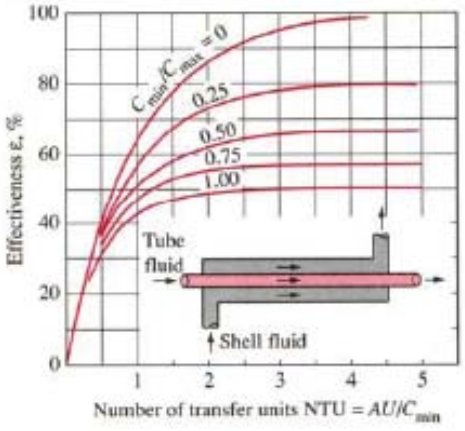
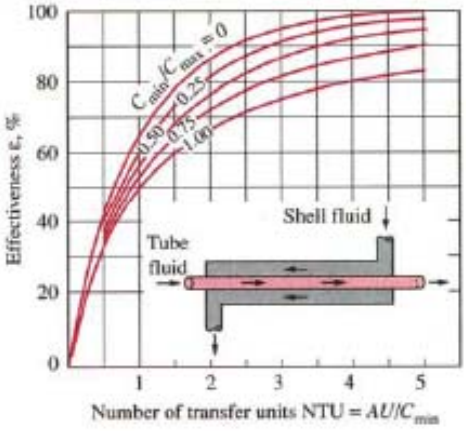
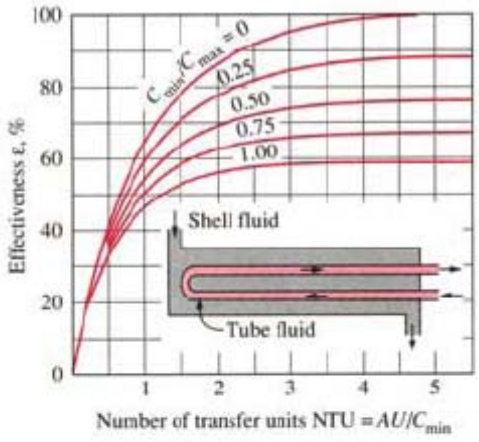
Effectiveness for heat exchangers (from Kays and London, Ref. 7).



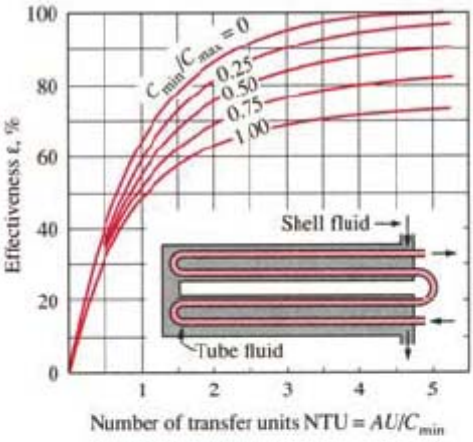
(*a*) Parallel-flow



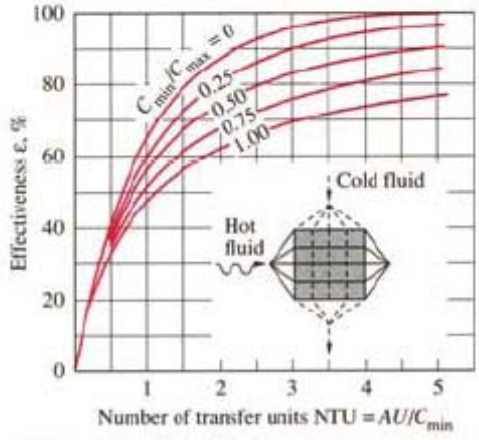
(*b*) Counter-flow



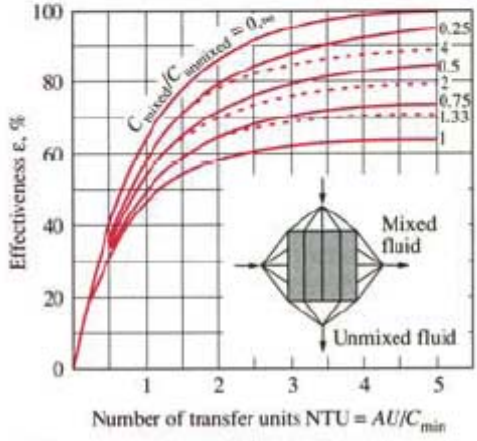
(*c*) One-shell pass and 2, 4, 6, tube passes



