iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 2 **Issue:** I **Month of publication:** January 2014

DOI:

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

Experimental Investigation of Shell and Tube Heat Exchanger Using Bell Delaware Method

K Anand[1], V K Pravin[2], P H Veena[3,]

[1]Thermal Power Engg., Dept. of Mechanical Engg. PDACE Gulbarga
[2]Thermal Power Engg, VTU Regional Centre Gulbarga.
Dept of mathematics,Smt V G womens college, Gulbarga

Abstract:* A heat exchanger is a device that is used to transfer thermal energy 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. Shell and tube heat exchangers in their various construction modifications are the most widespread and commonly used basic heat exchanger configuration in the process industries. In the present study, a water to water STHE wherein, hot water flows inside the tubes and cold water inside the shell is used to study and analyze the heat transfer coefficient and pressure drops for different mass flow rates and inlet and outlet temperatures, using Bell Delaware method. This method takes in to account heat transfer by bypass and leakage streams, hence minimizing losses and providing more realistic estimates of heat transfer and pressure drops.

***Keywords:* STHE, Heat transfer coefficient, shell &Tube heat exchanger, Pressure Drop, TEMA, Bell Delaware method.**

INTRODUCTION

Heat exchanger is a device of finite volume in which heat is exchanged between two media, one being cold and the other being hot.There are different types of heat exchangers; but the type widely used in industrial application is the shell and tube [1]. As its name implies, Shell-and-tube heat exchangers consist of a bundle of parallel tubes inside the shell that provides the heat-transfer surface separating the two fluid streams. The tube side fluid passes axially through the inside of the tubes; the shell-side fluid passes over the outside of the tubes. Baffles external and perpendicular to the tubes direct the flow across the tubes and provide tube support. Tube sheets seal the ends of the tubes, ensuring separation of the two streams. The process fluid is usually placed inside the tubes for ease of cleaning or to take advantage of the higher pressure capability inside the tubes [2].

The major components of this exchanger are tubes (tube bundles), shell, front end head, rear end head, baffles and tube sheets. The standard of the Tubular Exchanger Manufacturers Association (TEMA) describe various components in detail of shell and tube heat exchanger (STHE) [3].

In designing shell and tube heat exchangers, to calculate the heat exchange area, different methods were proposed[4][5]. Methods proposed for shell side design are as follows:

1) Kern Method
2) Donohue Method
3) Tinker Method
4) Devore’s Method
5) Mueller Method
6) Bell’s Method

Vol. 2 Issue I, January 2014
ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

7) Bell Delaware Method

8) Wills and Johnson Method

9) Taborek Method

And the methods proposed for tube side design are as follows:

1) Petukhov and Popov's Correlation

2) Mc Adam's Correlation

3) Petukhov and Kirrillov Correlation

4) Gnielinski Correlation

Among the above mentioned shell side design methods, Bell-Delaware is the most complete shell and tube heat exchanger design method. It is based on mechanical shell side details and presents more realistic and accurate results for the shell side heat transfer coefficient and pressure drop.

Bell developed a semi analytical method based on work done in the co-operative research program on shell and tube heat exchangers at the University of Delaware. His method accounts for major bypass and leakage streams. Bell Delaware method provides a manual check of shell side heat transfer coefficient and pressure drop values of a shell and tube heat exchanger. It gives more realistic estimates compared to Kern method, because leaks and bypass flows are considered [6][7].

BELL DELAWARE METHOD

In the Bell Delaware method, the fluid flow in the shell is divided into a number of individual streams A through F as shown in Fig 1 and 2. [8][9]

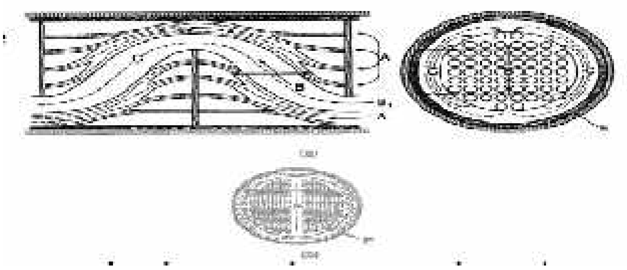


FIG 1

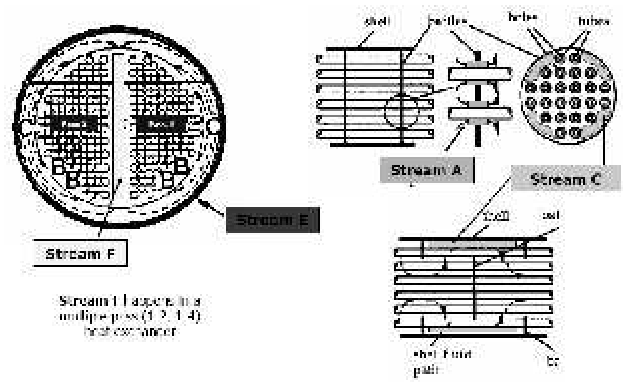


FIG 2

There are five different shell side flow streams in a baffled heat exchanger:

- Stream A as shown in FIG 1 and 2 is the leakage stream in the orifice formed by the clearance between the baffle tube hole and the tube wall. The tube hole leakage stream represents the flow from one baffle compartment to the next that passes through the annular openings between the oversized holes for the tubes in the baffles and the outside of the tubes. The flow is driven by the pressure drop from one baffle compartment to the next. The leakage occurs through the diametral clearance between the diameter of baffle hole minus the outside diameter of the tube. If the tubes are expande in to the baffles, then the diametral clearance is zero. If the diametral clearance becomes zero, then this bypass stream is completely eliminated.

