# ANALYSIS AND EXPERIMENTATION OF SHELL AND TUBE HEAT EXCHANGER WITH DIFFERENT ORIENTATION OF BAFFLES

[1] SayaliR.Bhandurge, [2] Prof.A.M.Wankhade, [3] Prof.P.K.Jadhao,

[1, 2, 3] Mechanical Engineering Department, SantGadge baba Amravati University,

[1, 2, 3] BabasahebNaik College of Engineering, Pusad, Maharashtra India.

## Abstract:-

An Experimentation along with CFD analysis is carried on single pass, counter flow shell and tube heat exchanger containing Baffles at $0^0$,$15^0$ orientation. To study the heat transfer rate and pressure drop of shell side fluid and compare the result with Bell-Delaware method.. Experimental setup is validated with help of Dittus-Boeltercorrelation. Nusselt number obtain from Experimental set up of $0^0$orientation and Dittus- Boeltercorrelation are within 5.72%.Experimental result of $0^0$orientation is also compare with CFD results in which Nusselt number are found to be within 12.50% and pressure drop is found within 5.55%.Results obtain from CFD analysis is also compare with Bell Delaware method and Nu in case of CFD is 3.35% of Bell-Delaware. . From this experimental, CFD and Bell Delaware analysis it is found that as baffle angle changes from 0 to 45 degree Nusselt no. is increases that is indirectly heat transfer rate is increase and pressure drop is reduces.Reduction in Pressure drop with increase in baffle orientation help in reducing the pumping cost of Shell and tube heat exchanger.

**Keywords**: - Nusselt number, Pressure drop, Baffle Inclination angle.

## 1. INTRODUCTION

A heat exchanger is a device built for efficient heat transfer from one medium to another in order to carry and process energy. They are widely used in petroleum refineries, chemical plants, petrochemical plants, natural gas processing, air-conditioning, refrigeration, and automotive applications. The most commonly used type of heat exchanger is the shell and tube heat exchanger. It is essential to mention that a heat exchanger is not only an apparatus for transferring heat from one medium to another, but is at the same time a pressure and/or containment vessel. In addition to heating up or cooling down fluids in just a single phase, shell and tube heat exchangers can be used either to heat a liquid to evaporate (or boil) it or used as condensers to condense a vapor back to a liquid. To increase the heat transfer rate in shell and tube type heat exchanger the segmental baffles are introduced inside the cover pipe. The flow arrangement is counter flow as it is more efficient than parallel flow arrangement. One of the most important parts in shell and tube heat exchangers is the baffles.

Baffles serve two important functions. They support the tubes during assembly and operation and help prevent vibration from flow induced eddies and direct the shell side fluid back and forth across the tube bundle

to provide effective velocity and Heat Transfer rates. The diameter of the baffle must be slightly less than the shell inside diameter to allow assembly, but must be close enough to avoid the substantial performance penalty caused by fluid bypass around the baffles. For most liquid applications, the cuts areas represent 20-25% of the shell diameter. For gases, where a lower pressure drop is desirable, baffle cuts of 40-45% is common.

Nomenclature

| | | |
|---|---|---|
| $A_s$ | Surface area (m₂, | |
| $A_s$ | Cross sectional area of pipe $(m^2)$ | |
| $C_p$ | Specific heat at constant pressure (J/kg°C) | |
| $D_i$ | Inner diameter of pipe (m) | |
| $D_o$ | Outer diameter of pipe (m) | |
| $d_o$ | Diameter of orifice (m) | |
| h | Average convective heat transfer coefficient $[W/m^{2}{}^{\circ}C]$ | |
| k | Thermal conductivity$[W/m°C]$ | |
| L | Pipe length (m) | |
| $\dot{m}$ | Mass flow rate of air (kg/s) | |
| Nu | Nusselt number | |
| Pr | Prandtl number | |
| Re | Reynolds number | |
| f | Friction factor | |
| $\Delta p$ | Pressure drop along length of tube $[N/m^2]$ | |
| $T_s$ | Average surface temperature (℃) | |
| $T_b$ | Bulk mean temperature(℃) | |
| $T_i$ | Inlet temperature(℃) | |
| $T_o$ | Outlet temperature(℃) | |
| $V_a$ | Velocity of air (m/s) | |

## 2. LITERATURE REVIEW

Verities of techniques have been implemented by researchers for heat transfer enhancement in past years for increase in heat transfer rate with low increase in pressure drop which are discussed below.

