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General procedure for effectiveness of complex assemblies of heat exchangers

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Abstract—A simple and systematic procedure is developed to determine the effectiveness and exit fluid temperatures of complex assemblies of identical heat exchangers. Three complex assemblies have been chosen to illustrate the procedure. The excellent agreements between the results of the procedure developed and those in the literature validate the procedure. Parametric studies, including those of coupling method, flow arrangement, ratio of heat capacity rates of both fluids, number of transfer units, and pass number, have been performed to investigate their effects on the effectiveness of assemblies with identical crossflow shell-and-tube heat exchangers. Moreover, the assembly with non-identical heat exchangers is also studied to examine the general applicability of the present procedure.

INTRODUCTION

COMPLEX assemblies of heat exchangers have been widely used in industry to provide high effectiveness and to meet space requirements. Each exchanger is termed as a pass of the resultant assembly. Many assemblies have been proposed in practical applications and three of them are presented in Fig. 1. These are termed as serial 1-*N*, serial 2-*N* and miscellaneous assemblies, respectively. To facilitate the presentation, crossflow shell-and-tube heat exchangers are chosen with solid lines denoting the flow path of the shell fluid and dashed lines that of the tube fluid. Due to the arbitrary characteristics of the coupling methods in these assemblies, it is necessary to develop a systematic procedure to evaluate their effectiveness before application.

By the matrix formulation, Domingos [1] proposed a general method to calculate the effectiveness and intermediate fluid temperatures in complex assemblies of heat exchangers. Pignotti [2] indicated that this method did not properly apply to all possible complex assemblies and proposed a generalized coupling scheme. Nevertheless, it is difficult to determine all coupling paths used in that scheme for very complex assemblies, making this scheme less attractive for practical application. For serial assemblies with identical passes, Gardner and Taborek [3] derived some relations which, with the functional form for effectiveness of a single pass heat exchanger, are used to find the effectiveness and temperature correction factors. It is applied to any number of passes for the serial 1-*N* assembly, but only even numbers of passes can be applied for the serial 2-*N* assembly. Chen and Tsai [4] developed a computational model to calculate the temperature correction factors for the serial 1-*N* assembly with any number of identical passes and those for the serial 2-*N* assembly with four identical passes. Due to complex mathematical manipulations required to determine the coefficients in the resultant polynomial, it is difficult to extend this model to other complex assemblies. Recently, Pignotti [5] established a simple relation between the thermal effectiveness of two heat exchanger configurations that differ from each other in the inversion of either one of the two fluids. Kandlikar and Shah [6] derived closed-form equations for plate heat exchangers with the number of thermal plates approaching infinity.

This work develops a simple and more systematic procedure to calculate the total effectiveness and outlet temperatures of both fluids at each pass for complex assemblies of heat exchangers. The assemblies shown in Fig. 1 are used to illustrate the application and validate this procedure. For these complex assemblies with identical crossflow shell-and-tube heat exchangers in which shell fluid is mixed and tube fluid is unmixed, effects of the ratio of heat capacity rates of fluids, *R*, number of transfer units, *Ntu*, flow arrangement, coupling method, and pass number on the effectiveness of these complex assemblies are also presented and discussed for the thermal design and evaluation of these complex assemblies.

THEORETICAL ANALYSIS

It is assumed that each fluid is completely mixed between passes and *R* is identical for each pass. During the formulation, passes are numbered along the flow path of shell fluid. The thermal effectiveness, *P*, of each fluid is defined as

$$P_t = \frac{T_{t,o} - T_{t,i}}{T_{s,i} - T_{t,i}} \qquad (1a)$$

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NOMENCLATURE

A_{ij}	elements of coefficient matrix defined in equation (19)
A	total heat transfer area of a complex assembly [m^2]
$\{B\}$	column matrix with unity elements
C	heat capacity rate of fluid [W K^{-1}]
E	effectiveness
F	temperature correction factor
j	pass index, $j = 1, 2, 3, \ldots, N$
M	non-dimensionalized inlet temperature difference defined in equation (3)
N	total pass number
Ntu	number of transfer units, $UA/C_{\min}$
n	zero and positive integers
O	non-dimensionalized temperature defined in equation (4)
P	thermal effectiveness defined in equation (2)
R	C_t/C_s
r	normalized mean temperature difference
$T(T_s)$	temperature of shell fluid [K]
$t(T_t)$	temperature of tube fluid [K]
U	overall heat transfer coefficient [W m^2 K^{-1}].

Superscript

j	jth pass.

