Make This Correction Factor Chart To Find Divided Flow Exchanger MTD

■ Here's how to construct a log mean temperature difference (LMTD) correction factor chart for one-tube pass, from which you may also calculate multi-tube pass true temperature difference.

These steps were developed by Dale L. Gulley, chief rating engineer for Western Supply Co., who assumes that divided flow is referred to as being shell type J.

Follow These Six Steps To Make The Chart

STEP 1: It is customary to define the true temperature as

$$\Delta t_m = \text{LMTD} \times F \qquad (1)$$

where a correction factor F is applied to the LMTD. In most cases F is taken from a chart. This approach will be used with one-tube pass but not with multi-tube pass.

Using Fig. 2 — a temperature vs tube length plot — as a guide, develop equations for the LMTD correction factor. The correction factor chart can be made by using these equations.

STEP 2: The mixed shell outlet temperature will be

$$T_2 = (T'_2 + T''_2)/2 \qquad (2)$$

Now set up heat and rate balances. Around the left side

$$\frac{WC}{2}(T_1 - T'_2) = wc(t_a - t_1) = \frac{UA}{2}\,\frac{(T_1 - t_1) - (T'_2 - t_a)}{\ln \dfrac{T_1 - t_1}{T'_2 - t_a}} \qquad (3)$$

or

$$\frac{UA}{wc} = \frac{2(t_a - t_1)}{(T_1 - t_1) - (T'_2 - t_a)} \ln \frac{T_1 - t_1}{T'_2 - t_a} \qquad (4)$$

Since $R = wc/WC$

STEP 3: From Eq. 3

$$R = \frac{T_1 - T'_2}{2(t_a - t_1)} \text{ and } t_a = \frac{T_1 - T'_2}{2R} + t_1 \qquad (5)$$

to simplify let $\alpha = (T_1 - T'_2)/2R$, then substituting in Eq. 3

$$\frac{UA}{wc} = \frac{2\alpha}{(T_1 - t_1) - (T'_2 - \alpha - \overset{t_1}{\cancel{T_1}})} \ln \frac{T_1 - t_1}{T'_2 - \alpha - t_1} \qquad (6)$$

let $UA/wc = \ln \phi$ and simplify

$$\ln \phi = \frac{2\alpha}{T_1 - T'_2 + \alpha} \ln \frac{T_1 - t_1}{T'_2 - \alpha - t_1} \qquad (7)$$

STEP 4: Removing ln from both sides and rearranging

$$\phi^{\frac{T_1 - T'_2 + \alpha}{2\alpha}} = \frac{T_1 - t_1}{T'_2 - \alpha - t_1} \qquad (8)$$

since $\alpha = (T_1 - T'_2)/2R$

$$\phi^{\frac{2R+1}{2}} = \frac{2R\,(T_1 - t_1)}{T'_2\,(2R+1) - T_1 - 2R\,t_1} \qquad (9)$$

rearranging

$$T_1 - T'_2 = \frac{2R\,(T_1 - \overset{t_1}{\cancel{t_2}})\,(\phi^{\frac{2R+1}{2}} - 1)}{(2R+1)\,\phi^{\frac{2R+1}{2}}} \qquad (10)$$

STEP 5: Now use the same procedure on the right side of the shell

$$T_1 - T''_2 = \frac{2R\,(T_1 - t_2)\,(\phi^{\frac{2R-1}{2}} - 1)}{(2R-1)\,\phi^{\frac{2R-1}{2}}} \qquad (11)$$

adding Eq. 9 and 10

$$2T_1 - (T'_2 + T''_2) = 2R\left[\frac{(T_1 - t_1)\,(\phi^{\frac{2R+1}{2}} - 1)}{(2R+1)\,\phi^{\frac{2R+1}{2}}} + \frac{(T_1 - t_2)\,(\phi^{\overset{2R-1}{\cancel{\frac{2R+1}{2}}}} - 1)}{(2R-1)\,\phi^{\frac{2R-1}{2}}}\right] \qquad (12)$$

substituting $2T_2 = T'_2 + T''_2$ and $P = \dfrac{t_2 - t_1}{T_1 - t_1}$

$$\boxed{P = \frac{\phi^{\frac{2R+1}{2}} - 1}{(2R+1)\,\phi^{\frac{2R+1}{2}}} + \frac{(1-P)\,(\phi^{\frac{2R-1}{2}} - 1)}{(2R-1)\,\phi^{\frac{2R-1}{2}}}} \qquad (13)$$

