An Experimental Approach for Enhancement of Heat Transfer Using TTHE: U Valve

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ABSTRACT
The conventional double pipe heat exchanger has less heat transfer rate, so to overcome this problem, this paper focuses on establishing the Triple Tube Heat Exchanger (TTHE) is modified constructive version of double concentric pipe heat exchanger by adding an intermediate tube for hot fluid. In this paper the experimental data obtained during the test in a double and triple concentric tube heat exchangers are very much impressive. However, U valve also fitted and were analyzed and the experiment results conforms the effectiveness of the triple tube heat exchanger.

Introduction
Recently, heat exchangers are widely used in industries, thermal power plants and different engineering applications. There is a rapid growth can be observed in the field of heat exchangers. Researchers are trying to increase the heat transfer rate of heat exchangers in an effective way. A heat exchanger may be defined as the equipment which transfers the energy from a hot fluid to cold fluid with maximum rate and minimum investments. It can also be said that heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact.

An impressive list of information is available in relevant references for double pipe heat exchanger. Many researchers have performed the design and analysis of double pipe heat exchanger [1-4]. Researchers have done theoretical as well as experimental analysis of triple concentric pipe heat exchanger. The set of equations for design and performance analysis have been developed. But the information available for TTHE is still less compared to double pipe heat exchanger. From the available literatures, the major contributions of researchers are as follows: C. A. Zuritz [5] developed a set of analytical equations for fluid temperatures at any axial location along the heat exchanger for parallel and counter flow configurations and conducted simulation of triple concentric pipe heat exchanger. The equations account for heat losses to the surroundings and are useful for design purposes. Simulations show that the creation of an annular region within the inner pipe increases the overall heat transfer efficiency and reduces the heat exchanger length requirement by almost 25%. D. P. Sekulic et al. [6] offered in detail a review on thermal design theory of three fluid heat exchanger, where they have allowed for third fluid temperature to vary according to main thermal communication while neglecting interaction with ambient. He used effectiveness-NTU (number of heat transfer units) approach and corresponding rating and sizing problems for the determination of the effectiveness or NTU for a three-fluid heat exchanger. Ahmet Unal [7] in his first part developed a mathematical model, consisting the derivation and possible solutions of the governing equations for both counter-flow and parallel-flow arrangements. The equations derived in this study can be used for both design calculations and performance calculations, besides they can be used for the determination of bulk temperature variation along the exchanger. Ahmet Unal [8] in his second part conducted several case studies for counter-flow arrangement in his second part based on the solution obtained in the first part. It has been demonstrated that demonstrates that: 1) the relative sizes of the tubes (the tube radii) play a very important role on the exchanger performance and/or on the exchanger length. 2) Optimizing triple tube heat exchanger effectiveness provides a considerable amount of increase in the exchanger performance. Ahmet Unal [9] derived the effectiveness-NTU relations for triple concentric tube heat exchanger including both counter-flow and parallel-flow arrangements. Some representative data are represented in graphical form. This graphs can be used for determining effectiveness of triple concentric pipe heat exchanger by using input parameters i.e. heat capacity ratio and number of transfer units. O. Garcia-Valladares [10] developed a numerical model for analyzing the behavior of triple concentric tube heat exchangers by means of a transient one-dimensional analysis of the fluid flow governing equations and the heat conduction in solids. He concluded that, the model developed can be an excellent tool to optimize the efficiency of triple concentric-tube heat exchangers, and consequently the energy consumption. Ediz Batmaz [11] developed a more generic way of calculating overall heat transfer coefficient in a triple tube heat exchanger for both counter-flow and parallel-flow arrangements using the energy balance equations on a control volume. Further, he derived the equations for determining the axial temperature distribution of the fluids.
He concluded that 1) overall heat transfer coefficients and the temperature profiles are useful for designing a heat exchanger to meet the process requirements. 2) Overall heat transfer coefficients values may also be useful for determining the convective heat transfer coefficient values (h). S Radulescu [12] established an algorithm for the calculation of partial coefficient of heat transfer for a fluid which flows through an inner annular space of a triple concentric-tube heat exchanger in transition regime based on experimental results. He developed a new correlation for design purposes on heat transfer devices, such as triple concentric pipe heat exchanger. The correlation obtained is:

$$Nu_H = 2.718 \times Re_H^{0.597} \times Pr_H^{1/3} \times (dh_2/L_1)^{2/3}$$

It molds the heat exchange for Reynolds values that go from 2264 to 7893 and for the velocities values between 0.11 and 0.36 m/s. The practical applicability of the obtained correlation in the study applies for Prandtl values between 3.30 and 3.70. G.A. Quadir et al. [13] analysed performance of heat exchanger for two flow arrangements, called N–H–C and C–H–N, and for insulated as well as non-insulated conditions of the heat exchanger. The three fluids being considered are hot water, cold water and normal tap water. Under N–H–C arrangement, normal water flows in the innermost pipe, hot water flows in the inner annulus, and the cold water flows in the outer annulus. All fluids flow parallel to each other. Cold and normal water are interchanged in the C–H–N arrangement keeping hot water flow unchanged. He concluded that the heat transfer between the three fluids considered is more effective in N–H–C arrangement of the heat exchanger as compared to that in C–H–N arrangement.

Here N-H-C: - Normal-Hot-Cold
C-H-N: - Cold-Hot-Normal

This study was devoted to the analysis of the heat transfer phenomenon in a triple tube heat exchanger (TTHE). During the literature review on the subject, it was seen that no procedure is available for accurate calculation of overall heat transfer coefficients in a TTHE. Therefore, initial studies focused on developing a procedure for accurate computation of the overall heat transfer coefficients and temperature profiles of the fluids in a TTHE. An effective overall heat transfer coefficient concept was also established. However, another type heat exchanger are shell and tube type but they are mostly use in laboratories [14]

**Methodology**

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact [14]. Heat exchanger have been classified in several ways, according to transfer process (direct contact, indirect contact), according to geometry of constructions (plate, tube, extended surfaces), according to heat transfer mechanisms (single phase, two phases), according to flow arrangements (parallel, counter, cross flow) [15-19]. The type of heat exchanger to be used is determined by the process and product specifications. Nevertheless, concentric tube heat exchanger play a major role in accomplishing the heat exchanger needs of food industry. The most common heat exchanger is double pipe heat exchanger [12]. A typical double pipes heat exchanger consists of one pipe places concentrically inside another of a large diameter pipe with appropriate fitting to direct the flow from one section to the next [13]. Introducing an intermediate pipe to a double concentric pipe heat exchanger provides triple pipe heat exchanger and the latter performs better compared to the prior one. Triple concentric pipes heat exchanger consists of three pipes of different diameters and three fluids exchange heats between them. Thus in this case, there are three sections: central pipe, inner annular space and outer annular space. In triple pipe heat exchangers, a thermal fluid is passed through an inner annular space and heat transfer mediums are passed through the central pipe and outer annular space. Diagram and line diagram of triple tube pipes were shown in fig. 1 & 2.

![Fig 1. Triple concentric pipes.](image)

![Fig 2. Line diagram of triple tube.](image)}
4.1.2 Intermediate tube -

Intermediate tube is made up of copper material, which is used for the flow of hot water. The photographic image of the experimental setup shown in Fig. 3

Dimension -

Outer diameter of the intermediate tube = 0.0179m
Thickness of the intermediate tube = 0.001m
Length of the intermediate tube = 1.3208m

4.1.3 Central tube -

Central tube is made up of copper material, which is used for the flow of cold water.

Dimension -

Outer diameter of the centre tube = 0.0115m
Inner diameter of the centre tube = 95m
Length of the central tube = 1.524m

Results & Discussion

The overall heat transfer coefficients of triple concentric pipe heat exchanger were found to be different for different mass flow rate. The results were shown in table 1, 2 and 3 respectively. Theoretically the energy balance equation i.e. total heat transferred by hot fluid should be equal to the sum of heat received by both the cold fluids, but in practical case for different mass flow rate there is some difference in the energy transferred. The parallel flow counter flow and combination of both were shown in fig. 4, 5 & 6 respectively. The flow regimes in triple pipe heat exchanger were observed to be: Transition in the central pipe and inner annular space and laminar in outer annular space.

