



## CALCULATION OF THE COEFFICIENT OF HEAT TRANSFER FOR EVAPORATION CONVECTIVE IN SATURATED STREAM FOR COOLING FLUIDS: R-12, R-22, R-134A, R-600 AND R-717

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**Abstract.** One major problem in the heat transfer process by convection is the determination of the heat transfer coefficient. This coefficient depends of the boundary layer conditions, which on the other hand, are influenced by the surface geometry, by the nature of fluid movement and by the number of thermodynamic and transport properties of the fluid. In this work is shown a procedure for calculating the heat transfer coefficient by convection for the evaporation-nucleation process which occurs in the generator of an absorption refrigeration system (ARS). The model proposed by Chen (1996) has been implemented in the Engineering Equation Solver – EES<sup>®</sup> and the analysis was made using four types of cooling fluids: R-12, R-22, R-134a, R-600 (butane) and R-717 (ammonia). Of that study it is concluded that R-12, R-22 and R-134a showed behaviors alike, however the R-134a presented the higher heat transfer coefficients. The behavior of the R-600 is different from the three other fluids, since it has not an intersection point between the macroscopic and microscopic heat transfer coefficients. The R-717 showed the highest heat transfer coefficients among the fluids studied.

**Keywords:** Transport properties, Heat transfer, Cooling fluids, Evaporation convective

## 1. INTRODUCTION

To determine the heat flux in the heat exchangers where involves the heat transfer by convection, it is necessary to know the overall heat transfer coefficient that is dependent of the convection coefficient. The determination of this coefficient depends of the process type (heating, boiling, evaporation, and condensation), the type of flow (internal or external) and the flow characteristic (laminar or turbulent) (Incropera and De Witt, 2002).

A thermal machine that has different heat transfer processes is the absorption refrigeration system (ARS). A system commonly used for residential applications is the commercial system manufactured by ROBUR<sup>®</sup>. Fig. 1 shows a schematic drawing of the system where can visualize its components: generator (GERA), rectifier (RET), condenser (COND), reduction valves 1, 2 and 3 (RV1, RV2, RV3), evaporator (EVA), heat exchanger concentric (TCC), absorber (ABS), absorber - air heat exchanger (ABAHE) and solution pump (SP).

In absorption refrigeration systems there are many types of processes where it is necessary to determine the heat transfer coefficients. It can be cited: 1) GERA occurs in a process of nucleate boiling, along with a forced convection boiling; 2) in the GERA, in the EVA, and in the RET there is a heat exchange in an unstable flow of a fluid outside the coil, that descends toward the bottom of the respective tanks; 3) in the heat exchanger formed by the coil into components as: GERA, RET and ABS, the model for determining the heat transfer coefficient becomes more difficult, due to spiral shape of the tube, which hinders the complete knowledge of the flow; 4) in the COND and in the ABAHE there are two types of heat exchange by convection, the first one occurs on the outside of the tube, which is characterized as a heat exchanger in cross flow in tube banks; the second occurs inside the tube COND (Araújo, 2010).

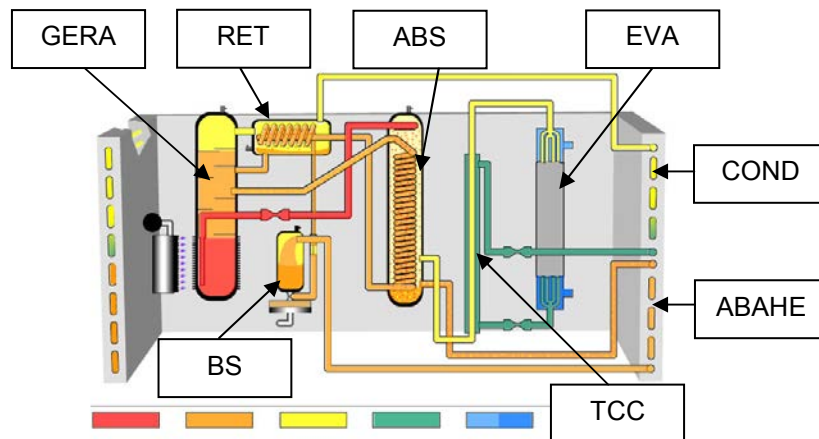


Figure 1. Schematic drawing of the ARS ROBUR®

In this work will be studied the procedure for calculating the heat transfer coefficient by convection for evaporation-nucleation process that occurs in the GERA of an ARS. The evaporation of the working fluid happens in the GERA, due to the heat provided by direct combustion of a gaseous fuel (liquefied petroleum gas, natural gas, etc). Inside the GERA may be considered an evaporation-nucleation, with the heat transfer coefficient being determined by the model proposed by Chen (1966), where a convective evaporation in the saturated state may be considered.

## 2. MATHEMATICAL FORMULATION

In GERA the evaporation of ammonia happens due to heat incoming into this component because of burning of the gaseous fuel. There is a heat transfer coefficient,  $h$ , inside and side of burning of the fuel. The  $h$  to the side of fuel combustion can be estimated in a manner that results in an acceptable temperature in the wall of GERA.

