

Comparison Of Bowman And Ronald LmtD Correction Charts

Saggarla Murali

Prof, Dept. of Mechanical Engg., JPN College of Engg., Mahabubangar, Telangana, India,
phone: 9440845882 (M)

ABSTRACT:- Mean Temperature Difference is a key factor for accurate design of shell and Tube Heat Exchangers. However, Accuracy of this depends on method by which it has been evaluated. Numerous Investigations have contributed analysis of the mean temperature difference for Heat Exchangers and presented them in the form of equations and Charts. When making heat exchanger calculations, Engineers generally rely on correction Charts. Perhaps, these charts on plain paper are not suitable for Automated Design, accurate reading is difficult and time consuming. This limitation can be greatly reduced by using CAD LMTD (Log Mean Temperature Difference) correction charts. This paper includes brief study review of the literature on Mean Temperature Difference to date and comparison of the graphs of Bowman and Ronald has been made. Further, The study has been extended to CAD LMTD correction charts for automated design. These charts have shown prominent to the user and provide good results with greater reading ability and accuracy.

Key words: Mean Temperature Difference, shell and Tube Heat Exchangers, CAD LMTD correction charts

I. Introduction

Multipass exchangers, heaters and coolers are often used in the process industries. Such equipment allows for a great deal of flexibility to a given heat-exchange process design. For example, multiple-shell passes may be used: (i) to improve the temperature difference between hot and cold streams for a given exchanger, in which the stream flows are not parallel or countercurrent; and (ii) to decrease the amount of floor space required for a given exchanger. Multiple-tube passes may be used: (i) to increase the fluid velocity in the tubes, thereby increasing the overall heat transfer coefficient; and (ii) to increase or decrease the available heat transfer area without increasing or decreasing the shell length. The numbers of shell and tube passes are limited by the maximum allowable pressure drop and by space considerations. Further, the number of tube passes is also limited by the amount of fluid passing through the tubes and by the maximum permissible shell diameter. The basic equation for the thermal design (i.e., finding the heat transfer area) of multipass exchangers, heaters and coolers is (Bell, 1984):

$$Q = UA \Delta T_M \quad (1)$$

$$\Delta T_M = F \Delta T_{LM} \quad (2)$$

Here, F is a correction factor that is so determined when it is multiplied by the logarithmic mean temperature difference (LMTD) for a single-pass counter-current exchanger, the product $F \Delta T_{LM}$ represents the true mean temperature difference (MTD) of an equivalent multipass exchanger. Correction Factor F typically depends on the four terminal temperatures and the configuration of heat exchanger.

This paper includes brief study review of the literature on mean temperature difference, conversion of correction factor graphs in to CAD graphs which are used in automated design and comparison of the graphs of R.A. Bowman [2] and Ronald E.[3].

II. Bowman-Mueller-Nagle F Relationship

Many researchers have attempted to determine the proper mean temperature differences for the numerous types of heat exchangers. In 1940, Bowman, Mueller and Nagle published ΔT_{LM} correction factors for many common types of exchangers. For typical shell and tube exchangers, they expressed F as a function of two dimensionless parameters:

$$F = f_1(P, R) \quad (3)$$

Where, P is the cold-fluid temperature efficiency

$$\text{Capacity ratio} \quad R = \frac{T_1 - T_2}{t_2 - t_1} \quad (4)$$

$$\text{Thermal efficiency } P = \frac{t_2 - t_1}{T_1 - t_1} \quad (5)$$

Bowman, Mueller and Nagle represented $F = f_1(P, R)$ by means of equations and graph for different types of exchangers. Based on the following assumptions Bowman, Mueller and Nagle developed equations of correction factor for one shell and two tube pass, two shell and four tube pass and at last the general equation.

1. The overall heat-transfer coefficient is constant throughout the exchanger.
2. The flow rate of each fluid is constant.
3. The specific heat of each fluid is constant.
4. There is no condensation or boiling.
5. Heat losses are negligible.
6. The heat-transfer surface of each pass is equal.
7. The temperature of the shell side fluid in any shell side pass is uniform over any cross section.

One-pass shell side, two-pass tube side

$$F_{1,2} = \frac{\left[\frac{\sqrt{R^2 + 1}}{R - 1} \right] \ln \left[\frac{1 - P}{1 - PR} \right]}{\ln \left[\frac{2 - P(1 + R - \sqrt{R^2 + 1})}{2 - P(1 + R + \sqrt{R^2 + 1})} \right]} \quad (6)$$

Graphic representation for one shell and two tube pass tube is shown in fig. 1.

