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EXPERIMENTAL DETERMINATION OF HEAT TRANSFER COEFFICIENTS IN A FINNED DOUBLE – PIPE EXCHANGER

Dr. Antonio Valiente Barderas
Faculty of Chemistry.
UNAM. C.U.
Mexico.

ABSTRACT

The author is a professor of Chemical Engineering in the Faculty of Chemistry at the National Autonomous University of Mexico (UNAM) and works in the so called Laboratory of Unit Operations. In this laboratory the students of the Chemical Engineering take practical courses in which they apply what they have learn in the theoretical courses. The author had presented in other articles [4,5,6.7] the importance of making experiments in a laboratory of Unit Operations.

KEYWORDS - ***Heat transfer, coefficients, double - pipe heat exchanger with longitudinal fins.***

1. INTRODUCTION

One of the peculiarities of the current teaching is the emphasis that is made in obtaining skills that requires a professional to practice with success. In the laboratory of Chemical Engineering from the Universidad Nacional Autónoma de Mexico, UNAM, chemical engineering students performed laboratory practices that allow them to put into practice their skills in the areas of knowledge, skills and attitudes. The experimental teaching is very important in the significant learning of the students of engineering. It foments the interactivity and the participation of the students, propitiating that they acquire knowledge, dexterities, habits and attitudes. In this work an experiment on heat transfer in a double tube heat exchanger with longitudinal fins is presented.

2. THE EQUIPMENT

The equipment installed in the Unit Operations Laboratory at the Faculty of Chemistry of the National Autonomous University of Mexico (UNAM) consists of a double-pipe heat exchanger with 12 longitudinal fins of rectangular profile, 0.5 inches high and 0.035 inches thick, located on the inner tube. The nominal diameter of the outer tube is 3 inches Cd.40 and the internal 1.5 inches both the tubes and the fins are made of commercial carbon steel. The exchanger have a U-bend connection. Each finned section is 1. 5 m and the length of the U connecting them is 10 inches. The exchanger introduces atmospheric air at the pressure of 586 mm Hg (Mexico City's atmospheric pressure) using a centrifugal fan. To measure the airflow, a 1 5/6 inch hole plate was installed and the pressure drop in the hole is measured by a differential pressure gauge. The heating medium used is saturated steam. Condensate is measured by a storage tank equipped with a steam trap.

