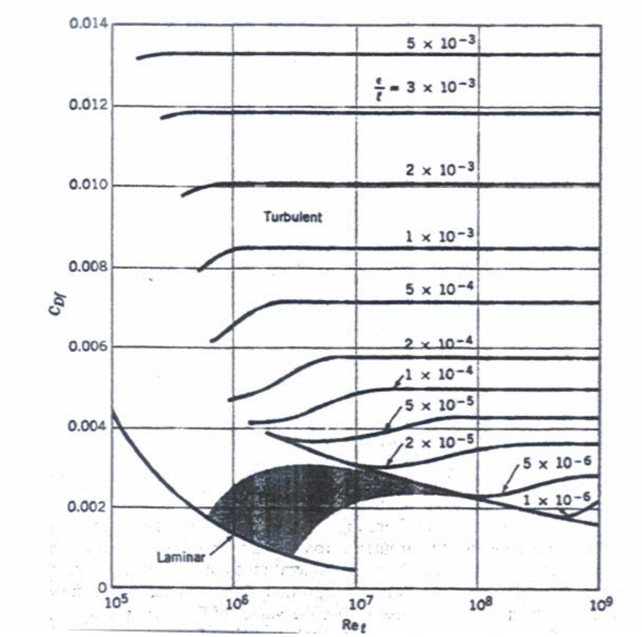


Figura 1. C_f *vs*. Re para flujo paralelo a una placa plana. Efecto de la rugosidad

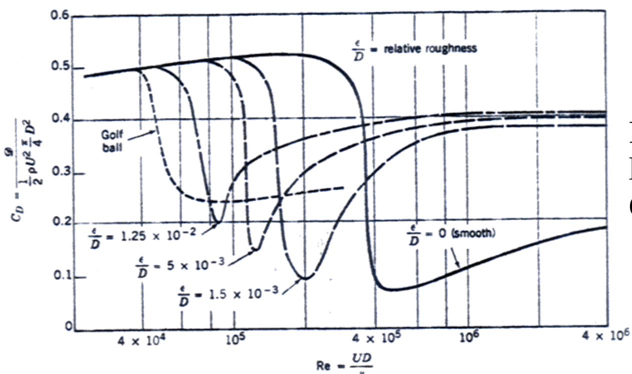


Figura 2. Efecto de la rugosidad sobre el C_D en esferas

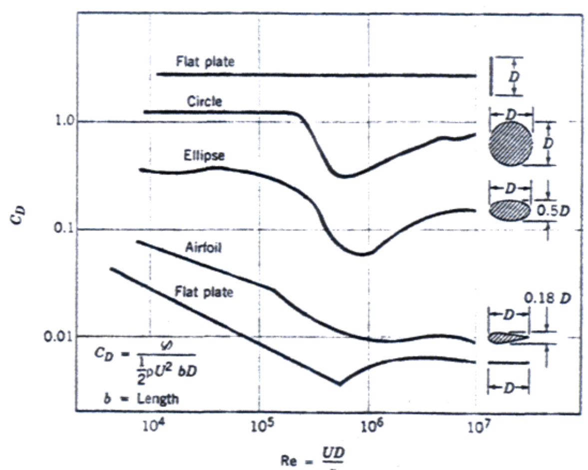
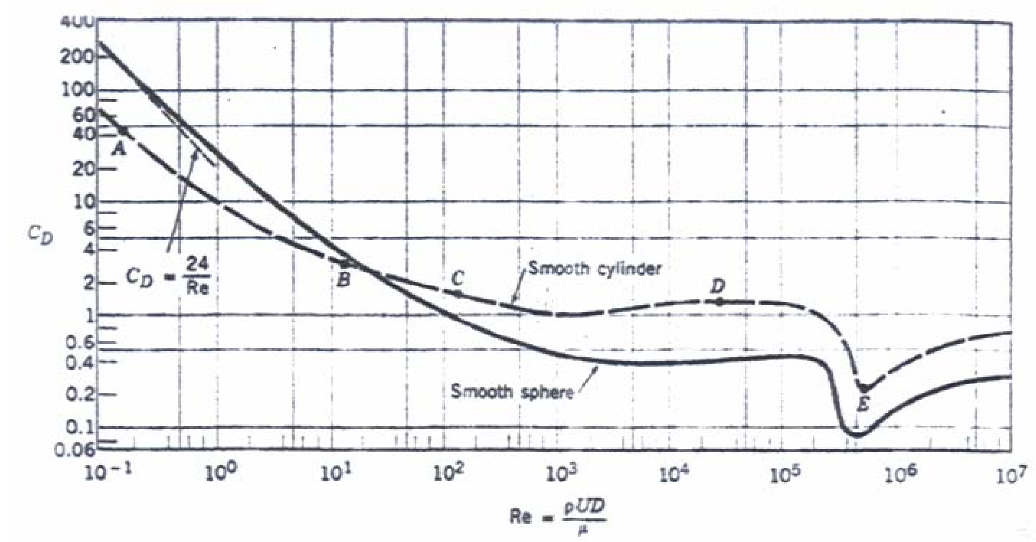


