from the 1963 Mostinki reduced pressure correlation presented in Table 2-3.

The inlet and outlet enthalpy of the ammonia-rich solution in the desorber is obtained considering the equilibrium conditions of the inlet and outlet of the heat exchanger. See equations (7) and (8).

\[
X_{\text{in}}; y_{\text{in}}; H_{\text{in}} = F(T_{\text{in}}; P_{\text{in}}; w_{\text{in}})
\]

(7)

\[
X_{\text{out}}; y_{\text{out}}; H_{\text{out}} = F(T_{\text{out}}; P_{\text{out}}; w_{\text{out}})
\]

(8)

With equations (3-22) and (3-23) the title of the steam is calculated, which, since it has previous subcooling, is calculated with equation (9).

\[
W = \frac{C_p \Delta T_{\text{sub}}}{H_{\text{Vsat}} - H_{\text{Lsat}}}
\]

(9)
2.3 MASS BALANCE

As visual support in Error! Fonte de referência não encontrada., the behavior of the solution within one of the channels of the plates of the desorber is observed, appreciating the phase change.

Figure 4. Behavior of the solution inside a desorber channel

The mass transfer coefficient is calculated by means of equation (2-22) and it is possible to determine the mean logarithmic difference of concentrations by the expression of equation (10), as shown by the references [15], [16].

\[ \Delta x_{LM} = \frac{(x_{eq} - x_i) - (x_{eq} - x_0)}{ln \left( \frac{x_{eq} - x_i}{x_{eq} - x_0} \right)} \]  (10)
2.4 NUMERICAL SIMULATION OF THE DESORBER

To develop the simulation, different basic concepts are taken into account, which were previously calculated. The system must start from a sketch that specifies the thickness, spaces, diameter of the pipe through which the fluid will enter, the arrangement that the channels will have, the design of the channels and that of the packages. In the design of the channels it is necessary to take into account the separation between plates that is given by each manufacturer, as well as the step, the crest and the Angle of the undulations of each plate. In figures 5. to 13 the design is significantly appreciated in CAD and its implications for the adequate development of the numerical model of both exchangers.

Figure 5. PHE corrugation sketch

![Figure 5. PHE corrugation sketch](source)

Source: Authors

Figure 6. Construction of the first corrugated strip of each plate. And fringe cut

![Figure 6. Construction of the first corrugated strip of each plate. And fringe cut](source)

Source: Authors
After this step it is recommended to use the sheet metal tool to establish an area to arrange the design to be welded or packed if desired.
It is important since with it it is possible to see where the leak is.

For the final plate, it must be taken into account that the cuts through which the fluid will enter must be removed.
When entering the assembly, the directions of each plate must be taken into account, as well as the final or blind plate and the initial plate through which the fluids will enter, when having the first arrangement with the position relations between the plate, a component matrix must be entered linear which will generate the number of real plates and finally we apply the position relationship to the initial plate so that we do not have problems with the fluids, in other words that there are no leaks in the process, after having the assembly from the exchanger, we go to the “Flow simulation” plugin.
In this complement we can observe the behavior of the hot water at the entrance of the desorber, how it is heating the mixture of Ammonia/Lithium Nitrate.

In this system, the SWEP parameters that correspond to the temperature, speed and pressure of both fluids are taken with these data we can execute the simulation of the exchanger.

Figure 15. Desorber

Source: Authors
Figure 16. Desorber

Source: Authors
3 RESULTS

In this system, two heat exchangers with different number of plates are created, which are entered the thermal parameters to each system to execute their simulation, then the results obtained in each simulation are presented.

The values of the heat transferred in each zone are added, see equation (11), finally obtaining the value of the total value of the heat transferred for the entire evaporator, which is \( \dot{Q}_d = 18.27 \text{ [kW]} \), just like the sum of the areas see equation (12) and the number of plates, obtaining the total number of plates necessary for heat transfer in the exchanger (24 plates). These results are presented and compared in Table 3.

Table 3. , with the data provided by the SWEP manufacturer for the same conditions obtained through the SSP G7 software.

\[
\dot{Q}_d = \dot{Q}_{d_{Z1}} + \dot{Q}_{d_{Z2}} \quad (11)
\]

\[
A_d = A_{d_{Z1}} + A_{d_{Z2}} \quad (12)
\]

In Error! Fonte de referência não encontrada., The variation of the forced boiling coefficient is presented as a function of the increase in the concentration in the ammonia-rich solution of the desorber.

