Algorithm for Program of the Vertical Thermo-siphon Re-boiler

Sonja Ketin (ketin.sonja@gmail.com)
Faculty of Maritime academic studies
Aleksandar JOVICIC
College of Engineering profesional Studies Cacak
Marko ANDREJIC
Military Academy

Original Article

Keywords: vertical thermosiphon re-boiler, algorithm, FORTRAN77

Posted Date: July 30th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-49240/v1

Abstract

Paper will present algorithm for 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.

Introduction

Paper presents the algorithm and 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).

Methods

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 petrochemicals and selected the best models. Orkizewski developed relations for the pressure gradient, two-phase density and acceleration expression for a given flow regime (Table 1).

Table 1

Comparing the results of the heat transfer Ht, W / (m^2 K) for example propane

FER/ 10^3	**1,12**	**1,51**	**1,89**	**2,29**	**2,65**	**3,00**	**3,29**	**3,61**
SARMA/10^3	2,67	3,12	3,38	3,57	3,72	3,85	3,96	4,06
Paper/10^3	5,84	6,02	6,25	6,47	6,59	6,81	7,04	7,27

Experimental

The purpose of a computer program is the calculation of pressure drop and heat transfer coefficient of heat in the vertical thermosiphon reboileru. 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
- 4. SUBROUTINE SLUG
- 5. SUBROUTINE TRANS
- 6. 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 nucleate test includes the calculation of the local heat transfer coefficient for each element of the two-phase flow.

Results And Discussion

Algorithm 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..

Conclusions

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 the 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 provide a good basis for their further development in order to broaden the application of multi-component system(Fig. 1.).

Nomenclatures

AC accelerative expression

AD steam output quality

AE precision of calculating the pressure balance between the inlet and outlet arms

AG speed increment

AH precision of nuclear boiling point

temperature calculation

ALAS the initial assumed value of the length of

the sensing heat zone

CP specific heat

CPL the specific heat of the fluid in the sensory heat zone

DT inner diameter of pipe

DE pipe diameter at the outlet of the reboiler

EPS absolute roughness

F Muddy's friction factor

G the gravitational constant

GC conversion factor

GT fluid mass flux

H heat transfer coefficient

H0985 heat transfer coefficient for RG = 0.985

HH1 temperature increment

K thermal conductivity

KH thermal conductivity of fluid in the zone of sensible heat

K2 increment of length of sensory heat zone

K3 increment of pressure drop in each element

K4 accuracy for the balance of pressures in each element

K5 accuracy for heat flux balance

L the length of the reboiler tube

LE,LI equivalent length of pipe inlet and outlet

M the maximum number of iterations

N number of increments in the two-phase region

NT number of pipes

N1,N2 parameters defined by Eqs

NB dimensionless number of bubble flow

NLM dimensionless number of nebular flow

NLS dimensionless piston flow number

NGV dimensionless gas velocity number

NW parameter defined by Eq

PE At the entrance to the distillation column

PIN pressure at the entrance to the reboiler

PR Prantl's number

PW saturation pressure corresponding to wall temperature

P11,P22 pressure at the beginning and end of each incremental reboiler

QM,QMC assumed and calculated value of heat flux

QV heat for two-phase flow

RH,RPS dirt resistance on the heating and process sides

S congestion factor 0.25

TI,TE temperature at the inlet and outlet of the reboiler

VL fluid inlet velocity

VR parameter defined by Eq

WT total mass flow through the reboiler tubes

WTVE boiling speed

X share of steam

References

[1] Sarma, N.V.L.S., Reddy P.J., Murti P.S., A Computer Design Method for Vertical ThermosyphonReboilers, Ind.Eng.Chem.ProcessDes.Develop., Vol 12(3), (1973),pp.273-290, DOI: 10.1021/i260047a012

[2] Griffith, P. and G.B. Wallis.,Two-Phase Slug Flow, Transactions of the ASME Journal of Heat Transfer. August,Vol. 83, No. 3, (1962), pp. 307-320

[3] Govier, G. W., Radford, B.A., Dunn, J. S. C., Can. J. Chem. Eng., Vol 35, [1], (1957) p.58,70

[4] Orkiszewski , J., Predicting Two-Phase Pressure Drops in Vertical Pipe, J. Petrol. Technol., Vol 19, (1967) p.829,838

[5] Nicklin, D.J., Wilkes, J.O., Davidson, J.F., Two-phase ¯ow in vertical tubes. Trans. Inst. Chem. Eng , (1962), 40, p.61, 68

[6] James, R,Fair, Petroleum Rafiner, Vol 39, (1960) p.105,120

[7] HUGHMARK, G. A. ,Designingthermosiphonreboilers, Chem. Eng. Prog. 57(7) , (1961), p.43,61

