International Journal of Science, Technology and Society
2015; 3(5): 254-259
Published online August 27, 2015 (http://www.sciencepublishinggroup.com/j/ijsts)
doi: 10.11648/j.ijsts.20150305.15
ISSN: 2330-7412 (Print); ISSN: 2330-7420 (Online)

Flow Analysis in Shell Side on the Effect of Baffle Spacing of Shell and Tube Heat Exchanger

Su Pon Chit, Nyein Aye San, Myat Myat Soe

Department of Mechanical Engineering, Mandalay Technological University, Mandalay, Myanmar

Email address:
suponchitmtu@gmail.com (S. P. Chit), nyeinayesan.mdy@gmail.com (N. A. San), myatmyatsoe.mtu@gmail (M. M. Soe)

To cite this article:
Su Pon Chit, Nyein Aye San, Myat Myat Soe. Flow Analysis in Shell Side on the Effect of Baffle Spacing of Shell and Tube Heat Exchanger. *International Journal of Science, Technology and Society*. Vol. 3, No. 5, 2015, pp. 254-259. doi: 10.11648/j.ijsts.20150305.15

Abstract: In this paper, the flow analysis in shell side on the effect of baffle spacing of shell and tube heat exchanger has been studied using theoretical and numerical methods. The researched is carried out in shell and tube heat exchanger for oil cooler of Locomotive. The shell side pressure drop for acceptable limits is 0.3 bar for shell and tube heat exchanger of oil cooler of Locomotive. In the theoretical method, the effect of different geometric parameters and thermal energy exchange in shell side flow has been considered. Theoretical is calculated for eight baffle spacings are namely 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9 of inside diameter of shell. Then, suitable baffle spacing occur 0.5 of inside diameter of shell because it is less than allowable pressure drop. The design is satisfied because the pressure drop for shell side 0.289 bar is lower than the limited pressure drop,0.3 bar. The flow of the shell side was also analyzed using COMSOL Multiphysis with suitable baffle spacing. The pressure values from the simulations results compared with theoretical.

Keywords: Baffle Spacing, Baffle Cut, COMSOL Multiphysis, Heat Exchanger, Pressure Drop

1. Introduction

The shell and tube heat exchangers are known as the work-horse of the chemical process industry when it comes to transferring heat. These devices are available in a wide range of configurations as defined by the Tubular Exchanger Manufacturers Association. The applications of single-phase shell-and-tube heat exchangers are quite large because these are widely used in chemical, petroleum, power generation and process industries. In essence, a shell and tube exchanger is a pressure vessel with many tubes inside of it. One process fluids flows through the tubes of the exchanger while the other flows outside of the tubes within the shell. The tube side and shell side fluids are separated by a tube sheet. In these heat exchangers, one fluid flows through tubes while the other fluid flows in the shell across the tube bundle. The design of a heat exchanger requires a balanced approach between the thermal design and pressure drop. The performance parameters include heat transfer, pressure drop, effectiveness etc. [1]

The tubes of a U-tube heat exchanger (Figure 1) are bent in the shape of a U. There is only one tube sheet in a U tube heat exchanger. However, the lower cost for the single tube sheet is offset by the additional costs incurred for the bending of the tubes and the somewhat larger shell diameter (due to the minimum U-bend radius), making the cost of a U-tube heat exchanger comparable to that of a fixed tube sheet exchanger. The advantage of a U-tube heat exchanger is that because one end is free, the bundle can expand or contract in response to stress differentials. In addition, the outsides of the tubes can be cleaned, as the tube bundle can be removed. The disadvantage of the U-tube construction is that the insides of the tubes cannot be cleaned effectively, since the U-bends would require flexible-end drill shafts for cleaning. Thus, U-tube heat exchangers should not be used for services with a dirty fluid inside tubes.