Sandeep K. Patel, Professor Alkesh M. Mavani [1] studied the Shell & Tube Heat Exchanger Thermal Design With Optimiztion of Mass Flow Rate And Baffle Spacing. This paper state a characteristic of heat exchanger design is the procedure of specifying a design. Heat transfer area and pressure drops and checking whether the assumed design satisfies all requirement or not. The purpose of this paper is how to design the shell and tube heat exchanger which is the majority type of liquid –to-liquid heat exchanger. General design considerations and design procedure are also illustrated in this paper. In design calculation HTRI software is used to verify manually calculated result. From literature review it can be concluded that, • There is increase in pressure drop with increase in fluid flow rate in shell and tube heat exchanger which increases pumping power. Genetic algorithm provide significant improvement in the optimal designs compared to the traditional designs. Genetic algorithm application for determining the global minimum heat exchanger cost is significantly faster and has an advantage over other methods in obtaining multiple solutions of same quality. Thus, providing more flexibility to the designer.KooroshMohammadi, Wolfgang Heidemann,§ and Hans Müller-Steinhagen[2] studied Effect of baffle orientation on heat transfer and pressure drop of shell and tube heat exchanger with and without leakage flows. The effect of baffle orientation on the heat transfer and pressure drop of shell and tube heat exchangers in the domain of turbulent flow is investigated numerically using the commercial CFD code FLUENT. The segmentally baffled shell and tube heat exchangers considered follow the TEMA standards and consist of 76 and 660 plain tubes respectively, with fixed outside diameter and arranged in a triangular layout. Air, water and engine oil with Prandtl numbers in the range of 0.7 to 206 are used

as shell-side fluids. The simulation results show a significant influence of the baffle orientation on the shell-side pressure drop and heat transfer of shell and tube heat exchangers. In the shell and tube heat exchanger with leakage flows the vertical baffle orientation seems to be more advantageous than the horizontal orientation. The benefit of vertical baffle orientation on horizontal baffle orientation is more noticeable for gases. Contrariwise, the simulation results for shell and tube heat exchangers without leakages show the advantage of the horizontal baffle orientation over the vertical orientation, particularly in the inlet and outlet zone for all investigated shell-side fluids. The comparison of calculation results with and without leakage flows presents different behaviour and underlines the importance of a consideration of tube-baffle leakage and bypass streams for the prediction of the performance factor of technical heat exchangers.Praveen Kumar Jha, K. K. Jain ,Dr. R. K. Dave,PoojaTiwar [3] Studied Analytical performance analysis of shell and tube heat exchanger by varying number of baffles and mass flow rate. In this paper they study an effort has made for Computational Fluid Dynamic (CFD) analysis of a single pass counter flow Shell and Tube Heat Exchanger (STHX) with varying number of baffles & comparing the mass flow rate i.e 1kg/sec and 2kg/sec. STHX is the most common and widely used type of heat exchangers in oil refineries, condensers and other large chemical processing plants. To analyze the performance of STHX, hot fluid has made to flow through shell and cold fluid is allowed to flow through the tube. Our analysis is based on shell side study to find out temperature at the inlet and outlet of shell side, pressure drop and velocity drop. These results shows that as the mass flow rate inside the shell increases temperature drop decreases because time to transfer heat from it minimizes.So it can be concluded that most optimum result obtained at

