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Prediction of Number of Shells and Log Mean Temperature Difference Correction Factor of Shell and Tube Heat Exchangers

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***Abstract:*-- This research study aims to predict LMTD Correction factor F and the number of shells needed to design a shell and tube, heat exchanger. There are various available approaches for heat exchanger analysis like LMTD, and effectiveness ε are two of these. Traditional analysis methods use heat exchanger charts to evaluate the expressions for Log Mean Temperature Difference (LMTD) Correction Factor' F' because it is difficult to calculate. In addition, these charts are limited to only one type of heat exchanger and are greatly nonlinear. The LMTD correction factor 'F' is challenging to read in regions of a steep slope. An analytic approach to determining LMTD correction factor 'F' is presented in this study, utilizing two non-dimensional parameters (P, W, G and R). By considering multi-pass shell and tube heat exchangers with any number of shell passes and even the number of tube passes per shell, a single algebraic equation is derived that specifies the LMTD correction factor for all of these heat exchangers. To calculate the correction factor, we must first find the number of shells, N, and the heat exchanger terminal temperatures, T. The new equation gives the value of 'F' calculated by the graph to agree with the value calculated from the equation. A set of equations have been derived to predict suitable the number of shells for a suitable correction factor 'F' and terminal temperatures of the shell tube heat exchanger.**

Index Terms:- Analytical and computation Anlysis, LMTD, correction factor, shell and tube heat exchanger, Analytical and graphical Methods.

1. INTRODUCTION

Heat exchangers are now used in almost every industry and process-engineering sector for reusing heat (Q) from process streams. Heat exchangers are commonly used in power plants, refrigeration systems, and air-conditioning systems, but they can also be found in various other industries, including chemical, nuclear, petroleum, cryogenic, and others[1]. Heat exchangers come in a wide range of shapes and sizes. An energy-generating fertiliser condenser, which can handle hundreds of megawatts of heat, or an electronic chip cooler, which can only transfer a few watts of thermal energy, can have a vast to minuscule energy transfer capacity[2]. As a result, the LMDT correction factor is required when designing the shell and tube heat exchanger to estimate the LMDT and Number of Shells.

1.1 Multi shell and tube heat exchangers.

Apart from the fluid flow in the tubes, the fluid that flows in the tubes of this type of exchanger is referred to as tube-side fluid[3]. According to the literature, the tube bundle is placed inside the shell, and baffles increase heat transfer by adding fluid to the shell when the flow is turbulent. [4]. This study increases the heat transfer rate between two streams while also increasing the surface area of contact. Industrial heat exchangers and some process plants commonly use multiple shell heat exchangers[5]. A multi-shell heat exchanger or multi-tube heat exchanger is used for various applications and required to power plants when multiple shells and tubes are used in the heat exchanger and used in different industries[6]. The graphic language travels from the shell to the tube bundle, across the tube bundle, and back to the shell[7][1][2][3][4][5]. The length of the tubes can be increased by using a single shell heat exchanger. The number of tubes increases, but this arrangement is unworkable. Because of the higher drop pressures and costs, this is possible. The shells are connected sequentially in a sequential connection; the shells are connected simultaneously in a parallel connection. It makes its way across the shells one by one—the consistency of the flow. There is a counterflow pattern as well as a parallel flow pattern in this. Life abounds in these liquids.

Both parallel and counter flow structures are present in the combination of shell and tube heat exchanger. As a result, a correction factor in the general heat equation must include the 'F' constant; the general heat equation is modified. Take a look at the formula Q = UA (F) LMTD. The number of errors determines the 'F' factor and also required to estimate the LMDT. Both the heat exchanger shells and tubes in the heat exchanger and terminal temperatures were predicted and

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used. The amount of heat is transferred and determined by the different types of heat exchangers and predicts the design requirements like LMDT and shells. In a multi-shell heat exchanger, having multiple shell-pass heat exchangers is critical. Everyone must estimate the number of shells when using the design correction factor F.

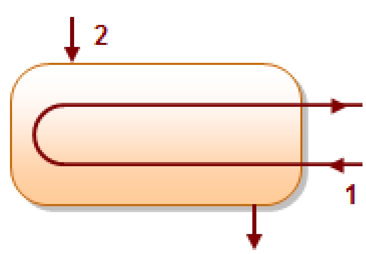
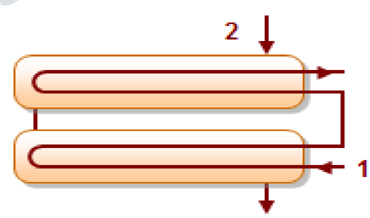
The amount of heat transfer has required for the computation of the correction factor and calculation of shells. Some iterative steps have been taken so far; alternative techniques for determining the number of shells and tubes are available, but they are difficult and time-consuming. It is possible to estimate 'U' as a whole and each of its constituent parts. The LMTD and the terminal heat transfer coefficients have a strong relationship. Single-pass heat exchangers do not represent actual temperature diversion accurately. To accurately calculate the mean temperature difference, follow these steps: A counterflow heat exchanger's terminal temperature is the same as its LMTD.

To multiply the number for the exchanger in question, a correction factor is used. F cannot be more than one. It maintains the proper temperature differential between the heat exchanger and the cooler. It was being looked into. Table 1 shows the heat exchanger's deviation from the ideal, which indicates its condition.

