

Operações Unitárias I

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TABLE 11.2 Representative Values of the Overall Heat Transfer Coefficient

Fluid Combination	U (W/m ² · K)
Water to water	850–1700
Water to oil	110–350
Steam condenser (water in tubes)	1000–6000
Ammonia condenser (water in tubes)	800–1400
Alcohol condenser (water in tubes)	250–700
Finned-tube heat exchanger (water in tubes, air in cross flow)	25–50

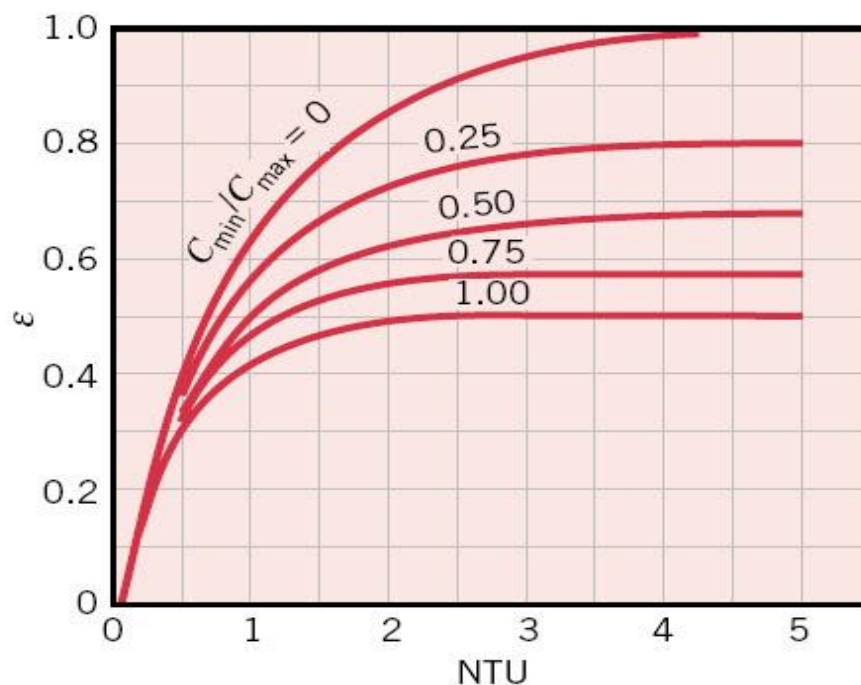
TABLE 11.3 Heat Exchanger Effectiveness Relations [5]

Flow Arrangement	Relation	
Concentric tube		
Parallel flow	$\varepsilon = \frac{1 - \exp[-NTU(1 + C_r)]}{1 + C_r}$	(11.28a)
Counterflow	$\varepsilon = \frac{1 - \exp[-NTU(1 - C_r)]}{1 - C_r \exp[-NTU(1 - C_r)]}$	$(C_r < 1)$
	$\varepsilon = \frac{NTU}{1 + NTU}$	$(C_r = 1)$ (11.29a)
Shell-and-tube		
One shell pass (2, 4, ... tube passes)	$\varepsilon_1 = 2 \left\{ 1 + C_r + (1 + C_r^2)^{1/2} \right. \\ \left. \times \frac{1 + \exp[-(NTU)_1(1 + C_r^2)^{1/2}]}{1 - \exp[-(NTU)_1(1 + C_r^2)^{1/2}]} \right\}^{-1}$	(11.30a)
n Shell passes ($2n, 4n, \dots$ tube passes)	$\varepsilon = \left[\left(\frac{1 - \varepsilon_1 C_r}{1 - \varepsilon_1} \right)^n - 1 \right] \left[\left(\frac{1 - \varepsilon_1 C_r}{1 - \varepsilon_1} \right)^n - C_r \right]^{-1}$	(11.31a)
Cross-flow (single pass)		
Both fluids unmixed	$\varepsilon = 1 - \exp \left[\left(\frac{1}{C_r} \right) (NTU)^{0.22} \{ \exp[-C_r(NTU)^{0.78}] - 1 \} \right]$	(11.32)
$C_{\max}$ (mixed), $C_{\min}$ (unmixed)	$\varepsilon = \left(\frac{1}{C_r} \right) (1 - \exp \{ -C_r [1 - \exp(-NTU)] \})$	(11.33a)
$C_{\min}$ (mixed), $C_{\max}$ (unmixed)	$\varepsilon = 1 - \exp \{ -C_r^{-1} [1 - \exp[-C_r(NTU)]] \}$	(11.34a)
All exchangers ($C_r = 0$)	$\varepsilon = 1 - \exp(-NTU)$	(11.35a)

