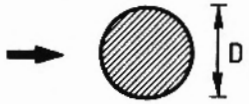
Table 10-18. Drag of Two-Dimensional Bluff Sections.

Notation C_D = drag coefficient = drag per unit span/$(0.5\,\rho U^2 D)$; D = characteristic width; Drag = force exerted parallel to the approach flow; Re = Reynolds number = UD/ν; U = free stream velocity; ρ = fluid density; ν = fluid kinematic viscosity. Consistent sets of units are given in Table 3-1. Data are for high Reynolds number, Re > ~10^4, incompressible, low-turbulent flow. → denotes direction of approaching free stream unless otherwise noted. Accuracy is approximately ±5%.

Geometry	Drag Coefficient, C_D, and Remarks

1. Circular Cylinder



Re	10^2	10^3	10^4	10^5	10^6	10^7
C_D	1.4	1.0	1.1	1.2	0.4	0.8

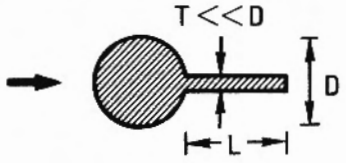
For Re < 1, $C_D \approx 8\pi/[\text{Re} \log_e (7.4/\text{Re})]$.
Also see Fig. 10-22. Ref. 10-134

2. Stranded Cable or Chain

Type	10^3 < Re < 10^4	10^4 < Re < 10^5
Stranded Steel Cable	1.5	1.3
Jacked Steel Cable	1.5	1.1
Braided Synthetic Cable	1.1	1.1
Plaited Synthetic Cable	1.2	0.99
Link Chain (Based on Link Width)	--	0.85

Ref. 10-159.

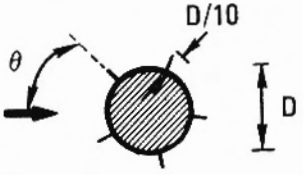
3. Circular Cylinder with Thin Fin



L/D	0	0.33	0.67	1.0	1.5	2.0	2.5
C_D	1.25	1.2	1.15	1.1	1.07	1.02	1.0

Re = 10^5, Ref. 10-160

4. Cylinder with Five Thin Fins



θ	C_D	C_L
-20	2.2	0.3
-10	2.5	0.25
0	2.7	0.0
10	2.5	-0.25
20	2.1	-0.4
30	1.5	-0.25
35	1.1	0.0
40	1.4	0.2
50	2.0	0.4
60	2.4	0.35

Re = 10^4, Ref. 10-161.

Table 10-18. Drag of Two-Dimensional Bluff Sections. *(Continued)*

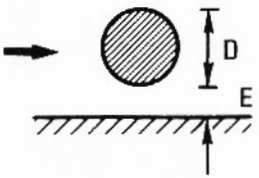
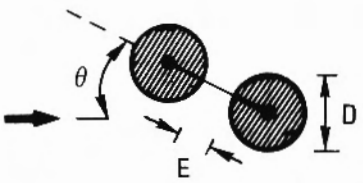
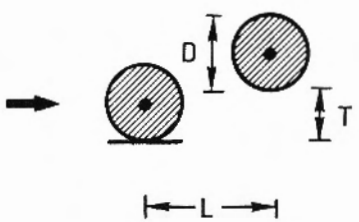
Geometry	Drag Coefficient, C_D, and Remarks
5. Cylinder Near a Wall 	E/D | C_D | C_L 0 | 0.8 | 0.6 0.25 | 1.1 | 0.25 0.5 | 1.2 | 0.15 1.0 | 1.3 | 0.05 1.5 | 1.2 | 0.02 2.0 | 1.2 | 0 4.0 | 1.2 | 0 6.0 | 1.2 | 0 $Re = 2 \times 10^4$, Ref. 10-162 Lift force is away from wall.
6. Two Cylinders in Tandem 	C_D vs. E/D and θ (deg) θ (deg) | 0.625 | 1.0 | 2.0 | 3.0 | ∞ 0 | 0.3 | 0.3 | 0.3 | 0.3 | 2.4 10 | 0.4 | 0.4 | 0.45 | 0.4 | 2.4 20 | 0.7 | 0.7 | 0.6 | 0.5 | 2.4 30 | 0.8 | 0.8 | 0.6 | 0.5 | 2.4 40 | 0.9 | 0.85 | 0.6 | 0.5 | 2.4 50 | 1.0 | 0.9 | 0.7 | 0.55 | 2.4 Ref. 10-163
7. Cylinder Downstream of Another Cylinder  Drag on Downstream Cylinder.	T/D = 0 L/D | C_D 1.0 | -0.4 1.5 | -0.2 2.0 | 0.0 2.5 | 0.2 3.0 | 0.2 4.0 | 0.3 T/D = 0.5 L/D | C_D 1.0 | 0.65 1.5 | 0.50 2.0 | 0.45 2.5 | 0.45 3.0 | 0.40 4.0 | 0.40 T/D = 1.0 L/D | C_D 1.0 | 1.1 1.5 | 1.0 2.0 | 0.70 2.5 | 0.70 3.0 | 0.65 4.0 | 0.65 T/D = 2 L/D | C_D 1.0 | 1.1 1.5 | 1.0 2.0 | 1.0 2.5 | 1.0 3.0 | 1.0 4.0 | 1.0 $10^4 < Re < 10^5$, Ref. 10-164