![Figure 4. Parallel flow heat exchanger](image)

![Figure 5. Counter flow heat exchanger](image)

Table 1. Parallel flow heat exchanger

<table>
<thead>
<tr>
<th>No. of observation</th>
<th>Hot water</th>
<th>Cold water</th>
<th>Central tube</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temperature (°C)</td>
<td>Time for 1ltr. Of water</td>
<td>Temperature (°C)</td>
</tr>
<tr>
<td></td>
<td>Inlet</td>
<td>Outlet</td>
<td>X sec</td>
</tr>
<tr>
<td>1</td>
<td>56.1</td>
<td>42.8</td>
<td>53.00</td>
</tr>
<tr>
<td>2</td>
<td>55.3</td>
<td>43.8</td>
<td>53.00</td>
</tr>
<tr>
<td>3</td>
<td>57.3</td>
<td>40.9</td>
<td>66.20</td>
</tr>
<tr>
<td>4</td>
<td>59.2</td>
<td>39.5</td>
<td>66.20</td>
</tr>
</tbody>
</table>

Table 2. Observation for counter flow triple tube heat exchanger

<table>
<thead>
<tr>
<th>Types of flow</th>
<th>No. of observation</th>
<th>Hot water</th>
<th>Cold water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temperature (°C)</td>
<td>Time for 1ltr. Of water</td>
<td>Temperature (°C)</td>
</tr>
<tr>
<td></td>
<td>Inlet (Ti)</td>
<td>Outlet (To)</td>
<td>X sec</td>
</tr>
<tr>
<td>Counter flow</td>
<td>1</td>
<td>58.1</td>
<td>47.6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>58.5</td>
<td>45.8</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>57.0</td>
<td>46.5</td>
</tr>
<tr>
<td>Parallel flow</td>
<td>1</td>
<td>55.8</td>
<td>49.6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>52.6</td>
<td>44.6</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>56.0</td>
<td>45.5</td>
</tr>
</tbody>
</table>

Table 3. Observation for double tube heat exchange

<table>
<thead>
<tr>
<th>Expt. No.</th>
<th>Mass flow rate (kg/sec)</th>
<th>Heat transfer coefficient (Watt/m2K)</th>
<th>QH (J)</th>
<th>QC1+QC2 (J)</th>
<th>H-(QC1+QC2)(J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner</td>
<td>Middle</td>
<td>Outer</td>
<td>αC1</td>
<td>αH</td>
<td>αC2</td>
</tr>
<tr>
<td>1</td>
<td>0.00935</td>
<td>0.018</td>
<td>0.029</td>
<td>2169.1</td>
<td>546.8</td>
</tr>
<tr>
<td>2</td>
<td>0.00935</td>
<td>0.018</td>
<td>0.021</td>
<td>2226.9</td>
<td>547.1</td>
</tr>
<tr>
<td>3</td>
<td>0.0129</td>
<td>0.015</td>
<td>0.024</td>
<td>2605.9</td>
<td>477.7</td>
</tr>
<tr>
<td>4</td>
<td>0.0129</td>
<td>0.015</td>
<td>0.018</td>
<td>2583.2</td>
<td>478.3</td>
</tr>
</tbody>
</table>
In this paper, the triple tube heat exchanger was analysed for temperature variation, heat transfer rate, pressure drop and mass flow rate. Number of experiments were performed to determine the heat transfer rate of the heat exchanger having a counter flow arrangement with normal water flow through the inner pipe whereas the hot water flows through inner annulus and inner pipe.

**Conclusion**

Experiments were conducted in a corrugated surface TTTE and the data gathered was used to compute the overall heat transfer coefficients, and the effectiveness values for each run.

- It was found that the effectiveness of the co-current runs in a TTTE was not always greater than the effectiveness of the theoretical co-current runs in a DTHE.
- The changes in calculated U values were also analysed for changes in flow rates of fluids and product inlet temperatures and the heat transfer rate is very efficient.
- The results were in good agreement with the literature with respect to the factors affecting the U values; supporting the reliability of the developed method.
- From the above study it may conclude that the TTTE with U valve showed an effective result in all expects. So it may be recommended for the commercial application.

**References**

References