To the side of the mixture in GERA the  $h$  is calculated according to the model proposed by Chen (1966), where it is the sum of the contribution microscopic ( $h_{mic}$ ) with the evaporation macroscopic ( $h_{mac}$ ):

$$h = h_{mic} + h_{mac} \quad (1)$$

The correlation macroscopic ( $h_{mac}$ ) has been proposed by Chen (1966) that is based on the equation of Dengler and Addmons (1956), with a generalization to satisfy the all applications with liquid non-metallic:

$$h_{mac} = h_i F(X_{tt}) Pr_l^{0.296} \quad (2)$$

where  $h_i$  is the coefficient of simple phase for the liquid,  $F(X_{tt})$  is a factor that is function of the Martinelli parameter for turbulent flow,  $X_{tt}$ , e  $Pr_l$  is the Prandtl number for the liquid solution. The value of  $h_i$  is determined using the equation of Dittus-Boelter:

$$h_i = 0.023(\lambda_l / D) Re_l^{0.8} Pr_l^{0.4} \quad (3)$$

where  $\lambda_l$  is the thermal conductivity of the liquid solution of ammonia-water,  $D$  is the internal diameter of the GERA and  $Re_l$  is the Reynolds number for the liquid solution. The Reynolds number and Prandtl number are determined by the Eqs. (4) e (5), respectively:

$$Re_l = \frac{G(1-x)D}{\mu_l} \quad (4)$$

$$Pr_l = \frac{c_p \mu_l}{\lambda_l} \quad (5)$$

The factor  $F(X_{tt})$  in Eq. (2) is given by the correlations proposed by Collier (1981). This factor presents two values, depending of the inverse of Martinelli parameter value,  $X_{tt}^{-1}$ . For  $X_{tt}^{-1} \leq 0.1$  the value of  $F(X_{tt})$  will be equal to 1. For  $X_{tt}^{-1} > 0.1$  the value of  $F(X_{tt})$  will be given by the equation:

$$F(X_{tt}) = 2.35 \left[ 0.213 + \frac{1}{X_{tt}} \right]^{0.736} \quad (6)$$

The Martinelli factor is given by:

$$X_{tt} = \left( \frac{1 - Q_u}{Q_u} \right) \left( \frac{f_l \cdot v_l}{f_v \cdot v_v} \right)^{0.5} \quad (7)$$

where  $Q_u$  is steam quality,  $f_l$  and  $f_v$  are the factors of friction along the tube for liquid and vapor phases, respectively,  $v_l$  and  $v_v$  are the specific volumes of liquid and vapor, respectively. The friction factor for the liquid phase is given by the following equation:

$$f_l = A_l \cdot \text{Re}_l^{-n_l} \quad (8)$$

where  $A_l$  and  $n_l$  depends on the Reynolds number value, whose conditions are shown in Tab. 1. The friction factor for the vapor phase is calculated according to Eq. (9), for the case in which the Reynolds number is higher than 0.1, otherwise, the value of  $f_v$  will be considered equal to 1.

$$f_v = A_v \cdot \text{Re}_v^{-n_v} \quad (9)$$

Table 1. Parameters for calculating the friction factor for the liquid phase and vapor.

	$A_{(l \text{ ou } v)}$	$n_{(l \text{ ou } v)}$
$\text{Re} < 2000$	16.000	1.000
$\text{Re} \geq 2000$	0.079	0.250

The contribution microscopic of the heat transfer coefficient,  $h_{mic}$ , is calculated according to the correlation given by Forster and Zuber (1955), which is applied to an evaporation-nucleation process. The expression may be written as follows:

$$h_{mic} = 0.00122 \left[ \frac{\lambda_l^{0.79} c_{pl}^{0.45} \rho_l^{0.49}}{\sigma^{0.5} \mu_l^{0.29} i_{lv}^{0.24} \rho_v^{0.24}} \right] \left[ T_{pde} - T_{sat}(p_l) \right]^{0.24} \left[ p_{sat}(T_{pde}) - p_l \right]^{0.75} S \quad (10)$$

where  $\sigma$  is the surface tension of the mixture,  $i_{lv}$  is the difference between the enthalpy of the mixture in the vapor phase saturated and the enthalpy of the mixture the saturated liquid phase,  $T_{pde}$  is the temperature of the wall of GERA,  $T_{sat}(p_l)$  is the saturation temperature for the pressure the saturated liquid,  $p_{sat}(T_{pde})$  is the saturation pressure for the temperature of the wall of GERA,  $S$  is the suppression factor for the correction of evaporation-nucleation, fully developed, which according to Chen (1966), shall be calculated by the following equation:

$$S(\text{Re}_{tp}) = \left[ 1 + 2.56 \times 10^{-6} \text{Re}_{tp}^{1.17} \right]^{-1} \quad (11)$$

In Eq. (11),  $S$  is a function of Reynolds number biphasic, which is given by the following equation:

$$\text{Re}_{tp} = \text{Re}_l \left[ F(X_{tt}) \right]^{1.25} \quad (12)$$

### 3. METHODOLOGY

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Calculation of the Coefficient of Heat Transfer for Evaporation Convective in Saturated Stream for Cooling Fluids

For study the behavior of the heat transfer coefficient,  $h$ , for different fluids, should be implemented the model calculation of  $h$  for saturated evaporation, proposed by Chen (1966). For this it was used the software EES<sup>®</sup> (F-Chart, 2013), due to ease of calculations of the thermal and physical properties.

The Chen's correlation to calculate the heat transfer coefficient is made according to the following steps (Carey, 1989):

- 1) for the specified  $G$ ,  $Q_u$  and the fluid properties, the Eqs. 4, 5 e 11 can be used to calculate  $Re_t$ ,  $Pe_t$  e  $X_{tt}$ , respectively;
- 2) the Eq. 6 can be used for obtaining the  $F(X_{tt})$ ;
- 3) the Eq. 10 can be used to calculate  $Re_{tp}$ . With the value of  $Re_{tp}$  calculated, it can be inserted in Eq. 9 so that the  $S$  value is determined.
- 4) With the results of steps (1) to (3) can be determine  $h_{mic}$  and  $h_{mac}$ . The overall heat transfer coefficient is then calculated using Eq. 1.

For validate the model implemented, the data obtained are compared with the results obtained by Carey (1989). Then, an analysis of heat transfer coefficients will be made for different refrigerants: R-12, R-22, R-134a, R-600 (butane) and R-717 (ammonia).