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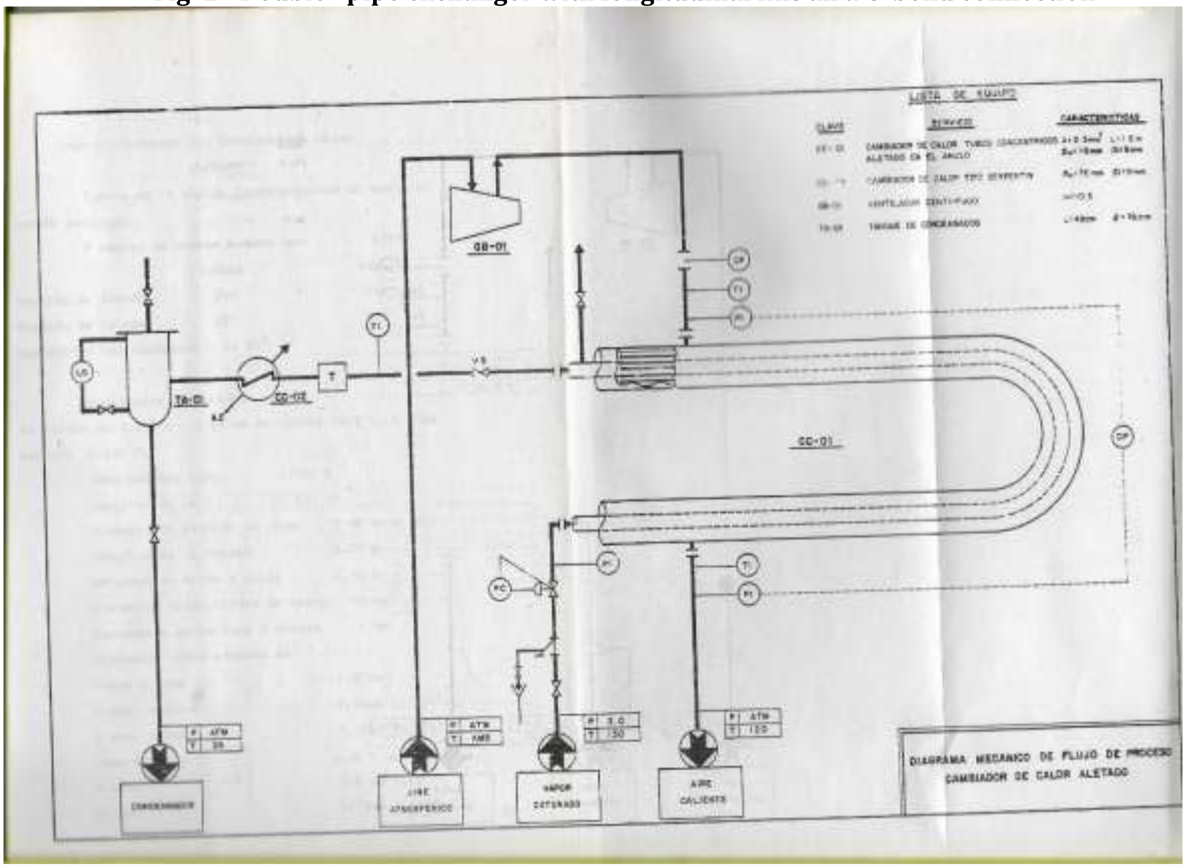
Fig. 1.- Double –pipe exchanger with longitudinal fins an a U-bend connection.



3. EXPERIMENTS

In one of the runs the students obtained the following data[1]:

Vapor gage pressure 3.5 kg / cm^2. Atmospheric pressure 586 mm Hg;

Vapor temperature 143 °C. Air inlet temperature 22°C; Air outlet temperature 124 °C.

Mass air expenditure 135 kg /h

4. CALCULATION OF THE EXPERIMENTAL HEAT TRANSFER COEFFICIENT

From this data, the students should obtain the experimental heat transfer coefficient and the theoretical coefficient.

Data:

Internal Inner Tube Diameter 1.61 inch = 0.04089 m

External Inner Tube Diameter 1.9 inch = 0.04826 m

Inner Diameter of External Tube 3.25 inches = 0.0828 m.

External diameter of external tube 3.5 inch = 0.0915 m .

Average air temperature: T air = (22+124)/ 2 = 73 .°C

Air data at 73 °C and at a pressure of 586 mm Hg

Density ρ = 0.788 kg / m^3.

Heat Capacity Cp = 0.25 Kcal / kg °C ; Viscosity = 20.6 x 10-6 Pa-s ;

Thermal conductivity k = 0.023 kcal / h m .C

Prandtl' number = 0.694

The heat exchanger equation is[2]:

$$Q = A_i U_i \Delta T_{ln}$$

And:

$$Q = M \, Cp \, \Delta T$$

Q= 135 (0.25) (124-22) = 3442.5 Kcal /h

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Ai= $\pi D_i L = \pi \times 0.04089 \times 1.5 \times 2 = 0.385\ m^2$

$$\Delta T_{ln} = \frac{(143-124)-(143-22)}{ln\frac{143-124}{143-22}} = 55\ °C$$

And :

$$U_i = \frac{3442.5}{55 \times 0.385} = 162.41\ \frac{kcal}{°C\ hm^2}$$

5. CALCULATION OF THE THEORETICAL COEFFICIENT

With the data obtained the students should predict the theoretical coefficient of heat transfer in the equipment, in order to compare it with the experimental one.