Table 1 Inlet and outlet temperature of different configuration of shell and Tube exchanger

SL.No	T1	T2	t1	t2	R	P	LMDT	F	LMDTc
1S2T	40	80	150	100	1.25	0.3636	64.8716	0.9149	59.3520
2S4T	40	80	150	100	1.25	0.3636	64.8716	0.9799	63.5656
3S6T	40	80	150	100	1.25	0.3636	64.8716	0.9911	64.2965
4S8T	40	80	150	100	1.25	0.3636	64.8716	0.9950	64.5491
5S10T	40	80	150	100	1.25	0.3636	64.8716	0.9968	64.6655
6S12T	40	80	150	100	1.25	0.3636	64.8716	0.9978	64.7286

Table 1 shows that LMDT correction factor and corrected values and graphs are shown in Figure 5 and used to multiply the number for the exchanger under consideration. F must less than one. It keeps the temperature of hot fluid and inlet temperature of cooled fluid maintain the constant and differential between the heat exchanger and the cooler at the proper level. 1S2T IS one shell and 2 tube like shell and tube are varying and shown in Table 1. It was being investigated. The heat exchanger's deviation from the ideal indicates its condition and shown in Table 1

Shell and Tube Heat Exchanger	Shell and Tube Heat Exchanger
 a) 1 Shell and 2 Tube Heat Exchanger(1S2T)	 b) 2 Shell and 4 Tube Heat Exchanger (2S4T)

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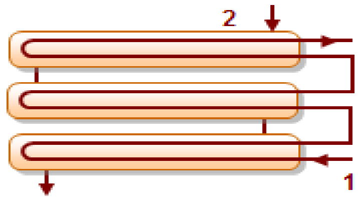
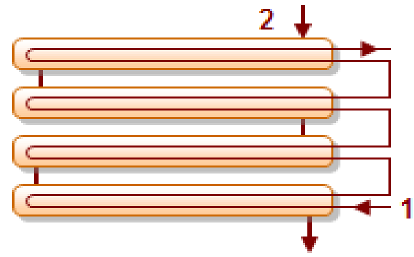
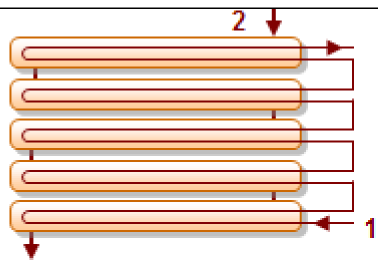


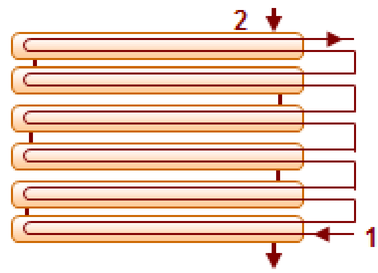
c) 3 Shell and 6 Tube Heat Exchanger(3S6T)



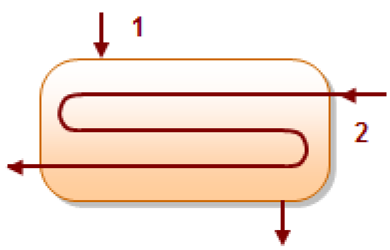
d) 4 Shell and 8tube Heat Exchanger(AS8T)



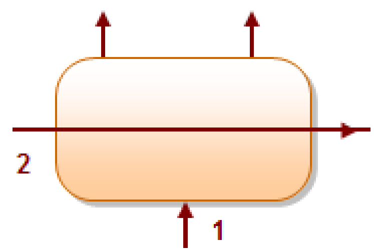
e) 5 Shell and 10tube Heat Exchanger(5S10T



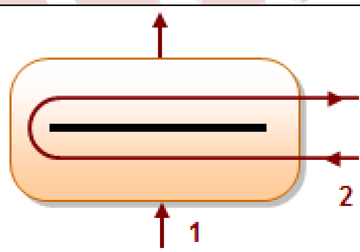
f) 6shell and 12 Tube Heat Exchanger(6S12T)



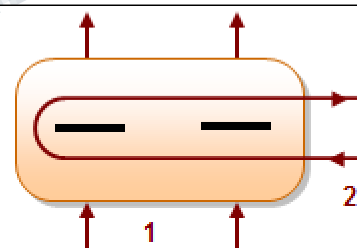
G)1shell and 3 Tube Heat Exchanger (1S3T)



g) 1shell and 1 Tube Heat Exchanger (1S1T)



I) 1shell and 2 Tube Heat Exchanger(1S2T with turbulent generator)



J) 1shell and 2 Tube Heat Exchanger (1S2T with two turbulent generator)

Figure 1 Types of Shell and Tube Heat Exchangers (a to J

2.0 CORRECTION FACTOR

2.1 Mathematical Modelling of Correction factor F

Comprehensive literature is available to calculate the Log Mean Temperature Difference correction factor used in the analysis of heat exchangers. In their pioneering paper, Bowman et al. [12] investigated the available data and presented a series of equations and charts to determine F for different heat exchangers and including multi-shell and tube ones. They expressed the correction factor F in terms of two non-dimensional variables, P and R, that are defined as

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$$P=\frac{t_2-t_1}{T_1-t_1}$$

$$R=\frac{T_1-T_2}{t_2-t_1}$$

$$F_{1-2}=\frac{\sqrt{R^2+1}}{(R-1)}\frac{\left(\ln\frac{1-P_{1,2}}{1-P_{1,2}R}\right)}{\ln\left(\frac{\frac{2}{P_{1,2}}-1-R+\sqrt{R^2+1}}{\frac{2}{P_{1,2}}-1-R-\sqrt{R^2+1}}\right)}$$

$$F_{2-4}=\frac{\sqrt{R^2+1}}{(R-1)}\frac{\left(\ln\frac{1-P_{2,4}}{1-P_{1,2}R}\right)}{\ln\left(\frac{\frac{2}{P_{2,4}}-1-R+\frac{2}{P_{2,4}}\sqrt{(1-P_{2,4})(1-P_{2,4})}+\sqrt{R^2+1}}{\frac{2}{P_{1,2}}-1-R+\frac{2}{P_{2,4}}\sqrt{(1-P_{2,4})(1-P_{2,4})}-\sqrt{R^2+1}}\right)}$$