Subscripts

i	inlet
j	jth pass
min	minimum
o	outlet
s	shell
t	tube
1	first pass.

$$P_s = \frac{T_{s,i} - T_{s,o}}{T_{s,i} - T_{t,i}}. \tag{1b}$$

It is clear that $P_s = RP_t$. In particular, P_t of the jth pass, $P_{t,j}$, is defined as

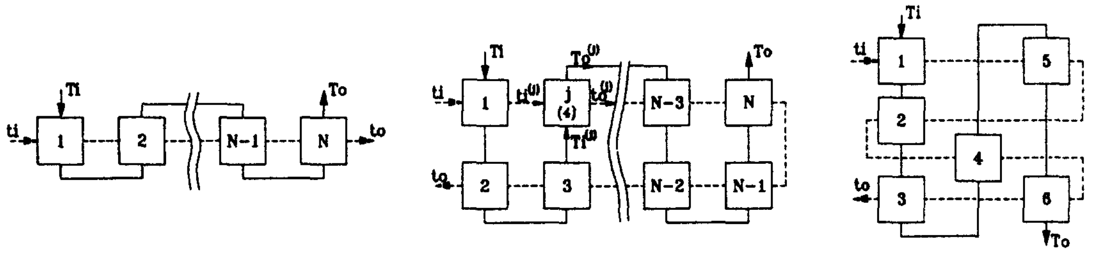
$$P_{t,j} = \frac{T^{(j)}_{t,o} - T^{(j)}_{t,i}}{T^{(j)}_{s,i} - T^{(j)}_{t,i}} \tag{2}$$

and $P_{s,j} = RP_{t,j}$. The non-dimensionalized inlet temperature difference between the shell and tube fluids of the jth pass, M_j, is defined as

$$M_j = \frac{T^{(j)}_{s,i} - T^{(j)}_{t,i}}{T_{s,i} - T_{t,i}}. \tag{3}$$

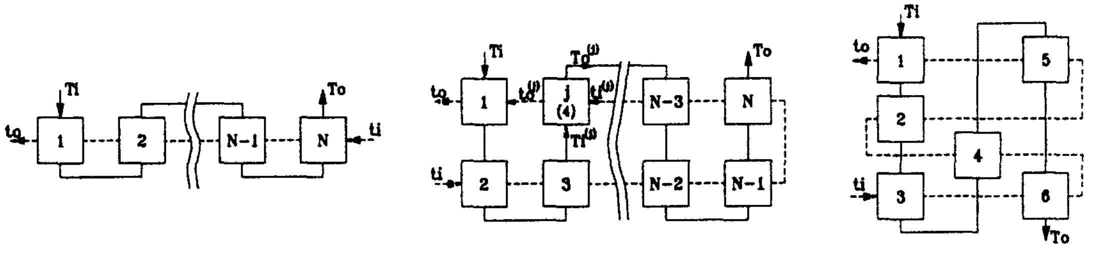
If all temperatures are non-dimensionalized as follows:

$$O_k = \frac{T_k - T_{t,i}}{T_{s,i} - T_{t,i}}, \quad k = \text{s or t} \tag{4}$$



serial 1-N assembly serial 2-N assembly miscellaneous assembly

a. Overall Parallel Flow



serial 1-N assembly serial 2-N assembly miscellaneous assembly

b. Overall Counterflow

FIG. 1. Assemblies of heat exchangers for the parallel flow and counterflow arrangements.

it is obvious that the non-dimensionalized outlet temperatures of shell and tube fluids of each pass are determined by the following recurrence relations

$$O^{(j)}_{s,o} = O^{(j)}_{s,i} - RM_jP_{t,j}, \quad j = 1, N \tag{5}$$

$$O^{(j)}_{t,o} = O^{(j)}_{t,i} + M_jP_{t,j}, \quad j = 1, N \tag{6}$$

with the starting conditions

$$O_{s,i} = 1, \quad O_{t,i} = 0. \tag{7}$$

By the above definition, it is self-evident that

$$P_t = \sum_{j=1}^{N} M_jP_{t,j}. \tag{8}$$

The remaining task is to determine the unknown M_j. Along the flow path of each fluid, adding the non-dimensionalized terminal temperature differences of shell fluid $(M_m, RP_{t,m})$ and tube fluids $(M_n, P_{t,n})$ of upstream passes of the jth pass to M_j results in the non-dimensionalized inlet temperature difference between the shell and tube fluids of the assembly. When this procedure is applied to all passes of the assembly, it results in N simultaneous equations, which are compactly expressed in matrix form as

$$[A]\{M\} = \{B\}. \tag{9}$$

After obtaining these M_j from equation (9), P_t is calculated by equation (8) and the effectiveness of the assembly, E, is determined by

$$E = \begin{cases} P_t, & \text{if } R \leq 1 \\ RP_t, & \text{if } R > 1. \end{cases} \tag{10}$$