In order to calculate the theoretical coefficient the equation used is[2]:

$$Q = A_i U_i \Delta T_{ln}$$

Where:

$$U_i = \frac{1}{\frac{1}{h_i'} + \frac{1}{h_{fi}'}}$$

Y $h_i' = \frac{h_i \times h_{di}}{h_i + h_{di}}$

$$h_{di} = \frac{1}{R_{di}}$$

$$h_f' = \frac{h_f \times h_{do}}{h_f + h_{do}}$$

$$h_{do} = \frac{1}{Rdo}$$

$$h_{fi}' = (\Omega A_f + A_o)\frac{h_{fi}'}{A_i}$$

Ui - total heat transfer coefficient based on the internal area of the inner tube.
Ώ- Fin efficiency.
Af - fin area ; Ao external area of the inner tube; Ai the inner area of the inner tube.
hi - heat transfer coefficient in the inner tube.
hdi - coefficient for internal dirt. hdo - coefficient for external dirt.
hf - heat transfer coefficient of the fins.
Rdi resistance from internal dirt, Rdo, resistance by external dirt.
hi'-heat transfer coefficient corrected by internal dirt.
hf'-dirt-corrected fin coefficient.
hfi'-fin coefficient corrected by internal area and dirt.

5.1. Internal heat transfer coefficient.

Inside the inner tube, saturated steam flows at 143°C. There are correlations [2] that allow the calculation of that coefficient. In general this is very large (between 5000 to 10 000 kcal / h m^2) compared to the heat transfer coefficient in the gases so it can be assumed as:

hi =5000 kcal /h m^2°C

The steam fouling resistance is obtained from text books [2] being Rdi =6.14 x 10-5

so hdi =16 286

and h'i =3825 kcal /h m^2°C

5.2. - Fin coefficient.

The air flows through the ring space and between the fins at 73°C and at a rate of 135.5 kg/h.

The heat transfer coefficient for gases flowing on longitudinal fins can be obtained by the following graph [3]:

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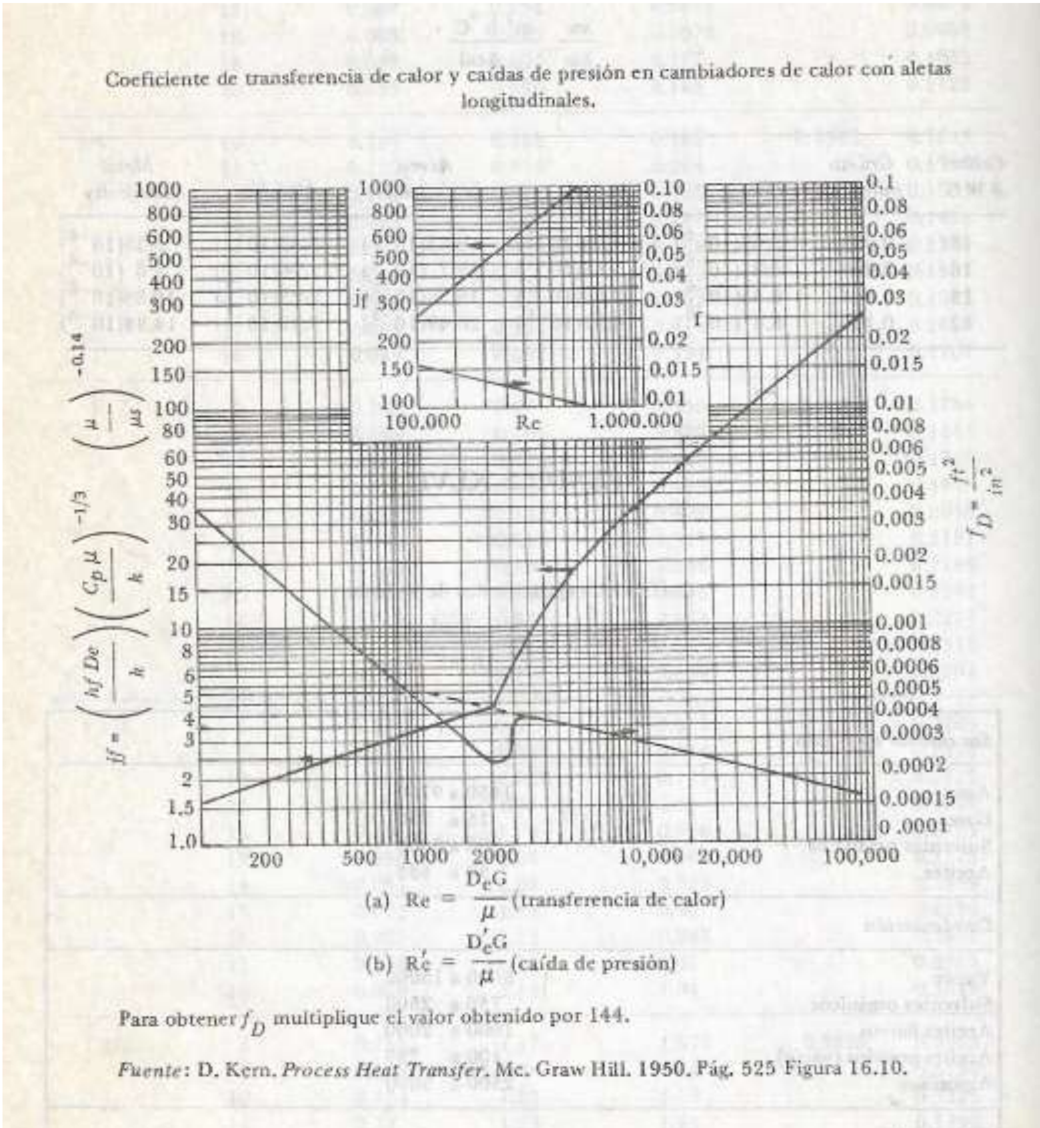