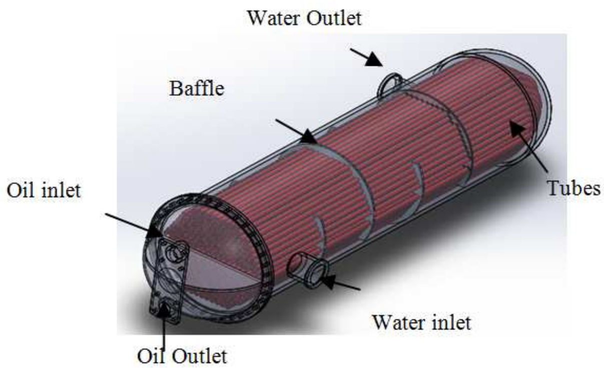

Figure 1. *U Tube Heat exchanger.*

A. Baffle Spacing

Type of baffle is used single segmental. Baffle spacing is the centerline-to-centerline distance between adjacent baffles. It is the most vital parameter in STHE design. The TEMA standards specify the minimum baffle spacing as one-fifth of the shell inside diameter or 2 in., whichever is greater. Closer spacing will result in poor bundle penetration by the shell-side fluid and difficulty in mechanically cleaning the outsides of the tubes. Furthermore, low baffle spacing results in a poor stream distribution. The maximum baffle spacing is the shell inside diameter. Higher baffle spacing will lead to predominantly longitudinal flow, which is less efficient than cross-flow, and large unsupported tube spans, which will make the exchanger prone to tube failure due to flow-induced vibration. [3]

Figure 2 depicts a single-segmental shell-and-tube bundle geometry with fixed tube sheets at both heads in which the shell-side flow makes one shell pass from one end of the tube bundle to the other with the flow directed across the tube bundle by the baffles. The inlet, central and outlet baffle spacing are shown and are identifies as L_{bi}, L_{bc} and L_{bo}, respectively.

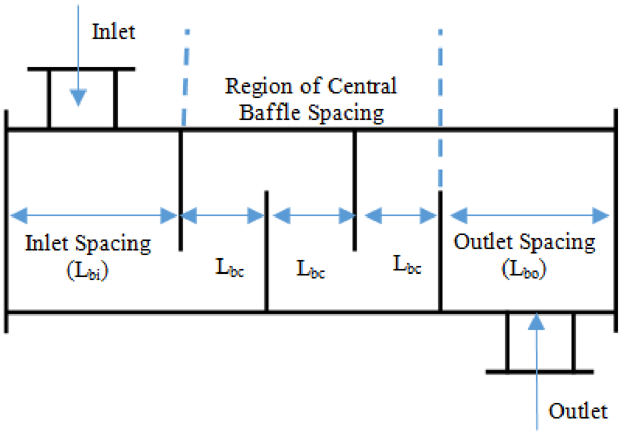

Figure 2. *Single-segmental Shell and Tube Heat Exchanger Showing Baffle.*

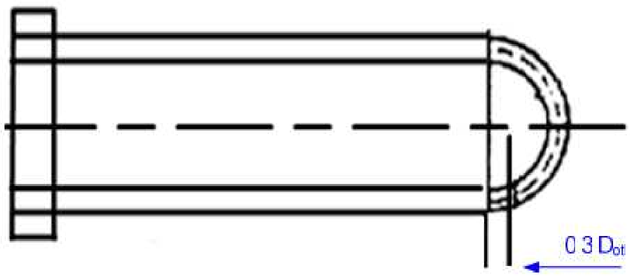

Figure 3. *Tube Length Dimension for U Tube.*

B. Baffle Cut

Baffle cut is the height of the segment that is cut in each baffle to permit the shell-side fluid to flow across the baffle. This is expressed as a percentage of the shell inside diameter. Although this, too, is an important parameter for STHE design, its effect is less profound than that of baffle spacing. Baffle cut can vary between 15% and 45% of the shell inside diameter. Both very small and very large baffle cuts are detrimental to efficient heat transfer on the shell side due to large deviation from an ideal situation, as illustrated in Figure 4.