STEP 6: To work up the LMTD correction chart, various values of ϕ are assumed. Using an assumed ϕ with a given R, a value for P is calculated from Eq. 13. Then using

$$F = \ln \frac{(1-P)/(1-PR)}{(R-1)(\ln \phi)} \qquad (14)$$

a point on the curve is calculated. In case $R = 1$, use the following equation

$$F = \frac{P}{(1-P)\ln\phi} \quad \ldots\ldots\ldots\ldots \quad (15)$$

The resulting LMTD correction factor chart for one-tube pass is shown in Fig. 1.

This Is How You Use The Chart for Multi-Tube Pass

A look at Fig. 3 shows there are two extra unknowns — intermediate tube side temperatures t_a and t_c. By utilizing the one-pass LMTD correction curve in Fig. 1, it is possible to leave only one unknown t_b, the intermediate tube side temperature between the upper and lower tube pass.

By assuming a value of t_b, the corrected LMTD of both the upper and lower tube pass can be calculated. Then a check is made to see if the heat transferred in the lower tube pass raises the tube temperature to the assumed value of t_b. If it doesn't t_b is adjusted and new temperature differences are determined. When t_b checks the assumed value, the LMTD of the two passes are combined into the final corrected LMTD.

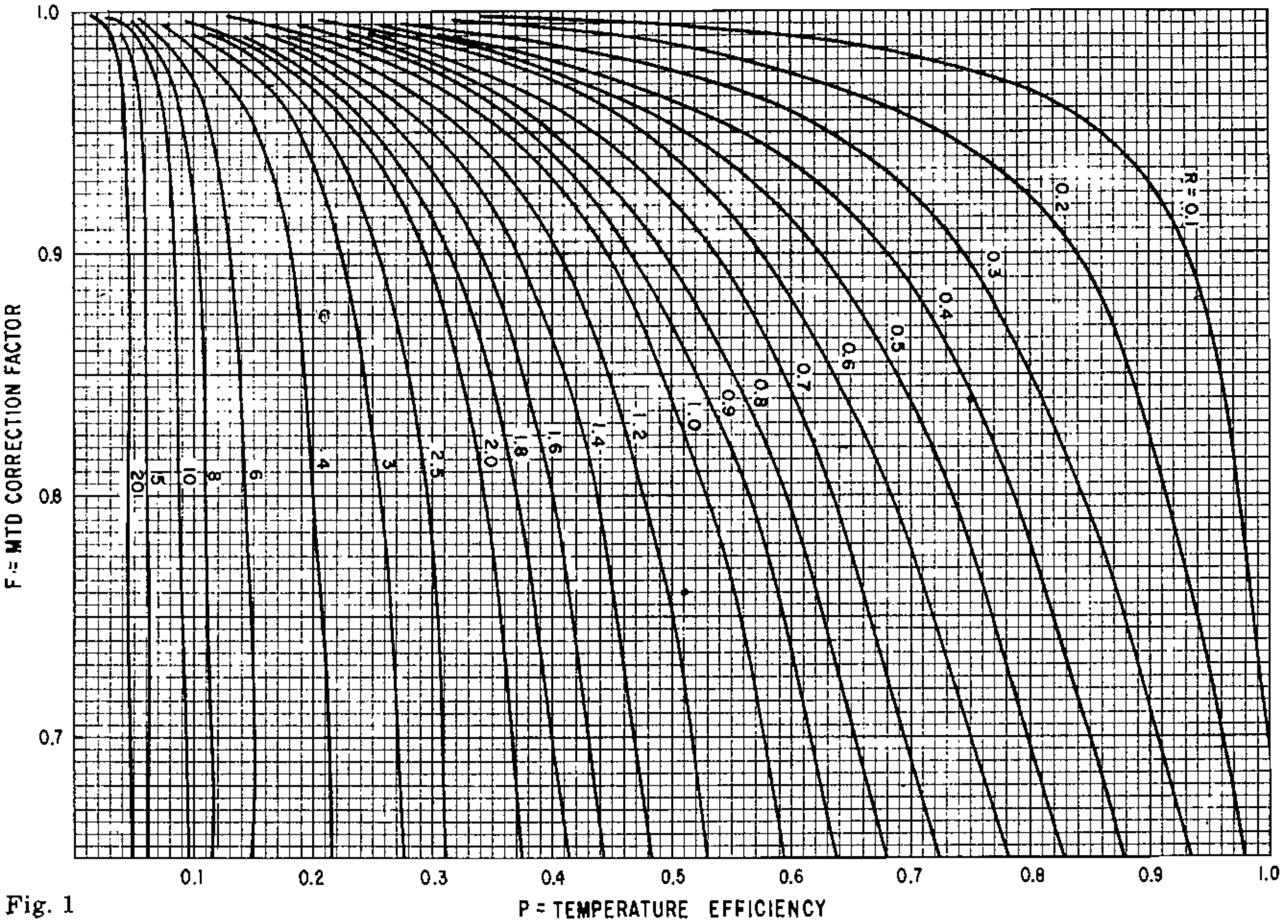
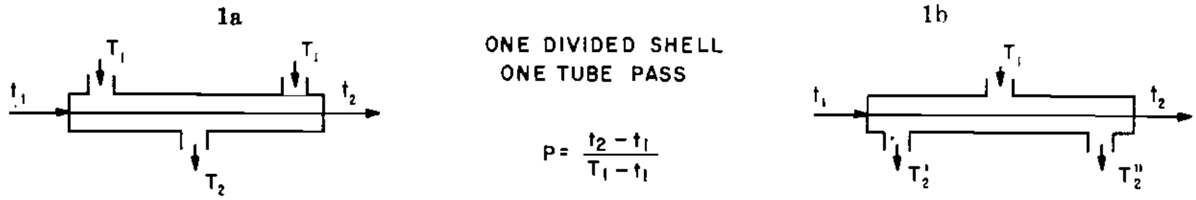


Fig. 1



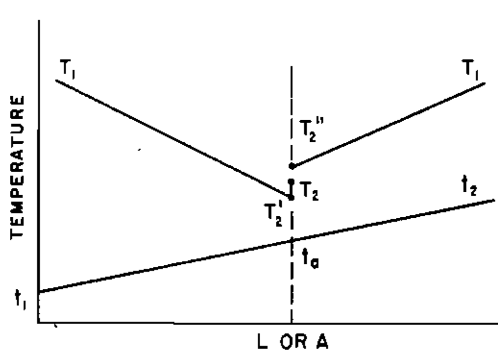


Fig. 2

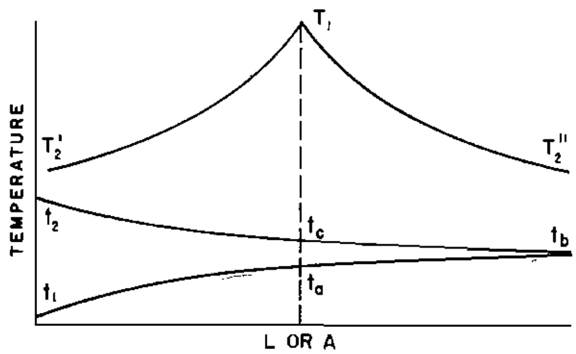


Fig. 3

Usually two trials of t_b are sufficient.