Table 10-18. Drag of Two-Dimensional Bluff Sections. *(Continued)*

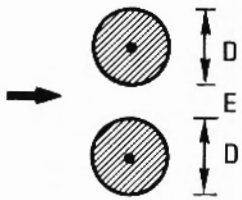
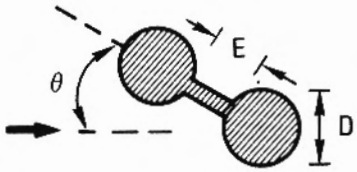
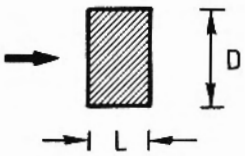
Geometry	Drag Coefficient, C_D, and Remarks
8. Two Cylinders Side by Side 	<table><tr><th>E/D</th><th>C_D</th><th>C_L</th></tr><tr><td>0</td><td>1.6</td><td>0.8</td></tr><tr><td>0.25</td><td>1.0</td><td>0.6</td></tr><tr><td>0.5</td><td>0.9</td><td>0.4</td></tr><tr><td>1.0</td><td>1.1</td><td>0.2</td></tr><tr><td>1.5</td><td>1.3</td><td>0.1</td></tr><tr><td>2.0</td><td>1.2</td><td>0.05</td></tr><tr><td>4.0</td><td>1.2</td><td>0.0</td></tr><tr><td>6.0</td><td>1.2</td><td>0.0</td></tr></table> C_D, C_L for each cylinder. $10^4 < Re < 10^5$, Ref. 10-164. Lift force is repulsive.
9. Two Cylinders Connected by a Thin Web 	<table><tr><th rowspan="2">θ (deg)</th><th colspan="3">C_D E/D</th></tr><tr><th>1.0</th><th>2.0</th><th>3.0</th></tr><tr><td>0</td><td>0.25</td><td>0.3</td><td>0.3</td></tr><tr><td>10</td><td>0.4</td><td>0.4</td><td>0.4</td></tr><tr><td>20</td><td>0.7</td><td>0.7</td><td>0.7</td></tr><tr><td>30</td><td>1.0</td><td>1.0</td><td>1.2</td></tr><tr><td>40</td><td>1.3</td><td>1.4</td><td>1.8</td></tr><tr><td>50</td><td>1.7</td><td>1.8</td><td>2.5</td></tr></table> Ref. 10-163.
10. Rectangle 	<table><tr><th>L/D</th><th>C_D</th><th>L/D</th><th>C_D</th></tr><tr><td>0.1≤</td><td>1.9</td><td>1.0</td><td>2.2</td></tr><tr><td>0.2</td><td>2.1</td><td>1.2</td><td>2.1</td></tr><tr><td>0.4</td><td>2.35</td><td>1.5</td><td>1.8</td></tr><tr><td>0.5</td><td>2.5</td><td>2.0</td><td>1.6</td></tr><tr><td>0.65</td><td>2.9</td><td>2.5</td><td>1.4</td></tr><tr><td>0.8</td><td>2.3</td><td>3.0</td><td>1.3</td></tr><tr><td></td><td></td><td>6.0</td><td>0.89</td></tr></table> $Re \sim 10^5$, Refs. 10-165; 10-102, p. 10-3.