Figure 2 Mathematical Modeling of Correction factor Shell and Tube Heat Exchangers

$P=\frac{t_2-t_1}{T_1-t_1}$ and $R=\frac{T_1-T_2}{t_2-t_1}$ (1)

They provided equations for correction factor F, for one shell-two tube pass exchanger and two-shell – four-tube pass exchanger. They also provided charts for determining the correction factor for two, four, six shell passes and multiple tubes passes. They have given an equation to calculate P for an N shell-side, and 2N tube-side passes (PN,2N) in terms of P for a one-shell-side, and two-tube side passes (P1,2) and R. Fakheri [10] [3] in his recent paper introduced two new non-dimensional variables, which are defined as. They provided equations for correction factor F, for one shell-two tube pass exchanger and two-shell – four-tube pass exchanger. They also provided charts for determining the correction factor for two, four, six shell passes and multiple tubes passes. They have given an equation to calculate P for an N shell-side, and 2N tube-side passes (PN,2N) in terms of P for a one-shell-side, and two-tube side passes (P1,2) and R. Fakheri [10] [13] in his recent paper introduced two new non-dimensional variables, which are defined

$$\rho=\frac{T_1-t_2}{T_2-t_1}, \qquad (2)$$

$$\emptyset=\frac{\sqrt{(T_1-T2)^2-\sqrt{(t_2-t_1)^2}}}{2[(T_1-T_2)-(t_1-t_2)]} \qquad (3)$$

He used these two variables for heat exchanger analysis and presented correlations to determine F in these two parameters for single shell and tube heat exchanger.

3.1 Analysis for the determination of LMTD correction factor

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Analysis for the determination of LMTD correction factor-F

$$F_{1-2} = \frac{\sqrt{R^2+1}}{(R-1)} \frac{\left(\ln\frac{1-P_{1,2}}{1-P_{1,2}R}\right)}{\ln\left(\frac{\frac{2}{P_{1,2}}-1-R+\sqrt{R^2+1}}{\frac{2}{P_{1,2}}-1-R-\sqrt{R^2+1}}\right)}$$

$$F_{2-4} = \frac{\sqrt{R^2+1}}{(R-1)} \frac{\left(\ln\frac{1-P_{2,4}}{1-P_{1,2}R}\right)}{\ln\left(\frac{\frac{2}{P_{2,4}}-1-R+\frac{2}{P_{2,4}}\sqrt{(1-P_{2,4})(1-P_{2,4})}+\sqrt{R^2+1}}{\frac{2}{P_{1,2}}-1-R+\frac{2}{P_{2,4}}\sqrt{(1-P_{2,4})(1-P_{2,4})}-\sqrt{R^2+1}}\right)}$$

$$F_{2-4} = \frac{\sqrt{R^2+1}}{(R-1)} \frac{\left(\ln\frac{1-P_{2,4}}{1-P_{1,2}R}\right)}{\ln\left(\frac{\frac{2}{P_{2,4}}-1-R+\frac{2}{P_{2,4}}\sqrt{(1-P_{2,4})(1-P_{2,4})}+\sqrt{R^2+1}}{\frac{2}{P_{1,2}}-1-R+\frac{2}{P_{2,4}}\sqrt{(1-P_{2,4})(1-P_{2,4})}-\sqrt{R^2+1}}\right)}$$

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

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

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

$$F_{N,2N}=\frac{\frac{\sqrt{R^2+1}}{(R-1)}\ln 1-\left[\frac{1-P_{N,2N}R}{1-P_{N,2N}}\right]^{\frac{1}{N}}}{\left[\frac{1+\left[\frac{1-P_{N,2N}R}{1-P_{N,2N}}\right]^{\frac{1}{N}}-\frac{\sqrt{R^2+1}}{(R-1)}+\frac{\sqrt{R^2+1}}{(R-1)}\left[\frac{1-P_{N,2N}R}{1-P_{N,2N}}\right]^{\frac{1}{N}}}{1+\left[\frac{1-P_{N,2N}R}{1-P_{N,2N}}\right]^{\frac{1}{N}}+\frac{\sqrt{R^2+1}}{(R-1)}-\frac{\sqrt{R^2+1}}{(R-1)}\left[\frac{1-P_{N,2N}R}{1-P_{N,2N}}\right]^{\frac{1}{N}}}\right]}$$

$$F_{N,2N}\frac{\tau\ln[W]^{1/N}}{\ln\left[\frac{1+[W]^{1/N}-\tau+\tau[W]^{1/N}}{1+[W]^{1/N}+\tau-\tau[W]^{1/N}}\right]}$$

For R=1 , $F_{N,2N} = \sqrt{2}\,\frac{P_{N,2N}}{N-NP_{N,2N}}\,\frac{1}{\ln\left[\frac{\left[\frac{N-NP_{N,2N}}{P_{N,2N}}\right]+\frac{1}{\sqrt{2}}}{\left[\frac{N-NP_{N,2N}}{P_{N,2N}}\right]-\frac{1}{\sqrt{2}}}\right]}$, $F_{N,2N} = \sqrt{2W^1}\frac{1}{\ln\left[\frac{\frac{1}{W^1}+\frac{1}{\sqrt{2}}}{\frac{1}{W^1}-\frac{1}{\sqrt{2}}}\right]}$