- Stream B in FIG 1 is the main effective crossflow stream, which can be related to flow across ideal tube banks.This is the preferred flow in the baffled shell and tube heat exchanger.

- Stream C as shown in FIG 1 and 2 is the tube bundle bypass stream in the gap between the outside of the tube bundle and inner shell wall. The diametral clearance for this flow to pass through is equal to the shell internal diameter minus the outer tube limit diameter of the tube bundle. The bundle bypass stream is reduced by minimizing the diametral clearance and by installing pairs of sealing strips around the perimeter of tube bundle to block this flow path and thereby force the fluid back in to the tube bundle.

Vol. 2 Issue I, January 2014
ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

- Stream E in FIG 1 is the leakage stream between the outer edge of the baffle and inner shell wall. The diametral clearance is equal to the shell internal diameter minus the diameter of the baffle and is minimized by decreasing the construction clearance between the shell and the baffle to its feasible minimum.

- Stream F shown in FIG 2 is the bypass stream in flow channel partitions due to omissions of tubes in tube pass partitions. This stream only refers to those openings oriented in the direction of the fluid flow. Pass partition openings oriented normal to the flow path do not cause a bypass. This bypass stream thus only occurs in some multipass tube layouts and they can be eliminated by placement of several dummy tubes in each bypass lane to drive the fluid back in to the tube bundle.

Each of the above streams introduces a correction factor to the heat transfer correlation for ideal cross-flow across a bank of tubes.[10]

$h_o = h_i * J_c * J_L * J_b * J_s * J_r$

Jc- Baffle Cut Correction Factor:

Jc is the correction factor for baffle cut and spacing. This factor takes into account the heat transfer in the window and calculates the overall average heat transfer coefficient for the entire heat exchanger.

It depends on the shell diameter and the baffle cut distance from the baffle tip to the shell inside diameter.

- For a large baffle cut, this value may decrease to a value of 0.53

- It is equal to 1.0 for a heat exchanger with no tubes in the window

- It may increase to a value as high as 1.15 for small windows with a high window velocity.

Jl – Baffle Leakage Correction Factor

Jl is the correction factor for baffle leakage effects including tube -to- baffle and shell-to-baffle leakage (A- and E-streams in FIG 1). If the baffles are put too close together, then the fraction of the flow in the leakage streams increases compared with the cross flow.

JI is a function of the:

- ratio of total leakage area per baffle to the cross flow area between adjacent baffles

- ratio of the shell-to-baffle leakage area to the tube-to-baffle leakage area.

A typical value of Jl is in the range of 0.7 and 0.8.

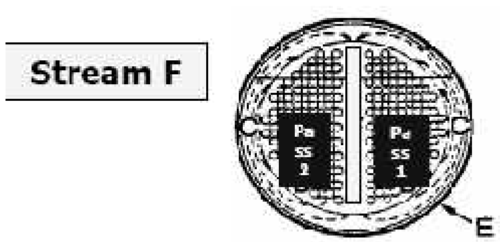
Jb – Bundle Bypass Correction Factor

Jb is the correction factor for bundle bypassing effects due to the clearance between the outermost tubes and the shell and pass dividers (C- and F-streams in FIG 1).

- For relatively small clearance between the outermost tubes and the shell for fixed tube sheet construction, Jb = 0.90.

- For a pull-through floating head, larger clearance is required, Jb = 0.7.

- The sealing strips (see figure8.14) can increase the value of Jb



INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

FIG 3

Js – Unequal baffle Spacing Correction Factor:

The unequal baffle spacing correction factor accounts for the adverse effect of an inlet and outlet baffle spacing Because of the nozzle spacing at the inlet and outlet and the changes in local velocities, the average heat transfer coefficient on the shell side will change.

The Js value will usually be between 0.85 and 1.00.

Jr – Laminar Flow Correction Factor:

In laminar flows, heat transfer is reduced by the adverse temperature gradient formed in the boundary layer as the flow thermally develops along the flow channel. Jr accounts for this effect. Jr applies if the shell-side Reynolds number, Res, is less than 100.

- If Res < 20, it is fully effective.
- This factor is equal to 1.00 if Res> 100.

Colburn j-factor

Colburn-j factor is used in heat transfer in general and free and forced convection calculations in particular.

It is equivalent to (St.Pr2/3) where St is Stanton number .

Colburn j-factor is a function of:

- Shell side Reynolds number based on the outside tube diameter and on the minimum cross section flow area at the shell diameter
- Tube layout
- Pitch size

In the present study, efforts have been made to study in detail Bell Delaware method and apply this method in calculating heat transfer coeffient, Reynold's number, pressure drops, overall heat transfer coefficient etc for a heat exchanger which has been designed and fabricated for our experimental investigations. The heat transfer fluid used is water. Hot water flows inside the tubes and cold water flows inside shell. At the end of the calculations, it is found that heat transfer coefficient (both shell side and overall) calculated using Bell Delaware method is much more than the one calculated using other methods, since Bell Delaware method takes in to account, heat transfer even by bypass and leakage streams.

FLUID PROPERTIES CONSIDERED

Shell side fluid properties:

ρ_s = 1000 kg/m^3

μ_s = 0.00088 N-s/ m^2

C_{ps} = 4.187kJ/kg'K

K_s = 0.00098 kJ/s-m'K.