Two-pass shell side, four-pass tube side

$$F_{2,4} = \frac{\left[\frac{\sqrt{R^2 + 1}}{2(R - 1)} \right] \ln \left[\frac{1 - P}{1 - PR} \right]}{\ln \left[\frac{A + B + \sqrt{R^2 + 1}}{A + B - \sqrt{R^2 + 1}} \right]} \quad (7)$$

The numerators of Eq. (6) and (7) become indeterminate when $R = 1$. The usual treatment of such indeterminate is:

$$\frac{1}{R - 1} \ln \left[\frac{1 - P}{1 - PR} \right] = \frac{P}{1 - P} \quad (8)$$

Finally they represented a general method for calculating F factors for three-six, four -eight, five-ten and six-twelve exchangers, from the factors of one-two exchangers. They stated that, at any particular values of F and R, the value of P for an exchanger having N shell side passes and 2N tube side passes is related to P of a one-two exchanger by the Equation

$$P_{N,2N} = \frac{1 - \left[\frac{1 - P_{1,2}R}{1 - P_{1,2}} \right]^N}{R - \left[\frac{1 - P_{1,2}R}{1 - P_{1,2}} \right]^N} \quad (9)$$

For the special case of $R = 1$, Eq. (9) becomes indeterminate, and the usual treatment of such indeterminate yields:

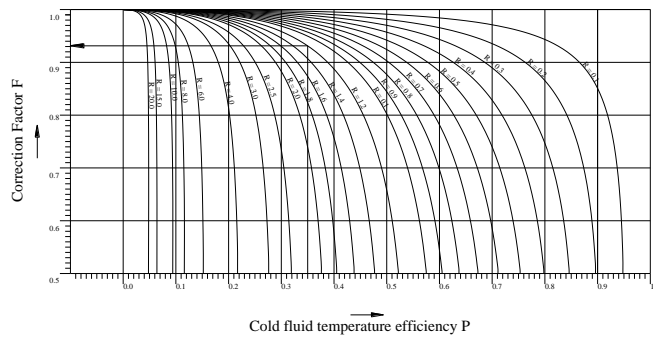


Fig. 1 Correction factor for log mean Temperature Difference of one shell two tube pass Exchanger (Bowman)

$$P_{N,2N} = \frac{P_{1,2}N}{(P_{1,2}N - P_{1,2} + 1)} \tag{10}$$

III. Ronald E. Wales Curves

Ronald E. Wales[3] Presented another method for determining Correction factor in terms of new dimensionless parameter G, and it is defined as the ratio of the outlet temperature gap (or approach) to the inlet temperature deference. Values of G can range from +1 (no heat exchange) to -1 (highest heat exchange).

$$G = \frac{T_1 - t_2}{T_1 - t_1} \tag{11}$$

For typical shell and tube exchangers, it shows that,

$$F = f_2(G, R) \tag{12}$$

Examination of the definitions of P, R and G in, respectively, Eq. (4), (5) and (11) will show that they are related algebraically by:

$$P = (1-G) / (1+R) \tag{13}$$

Substituting the cold-fluid temperature efficiency term, P, from (13) into (6) and (7), Simplifying, yields the following equations for the ΔT_M correction factors of one-two and two-four shell and tube exchangers

$$F_{1,2} = \frac{\left[\frac{\sqrt{R^2 + 1}}{R - 1} \right] \ln \left[\frac{R + G}{1 + GR} \right]}{\ln \left[\frac{C + D}{C - D} \right]} \tag{14}$$

Graphic representation for one shell and two tube pass tube is shown in fig. 2.

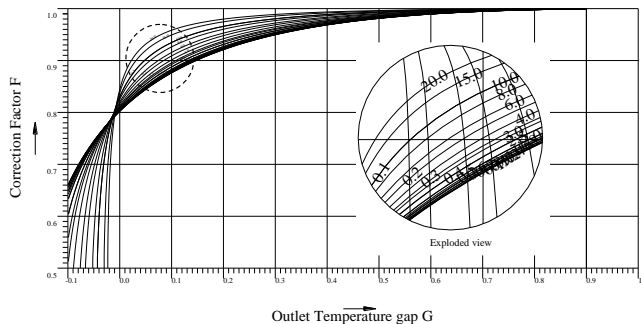


Fig. 2 Correction factor for log mean Temperature Difference of one shell two tube pass Exchanger (Ronald)

$$F_{2,4} = \frac{\left[\frac{\sqrt{R^2 + 1}}{2(R-1)} \right] \ln \left[\frac{R+G}{1+GR} \right]}{\ln \left[\frac{C + 2[(R+G)(1+GR)]^{1/2} + D}{C + 2[(R+G)(1+GR)]^{1/2} - D} \right]} \quad (15)$$

In Eq. (14) and (15)

$$C = (R+1)(1+G) \text{ and } D = [(1-G)(R^2 + 1)]^{1/2}$$

The numerators in Eq. (14) and (15) become indeterminate when R=1, by usual treatment:

$$\frac{1}{R-1} \ln \left[\frac{R+G}{1+GR} \right] = \frac{1-G}{1+G} \quad (16)$$

Finally, for any particular values of F and R, the value of G for an exchanger having N shell side passes and 2N tube side passes is related to G for a one-two exchanger by:

$$G_{N,2N} = 1 - (1+R) \frac{\left[\frac{1+RG_{1,2}}{R+G_{1,2}} \right]^N}{R - \left[\frac{1+RG_{1,2}}{R+G_{1,2}} - R \right]^N} \quad (17)$$

CAD GRAPHS

Generally, heat exchanger designers rely on correction graphs presented on plain paper. However, these are not suitable for automated design. Reading exact values from these graphs is difficult and time consuming. Infinite paper size of CAD editor provides higher zooming in making exact reading of values in shorter time.