Graphic 1.- Heat transfer coefficient vs. Reynolds.

Where De is the equivalent diameter and G the mass gas velocity in the space between the fins.

De = (4 flow area)/ (Wet perimeter.).

Annular area of flow== $\frac{\pi}{4}(D_2^2 - D_1^2) - Number\ of\ fins = \frac{\pi}{4}(7.7924^2 - 4.826^2) - 12(1.27)(0.0889) = 0.2669\ cm^2 = 0.002669 m^2$

Wet-perimeter = $\pi D_1 + Number\ of\ fins(2)L = \pi 0.04826 + 24(2)(0.0127) = 0.7612\ m$

So : De =$\frac{4\times 0.002669}{0.7612} = 0.014\ m$

G = 135.4/(3600)(0.002669)=14.09 kg / m^2 s

Then the Reynolds' number is: Re =$\frac{0.014\times 14.09}{20.6\times 10^{-6}} = 9575$

From the graphic 1 jf= 35

So: 35 =$\left(h_f \frac{0.014}{0.023}\right)(0.594)^{-0.333}$; hf= 49.5 kcal /h m^2°C

Rdo= 3.07 x 10^{-4}; hdo = 3257 y $h_f' = \frac{3257\times 49.5}{3257+49.5} = 48.75 \frac{kcal}{h°Cm^2}$

5.3 Calculation of fin efficiency.

For these fins efficiency is calculated by[2]:

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$\Omega = \frac{Tanh\,BL}{BL}$; B=$\sqrt{\frac{h'_f P}{k\,A}}$
P = fin perimeter 1.5x 2x2 x 6 m.
k - Thermal conductivity of the fin (38.92) carbon steel.
A -area of heat transfer per conduction in the fin; A=0.000889 x 1.5x2-0.00267 m2 ;
Y a = thickness of the fin 0.000889 m ; L - height of the fin 0.0127 m (see attached figure).