Tube side fluid properties:

ρ_t = 1000 kg/m^3

μ_t= 0.00086 N-s/ m^2

C_{pt} = 4.187kJ/kg'K

K_t = 0.00098 kJ/s-m'K.

HEAT EXCHANGER SPECIFICATIONS

In the present study, a stainless steel shell and tube heat exchanger is used to study the various parameters of the heat exchanger such as heat transfer coefficient, Reynolds's number, pressure drop, Overall heat transfer coefficient etc using water as a heat transfer medium. The design method used in calculating the parameters is Bell Delaware Method.[11][12][13]

Specifications of the heat exchanger are as follows:

Shell diameter (Ds)	0.2m
Tube inside diameter (Di)	0.016m
Tube outside diameter (Do)	0.01924m
Pitch (Pt)	0.03m
Length of shell (Ls)	0.8m
Length of tube (Lt)	0.825m
Length of baffle (Lb)	0.2m
Number of baffles (Nb)	4
Number of tubes (Nt)	18
Number of shell passes (ns)	1
Number of tube passes (nt)	2
Clearance (C)	0.01076m

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

Bundle to shell diametrical clearance (Δb)	0.028m
Shell to baffle diametrical clearance (Δsb)	0.0254m
Tube to baffle diametrical clearance (Δtb)	0.0005m

Nomenclatures:

S_m = Area of the shell side cross flow section (m^2).
P_t = Tube pitch (m).
D_o = Tube outside diameter (m).
D_i = Tube inside diameter (m).
D_s = Shell inside diameter (m).
L_b = Baffle spacing (m)
L_s= Length of shell (m).
L_t = Length of tube (m).
t_b = Tube thickness (m).
G_s= Shell side mass velocity (kg/ m^2-s).
G_t = Tube side mass velocity (kg/ m^2-s).
U_s= Shell side linear velocity (m/s).
U_t = Tube side linear velocity (m/s).
m_s= Mass flow rate of the fluid on shell side (kg/s).
m_t= Mass flow rate of the fluid on tube side (kg/s).
ρ_s = Shell side fluid density (kg/m^3).
ρ_t = Tube side fluid density (kg/m^3).
R_{es}= Shell side Reynolds number.
R_{et} = Tube side Reynolds number.
P_{rs}= Shell side Prandtl number.
P_{rt} = Tube side Prandtl number

μ_s = Shell side fluid Viscosity (N-s/ m^2).
μ_t = Tube side fluid viscosity (N-s/ m^2).
μ_w = Viscosity a wall temperature (N-s/ m^2).
C_{ps} = Shell side fluid heat capacity (kJ/kg'K).
C_{pt} = Tube side fluid heat capacity (kJ/kg'K).
K_s = Shell side fluid thermal conductivity (kJ/s-m'K).
K_t = Tube side fluid thermal conductivity (kJ/s-m'K).
h_o= Shell side heat transfer coefficient (W/ m^2'K).
h_i = Shell side ideal heat transfer coefficient (W/ m^2'K).
N_b= Number of baffles.
N_t = Number of tubes.
f = Friction factor.
ΔP_s= Shell side pressure drop (Pa).
n_p = Number of tube passes.
C = Clearance between tubes.
Δ_b = Bundle to shell diametrical clearance.
Δ_{sb}=Shell to baffle diametrical clearance.
Δ_{tb}=Tube to bundle diametrical clearance.
N_{ss}/N_c=Sealing strips per cross flow row.
$D_{otl}=D_s - \Delta_b$
$\Theta = \{D_s-(2*L_c)\}/ D_{otl}$
F_c=Fraction of total number of tubes in a crossflow section.
J_c=Correction factor for baffle cut and spacing.
S_{sb}=Shell to baffle leakage area (m^2).

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

S_{tb}=Tube to baffle leakage area (m^2).
F_{bp} = Fraction of the crossflow area available for bypass flow.
S_w= Window flow area (m^2).
N_c = Number of tube rows crossed in one crossflow section.
N_{cw}=Effective number crossflow rows in window zone.
ΔP_c=Ideal cross flow pressure drop through one baffle space (Pa).
ΔP_w= Window zone pressure drop (Pa).
R_L= correction factor for baffle leakage effect on pressure drop
R_b= correction factor on pressure drop for bypass flow.

Calculation Of Shell Side Heat Transfer Coefficient Using Bell Delaware Method:

Experimental study is done on the shell and tube water / water heat exchanger and various parameters are calculated for different mass flow rates and at varying inlet and outlet temperatures. Calculations shown below are made for mass flow rate of .0267kg/s.