considered Baffle angle is at 8 Baffles at the mass flow rate of 1Kg/Sec.Ankit Uppal, Dr. Vinod Kumar, Dr. Chanpreet Singh[4] studiedCFD analysis of heat transfer enhancement in a heat exchanger using various baffle arrangements.The present study reports the heat transfer enhancement in a heat exchanger tube by installing seven different baffle arrangements. The purpose of the study is to find out the optimum baffle shape and arrangement According to results, it concluded that in case of single baffle used, rate of heat transfer is maximum for rectangular shape baffle surface and in case of baffle combinations; rate of heat transfer is maximum for rectangular and triangular baffle. The reason behind maximum heat transfer rate was that due to use of baffles, turbulence was increased as they allow more mixing of fluid layers and resulted in increase of heat transfer through the heat exchanger tube.Avinash D Jadhav, Tushar A Koli, [5] studied CFD analysis of shell and tube heat exchanger to study the effect of baffle cut on the pressure drop. In this paper the shell side of a small shell-and-tube heat exchanger is modelled with sufficient detail to resolve the flow and temperature fields. From the CFD simulation results, for fixed tube wall and shell inlet temperatures, shell side heat transfer coefficient, pressure drop and heat transfer rate values are obtained. The sensitivity of the shell side flow and temperature distributions to the mesh density, the order of discretization and the turbulence modelling is observed. By varying baffle cut values of 25% and 30%, for 0.5, 1 and 2 kg/s shell side flow rates, the simulation results are compared with the results from the Kern and Bell–Delaware methods. Using CFD, together with supporting experiments, may speed up the shell-and-tube heat exchanger design process and may improve the quality of the final design. In the near future, improvements in the computer technology will make full CFD simulations of much larger shell-and-tube heat exchangers

possible.Nishank Kumar Pandey, Dr. RohitRajvaidya[6] studied computational fluid dynamics analysis of single pass shell & tube heat exchanger with different orientation of baffles and without baffles.In this specific project an endeavor is design for CFD evaluation of Single Pass Shell & Tube Heat Exchanger with Different Orientation of Baffles and Without Baffles with counter flow of fluid. In order to research the performance of the heat exchanger, hot fluid was designed to flow inside the seven tubes and cold fluid flows through outer pipe & tube material using Copper as well as Brass & Shell Material using Carbon Steel. The baffles utilized in heat exchanger are usually segmental baffles cut of 25%. The introduction of baffles, force the fluid to have a turbulent flow, thus improving the heat transfer rate. The outcomes of heat transfer rate for flow of fluid with vertical segmental baffle inside heat exchanger are in comparison with the heat exchanger without having baffles. The result of heat transfer rate & pressure drop for flow of fluid for $0^0$ baffles is also compared with baffle at $30^0$ orientations. They Study the heat transfer in the heat exchanger at different velocity, the end result coming out from heat exchanger having baffles located at outer pipe will be more efficient via heat exchanger without having baffles and The outcomes of heat transfer coefficient coming out by utilization of $30^o$ baffles will be more efficient than $0^o$ baffles. As the angle of inclination increases, the heat transfer rate of heat exchanger also increases also the Reynolds number increases in the heat exchanger, the heat transfer coefficient will increase.SwarupS.DeshpandeShreeniket A Hinge [7] studiedThis paper primarily focuses on the design and comparative analysis of Single segmental Shell and tube Heat Exchanger with perpendicular & parallel baffle cut orientation. For designing Kern Method is used. It predicts heat transfer coefficient, Pressure drop of both arrangements. This method gives us clear idea that rate of heat transfer is greater in Perpendicular-cut baffle orientation than Parallel-cut , Pressure drop approximately remaining same. The Shell side fluid used is Lithium-bromide with average concentration of 58.5% and tube side fluid is hot water. All other parameters of fluid remaining same. From this paper it is evident that there is significant drop in the Reynolds Number corresponding to vertical flow which in turn has a direct impact on the shellside heat transfer coefficient which is found to be lower than that for horizontal flow. However the shell-side pressure drop for the vertical flow is in the same range as that for the horizontal flow design. Also there is a noticeable drop in the Nusselts Number for the proposed design with the Prandtl number being the same for both designs. Therefore based on the results we conclude that changing the flow pattern to vertical to improve the shell-side heat transfer coefficient is not feasible.Ajithkumar M.S., Ganesha T., M. C. Math [8] studiedCFDanalysis to study the effects of inclined baffles on fluid flow in a shell and tube heat exchanger.They analyze the performance of STHX,for that hot fluid has made to flow through tubes and cold fluid is allowed to flow through the shell. Their main objective is to design the STHX with segmental and helical baffles and to study the flow and temperature field inside the shell side. Also, attempts were made to investigate the effects and heat transfer characteristics of a STHX for three different baffle inclinations namely 0°, 10°, and 20° for a given baffle cut of 36%.The study indicated that flow pattern in the shell side of the heat exchanger with continuous helical baffle was forced to rotate the fluid, which results in significant increase in heat transfer rate and heat transfer coefficient per unit pressure drop than segmental baffle STHX. From the CFD simulation results, the shell side outlet temperature, pressure drop, optimum baffle inclination and optimal mass

