Temperature Distribution Analysis along the Length of Floating Head Multi Stream Heat Exchanger

Mateen Ahmad, Waseem Saeed, and Khaqan Javed

Abstract*—Heat transfer between two streams is common and simple and well established and perfectly commercialized. Normally, the exchanger that is used for this purpose is shell and tube heat exchanger but in some industrial production unit where more than one reactant is to be preheated or pre-cooled for chemical reaction and same as post heating and post cooling required of multiple streams at same or different temperatures, Problem that is associated with such type shell and tube heat exchanger is that it can't handle the multiple stream and for handling multiple streams we required more number of exchangers due to which capital cost increases and required more care of handling because the number of units increases. To overcome this problem, we need more than one heat sinks with one or more than one heat source that will minimize the covered volume per unit heat transfer area, the number of unit operation, operation time, man power and the capital cost with increasing thermal efficiency and heat utilization so to overcome this problem we need to move towards multi stream heat exchanger for handling multiple streams at once for heat exchange. Multi stream heat exchanger is opening of a new class of heat transfer equipment which deals more than two different streams for heat exchange. Such a way number of units can be reduced, which minimize time and space. With a little bit increase in complexity the operational cost will decrease and improve the thermal efficiency of heat transfer equipment, which minimize thermal losses and maximize the heat utilization which directly decrease the equipment size and capital cost. In the previous study we have discuss our research on the fabrication and Comparative Study of Floating Head (Triple pipe) Multi Stream Heat Exchanger with Shell & Tube This work is about the investigation involves the tentative examination of the heat exchange through the Floating Head Multi-Stream Heat Exchanger to evaluate the temperature distribution along the length, in which cool liquids are flowing through the inner and external pipe and hot liquid is moving through the central pipe of the exchanger.

***Index Terms*—Temperature distribution, floating head, multi-stream, heat exchange.**

I. Introduction

Heat exchanger is used for the transference of heat among the fluids (hot and cold fluid), but while transferring heat it must be with maximum rate and minimum capital cost. There are many Kinds of heat exchangers that are characterized in several ways, according to the heat transfer mechanism or according to the flow arrangement (Parallel, Counter, and cross-flow). Some types of heat exchangers that are using in industries are plate type heat exchanger, shell-and-tube heat exchanger, double pipe heat exchanger, and helical tube heat exchanger One fluid flow through an arrangement of metal tubes in the shell-and-tube heat exchanger and the second fluid flow through a fixed shell that encompasses them. The arrangement of tubes is called tube bundle it might have a configuration as plane, longitudinal, or fin type. The shell and tube heat exchanger are utilized for high-pressure applications the two liquids can float in the same opposite direction. Plate type heat exchangers are composed of thin steel plates or fins inside a major surface region because of which it exchanges additional heat. When compared with the shell-and-tube heat exchanger has lower volume and cost and is used for low-pressure applications A double pipe heat exchanger includes one pipe inside another wide pipe. One liquid stream through the inner pipe and other streams through the annulus among the two pipes. The wall of the inner pipe is the heat exchange surface [1]. Heat exchange between two streams is extremely normal and many industries are working such equipment's yet now there is a requirement for the change in heat exchanger device with the goal that heat energy loss to the surrounding could be limit so an effective heat exchanger could be acquired. Along these lines, there is have to move towards Multi-Stream Heat Exchanger to ensure heat exchange between multi streams in minimal time, minimal volume, and minimum cost. To resolve this problem, we need a new Kind of heat exchanger which can handle multiple streams at once so for this a new type of heat exchanger, i.e., The Floating Head Multi-Stream heat exchanger (Triple pipe) is a modified constructive version of heat exchanger, which is constructed by three concentric tubes of the same length which are connected with the floating head. Floating head multi-Stream heat exchangers have some advantages compared to fixed triple concentric pipe heat exchanger as in the floating head, it is easy to remove tubes for cleaning and this floating head exchanger having the advantage of low maintenance cost. The Floating Head Multi-Stream heat exchanger gives higher efficiency then all other exchangers an on the bases of technical and economic advantages such as floating head multi stream heat exchanger gives higher heat duty, effectiveness and higher heat approach heat [2], [3].