TABLE 11.4 Heat Exchanger NTU Relations

Flow Arrangement	Relation
Concentric tube	
Parallel flow	$NTU = -\frac{\ln[1 - \varepsilon(1 + C_r)]}{1 + C_r} \quad (11.28b)$
Counterflow	$NTU = \frac{1}{C_r - 1} \ln\left(\frac{\varepsilon - 1}{\varepsilon C_r - 1}\right) \quad (C_r < 1)$
	$NTU = \frac{\varepsilon}{1 - \varepsilon} \quad (C_r = 1) \quad (11.29b)$
Shell-and-tube	
One shell pass (2, 4, . . . tube passes)	$(NTU)_1 = -(1 + C_r^2)^{-1/2} \ln\left(\frac{E - 1}{E + 1}\right) \quad (11.30b)$
	$E = \frac{2/\varepsilon_1 - (1 + C_r)}{(1 + C_r^2)^{1/2}} \quad (11.30c)$
n Shell passes ($2n, 4n, . . .$ tube passes)	Use Equations 11.30b and 11.30c with
	$\varepsilon_1 = \frac{F - 1}{F - C_r} \quad F = \left(\frac{\varepsilon C_r - 1}{\varepsilon - 1}\right)^{1/n} \quad NTU = n(NTU)_1 \quad (11.31b, c, d)$
Cross-flow (single pass)	
$C_{\max}$ (mixed), $C_{\min}$ (unmixed)	$NTU = -\ln\left[1 + \left(\frac{1}{C_r}\right) \ln(1 - \varepsilon C_r)\right] \quad (11.33b)$
$C_{\min}$ (mixed), $C_{\max}$ (unmixed)	$NTU = -\left(\frac{1}{C_r}\right) \ln[C_r \ln(1 - \varepsilon) + 1] \quad (11.34b)$
All exchangers ($C_r = 0$)	$NTU = -\ln(1 - \varepsilon) \quad (11.35b)$

Gráficos dos valores ε x NUT.

**FIGURE 11.10** Effectiveness of a parallel-flow heat exchanger (Equation 11.28).

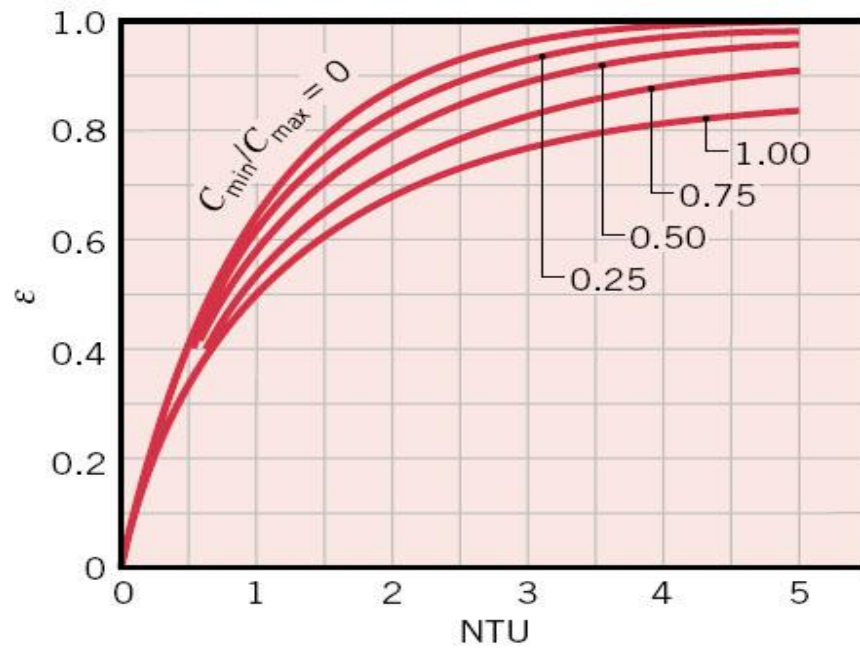


FIGURE 11.11 Effectiveness of a counterflow heat exchanger (Equation 11.29).

