UNIVERSITY OF EAST SARAJEVO

FACULTY OF MECHANICAL ENGINEERING

QUALITY FEST 2017

PROCEEDINGS

26th - 28th October 2017,
East Sarajevo - Jahorina, B&H, RS
Hotel Bistrica

University of East Sqarajevo
Faculty of Mechanical Engineering
QUALITY FEST
October 26th-28th , 2017.
Jahorina, RS, B&H

PROCEEDINGS

1st International Conference for Quality Research (B&H)
11th International Quality Conference (Serbia)
11th International Conference ICQME (Montenegro)

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ПАЛЕ

The conference has been supported by:

PREFACE

The Quality fest is being held for the first time in the Republic of Srpska, Bosnia and Herzegovina. In addition to the First National Conference on Quality of BiH, the First International Quality Conference in BiH is being held at the Quality Festival, as well as 44 National Quality Conference of Serbia, 11th International Conference on Quality (Serbia), 21st SQM 2017 (Montenegro) and 11th. international conference ICQME (Montenegro).

At the previous conferences, some important issues of quality, quality management, engineering, environmental management and food safety were discussed. Lectures to be presented at this annual conference include those areas, but thay are also extended to other areas of science on quality, quality management and standardization. The special value of the conference is in a wide aspect of the issues related to the quality of production and the quality of products and services, as well as interdisciplinarity, since many authors from the practice works from the practice, universities and institutes dealt with topics in the field of machine industry, electrical industry, food industry, education ...

The conference program is divided into 3 thematic units: Global Quality, Quality basic, Quality Engineering and Management. Participation at the national conference were reported by 63 authors from the 5 countries with a total of 28 papers, while at the international conference 80 was reported from the 11 countries with 26 papers. In addition, 5 introductory reports will be presented at the conference, and through discussion on two roundtables ("ISO 9001: 2015" and "Quality Infrastructure in BiH") will discuss the current state of arts and opportunities for improving the application of the actually quality standards in the Republic Bosnia and Herzegovina and the countries of the region.

The presence of a large number of participants from the countries of the region, as well as issues wich will be presented at the conference, coincide with the efforts of the countries of the region in the way to EU and European integration.Based on the above, it can be assumed that the presence of scientific workers, researchers and practitioners will represent not only the exchange of knowledge and achievements in the quality of processes, products and services, but also a serious attempt to unify productive work and create new values with economic development and strengthening awareness of the need for quality improvement as a prerequisite for sustainable development and the preservation of the true values of society.

In the name of the Scientific and Organizational Committee of the QFEST 2017, we wish to express our gratitude to all authors, reviewers, institutions and individuals who contributed to the realization of this Conference.

East Sarajevo, October, 26th 2017.

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IMPACT OF CHANGE IN ENTRY TEMPERATURE OF HEATED FLUID ON TERMIC CHARACTERISTICS OF OPOSITE DIRECTIONAL HEAT EXCHANGER „BEAN OF PIPES IN A SHELL“

Dragan Cvetković[1], Aleksandar Nešović[2]

Abstract: Although the most simple type and despite the fact there are more efficient heat exchangers, those of a type “pipe and a shell” are used often. Goal of this paper is to show how change in temperature in heat fluid on the entrance into the heat exchanger affects its thermal characteristics. Object of research is opposite stream heat exchanger “flux of pipes in shell.” Role of working fluid on the side of primary has water, as on side of secondary. Research is conducted numerically and commercial software ANSYS Workbench 15.0 was used.

Key words: heat exchanger, ANSYS, heated fluid, heat transfer, mean logarithmic temperature difference.

1 INTRODUCTION

Heat exchanger “pipe and shell“is the oldest group of heat exchangers. Although they have lower percentage of usefulness when compared to other heat exchangers, they are used frequently in different process systems. Reason for their frequent use is simple construction, easy installation, easy cleaning and maintenance. Main representative of this group of heat exchangers is „beam of pipes in a shell“ [1] [2].

With this kind of construction, beam of pipes is placed in a bigger pipe which represents a shell. Heat exchange is done between a fluid that streams inside beam of pipes and a fluid that streams between beam of pipes and a shell so that active surface for heat exchange is defined by number of pipes which are part of the beam, by its outer diameter and by its length [3] [4].