Figure 3 Analysis for the determination of LMTD correction factor F

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Kern [20] provides correction factor charts for if a number of shells and even number of tube passes. He presented the correction factor F as a function of two variables, R and S, which depends on the inlet and exit temperatures of the heat exchanger of both the fluids. Roetzel and Nicole [11] recognized the potential usefulness of explicit representations of LMTD Correction factors in developing computerized packages for heat exchanger design. Taborek [12] interpreted the above parameters P and R as the capacity ratio and a measure of heat exchanger effectiveness. Tucker [13] recently discovered an error in one of the charts for the cross flow heat exchangers correction factor. He found that for a cross-flow heat exchanger with a capacity ratio of unity (R=1) and P=0.6, the LMTD correction factor F read off the chart is 3 per cent and powerful combination of low values of R and values of P approaching unity the error is considerably greater. Wales [14] defined correction factor by introducing a new parameter Gas

$$G = \frac{T_2 - t_2}{T_1 - t_1}, \qquad (4)$$

Bowman et al. [2] developed an equation to determine correction Factor 'F' for two shells and four tube pass heat exchanger; besides that, they also presented a series of charts to determine the correction factors for various arrangements of shell and even number of tube passes. To express F, they have chosen two non-dimensional variables. The above two variables are interpreted as the capacity ratio and a measure of heat exchanger effectiveness. Reading of charts for the determination of F, particularly in the steep regions of the curves, reduces the accuracy. The present analysis is to derive a single expression. Determination of correction factor F, for any shell and multiple of the tube, passes. The breakthrough paper by Bowman et al. [2] provided the following expression to determine the correction factor for the shell, and tube heat exchangers with one shell and two tubes pass exchangers as

$$F_{1-2} = \frac{\sqrt{R^2+1}}{(R-1)} \frac{\left(ln\frac{1-P_{1,2}}{1-P_{1,2}R}\right)}{ln\left(\frac{\frac{2}{P_{1,2}}-1-R+\sqrt{R^2+1}}{\frac{2}{P_{1,2}}-1-R-\sqrt{R^2+1}}\right)} \qquad (5)$$

$$F_{2-4} = \frac{\sqrt{R^2+1}}{(R-1)} \frac{\left(ln\frac{1-P_{2,4}}{1-P_{1,2}R}\right)}{ln\left(\frac{\frac{2}{P_{2,4}}-1-R+\frac{2}{P_{2,4}}\sqrt{(1-P_{2,4})(1-P_{2,4})}+\sqrt{R^2+1}}{\frac{2}{P_{1,2}}-1-R+\frac{2}{P_{2,4}}\sqrt{(1-P_{2,4})(1-P_{2,4})}-\sqrt{R^2+1}}\right)} \qquad (6)$$

Bowman et al. [2] also showed that Eq. (5) could also be used for N shell 2N tube pass exchanger provided P1,2 is related to the P for a multi-shell multi-tube heat exchanger (PN,2N) by the following expression

$$P_{N,2N} = \frac{1-\left[\frac{1-P_{1,2}\ R}{1-P_{1,2}}\right]^N}{R-\left[\frac{1-P_{1,2}\ R}{1-P_{1,2}}\right]^N} \qquad (7)$$

$$\left[\frac{1-P_{1,2}\ R}{1-P_{1,2}}\right]^N = \left[\frac{1-P_{N,2N}\ R}{1-P_{N,2N}}\right]^N \qquad (8)$$

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

Substituting Eq. (5) into Eq. (6) and after simplification

$$F_{N,2N} = \frac{\frac{\sqrt{R^2+1}}{(R-1)}\ ln1-\left[\frac{1-P_{N,2N}\ R}{1-P_{N,2N}}\right]^{\frac{1}{N}}}{\left[\frac{1+\left[\frac{1-P_{N,2N}\ R}{1-P_{N,2N}}\right]^{\frac{1}{N}}-\frac{\sqrt{R^2+1}}{(R-1)}+\frac{\sqrt{R^2+1}}{(R-1)}\left[\frac{1-P_{N,2N}\ R}{1-P_{N,2N}}\right]^{\frac{1}{N}}}{1+\left[\frac{1-P_{N,2N}\ R}{1-P_{N,2N}}\right]^{\frac{1}{N}}+\frac{\sqrt{R^2+1}}{(R-1)}-\frac{\sqrt{R^2+1}}{(R-1)}\left[\frac{1-P_{N,2N}\ R}{1-P_{N,2N}}\right]^{\frac{1}{N}}}\right]} \qquad (10)$$

Substituting W of Eq.10 in place of $W = \frac{1-P_{N,2N}\ R}{1-P_{N,2N}}$

$$F_{N,2N}\ \frac{\tau ln[W]^{1/N}}{ln\left[\frac{1+[W]^{1/N}-\tau+\tau[W]^{1/N}}{1+[W]^{1/N}+\tau-\tau[W]^{1/N}}\right]} \qquad (11)$$

Eq. (11) is used to determine the LMTD correction factor in case N shells 2N tube pass heat exchanger. The correction factor is a function of two variables W, Γ which are in turn functions of the terminal temperatures of the heat exchanger.

Special Case For R=1 Eq. (2 and 3) becomes indeterminate

$$\lim_{R\to1} F_{1-2} = \lim_{R\to1} \frac{\sqrt{R^2+1}}{ln\left(\frac{\frac{2}{P_{1,2}}-1-R+\sqrt{R^2+1}}{\frac{2}{P_{1,2}}-1-R-\sqrt{R^2+1}}\right)} \times \lim_{R\to1} \frac{\left(ln\frac{1-P_{1,2}}{1-P_{1,2}R}\right)}{(R-1)} \qquad (12)$$

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$$F_{1,2} = \frac{\frac{\sqrt{2}P_{1,2}}{(1-P_{1,2})}}{\left[\frac{\frac{2}{P_{1,2}}-2+\sqrt{2}}{\frac{2}{P_{1,2}}-2-\sqrt{2}}\right]} \quad (13)$$

$$F_{2-4} = \frac{\sqrt{R^2+1}}{(R-1)}\frac{\left(ln\frac{1-P_{2,4}}{1-P_{1,2}R}\right)}{ln\left(\frac{\frac{2}{P_{2,4}}-1-R+\frac{2}{P_{2,4}}\sqrt{(1-P_{2,4})(1-P_{2,4})}+\sqrt{R^2+1}}{\frac{2}{P_{1,2}}-1-R+\frac{2}{P_{2,4}}\sqrt{(1-P_{2,4})(1-P_{2,4})}-\sqrt{R^2+1}}\right)} \quad (14)$$