flow rate were determined. MNeerajkumar, Dr. Pradeep kumarJhinge, [9] studied effect of segmental baffles at different orientation on the performances of single pass shell and tube heat exchanger.        In this paper, experimentation of single pass, counter flow shell and tube heat exchanger containing segmental baffles at different orientations has been conducted to calculate some parameters (heat transfer rate and pressure drop) at different Reynolds number in laminar flow. In the present work, an attempt has been made to study the effect of increase in Reynolds number at different angular orientation " " of the baffles. The range of " " vary from 0° to 45° (i.e 0°, 15°, 30° and 45°) and Reynolds number ranges from 500 to 2000 (i.e 500, 1000, 1500 and 2000). Based on the experimental result it has been observed that the angular orientation of baffles and the Reynolds number effects the heat transfer rate and pressure drop in the shell and tube heat exchanger. The heat transfer rate increases up to 30° angular orientation of the baffles and after that there is a drop in heat transfer rate at   = 45°.

# 3.        MATHEMATICAL EQUATIONS

The Nusselt number are calculated from experimental data in turbulent flow region. Equations used for calculation of parameters are listed below.The mass flow rate of water is calculated by,

$\dot{m} = \rho\, A_c V_w$

Where $\rho$ is the density of water, $A_c$ is the cross sectional area, $V_w$ is the velocity of water Heat Transfer Calculation,

$$Q = m_h \times cp_h \times (T_{hi} - T_{ho})$$

The average heat transfer coefficient is calculated as

$$Q = h \times A_s \times (T_s - T_{bm})$$

The average Nusselt number is calculated as

$$Nu = \frac{h \times d}{k_{water}}$$

The Reynolds number is obtained as

$$Re = \frac{\rho v D}{\mu}$$

where $\mu$ is dynamic viscosity of fluid. Prandtl number is given as

$$p_r = \frac{\mu c_p}{k}$$

Equation used in Bell-Delaware Analysis, Shell-Side Reynolds number, $Re_s$

$Re_s = \frac{d_o G_s}{\mu_s}$

The maximum shell-side cross flow mass velocity, $G_s$

$G_s = \frac{\dot{m}}{s_m}$

The ideal tube bank-based coefficient $h_i$ is calculated from,

$$h_i = J_i (cp)s \left(\frac{ms}{As}\right) \left(\frac{ks}{(cp)s\mu s}\right)^{\frac{2}{3}} \left(\frac{\mu s}{\mu s, w}\right)^{0.14}$$

heat transfer coefficient $h_s$ is expressed as,

$h_s = h_i (J_c \times J_i \times J_b \times J_s \times J_r)$

pressure drop in the interior cross flow section,

$\Delta pc = \Delta pbi(Nb-1)RlRb$

pressure drop in an equivalent ideal tube bank in one baffle compartment of central baffle spacing,

$$\Delta pbi = 4fi\frac{Gs^2}{2\rho s}\left(\frac{\mu s,w}{\mu s}\right)^{0.14}Ntcc$$