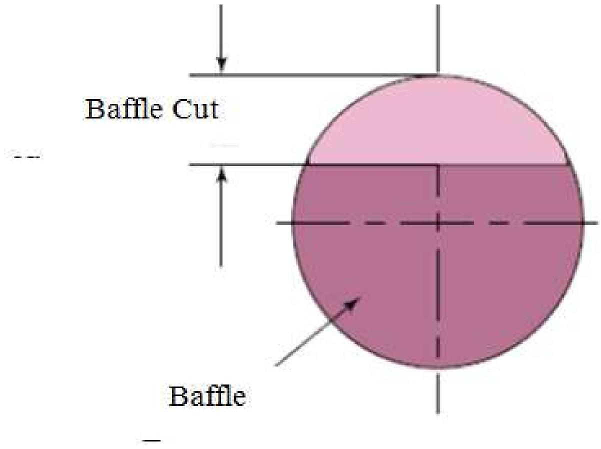

Figure 4. *Segmental Baffle Cut (%).*

2. Pressure Drop in Preliminary Calculation

A selected shell and tube heat exchanger must satisfy the process requirements with the allowable pressure drops until the next scheduled cleaning of plant. The methodology to evaluate thermal parameters is explained with suitable assumptions. The following are the major assumptions made for the pressure drop analysis;

1. Flow is steady and isothermal, and fluid properties are independents of time.
2. Fluid density is dependent on the local temperature only or is treated as constant.
3. The pressure at a point in the fluid is independent of direction.
4. Body force is caused only by gravity.
5. There are no energy sink or sources along streamline; flow stream mechanical energy dissipation is idealized as zero.
6. The friction factor is considered as constant with passage flow length.[2]

Table 1. *Specifications of theShell and Tube Heat Exchanger for Oil Cooler.*

Shell diameter, D_s	380 mm
Tube inside diameter, d_o	15 mm
Tube outside diameter, d_i	13.5 mm
Pitch,pt	1.25
Length of tube, L	1250 mm
Number of baffles	4
Number of tubes	262
Number of shell pases	1
Number of tube pases	2
Clearance	5 mm
Bundle to shell clearance	28 mm
Shell to baffle diameterical clearance	10 mm
Centeral Baffle Spacing, L_{bc}	$0.2D_s$ to $0.9D_s$

In the present study, a cast iron steel shell and tube heat exchanger is used to study the various parameters of the heat exchanger such as heat transfer coefficient, Reynold's number, pressure drop, overall heat transfer coefficient etc using water as a heat transfer medium. The design method used in calculating the parameter is Bell Delaware Method.

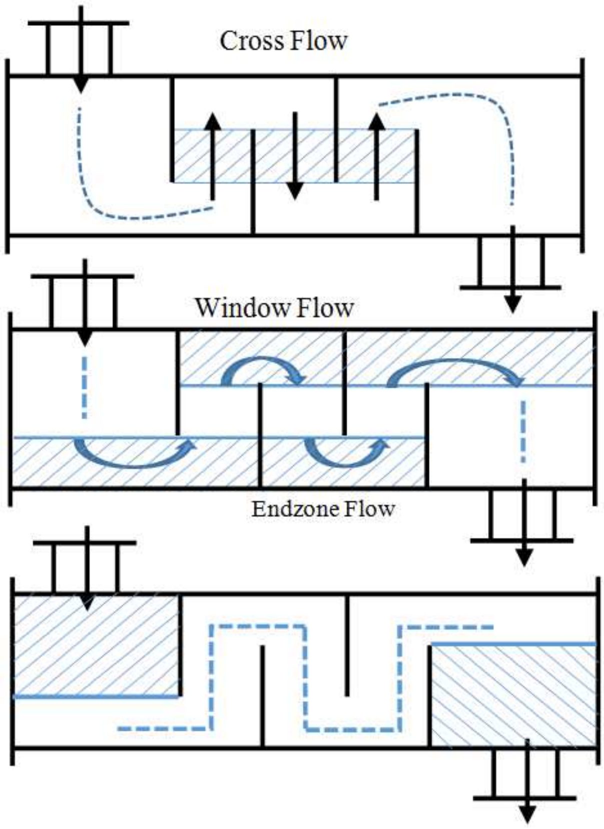

Figure 5. *Pressure Drop Regions in Shell Side Flow.*

The shell side pressure drop depends on the number of tubes, the number of times the fluid passes the tube bundle between the baffles and the length of each crossing.[7] The pressure drop on the shell side is calculated by the following expression;