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II. Literature Review

Many researchers performed and analyzed experiments on the shell and tube heat exchanger, then they have done both

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theoretical and experimental analysis of multi-stream heat exchanger (triple pipe). Floating Head Multi-Stream (Triple Pipe) Heat Exchanger consists of tube space, inner annular space and outer annular space. The set of equations for style and performance analysis of Floating Head Multi-Stream (Triple Pipe) Heat Exchanger are developed. however, the Knowledge that is available for Floating Head Multi-Stream (Triple Pipe) Heat Exchanger remains less compared to the shell and tube heat exchanger. Garcá, V. *et al* developed a close steady state and transitory numerical model of the thermal and vibrant performance of Multi Stream (Triple Pipe) Heat Exchanger. The governing Equation within the tubing and also for annulus (Inner and outer) with the energy calculations within the tube walls plus insulation area unit solved [4]. Quadir, G.A. *et al* They distributed the search for the presentation of Multi stream (Triple Pipe) Heat Exchanger victimization finite component methodology underneath steady state condition for numerous flow patterns and insulated and non-insulated conditions of heat exchanger. Three fluids that be situated for this are Cold fluid. (Inner tube), Hot fluid. (Central tube), Cold fluid. (Outer tube) They performed experimentation on Multi-Stream (Triple Pipe) Heat Exchanger at the steady state conditions for two totally changed flow engagements [5]. Sekulic, D. P. *et al* presents splendidly a review on the methodology on the thermal design of theory of three fluid exchangers wherever they indorsed the temperature of the third fluid to vary in Keeping with main thermal communication by neglecting interaction with close. Effectiveness- NTU (Number of Transfer Units), approach, equivalent rating and size issues was used for the determination of the effectiveness or NTU for a three-fluid exchanger [6] Ahmet, U and *et al*. uses Effectiveness-NTU relations for triple co-axial multi tube heat exchanger as well as each counter-flow and parallel flow arrangement was derived. Some descriptive information is present in graphical form. Graph is used for deciding the effectiveness of triple co-centric pipe multi stream heat exchanger by mistreatment input parameters i.e., heat capability quantitative relationship plus, the variety of transfer units. [7]. Birol, B. *et al* planned an additional grace of heat energy storing system that consisted of a threefold concentric-tube arrangement through study so, a numerical investigation was conducted. They used total heat approach for same supported the numerical calculations, On the basis of calculations, mathematical calculations, the outcomes of structure limitations for example mass flow rate, the inlet temperature of the heat transfer fluid and deviation of the tube radii on the system performance measured [8]. Saeid, S. *et al* conduct investigation on thermal performance for Floating Head Multi-Stream (Triple Pipe) Heat Exchanger Has done by them for separately, for the co and counter-current flow arrangements is done by Saied and Seetharamu that is restricted to insulated surroundings [9]. Krishna. *et al* explored a result for the longitudinal heat conductivity within the splitting walls on the performance of a refrigerant exchanger having thermal contact among three fluids and therefore the result of heat to the cold fluid in the outflow of non-concentric investigated [10]. Guo. *et al* The thermal resistance and the exchanger effectiveness relations present well by Guo *et al*, he added a pipe to the double concentric pipe exchanger changing this one to the triple pipe and he determines that its performance is higher related to the previous one. The related method was accepted for the heat usage of milk during a whorled triple pipe exchanger [11], [12]. Radulescu S. *et al* established an algorithmic program for the calculation of fractional constant of heat transfer for a fluid that flows through an inner ring-shaped house of a Multi-Stream (Triple Pipe) Heat Exchanger in the transition regime that backing experimental results. He established a new co-relation for policy of heat transfer exchangers, for example Multi-Stream (Triple Pipe) Heat Exchanger [13], [14].