Table 10-18. Drag of Two-Dimensional Bluff Sections. *(Continued)*

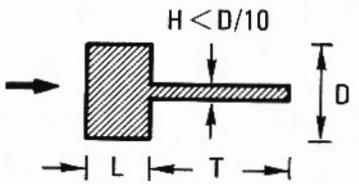
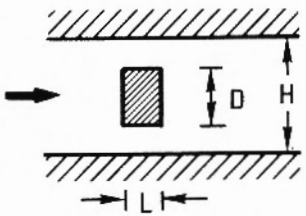
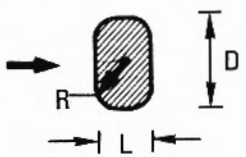
Geometry	Drag Coefficient, C_D, and Remarks
11. Rectangle with Thin Splitter Plate 	C_D vs T/D L/D | 0 | 5 | 10 0.1< | 1.9 | 1.4 | 1.38 0.2 | 2.1 | 1.40 | 1.43 0.4 | 2.35 | 1.39 | 1.46 0.6 | 1.8 | 1.38 | 1.48 0.8 | 2.3 | 1.36 | 1.47 1.0 | 2.0 | 1.33 | 1.45 1.5 | 1.8 | 1.30 | 1.40 2.0 | 1.6 | -- | 1.33 Re = 5×10^4, Refs. 10-131, 10-166.
12. Rectangle in a Channel 	$C_D = \left(1 - \frac{D}{H}\right)^{-n} C_D\Big\|_{H=\infty}$ frame 10 for $0 < D/H < 0.25$. L/D | 0.1< | 0.25 | 0.50 | 1.0 | 2.0 n | 2.3 | 2.2 | 2.1 | 1.2 | 0.4 Re > 10^3, Ref. 10-131.
13. Rectangle with Rounded Corners 	L/D | R/D | C_D 0.5 | 0 | 2.5 0.021 | 2.2 0.083 | 1.9 0.250 | 1.6 1.0 | 0 | 2.2 0.021 | 2.0 0.167 | 1.2 0.333 | 1.0 L/D | R/D | C_D 2.0 | 0 | 1.6 0.042 | 1.4 0.167 | 0.7 0.50 | 0.4 6.0 | 0. | 0.89 0.5 | 0.29 Re = 10^5, Refs. 10-132; 10-162; 10-102, p. 10-3.

Table 10-18. Drag of Two-Dimensional Bluff Sections. *(Continued)*

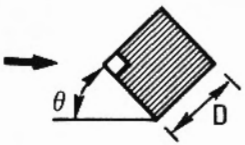
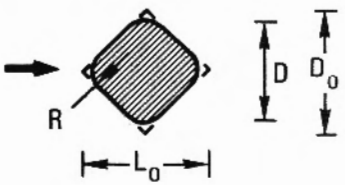
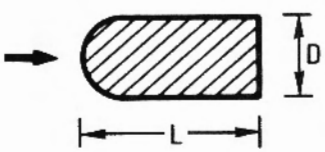
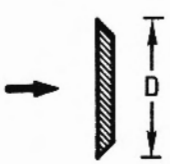
Geometry	Drag Coefficient, C_D, and Remarks
14. Inclined Square 	<table><tr><td>θ(Deg)</td><td>0</td><td>5</td><td>10</td><td>15</td><td>20</td><td>25</td><td>30</td><td>35</td><td>40</td><td>45</td></tr><tr><td>C_D</td><td>2.2</td><td>2.1</td><td>1.8</td><td>1.3</td><td>1.9</td><td>2.1</td><td>2.2</td><td>2.3</td><td>2.4</td><td>2.4</td></tr></table> Re = 4.7×10^4, Ref. 10-275.
15. Diamond with Rounded Corners 	<table><tr><th>L_o/D_o</th><th>R/D_o</th><th>C_D</th><th></th></tr><tr><td>0.5</td><td>0.021</td><td>1.8</td><td rowspan="3">Fore and aft corners not rounded.</td></tr><tr><td></td><td>0.083</td><td>1.7</td></tr><tr><td></td><td>0.167</td><td>1.7</td></tr><tr><td>1.0</td><td>0.015</td><td>1.5</td><td></td></tr><tr><td></td><td>0.118</td><td>1.5</td><td></td></tr><tr><td></td><td>0.235</td><td>1.5</td><td></td></tr><tr><td>2.0</td><td>0.040</td><td>1.1</td><td rowspan="3">Lateral corners not rounded</td></tr><tr><td></td><td>0.167</td><td>1.1</td></tr><tr><td></td><td>0.335</td><td>1.1</td></tr></table> Re = 10^5, Ref. 10-132.
16. Rounded Nose Section 	<table><tr><th>L/D</th><th>C_D</th></tr><tr><td>0.5</td><td>1.16</td></tr><tr><td>1.0</td><td>0.90</td></tr><tr><td>2.0</td><td>0.70</td></tr><tr><td>4.0</td><td>0.68</td></tr><tr><td>6.0</td><td>0.64</td></tr></table> Ref. 10-102, p. 3-12.
17. Thin Flat Plate Normal to Flow 	1.9 Re ∿ 10^5, Ref. 10-165.