Step 1: Calculated the number of tube rows crossed in one crossflow section N_c.[5]

$$N_{tcc} = \frac{D_s}{L_{pp}}\left[1-2\left(\frac{B_c}{100}\right)\right]$$

$$L_{pp} = 0.866\ L_{tp}$$

Step 2: Calculate the window flow area S_w.

$$S_w = \frac{D_s^2}{4}\left[\cos^{-1}(D_B) - D_B\left(1-D_B^2\right)^{1/2}\right] - \frac{N_t}{8}(1-F_c)\pi d_o^2$$

$$D_B = 1-2\left(\frac{B_c}{100}\right)$$

Step 3: Calculate the number of effective N_{cw}.

$$N_{cw} = \frac{0.8}{L_{pp}}\left[\frac{B_c D_s}{100}\right]$$

Step 4: Calculate the window zone pressure drop Δp_w.

$$\Delta p_w = R_\mu R_l\left[(2+0.6N_{cw})\frac{m^2{}_w}{2\rho}\right]$$

$$m_w = \frac{m^\circ{}_s}{\sqrt{S_m S_w}}$$

Step 5: Estimate the correction factor on pressure drop for by pass flow R_b.

$$F_{sbp} = \frac{S_b}{S_m}$$

$$S_b = L_{bc}\left[(D_s - D_{otl}) + L_{pl}\right]$$

$$r_{ss} = \frac{N_{ss}}{N_{tcc}}$$

$$R_b = \exp\left[-C_{bp}F_{sbp}\left(1-\sqrt[3]{2r_{ss}}\right)\right]$$

Step 6: Estimate the correction factor for baffle leakage effect on pressure drop R_l.

$$R_l = \exp\left[-1.33(1+r_{ss})r_{lm}{}^p\right]$$

$$p = -0.15(1+r_s)+0.8$$

Step 7: Calculate the ideal cross flow pressure drop through one baffle space ΔP_b.

$$\Delta p_{bi} = \frac{2f_i\ N_{tcc}\ m^2{}_s}{\rho_s\ S_m}R_\mu$$

$$\Delta p_b = \Delta p_{bi}R_b R_l$$

$$S_m = L_{bc}\left[(D_s - D_{otl}) + \frac{(D_{otl}-d_o)(L_{tp}-d_o)}{L_{tp}}\right]$$

Step 8: Calculate the pressure drop in the two end zones of the tube bundle Δp_e.

$$\Delta p_e = \Delta p_{bi}\left(1+\frac{N_{tcw}}{N_{tcc}}\right)R_b R_s$$

$$R_s = \left(\frac{L_{bc}}{L_{bo}}\right)^{2-n} + \left(\frac{L_{bc}}{L_{bi}}\right)^{2-n}$$

Step 9: Calculate the total shell side pressure drop ΔP_s. [4]

$$\Delta P_s = (N_b - 1)\Delta p_b + N_b\Delta p_w + 2\ \Delta p_e$$

3. Results and Discussion

In this paper, the effect of baffle spacing of shell and tube heat exchanger for oil cooler of Locomotive with geometry parameters is considered. Segmental baffles normally should not be spaced closer than 0.4 of the shell inside diameter or 0.152 meters, whichever is greater and 0.6 of shell inside diameter, the least baffle spacing is considered 0.228 meters [10].