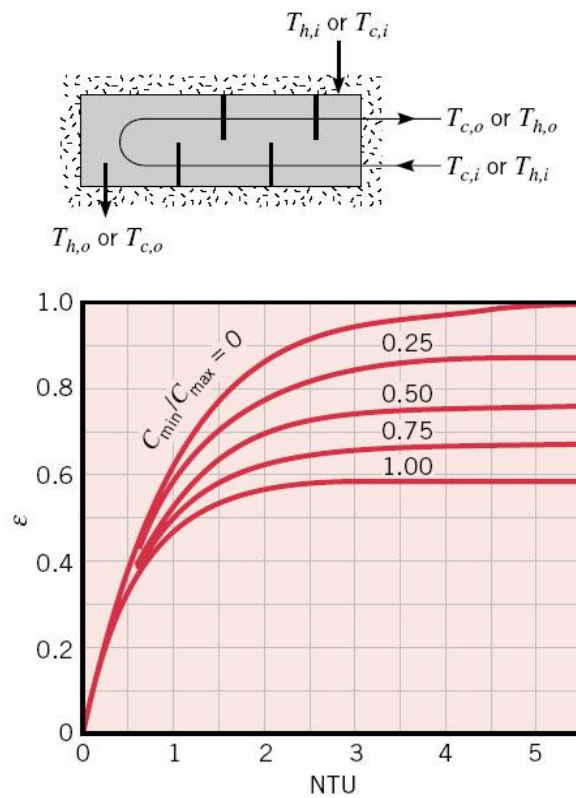


FIGURE 11.12 Effectiveness of a shell-and-tube heat exchanger with one shell and any multiple of two tube passes (two, four, etc. tube passes) (Equation 11.30).

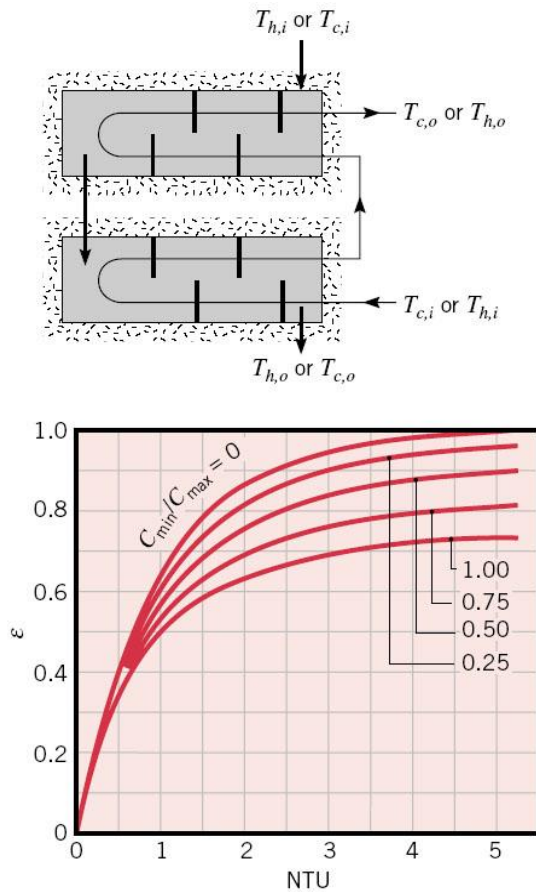


FIGURE 11.13 Effectiveness of a shell-and-tube heat exchanger with two shell passes and any multiple of four tube passes (four, eight, etc. tube passes) (Equation 11.31 with $n = 2$).

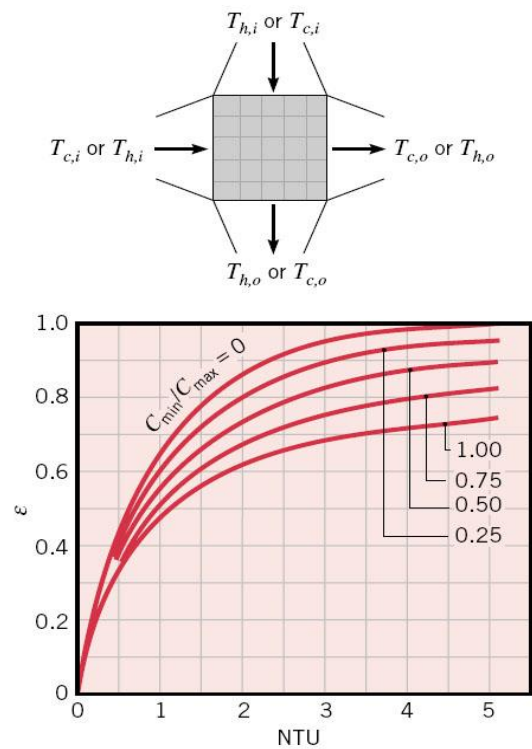


FIGURE 11.14 Effectiveness of a single-pass, cross-flow heat exchanger with both fluids unmixed (Equation 11.32).

