

## Chapter 7

**TABLE 7.7** Summary of convection heat transfer correlations for external flow<sup>a</sup>

Correlation		Geometry	Conditions <sup>b</sup>
$\delta = 5x Re_x^{-1/2}$	(7.17) (Ana.)	Flat plate	Laminar, $T_f$
$C_{f,x} = 0.664 Re_x^{-1/2}$	(7.18) (Ana.)	Flat plate	Laminar, local, $T_f$
$Nu_x = 0.332 Re_x^{1/2} Pr^{1/3}$	(7.21) (Semi-Ana.)	Flat plate	Laminar, local, $T_f$ , $Pr \geq 0.6$ <sup>d</sup>
$\delta_t = \delta Pr^{-1/3}$	(7.22) (Semi-Ana.)	Flat plate	Laminar, $T_f$
$\bar{C}_{f,x} = 1.328 Re_x^{-1/2} = 2C_{f,x}$	(7.24)	Flat plate	Laminar, average, $T_f$
$\bar{Nu}_x = 0.664 Re_x^{1/2} Pr^{1/3} = 2Nu_x$	(7.25)	Flat plate	Laminar, average, $T_f$ , $Pr \geq 0.6$ <sup>d</sup>
$Nu_x = 0.564 Pe_x^{1/2}$	(7.26) (Semi-Ana.)	Flat plate	Laminar, local, $T_f$ , $Pr \leq 0.05$ , $Pe_x \geq 100$
$C_{f,x} = 0.0592 Re_x^{-1/5}$	(7.28) (exp.)	Flat plate	Turbulent, local, $T_f$ , $Re_x \leq 10^8$
$\delta = 0.37x Re_x^{-1/5} \approx \delta_t$	(7.29) (exp.)	Flat plate	Turbulent, $T_f$ , $Re_x \leq 10^8$
$Nu_x = 0.0296 Re_x^{4/5} Pr^{1/3}$	(7.30) (Chilton-Colburn)	Flat plate	Turbulent, local, $T_f$ , $Re_x \leq 10^8$ , $0.6 \leq Pr \leq 60$
$\bar{C}_{f,L} = 0.074 Re_L^{-1/5} - 1742 Re_L^{-1}$	(7.33)	Flat plate	Mixed, average, $T_f$ , $Re_{x,c} = 5 \times 10^5$ , <sup>e</sup> $Re_L \leq 10^8$
$\bar{Nu}_L = (0.037 Re_L^{4/5} - 871) Pr^{1/3}$	(7.31)	Flat plate	Mixed, average, $T_f$ , $Re_{x,c} = 5 \times 10^5$ , <sup>e</sup> $Re_L \leq 10^8$ , $0.6 \leq Pr \leq 60$
$\bar{Nu}_D = C Re_D^m Pr^{1/3}$ (Table 7.2) (Table 7.3 for non-circular cylinders)	(7.44) (exp.)	Cylinder	Average, $T_f$ , $0.4 \leq Re_D \leq 4 \times 10^5$ , $Pr \geq 0.7$
$\bar{Nu}_D = C Re_D^m Pr^n (Pr/Pr_s)^{1/4}$ (Table 7.4)	(7.45) (exp.)	Cylinder	Average, $T_\infty$ , $1 \leq Re_D \leq 10^6$ , $0.7 \leq Pr \leq 500$
$\bar{Nu}_D = 0.3 + [0.62 Re_D^{1/2} Pr^{1/3} \times [1 + (0.4/Pr)^{2/3}]^{-1/4} \times [1 + (Re_D/282,000)^{5/8}]^{4/5}]$ (7.46)	(exp.)	Cylinder	Average, $T_f$ , $Re_D Pr \geq 0.2$
$\bar{Nu}_D = 2 + (0.4 Re_D^{1/2} + 0.06 Re_D^{2/3}) Pr^{0.4} \times (\mu/\mu_s)^{1/4}$ (7.48)	(exp.)	Sphere (solid)	Average, $T_\infty$ , $3.5 \leq Re_D \leq 7.6 \times 10^4$ , $0.71 \leq Pr \leq 380$ , $1.0 \leq (\mu/\mu_s) \leq 3.2$
$\bar{Nu}_D = 2 + 0.6 Re_D^{1/2} Pr^{1/3}$	(7.49) (exp.)	Falling drop	Average, $T_\infty$
$\bar{Nu}_D = C_1 C_2 Re_{D,max}^m Pr^{0.36} (Pr/Pr_s)^{1/2}$ (Tables 7.5, 7.6)	(7.50), (7.51) (exp.)	Tube bank <sup>c</sup>	Average, $\bar{T}$ , $10 \leq Re_D \leq 2 \times 10^6$ , $0.7 \leq Pr \leq 500$

<sup>a</sup>Correlations in this table pertain to isothermal surfaces; for special cases involving an unheated starting length or a uniform surface heat flux, see Section 7.2.4 or 7.2.5.

<sup>b</sup>The temperature listed under "Conditions" is the temperature at which properties should be evaluated.

<sup>c</sup>For tube banks and packed beds, properties are evaluated at the average fluid temperature,  $\bar{T} = (T_i + T_o)/2$ .

<sup>d</sup>For  $0.05 < Pr < 0.6$ , use (7.27) and  $\bar{Nu}_x = 2Nu_x$ .

<sup>e</sup>For other values of  $Re_{x,c}$ , use (7.31)–(7.33).

$$Re_{D,max} = \frac{V_{max} D}{\nu}$$

$$V_{max} = \begin{cases} (7.52) & \text{Aligned} \\ \max(7.52, 7.53) & \text{Staggered} \end{cases}$$