By rearranging Eq. (3)

$$F_{N.2N} = \frac{(1-P_{1,2})^N-(1-P_{1,2}R)^N}{R(1-P_{1,2})^N-(1-P_{1,2}R)^N} \quad (15)$$

$$\lim_{R\to1} P_{N.2N} = \lim_{R\to1}\frac{(1-P_{1,2})^N-(1-P_{1,2}R)^N}{R(1-P_{1,2})^N-(1-P_{1,2}R)^N} \quad (16)$$

$$P_{N.2N} = \frac{N(P_{1,2})}{(1-P_{1,2})^N+N(P_{1,2})} \quad (17)$$

$$P_{N.2N} = \frac{(P_{N,2N})}{(N-P_{N,2N})^N+(P_{N,2N})} \quad (18)$$

By substituting Eq. (10) into Eq.

$$F_{N,2N} = \sqrt{2}\,\frac{P_{N.2N}}{N-NP_{N.2N}}\,\frac{1}{ln\left[\frac{\left[\frac{N-NP_{N.2N}}{P_{N.2N}}\right]+\frac{1}{\sqrt{2}}}{\left[\frac{N-NP_{N.2N}}{P_{N.2N}}\right]-\frac{1}{\sqrt{2}}}\right]} \quad (19)$$

$$F_{N,2N} = \sqrt{2W^1}\,\frac{1}{ln\left[\frac{\frac{1}{W^1}+\frac{1}{\sqrt{2}}}{\frac{1}{W^1}-\frac{1}{\sqrt{2}}}\right]} \quad (20)$$

3.2 Analysis for the determination of the number of shells (N)

Industries require multi-shell heat exchangers in order to carry out the required heat transfer processes.

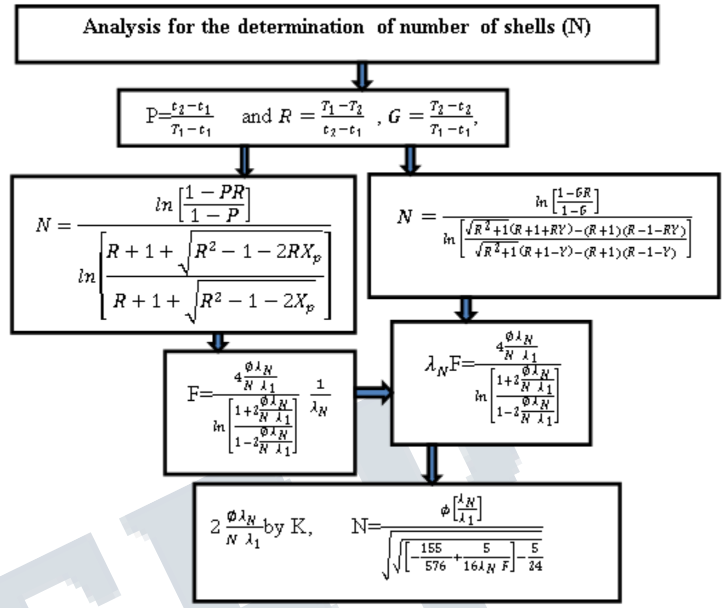

Figure 4 **Analysis for the determination of the number of shells (N)**

The designer has to design a heat exchanger for a specified design value of 'F'. When multi-shell arrangements are necessary, it requires estimating the number of shells that are required. Several methods are available so far for determining the number of shells. However, all these are iterative methods, and values are to be assumed for some factors. To select the values for these factors, there is no definite criterion. Traditionally a tedious trial and error procedure is used in which the number of shells is changed continuously, and a new F value is determined until a required solution is arrived at. Ahmad et al. [1] gave an analytical expression for calculating the number of shells directly

$$N = \frac{ln\left[\frac{1-PR}{1-P}\right]}{ln\left[\frac{R+1+\sqrt{R^2-1-2RX_p}}{R+1+\sqrt{R^2-1-2X_p}}\right]} \quad (21)$$

Using Eq. (21), the designer has to assume a value for Xp to determine the number of shells. Then F can be determined, and Xp should be modified to get the required value of F, in an iterative process.Gulyani [6] proposed another equation to determine the number of shells. He used another parameter Y.

$$N = \frac{ln\left[\frac{1-GR}{1-G}\right]}{ln\left[\frac{\sqrt{R^2+1}(R+1+RY)-(R+1)(R-1-RY)}{\sqrt{R^2+1}(R+1-Y)-(R+1)(R-1-Y)}\right]} \quad (22)$$

In Eq. (22), some value is attributed to (Y must be assumed some value) determine the number of shells. In this process also Y should be changed iteratively to determine the desired F. Fakheri [10] [4] developed a general expression for determining the correction factor F, in terms of a number of shells (N) and non-dimensional parameters φ, λ N , λ1, which depends on the inlet and exit temperatures of both the fluids. This single expression, which is a simple form, can determine the correction factor of multi-pass shell and tube heat exchangers with any number of shell passes and even the number of tube passes per shell. The equation for correction Factor, F developed as

$$F=\frac{4\frac{\emptyset}{N}\frac{\lambda_N}{\lambda_1}}{ln\left[\frac{1+2\frac{\emptyset}{N}\frac{\lambda_N}{\lambda_1}}{1-2\frac{\emptyset}{N}\frac{\lambda_N}{\lambda_1}}\right]}\ \frac{1}{\lambda_N} \quad (23)$$