Table 10-18. Drag of Two-Dimensional Bluff Sections. *(Continued)*

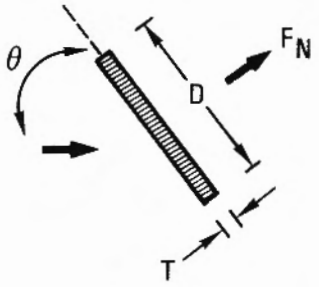
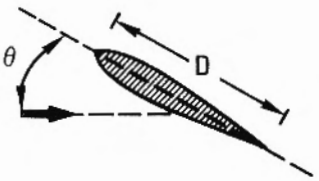
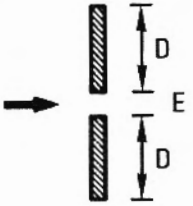
Geometry	Drag Coefficient, C_D, and Remarks
18. Thin Flat Plate Inclined to Flow  $T < 0.1\,D$	$C_N \approx \begin{cases} 2\pi \tan\theta, & \theta < 8° \\ \dfrac{1}{0.222 + 0.283/\sin\theta}, & 90° \geq \theta > 12° \end{cases}$ $C_L = C_N \cos\theta$ $C_D = C_N \sin\theta$ There is a discontinuity in the range $8° < \theta < 12°$ with $C_N \approx 0.8$ as flow separates from upper surface. See Table 10-14 for $\theta = 0°$. Refs. 10-168; 10-169, p. 41; 10-224, p. 21-1.
19. Thin Lifting Foil 	C_D = order of 0.01 , $C_L = 2\pi \sin\theta$, $C_M = \pi/4 \sin 2\theta$, } for $\theta < 8°$ C_M clockwise about leading edge. $C_M \approx 0$ about point D/4 behind leading edge. Ref. 10-169, pp. 41-42. Also see Section 10.5.
20. Two Thin Plates Side by Side 	E/D | C_D 0.5 | 1.42 or 2.20 } multiple values 1.0 | 1.52 or 2.13 } due to 2.0 | 1.9 or 2.10 } jet switch 3.0 | 2.0 5.0 | 1.96 10.0 | 1.9 15.0 | 1.9 $Re = 4 \times 10^3$, Ref. 10-170. Drag on each plate.

Table 10-18. Drag of Two-Dimensional Bluff Sections. *(Continued)*

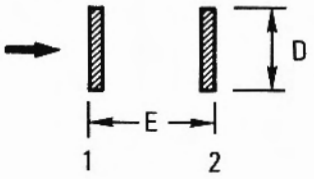
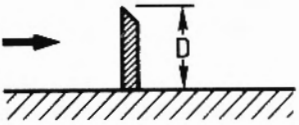
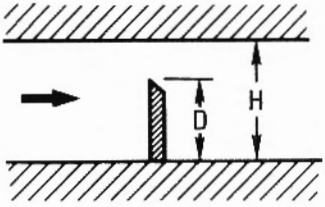
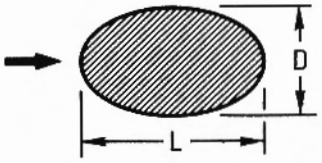
Geometry	Drag Coefficient, C_D, and Remarks
21. Two Thin Plates in Tandem 	E/D | C_{D1} | C_{D2} 2 | 1.80 | 0.10 3 | 1.70 | 0.67 4 | 1.65 | 0.76 6 | 1.65 | 0.95 10 | 1.9 | 1.00 20 | 1.9 | 1.15 30 | 1.9 | 1.33 ∞ | 1.9 | 1.9 $Re = 4 \times 10^3$, Ref. 10-170.
22. Thin Plate Extending from a Wall 	1.4 $Re = 5 \times 10^4$, Refs. 10-131, 10-166. See Table 10-15 for other protuberances from a surface.
23. Thin Plate Extending Part Way Across a Channel 	$C_D = \frac{1.4}{(1 - D/H)^{2.85}}$ for $0 < D/H < 0.25$. $Re > 10^3$, Ref. 10-131.
24. Ellipse 	D/L | C_D 0.125 | 0.22 0.25 | 0.3 0.50 | 0.6 1.0 | 1.0 2.0 | 1.6 $Re = 10^5$, Refs. 10-132, 10-167.