The pressure drop in the two end zones $\Delta p_e$

$$\Delta pe = \Delta pbi\left(1 + \frac{Ntcw}{Ntcc}\right)RbRs$$

the total shell-side pressure drop ^ps, excluding nozzles, is

$\Delta ps = \Delta pc + \Delta pw + \Delta pe$

# 4. EXPERIMENTAL SETUP

Experimental setup consists of Storage tank. Inside of tank heater coil & pump is mounted so that hot water is pumped and passes through Shell. Hot water temperature is measured with the help of J-type thermocouple. Water is heated until $75^0C$. Heater input is control by Dimmerstat and set at value such that constant supply of water at $75^0C$ is obtained. Thermostat is used which shut off power to heater as $75^0C$ temperature of water exceeds. Flow control valve (Regulator Valve & Ball valve) are used to maintain the measured of quantity flow through the test section. Orifice meter

along with U –tube manometer are used to measure the mass flow rate of Fluid.5 J-type Thermocouple are used to measure inlet and outlet temperature of shell and tube fluid and to measure the surface temperature. Outer surface of test tube is well insulated with asbestos insulation to reduce convective heat loss to surrounding. Connecting pipe of 38mm diameter are used, inside of pipe orifice plate is mounted having diameter of 15mm with the help of flange arrangement. Stainless steel of SS304 material is Used for Shell having outer diameter of 160mm, inner diameter of 152mm and 1000mm length of test section is used. Tube is made up of Copper material having outer diameter 20mm, inner diameter 16mm and length of 1000mm is used.19 tubes are inserted in shell during this triangular pitch of 30mm is maintained.Baffles are made up of SS304 material having thickness of 3mm such 10 baffle are mounted at distance of 86mm each i.e. baffle spacing of 86mm is maintained.



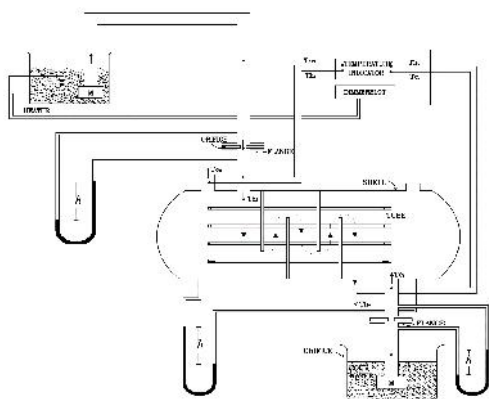**Figure.1 Actual Photograph of Shell and tube along with baffle arrangement.**



**Figure.2: 2D Sketch of Experimental Setup**

# 5. RESULT & DISCUSSION
## 5.1 Validation of Experimental Setup.
In the beginning, results of the present single pass counter flow Shell and tube heat exchanger with $0^0$ orientation of baffles are validated with those obtained from the standard empirical correlation of Dittus-Boelter as given below;

Nusselt number correlation

Empirical correlation of Dittus-Boelter;
$$Nu = 0.023Re^{0.8}Pr^{0.4}$$
$$Nu = 0.023 \times (26330)^{0.8} \times 5.39^{0.4}$$

| Baffle Inclination | | Heat transfer Coefficient W/(m^2 k) | Nu | Shell side Pr.drop (Pa) |
|---|---|---|---|---|
| O Degree | Result of Experimentation | 717.1166 | 164.5 | 4680.87 |
| | Result Of CFD Analysis | 627.44 | 143.9 | 4956.2 |
| | Result of Bell Delaware Calculation | 605.38 | 38.9 | 4212.7 |