III. Material and Methods

Floating head multi-Stream heat exchangers are built by three concentric tubes of a similar length which are associated with a floating head. Experimental is done in the Floating Head Multi-Stream Heat Exchanger Two cold fluids flow through the inner and outer tube in the same direction. Hot water moves through the Central tube. Heat exchange from the hot liquid to cold fluid streams occur without phase change. All tubes having a similar length and different diameters and all tubes are associated with the Floating head rather than the fixed design we utilize the floating head as its configuration increase the flexibility for cleaning and give low maintenance cost. The experimental setup is a plan as we have shown in Fig. 1 (schematic diagram of the experiment) to such an extent that cool fluids circles from the tank by pumps and stream rate is maintained by utilizing the flowmeter. The hot liquid is first heated by the heater in the storage tank and afterward circulates by the pump and the flow rate is maintained. In the experimental setup as shown in Fig. 2, cold fluid permits to flow through the inner and external tube. The hot liquid is permitting to move through the central tube. All three fluids are permitting to flow in the same direction i.e., in a co-current direction. The Floating head multi stream heat exchanger which is used for this experiment was designed with the following dimensions as shown in Table I.

TABLE I: Parameters of Floating Head Multi-stream Heat Exchanger

Inner tube diameter	D_i	0.04ft
Length of the inner tube	L_i	1.8ft
Central tube diameter	D_c	0.4ft
Length of the central tube	L_c	1.5ft
Outer tube diameter	D_o	0.29
Length of the outer tube	L_o	1.5ft
Head diameter	H_d	0.08ft
Length of head	H_l	0.33ft

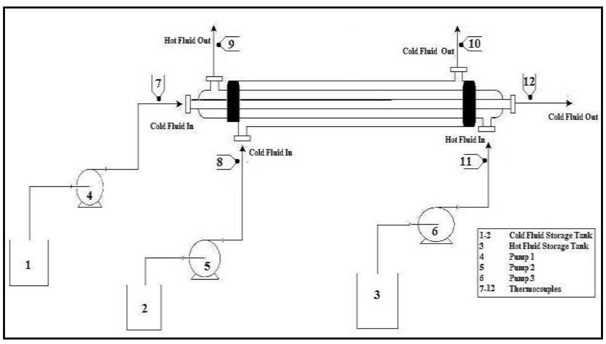

Fig. 1. Schematic diagram for multi stream exchanger.

Fig. 2. Experimental setup for floating head multi stream exchanger.

IV. Result and Discussion

A. Temperatures Distribution along Inner Pipe

To investigate the trend of the temperature of cold fluid which was flowing through inner pipe and was in in contact with hot fluid stream, fluid was allowed to flow through the inner pipe and check the results of changing of the temperature at different length of inner pipe and get different values which are shown in Table II.

TABLE II: Temperature Distribution along Length of Inner Pipe

Sr No	Length of Inner Pipe (ft)	Temperature (K)
1	0.0	316.5
2	0.5	322.0
3	1.0	326.0
4	1.5	328.5

B. Temperatures Distribution along Central Pipe

To investigate the trend of the temperature of hot fluid which was flowing through central pipe and was in in contact with two cold fluid streams one was in inner pipe and one was outer pipe, results of changing of the temperature of hot fluid at different length of central pipe shown in Table III.

TABLE III: Temperature Distribution along Length of Central Pipe

Sr No	Length of Central Pipe (ft)	Temperature (K)
1	0	343
2	0.5	335
3	1.0	332
4	1.5	330

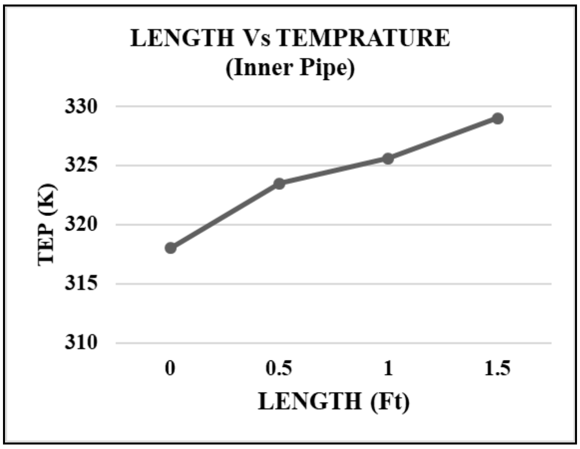

Fig. 3. Temperature distribution of cold fluid in inner pipe along the length of exchanger.