Within this subgroup of heat exchangers there are different constructions. Beam can contain straight pipes, „U“ shaped pipes or spiral ones. According to direction of stream, these heat exchangers can be one directional or opposite directional. As for number of passes of fluids that take part in heat exchange, there are heat exchangers with one, two or more passes. Also, one or two fluids can take part in heat exchange. Fluids that take part in the exchange can ne in fluid or gas phase [3].

There are many scientific papers which present research results in relation to „pipes and shall“ heat exchangers.

B. Jayachandriah and K. Rajasekhar examined [5] how choice of materials that were used to make beam of pipes impacts exit temperature of working fluids that are

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used for heat exchange in heat exchanger " Pipes and shell." Impact of copper and steel pipes has been examined through the experiment.

Vindhya Vasiny Prasad Dubey and others [6] examined impact of choice of materials on coefficient of heat passage and exchanged heat flux in heat exchanger, while materials of shell and pipe are changed. Materials used in this analysis are steel, copper and aluminum.

Impact of Reynolds number on pressure fall and coefficient of heat exchange and the exchanger were examined by Rehman [7]. Research has been conduced numerically (ANSYS Workbench) and experimentally.

Objective of this paper is to see how change in temperature of fluid on the entrance of heat exchanger impacts exit temperature of heat fluid and mean logarithmic difference of temperatures. Also, it will be shown that exit temperature of primary from every pipe inside beam is not the same, despite the entry temperature is the same.

2 OBJECT OF RESEARCH

2.1 Construction of heat exchangers

Object of research is opposite directional heat exchanger „beam of pipes in a shell" with one passage of primary hear fluid and one passage of secondary heat fluid. (Figure 1, Figure 2).

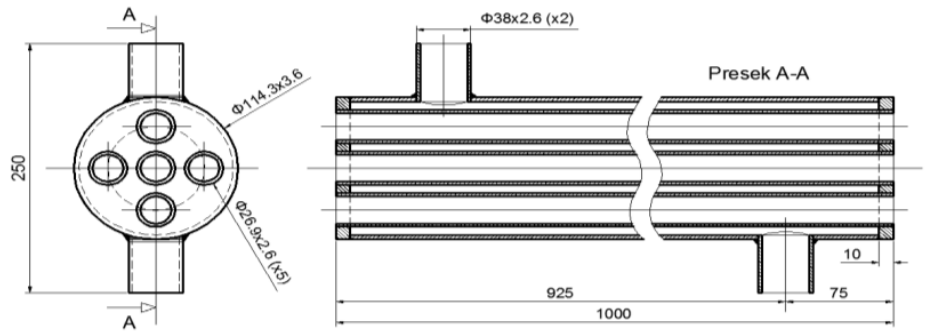

Figure 1. *Opposite directional heat exchanger „beam of pipes in a shell"*

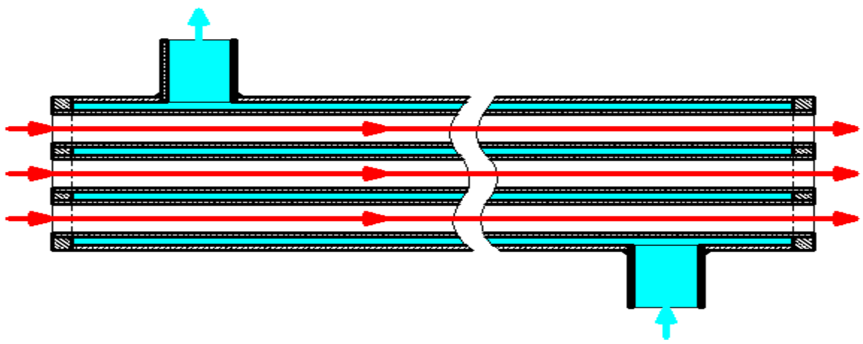

Figure 2. *Electric streams of working fluids inside of analyzed heat exchanger (primary – red colored, secondary – blue colored)*

As it can be seen (Figure 1) total length of heat exchangers is 1000 mm. Beam consists of 5 straight pipes, each with diameter of ∅26,9x2,6 mm. Secondary both enters and departs the heat exchanger through pipe with diameter of ∅38x2,6 mm. Diameter of shell is ∅114,3x3,6mm[8].

Complete heat exchanger is made of custom steel pipes, which can be seen in the following table below (Table 1).