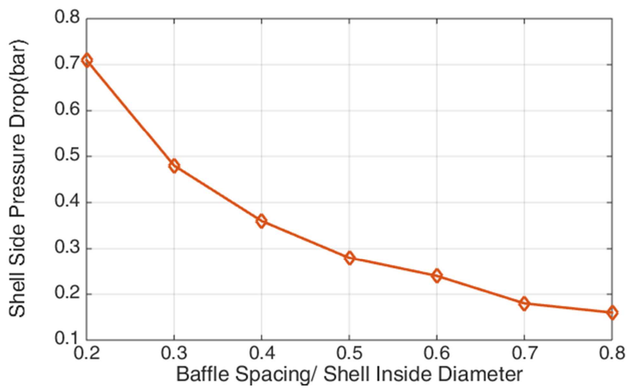

Figure 6. *Pressure Drop in Shell Side on Baffle Spacing.*

Variation of shell side pressure drop versus baffle spacing is shown in Figure 6. It is found that with the increase of baffle spacing, pressure drop decreases. The maximum allowable pressure drop for transmission oil cooler of Diesel Locomotive occurs at baffle spacing 0.19 m (0.5D_s) under the shell side pressure drop for acceptable limits 0.3bar.

In all of the preliminary simulation, flow inside the shell is observed to be turbulent viscous model is selected to be K-ε turbulent model. [8] The result is investigated using the heat exchanger model with 0.4Ds to 0.6Ds baffle spacing for 25% baffle cut. In Figure 8, 10 and 12, velocity path lines for four baffles are given for the shell side velocity flow of 1.2m/sec, inlet boundary condition and outlet boundary condition is pressure, no viscous stress.

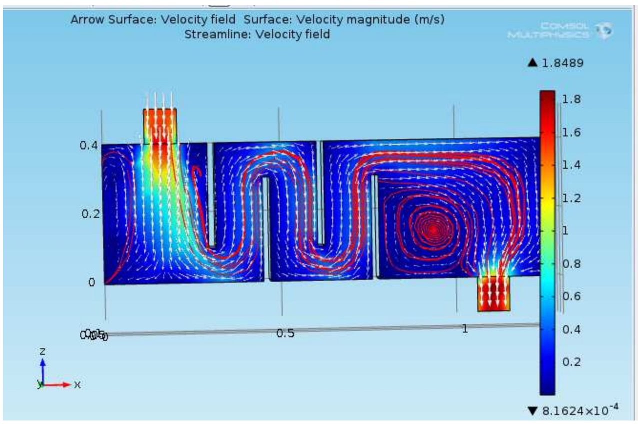

Figure 7. *Velocity on Shell Side when Baffle Spacing 0.4Ds.*

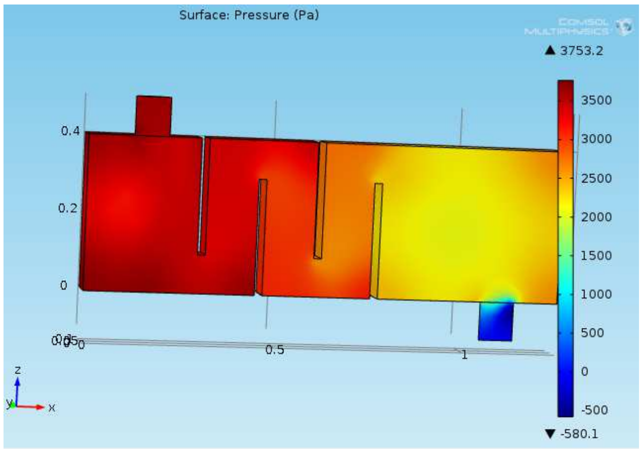

Figure 8. *Pressure on Shell Side when Baffle Spacing 0.4Ds.*

The flows hits the baffle plate, and the direction of the flow is changed.In Figure 7, the shell space behind the baffle is not effectively used for cross flow, as marked with a circle. For this reason, the pressure drop occurs high mark in Figure 8 and total pressure drop is 0.3 bar.