STEP 1: Calculate the shell side area at or near the centre line for one cross flow section S_m,

$$S_m = L_b*[(D_s - D_{otl}) + \{(D_{otl} - D_o)*(P_t - D_o)\}/P_t]$$

$$S_m = .2*[(.2 - .172) + \{(.172 - .01924)*(.03 - .01924)\}/.03]$$

$$S_m = 0.017 \text{ m}^2$$

STEP 2: Calculate shell side mass velocity G_s and linear velocity U_s.

$$G_s = m_s / S_m$$

$$G_s = .020 / .017$$

$$G_s = 1.1764 \text{ kg/ m}^2\text{-s}$$

$$U_s = G_s / \rho_s$$

$$U_s = 1.1764 / 1000$$

$$U_s = .0011764 \text{ m/s}$$

STEP 3: Calculate shell side Reynolds number R_{es}.

$$R_{es} = (G_s * D_o) / \mu_s$$

$$R_{es} = (1.1764 * .01924) / .00088$$

$$R_{es} = 25.72$$

STEP 4: Calculate shell side Prandtl number P_{rs}.

$$P_{rs} = (C_{ps} * \mu_s) / K_s$$

$$P_{rs} = (4.187 * .00088) / .00098$$

$$P_{rs} = 3.7597$$

STEP 5: Calculate the colburn j factor j_i.

$$j_i = a_1*[\{1.33 / (P_t / D_o)\} \wedge a]*(R_{es} \wedge a_2)$$

$$j_i = 1.36*[\{1.33 / (.03 / .01924)\} \wedge .826]*(25.72 \wedge -.657)$$

$$j_i = 0.1412$$

STEP 6: Calculate the value of the coefficient a.

$$a = a_3 / [1 + \{0.14*(Res \wedge a4)\}]$$

$$a = 1.450 / [1 + \{0.14*(25.72 \wedge .519)\}]$$

$$a = 0.826$$

Where, a_1=1.360, a_2 = -.657, a_3 = 1.450 and a_4 = .519 for R_{es} < 100, are the coefficients to be taken from the table given in Kakac book for the obtained value of Reynolds number and pitch and layout.

STEP 7: Calculate the ideal heat transfer coefficient h_i.

$$h_i = j_i * C_{ps} * (m_s / S_m) * \{(1/P_{rs}) \wedge (2/3)\} * \{(\mu_s / \mu_w) \wedge 0.14\}$$

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

h_i = .1412 *4.187*(.020/ .017)*{(1/3.7597)^(2/3)}*{(.00088 / .00088)^0.14}

$h_i = 0.287$ W/ m²'K

STEP 8: Calculate the fraction of total tubes in crossflow F_c.

Consider, $\Theta = \{D_s-(2*L_c)\}/ D_{otl}$

$\Theta = \{.2 - (2*.05\}/ .172$

$\Theta = 0.581$ rad

$$F_c =(1 /\pi)*[\pi +(2*\Theta) *\sin\{\cos^{-1}(\Theta)\}-\{2* \cos^{-1}(\Theta)\}]$$

$$F_c=(1 /\pi)*[\pi +(2*.581) *\sin\{\cos^{-1}(.581)\}-\{2*\cos^{-1}(.581)\}]$$

$F_c =0.695$

Here L_c = 0.25* .2 = 0.05 for 25% baffle cut.

STEP 9: Calculate the correction factor for baffle cut and spacing J_c.

The value of J_c can be obtained from the *fig 2.33 of wolverine tube heat transfer data book Page No. 107* for the corresponding value of F_c.

$J_c = 1.05$

STEP 10: Calculate shell to baffle leakage area for one baffle S_{sb}.

$$S_{sb} = D_s*(\Delta sb / 2)*[\pi - \cos^{-1}(\Theta)]$$

S_{sb} = .2*(.0254 / 2)*[π - cos⁻¹(.581)]

$S_{sb} = 0.00556$ m²

STEP 11: Calculate tube to baffle leakage area for one baffle S_{tb}.

$$S_{tb} = (\pi*D_o)*(\Delta tb / 2)*N_t*[(1 +F_c)/ 2]$$

$S_{tb} = (\pi*.01924)*(.0005 / 2)*18*[(1 +.695)/ 2]$

$S_{tb} = 0.0002305$ m²

STEP 12: Calculate

$(S_{sb} + S_{tb}) / S_m$

(.00556 + 0.0002305) / .017

$(S_{sb} + S_{tb}) / S_m = 0.349$

$S_{sb} / (S_{sb} + S_{tb})$

0.00556 / (0.00556+0.0002305)

$S_{sb} / (S_{sb} + S_{tb}) = 0.9601$

STEP 13: Calculate the correction factor for baffle leakage effects J_L:The value of J_L can be obtained from the *fig 2.34 of wolverine tube heat transfer data book Page No. 108* for the corresponding value obtained in step 12 above.

$J_L = 0.89$

STEP 14: Calculate the fraction of the crossflow area available for bypass flow F_{bp}.

$$F_{bp} = (L_b / S_m)*(Ds - D_{otl})$$

F_{bp} = (.2 / .017)*(.2- .172)

$F_{bp} = 0.3383$

STEP 15: Calculate the correction factor for bundle bypassing effects due to the clearance between the outermost tubes and the shell and pass dividers J_b.

The value of J_b can be obtained from the *fig 2.35 of wolverine tube heat transfer data book Page No. 109* for the corresponding value of F_{bp}.

$J_b = 0.96$

STEP 16: The correction factors J_s and J_r are equal to 1 for $R_{es}>=100$. But for $R_{es}<100$, J_r can be obtained from *Fig. 2.37 of wolverine tube heat transfer data book Page No. 111.*

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

$J_r = 0.88$

STEP 17: Calculate the shell side heat transfer coefficient for the exchanger h_o.

$h_o = h_i * J_c * J_L * J_b * J_s * J_r$

$h_o = 0.287 * 1.05 * 0.89 * 0.96 * 0.88$

$h_o = 0.258$ W/ m²'K

Calculation Of Shell Side Pressure Drop Using Bell Delaware Method:

STEP 1: Calculate the number of tube rows crossed in one crossflow section N_c.