For the analysis will be generated graphs  $Q_u$  vs  $h$ , for different fluids, and the behavior of the heat transfer coefficients will be analyzed, and it will be verified the behavior of  $h_{mic}$  and  $h_{mac}$ .

#### 4. RESULTS AND DISCUSSIONS

With the model proposed by Chen (1966) implemented in EES<sup>®</sup>,  $h_{mic}$ ,  $h_{mac}$  and  $h$  values were calculated, to check whether the result is agreeing with those obtained by Chen (1966). An example proposed by Carey (1986) will be used to validate the model.

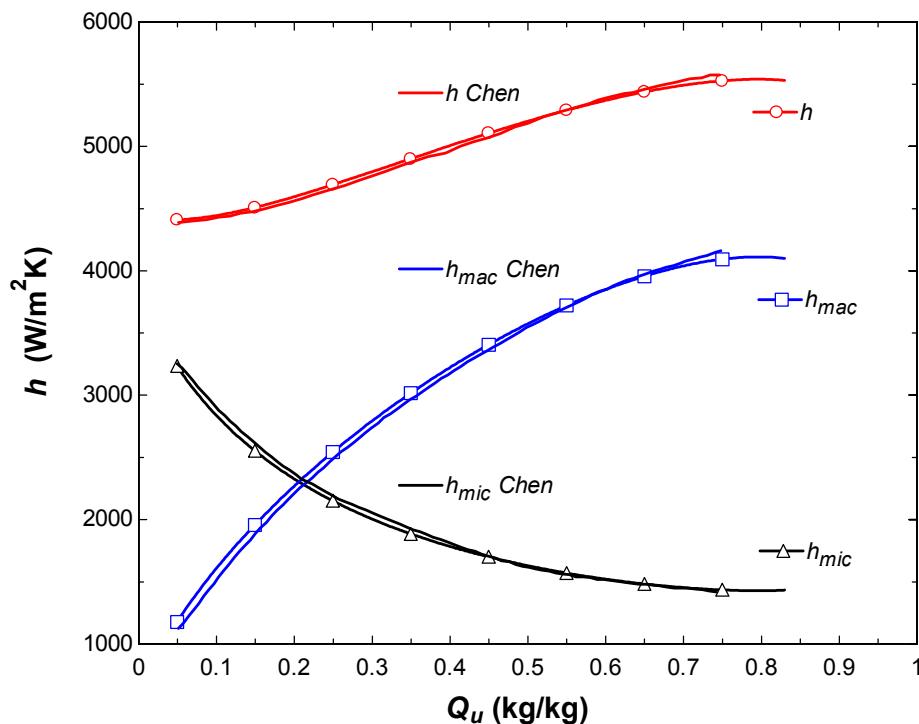


Figure 2. Comparison between the model calculated by Carey (1986) and the model implemented in this work

Carey (1986) proposes a case of saturated evaporation for a process with the following conditions: working fluid: R-12; saturation pressure: 384.5 kPa; the mass flow,  $G$ : 300 kg/m<sup>2</sup>·s; diameter tube,  $D$ : 1 cm; Overheating Wall: 283.15 K. The Fig. 2 shows the curves for  $h_{mic}$ ,  $h_{mac}$  and  $h$  obtained in the calculation and that obtained by Carey.

It is observed that there was a good agreement between data obtained in the model implemented and the data obtained by Carey in the three curves. The small difference is due to differences in the calculations of the properties because the models adopted by Chen and the used in the EES<sup>®</sup>. In EES the properties are based on the work of Liley and Desai, *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

With the validation of the model, the same example was studied with different working fluids: R-12, R-22, R-134a, R-600 and R-717.

The Figure 3 shows the curves for R-12. The curve of the contribution microscopic,  $h_{mic}$ , decreases with increase in steam quality. Its greatest value occurs when  $Q_u$  is zero, this point  $h_{mic}$  has a value of 3,668.00 W/m<sup>2</sup>·K. The measure which steam quality increases, the  $h_{mic}$  decreases to 1,436.00 W/m<sup>2</sup>·K. Contrary the behavior of  $h_{mic}$ ,  $h_{mac}$  grows as we the steam quality increases. The maximum and minimum values of  $h_{mac}$  are 4,088.00 e 741.70 W/m<sup>2</sup>·K, respectively. When the steam quality equals 0.2052 kg/kg, the  $h_{mic}$  e  $h_{mac}$  values are equal to approximately 2,305.00 W/m<sup>2</sup>·K. This point is highlighted in Fig. 3 by the intersection of lines L1 and L2. The  $h$ , that by Eq (1), is given by the sum of  $h_{mic}$  and  $h_{mac}$ , increases with increase of the steam quality. The  $h$  curve shows an inflection point when  $Q_u$  is equals 0.3575 kg/kg (line L3). For  $Q_u < 0.2052$  kg/kg,  $h$  receives a larger share of  $h_{mic}$ , than the  $h_{mac}$ , however, for  $Q_u > 0.2052$  kg/kg the  $h$  is strongly influenced by  $h_{mac}$ . The maximum value of  $h$  occurs for a  $Q_u$  equal the 0.8438 kg/kg and has a value equal the 5,950.00 W/m<sup>2</sup>·K.