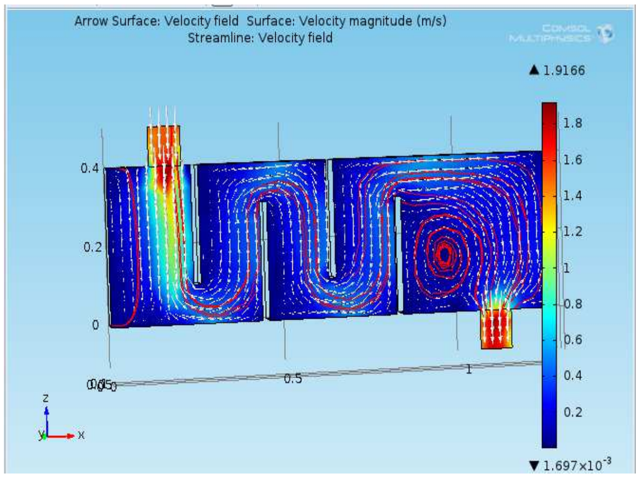

Figure 9. *Velocity on Shell Side when Baffle Spacing 0.5Ds.*

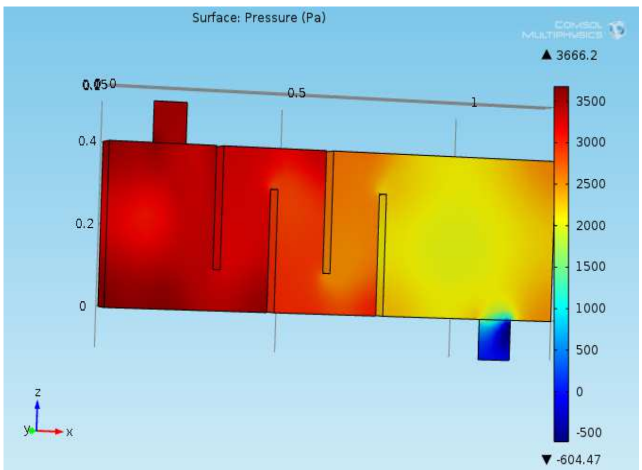

Figure 10. *Pressure on Shell Side when Baffle Spacing 0.5Ds.*

In Figure 9, the flow is obseved to be well developed.The cross flow throughout the shell volume and the recirculation zone appears little. So, pressure drop is effectively average in Figure 10, the simulation result gain 0.3 bar.

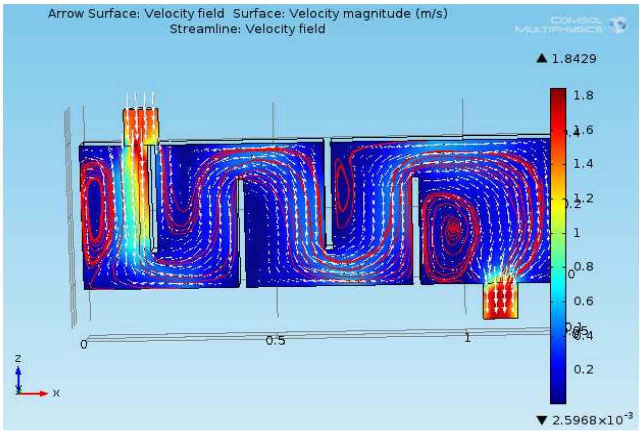

Figure 11. Velocity on Shell Side when Baffle Spacing 0.6Ds.

Figure 12. Pressure on Shell Side when Baffle Spacing 0.6Ds.

In Figrue 11, the velocity stream line of recirculation two zones appear and also occur decreasing pressure drop result in Figure 12 and is 0.23 bar.

Hence, it is observed that 0.5Ds baffle spacing gives better pressure drop compare with other baffle spacing under allowable pressure drop for transmission oil cooler for Locomotive. It occurs same pressure drop in simulation. So, 0.5Ds baffle spacing is good for theoretical and simulation.