Result from the Fig. 3 shows that the temperature of the fluid in the inner pipe increases as the length of the pipe increases, it is because of that the hot fluid which was flowing through the central pipe was flowing in opposite direction so as the length of the inner pipe increase the contact time of cold fluid which was flowing in inner pipe increases with the hot fluid. So, from the results we can see that initially, the temperature of the fluid in the inner pipe was 316.5K when the length was 0.0 ft. but as the length of the pipe increased from 0.0 ft. to 1.5ft. the temperature of the fluid in inner pipe reaches from 316.5K to 328.5K from the above result it is interesting to note that from the length 0ft to 0.5ft change of temperature is higher than other value which show that the initially the transfer of the heat from hot fluid to inner fluid is higher.

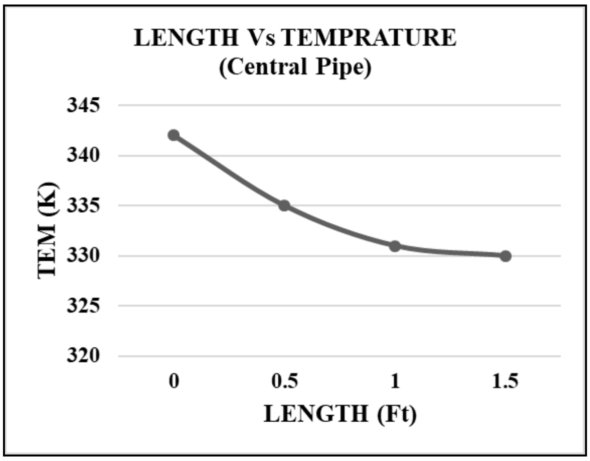

Fig. 4. Temperature distribution of hot fluid in central pipe along length of exchanger.

Result from the Fig. 4 shows that the temperature of the hot fluid in the central pipe decrease as it loses its heat and its temperature initially was 343K when the length was 0.0ft. but when its length increases from 0.0ft to 1.5ft temperature decreases from 343K to 330K.From the above results it is notify that total change of temperature is almost 13K Since hot fluid is flowing in the central pipe and is in contact with two cold fluids from the inner side and from the outer side and we can see from the result that total change of temperature of hot stream is not much higher also results show that initially change of temperature was higher from 343K to 335K when length change was 0ft to 0.5ft but from the length 1ft to 1.5 ft the temperature change was 330K to 228K it is because at this stage contact time between hot and cold fluid is very less.

C. Temperature Distribution along Outer Pipe:

To investigate the trend of the temperature of cold fluid which was flowing through outer pipe and it was also in in contact with hot fluid streams, results of changing of the temperature of cold fluid at different length of outer pipe shown in Table IV.

TABLE IV. Temperature Distribution along Length of Outer Pipe

Sr No	Length of Outer Pipe (ft)	Temperature (K)
1	0	322
2	0.5	325
3	1.0	328
4	1.5	331

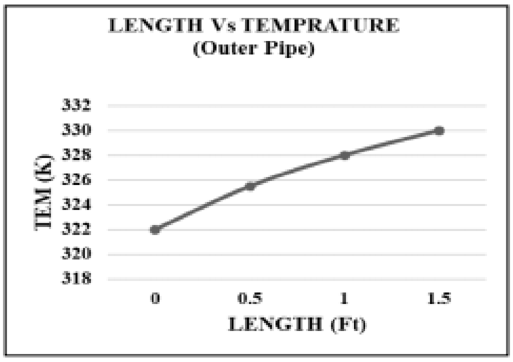

Fig. 5.Temperature distribution of cold fluid in outer pipe along length of exchanger.

Results from the table IV and Fig.5 show that the temperature of the fluid inside the outer pipe rises to 328.5K from its entry temperature of 316.5K when the length changes from 0ft to 0.5ft as shown in the table IV also we can see that when the length change from 0ft to 0.5ft then temperature changes from 322K to 325K and from the length 1ft to 1.5ft change remain in same trend i.e., from 328K to 330K.