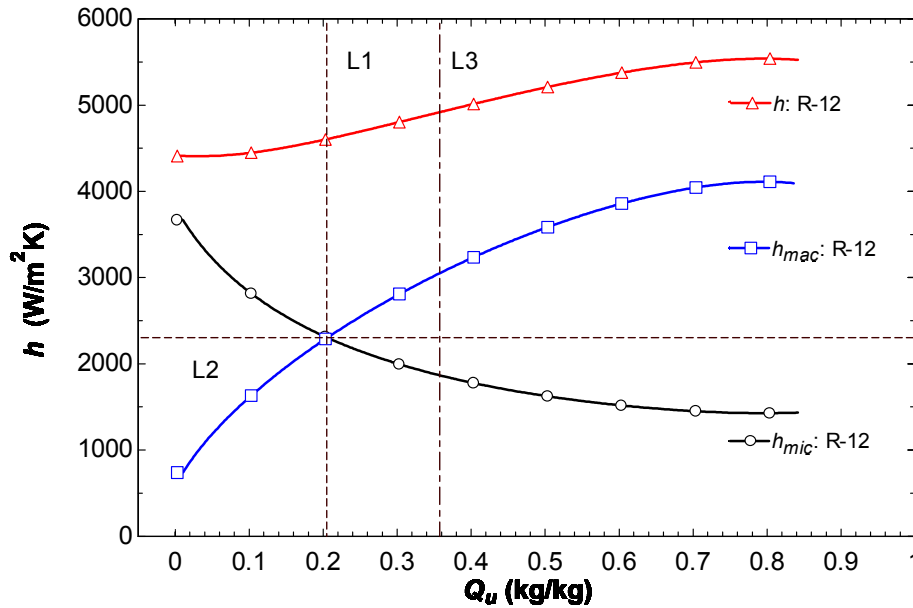


Figure 3. Curves for  $h$ ,  $h_{mic}$  e  $h_{mac}$  for the working fluid R-12

Figure 4 shows the behavior of the curves  $h$ ,  $h_{mic}$  e  $h_{mac}$  for fluid R-134a. The behavior of the curve of R-134a is similar to that observed in R-12, however, the calculated values of  $h$  are higher than those calculated for the R-12. The minimum value of  $h$  is equal 5,524.00 W/m<sup>2</sup>·K for  $Q_u$  equal to zero. The maximum value of  $h$  is equal 7,846.00 W/m<sup>2</sup>·K for  $Q_u$  equal to 0.7958 kg/kg.

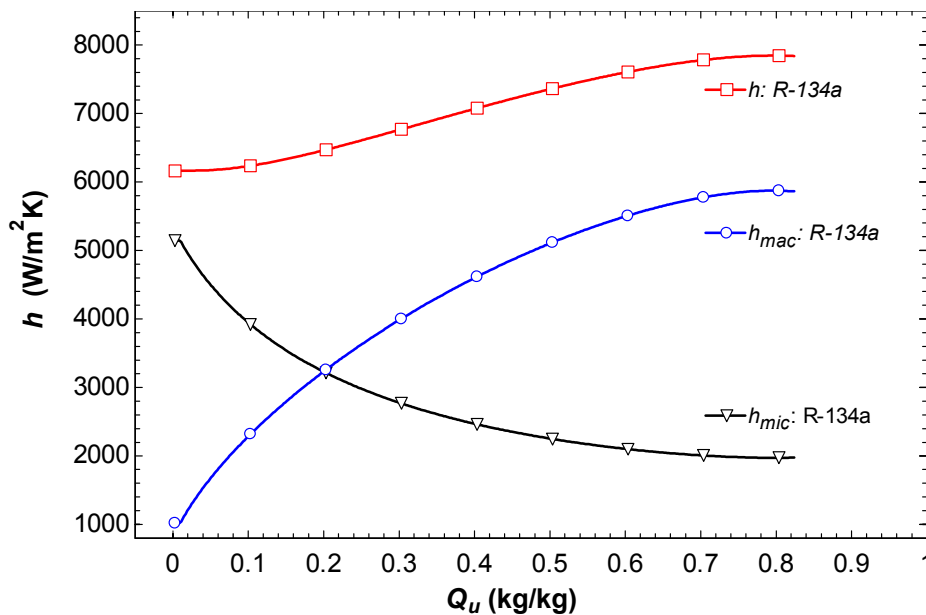


Figure 4. Curves for  $h$ ,  $h_{mic}$  and  $h_{mac}$  for the working fluid R-134a

The Figure 5 shows curves for two working fluids R-12 and R-134a. It is observed that the values for  $h$ ,  $h_{mic}$  and  $h_{mac}$  of the R-134a have values higher than R-12 indicating that R-134a has a higher heat transfer capacity than R-12. The curve of the  $h_{mic}$ , has greater slope in the R-134a of the than R-12, indicating that the R-12 is less sensible to the variation of steam quality. The same behavior is observed for the curve of the  $h_{mac}$ , and this increases with increasing steam quality. The  $h_{mac}$  for the R-134a increases drastically with the increase of quality of steam, peaking at 5,862.00 W/m<sup>2</sup>·K for  $Q_u$  equal 0.8238 kg/kg. It is emphasized that  $h_{mac}$  above  $Q_u$  equal 0.54 kg/kg has values higher than the  $h_{mac}$  of the R-12. This point corresponds to the intersection of curves of the  $h_{mac}$ : R-134a and  $h$ : R-12 (Fig. 5).