The mean temperature difference, r, of the assembly is determined from the definition by

$$r = E/Ntu \tag{11}$$

and the temperature correction factor (TCF), F, of the assembly is obtained by [7]

$$F = \frac{X(P_t, R)}{Ntu} \frac{C_t}{C_{\min}} \tag{12}$$

where

$$X(P_t, R) = \frac{1}{R-1} \cdot \ln\left(\frac{1-P_t}{1-RP_t}\right), \quad R \neq 1$$

$$= \frac{P_t}{1-P_t}, \quad R = 1. \tag{13}$$

Up to now, no restriction on identical passes is required. This procedure can also be applied to assembly, coupled by passes of various types of heat exchangers if they satisfy the assumptions mentioned in the beginning of this section and the effectiveness of each pass is known. For assembly with identical passes, Ntu_j and $P_{t,j}$ can be represented by Ntu_1 and $P_{t,1}$ [4] and Ntu_1 is related to the Ntu of assembly by

$$Ntu = Ntu_1 \cdot N. \tag{14}$$

To illustrate the application of this procedure, an overall counterflow miscellaneous assembly is chosen. For the pass j, say 4, the upstream passes are 1, 2, 3 along the flow path of shell fluid and 6, 3 along the tube fluid. Applying the procedure to this pass gives

$$M_1RP_{t,1} + M_2RP_{t,1} + M_3RP_{t,1} + M_4 + M_6P_{t,1} + M_3P_{t,1} = 1 \tag{15}$$

and the remaining passes give similar equations. After rearrangement, these equations are expressed as equation (9).

RESULTS AND DISCUSSION

For the crossflow shell-and-tube heat exchanger, the temperature effectiveness of tube fluid is determined by the relation of Smith [8], which is a function of R and Ntu. Several verifications have been made to assess the developed procedure and only some of them are presented here. Since the exact expressions of the mean temperature difference are available for serial 1-N assemblies with both flow arrangements [9], the mean temperature differences calculated by the present model have been compared with the exact ones for various R and pass numbers. Figure 2 presents a typical comparison and shows that the calculated results are in good agreement with the exact ones [9]. Applying Domingos' model [1] to serial 2-N assemblies with four passes results in expressions of the P_t-factor for the parallel flow arrangement as

$$P_t = \frac{4P_{t,1} - 6(1+R)P_{t,1}^2 + 4(1+R+R^2)P_{t,1}^3 - (1+R+R^2+R^3)P_{t,1}^4}{1 - 3RP_{t,1}^2 + (1+R)RP_{t,1}^3} \tag{16}$$

and for the counterflow arrangement as

$$P_t = \frac{4P_{t,1} - 6(1+R)P_{t,1}^2 + 4(1+R)^2P_{t,1}^3 - (1+R)^3P_{t,1}^4}{1 - 3RP_{t,1}^2 + 3R(1+R)P_{t,1}^3 - R(1+R)^2P_{t,1}^4}. \tag{17}$$

Figure 3 compares the results of the present model with those obtained by Domingos' model [1] for this case and shows that both models give almost identical results. These assessments validate the accuracy and reliability of the present model.

For the same number of identical passes, it is of

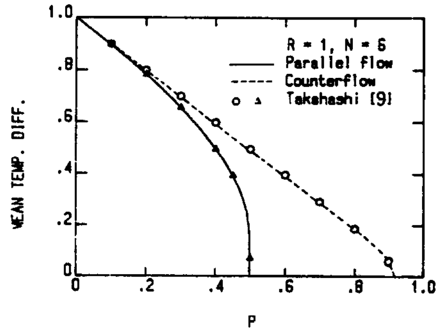


FIG. 2. Dependence of mean temperature difference on the P-factor for serial 1-N complex assemblies.