Table 1. *Characteristics of custom steel pipes from Ansys Fluent*

Size	Sign	Unit	Value
Density	ρ_c	[kg/m^3]	8030
Specific heat	c_c	[J/kg K]	502,48
Heat conductibility	λ_c	[W/m K]	16,27

Water has the roles of primary and secondary so that heat exchanger is classifies as „water-water. “

Physical and chemical characteristics of water are provided in the table below (Table 2).

Table 2*. Physical and chemical characteristics of water from Ansys Fluent*

Size	Sign	Unit	Value
Density	ρv	[kg/m3]	998,2
Specific heat	cv	[J/kg K]	4182
Heat conductibility	λv	[W/m K]	0,6
Dynamic viscosity	μv	[kg/s m]	0,001003

2.2 Thermodynamic calculation of heat exchangerslets

Power of heat exchanger is determined by formula (1)[1] [4].

$$Q = A_{ak} \cdot U \cdot \Delta T_m \qquad (1)$$

where is:

Q	[W]	- power of heat exchanger;
A_{ak}	[m^2]	- active surface for heat exchange of heat energy;
U	[W/m^2 K]	- coefficient of heat passage;
ΔT_m	[K]	- mean logarithmic difference between temperatures.

Active surface for heat exchange is in this case determined on the following way (2.2.2) [4].

$$A_{ak} = n \cdot d_s \cdot \pi \cdot L_{ak} \qquad (2)$$

Where is:

n	[-]	- number of pipes contained in a beam;
d_s	[m]	- outside diameter of pipes in a beam;
L_{ak}	[m]	- Length of pipes that take part in the exchange actively.

To calculate coefficient of heat passage, this formula is used (3). Mean logarithmic difference of temperatures (with opposite directional heat exchanger) is determined by formula (4) [9].

$$U = \frac{1}{\frac{1}{h_1} \cdot \frac{d_s}{d_u} + \frac{\delta_c}{\lambda_c} \cdot \frac{d_s}{\left(\frac{d_s + d_u}{2}\right)} + \frac{1}{h_2}} \tag{3}$$

$$\Delta T_m = \frac{(T_{1u} - T_{2i}) - (T_{1i} - T_{2u})}{\ln \frac{(T_{1u} - T_{2i})}{(T_{1i} - T_{2u})}} \tag{4}$$

Where is:

h_1, h_2	[W/m² K]	- coefficient of heat passage on the side of primary (on side of secondary);
d_u	[m]	- inside diameter of pipes in the beam;
δ_c	[m]	- thickness of pipe's wall in the beam;
λ_c	[W/m K]	- heat conductibility of pipe in the beam;
$T_{1u}, T_{1\iota}$	[K]	- temperature of the primary on the entrance (on the exit);
$T_{2u}, T_{2\iota}$	[K]	- Temperature of the secondary on the entrance (on the exit).

Coefficient of heat passage (5) depends from the *Nusselt*'s number (*N_u*) of hydraulic radius (*R_h*), and heat conductibility of primary and secondary, in this case water (*λ_v*) [1] [4].

$$h = \frac{N_u \cdot \lambda_v}{R_h} \tag{5}$$

Where is:

N_u	[-]	- *Nusselt*'s number;
R_h	[m]	- hydraulic radius;
λ_v	[W/m K]	- Heat conductibility of fluids (water).

For the case of forced convection, *Nusselt*'s number determined by size in expression (6) [10].

$$\mathrm{N_u} = \mathrm{c} \cdot \mathrm{R_e^n} \cdot \mathrm{P_r^m} \cdot \mathrm{G_r^r} \cdot \left(\frac{\mathrm{P_r}}{\mathrm{P_{rc}}}\right)^{0.25} \tag{6}$$

Where is:

R_e	[-]	- *Reynolds* number;
P_r	[-]	- *Prandtl's number*;
G_r	[-]	- *Grashof*'s number;
P_{rc}	[-]	- *Prandtl*'s number of pipe's wall;
c, *n*, *m*, *r*	[-]	- Coefficients that depend from stream direction.

2.3 Method of final volumes

Method of final volumes (Figure 3) j is one of the most applied methods in modeling of fluid streams. First of all, calculated volume is exchanged with certain number of controlled volume. After that laws of preservation are applied on every controlled volume [11].