4. Conclusion

In this research, in current numerical analysis, entire geometry to shell and tube heat exchanger including entrance and exist regions were considered as a domain of calculation, theoretical and numerical results have been compared a wide range of baffle spacing. Thus, as baffle spacing is reduced, pressure drop increases at a much faster rate than does the heat-transfer coefficient. This means that there will able baffle spacing to shell inside diameter that will result in the highest of pressure drop to heat transfer. This optimum ratio is normally between 0.4 and 0.6Ds for oil cooler of Locomotive.

Acknowledgment

The author wishes to express his deepest gratitude to His Excellency Dr. Ko Ko Oo, Union of Minister, Ministry of Science and Technology, for allowing him to attend the Doctorate Engineering Course at Mandalay Technological University. The author is deeply gratitude to Dr. Myint Thein, Rector, Mandalay Technological University, for guidance and advice. The author would like to thank Dr. Tin San (Associate Professor and Head), Dr. Win Pa Pa Myo (Associate Professor), Dr. Nyein Aye San (Lecturer), Dr. Myat Myat Soe (Associate Professor) and all teachers from Department of Mechanical Engineering, Mandalay Technological University for kindness, graceful, attitude and permission to do this paper. The author's special thanks are sent to parents for their guidance from childhood till now.

Nomenclature

Symbol	Quantity
d_o	Outside diameter
G_s	Shell side mass velocity(kg/ m^2-s)
L	Tube Length(m)
m_s	Mass flow rate of water on shell side(m/s)
D_s	Shell inside diameter(m)
L_b	Baffle Spacing(m)
ΔP_{total}	Shell side pressure drop (bar)
S_m	Area of the shell side cross flow section (m^2
S_{sb}	Shell to baffle leakage area (m^2)
S_{tb}	Tube to baffle leakage area (m^2)
F_{bp}	Fraction of the crossflow area for bypass flow (m^2)
S_w	Window area flow (m^2)
N_c	Number of tube rows crossed in crossflow section
N_{cw}	Effective number of crossflow rows in window zone
ΔP_c	Ideal crossflow pressure drop through one baffle space (bar)
ΔP_w	Window zone pressure drop (bar)
Rl	Correction factor for baffle leakage effect on pressure drop

References

[1] J.P. Holman, 1963, Heat Transfer, 8thed, McGraw-Hill Book Company

[2] Bell KJ. Delaware method for shell side design. In: Kakac S, Bergles AE, Mayinger F, editors. Heat exchanger: thermal-hydraulic fundamentals and design. New York: Hemisphere; 1981.p. 581 -618.

[3] Halle H, Chenoweth JM, Wabsganas MW. Shell side water flow pressure drop distribution measurements in an industrial-sized test heat exchanger Eng 1994; 15: 42-56.

[4] Gaddis ES, Gnielinski V. Pressure drop on the shell side of the shell side of shell and tube heat exchangers with segmental baffles. Chem Eng Process 1997; 36: 149-59.

[5] Taborek, J., 1998. Shell and Tube Heat Exchangers in Single Phase Flow. In Handbook of Heat Exchanger Design. Begell House, New York.

[6] Shan, R.K. and D. Sekulic, 2003. Fundamentals of Heat Exchanger Design. Wiley New York.

[7] Professor John R. Thom, 2004, "Wolverine. Single Phase Shell Side Flows and Heat Transfer Data BookII", Wolverine Tube Inc, www.Wolverine.com.

[8] R. Hesseini, A. Hesseini-Ghaffar, M. Soltani, "Experimental determination of shell side heat transfer coefficient and pressure drop for an oil cooler shell and tube heat exchanger with three different tube bundles", Applied Therminal Engineering 27 (2007).

[9] M. M. E-Fawal, A. A. Fahmy and B. M, Taher, " Modelling of Economical Design of Shell and Tube Heat Exchanger using Specificed Pressure Drop", Journal of American Science, 2011.

[10] COMSOLAB, "Turbulent Flow Through Reactor," Heat transfer Module Library, Version: COMSOL 4.3b, 2012.