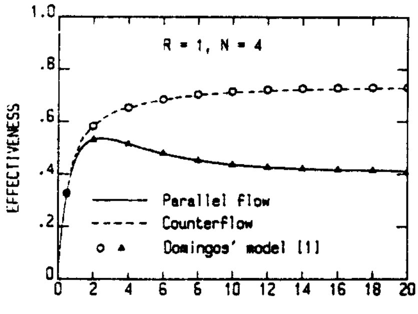
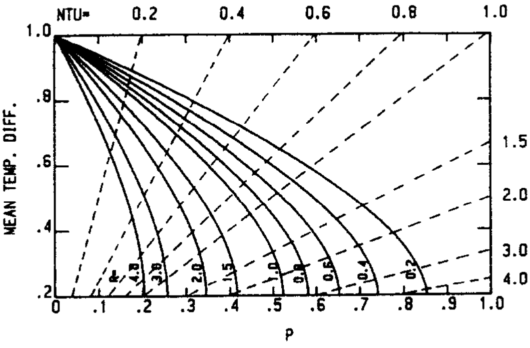


FIG. 3. Dependence of effectiveness of serial 2-N complex assemblies with four passes on the Ntu.

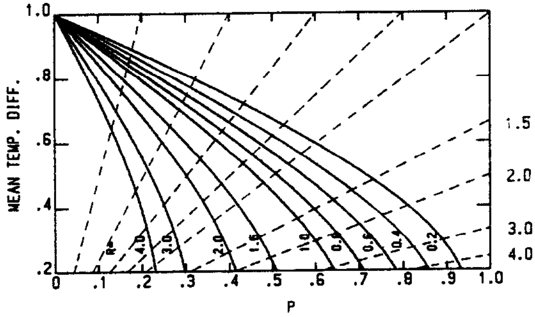
practical interest to investigate the effects of R, Ntu, flow arrangement, and coupling method on the effectiveness of these complex assemblies. Before these effects are presented, a dual chart [10] which plots r versus P_t with Ntu and R as parameters will be displayed to satisfy the diversified needs for exchanger design. Since F versus P_t plots for serial assemblies are available in the literature and r can be calculated in terms of F, R and P_t with equations (11)–(13) without difficulty, the dual charts of serial assemblies are not given here and only those for the miscellaneous assembly are shown in Fig. 4 for both flow arrangements. It is seen that the mean temperature difference and P_t both decrease with the increase of R at constant Ntu for both flow arrangements.

Figure 5 shows that R as well as its inverse $1/R$ both have a similar effect on the effectiveness of serial assemblies. Thus, only the results of R less than unity are presented hereafter. For a constant Ntu, the effectiveness of serial assemblies decreases with an increase of R, which is less than unity for both flow arrangements. As R approaches zero, the effectiveness of each complex assembly approaches a nearly constant value regardless of the flow arrangement. As shown in Fig. 6, for a constant R and with increasing Ntu, the effectiveness of serial assemblies increases for the counterflow arrangement. For the parallel flow arrangement, while the effectiveness of serial 1-N assemblies approaches its asymptote monotonically with increasing Ntu, that of the serial 2-N complex assembly has a maximum at an optimal Ntu value which decreases as R increases. The effectiveness decreases as Ntu exceeds the optimal value. Consequently, the effectiveness of the serial 2-N complex assembly becomes lower than that of a serial 1-N assembly at the crossover Ntu values, which also decreases as R increases.

As is also shown in Figs. 5 and 6, the counterflow arrangement is found to be superior to the parallel flow arrangement in serial assemblies, which is consistent with the results of ref. [4]. To illustrate the effects of passes on overall heat exchange, Fig. 7 shows

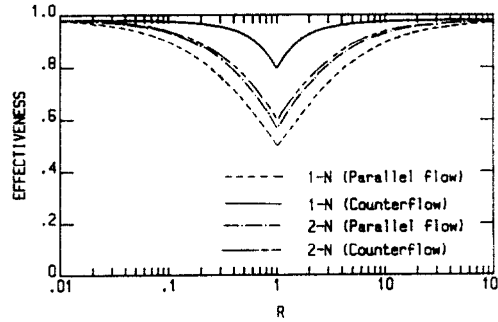


a. Parallel flow arrangement

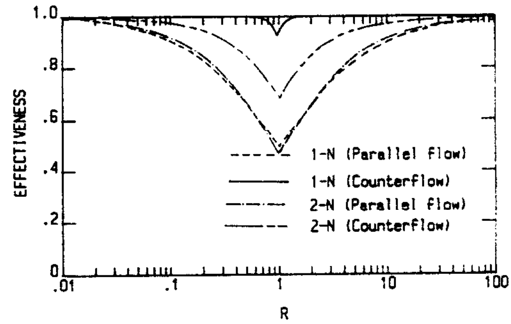


b. Counterflow arrangement

FIG. 4. Dual chart for miscellaneous assemblies.