**Table1: Comparitive Result of Experimentation,CFDand Bell-Delaware analysis for 0 degree orientation.**

$$Nu = 155.1400$$

% Nu increase is calculated by,

$$\%Nu_{increase} = \frac{Nu_{by\ Experimentation} - Nu_{By\ D-B}}{Nu_{by\ Experimentation}} \times 100$$

$$\%Nu_{increase} = \frac{164.55 - 155.1400}{164.55} \times 100$$

$$Nu_{increase} = 5.72\%$$

It is found that Nusselt numbers obtain from present experimental setup having $0^0$ degree orientation of baffles agree well with those achieved from Dittus-Boelter correlation within ±5.72 %. In this way Experimental set up is first validate with standard Empirical correlation of Dittus-Boelter.It is found that Nusselt number obtain from present experimental setup having $0^0$ degree of baffle orientation agree well with those achieved from CFD analysis within ±12.50 % and with Bell-Delaware analysis is within

±15.58 % , whereas Nusselt number obtain from CFD Result and from Bell-Delaware analysis is within ± 3.5146%. Pressure drop obtain from Experimentation and CFD analysis for $0^0$ degree of baffle orientation is well within ± 5.55% and with Bell-Delaware analysis is within ± 9.99%, whereas Pressure drop obtain from CFD analysis and from Bell-Delaware analysis is within ± 14.99%.It is found that Nusselt number obtain from CFD analysis having $15^0$ degree of baffle orientation agree well with those achieved from Bell -Delaware analysis within ±12% . Shell side pressure drop obtain from CFD analysis having $15^0$ baffle orientation agree well with those achieved from Bell-Delaware analysis is within ± 15.01%.Whereas due to increase in Baffle orientation from $0^0$ to $15^0$Heat transfer coefficient is increase by 10.6167%, Nusselt number is increase by 10.6167% and Shell side Pressure drop is decrease by 5% in case of CFD analysis. In case Bell –Delaware analysis due to change in Baffle angle from $0^0$ to $15^0$ degree heat transfer coefficient is increase by 2% ,Nusselt number is increase by 1.99% and Shell side Pressure Drop is decrease by 5.02%.

## CONCUSION

In the present work Experimentation along with CFD analysis is carried on single pass, counter flow shell and tube heat exchanger containing Baffles at $0^0$.The results are presented in the form of Nusselt number, heat transfer rate and pressure drop. The overall conclusions are as follows,

The experimental setup is validate with Dittus-Boelter correlation. The results are in good agreement within 5.72% for Nusselt number. It is found that Nusselt number obtain from present experimental setup having $0^0$ degree of baffle orientation agree well with those achieved from CFD analysis within ±12.50 % and with Bell-Delaware analysis is within ±15.58 % , whereas Nusselt number obtain from CFD Result and from Bell-Delaware analysis is within ±

3.5146%. Pressure drop obtain from Experimentation and CFD analysis for $0^0$ degree of baffle orientation is well within ± 5.55% and with Bell-Delaware analysis is within ± 9.99%, whereas Pressure drop obtain from CFD analysis and from Bell-Delaware analysis is within ± 14.99%.Due to change in baffle inclination angle more turbulence will be created across the shell side, because of this heat transfer coefficient is increases which results in increase of Nusselt number and hence the heat transfer rate will increase.