Using Eq. (23), an approximate expression for determining the number of shells can be arrived at without using an iterative method. The equation for several shells: Eq. (23) can be rearranged as

$$\lambda_N F=\frac{4\frac{\emptyset}{N}\frac{\lambda_N}{\lambda_1}}{ln\left[\frac{1+2\frac{\emptyset}{N}\frac{\lambda_N}{\lambda_1}}{1-2\frac{\emptyset}{N}\frac{\lambda_N}{\lambda_1}}\right]} \quad (24)$$

By replacing equation (24) $2\frac{\emptyset}{N}\frac{\lambda_N}{\lambda_1}$ by K

Assuming $2\frac{\emptyset}{N}\frac{\lambda_N}{\lambda_1} \leq One$ and using Taylor's series of $ln\frac{1+K}{1-K}$, $15+5K^2+3k^4=\frac{15}{\lambda_N F}$, By Converting Eq(4.5) into polynomial form

$5\left[1-\frac{1}{\lambda_N F}\right]+\frac{5}{3}K^2+K^4=0$, This equation has two imaginary and two real roots; the real roots are

$2\frac{\phi}{N}\frac{\lambda_N}{\lambda_1}=\pm\sqrt{-\frac{5}{6}+\sqrt{\frac{25}{36}-5\left[1-\frac{1}{\lambda_N F}\right]}}$, Leaving negative sign, as K is positive By rearranging the terms of Eq. (4.7) on condition that the values in the
the square root is positive results that F≤ 1.125

$$N=\frac{\phi\left[\frac{\lambda_N}{\lambda_1}\right]}{\sqrt{\sqrt{\left[-\frac{155}{576}+\frac{5}{16\lambda_N F}\right]}-\frac{5}{24}}} \quad (25)$$

Using Eq. (25), N can be calculated for the given design value of F, φ can be calculated from terminal temperatures of the heat exchanger If the resultant N ≥ 2φ , If F ≤ 1.125 which is always true. The value calculated from Eq. 25 rounded to the nearest integer will give the number of shells for the specified correction factor. Eq. (25) is a direct and simple expression to determine the number of shells in a multi-shell tube heat exchanger. This equation avoids earlier iterative methods for the determination of the number of shells to meet the design correction factor for a multi-shell tube heat exchanger

4.0 Results and discussion

Based on analysis of LMDT correction factor and number of shell prediction for six different shell and tube heat exchangers. By considering the equations given in reference [2], a simplified expression for the correction factor F, in terms of non-dimensional parameters ‘W’ , Γ and number of shells N of the heat exchanger have been given through mathematical analysis. This expression can be used accurately to determine F's correction factor for a heat exchanger having any number of shells. So far, expressions for determining the correction factor for one shell and two shell heat exchangers are available. However, for heat exchangers having more than two shells, only charts are available. Charts are also drawn for heat exchangers having different shells. The correction factors obtained are almost equal to the values given in reference [2]. Comparison of results obtained from the new expression against the previous expression and shown in Figure 5 and calculated and graph values are tabulated from 2 to 7.

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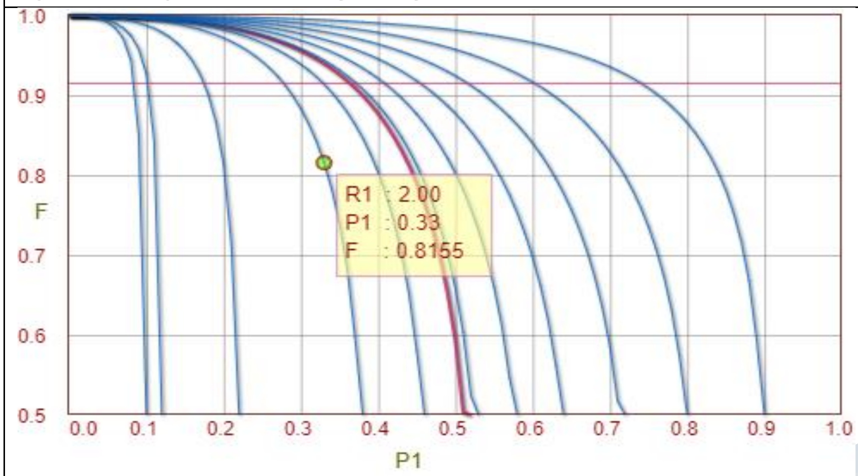
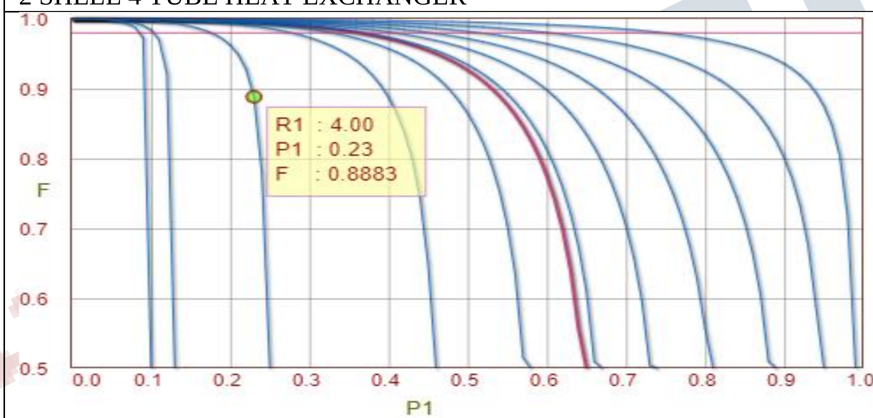
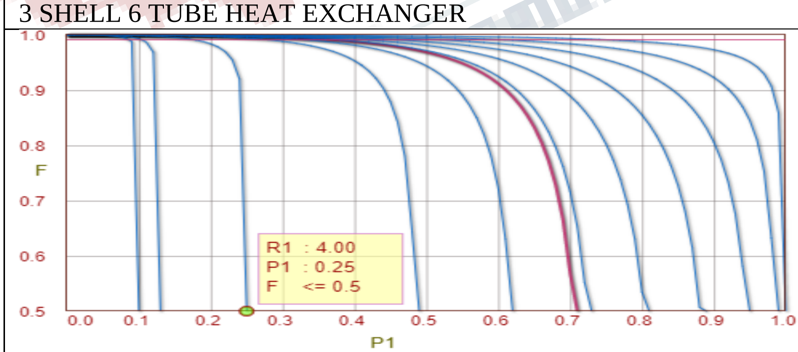
1SHELL 2 TUBE HEAT EXCHANGER	Experiments Data
	T1=40 ^{0}C T2=80 ^{0}C t1=150 ^{0}C t2=100 ^{0}C P=0.3636 R=1.25 LMDT=64.8716 ^{0}C F=0.9149 LMDTc=59.3520 ^{0}C
2 SHELL 4 TUBE HEAT EXCHANGER	Experiments Data
	T1=40 ^{0}C T2=80 ^{0}C t1=150 ^{0}C t2=100 ^{0}C P=0.3636 R=1.25 LMDT=64.8716 ^{0}C F=0.9799 LMDTc=63.5656 ^{0}C
3 SHELL 6 TUBE HEAT EXCHANGER	Experiments Data
	T1=40 ^{0}C T2=80 ^{0}C t1=150 ^{0}C t2=100 ^{0}C P=0.3636 R=1.25 LMDT=64.8716 ^{0}C F=0.9911 LMDTc=64.2965 ^{0}C
4 SHELL 8 TUBE HEAT EXCHANGER	Experiments Data