$N_c = (D_s / P_{tp}) * [1 – \{(2 * L_c)/D_s\}]$

$N_c = (.2 / .02598) * [1 – \{(2 * .05)/.2\}]$

$N_c = 3.85 = 4$

Where, $P_{tp} = 0.866 * P_t$

$P_{tp} = 0.866 * .03$

$P_{tp} = 0.02598$

STEP 2: Calculate the ideal cross flow pressure drop through one baffle space ΔP_b.

$\Delta P_b = [(2 * f_s * m_s^2 * N_c) / (\rho_s * s_m^2)] * [(\mu_s / \mu_w)$^0.14]

$\Delta P_b = [(2 * .000125 * .020^2 * 4) / (1000 * .017^2)] * [(.00088/ .00088)$ ^0.14]

$\Delta P_b = 1.38 * 10^{-6}$ Pa

STEP 3: Calculate the window flow area S_w.

$S_w = (D_s^2/4) * [\cos^{-1}\Theta - \{\Theta * \sqrt{(1-\Theta^2)}\}] - [(N_t/8) * (1-F_c) * \pi * D_o^2]$

$S_w = (.2^2/4) * [\cos^{-1}.581 - \{.581 * \sqrt{(1-.581^2)}\}] - [(18/8) * (1-.695) * \pi * .01924^2]$

$S_w = 0.004$ m²

STEP 4: Calculate the number of effective cross flow rows in window zone N_{cw}.

$N_{cw} = (0.8 * L_c) / P_{tp}$

$N_{cw} = (0.8 * .05) / .02598$

$N_{cw} = 1.54$

STEP 5: Calculate the window zone pressure drop ΔP_w.

$\Delta P_w = [\{(26\ \mu_s\ m_s) / (\rho_s \sqrt{(S_m\ S_w)}\} * \{(N_{cw} / (P_t - D_o)) + (L_b/D_w^2)\}] + [m_s^2 / (2\ \rho_s\ S_m\ S_w)]$

$\Delta P_w = [\{(26 * .00088 * .020) / (1000 * \sqrt{(.017 * .004)}\} * \{(1.54 / (.03 - .01924)) + (.2/.022^2)\}] + [.020^2 / (2 * 1000 * .017 * .004)]$

$\Delta P_w = 0.037$ Pa

STEP 6: Estimate the correction factor on pressure drop for bypass flow R_b.

The value of R_b can be obtained from the fig 2.39 of wolverine tube heat transfer data book for the corresponding value of F_{bp}.

$R_b = 0.78$

STEP 7: Estimate the correction factor for baffle leakage effect on pressure drop R_L

Vol. 2 Issue I, January 2014
ISSN: 2321-9653

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

The value of R_L can be obtained from the fig 2.38 of wolverine tube heat transfer data book for the corresponding value obtained in step 12 above.

$R_L = 0.78$

STEP 8: Calculate the total pressure drop across shell ΔP_s

$\Delta P_S = [\{(N_b - 1)*\Delta P_b*R_b\} + (N_b*\Delta P_w)]*R_L + [2*\Delta P_b*R_b*\{1+(N_{cw}/N_c)\}]$

$\Delta P_S = [\{(4-1)* 1.38*10^{-6}\_*.78\} + (4*0.037)]*.78 + [2*1.38*10^{-6} *.78*\{1+(1.54/4\}]$

$\Delta P_S = 0.115$ Pa

Calculation Of Tube Side Heat Transfer Coefficient:

STEP 1:Calculate the tube side cross flow section area A_t.

$A_t = \{(\pi* D_i^2) / 4\}*(N_t / 2)$

$A_t = \{(\pi* .016^2) / 4\}*(18/ 2)$

$A_t = .0018\ m^2$

STEP 2: Calculate the tube side mass velocity G_t and linear velocity U_t.

$G_t = m_t / A_t$

$G_t = .0158/ .0018$

$G_t = 8.78\ kg/ m^2\text{-s}$

$U_t = G_t / \rho_t$

$U_t = 8.78/ 1000$

$U_t = .00878$ m/s

STEP 3: Calculate the tube side Reynolds number R_{et}.

$R_{et} = (G_t* D_i) / \mu_t$

$R_{et} = (8.78* .016) / .00086$

	Shell side (Cold Water)	R1	R2	R3	R4	R5
1	Mass flow rate (Kg/sec)	0.02	0.0257	0.0299	0.035	0.0397
2	Temperature at inlet (^{o}c)	29.5	29.7	30.1	30.6	31.2
3	Temperature at outlet (^{o}c)	29.4	32.2	33	33.5	33.9
4	Reynolds number	25.65	32.96	38.346	44.887	50.915
5	Prandtl number	3.76	3.76	3.76	3.76	3.76
6	Heat transfer coefficient (W/ m^2'K).	0.26	0.286	0.302	0.32	0.336
7	Pressure drop (Pa)	0.115	0.169	0.215	0.278	0.343
8	Over all heat transfer coefficient	0.215	0.236	0.262	0.285	0.328

$R_{et} = 163.35$

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

STEP 4: Calculate the tube side Prandtl number P_{rt}.

$$P_{rt} = (C_{pt}*\mu_t) / K_t$$

P_{rt} = (4.187*.00086) / .00098

P_{rt} = 3.674

STEP 5: Calculate the friction factor f.

$$f = \{(1.58*Ln\ R_{et}) – 3.28\} \wedge (-2)$$

f = {(1.58*Ln 163.35) – 3.28} ^ (-2)

f = 0.0439

STEP 6: Calculate the tube side Nusselt number N_{ut}.