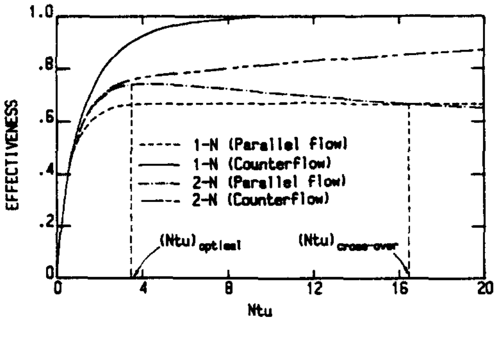


a. Ntu = 4, N = 10

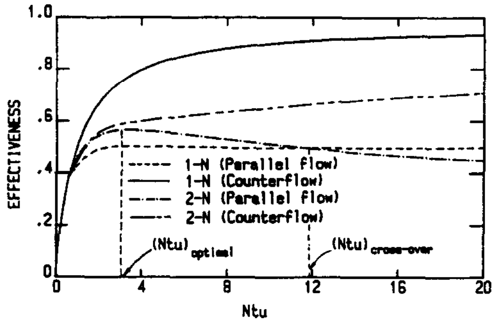


b. Ntu = 16, N = 10

FIG. 5. Effect of R on the effectiveness of serial complex assemblies.



a. R = 0.5, N = 10



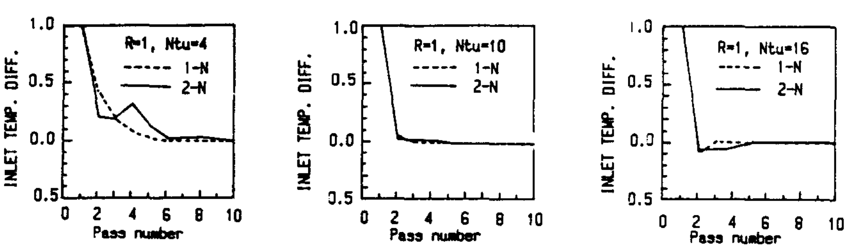
b. R = 1, N = 10

FIG. 6. Effect of *Ntu* on the effectiveness of serial assemblies.

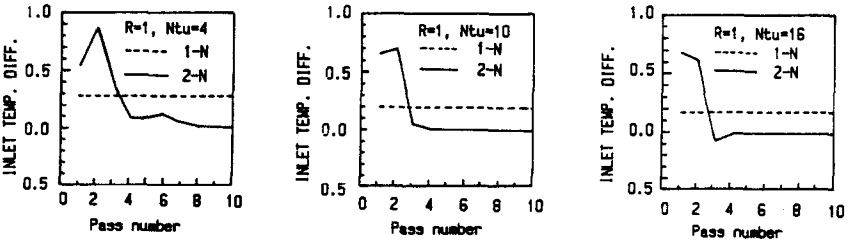
the inlet temperature differences between both fluids in different passes of serial assemblies for both flow arrangements for various *Ntu* values. It reveals that some passes become inactive in heat exchange at high *Ntu* values. Moreover, at higher *Ntu* values, the heat duties of the heat exchanging fluids are interchanged in some passes. It is seen that, for the counterflow arrangement, the serial 2-*N* complex assembly is more prone to the aforementioned pass inactivity than the serial 1-*N* complex assembly. Although not shown in these figures, these findings are also true for the miscellaneous assembly.

For all the assemblies studied, if the flow directions of both fluids are reversed simultaneously, it is found that the coefficient matrix after flow reversal becomes the transpose of that prior to flow reversal. When both fluids are interchanged, the coefficient matrix after flow interchange is formed by replacing P_t and R in that prior to flow interchange by RP_t and $1/R$, respectively. As indicated in ref. [2], a complex assembly preserving the flow reversibility and stream symmetry is required to keep its effectiveness unchanged under the transformations of flow direction and fluid interchange, respectively. Table 1 shows, for the parallel flow as well as the counterflow arrangements, that the flow reversibility is preserved in all the assemblies studied. However, only the serial 1-*N* complex assembly preserves the stream symmetry. This is because the serial 2-*N* and miscellaneous assemblies do not satisfy the necessary condition of geometrical symmetry [11] under the interchange of the fluids. However, all assemblies preserve stream symmetry if R is equal to unity.

