Table 10-15. Drag of Protuberances.

Notation: C_D = coefficient of drag of a protuberance for boundary layer thickness much less than height, $h \gg \delta$, where δ is the boundary layer thickness and h is the protuberance height. The drag force is $F_D = \frac{1}{2}\rho U^2 A C_D$ for $h \gg \delta$. A is the projected area A = bh for two-dimensional sections and rectangular bodies where b is width. See text for drag force for h comparable to δ. (Refs. 10-99. 10-102, 10-106, 10-107.) Errors in C_D of ±20% can be expected. Also see Tables 10-17 and 10-19 and Chapter 11.

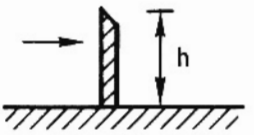
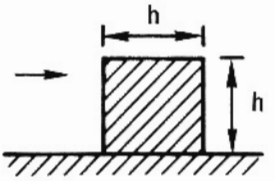
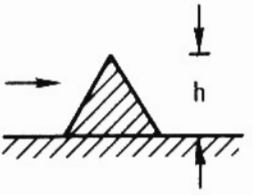
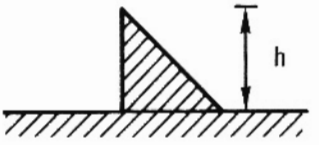
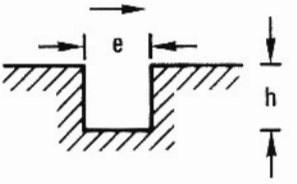
Protuberance	Drag Coefficient, C_D and Remarks
1. Fence Section 	1.4 (also see Fig. 10-14)
2. Square Section 	1.2
3. Equilateral Triangle Section 	1.0
4. Right Triangle 	→ 1.3 ← 1.0
5. Gap Section 	0.01 h > e > 0.1 h 0.25 8h > e > 20 h (also see Ref. 10-105)

Table 10-15. Drag of Protuberances. *(Continued)*

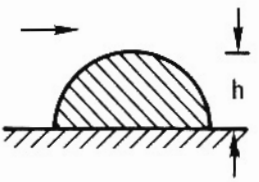
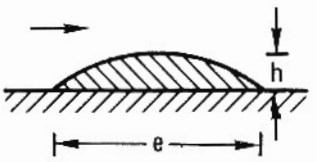
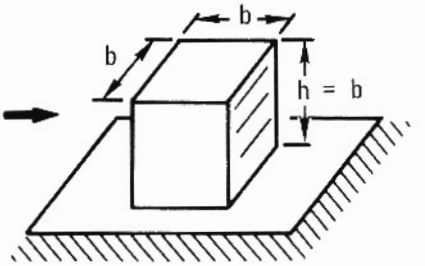
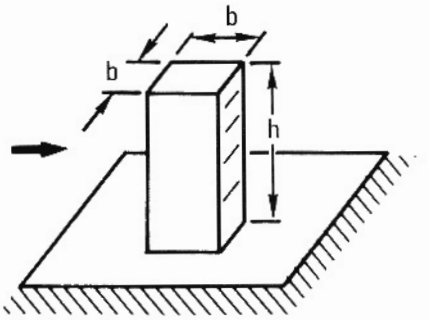
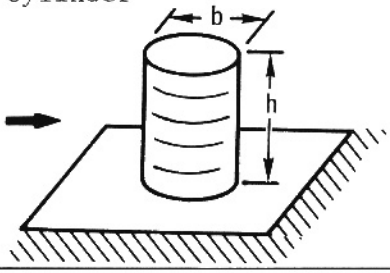
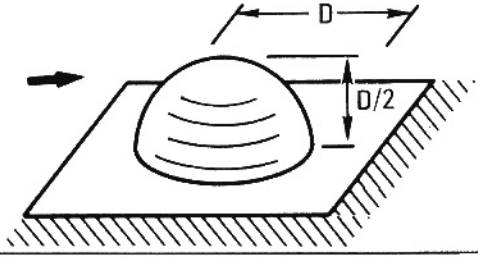
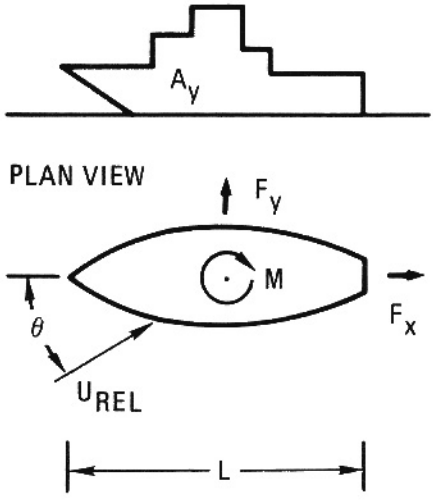
Protuberance	Drag Coefficient, C_D and Remarks
6. Semicircle Section 	0.8
7. Bump Section 	$15(h/e)^2$, for $0 < h/e < 0.16$
8. Sheet Metal Joint Section 	→ 0.4 ← 0.2
9. Cube 	Flow normal to face (shown) C_D = { 1.05 Ref. 10-102 1.65 Ref. 10-106 1.18 Ref. 10- Flow diagonal to face C_D = { 0.80 Ref. 10-102 1.65 Ref. 10-106 $A = b^2$
10. Rectangular Solid 	Flow normal to face (shown) C_D = { 1.3 Ref. 10-106 1.5 Ref. 10-102 Flow diagonal to face C_D = { 1.25 Ref. 10-106 1.05 Ref. 10-102 $A = b^2$. $1 < h/b < 4$.

Table 10-15. Drag of Protuberances. *(Continued)*

Protuberance	Drag Coefficient, C_D and Remarks
11. Cylinder 	$C_D = 0.75$ $0.5 < h/b < 5$
12. Hemisphere 	$0.4 < C_D < 0.6$, $10^3 < Re < 2 \times 10^4$. $C_D = 0.1$, $Re > 2 \times 10^5$. $Re = UD/\nu$. ν is kinematic viscosity. $A = \pi D^2/8$.
13. Ship hull above waterline 	$F_x = \frac{1}{2} \rho U_{rel}^2 A_x C_x$ $F_y = \frac{1}{2} \rho U_{rel}^2 A_y C_y$ $M = \frac{1}{2} \rho U_{rel}^2 A_y L C_M$ $C_y = 0.9 \sin \theta$ $C_x = 0.6 \sin \theta$ $C_M = 0.1 \sin \theta$ } Typical values Ref. 10-105 A_x = frontal projected area A_y = lateral projected area (shown) U_{rel} = relative wind.