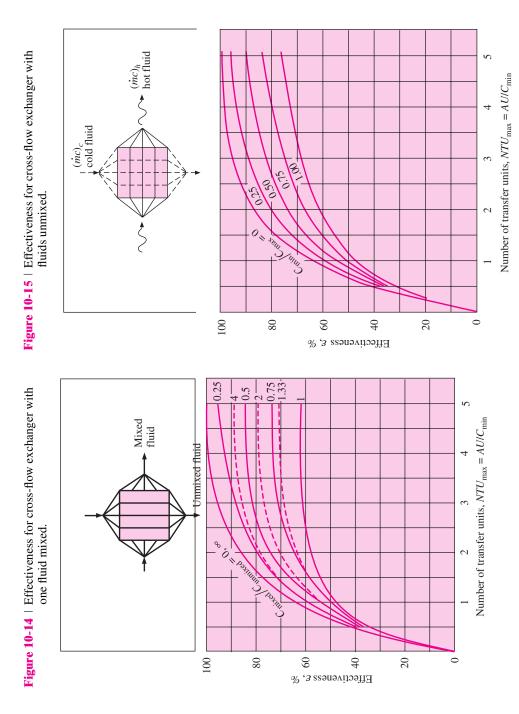
19:51

Figure 10-13 | Effectiveness for counterflow exchanger performance. Number of transfer units,  $NTU_{\text{max}} = AU/C_{\text{min}}$ Cold fluid  $(\dot{m}c)_c = C_c$ Hot fluid  $(\dot{m}c)_h = C_h$ Heat-transfer surface 100 80 09 40 20 0 Effectiveness 8, % Figure 10-12 | Effectiveness for parallel-flow exchanger Number of transfer units,  $NTU_{\text{max}} = AU/C_{\text{min}}$ Cold fluid  $(\dot{m}c)_c$ Hot fluid  $(\dot{m}c)_h$ Heat-transfer surface 0.75 1.00 0.50 performance. 100 80 20 9 40

Effectiveness 8, %

14:59



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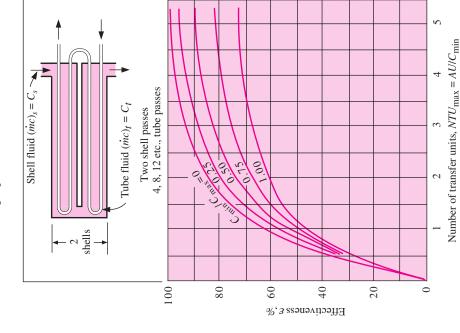
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Figure 10-16 | Effectiveness for 1-2 parallel counterflow exchanger performance.

**Figure 10-17** | Effectiveness for 2-4 multipass counterflow exchanger performance.



Number of transfer units,  $NTU_{\text{max}} = AU/C_{\text{min}}$ 2, 4, 6 etc., tube passes One shell pass Tube fluid  $(\dot{m}c)_t = C_t$ Shell fluid  $(\dot{m}c)_s = C_s$ 0.75 100 80 9 Effectiveness 8,%

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## **10-6** Effectiveness-NTU Method

**Table 10-3** | Heat-exchanger effectiveness relations.

$N = \text{NTU} = \frac{UA}{C_{\min}}$ $C = \frac{C_{\min}}{C_{\max}}$	
Flow geometry	Relation
Double pipe:	
Parallel flow	$\epsilon = \frac{1 - \exp[-N(1+C)]}{1+C}$
Counterflow	$\epsilon = \frac{1 - \exp[-N(1 - C)]}{1 - C \exp[-N(1 - C)]}$
Counterflow, $C = 1$	$\epsilon = \frac{N}{N+1}$
Cross flow:	
Both fluids unmixed	$\epsilon = 1 - \exp\left[\frac{\exp(-NCn) - 1}{Cn}\right]$ where $n = N^{-0.22}$
Both fluids mixed	$\epsilon = \left[\frac{1}{1 - \exp(-N)} + \frac{C}{1 - \exp(-NC)} - \frac{1}{N}\right]^{-1}$
$C_{\mathrm{max}}$ mixed, $C_{\mathrm{min}}$ unmixed	$\epsilon = (1/C)\{1 - \exp[-C(1 - e^{-N})]\}$
$C_{ m max}$ unmixed, $C_{ m min}$ mixed	$\epsilon = 1 - \exp\{-(1/C)[1 - \exp(-NC)]\}$
Shell and tube:	
One shell pass, 2, 4, 6,	$\epsilon = 2 \left\{ 1 + C + (1 + C^2)^{1/2} \right\}$
tube passes	$\times \frac{1 + \exp[-N(1 + C^2)^{1/2}]}{1 - \exp[-N(1 + C^2)^{1/2}]} \right\}^{-1}$
Multiple shell passes, $2n$ , $4n$ , $6n$ tube passes $(\epsilon_p = \text{ effectiveness of each shell pass}, n = \text{number of shell passes})$	$\epsilon = \frac{\left[ (1 - \epsilon_p C) / (1 - \epsilon_p) \right]^n - 1}{\left[ (1 - \epsilon_p C) / (1 - \epsilon_p) \right]^n - C}$
Special case for $C = 1$	$\epsilon = \frac{n\epsilon_p}{1 + (n-1)\epsilon_p}$ $\epsilon = 1 - e^{-N}$
All exchangers with $C = 0$	$\epsilon = 1 - e^{-N}$

**Table 10-4** | NTU relations for heat exchangers.

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$C = C_{\min}/C_{\max}$ $\epsilon = \text{effective}$	eness $N = NTU = UA/C_{min}$
Flow geometry	Relation
Double pipe:	
Parallel flow	$N = \frac{-\ln[1 - (1 + C)\epsilon]}{1 + C}$
Counterflow	$N = \frac{-\ln[1 - (1 + C)\epsilon]}{1 + C}$ $N = \frac{1}{C - 1} \ln\left(\frac{\epsilon - 1}{C\epsilon - 1}\right)$
Counterflow, $C = 1$	$N = \frac{\epsilon}{1 - \epsilon}$
Cross flow:	
$C_{\rm max}$ mixed, $C_{\rm min}$ unmixed	$N = -\ln\left[1 + \frac{1}{C}\ln(1 - C\epsilon)\right]$
$C_{\rm max}$ unmixed, $C_{\rm min}$ mixed	$N = \frac{-1}{C} \ln[1 + C \ln(1 - \epsilon)]$
Shell and tube:	C
One shell pass, 2, 4, 6,	$N = -(1+C^2)^{-1/2}$
tube passes	$\times \ln \left[ \frac{2/\epsilon - 1 - C - (1 + C^2)^{1/2}}{2/\epsilon - 1 - C + (1 + C^2)^{1/2}} \right]$
All exchangers, $C = 0$	$N = -\ln(1 - \epsilon)$

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