The effectiveness of the three assemblies is compared in Fig. 8 for both flow arrangements. For the parallel flow arrangement, owing to the occurrence of parallel flow and counterflow in the intermediate passes introduced by the complex coupling of the serial 2-*N* and miscellaneous assemblies, their effectivenesses are higher than that of the serial 1-*N* complex assembly at low *Ntu* values. However, due to the aforementioned degradation of effectiveness with the increase in *Ntu*, the opposite trends are found at high *Ntu* values. For the counterflow arrangement, the occurrence of parallel flow and counterflow in the intermediate passes causes the effectiveness of the



a. Parallel flow



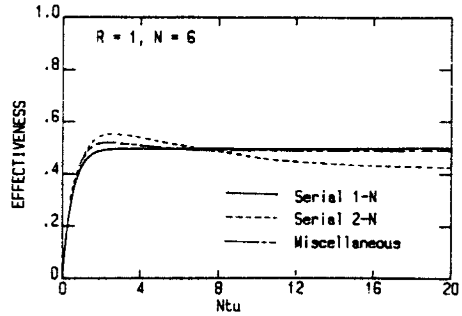
b. Counterflow

FIG. 7. Inlet temperature differences between shell and tube fluids of passes of serial complex assemblies ($N = 10$).

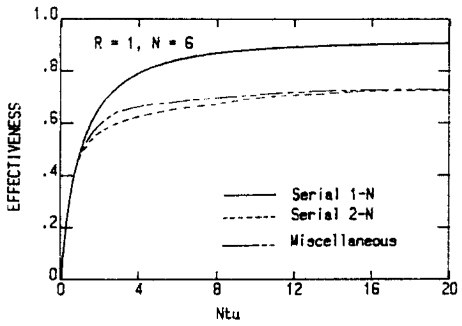
Table 1. Effect of flow transformation on the effectiveness for the parallel flow and counterflow arrangements

		Overall parallel flow						Overall counterflow					
		$R = 0.5$			$R = 1$			$R = 0.5$			$R = 1$		
Ntu	Flow type†	Serial 1-*N*	Serial 2-*N*	Miscellaneous	Serial 1-*N*	Serial 2-*N*	Miscellaneous	Serial 1-*N*	Serial 2-*N*	Miscellaneous	Serial 1-*N*	Serial 2-*N*	Miscellaneous
4	NA	0.665	0.727	0.695	0.500	0.544	0.515	0.922	0.786	0.820	0.790	0.624	0.659
	FR	0.665	0.727	0.695	0.500	0.544	0.515	0.922	0.786	0.820	0.790	0.624	0.659
	FI	0.665	0.727	0.690	0.500	0.544	0.515	0.922	0.786	0.828	0.790	0.624	0.695
10	NA	0.667	0.667	0.667	0.500	0.469	0.495	0.992	0.857	0.867	0.882	0.694	0.709
	FR	0.667	0.667	0.667	0.500	0.469	0.495	0.992	0.857	0.867	0.882	0.694	0.709
	FI	0.667	0.662	0.666	0.500	0.469	0.495	0.993	0.861	0.899	0.882	0.694	0.709
16	NA	0.667	0.633	0.653	0.500	0.436	0.492	0.998	0.888	0.885	0.902	0.722	0.703
	FR	0.667	0.633	0.653	0.500	0.436	0.492	0.998	0.888	0.885	0.902	0.722	0.730
	FI	0.667	0.620	0.669	0.500	0.436	0.492	0.999	0.899	0.930	0.902	0.722	0.730

† NA, normal arrangement; FR, flow reversal; FI, fluid interchange.



a. Parallel flow arrangement

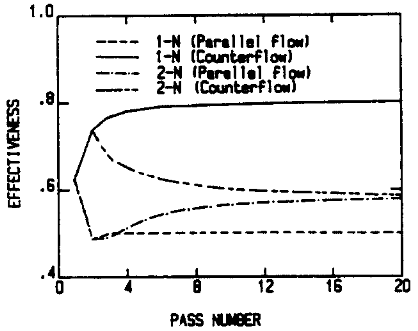


b. Counterflow arrangement

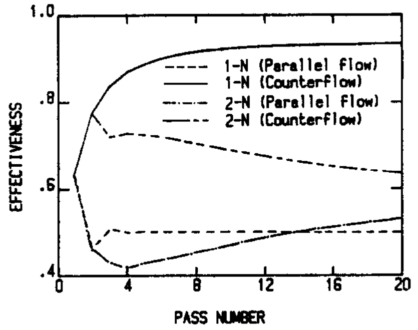
FIG. 8. Effect of coupling method of complex assemblies on the effectiveness.