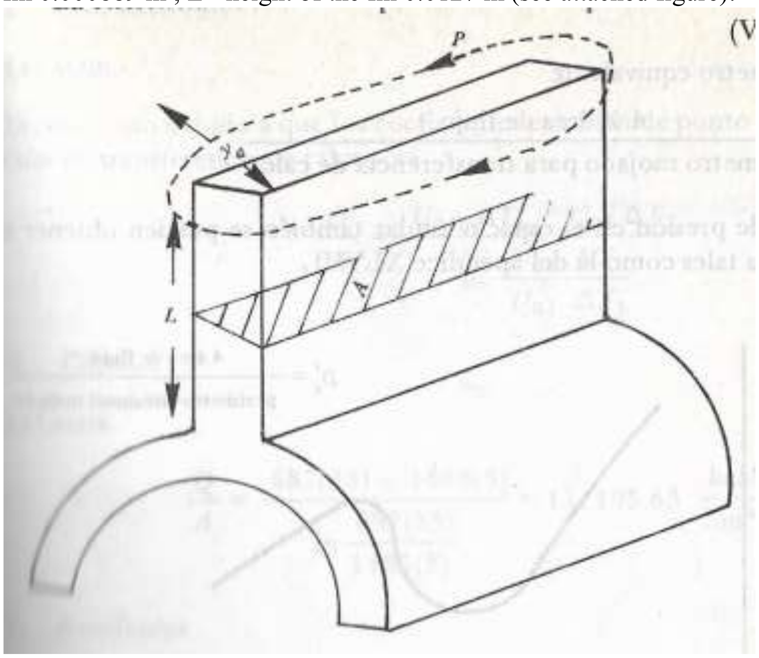

Fig. 2.- Longitudinal fin.

B=$\sqrt{\frac{48.75\times 6}{38.92\times 0.00267}} = 53.05$; BL = 53.05x 0.0127=0.67

So : $\Omega = \frac{\tanh BL}{BL} \cong 0.93$

5.4. Calculation of the theoretical fin coefficient

Areas
Ao=0.04826x 3.14 x 1.5x 2=0.4546 m^2; Ai = 0.04089x 3.14 x 1.5x 2=0.385 m^2
Af= 2x 12x (0.0127) x 1.5 x 2 =0.9144 m^2

Therefore: $h'_{fi} = (0.93 \times 0.9144 + 0.4546)\frac{48.75}{0.385} = 165.24\frac{kcal}{°C\,hm^2}$

5.6. - Overall theoretical heat transfer coefficient.

$$U_i = \frac{1}{\frac{1}{3825}+\frac{1}{165.24}} = 158.39\ \frac{kcal}{hm^2°C}$$

6. CONCLUSIONS

Chemical engineering students through simple experiments can understand how heat exchangers work. They also practice their mathematical, intellectual, linguistic and social, communication skills and their attitudes towards experimentation as a means of obtaining information from the universe around them. Students had during the experiment to take experimental data and from that data, they first calculated the experimental coefficient, then using the equations and knowledge acquired in the course of Heat Engineering had to evaluate the theoretical coefficient. The data obtained show that the theoretical coefficient is quite close to the experimental coefficient.

7. REFERENCES

1. *Ramos Santana Irma- Diseño de una práctica sobre cambiadores de calor aletados - Tesis – Fac. de Química- UNAM- México- 19872.*
2. *Valiente Barderas Antonio- Problemas de Transferencia de Calor-Ed. Limusa - México-1988.*
3. *D.Kern- Process Heat transfer-Mc Graw Hill-1950.*
4. *Valiente B. A- Experimental determination of diffusion coefficients in liquid mixtures in a*

laboratory of transport Phenomena – International Journal of general engineering and technology- Vo. 5, Issue 4, June 2016 – pp. 11-16.

5. *A.- Valiente-Determination of the typical performance curves of centrifugal pumps in an Unit Operations laboratory-EPRA International Journal of multidisciplinary research –Vol. 4-Issue 3-March 2018-pp. 17-26.*
6. *A. Valiente-Experimental determination of discharge coefficients for orifice meters in an Unit Operation Laboratory- EPRA International Journal of Multidisciplinary Research -Vol. 3-Issue 9 –sept 2017- pp. 44-50.*