In Error! Fonte de referência não encontrada., the comparison of the model on the effect of the variation of the flow of hot water in the power of the desorber with the experimental data of the reference [5] is presented. [5].
In Erro! Fonte de referência não encontrada. shows the comparison of the model on the effect of the variation of the hot water flow on the pressure difference in the desorber in relation to the manufacturer's data (SWEP). In

4 ABSORBER MODEL

, Comparison of the model on the effect of the variation of the hot water flow on the pressure difference in the desorber but with the experimental data presented in Ref. [5].

Figure 17. Variation of the forced boiling coefficient as a function of the increase in concentration in the solution rich in ammonia in the desorbed.

![Graph showing variation of the forced boiling coefficient as a function of concentration (Source: Authors)](image)

Figure 18. Comparison of the model on the effect of the variation of the flow of hot water on the power of the desorber with the experimental data.

![Graph comparing model and experimental data for the effect of hot water flow on desorber power (Source: Authors)](image)
Figure 19. Comparison of the model on the effect of the variation of the hot water flow on the pressure difference in the desorber with the manufacturer's data (SWEP)

![Graph showing comparison](image)

Source: Authors

Figure 20. Comparison of the model on the effect of the variation of the hot water flow on the pressure difference in the desorber with respect to the experimental data.

![Graph showing comparison](image)

Source: Authors

4 ABSORBER MODEL

The mathematical model of an absorber with ammonia/lithium nitrate, using plate heat exchangers, where the absorption process of the superheated ammonia that comes from the refrigerant exchanger occurs inside the channels. The characteristics of the absorber are presented in the Table.

The points for the development plate absorber model are shown in the diagram of Erro! Fonte de referência não encontrada.
Table 4. Characteristics of the absorber are presented

<table>
<thead>
<tr>
<th>Description</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presión de trabajo</td>
<td>P&lt;sub&gt;b&lt;/sub&gt;</td>
<td>647.8</td>
<td>kPa</td>
</tr>
<tr>
<td>Fluido de trabajo</td>
<td>NH&lt;sub&gt;3&lt;/sub&gt;-LiNO&lt;sub&gt;3&lt;/sub&gt;</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Absorción</td>
<td>ABS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fabricante</td>
<td>SWEP</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Intercambiador de placas</td>
<td>B25T</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Área lateral de cada placa</td>
<td>A&lt;sub&gt;p&lt;/sub&gt;</td>
<td>2.02</td>
<td>m&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Distancia entre cada placa</td>
<td>b</td>
<td>0.002</td>
<td>m</td>
</tr>
<tr>
<td>Espesor de cada placa</td>
<td>e</td>
<td>0.004</td>
<td>m</td>
</tr>
<tr>
<td>Ancho de cada placa</td>
<td>W</td>
<td>0.117</td>
<td>m</td>
</tr>
<tr>
<td>Ancho interno de la placa</td>
<td>L&lt;sub&gt;p&lt;/sub&gt;</td>
<td>0.072</td>
<td>m</td>
</tr>
</tbody>
</table>

Source: Authors

Figure 21. Plate absorber schematic diagram

Source: Authors

4.1 MODEL METHODOLOGY

Unlike the desorber, in the case of the absorber, the heat transfer coefficients of the models for the liquid solution have been correlated only in terms of dimensionless numbers such as Re, Pr and Dh, RVL, among others, due to the fact that the phenomena that occur are totally different, which is why in the absorber the model has only been developed for a single work zone, the absorption zone, in Error! Fonte de referência não encontrada. the diagram of the zone is presented with the variables corresponding to each point. The diagram of the plate absorber with the accumulation tank, which ensures that it supplies the amount of liquid solution required by the solution pump, is presented in Error! Fonte de referência não encontrada.
The correlation used for the film convective coefficient on the solution side of the absorber is proposed by Amaris in 2013, selected for the good experimental results obtained by the author for an ammonia/lithium nitrate plate heat exchanger. Obtaining the correlations of the heat transfer coefficients for the solution and the vapor phase at the interface.
For which it was necessary to calculate Re and Pr of the solution, with a limitation of 24<Pr<37 and 0,06<Re<54.