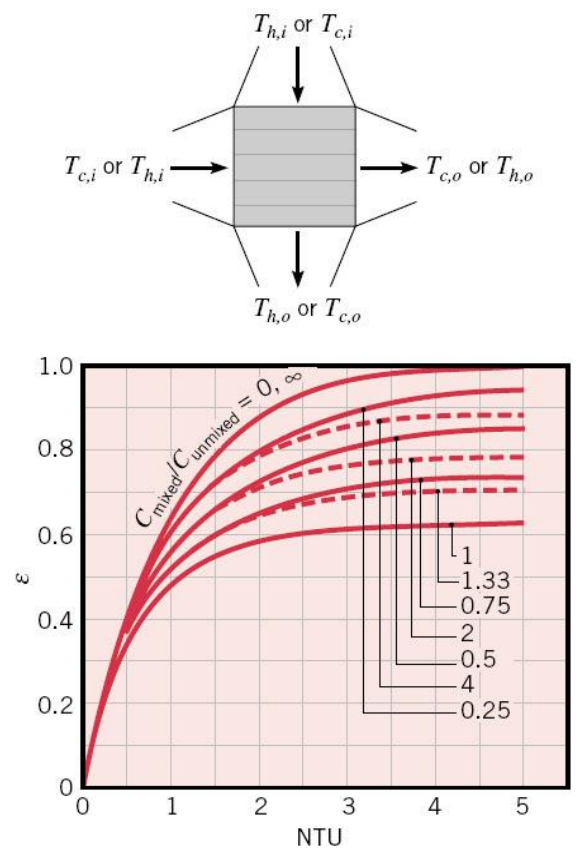


FIGURE 11.15 Effectiveness of a single-pass, cross-flow heat exchanger with one fluid mixed and the other unmixed (Equations 11.33, 11.34).

Gráficos dos fatores F de correção.

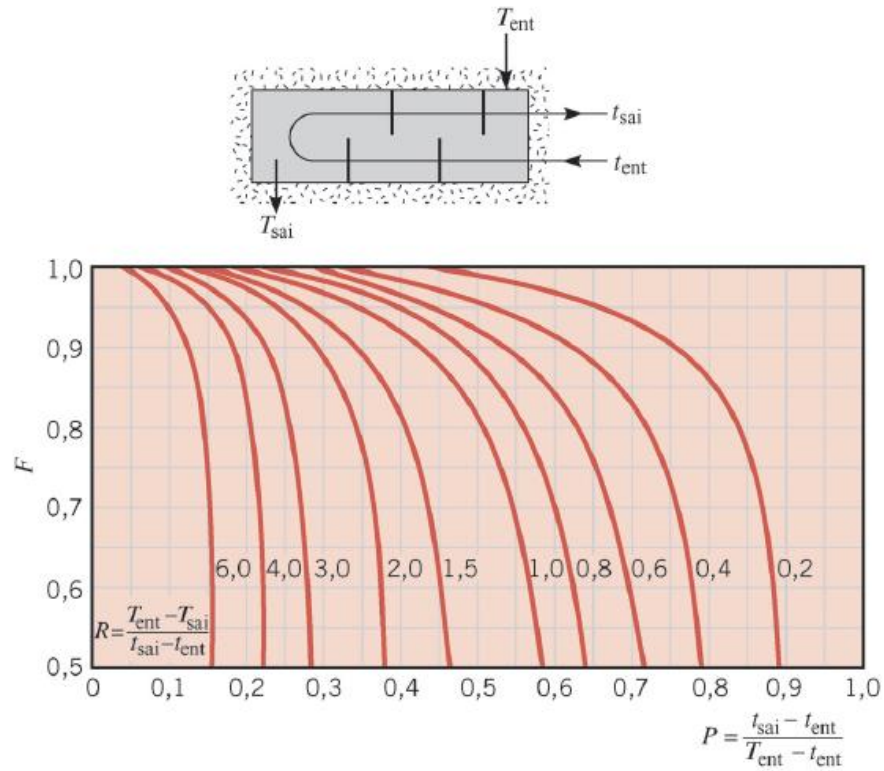


FIGURA 11S.1 Fator de correção para um trocador de calor casco e tubos com um passe no casco e qualquer múltiplo de dois (dois, quatro etc.) passes nos tubos.