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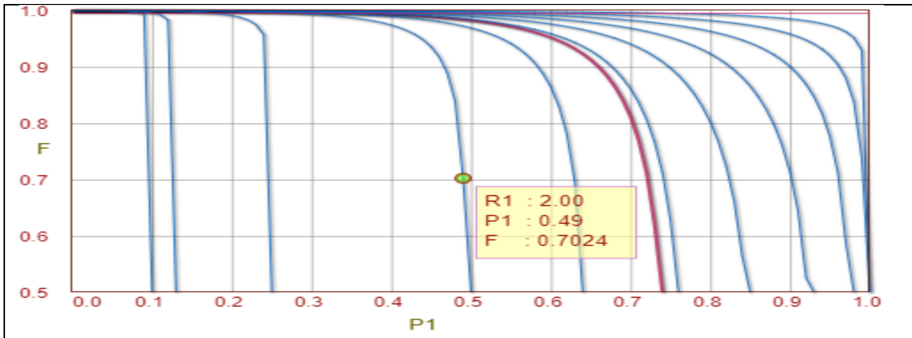
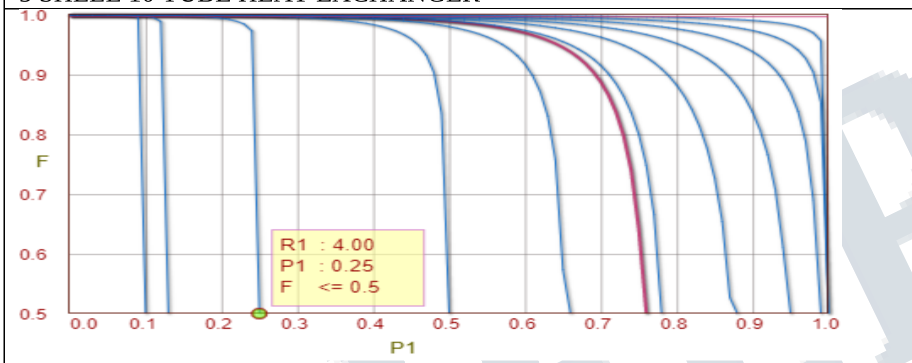
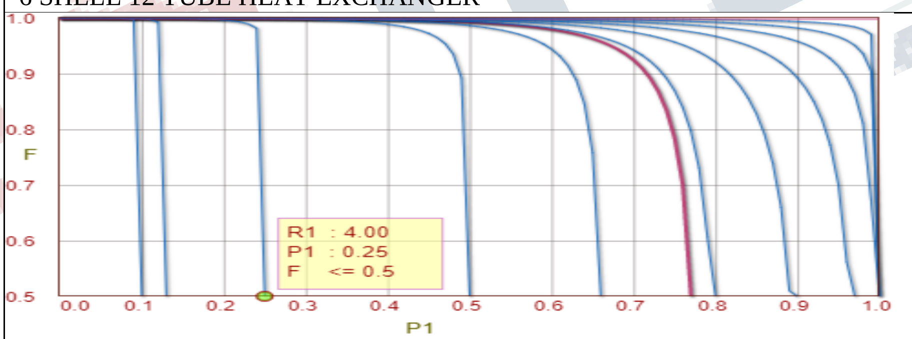
	$T1=40\ ^0C$ $T2=80\ ^0C$ $t1=150\ ^0C$ $t2=100\ ^0C$ P=0.3636 R=1.25 $LMDT=64.8716\ ^0C$ F=0.9950 $LMDTc=64.5491\ ^0C$
5 SHELL 10 TUBE HEAT EXCHANGER	Experiments Data
	$T1=40\ ^0C$ $T2=80\ ^0C$ $t1=150\ ^0C$ $t2=100\ ^0C$ P=0.3636 R=1.25 $LMDT=64.8716\ ^0C$ F=0.9968 $LMDTc=64.6655\ ^0C$
6 SHELL 12 TUBE HEAT EXCHANGER	Experiments Data
	$T1=40\ ^0C$ $T2=80\ ^0C$ $t1=150\ ^0C$ $t2=100\ ^0C$ P=0.3636 R=1.25 $LMDT=64.8716\ ^0C$ F=0.9978 $LMDTc=64.7286\ ^0C$