Due to increase in Baffle orientation from $0^0$ to $15^0$Heat transfer coefficient is increase by 10.6167%, Nusselt number is increase by 10.6167% and Shell side Pressure drop is decrease by 5% in case of CFD analysis. In case Bell –Delaware analysis due to change in Baffle angle from $0^0$ to $15^0$ degree heat transfer coefficient is increase by 2% ,Nusselt number is increase by 1.99% and Shell side Pressure Drop is decrease by 5.02%.For this counter flow shell and tube heat exchanger with 10 baffles and baffle inclination of $15^0$ gives slightly better result which gives higher heat transfer rate and low pumping cost as compare to $0^0$ degree of Baffle inclination.

| Baffle Inclination | | Heat transfer Coefficient W/(m^2 k) | Nu | Shell side Pr.drop (Pa) |
|---|---|---|---|---|
| 0 Degree | Result Of CFD Analysis | 627.44 | 143.9 | 4956.2 |
| | Result of Bell Delaware Calculation | 605.38 | 138.91 | 4212.79 |
| 15 Degree | Result Of CFD Analysis | 701.9656 | 161.07 | 4708.2 |
| | Result of Bell Delaware Calculation | 617.73 | 141.74 | 4001.4 |

**Table 2: Comparative Result of CFD and Bell-Delaware analysis for 15 Degree orientation**

# REFERENCES

[1]. Nishank Kumar Pandey[1], Dr.Rohit Rajvaidya[2], "Computational fluid dynamics analysis of single pass shell & tube heat exchanger with different orientation of baffles and without baffles", International journal for research in applied science and engineering technology (ijraset) August 2014 Vol. 2 Issue VIII, ISSN: 2321-9653.

[2]. Neeraj kumar[1], Dr. Pradeep kumar Jhinge[2], "Effect of segmental baffles at differentorientation on the performances of singlepass shell and tube heat exchanger", International Journal of Engineering Trends and Technology (IJETT) – Volume 15 Number 9 – Sep 2014.

[3]. Ajithkumar M.S.1, Ganesha T.2, M. C. Math[3], "CFD analysis to study the effects of inclined baffles on fluid flow in a shell and tube heat exchanger", International Journal of Research in Advent Technology, Vol.2, No.7, July 2014 E-ISSN: 2321-9637.

[4]. Swarup Deshpande[1], Shreeniket A Hinge[2], "Design and performance study of shell and tubeheat exchanger with single segmental bafflehaving perpendicular & parallel-cut orientation", International Journal of Engineering Research & Technology (IJERT), Vol. 3Issue 11, November-2014, ISSN: 2278-0181.

[5]. Arjun K.S. and Gopu K.B., "Design of Shell and Tube Heat Exchanger Using Computational Fluid Dynamics Tools"Research Journal of Engineering Sciences, Vol. 3(7), 8-16, July (2014),ISSN2278 – 9472.

[6]. Ankit Uppal[1], Dr. Vinod Kumar[2], Dr.Chanpreet Singh[3], "CFD analysis of heat transfer enhancement in a heat exchanger using various baffle arrangements",IJRMET,Vol. 4, Issue 2, May - October 2014 ISSN : 2249-5762.

[7]. Amarjit Singh[1] and Satbir S. Sehgal[2], "Thermohydraulic analysis of shell-and-tube heat exchanger with segmental baffles", Hindawi Publishing Corporation ISRN Chemical Engineering, Volume 2013, Article ID 548676.

[8]. P.S.Gowthaman[1],S.Sathish[2], "Analysis of Segmental and Helical baffle in shell and tube heat exchanger", International Journal of Current Engineering and Technology,February 2014 E-ISSN – 4106,P-ISSN 2347- 5161.

[9]. Vindhya Vasiny Prasad Dubey et.al. "Steady state thermal analysis of shell and tube type Heat exchanger to demonstrate the heat transfer capabilities of various thermal material using Ansys",Global journal of researches in engineering ,Volume 14 ,2014,ISSN2249-4596.

[10]. Sandeep K.Patel[1],Prof.Alkesh M.Mavani[2], "Shell & Tube heat exchanger thermal design with optimization of mass flow rate and Baffle spacing",International Journal of Advanced Engineering Research and studies,E-ISSN2249-8974.