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A NUMERICAL STUDY OF THE IMPACT OF HEAT TRASPHER AND PRESSURE DROP
NUMERIČKA STUDIJA UTICAJA PRENOSA TOPLOTE I PADA PRITISKA

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Summary: *Vertical thermo-siphon re-boilers are often used in the chemical industry, especially in petrochemical facilities. Many authors have dealt with the estimations of the pressure drop and heat transfer in these devices . This numerical study will present a program and estimation of the vertical thermo-siphon re-boiler, using the FORTRAN77 programming language that is based on the method of Sarm and al. Unlike previously proposed approaches and the literature this method in the estimation of the pressure drop in pipes apparatus, takes into account the mechanism of the two-phase flow. The results of the program are analyzed in detail and discussed in the exploitation of real examples.*
Keywords: *software, hear transfer, pressure drop, vertical thermosiphon reboiler*

Rezime: *Vertikalni termosifonski rebojleri se često primenjuju u hemijskoj industriji, naročito u petrohemijskim postrojenjima. Mnogi autori su se bavili proračunom pada pritiska i prenosa toplote u ovim aparatima. U radu biće prikazan uspostavljen program, a proračun vertikalnog termosifonskog rebojlera, na programskom jeziku FORTRAN77 koji je zasnovan na metodi Sarm-e i saradnika. Za razliku od pristupa koji su ranije predlozeni i literature ova motoda pri proračunu pada pritiska u cevima aparata, uzima u obzir mehanizam dvozanog toka. Rezultati programa su detaljno analizirani i prodiskutovani pri eksploataciji na realnim primerima.*
Ključne reči: *softver, prenos toplote, pad pritiska, vertikalni termosifonski rebojler*

INTRODUCTION

Evaporators are devices in which the transformation of the liquid phase into the gas phase occurs from one side of the surface area for heat exchange. We can divide them as follows: Boilers for stoking, Evaporators without stoking. Evaporators without stoking: Generators without steam, utilization Boilers, Evaporators in a broader sense

a) Evaporators in the narrow sense
b) Re-boilers

Evaporators in the narrow sense: evaporators in power plants, evaporators. Re-boilers: can be classified according to the mechanism of fluid flow in them: natural convection, forced convection. Natural convection: with the steam space, with the immersed body, Thermo-siphon. Forced convection: horizontal, vertical. Re-boilers with natural convection - the movement of fluids is achieved on the basis of the difference of the density of the liquid in supply pipe tubes and liquid vapor mixture in the pipes of the re-boiler. This category includes re-boilers with the steam space and the immersing heating body, it is used to generate saturated and superheated steam.

Thermo-siphon re-boilers - this type of device is often used in: the horizontal orientation of the pipe, the vertical orientation of the pipe. Characteristics of the horizontal thermo-siphon re-boilers: the heating medium is usually water vapor, fluid movement is the natural convection. Sketch of the vertical thermo-siphon re-boiler (Figure 1.)

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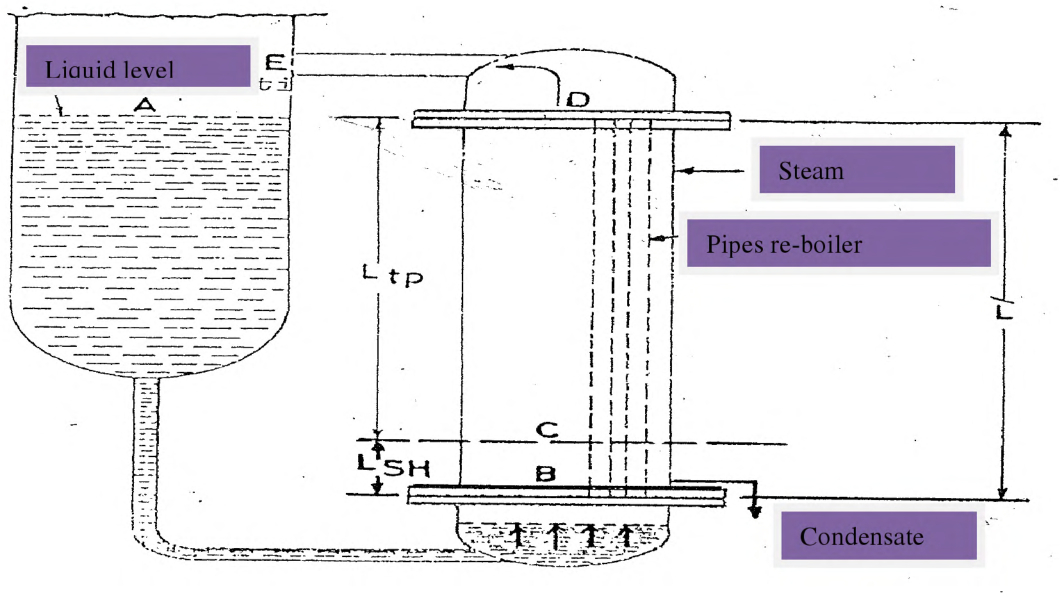