Goal of this method is to translate differential equations that describe every control volume to algebra equations by applying integrals. After translated, they are to be solved [11].

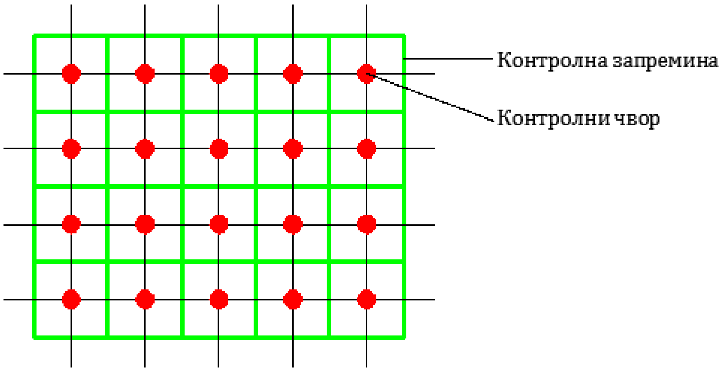

Figure 3. *Method of final volumes*

By using regular equation of preservation (7) it is possible to describe all equations of preservation that are described by streaming and heat transfer [11].

$$\frac{\partial(\rho \cdot \Phi)}{\partial t} + div(\rho \cdot \vec{w} \cdot \Phi) = div(\Gamma \cdot grad\Phi) + S_{\Phi} \qquad (7)$$

By making integral to the equation (7) according the control volume and time it is possible to get integral form of preservation equation (8) which represents basis for application of final volumes method [11].

$$\int_{\Delta t} \frac{\partial}{\partial t}\left(\int_{CV} \rho \cdot \Phi \cdot dV\right) \cdot dt + \int_{\Delta t}\int_{A} \vec{n} \cdot (\rho \cdot \vec{w} \cdot \Phi) \cdot dA \cdot dt = \\ = \int_{\Delta t}\int_{A} \vec{n} \cdot (\Gamma \cdot grad\Phi) \cdot dA \cdot dt + \int_{\Delta t}\int_{CV} S_{\Phi} \cdot dV \cdot dt \qquad (8)$$

3 RESULTS AND DISCUSION

On the following figures (Figure 4 and, Figure 5) temperature field is shown in meridian plain of heat exchanger when temperature of primary on the entrance were 40°C, 65°C and 90°C.

Adopted temperature of secondary on the entrance is same in all cases and it is 30°C. It is same for speed of primary and secondary (in all examined cases it amounts to 0,02 m/s).

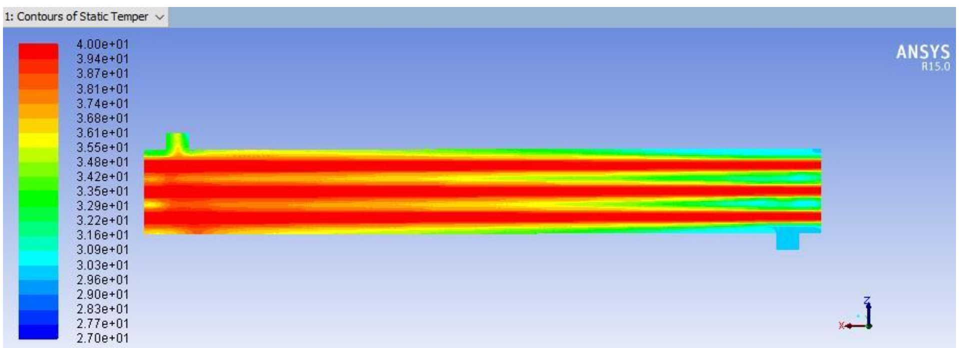

Figure 4. *Temperature field in meridian plain (temperature of primary on the entrance into the heat exchanger is 40°C)*

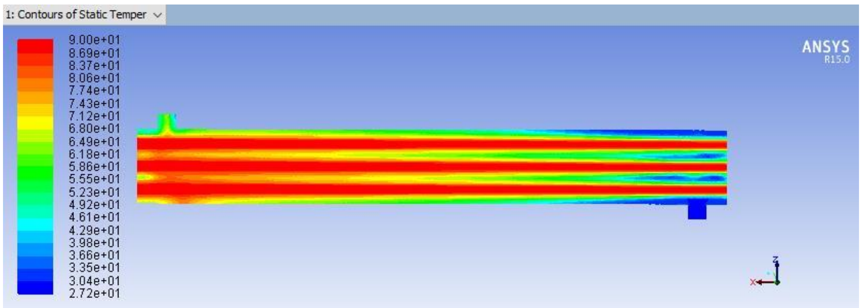

Figure 5. *Temperature field in meridian plain (temperature of primary on the entrance into the heat exchanger is 90°C)*

On the figures below (Figure 6, Figure 7, Figure 8) it is shown that temperature field in plain normal to the direction of pipe (distance of plain from place of the entrance of primary into the heat exchanger is 500 mm.