(*d*) Two-shell passes and 4, 8, 12, tube passes



(*e*) Cross-flow with both fluids unmixed



(*f*) Cross-flow with one fluid mixed and the other unmixed

Effectiveness relations for heat exchangers: NTU $= UA/C_{min}$ **and** $C = C_{min}/C_{max} = (\dot{m}C_p)_{min}/(\dot{m}C_p)_{max}$

Heat exchanger type	Effectiveness relation
1 *Double pipe:*	
Parallel-flow	$\varepsilon = \dfrac{1 - \exp[-\text{NTU}(1 + C)]}{1 + C}$
Counter-flow	$\varepsilon = \dfrac{1 - \exp[-\text{NTU}(1 - C)]}{1 - C\exp[-\text{NTU}(1 - C)]}$
2 *Shell and tube:*	
One-shell pass 2, 4, . . . tube passes	$\varepsilon = 2\left\{1 + C + \sqrt{1 + C^2}\,\dfrac{1 + \exp[-\text{NTU}\sqrt{1 + C^2}]}{1 - C\exp[-\text{NTU}\sqrt{1 + C^2}]}\right\}^{-1}$
3 *Cross-flow (single-pass)*	
Both fluids unmixed	$\varepsilon = 1 - \exp\left\{\dfrac{\text{NTU}^{0.22}}{C}[\exp(-C\,\text{NTU}^{0.78}) - 1\right\}$
C_{max} mixed, C_{min} unmixed	$\varepsilon = \dfrac{1}{C}(1 - \exp\{1 - C[1 - \exp(-\text{NTU})]\})$
C_{min} mixed, C_{max} unmixed	$\varepsilon = 1 - \exp\left\{-\dfrac{1}{C}[1 - \exp(-C\,\text{NTU})]\right\}$
4 *All heat exchangers with* $C = 0$	$\varepsilon = 1 - \exp(-\text{NTU})$

Source: Kays and London, Ref. 7.

NTU relations for heat exchangers NTU $= UA/C_{min}$ **and** $C = C_{min}/C_{max} = (\dot{m}C_p)_{min}/(\dot{m}C_p)_{max}$

Heat exchanger type	NTU relation
1 *Double-pipe:*	
Parallel-flow	$\text{NTU} = -\dfrac{\ln[1 - \varepsilon(1 + C)]}{1 + C}$
Counter-flow	$\text{NTU} = \dfrac{1}{C - 1}\ln\left(\dfrac{\varepsilon - 1}{\varepsilon C - 1}\right)$
2 *Shell and tube:*	
One-shell pass 2, 4, . . . tube passes	$\text{NTU} = -\dfrac{1}{\sqrt{1 + C^2}}\ln\left(\dfrac{2/\varepsilon - 1 - C - \sqrt{1 + C^2}}{2/\varepsilon - 1 - C + \sqrt{1 + C^2}}\right)$
3 *Cross-flow (single-pass)*	
C_{max} mixed, C_{min} unmixed	$\text{NTU} = -\ln\left[1 + \dfrac{\ln(1 - \varepsilon C)}{C}\right]$
C_{min} mixed, C_{max} unmixed	$\text{NTU} = -\dfrac{\ln[C\ln(1 - \varepsilon) + 1]}{C}$
4 *All heat exchangers with* $C = 0$	$\text{NTU} = -\ln(1 - \varepsilon)$

Source: Kays and London, Ref. 7.