The usual equation for weighting LMTDs is

$$\frac{Q}{\sum\left(\frac{\text{zone duty}}{\text{zone LMTD}}\right)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

Because the tube temperature drop is directly proportional to the heat transferred, the LMTDs for two-tube passes may be weighted by the following equation:

$$\frac{t_2 - t_1}{\frac{t_b - t_1}{(LMTD)_L} + \frac{t_2 - t_b}{(LMTD)_u}} = \Delta t_m \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

Let's take an example and follow it through the procedure.

EXAMPLE: The shell fluid cools from 140 F to 100 F and the tube fluid heats up from 80 F to 100 F.

The procedure is...

1. Assume a value of t_b. A good first try is $t_b = t_1 + 0.6\ (t_2 - t_1)$ $\quad t_b = 80 + 0.6\ (20) = 92$

2. Calculate the LMTD in the lower tube pass by using Fig. 1.

HOT FLUID		COLD FLUID		DIFF.
140	−	92	=	48
100	−	80	=	20
LMTD = 32		R = 3.33		P = 0.2

From. Fig. 1, F = 0.92

$$\Delta t_m = LMTD \times F = 32 \times 0.92 = 29.4$$

3. Calculate the LMTD in the upper tube pass using Fig. 1.

HOT FLUID		COLD FLUID		DIFF.
140	−	100	=	40
100	−	92	=	8
LMTD = 19.9		R = 5		P = 0.167

From Fig. 1, F = 0.845

$$\Delta t_m = LMTD \times F = 19.9 \times 0.845 = 16.8$$

4. Calculate t_b. Since temperature rise in each pass is proportional to its LMTD:

$$t_b = t_1 + \frac{(t_2 - T_1)\ (LMTD)_1}{(LMTD)_1 + (LMTD)_u}$$

$$= 80 + \frac{29.4 \times 20}{29.4 + 16.8} = 92.7$$

5. If t_b doesn't check assumed value, recalculate one tube pass LMTD using the last t_b.

Assumed $t_b = 92.0$, calculate $t_b = 92.7$

Using $t_b = 92.7$

Upper $\Delta t_m = 28.8$ and lower $\Delta t_m = 16.4$

6. Calculate the corrected LMTD by Eq. 17.

$$\Delta t_m = \frac{t_2 - t_1}{\left[\frac{t_b - t_1}{(LMTD)_L}\right] + \left[\frac{t_2 - t_b}{(LMTD)_u}\right]} = \frac{20}{\frac{12.7}{28.8} + \frac{7.3}{16.4}} = 22.6$$

Using this example, the different Δt_m's would stack up as follows:

Normal 1-2 flow	23.3
Divided Flow	
One-tube pass	24.0
Multi-tube pass	22.6

How does this correction factor compare with that of a normal one-shell pass, two-tube pass correction?

At the highest values of R — 10 and 20 — the two are the same. As the values of R decrease below 10, the divided flow correction becomes progressively higher than the normal 1-2 correction.

It has been customary to use a normal 1-2 correction for one-tube pass, divided flow. While this is accurate at high values of R, it is quite conservative at very low values of R. For example:

when R = 0.1 and P = 0.92

F = 0.8 for normal 1-2 flow

F = 0.915 for one-tube pass, divided flow

Whether the nozzles are arranged as in Fig. 1a or Fig. 1b will make no difference in the correction factor. ■

Pressure Vessel Arrives At Refinery From Steel Plant

■ Huge pressure vessel — 131 ft long and 17½ ft in diameter — is cautiously moved through entrance to Tidewater Oil Co.'s Avon, Calif., refinery on a 78-wheel heavy duty rig. Rear truck unit has independent steering to help negotiate turns. The vessel, one of 12 to be utilized in refinery expansion, was loaded on rig at Kaiser Steel's Napa plant, where it was fabricated, then carried on a barge to the Avon plant. ■