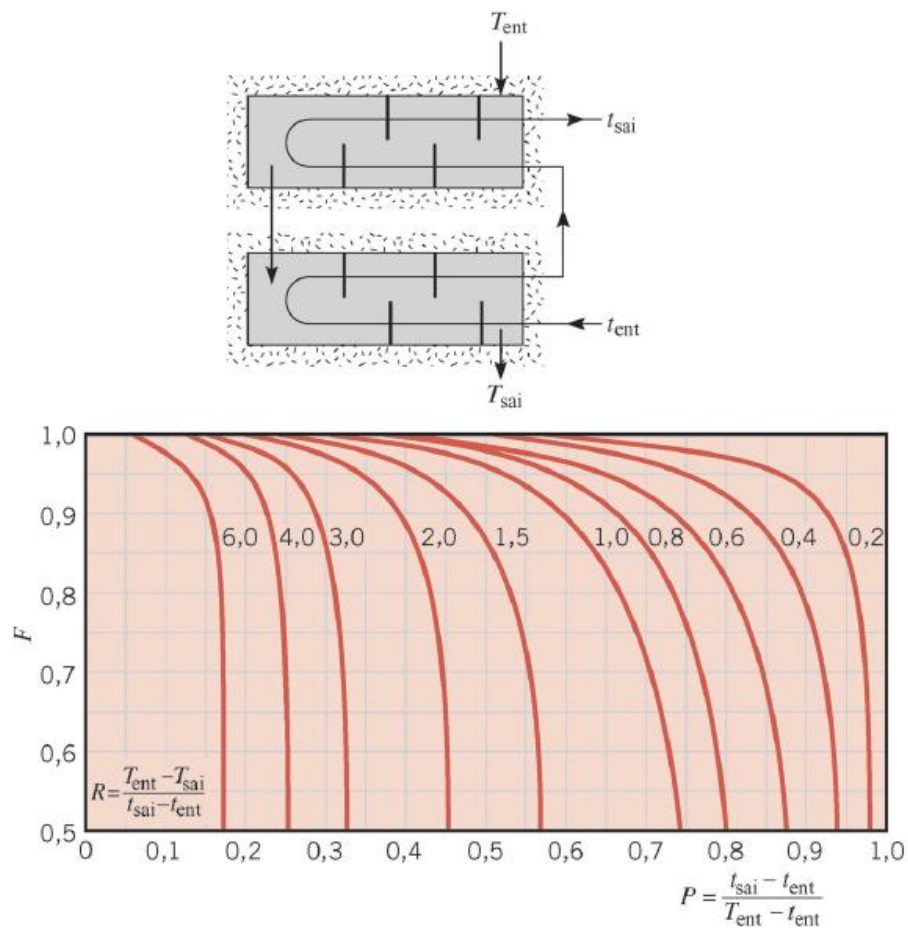


FIGURA 11S.2 Fator de correção para um trocador de calor casco e tubos com dois passes no casco e qualquer múltiplo de quatro (quatro, oito etc.) passes nos tubos.

