Coeficientes de atrito:

Tabela 6-3 Coeficientes de arrasto de objetos bidimensionais para \( \text{Re} = 10^5 \)

<table>
<thead>
<tr>
<th>Placa</th>
<th>( C_D = 2,0 )</th>
<th>Meio tubo</th>
<th>( C_D = 1,2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cilindro quadrado</td>
<td>( C_D = 2,1 )</td>
<td>Triângulo equilátero</td>
<td>( C_D = 2,3 )</td>
</tr>
<tr>
<td>Cilindro circular</td>
<td>( C_D = 1,6 )</td>
<td>Cilindro elíptico</td>
<td>( C_D = 2,0 )</td>
</tr>
<tr>
<td>Meio cilindro</td>
<td>( C_D = 1,6 )</td>
<td>Cilindro elíptico</td>
<td>( C_D = 0,2 )</td>
</tr>
<tr>
<td>Placa</td>
<td>( C_D = 1,7 )</td>
<td>Cilindro elíptico</td>
<td>( C_D = 0,15 )</td>
</tr>
<tr>
<td>Re = ( \frac{U_t}{v} )</td>
<td>( C_D = 0,25 )</td>
<td>Cilindro elíptico</td>
<td>( C_D = 0,1 )</td>
</tr>
<tr>
<td>( t = ) Altura projetada normal a ( U )</td>
<td></td>
<td>Laminar Turbuleto</td>
<td>( C_D = 0,6 )</td>
</tr>
</tbody>
</table>

Drag coefficients \( C_D \) of various two-dimensional bodies for \( \text{Re} > 10^4 \) based on the frontal area \( A = bD \), where \( b \) is the length normal to the direction of the paper (for use in the drag force relation \( F_D = C_D A \rho V^2/2 \) where \( V \) is the free-stream velocity away from the body).
Tabela 6.4 Coeficiente de arrasto de objetos tridimensionais $\text{Re} = 10^4$ ($C_D$ Baseado na área frontal)

<table>
<thead>
<tr>
<th>Objeto</th>
<th>$\frac{b}{t}$</th>
<th>$C_D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cilindro quadrado</td>
<td>$\infty$</td>
<td>2,10</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1,06</td>
</tr>
<tr>
<td>Cone de 60°</td>
<td></td>
<td>0,50</td>
</tr>
<tr>
<td>Disco</td>
<td></td>
<td>1,17</td>
</tr>
<tr>
<td>Casca semi-esférica</td>
<td></td>
<td>1,42</td>
</tr>
<tr>
<td>Placa retangular</td>
<td></td>
<td>0,38</td>
</tr>
</tbody>
</table>

$\frac{b}{t} = 1$

$\frac{b}{t} = \infty$

Paraquedas

$C_D = 1,20$

Disco anular

$C_D = 1,20$

Cilindro circular

$\frac{L}{d} = 0,5$

$C_D = 1,15$

<table>
<thead>
<tr>
<th>$\frac{L}{d}$</th>
<th>$C_D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0,90</td>
</tr>
<tr>
<td>2</td>
<td>0,85</td>
</tr>
<tr>
<td>4</td>
<td>0,87</td>
</tr>
<tr>
<td>8</td>
<td>0,99</td>
</tr>
</tbody>
</table>

Elipsóide

Re baseado em $L$ ou $t$ a altura projetada normal a $U$

<table>
<thead>
<tr>
<th>$\frac{L}{t}$</th>
<th>$C_D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0,47</td>
</tr>
<tr>
<td>2</td>
<td>0,25</td>
</tr>
<tr>
<td>4</td>
<td>0,20</td>
</tr>
<tr>
<td>8</td>
<td>0,23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\text{Re} = 10^6$</th>
<th>$\text{Re} = 10^7$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,090</td>
<td>0,040</td>
</tr>
<tr>
<td>0,065</td>
<td>0,041</td>
</tr>
<tr>
<td>0,100</td>
<td>0,078</td>
</tr>
</tbody>
</table>

---

Representative drag coefficients $C_D$ for various three-dimensional bodies for $Re > 10^4$ based on the frontal area
(for use in the drag force relation $F_D = C_D A \rho V^2/2$ where $V$ is the free-stream velocity away from the body)