CAD Graphs generally generated using basic equations of graphs. Some times in open literature these equations may not be available, in such cases, with small corrections, can be generated by reproducing graphs presented on a paper in CAD environment using 2D tools. Call these graphs on to CAD environment at appropriate time whenever designer needs. User can read the values with ease and greater accuracy. This methodology can be extended to any curve. Fig .1, fig .2 and fig.3 have been drawn using the former method.

Every entity in Auto CAD environment identified by unique entity handle. Entity handle is a permanent alphanumeric name given to entities in drawing. These entity handles can be used to identify one particular curve (R=1.2) making other curves deactivated. Intersection of this curve with vertical line (P = 0.35) is automatically identified, from there a horizontal line is made to draw. Intersection of this horizontal line with vertical line P=0 gives value of correction factor (F= 0.93).

IV. Comparison Of Bowman And Ronald Correction Factor Curves

Ronald. E., in his pioneering work stated that, Bowman and Ronald equations are mathematically equivalent, G is more powerful parameter than either P or R, The correction factor F is same for R and 1/R, same whether the shell side fluid enters at the fixed or floating head end of the shell and correction factor is also same whether the hot fluid is in the shell side or tube side.

Moreover, In the present work while simulating (fig. 3)the following observations have been noticed for increase in values of R from 0.1 to 20.

1. Curve slopes are initially decreasing and then increasing (fig.2 exploded view)
2. At G nearly equal to 0.08 all the curves are converging (fig. 2)
3. G is taking more higher negative values as shown in table 1

Because of the three reasons mentioned above, the curves obtained by Ronald are staggered and overlapping. User will generally feel more difficult in selecting particular curve. High negative values of G and greater slopes of the curves may give in accurate reading of the correction factor.

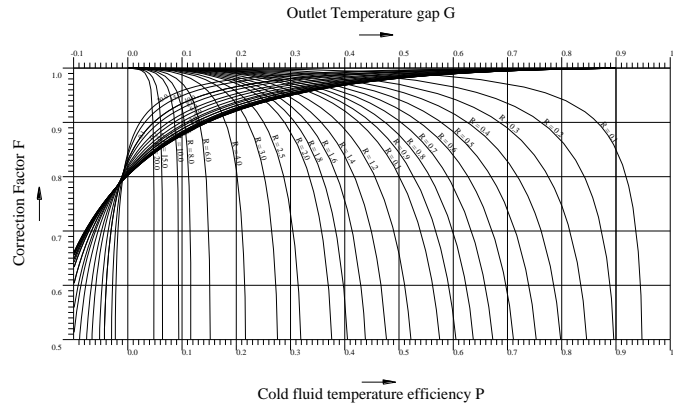


Fig. 3 Correction factor for log mean Temperature Difference of one shell two tube pass Exchanger (combined)

R	0.1	0.5	1	1.6	2	3	6	8	10	15	20
P 0.1	0.89	0.85	0.8	0.74	0.7	0.6	0.3	0.1	-0.1	-0.6	-1.1
0.2	0.78	0.7	0.6	0.48	0.4	0.2	-0.4	-0.8	-1.2	-2.2	-3.2
0.3	0.67	0.55	0.4	0.22	0.1	-0.2	-1.1	-1.7	-2.3	-3.8	-5.3
0.4	0.56	0.4	0.2	-0.04	-0.2	-0.6	-1.8	-2.6	-3.4	-5.4	-7.4
0.5	0.45	0.25	0	-0.3	-0.5	-1	-2.5	-3.5	-4.5	-7	-9.5
0.6	0.34	0.1	-0.2	-0.56	-0.8	-1.4	-3.2	-4.4	-5.6	-8.6	-11.6
0.7	0.23	-0.05	-0.4	-0.82	-1.1	-1.8	-3.9	-5.3	-6.7	-10.2	-13.7
0.8	0.12	-0.2	-0.6	-1.08	-1.4	-2.2	-4.6	-6.2	-7.8	-11.8	-15.8
0.9	0.01	-0.35	-0.8	-1.34	-1.7	-2.6	-5.3	-7.1	-8.9	-13.4	-17.9
1	-0.1	-0.5	-1	-1.6	-2	-3	-6	-8	-10	-15	-20

V. Conclusions

The writers are very thankful to the authors for their enormous work. However, it seems, it would not be good, if no comment is made.

Definitely the equations of Bowman and Ronald are similar and give same friction factor values. But, Because of reasons mentioned above, the authors feel that Bowman Curves are more suitable for calculating log mean temperature difference (LMTD) correction factor.

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