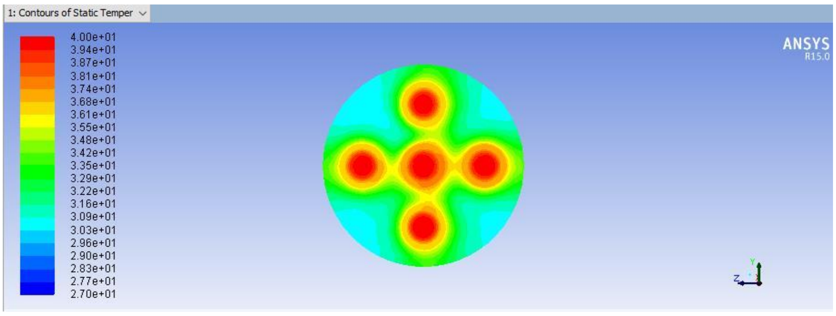

Figure 6.*Temperature field in plain normal to the direction of pipes (temperature of primary on the entrance is 40°C)*

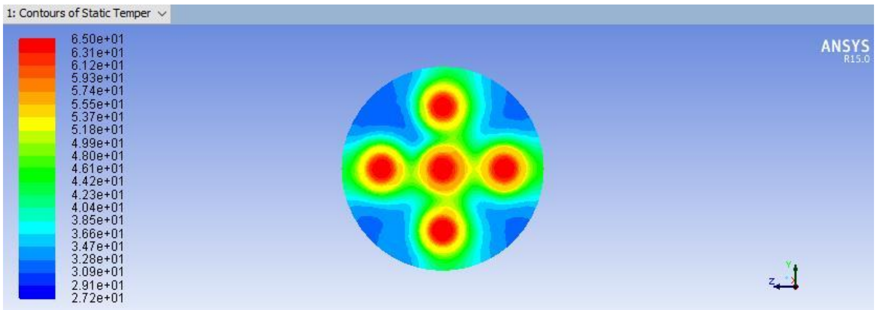

Figure 7.*Temperature field in plain normal to the direction of pipes. (temperature of primary on the entrance into the heat exchanger is 65°C)*

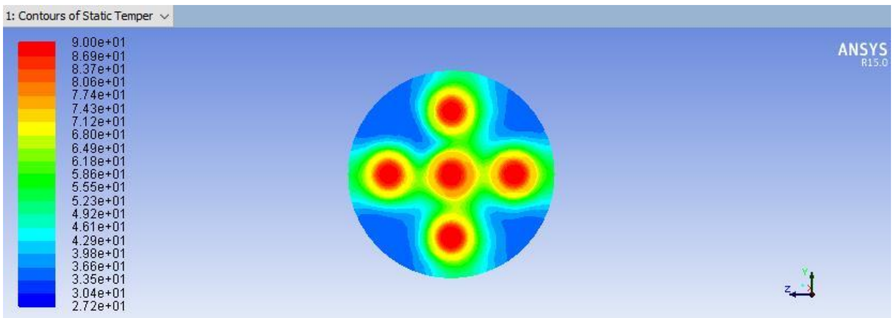

Figure 8.*Temperature field in the plain normal to the direction of pipe (temperature of primary on the entrance into the heat exchanger is 90°C)*

Way by which temperature of primary on the entrance into the heat exchanger impacts the temperature of secondary on the exit and to the total mean logarithmic differences of temperatures is shown on the diagram (Figure 8).