<table>
<thead>
<tr>
<th>Shape</th>
<th>Equation</th>
<th>$C_D$ Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cube, $A = D^2$</td>
<td></td>
<td>$C_D = 1.05$</td>
</tr>
<tr>
<td>Thin circular disk, $A = \pi D^2/4$</td>
<td></td>
<td>$C_D = 1.1$</td>
</tr>
<tr>
<td>Cone (for $\theta = 30^\circ$), $A = \pi D^2/4$</td>
<td></td>
<td>$C_D = 0.5$</td>
</tr>
<tr>
<td>Sphere, $A = \pi D^2/4$</td>
<td></td>
<td>$C_D = 0.4$</td>
</tr>
<tr>
<td>Ellipsoid, $A = \pi D^2/4$</td>
<td></td>
<td>$C_D = 1.2$</td>
</tr>
<tr>
<td>Laminar: $C_D = 0.5$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbulent: $C_D = 0.2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemispher, $A = \pi D^2/4$</td>
<td></td>
<td>$C_D = 0.4$</td>
</tr>
<tr>
<td>Short cylinder, vertical, $A = \pi D^2/4$</td>
<td>$L/D$</td>
<td>$C_D$ Values</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.9</td>
</tr>
<tr>
<td>Short cylinder, horizontal, $A = \pi D^2/4$</td>
<td>$L/D$</td>
<td>$C_D$ Values</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>1.0</td>
</tr>
<tr>
<td>Streamlined body, $A = \pi D^2/4$</td>
<td></td>
<td>$C_D = 0.04$</td>
</tr>
<tr>
<td>Parachute, $A = \pi D^2/4$</td>
<td></td>
<td>$C_D = 1.3$</td>
</tr>
<tr>
<td>Tree, $A =$ frontal area</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$V$, m/s</td>
<td>$C_D$ Values</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.4–1.2</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>0.3–1.0</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0.2–0.7</td>
</tr>
</tbody>
</table>

Person (average)

- Standing, $C_D A = 9 \text{ ft}^2 = 0.84 \text{ m}^2$
- Sitting, $C_D A = 6 \text{ ft}^2 = 0.56 \text{ m}^2$

Bikes

- Upright: $A = 5.5 \text{ ft}^2 = 0.51 \text{ m}^2$
  $C_D = 1.1$
- Drafting: $A = 3.9 \text{ ft}^2 = 0.36 \text{ m}^2$
  $C_D = 0.50$
- Racing: $A = 3.9 \text{ ft}^2 = 0.36 \text{ m}^2$
  $C_D = 0.9$
- With fairing: $A = 5.0 \text{ ft}^2 = 0.46 \text{ m}^2$
  $C_D = 0.12$

Semitruck, ($A =$ frontal area)

- Without fairing: $C_D = 0.96$
- With fairing: $C_D = 0.76$

Automotive ($A =$ frontal area)

- Minivan, $C_D = 0.4$
- Passenger car, $C_D = 0.3$

High-rise buildings ($A =$ frontal area)

$C_D = 1.4$
Placa Plana

**Convecção forçada – Propriedades avaliadas a Text**

<table>
<thead>
<tr>
<th>Fluxo</th>
<th>Local</th>
<th>Médio</th>
<th>Constate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laminar</td>
<td>$ Nu_x = 0.332 \cdot Re_x^{\frac{1}{2}} \cdot Pr^{\frac{1}{3}}$</td>
<td>$ Nu = 0.664 \cdot Re_L^{\frac{1}{2}} \cdot Pr^{\frac{1}{3}} $</td>
<td>T</td>
</tr>
<tr>
<td>$ Re_x &lt; 5.10^3 $</td>
<td>$ Nu_x = 0.46 \cdot Re_x^{\frac{1}{2}} \cdot Pr^{\frac{1}{3}} $</td>
<td>Não há</td>
<td>Q</td>
</tr>
<tr>
<td>Transição</td>
<td>$ 5.10^3 &lt; Re_x &lt; 5.10^5 $</td>
<td>$ Nu = \sqrt{Nu_L^2 + Nu_T^2} $</td>
<td>T</td>
</tr>
<tr>
<td>Turbulento</td>
<td>$ 5.10^5 &lt; Re_x &lt; 10^7 $</td>
<td>$ Nu_x = \frac{0.0296 \cdot Re_x^{0.8} \cdot Pr}{1 + 2.185 \cdot Re_x^{-0.1} (Pr^{3} - 1)} $</td>
<td>T/Q</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$ Nu = \frac{0.037 \cdot Re_x^{0.8} \cdot Pr}{1 + 2.443 \cdot Re_x^{-0.1} (Pr^{3} - 1)} $</td>
<td></td>
</tr>
</tbody>
</table>