Figura 3. Efecto de la forma sobre C_D



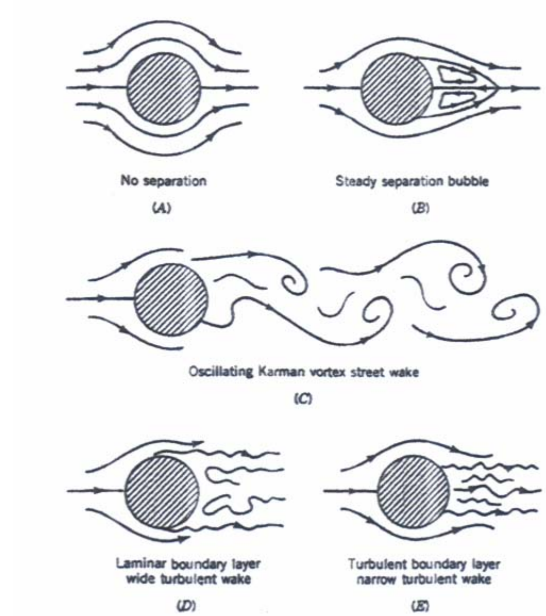


Figura 4. Efecto del número de Reynolds sobre el coeficiente de arrastre de una esfera

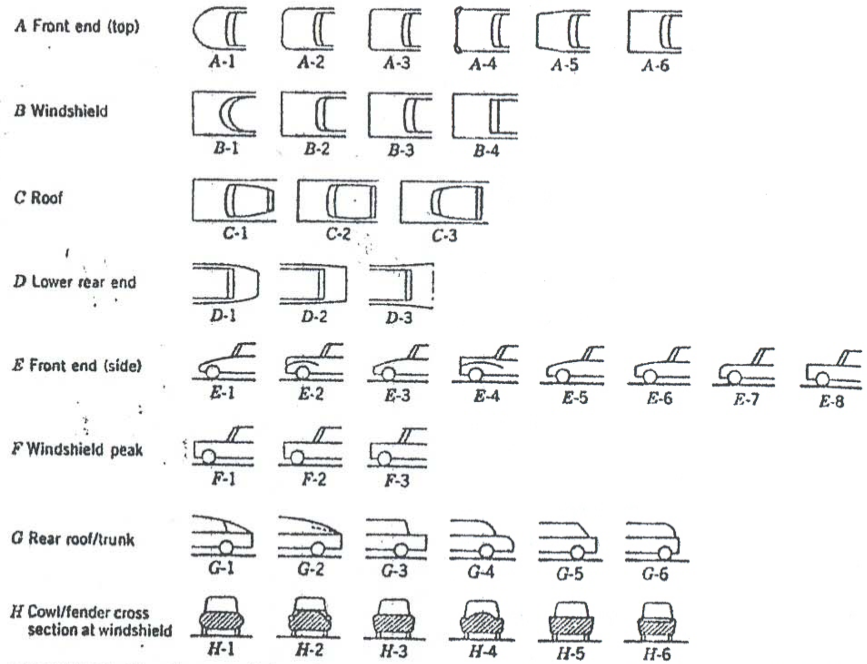


FIGURE 9.29 Characteristics of automobile components for use with the data of Table 9.5 to determine the drag coefficient for automobiles (Ref. 12 with permission).