serial 2-*N* and miscellaneous assemblies to be lower than that of the serial 1-*N* complex assembly for all *Ntu* values. Moreover, at high *Ntu* values, the effectiveness of the miscellaneous assembly approaches that of the serial 2-*N* complex assembly, which implies that the effect of complex coupling can be neglected for the counterflow arrangement if *Ntu* is high. For both flow arrangements, the effectiveness of the miscellaneous assembly is found to be between those of the serial 1-*N* and 2-*N* complex assemblies in which the passes are more regularly coupled. Thus, the effectiveness of the serial complex assembly gives the upper and lower bounds for that of the miscellaneous assembly.

For a constant *Ntu*, it is important to investigate the dependence of the effectiveness of a complex assembly with identical passes on the pass number. Figure 9 presents such a dependence for serial complex assemblies. For various *Ntu*, only the effectiveness of the serial 1-*N* complex assembly with the counterflow arrangement shows monotonic dependence on the pass number. Other cases show oscillatory dependence for small pass numbers and monotonic dependencies as the pass number increases further. In the serial 1-*N* complex assembly, the effectiveness of both flow arrangements approaches their respective asymptotes with the increase of pass number [4]. This shows that the flow arrangement has a significant influence on the effectiveness of this complex assembly whatever the pass number may be. In the serial 2-*N* complex



a. R = 1, Ntu = 4



b. R = 1, Ntu = 16

FIG. 9. Effect of pass number on the effectiveness of serial complex assemblies.

assembly, the effectiveness of the parallel flow arrangement increases and that of the counterflow arrangement decreases as the pass number exceeds that where the oscillatory dependence occurs. Furthermore, they asymptotically approach each other as the pass number increases, which is consistent with ref. [3]. This implies that the flow arrangement has no effect on the effectiveness of the serial 2-*N* complex assembly if the number of passes exceeds the asymptotic value of *N*, which is found to increase with increasing *Ntu* (Fig. 9).

In addition to the foregoing discussion, a parallel flow serial 1-*N* assembly with non-identical passes shown in Fig. 1(a) was chosen to illustrate the extension of the present procedure applied to non-identical heat exchangers. Since both fluids have the same flow paths in this case, the upstream passes of the *j*th pass are pass $1, 2, \ldots, j-1$ for both fluids. The equation of the *j*th pass is written as

$$\sum_{m=1}^{j-1} M_m R P_{t,m} + M_j + \sum_{n=1}^{j-1} M_n P_{t,n} = 1 \qquad (18)$$

in which $P_{t,m} = P_{t,n}$ if $m = n$. Applying the procedure to all passes gives, after rearrangement, the expressions for the elements of $[A]$, $A_{i,j}$ as

$$A_{ij} = \begin{cases} 0, & j > i \\ 1, & j = i \\ (1+R)P_{t,j}, & j < i. \end{cases} \qquad (19)$$

Due to the special feature of the coefficient matrix in this case, an explicit expression for the P_t of this case can be derived as

$$P_t = \frac{1 - \prod_{j=1}^{N} [1-(1+R)P_{t,j}]}{1+R} \qquad (20)$$

which is identical to those derived by other models [1, 2]. The extension of this procedure to assembly coupled by non-identical passes is thus shown to be straightforward and reliable.

CONCLUSIONS

This work presents a simple, general and systematic procedure to determine the effectiveness and fluid temperatures for assemblies of heat exchangers. The main task in this procedure is the formulation and solution of a matrix equation in which the coefficient matrix is derived for a given complex assembly of heat exchangers. Explicit expressions are derived for some cases. The validity of this procedure has been determined by its application to three complex assemblies of heat exchangers.

For assemblies in Fig. 1 with identical crossflow shell-and-tube heat exchangers in which the hot fluid is on the shellside and the cold fluid on the tubeside, some parametric studies, including those of *R*, *Ntu*, flow arrangement, coupling method, and pass number, have been conducted to investigate their effects. The conclusions drawn from these studies are as follows.

(1) At a constant *Ntu*, *R* has a similar effect on the effectiveness to that of its inverse. For each complex assembly, the effectiveness decreases with the increase of *R* for $R < 1$. Furthermore, as *R* approaches zero, the effectiveness approaches a common value regardless of the flow arrangement. For the serial 2-*N* and miscellaneous assemblies with the parallel flow arrangement, the enhancement from the increase of *Ntu* is degraded as *Ntu* exceeds the optimal value, which decreases with increasing *R*. At a constant *R* and with increasing *Ntu*, some passes become inactive in heat exchange and the heat duties of the fluids are interchanged in some passes.