**Convecção natural – Propriedades avaliadas a** \( \frac{(T_p + T_{ext})}{2} \)

**Vertical**

<table>
<thead>
<tr>
<th>Constate</th>
<th>Fluxo</th>
<th>Local</th>
<th>Médio</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>$ Ra_x = g \rho \cdot q_{c_i} \beta (T_p - T_x) x^3 \frac{k \mu}{\rho} $</td>
<td>$ Nu_x = 0.68 + 0.503 \cdot [Ra_x \cdot \psi (Pr)]^{\frac{1}{3}} $</td>
<td>$ Nu = 0.68 + 0.67 \cdot [Ra_L \cdot \psi (Pr)]^{\frac{1}{3}} $</td>
</tr>
<tr>
<td></td>
<td>$ Ra_x &lt; 10^9 $</td>
<td>$ Nu_x = 0.68 + 0.503 \cdot [Ra_x \cdot \psi (Pr)]^{\frac{1}{3}} $</td>
<td>$ Nu = 0.68 + 0.67 \cdot [Ra_L \cdot \psi (Pr)]^{\frac{1}{3}} $</td>
</tr>
<tr>
<td></td>
<td>Turbulento</td>
<td>$ Nu_x = 0.68 + 0.503 \cdot [Ra_x \cdot \psi (Pr)]^{\frac{1}{3}} $</td>
<td>$ Nu = 0.68 + 0.67 \cdot [Ra_L \cdot \psi (Pr)]^{\frac{1}{3}} $</td>
</tr>
<tr>
<td>Q</td>
<td>$ Ra_x^* = g \rho^2 c_i \beta qr' x^4 \frac{\mu k^2}{\rho^2} $</td>
<td>$ Nu_x = 0.68 + 0.503 \cdot [Ra_x^* \cdot \Phi (Pr)]^{\frac{1}{3}} $</td>
<td>$ Nu = 0.68 + 0.67 \cdot [Ra_L^* \cdot \Phi (Pr)]^{\frac{1}{3}} $</td>
</tr>
<tr>
<td></td>
<td>$ Ra_x &lt; 10^9 $</td>
<td>$ Nu_x = 0.68 + 0.503 \cdot [Ra_x^* \cdot \Phi (Pr)]^{\frac{1}{3}} $</td>
<td>$ Nu = 0.68 + 0.67 \cdot [Ra_L^* \cdot \Phi (Pr)]^{\frac{1}{3}} $</td>
</tr>
<tr>
<td></td>
<td>Turbulento</td>
<td>$ Nu_x = 0.68 + 0.503 \cdot [Ra_x^* \cdot \Phi (Pr)]^{\frac{1}{3}} $</td>
<td>$ Nu = 0.68 + 0.67 \cdot [Ra_L^* \cdot \Phi (Pr)]^{\frac{1}{3}} $</td>
</tr>
</tbody>
</table>

**Horizontal**

<table>
<thead>
<tr>
<th>Constate</th>
<th>Fluxo</th>
<th>Quente / Fria</th>
<th>Fria / Quente</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>$ 10^4 &lt; Ra_L &lt; 10^7 $</td>
<td>$ Nu_L = 0.54 Ra_L^{\frac{1}{3}} $</td>
<td>$ - $</td>
</tr>
<tr>
<td></td>
<td>$ 10^7 &lt; Ra_L &lt; 10^{11} $</td>
<td>$ Nu_L = 0.15 Ra_L^{\frac{1}{3}} $</td>
<td>$ - $</td>
</tr>
<tr>
<td></td>
<td>$ 10^5 &lt; Ra_L &lt; 10^{10} $</td>
<td>$ Nu_L = 0.27 Ra_L^{\frac{1}{3}} $</td>
<td>$ - $</td>
</tr>
</tbody>
</table>