Nusselt number is calculated using Gnielinski Correlation

$$N_{ut} = \{(f /2)*(Ret -1000)* P_{rt}\}/\{1+ (12.7*\sqrt{}\ (f /2)*(P_{rt} \wedge (2/3))-1)\}$$

N_{ut} = {(.0439 /2)*(163.35 -1000)* 3.674}/{1+ (12.7*√ (.0439/2)*(3.674 ^ (2/3))-1)}

N_{ut} = -18.75

STEP 7: Calculate the tube side heat transfer coefficient h_i.

$$h_i = (N_{ut} * K_t) / D_i$$

h_i = (-18.75 * .00098) / .016

h_i = -1.15 W/ m^2’K

Calculation Of Overall Heat Transfer Coefficient:

$$1/Uc = (1/ h_o) + \{(Do/D_i)*(1/h_i)\}+ \{D_o*Ln(D_o/D_i)\}/(2k)$$

1/Uc = (1/ .258) + {(.01924/.016)*(1/-1.15)}+ {.01924*Ln (.01924/.016)}/(2*.00098)

Uc = 0.215 W/ m^2’K

Calculation Of Tube Side Pressure Drop:

$$\Delta P_t = [\{(4* f* L_t* n_p) / D_i\} + (4* n_p)]*[(\rho t* U_t^2) / 2]$$

ΔP_t = [{(4*.0439*.825*2)/.016} + (4*2)]*[(1000*.00878^2) / 2]

ΔP_t = 1.006 Pa

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

Shell side results for five sample readings are shown in the table below:

GRAPHS:

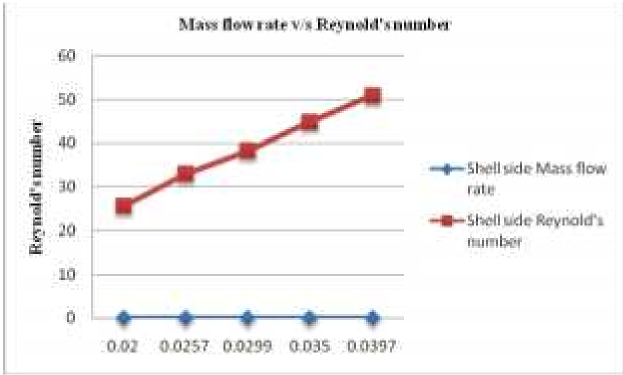


Fig a. Variation of Reynold's number w.r.t Flow rate on the Shell side

Results & Discussion

Tube side results for five sample readings are as below:

	Tube side (Hot Water)	R1	R2	R3	R4	R5
1	Mass flow rate (Kg/sec)	0.0158	0.0198	0.0262	0.0293	0.0365
2	Temperature at inlet (°c)	55.3	55.7	53.4	55.6	55.6
3	Temperature at outlet (°c)	37.1	42.4	44.2	45.2	46.8
4	Reynolds number	163.307	204.65	270.80	302.84	377.26
5	Prandtl number	3.674	3.674	3.674	3.674	3.674
6	Heat transfer coefficient (W/ m^2'K).	-1.288	-1.114	-0.914	-0.838	-0.691
7	Pressure drop (Pa)	1.006	1.433	2.256	2.715	3.928