Table 10-18. Drag of Two-Dimensional Bluff Sections. *(Continued)*

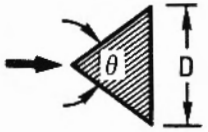
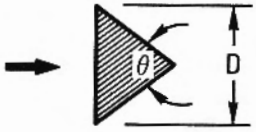
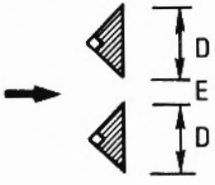
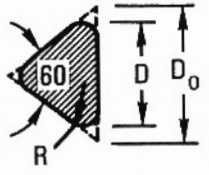
Geometry	Drag Coefficient, C_D, and Remarks
25. Isosceles Triangle with Point into Flow 	θ (deg) / C_D: 30 / 1.1; 60 / 1.4; 90 / 1.6; 120 / 1.75 Re = 10^4, Ref. 10-167.
26. Isosceles Triangle with Point Out of Flow 	θ (deg) / C_D: 30 / 1.9; 60 / 2.1; 90 / 2.15; 120 / 2.05 Re = 10^4, Ref. 10-167.
27. Two Isosceles Right Triangles Side by Side 	E/D / C_D / C_L: 0 / 1.7 / 0.5; 0.25 / 1.2 or 0.4 / 0.3 or 0.4; 0.5 / 1.2 or 1.8 / 0.2 or 0.3; 1.0 / 1.1 or 1.9 / 0.15 or 0.25 (multiple values due to jet switch); 2.0 / 1.75 / 0.1; 3.0 / 1.75 / 0.08 Lift force is repulsive. Re = 2×10^4, Ref. 10-162.
28. Rounded Isosceles Triangle 	R/D / C_D (→) / C_D (←): 0. / 1.4 / 2.1; 0.021 / 1.2 / 2.0; 0.083 / 1.3 / 1.9; 0.25 / 1.1 / 1.3 Re = 10^5, Ref. 10-132.

Table 10-18. Drag of Two-Dimensional Bluff Sections. *(Continued)*

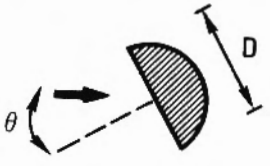
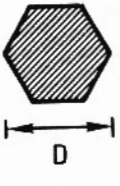
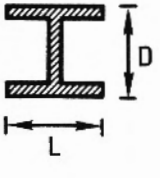
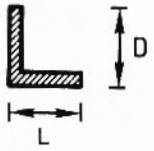
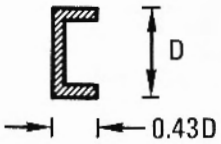
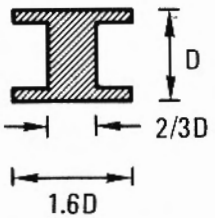
Geometry	Drag Coefficient, C_D, and Remarks
29. D Section 	θ (deg) / C_D / C_L: 0 / 2.15 / 0; 20 / 1.85 / 0.65; 40 / 0.90 / 1.40; 60 / 0.85 / 1.05; 80 / 0.5 / 0.16; 90 / 0.55 / -0.30; 120 / 0.90 / -0.05; 140 / 1.15 / 0.03; 160 / 1.20 / 0.01; 180 / 1.15 / 0. Ref. 10-171.
30. Cup Section 	→ C_D = 2.3 ← C_D = 1.1 Re = 2×10^4, Ref. 10-167.
31. Hexagon 	→ C_D = 1.0 ↑ C_D = 0.7 Ref. 10-161.
32. I Shape 	Flow Direction / C_D L/D = 0.5 / C_D L/D = 1.0: → 2.05 / 1.6; ↑ 0.9 / 1.9

Table 10-18. Drag of Two-Dimensional Bluff Sections. *(Continued)*

Geometry	Drag Coefficient, C_D, and Remarks
33. L Shape 	C_D L/D 0.5 / C_D L/D 1.0 / C_L L/D 0.5 / C_L L/D 1.0 → 2.0 2.0 -0.1 -0.3 ↗ -- 2.0 -- 0 ↑ -- 2.0 -- 0.3 ← 1.9 1.8 0.95 2.1 ↙ 1.8 2.5 -0.7 0 ↓ 1.7 1.8 -1.7 -2.1 Ref. 10-172.
34. Channel Section 	→ 1.8 ← 2.05 ↑ 0.6 Ref. 10-172.
35. Built-Up Section 	→ 1.4 ↑ 2.2 Ref. 10-172.