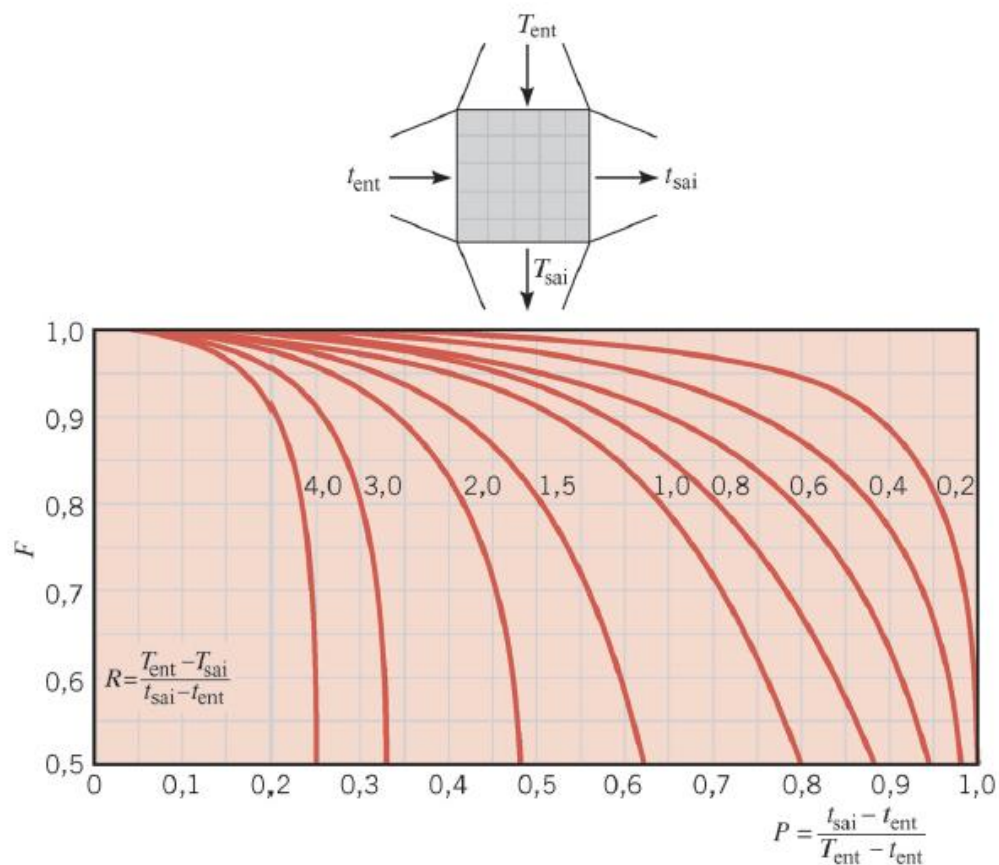


FIGURA 11S.3 Fator de correção para um trocador de calor de escoamento cruzado, com passe único, com os dois fluidos não-misturados.

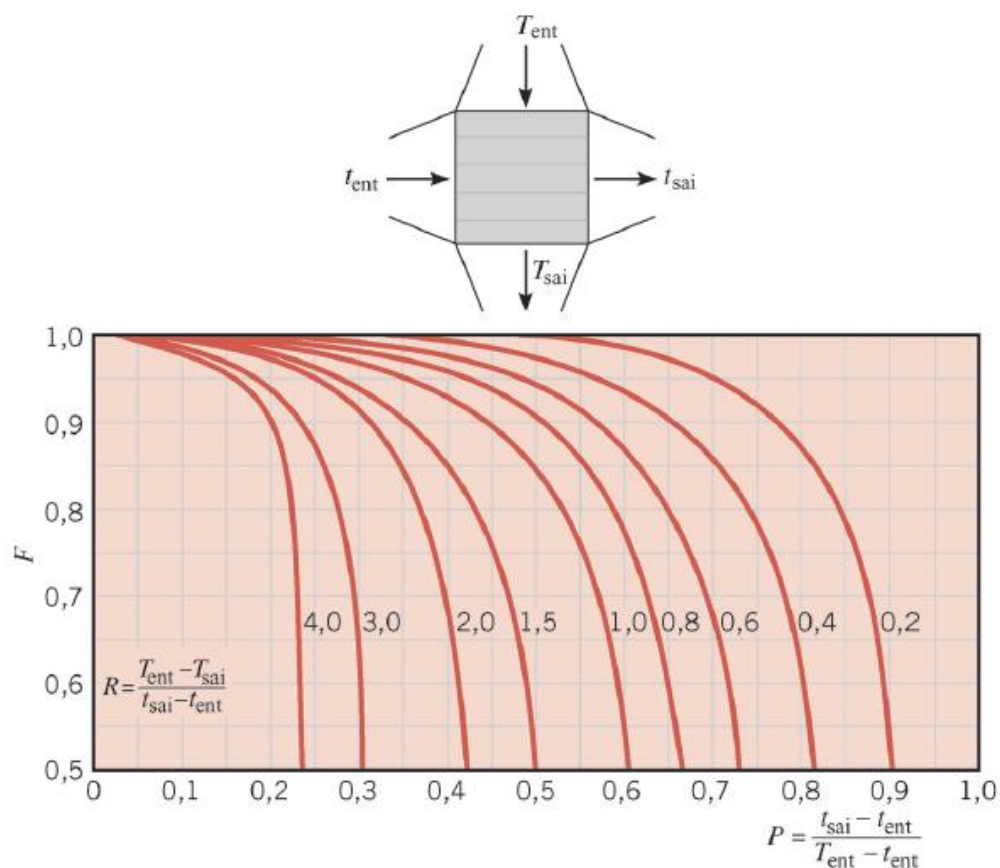


FIGURA 11S.4 Fator de correção para um trocador de calor de escoamento cruzado, com passe único, com um fluido misturado e o outro não-misturado.