Figure 1. Sketch of the vertical thermo-siphon re-boiler

Suitable for operation: under vacuum, at atmospheric pressure, at elevated pressure. Structures: one approach of the fluid through a pipe, inlet of the heating media on top (in the mantle), pipe diameter 25-50mm, height 2.5-3.7 m, inlet pipe: approximately 50% of the surface intersections of all pipes (reduces the tendency of the unstable flow in the re-boiler) alternatively silencer is used in the inlet pipe, provides Pusis > Ppotp, increasing the resistance of the silencer improves deposition of impurities, liquid in the re-boiler is maintained at the height of the upper pipe sheet, for the operation under vacuum: height of liquid is 30-60% of the pipe.

Thermo-siphon re-boilers with boiling in the vertical pipes The vertical thermo-siphon re-boilers play a major role in chemical process industry and require complex calculations in order to obtain optimal devices. During the fluid flow through vertical thermo-siphon re-boiler VTR the heat exchange occurs with the appearance of boiling. Then several mechanisms of the mixture flows can occur that depend on the speed of flow, the physical characteristics of the components, pipe diameter and their orientations. In thermal hydraulic calculation VTR attention is payed to the heat transfer and the transfer of momentum but with limited reach of liquid.

Types of two-phase flow mechanisms that are encountered during the time of passage of the gas-liquid mixture through a pipe of the vertical thermo-siphon re-boiler are:

1. Blister (bubble)
2. Piston (Slug)
3. Annular
4. Misty (Mist)

These flow regimes also occur at higher vapor of the mixtures. Piston flow (unstable state of the regime of mixture flow) preferred to be minimized. In an extreme regime of two-phase flow (mist flow), which is an extreme regime of two-phase flow, the heat flux is very small and should be avoided. Calculation of VTR requires a good knowledge of different types of flow regimes, the conditions of their beginning and region of the event. There is no completely satisfactory method in the open literature for estimation of the regime of two-phase flow in the vertical pipe.

Griffith, Walls and Govier (2,3) showed the diagram to identify the flow regime. Orkizewski (4) using a large number of experimental data of the vertical flow and the results of Griffith, Wallis. Dunn's Ross and I Nicklih (2,3,5) formed a dimensionless numbers and correlations for two-phase flow regime identification..

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The mechanism of flow in a vertical thermo-siphon re-boiler shows a sketch vertical thermo-siphon re-boiler and the connection of the re-boiler with the distillation column. The liquid from the distillation column (intersection A) flows through the inlet prong of the heat exchanger and is supplied into the bottom of the channel and is distributed evenly through the pipes. The pipes are heated by means of heating medium, which flows through the layer of the re-boiler. The process fluid in the pipes is below the temperature of boiling due to the effects of static pressure, hydrodynamic losses in pipes as well as due to heat loss. Input fluid in the pipes of the re-boiler receives first noticeable heat. It takes place from point B to point C, where the temperature of the liquid reaches a saturation temperature on at the appropriate saturation pressure. Length B-C in Figure 1 represents the length of the zone of the noticeable heat. The evaporation of the fluid starts in the C point and mixtures of fluid and gas continue to flow through the rest of the length of the pipe. Length C-D in Figure 1 is the length of the two-phase region. The length of D-E is horizontal adiabatic two-phase flow.

The pressure drop The total pressure drop in the system is the result of input from three effects: static drop, pressure drop due to friction, pressure drop due to the increase of the speed of the two-phase gas-liquid mixture (acceleration).

For a system with specific physical properties, heat flux and pipe geometry, the flow through the pipes of the exchangers is controlled by the balance of pressure of the input and output branches (between A-E and B-E . It is necessary to calculate: The total pressure drop in the pipe exchangers (B-D) and Pressure drop at the inlet and outlet of the pipe (A-B, D-E)

Heat transfer Flow of the gas-liquid mixtures through pipes of the re-boiler is not continuous but pulsating. Amplitude of pulsation is controlled by heat transfer. At high values of heat flux, pulsations amplitude is high enough to suck in the vapor into the part of the liquid and that is called a locked vapor. This is called the agitated lane by Lee and it corresponds to the permitted maximum heat flux.