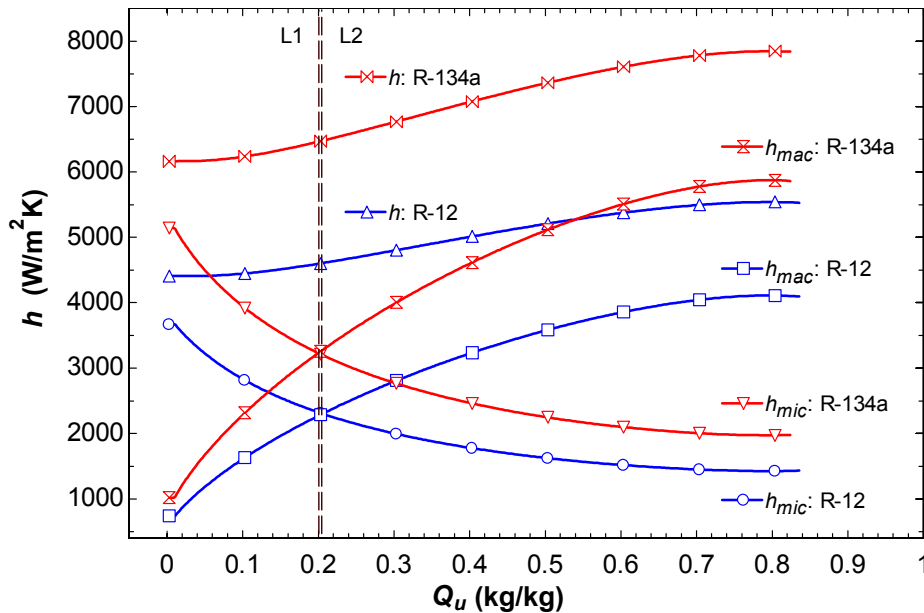


Figure 5. Comparison of curves of  $h$ ,  $h_{mic}$  e  $h_{mac}$  of the working fluids for R-12 and R-134a

The Figure 6 shows the behavior of the curves  $h$ ,  $h_{mic}$  and  $h_{mac}$  for the fluid R-22. The behavior of these curves is similar to the fluid R-12 and R-134a. For R-22 can observe a inflection point in  $Q_u$  equal to 0.40 kg/kg in the curve of  $h$  (line L1).

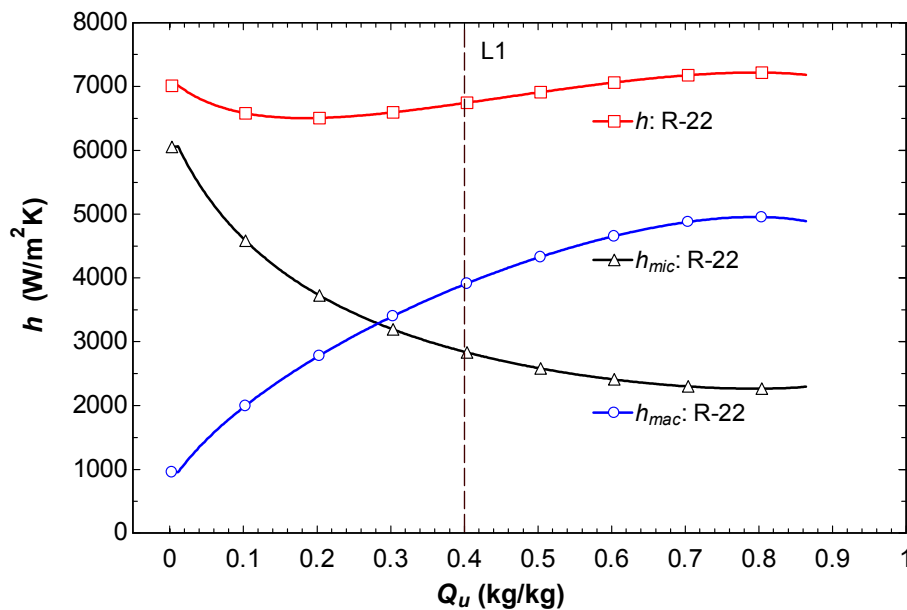


Figure 6. Curves for  $h$ ,  $h_{mic}$  and  $h_{mac}$  for the working fluid R-22

The curve of the  $h$  for R-22 presents points of the minimum and maximum, as shown in Fig. 6. The minimum point occurs at  $Q_u$  equal 0.1892 kg/kg and  $h$  equal 6,504.00 W/m<sup>2</sup>·K. The  $h$  maximum occurs at  $Q_u$  equal 0.7938 kg/kg and  $h$  equal 7,219.00 W/m<sup>2</sup>·K. The inflection point in the curve  $h$  is shown by the line L1.

Figure 7 shows a comparison between curves for R-22 and R-134a. The values of  $h_{mac}$  have values very close, for liquid condition ( $Q_u = 0$ ). For the R22 the value of the  $h_{mac}$  is equal to 961.20 W/m<sup>2</sup>·K and for R-134a is 1,023.00 W/m<sup>2</sup>·K. When  $Q_u$  increases,  $h_{mac}$  increases for both fluids, however, for R-134a this increase is more accentuated, peaking at 5,862.00 W/m<sup>2</sup>·K.

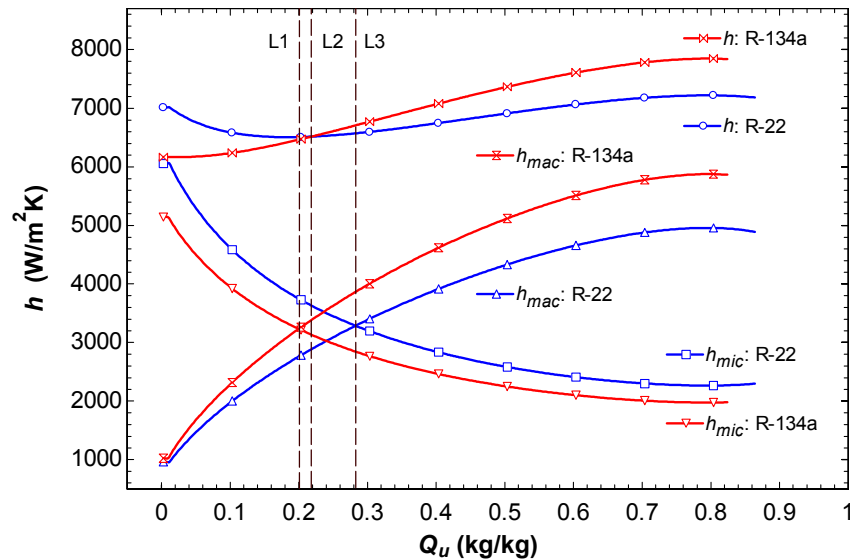


Figure 7. Comparison of curves of  $h$ ,  $h_{mic}$  e  $h_{mac}$  of the working fluids for R-22 and R-134a

The point where the macroscopic and microscopic contributions are equal is different in the two fluids. In the R-134a occurs when  $Q_u$  equal 0.2052 kg/kg and  $h$  equal 3,201.00 W/m<sup>2</sup>·K and R-22, this point occurs when  $Q_u$  equal 0.2833 kg/kg and  $h$  equal 3,282.00 W/m<sup>2</sup>·K. These points are highlighted by the lines L1 and L3, respectively. The point where the R-22 and R-134a have the same  $h$  occurs when  $Q_u$  equal 0.2152 kg/kg and  $h$  equal 6,512.00 W/m<sup>2</sup>·K. The right of this point  $h$ : R-134a increases faster than  $h$ : R-22. This because the macroscopic contribution largest is in the R-134a of the than in the R-22.