The absorber mass transfer correlations were also taken from Amaris 2013.

\[
\text{Nu}_{\text{sol}} = 0.4 \left( \frac{\rho_{\text{sol}} \cdot \nu \cdot \Delta \rho_{d}}{\mu_{\text{sol}}} \right)^{0.25} \left( \frac{\nu \cdot \Delta \rho_{d}}{g \cdot d_{p}} \right)^{0.25} \frac{\mu_{\text{sol}} \cdot C_{\text{sol}} \cdot V}{\lambda_{\text{sol}}} \]

\[
\text{Nu}_{\text{sol}} = 0.0075 \cdot C_{\text{sol}} \cdot V \cdot \frac{\lambda_{\text{sol}}}{C_{\text{sol}} \cdot \mu_{\text{sol}}}^{0.22}
\]

For the convective film coefficient on the water side, the correlation of Nu for single-phase coefficients with forced circulation for vertical tubes and plates. The properties of the fluids in each state are presented in Properties of the fluids for each state.

\[
\text{Nu} = 0.27 \times 10^{-3} + \text{Re}^{0.36} \cdot \text{Pr}^{1.99}
\]

For the convective film coefficient on the water side, the correlation of Nu for single-phase coefficients with forced circulation for vertical tubes and plates. The properties of the fluids in each state are presented in Properties of the fluids for each state.

\[
\text{Nu} = 0.27 \times 10^{-3} + \text{Re}^{0.36} \cdot \text{Pr}^{1.99}
\]

Table 4. Fluid properties for each state

<table>
<thead>
<tr>
<th>Estado del fluido</th>
<th>Calor específico [kJ/kg·K]</th>
<th>Conductividad [W/m·K]</th>
<th>Viscosidad [kg/m·s]</th>
<th>Densidad [kg/m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amoniaco Gas recalentado</td>
<td>3,016</td>
<td>0,08015</td>
<td>0,00001112</td>
<td>10,17</td>
</tr>
<tr>
<td>NH3/LiNO3 líquido rico</td>
<td>3,207</td>
<td>0,4355</td>
<td>1,107</td>
<td>995,4</td>
</tr>
<tr>
<td>NH3/LiNO3 líquido pobre</td>
<td>3,005</td>
<td>0,4139</td>
<td>4,628</td>
<td>1048</td>
</tr>
<tr>
<td>Agua de disipación</td>
<td>4,183</td>
<td>0,6031</td>
<td>0,000796</td>
<td>995,6</td>
</tr>
</tbody>
</table>

Source: Authors

Because this exchanger was not divided into zones, but there is a phase change of the ammonia in the superheated vapor state that is absorbed by the liquid solution poor in refrigerant, 3 types of heat are calculated, which will be added, obtaining the total heat transferred by the absorption process in the exchanger. The heat 1, defined in equation
(14) and from now on called $Q_{sl}$, represents the sensible heat of the liquid, which corresponds to the heat transferred after the point of absorption or interface, the interface represents the limit of vapor-liquid exchange of the fluids. This heat is calculated by means of the liquid constant ($C_{tl}$) which is calculated by the expression of equation (15).

In the Error! Fonte de referência não encontrada., The diagram of the absorber with the VL interface can be seen. The heat 2, expressed in equation (16) and called $Q_{sv}$, represents the sensible heat on the steam side, that is to say that this is the heat that passes from the breast of the steam to the interface, this heat is calculated by means of the steam constant ($C_{tv}$) which is calculated by the expression of equation (17). The third heat is the interfacial latent heat ($Q_{\lambda}$) which represents the energy generated by the absorption of ammonia, where it changes phase, this heat is calculated by the expression of the equation (18).

$$Q_{sl} = C_{tl} \times (T_{int} - T_{l})$$  \hspace{1cm} (14)

$$C_{tl} = \frac{NH_3CP_l + NH_3LiNOCP_l}{h_l} \frac{h_l}{1 - e^{-\frac{NH_3CP_l + NH_3LiNOCP_l}{h_l}}}$$  \hspace{1cm} (15)

$$Q_{sv} = C_{tv} \times (T_{v} - T_{int})$$  \hspace{1cm} (16)

$$C_{tv} = \frac{NH_3CP_v + NH_3LiNOCP_v}{h_v} \frac{h_v}{1 - e^{-\frac{NH_3CP_v + NH_3LiNOCP_v}{h_v}}}$$  \hspace{1cm} (17)

$$Q_{\lambda} = (NH_3 + LiNO_3) \times \lambda_{AB}$$  \hspace{1cm} (18)

Where $\lambda_{AB}$ represents the enthalpy of phase change and is calculated by equation (19).

$$\lambda_{AB} = H_v - H_l$$  \hspace{1cm} (19)
Where \( H_v \) and \( H_l \) represent the specific enthalpy of the vapor phase and the liquid phase respectively.