EXISTING METHODS OF CALCULATIONS OF THE VERTICAL THERNO-SIPHON RE-BOILER VTR

Several methods of analysis are available, but one of the first who published works on this topic were Fair (6) and Hughmark (7,8,9,10). Fair's method provides procedures for the calculation of pressure drop and heat transfer along the entire pipe exchangers, using the increment of the proportion of the gas phase and the correlation developed by Lochart-Martinelli (11) for two-phase flow. The method includes the calculation of proportion and errors using a series of diagrams. Using Lochard-Marinelli parameter Fair thus does not introduce the factor that would accurately encompass vertical flow so Davids proposed Froude number thus modified the previous method. The correlation for the calculation of fluid retention is given in the expression of Lochard-Mrtinelli parameter, and is valid for the mass flux greater or equal to 567 kW/m2. For the mass flux less than 567 kW/m2 deviation of the Lochard-Martinelli parameter is a function of the total mass velocity. This method represents the isothermal conditions in the pipe exchangers and constant difference between the temperature of the pipe wall and the fluid. Correlation for calculating the coefficients of the transfer of the boiling heat is Hughmark's and is more or less similar to Fair's. Bankof's modified correlation was used to calculate the retention of fluid and gas. Chensho's correlation (13) explains the effect of flow on the boiling rate/speed, and was used to calculate the hb coefficients. This correlation takes into account the changes in physical properties. The above method does not consider the different flow regimes for the calculation of pressure drop and heat transfer.

Calculation methods of the vertical thermo-siphone re-boiler This method proposed by Sarma (1), is based on consideration of the two-phase flow regime during the calculation of the pressure drop and heat transfer coefficient. Calculation of heat transfer can be divided into estimating the nucleation boiling and convective heat transfer coefficient of notable heat zone and the two-phase region. The equations proposed by Orkizewski (4) for vertical two-phase flow are used in the proposed method. Orkizewski made an analysis of the results of Griffith, Wallis, Duns and Ross (2) pressure drop to their data bank of

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petrochemicals and selected the best models. Orkizewski developed relations for the pressure gradient, two-phase density and acceleration expression for a given flow regime.

METHODOLOGY (COMPUTER PROGRAM)

The purpose of a computer program is the calculation of pressure drop and heat transfer coefficient of heat in the vertical thermosiphon rebojleru. The program was compiled in FORTRAN 77.

The program consists of six sub-programs used in the main program.

1. SUBROUTINE Hold up (to calculate the hold up for fluid and gas)
2. FUNCTION FF (for calculating Mudy friction factor)
3. SUBROUTINE BUBBLE
2. SUBROUTINE SLUG
3. SUBROUTINE TRANS
4. SUBROUTINE MIST (to calculate the two-phase density and pressure gradient depending on the flow regime)

Program for calculating the pressure drop includes: pressure drop in the inlet and outlet arm and check the balance of pressure in the appropriate boundary fluids. Each iteration involves calculating the length of the zone sensible heat (LSH), the number of tubes (Nt), inlet pipe length (L), pressure drop, the share of steam, water retention, etc. The computed values can be printed for each iteration. This allows process engineers to do the necessary changes in calculating and so minimize piston flow and to avoid the misty stream. It is important to varying lengths of pipes (L), diameter (Dt) and heat flux to obtain different results, and they allow us to get to the appropriate minimum optimum equipment. This process includes a number of connected loops, involving iterative calculation method of trial and error. Program calculating heat transfer, except nukleatskog test includes the calculation of the local heat transfer coefficient for each element of the two-phase flow.

RESULT AND DISCUSSION

Numerical results of examples reboilera propane column with different combinations of tube geometry, heat flux and inlet pressure drop. For a given heat flux and the geometry of the pipe; partition coefficient of heat transfer and pressure drop of fluid tends to decrease with increasing inlet pressure drop. Reducing the speed Vl can be attributed to the reduction of the available pressure at the entrance to reboiler. From table for a certain pecking speed, increase speed Vl accompanied by a reduction in the share of the money. The coefficient of thermal transitions can show other variations.The influence of the geometry of the pipe to fluid retention along the entire length of the pipe shows the variation of heat transfer coefficient along the entire length of the pipe. In all cases, the piston area throughout the two-phase fault zone and is therefore approximate S shape. In table 1 we made a comparison of certain values in the case of propane.