Total mean value of temperature o primary on the exit from heat exchanger is calculated according to the equations (9), (10), (11).

$$T_{1i_{u\,sr}} = \frac{\frac{\sum_{a=1}^{n} T_{1i_a}^{c_1}}{n} + \frac{\sum_{a=1}^{n} T_{1i_a}^{c_2}}{n} + \cdots + \frac{\sum_{a=1}^{n} T_{1i_a}^{c_j}}{n}}{\max(1,2,\ldots,j)} \tag{9}$$

$$T_{1i_{u\,sr}} = \frac{\frac{\sum_{a=1}^{n}\left(T_{1i_a}^{c_1} + T_{1i_a}^{c_2} + \cdots + T_{1i_a}^{c_j}\right)}{n}}{j} \tag{10}$$

$$T_{1i_{u\,sr}} = \frac{\sum_{a=1}^{n} T_{1i_{sr}}}{n \cdot j} \tag{11}$$

Value of total mean temperature of primary on the exit depending from the entry temperature of primary shown on Figure 9.

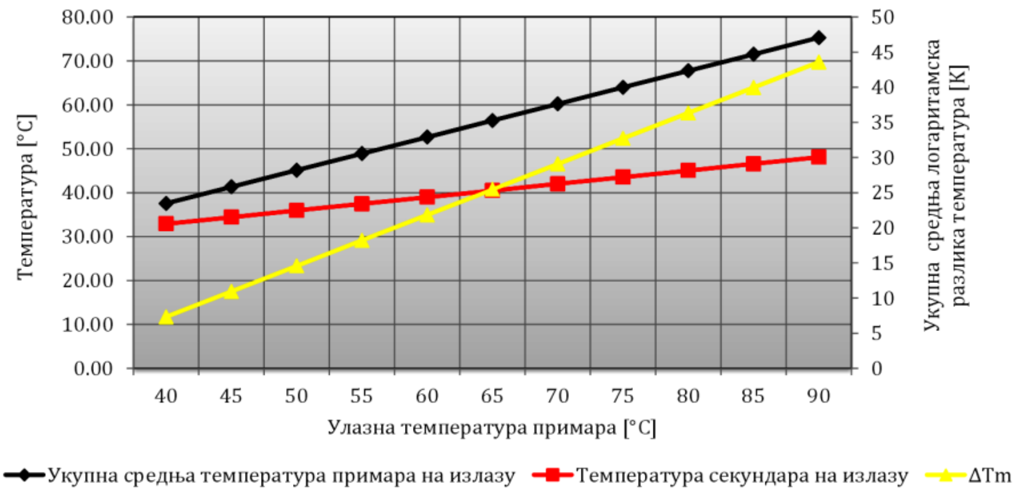

Figure 9. *Dependence between entry temperature of primary and exit temperature of secondary*

Mean temperature of primary on the exit from every pipe contained by flux for every examined case is shown in the following table (Table 3). Table 3 is followed by Figure10.

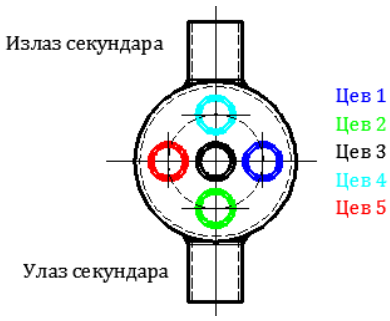

Figure 10. *Position of pipes inside flux*

Table 3. *Mean temperature of primary on the exit from every pipe contained by the flux*

Entry temperature of primary [°C]	**Exit temperature of primary [°C]**				
	Pipe 1	Pipe 2	Pipe 3	Pipe 4	Pipe 5
40	37,48	37,57	37,8	37,54	37,37
45	41,21	41,36	41,7	41,31	41,05
50	44,95	45,15	45,6	45,08	44,74
55	48,69	48,94	49,5	48,85	48,42
60	52,43	52,72	53,4	52,63	52,11
65	56,16	56,51	57,3	56,4	55,79
70	59,89	60,3	61,19	60,17	59,48
75	63,61	64,09	65,08	63,94	63,17
80	67,33	67,87	68,96	67,71	66,85
85	71,06	71,66	72,85	71,49	70,54
90	74,79	75,45	76,74	75,26	74,22

Change in temperature along every pipe contained by flux is not the same. That is why mean temperatures of primary are different on the entry to each pipe in the flux. If change in temperature is followed it will always be higher than mean temperature in plain and it goes through the point of interest.