`tabela.odt`
Cilindros, tubos e esferas

Isotérmico

<table>
<thead>
<tr>
<th>Convecção</th>
<th>Fluxo</th>
<th>Cilindro</th>
<th>Esfera</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Re}_{LC} &lt; 1 )</td>
<td>( \overline{N}u = 0,75 \text{Re}_{LC} \text{Pr}_r^{1/3} )</td>
<td>( \overline{N}u = 1,01 \text{Re}_{LC} \text{Pr}_r^{1/3} )</td>
<td></td>
</tr>
<tr>
<td>( 1 &lt; \text{Re}_{LC} &lt; 10^5 )</td>
<td>( \overline{N}u = \overline{N}u_0 + \frac{\text{Nu}_L^2 + \text{Nu}_T^2}{2} )</td>
<td>( \overline{N}u = 0,664 \text{Re}_{L}^{1/2} \text{Pr}_r^{1/3} )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \overline{N}u = \frac{0,037 \text{Re}_{L}^{0.5} \text{Pr}<em>r}{1 + 2,443 \text{Re}</em>{L}^{-0.1} (\text{Pr}_r^{3/2} - 1)} )</td>
<td></td>
</tr>
</tbody>
</table>

Forçada

<table>
<thead>
<tr>
<th>Objeto</th>
<th>( \text{Lc} )</th>
<th>( \overline{N}u_0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fio, cilindro, tubo</td>
<td>( \pi \cdot \frac{d}{2} )</td>
<td>0,3</td>
</tr>
<tr>
<td>Esferas</td>
<td>d</td>
<td>2,0</td>
</tr>
</tbody>
</table>

[tabela 6.5]

<table>
<thead>
<tr>
<th>Geometria / objeto</th>
<th>( \text{Lc} )</th>
<th>( \overline{N}u_0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placa inclinada</td>
<td>( x )</td>
<td>0,68</td>
</tr>
<tr>
<td>Disco inclinado</td>
<td>( \frac{9}{11}d )</td>
<td>0,56</td>
</tr>
<tr>
<td>Cilindro vertical</td>
<td>( L )</td>
<td>0,68</td>
</tr>
<tr>
<td>Cilindro horizontal</td>
<td>( \pi \cdot d )</td>
<td>0,36 ( \pi )</td>
</tr>
<tr>
<td>Cone</td>
<td>( \frac{4}{5}L )</td>
<td>0,54</td>
</tr>
<tr>
<td>Esfera</td>
<td>( \pi \cdot \frac{d}{2} )</td>
<td>( \pi )</td>
</tr>
<tr>
<td>Esferóide</td>
<td>( 3 \pi \frac{V}{A} )</td>
<td>( \frac{A^3}{36V^2} )</td>
</tr>
</tbody>
</table>

\( \text{Lc} \) é medido ao longo da superfície [tabela 6.6]

Grupos adimensionais:

- Grashof \( Gr = \frac{g \beta (T_p - T_\infty) x^3}{v^2} \) [6.48]
- Nusselt \( Nu = \frac{h_x x}{k} \) [6.19]
- Prandt \( Pr = \frac{c_p \mu}{k} \) [6.3]
- Rayleigh \( Ra = \frac{g \rho^2 c_p \beta (T_p - T_\infty) x^3}{k \mu} \) \( = \text{Gr} \cdot Pr \) [6.50]

Rayleigh \( Ra^* = \frac{g \rho^2 c_p \beta q'_{\gamma' r} x^4}{\mu k^3} \) [6.58] Fluxo de calor constante \( \beta = \frac{1}{T} (K) \) coef. de expansão do gás.
### Escoamentos internos:

<table>
<thead>
<tr>
<th>Fluxo</th>
<th>Constante</th>
<th>Duto circular</th>
<th>Outras formas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>( T_m(x) = \frac{\dot{q}'' x A}{m C_p} + T_{mc} ) [7.20]</td>
<td>( A = P.x ); ( T_p = \frac{\dot{q}'' p}{h_x} + T_m ) [7.21]</td>
<td>Laminar plenamente desenvolvido</td>
</tr>
<tr>
<td></td>
<td>Local p/</td>
<td>( P_e \frac{d}{L} &gt; 10^4 )</td>
<td>( Nu_x = 1,302 \left( P_e \frac{d}{L} \right)^{1/3} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( P_e \frac{d}{L} &lt; 10^3 )</td>
<td>( Nu_x = 4,36 )</td>
</tr>
<tr>
<td></td>
<td>Médio p/</td>
<td>( P_e \frac{d}{L} &gt; 100 )</td>
<td>( \bar{Nu} = 1,953 \left( P_e \frac{d}{L} \right)^{1/3} )</td>
</tr>
<tr>
<td></td>
<td>Médio p/</td>
<td>( P_e \frac{d}{L} &lt; 10 )</td>
<td>( \bar{Nu} = 4,36 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \frac{T_p - T_m(x)}{T_p - T_{mc}} = e^{-\frac{h_{pp} x}{m C_p}} ) [7.22]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local p/</td>
<td>( P_e \frac{d}{L} &gt; 100 )</td>
<td>( Nu_x = 1,077 \left( P_e \frac{d}{L} \right)^{1/3} )</td>
</tr>
<tr>
<td></td>
<td>Local p/</td>
<td>( P_e \frac{d}{L} &lt; 100 )</td>
<td>( Nu_x = 3,66 )</td>
</tr>
<tr>
<td></td>
<td>Médio:</td>
<td>( \bar{Nu} = \left( 3.66^3 + 1,61^3 \right) \left( P_e \frac{d}{L} \right)^{1/3} )</td>
<td></td>
</tr>
</tbody>
</table>

### Turbuleto

| Q / T | \( 0,5 < Pr < 1,5 \) | \( Nu = 0,0214 \left( Re^{4/5} - 100 \right) \cdot Pr^{2/5} \left[ 1 + \left( \frac{d_h}{L} \right)^{2/3} \right] \) [7.28] |
|       | \( 1,5 < Pr < 500 \) | \( \bar{Nu} = 0,012 \left( Re^{0,87} - 280 \right) \cdot Pr^{2/5} \left[ 1 + \left( \frac{d_h}{L} \right)^{2/3} \right] \) [7.29] |
|       | Correção radial para das propriedades para líquidos: \( Nu_{corr} = Nu \left( Pr_m / Pr_p \right)^{0,11} \) |
|       | \( d_h = 4 \left( \frac{Area}{Perímetro} \right) \) : Quadrado: \( d_h = a \), triângulo: \( d_h = 2a \) |
|       | Placas paralelas: \( d_h = \frac{a}{\sqrt{48}} \) |

Para tubos rugosos:

- Proposta Chilton-colburn:
  \( f = \frac{1}{8} \cdot St \cdot Pr^{2/3} \)
- \( f \) é o fator de atrito retirado do diagrama de Moody (pg. 242)

\( St = \frac{Nu}{Re \cdot Pr} \)

\( \bar{Nu} = \frac{f}{8} \cdot Re_{dh} \cdot Pr^{1/3} \)

### Variação das propriedades na direção radial:

\( Nu_{corr} = Nu \left( \mu_m / \mu_p \right)^{0,14} \) onde \( m \) refere-se à temperatura de mistura e \( p \) da parede

\( Pe = Re \cdot Pr \) (Peclet)

\( Re = U \frac{d_h}{v} \)

\( h = k \frac{Nu}{L} \left[ \frac{W}{m^2 \cdot ^{0}C} \right] \)

\( \dot{Q} = L \cdot h \left( T_p - T_{mc} \right) \) [W/m]