Figure 5 Shell and Tube heat exchanger LMDT correction factor comparisons

Figure 5 shows that variation of of LMDT correction factor and corrected values for one shell and two tubes and shell various from 1 to 6 shell and also tubes increase with 2 to 10 tubes. Results are obtained from graph and shown figure 5. The same approach used to predict the P and R-values changer and F calculated and compared with graph values and shown in table 2 to 7. The errors between the two values are negligible. From the above two comparisons, the new expression obtained in the present work is in agreement with graphs already existing in the literature. Hence a single expression is sufficient for any number of shells of the heat exchanger. Using this new expression for N, the designer can estimate the number of shells by adjusting the value obtained to its nearest integer. Calculation and graph value of Correction factor are tabulated in Table 2 to 7 From the tabl 1 P and R values various from different values and shown in table 1.

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Table2: Correction Factor for a two-shell heat four-tube exchanger

R=3.0		R=1.0		R=0.2	
P	F	P	F	P	F
0.321	0.50	0.730	0.50	0.999	0.50
0.320	0.56	0.600	0.89	0.980	0.71
0.280	0.92	0.50	0.95	0.90	0.93
0.200	0.98	0.40	0.98	0.80	0.97
0.150	0.99	0.30	0.99	0.50	0.99

Table3: Correction Factor for a three shell six-tube heat exchanger

R=3.0		R=1.0		R=0.4	
P	F	P	F	P	F
0.332	0.50	0.825	0.50	0.986	0.50
0.30	0.94	0.70	0.88	0.980	0.63
0.20	0.98	0.60	0.95	0.80	0.96
0.16	0.99	0.49	0.99	0.60	0.99

Calculation and graph value of Correction factor are tabulated in Table 2 to 7 From the tabl 3, P and R values various from different values and shown in table 3. R values decreased from 3 to 0.4 and used different P values and shown in table 3.

Table 4: Correction Factor for a four-shell eight-tube heat exchanger

R=2.5		R=1.0		R=0.6	
P	F	P	F	P	F
0.398	0.50	0.842	0.50	0.962	0.50
0.39	0.87	0.80	0.88	0.80	0.96
0.30	0.98	0.66	0.96	0.70	0.98
0.20	0.99	0.50	0.99	0.60	0.99

Table 5: Correction Factor for five shell ten tube heat exchanger

R=2.5			R=1.8			R=0.2	
P	F-Calculated	From Graph	P	F-Calculated	From Graph	P	F
0.3	0.948	0.93	0.40	0.9269	0.92	0.999	0.50
0.32	0.9345	0.92	0.43	0.91	0.88	0.980	0.71
0.35	0.851	0.84	0.45	0.83	0.82	0.90	0.93
0.37	0.685	0.70	0.47	0.7527	0.75	0.80	0.97

Table 6: Correction Factor for a six shell 12 tube heat exchanger

R=2.0			R=1.6			R=0.2	
P	F-Calculated	From Graph	P	F-Calculated	From Graph	P	F
0.42	0.934	0.93	0.50	0.926	0.92	0.999	0.50
0.45	0.878	0.87	0.52	0.90	0.88	0.980	0.71
0.46	0.842	0.85	0.55	0.832	0.82	0.90	0.93
0.47	0.78	0.76	0.57	0.7326	0.72	0.80	0.97

Calculation of LMDT correction factor and graph value of LMDT Correction factor are tabulated in Table 6 and 7. From the tabl 6 and 7, P and R values various from different values and shown in table 6 and 7. R values selected from 2.5 to 0.4 and different P values are used and shown in table 6and 7.

Table 7: Correction Factor for 2shell 4 tube heat exchanger comparison

R=1.0			R=0.8			R=0.2	
P	F-Calculated	From Graph	P	F-Calculated	From Graph	P	F
0.72	0.97	0.978	0.70	0.99	0.986	0.999	0.50
0.75	0.96	0.966	0.78	0.97	0.98	0.980	0.71
0.8	0.91	0.93	0.82	0.96	0.97	0.90	0.93
0.85	0.82	0.81	0.89	0.92	0.906	0.80	0.97

Prediction of LMDT correction factor and graph value of LMDT Correction factor are tabulated in Table 7. From the tabl 7, P and R values various from different values and shown in table 7 . R values selected from 1.0 to 0.2 and different P values are used and shown in table 7.

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5.0 Conclusions

Based on this analysis and with the help of computation and predicted given shell and tube heat exchangers. In this research study obtained, a new expression for determining Log Mean Temperature Difference Correction Factor F, in terms of two non-dimensional parameters P, R has been analyzed. This new expression presents a single equation to find out the correction factor F, precisely for any number of shells and even number of tube passes. Owing to the development of a new equation for F, reading of F from charts can be avoided. An approximate equation for estimating the number of shells for a design value of F has also been analyzed. This equation avoids earlier iterative methods used to determine the number of shells of a multi-shell tube heat exchanger to meet a given correction factor.

NOMENCLATURE

T1 = hot fluid inlet temperature, K
T2 = hot fluid outlet temperature, K
t1 = cold fluid inlet temperature, K
t2 = cold fluid outlet temperature, K
A = Surface, m^2
F = Correction factor, dimensionless
G ,R, P = Dimensionless quantity
LMTD = Log Mean Temperature Difference, K

$P = \frac{t_2 - t_1}{T_1 - t_1}$

$R = \frac{T_1 - T_2}{t_2 - t_1}$

$K = 2\frac{\emptyset \, \lambda_N}{N \, \lambda_1}$

$G = \frac{T_2 - t_2}{T_1 - t_1}$

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