The Figure 8 shows the behavior of the curves  $h$ ,  $h_{mic}$  and  $h_{mac}$  for the fluid R-600.  $h_{mic}$  has a small variation when the steam quality increases.  $h_{mac}$  increases dramatically with increasing  $Q_u$ . The maximum value of  $h_{mac}$  occurs in  $Q_u$  equal to 0.8739 kg/kg and  $h_{mac}$  equal to 14,358.00 W/m<sup>2</sup>·K. The maximum value of  $h$  takes place for the same value of  $Q_u$  of  $h_{mac}$  and for  $h$  of 14,931.00 W/m<sup>2</sup>·K.

The point where the macroscopic and microscopic contributions are equal occurs for a very low vapor quality, 0.02502 kg/kg. The behavior of the curve of the  $h$  is heavily influenced by the curve of the  $h_{mac}$ , this due to the variation of  $h_{mic}$  with respect to  $Q_u$  is very small.

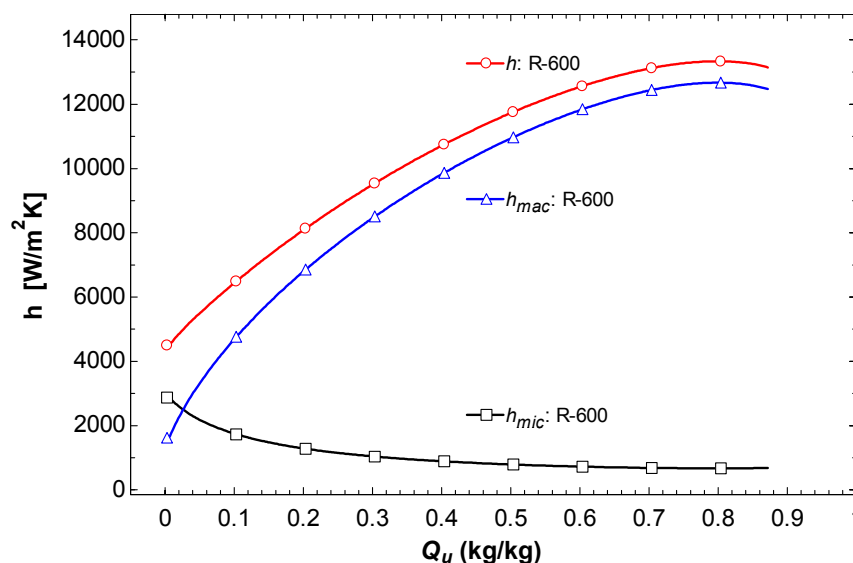


Figure 8. Curves for  $h$ ,  $h_{mic}$  and  $h_{mac}$  for the working fluid R-600 (butane)

Figure 9 shows a comparison between curves for R-600 and R-134a.  $h_{mic}$  of the R-600 is very less than  $h_{mic}$  of the R-134a, however,  $h_{mac}$  is much higher in R-600, this varies from 4,684.00 to 1,3243.00 W/m<sup>2</sup>·K, whereas in the R-134a varies from 2,284.00 to 5,719.00 W/m<sup>2</sup>·K. The point where the macroscopic and microscopic contributions are equal occurs at different  $Q_u$ . For R-134a, this point occurs when  $Q_u$  equals 0.20 kg/kg (line L2) and for R-600 occurs in  $Q_u$  equal to 0.02502 kg/kg (line L1). This point on the R-600 occurs at a very low vapor quality, the region of influence of the microscopic contribution in the value of  $h$  is very small. For the R-600 this range occurs between  $0.0000 \leq Q_u \leq 0.02502$  kg/kg and for R-134a, this range occurs between  $0.0000 \leq Q_u \leq 0.2000$  kg/kg.

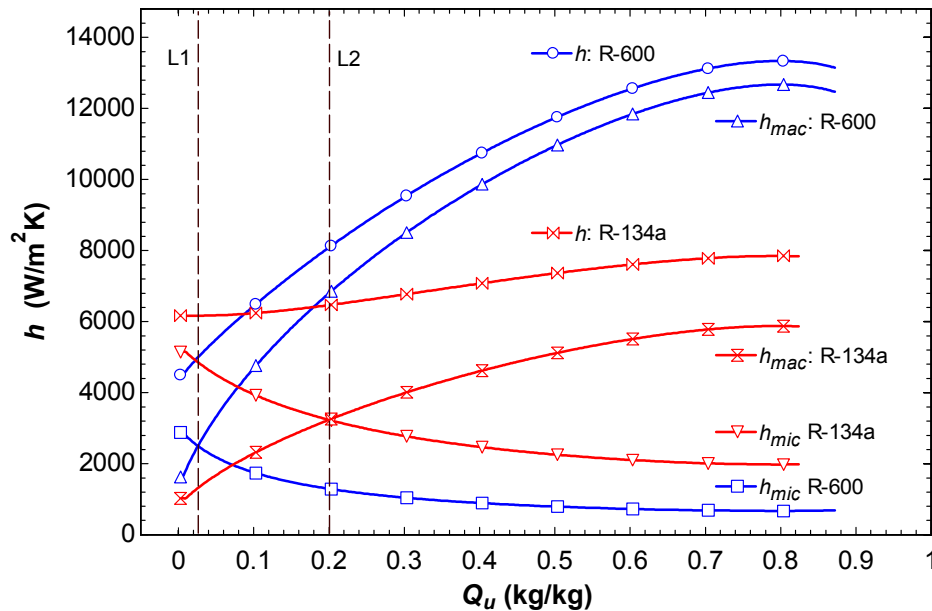


Figure 9. Comparison of curves of  $h$ ,  $h_{mic}$  e  $h_{mac}$  of the working fluids for R-600 and R-134a