---

**Notas:**

<table>
<thead>
<tr>
<th>Configuração</th>
<th>Temp.</th>
<th>( \dot{Q} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Círculo</td>
<td>3,66</td>
<td>4,36</td>
</tr>
<tr>
<td>Quadrado</td>
<td>2,98</td>
<td>3,61</td>
</tr>
<tr>
<td>Retângulo 2x1</td>
<td>3,39</td>
<td>4,12</td>
</tr>
<tr>
<td>Retângulo 8x1</td>
<td>5,6</td>
<td>6,49</td>
</tr>
<tr>
<td>Planos paralelos ( \infty \times 1 )</td>
<td>7,56</td>
<td>8,24</td>
</tr>
<tr>
<td>Triângulo equilátero</td>
<td>2,35</td>
<td>3</td>
</tr>
</tbody>
</table>
Função erro de Gauss:

<table>
<thead>
<tr>
<th>Material</th>
<th>( r ) (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riveted steel</td>
<td>0.003–0.03</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.001–0.01</td>
</tr>
<tr>
<td>Wood slat</td>
<td>0.0008–0.0005</td>
</tr>
<tr>
<td>Cast iron</td>
<td>0.0005</td>
</tr>
<tr>
<td>Galvanized iron</td>
<td>0.0004</td>
</tr>
<tr>
<td>Asphalted cast iron</td>
<td>0.0005</td>
</tr>
<tr>
<td>Commercial steel</td>
<td>0.00015</td>
</tr>
<tr>
<td>Drawn tubing</td>
<td>0.000005</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fluid at 60°F ( v ) (ft/s)</th>
<th>0.0400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1.2176–0.001</td>
</tr>
<tr>
<td>Air (14.70 psi)</td>
<td>0.0001593</td>
</tr>
</tbody>
</table>

| Reynolds number \( R = \frac{VD}{v} \) (V in fps, \( D \) in ft, \( v \) in ft/s) |
|----------------------------------|-------|
| 0                                | 0.0000 |
| 0.0200                           | 0.5200 |
| 0.0400                           | 0.5400 |
| 0.0600                           | 0.5600 |
| 0.0800                           | 0.5800 |
| 0.1000                           | 0.6000 |
| 0.1200                           | 0.6200 |
| 0.1400                           | 0.6400 |
| 0.1600                           | 0.6600 |
| 0.1800                           | 0.6800 |
| 0.2000                           | 0.7000 |
| 0.2200                           | 0.7200 |
| 0.2400                           | 0.7400 |
| 0.2600                           | 0.7600 |
| 0.2800                           | 0.7800 |
| 0.3000                           | 0.8000 |
| 0.3200                           | 0.8200 |
| 0.3400                           | 0.8400 |
| 0.3600                           | 0.8600 |
| 0.3800                           | 0.8800 |
| 0.4000                           | 0.9000 |
| 0.4200                           | 0.9200 |
| 0.4400                           | 0.9400 |
| 0.4600                           | 0.9600 |
| 0.4800                           | 0.9800 |
| 0.5000                           | 1.0000 |

| \( VD \) for water at 60°F (V in fps, \( D \) in inches) |
|----------------------------------------------------------|-------|
| 0.1                                                       | 0.2   |
| 0.2                                                       | 0.4   |
| 0.3                                                       | 0.6   |
| 0.4                                                       | 0.8   |
| 0.5                                                       | 1.0   |

| \( VD \) for atmospheric air at 60°F |
|---------------------------------------|-------|
| 0.1                                    | 0.2   |
| 0.2                                    | 0.4   |
| 0.3                                    | 0.6   |
| 0.4                                    | 0.8   |
| 0.5                                    | 1.0   |

Moody Diagram

- Lamellar flow
- Critical zone
- Transition zone
- Complete turbulence, rough pipes, \( R > 3500,\) \( \nu = 1.14 - 2 \log r \)

Conversion factors:
- \( 1 \) ft = 0.3048 m
- \( 1 \) in = 2.54 cm
- \( 1 \) lb = 0.45359 kg
- \( 1 \) kcal = 4.184 kJ

Acceleration at sea level latitude 45°, \( g = 2.74174 \) ft/s²

Calculated values

- \( r = \frac{\nu}{D} \) (in ft ft²/s)
- \( f = 0.5 \) for smooth pipes
- \( f = 0.40 \) for pipes of \( R > 2000 \)
- \( f = 0.32 \) for \( R > 4000 \)
- \( f = 0.28 \) for \( R > 8000 \)

- \( \frac{V}{D} \) in ft/s
- \( D \) in ft

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