(2) The flow arrangement plays an important role in determining the effectiveness of a complex assembly. However, it has no effect on the serial 2-*N* complex assembly if the pass number is greater than the asymptotic value, which increases with the increase in *Ntu*. To obtain higher effectiveness, the flow directions of both fluids should be arranged in a counterflow sense. Flow reversibility has been shown to be preserved for all the assemblies studied. However, only the serial 1-*N* complex assembly preserves stream symmetry.

(3) For a constant number of passes, complex coupling enhances the effectiveness of the resultant complex assembly for the parallel flow arrangement at low *Ntu*. However, it reduces the effectiveness if *Ntu* is

higher than the optimal value, which decreases with increasing *R*. For the counterflow arrangement, complex coupling degrades the effectiveness at all *Ntu* values. Moreover, the effect of complex coupling can be neglected at high *Ntu* values. The effectiveness of serial assemblies gives the upper and lower bounds for miscellaneous assemblies.

(4) For a small number of passes, the effectiveness of the serial complex assembly, except for the serial 1-*N* complex assembly with a counterflow arrangement, shows an oscillatory dependence on the pass number. For both flow arrangements, while the effectivenesses of serial 1-*N* assemblies approach their respective asymptotes, those of serial 2-*N* assemblies approach a common asymptotic value as the pass number increases.

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PROCEDURE GENERALE POUR L'EFFICACITE DES ASSEMBLAGES COMPLEXES D'ECHANGEURS DE CHALEUR

Résumé—Une procédure simple et systématique est développée pour déterminer l'efficacité et les températures de sortie du fluide des assemblages complexes d'échangeurs thermiques identiques. Trois assemblages complexes sont choisis pour illustrer la procédure. Les excellents accords entre les résultats de la procédure développée et ceux trouvés dans la littérature valident cette procédure. Des études paramétriques incluant celles de la méthode de couplage, d'arrangement d'écoulement, du rapport des capacités thermiques des deux fluides, du nombre d'unités de transfert et du nombre de passes ont été conduites pour étudier leurs effets sur l'efficacité des assemblages. Néanmoins l'assemblage d'échangeurs différents est étudié pour examiner l'applicabilité de la présente procédure.

EIN ALLGEMEINES VERFAHREN ZUR BESTIMMUNG DES WIRKUNGSGRADES KOMPLEXER WÄRMETAUSCHER-ANORDNUNGEN

Zusammenfassung—Es wird ein einfaches und systematisches Verfahren entwickelt zur Bestimmung des Wirkungsgrades und der Austrittstemperaturen einer komplexen Anordnung von gleichartigen Wärmetauschern. Drei Anordnungen werden gewählt, um das Verfahren vorzustellen, das eine hervorragende Übereinstimmung mit Ergebnissen aus der Literatur liefert. Es wird über eine Parameteruntersuchung berichtet, die das Verfahren der Kopplung, die Strömungsanordnung, das Verhältnis der Wärmekapazitäten der beiden Fluide, *NTU* sowie die Anzahl der Durchgänge umfaßt. Dabei wird der Wirkungsgrad der Anordnungen aus gleichartigen Kreuzstrom-Rohrbündel-Wärmeaustauschern bestimmt. Außerdem wird auch eine Anordnung mit nicht-gleichartigen Wärmeaustauschern untersucht, um die allgemeinere Anwendbarkeit des Verfahrens zu überprüfen.

ОБЩАЯ МЕТОДИКА ОПРЕДЕЛЕНИЯ ЭФФЕКТИВНОСТИ СЛОЖНЫХ АНСАМБЛЕЙ ТЕПЛООБМЕННИКОВ

Аннотация—Разработана простая систематическая методика определения эффективности и температур жидкости на выходе для сложных ансамблей идентичных теплообменников. Для иллюстрации ее применения выбраны три сложных ансамбля. Достоверность методики подтверждена хорошим соответствием между результатами, полученными по предложенной методике, и имеющимися в литературе данными. Выполнены параметрические исследования, включающие метод взаимодействия, структуру течения, отношение теплоемкостей обеих жидкостей, количество переносимых единиц, а также циркуляционное число с целью установления их влияния на эффективность ансамблей идентичных кожухо–трубных теплообменников с поперечным обтеканием. Для оценки общей применимости предложенной методики изучается также ансамбль неидентичных теплообменников.