[8] Hughmark, G. A., Designing thermosiphonreboilers, Chem. Eng. Prog., 58(4), (1962) p.62,65

[9] Hughmark, G. A., Designing thermosiphonreboilers, Chem. Eng. Progr. 60(7), (1964), p. 59,61

[10] Hughmark GA. Designing thermosiphonreboilers, ChemEngProg ;65(7), (1969), p.67,70

[11] Lockhart,R.W., Martinelli,R.C., Proposed Correlation of Data for Phase Flow, Two Component Flow in Pipes, Chem. Eng. Prog., Vol 45, (1949), pp. 39–48

[12] Bankoff, S. G., A Note on Latent Heat Transport in Nucleate Boiling,.AIChE Journal, Vol. 8, No. 1, (1962) pp. 63-65

[13] J.C.Chen, Ind.Eng.Chem.Process.Des.Dev, Correlation for Boiling Heat Transfer to Saturated Fluids in Convective Flow, Vol 5(3) ,(1949), pp.322-329, DOI:10.1021/i260019a023

[14] Hsu, Y.Y., On the Range of Active Nucleation Cavities on Heating Surface, Presented at the Winter Annual Meeting of ASME New York,, N.Y., No.61-WA-177,1961

[15] Collier J.B., Pulling D.J. Heat transfer to Two-Phase ' Gas-Liquid Systems., Pt. II: Further Data on Steam-Water Mixtures, U.K. Re.pt. AERE-R-3809, 1962.

[16] D.C.Lee, J.W.Dosey, G.Z.Moore, F.DREW Mayfield, Chemical Engineering Progress , Heat Transfer, Chapter five, 1959

[17] Dz.G.Kollver, Kipenie V vertikalnjihtrubahKipenie i isparenieRaza, 2.7

[18] American Petroleum Institute, API technical databook (Petroleum Refining), Washington, DC, 1977

[19] Stefanov, S., Skobalj, D.(2014) New software for the heat transfer, IV International Symposium Engineering Management and Competitiveness 2014 EMC2014, Zrenjanin, Serbia.