Change in temperature of every pipe in flux (for case when temperature of primary on the entrance to heat exchanger is 40°C) is shown on the diagram (Figure 11).

On Figure 12 change of temperature is shown when the entrance temperature of primary is 65°C, while on the Figure 13 for entrance temperature of primary is 90°C.

Diagrams on Figure 11, Figure 12 and Figure 13 are analogue to the Figure 10 and Table 11.

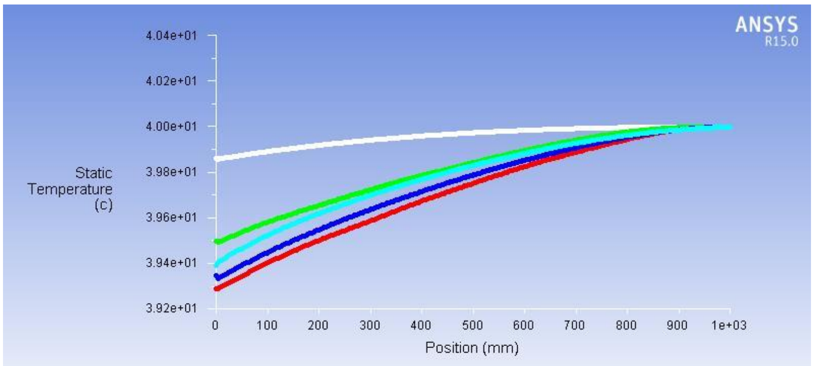

Figure 11. *Change in temperature along the axis of all pipes in the flux (temperature of primary on the entrance into the heat exchanger is 40°C*

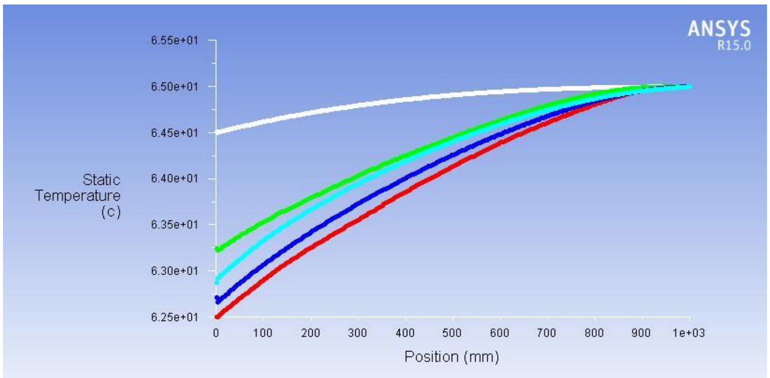

Figure 12. *Change in temperature along axis of all pipes in flux (temperature of primary on the entrance to the heat exchanger is 65°C)*

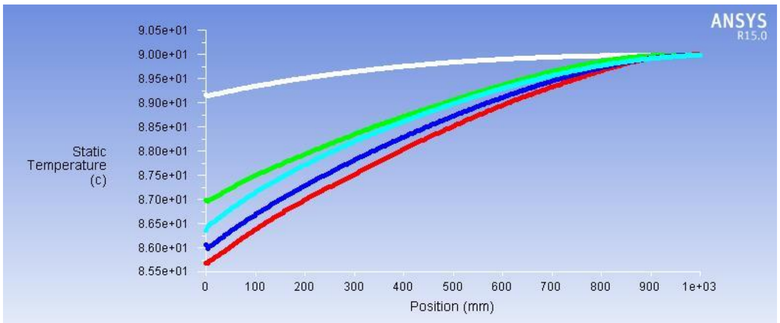

Figure 13. *Change of temperature along axes of all pipes in flux (temperature of primary on the entry into the heat exchanger is 90°C)*

4 CONCLUSION

Heat exchangers are used frequently in heating and air conditioning facilities and in other process systems. Amongst them, heat exchangers “flux of pipes in a shell” take very important place.

Inside this paper, possibility to change working parameter, such as temperature on the side of primary (while other parameters stay unchanged) has been examined. This is done frequently in practice. By changing entry temperature, exit temperature of secondary, mean logarithmic difference in temperatures and finally strength of exchanger are impacted greatly.

Research has shown that, if temperature of primary on the entry to the exchanger is higher, exit temperature of the secondary (and mean logarithmic difference in temperatures) will be higher as well. Also, the difference between entry and exit temperatures will be higher.

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