V. Conclusion

From the above discussion we can see that the Floating Head Multi-Stream Heat Exchanger gives great heat exchange even though floating head multiteam heat exchanger uses single heat source and transfer heat to cold stream simultaneously also from the results we can see that thermal efficiency and viability are better so we can state that it is a compact version of the heat exchanger where we can manage more than two distinct streams for heat Exchange so we can say that is a compact version of heat exchanger because it reduces the operational and capital cost because by using this we can deal with more than two different streams for heat exchange.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Mateen Ahmad. (Ph.D. Student), construct multi-stream heat exchanger and also done experiments with the help of Waseem Saeed (MS Student) who also conducts experiments and wrote the manuscript, Khaqan Javed (Assistant Professor) design study and review all experimental study and manuscript also HOD of department of chemical engineering and technology UET Lahore, Pakistan also contributes his backward knowledge related to Heat transfer to check our work

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References

[1] M. Ahmad, K. K. Javed, and M. Usama, "Sizing and experimental performance analysis of floating head multi stream heat exchanger," *Open Access International Journal of Science and Engineering*, vol. 2, pp. 127-130, 2017.

[2] M. Ahmad, K. Javed, and M. Usama, "Comparative study of floating head multi stream heat exchanger with shell and tube heat exchanger," *International Journal of Advance Scientific Research and Engineering Trends*, vol. 2, pp. 1-5, 2017.

[3] Kakac and H. Liu, *Heat Exchangers Selection, Rating, and Thermal Design*, CRC Press, New York, pp. 283-328, 1998.

[4] D. Saurabh, P. K. Tamkhade, and M. Lele, "Design development and heat transfer analysis of a triple concentric tube heat exchanger," *International Journal of Current Engineering and Technology*, pp. 1-6, 2016.

[5] G. A. Quadir, S. Jarallah, S. Ahmed, and I. Anjum, "Numerical investigation of performance of a triple pipe heat exchanger", *International Journals of Heat and Mass Transfer*, vol. 62, pp. 1-5, 2013.

[6] D. P Sekulic and R. K. Shah, "Thermal deign theory of three fluid heat exchanger," *Advances in Heat Transfer*, vol. 26, pp. 219-328, 1995.

[7] A. Unal, "Theoretical analysis of triple concentric tube heat exchanger," *Advance in Heat Transfer*, vol. 25, pp. 949-958, 1998.

[8] B. Başal and A. Ünal, "Numerical evaluation of a triple concentric-tube latent heat thermal energy storage," *Solar Energy*, vol. 92, pp. 196–205, 2013.

[9] G. F. Hewitt and S. J. Pugh, "Approximate design and costing methods for heat exchangers," *Heat Transfer Engineering*, vol. 28, pp. 76-86, 2007.

[10] K. Veerabhadrappa, G. Vinayakaraddy, K. N. Seetharamu, P. G. Hegde, and V. Krishna, "Transient behavior of three-fluid heat exchanger with three thermal communications under step change in inlet temperature of fluids using finite element method," *Applied Thermal Engineering*, vol. 108, pp. 1390-1400, 2016.

[11] K. P. Singh, A. I. Soler, and C. Hill, "Mechanical design of heat exchangers and pressure vessel components" heat exchanger design targets for minimum area and cost," *Chemical Engineering Research and Design*, vol. 78, pp. 161-167, 2001.

[12] T. Jerry, "Strategy of heat exchanger design," *Two-Phase Flow Heat Exchangers*, pp. 473-493, 1998.

[13] W. Xiaoa, K. Wanga, X. Jiangab, X. Lia, X. Wua, and G. Hea, "Simultaneous optimization strategies for heat exchanger network synthesis and detailed shell-and-tube heat-exchanger design involving phase changes using GA/SA," *Energy*, vol. 183, pp. 1166-1177, 2019.

[14] R. K. Shah and D. P. Sekulic, *Fundamentals of Heat Exchanger Design*, John Wiley & Sons, 2003.

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