Figures

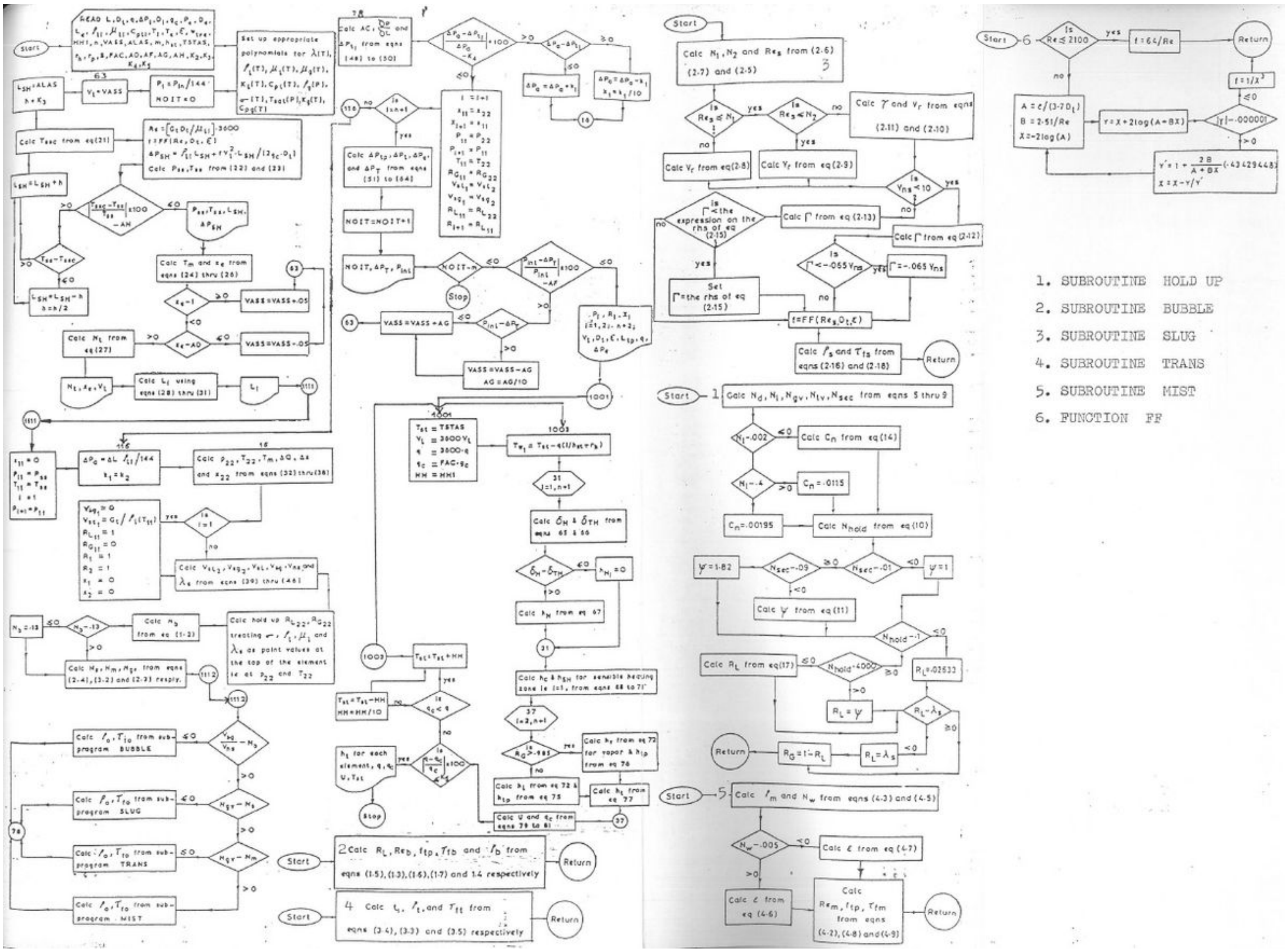

Figure 1

Algorithm for program of the vertical thermo-siphon reboiler

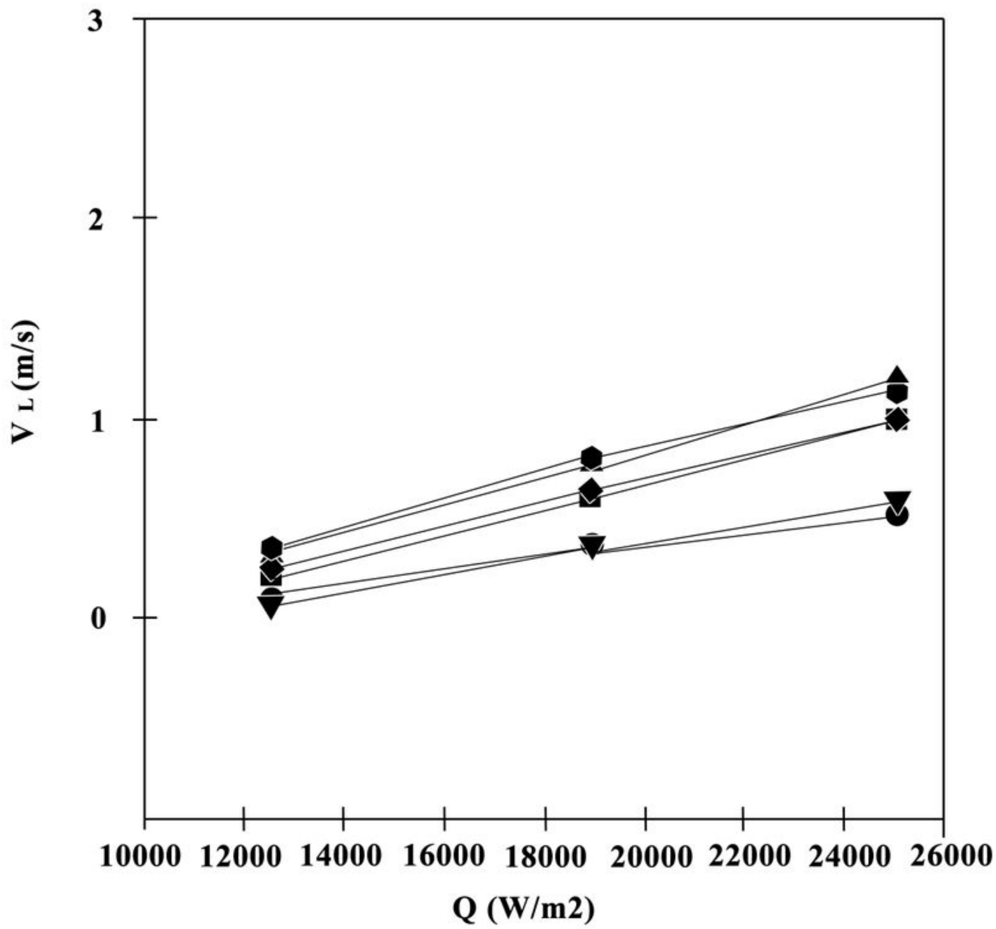

Figure 2

The ratio of velocity VL flow and heat flux