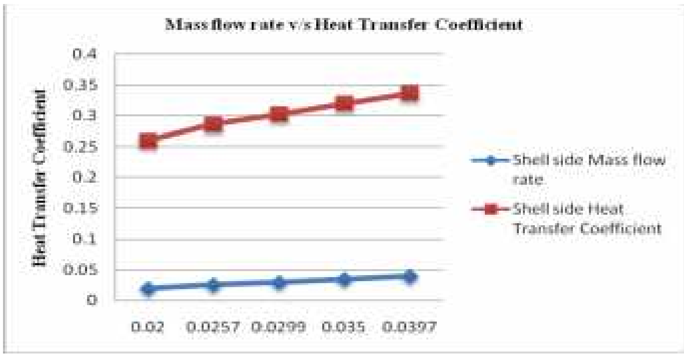


Fig b. Variation of Heat Transfer Coefficient w.r.t Flow rate on the Shell side

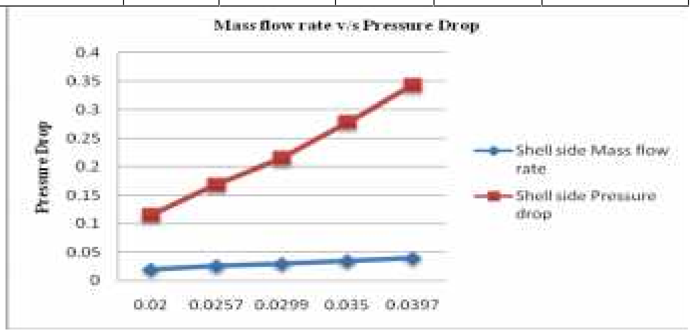


Fig c. Variation of Pressuer drop w.r.t Flow rate on the Shell side

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

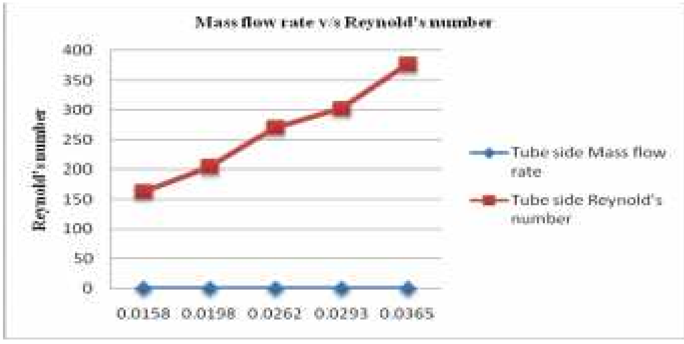


Fig d. Variation of Reynold's number w.r.t Flow rate on the Tube side

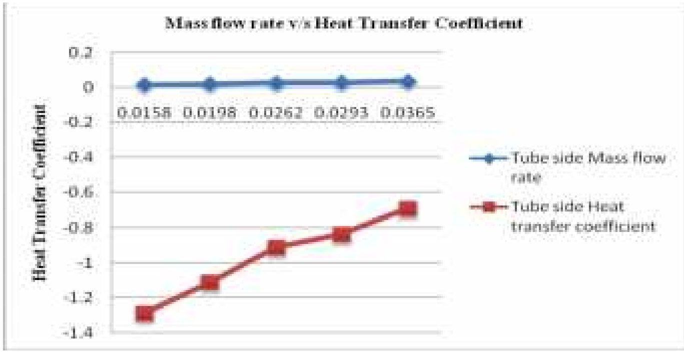


Fig e. Variation of Heat Transfer Coefficient w.r.t Flow rate on the Tube side

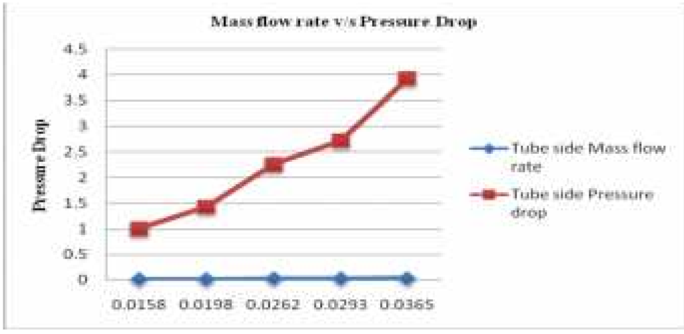


Fig f. Variation of Pressure drop w.r.t Flow rate on the Tube side.

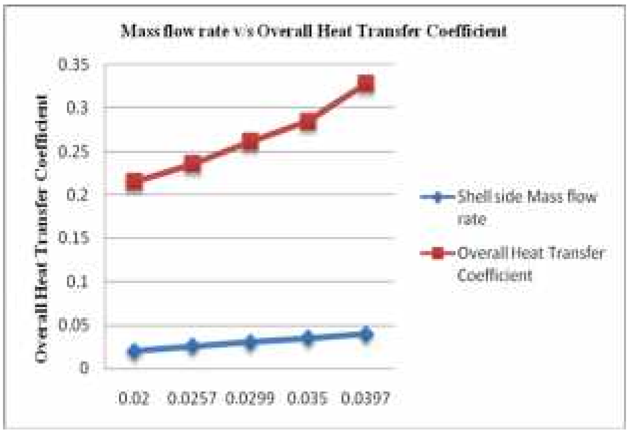


Fig g. Variation of Overall Heat Transfer Coefficient w.r.t Flow rate of the Exchanger.

CONCLUSION:

The shell and tube heat exchanger is analyzed using Bell Delaware method and heat transfer coeffient, Reynold's number, pressure drops, overall heat transfer coefficient etc are calculated for various mass flow rates and the results are shown in the graphs above. It is emphasized that, shell side heat transfer coefficient increases with increasing mass flow rate. Also the shell side pressure increase rapidly with increasing flow rate.

Also it was found that the overall heat transfer coefficient of the shell and tube heat exchanger increases with increasing flow rate. This heat transfer coefficient is much more when calculated using Bell Delaware method than the one calculated using other methods, since Bell Delaware method takes in to account, heat transfer even by bypass and leakage streams.

REFERENCES:

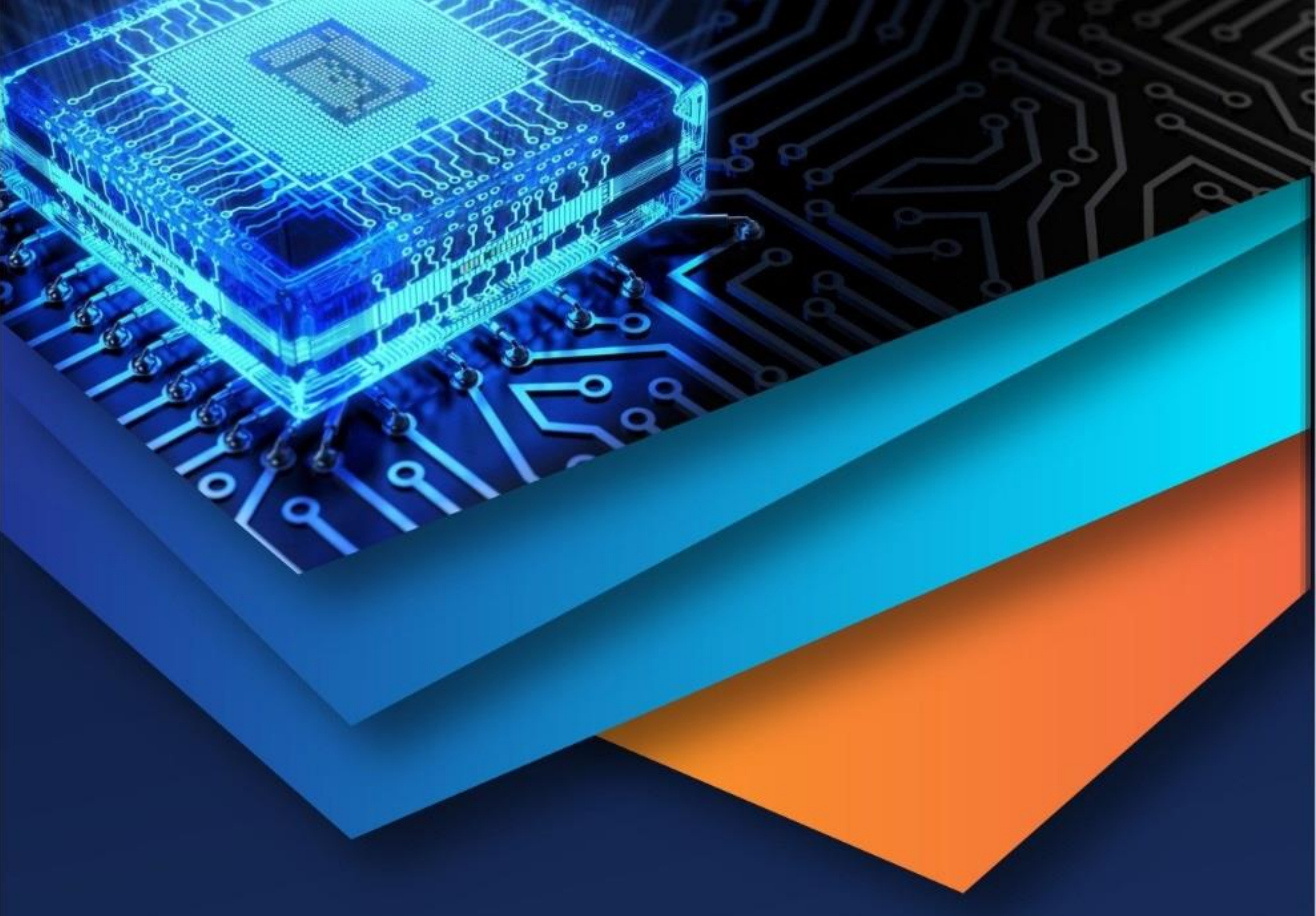
[1]Ebieto, CE and Eke G B, "Performance Analysis of Shell and Tube Heat Exchangers: A case study "Department of Mechanical Engineering, Faculty of Engineering, University of Port Harcourt, Port Harcourt, Nigeria .Journal of Emerging trends in engineering and applied sciences(JETEAS) 3(5):899-903.

[2]The Fundamentals of Heat Exchangers, by Dean A. Bartlett

[3]Tubular Exchanger Manufacturers Association, "Standards of the Tubular Exchanger Manufacturers Association," 7th Ed., TEMA, New York (1988).

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

[4] Mauro A. S. S. Ravagnani[1], Aline P. Silva[1] and Jose A. Caballero[2] "Optimal Shell and Tube Heat Exchangers Design" State University Of Maringa[1,]University Of Alicante[2], Brazil[1], Spain[2].
[5] Sadik kakac, "Heat Exchangers Selection, Rating and Thermal Design", 2002.
[6] Wolverine Tube, INC, Single phase shell side flows and heat transfer.
[7] Wolverine Tube Heat Transfer Data book, Delaware method for shell side rating and shell and tube heat exchangers.
[8] D. Gulley, Gulley & Associates, Tulsa, Oklahoma, More accurate exchanger shell side calculations,
[9] Sandeep K. Patel, Professor Alkesh M. Mavani"Shell & tube heat exchanger thermal designWith optimization of mass flow rate and baffle spacing" International Journal of Advanced engineering Research and Studies IJAERS/Vol .II/Issue I/Oct.-Dec.,2012/130-135
[10] John E Edwards, "Design and Rating Shell & tube heat exchanger"
[11]Bell k. j. delaware method for shell-side design, in: serth r.w., process heat transfer principles and applications, elsevier science & technology books, 2007, pp. 145.
[12]Tinker t. (1951) "shell-side characteristic of shell-and-tube heat exchangers", parts ii, iii, and in:proceedings of general discussion on heat transfer, institute of mechanical engineers and American society of mechanical engineers, london, new york,pp. 89.
[13]Mukherjee R, Effective design Shell and Tube Heat exchangers, Chemical Engg Progress,(1998), 1-8.
[14]Comparative Analysis of Finned Tube and Bared Tube Type Shell and Tube Heat Exchanger ShivKumar Rathore, Ajeet Bergaley, International Journal of Engineering and Innovative Technology (IJEIT)Volume 2, Issue 1, July 2012, ISSN: 2277-3754 ISO 9001:2008 Certified.



doi crossref
10.22214/IJRASET

INDEX COPERNICUS
45.98

ISRA JIF
IMPACT FACTOR:
7.129

SJIFactor Scientific Journal Impact Factor
TOGETHER WE REACH THE GOAL
IMPACT FACTOR:
7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)