Figure 24. Schematic of the absorber with the VL interface

![Schematic of the absorber with the VL interface](image_url)

Source: Authors

The ammonia flux that crosses the boundary bed from the vapor trough to the interface is calculated by equation (20)

\[
NH_3 = (NH_3 + LiNO_3) y_{NH_3} - \rho_v \beta_v \left( \frac{dy_{NH_3}}{d\eta} \right) \tag{20}
\]

Where \( NH_3 \) represents the absorbed flux of ammonia at the interface and \( \rho_v \beta_v \) are the density and diffusivity in the vapor phase and \( \eta \) refers to the resistance of mass transfer.

The mass transfer coefficient is obtained by equation (21)

\[
NH_3 + LiNO_3 = h_m \left( \ln \frac{y_{\text{int}}}{Z-y} \right) \tag{21}
\]
Where $Z$ represents the ratio of the ammonia flux between the absorbed solution at the interface, and represents the mass fraction of ammonia in the vapor phase. $Z$ is obtained by equation (22).

$$Z = y_{NH3} - \frac{\rho_v \beta_v}{NH3+LiNO3} \left( \frac{dy_{NH3}}{d\eta} \right)$$  \hspace{1cm} (22)

The model manages to calculate the values at the outlet of the solution and dissipation water temperatures, the heat transfer coefficients for the solution and the water and the mass for the solution side, the number of plates needed, the area length of the plates.

4.2 ABSORBER NUMERICAL SIMULATION

In order to develop the numerical simulation of the absorber, taking into account the correlations and data taken, the CAD design and its implications for the proper development of the numerical model of the exchanger, the behavior of the solution in the heat exchange process is shown below. Heat between the absorption of the solution with the ammonia vapor and the heat dissipation water.

Figure 25. Detailed view of the heat exchange process between the absorption of the solution with the ammonia vapor and the heat dissipation water.

Source: Authors
In this image you can capture the behavior of the fluid in its divisions that developed in the plates which doesn’t allow direct contact between fluids and liquids.

5 RESULTS

With the values obtained by the model, a verification of the same was carried out with the data from the manufacturer SWEP and the experimental data from ref[5].
Table 6, the comparison with the manufacturer's data is observed and in the Error! Fonte de referência não encontrada. A comparison was made with the manufacturer's data of the pressure difference as a function of the flow rate of the absorber dissipation water.

<table>
<thead>
<tr>
<th>Absorbedor</th>
<th>Area de transferência m²</th>
<th>Nº de placas</th>
<th>Fluo de calor kW/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabricante</td>
<td>2,04</td>
<td>34</td>
<td>7,353</td>
</tr>
<tr>
<td>Modelo</td>
<td>2,02</td>
<td>33</td>
<td>7,501</td>
</tr>
</tbody>
</table>

Source: Authors

Figure 28. Comparison with the manufacturer's data of the difference in pressure as a function of the flow rate of the absorber dissipation water.

Subsequently, a variation of the longitudinal area of the plate was carried out, observing the influence of the increase in the area on the temperature profiles of the dissipation water, the temperature of the solution in the liquid state and the concentration of the solution; this variation is observed in the Error! Fonte de referência não encontrada..

In Error! Fonte de referência não encontrada., the absorbed flow and vapor-liquid ratio (RVL) are observed along the longitudinal area of the heat exchanger
6 CONCLUSIONS

In this paper, the thermodynamic model of the simple effect absorption refrigeration cycle with ammonia/lithium nitrate was presented, which served as the basis for the development of mathematical models of the different thermal components of the chiller.

The mathematical models of each component were developed based on the theory and previous research of the scientific community and specifically on the work carried out by the CREVER group, with regard to models and characterization of heat and mass...
transfer processes in single and two-phase mass heat exchangers. The models are based on a set of equations capable of calculating the overall film heat transfer coefficient, the inlet and outlet conditions of each component, the heat transfer area, the number of plates required for transfer, and for the absorber and desorber cases, the mass transfer coefficient. Being validated with the existing data in the literature and others supplied by the manufacturer of the plate heat exchangers, the comparative analysis shows us that the model has a good fit, with an error range of ± 10%. With this comparative analysis it is also found that the number of plates calculated by the models is lower than the real ones, this is due to the fact that the design heat transfer coefficients are slightly higher than the real coefficients.

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