Due to the high increase of the  $h_{mac}$ , and the small variation of  $h_{mic}$ , curve of  $h$  has a similar behavior to the curve of  $h_{mac}$ .

The Figure 10 shows the behavior of the curves  $h$ ,  $h_{mic}$  and  $h_{mac}$  for the fluid R-717 (ammonia). The values for  $h$ ,  $h_{mic}$  and  $h_{mac}$  are very high when compared to other fluids studied.

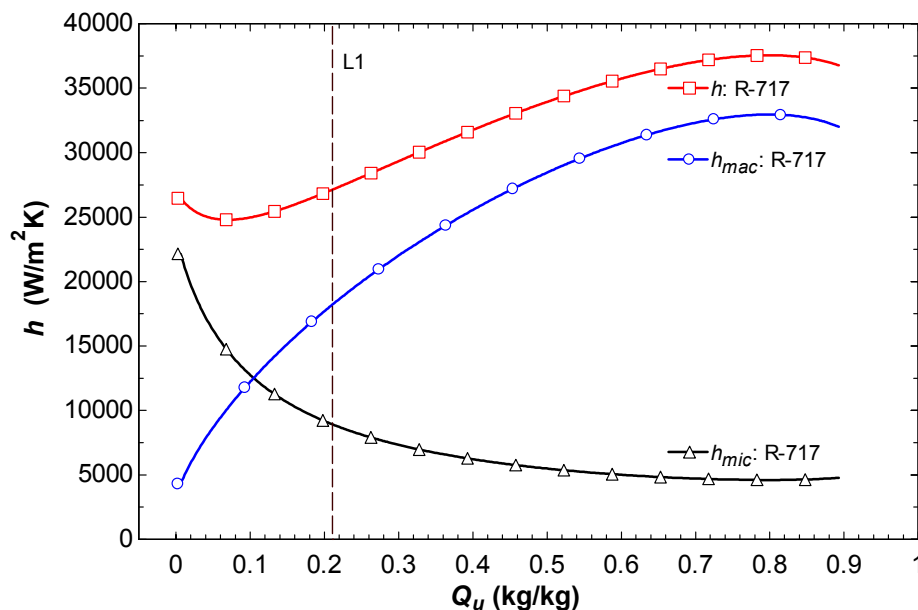


Figure 10. Curves for  $h$ ,  $h_{mic}$  and  $h_{mac}$  for the working fluid R-717 (ammonia)

The microscopic contribution is dominant in the calculation of  $h$  until  $Q_u$  equal to 0.1057 kg/kg. Above this value, the value of  $h$  is strongly influenced by the value of  $h_{mac}$ . The curve of  $h$  has an inflection point when  $Q_u$  achieves a



value equal to 0.2100 kg/kg (line L1) and  $h$  has a value of 2,7119.00 W/m<sup>2</sup>·K.  $h$  has a maximum value of 37,558.00 W/m<sup>2</sup>·K ( $Q_u = 0.7989$  kg/kg) and a minimum of 24784.00 W/m<sup>2</sup>·K.

Figure 11 shows the curves for  $h$  for the fluids R-12, R-22, R134a and R-600. The fluid which has minors heat transfer coefficients, to the problem under study, is the R-12. The heat transfer coefficient of the R-22 is closest to the R134a. For a quality steam from 0.0000 to 0.2200 kg/kg, the  $h$  of the R-134a is lower than the R-22. Above of  $Q_u$  equal to 0.2200 kg/kg, The  $h$  of the R-134a exceeds the values of  $h$  for R-22.