Table 1. Comparing the results of the heat transfer Ht, W / (m2 K) for example propane

FER	1124.32	1510.45	1890.90	2288.39	2651.81	3003.87	3293.47	3611.46			Nt=218
SARMA	2673.86	3127.68	3383.48	3570.66	3721.52	3849.57	3961.84	4062.48	Vl=0.33528	Q=12618.4	Nt=324
This paper	5846.75	6019.10	6246.24	6473.38	6586.94	6814.06	7041.22	7268.35	Vl=0.33528	Q=12618.4	Nt=397

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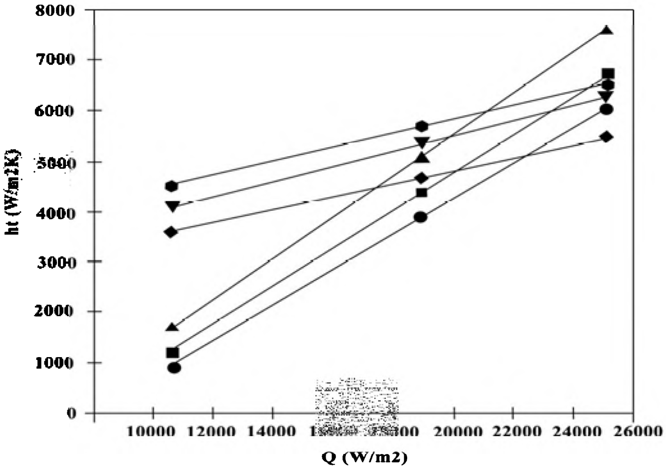

Figure 2. The ratio of the coefficient of heat transfer in two-phase flow and heat flux

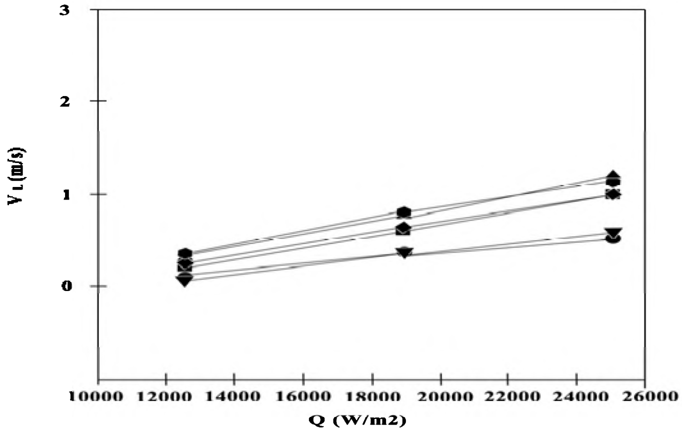

Figure 3. The ratio of velocity VL flow and heat flux

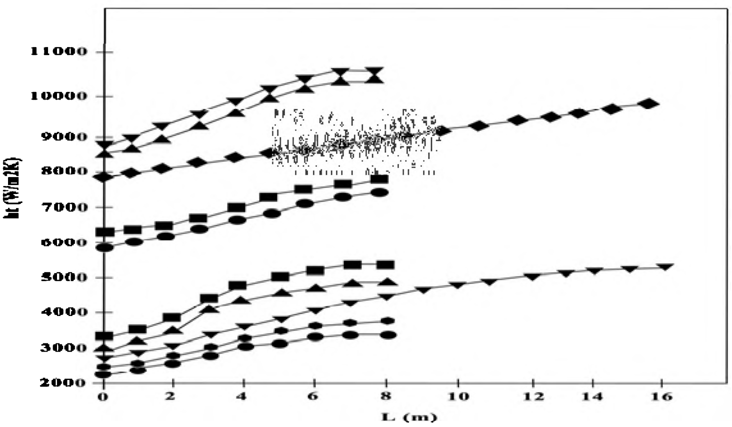

Figure 4. Changing the heat transfer coefficient along the tube reboiler

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CONCLUSION

This paper presents the results of programs written in FORTRAN77 programming language for the design of vertical thermo-siphon re-boilers with boiling in pipes. Thus, starting from the block diagram and a set of model equations for the calculation of pressure drop and heat transfer, which are taken from the literature (1), it was necessary to establish an appropriate algorithm. Written program has been tested on the example of boiling propane in a wider range of process conditions (heat transfer, vapor phase composition at the exit of the device) as well as a series of geometric characteristics of the device (pipe diameters and lengths). The results are satisfactory agreement with the corresponding values from the literature (1). Bearing in mind that the convergence criteria are input data to the calculation, as well as the fact that their values are not listed in the literature (1) in this paper the ranges of their numeric values are defined by systematic usage of the software. All the data on distribution of heat flow, pressure drop, distribution of heat transfer coefficients and the proportion of gas and liquid phases by the height of pipe are shown in detail. Based on this, conclusions can be made about the length of each zone of the two-phase flow. The results from this study were compared with values from the literature (1) and by using the graphic way. This comparison shows that there are different degrees of matching results. Depending on the calculated value. One possible reason for obtaining a deviation could be attributed to possible errors in the model equations that could not be verified because of he unavailability of the literature. This possibility is pointed out by the facts that we have learned on a few incorrect model equations which will, luckily, be removed. In this sense, further work on this model could include a more detailed check of the model equations according to the original literature. The algorithm and the program that was used in this study provides a good basis for their further development in order to broaden the application of multi-component system.

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