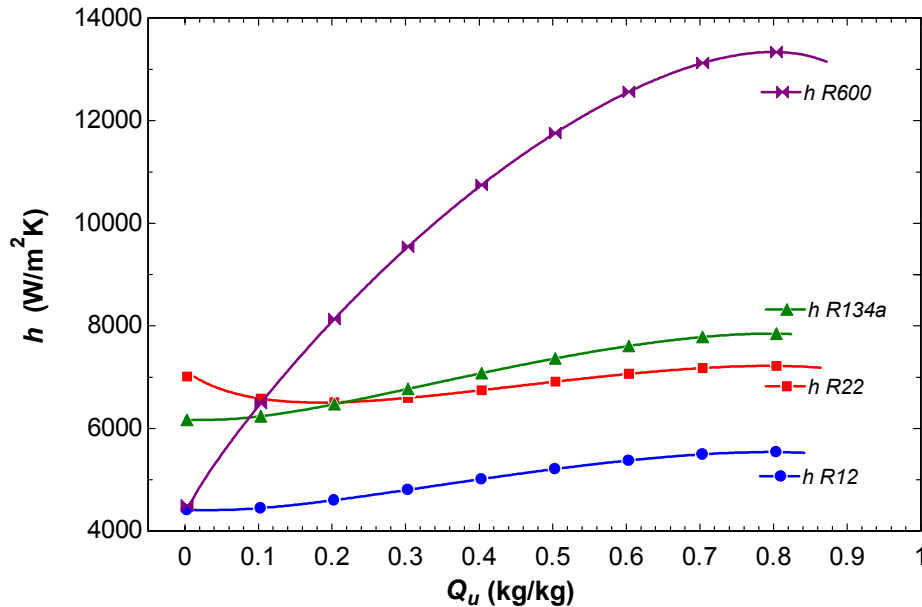


Figure 11. Curves for  $h$  for the working fluid R-12, R-22, R-134a and R-600

The slope of curve of the  $h$  for R-600 is very sharply. For a vapor quality near zero, value of  $h$  of the R-600 is close to that of R-12 ( $h$ : R-600 = 4,497.00 W/m<sup>2</sup>·K and  $h$ : R-12 = 4,410.00 W/m<sup>2</sup>·K) and lower than the R-22 and of the R-134a. For values greater than  $Q_u$  equal to 0.1000 kg/kg, the value of  $h$  of the R-600 overcomes the values of the R-22 and of the R-134.

Figure 12 shows the curves of the R-600 and R-717. The values of  $h$  for R-717 are far superior to the R-600. The difference between the maximum values is 22,627.00 W/m<sup>2</sup>·K.

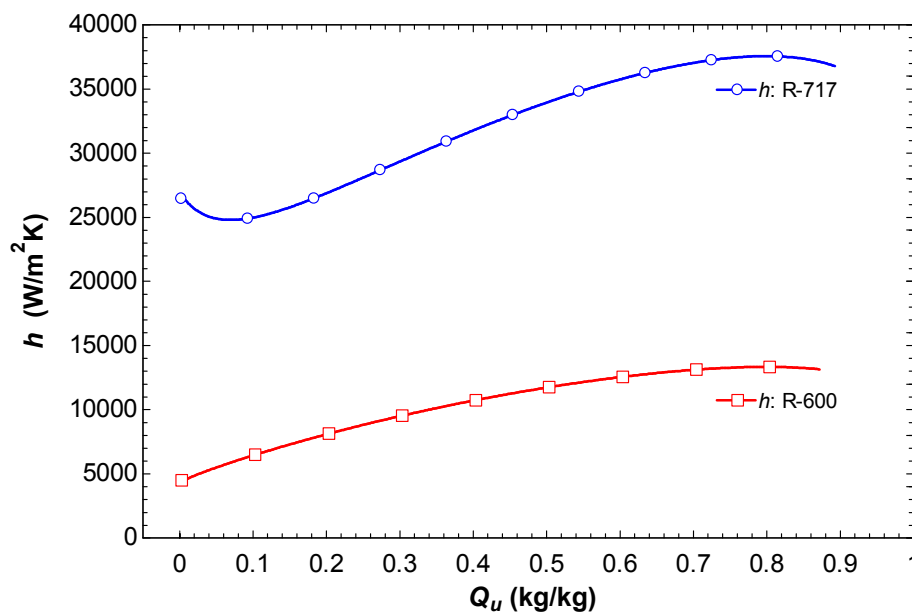


Figure 12. Curves for  $h$  for the working fluid R-600 and R-717

## 5. SUMMARY

In this work a procedure of calculation to determining the heat transfer coefficient an evaporation-nucleation process has been studied. It was analyzed the problem proposed by Carey (1989). The model proposed by Chen (1966) was implemented in the EES<sup>®</sup> and the results were compared with data obtained by Carey, where it was observed a good approximation of the data.

It was analyzed the following fluids: R-12, R-22, R-134<sup>a</sup>, R-600 and R-717, on the same problem proposed by Carey (1989), reaching the following conclusions:

- the values for  $h$ ,  $h_{mic}$  and  $h_{mac}$  of the R-134a have values higher than R-12 indicating that R-134a has a higher heat transfer capacity than R-12;
- the  $h_{mac}$  for the R-134a increases drastically with the increase of quality of steam, peaking at 5,862.00 W/m<sup>2</sup>·K for  $Q_u$  equal 0.8238 kg/kg;
- for R-22 and R-134a, the values of  $h_{mac}$  have values very close, for liquid condition ( $Q_u = 0$ );
- the point where the macroscopic and microscopic contributions are equal, is different in the two fluids. In the R-134a occurs when  $Q_u$  equal 0.2052 kg/kg and  $h$  equal 3,201.00 W/m<sup>2</sup>·K and R-22, this point occurs when  $Q_u$  equal 0.2833 kg/kg and  $h$  equal 3,282.00 W/m<sup>2</sup>·K;
- the point where the R-22 and R-134a have the same  $h$  occurs when  $Q_u$  equal 0.2152 kg/kg and  $h$  equal 6,512.00 W/m<sup>2</sup>·K;
- $h_{mac}$  is much higher in R-600, this varies from 4,684.00 to 1,3243.00 W/m<sup>2</sup>·K, whereas in the R-134a varies from 2,284.00 to 5,719.00 W/m<sup>2</sup>·K;
- for the fluid R-717 (ammonia), the values for  $h$ ,  $h_{mic}$  and  $h_{mac}$  are very high when compared to other fluids studied;
- the fluid which has minors heat transfer coefficients, to the problem under study, is the R-12;
- the heat transfer coefficient of the R-22 is closest to the R134a. For a quality steam from 0.0000 to 0.2200 kg/kg, the  $h$  of the R-134a is lower than the R-22;
- the slope of curve of the  $h$  for R-600 is very sharply;
- for a vapor quality near zero, value of  $h$  of the R-600 is close to that of R-12 ( $h$ : R-600 = 4,497.00 W/m<sup>2</sup>·K and  $h$ : R-12 = 4,410.00 W/m<sup>2</sup>·K) and lower than the R-22 and of the R-134a;
- $h$  for R-717 are far superior to the R-600. Showing a difference between the maximum values of 22,627.00 W/m<sup>2</sup>·K.

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## 8. RESPONSIBILITY NOTICE

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