acting on an area of size A. That is, $\mathcal{D} = \frac{1}{2}\rho U^2 A C_D = \frac{1}{2}\rho U^2 A$ if $C_D = 1$. Typical nonstreamlined objects have drag coefficients on this order.

9.4 LIFT

As is indicated in Section 9.1, any object moving through a fluid will experience a net force of the fluid on the object. For symmetrical objects, this force will be in the

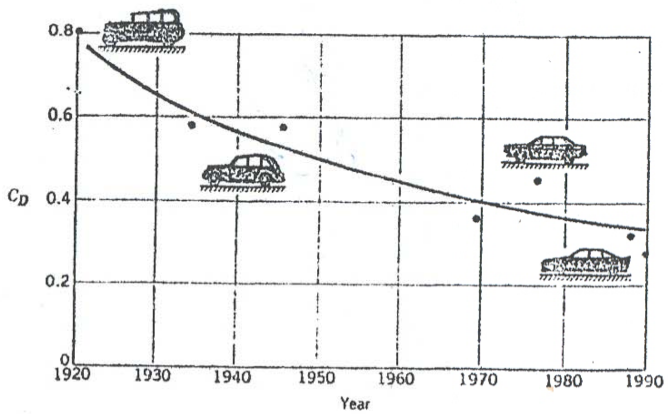


FIGURE 9.30 The historical trend of streamlining automobiles to reduce their aerodynamic drag and increase their miles per gallon (adapted fr[illegible]ef. 5).

Shape	Reference area A (b = length)	Drag coefficient $C_D = \frac{\mathcal{D}}{\frac{1}{2}\rho U^2 A}$	Reynold number $Re = \rho UD/\mu$
Square rod with rounded corners	$A = bD$	R/D | C_D: 0 | 2.2; 0.02 | 2.0; 0.17 | 1.2; 0.33 | 1.0	$Re = 10^5$
Rounded equilateral triangle	$A = bD$	R/D | C_D (→) | C_D (←): 0 | 1.4 | 2.1; 0.02 | 1.2 | 2.0; 0.08 | 1.3 | 1.9; 0.25 | 1.1 | 1.3	$Re = 10^5$
Semicircular shell	$A = bD$	→ 2.3; ← 1.1	$Re = 2 \times 10^4$
Semicircular cylinder	$A = bD$	→ 2.15; ← 1.15	$Re > 10^4$
T-beam	$A = bD$	→ 1.80; ← 1.65	$Re > 10^4$
I-Beam	$A = bD$	2.05	$Re > 10^4$
Angle	$A = bD$	→ 1.98; ← 1.82	$Re > 10^4$
Hexagon	$A = bD$	1.0	$Re > 10^4$
Rectangle	$A = bD$	ℓ/D | C_D: ≤0.1 | 1.9; 0.5 | 2.5; 0.65 | 2.9; 1.0 | 2.2; 2.0 | 1.6; 3.0 | 1.3	$Re = 10^5$

FIGURE Typical dra[illegible] cients for r[illegible] two-dimen[illegible] objects (R[illegible] and 6).

direction of the free stream—a drag, $\mathcal{D}$. If the object is not symmetrical (or if not produce a symmetrical flow field, such as the flow around a rotating sphere) may also be a force normal to the free stream—a lift, $\mathcal{L}$. Considerable effort ha[illegible] put forth to understand the various properties of the generation of lift. Some c[illegible] such as an airfoil, are designed to generate lift. Other objects are designed to the lift generated. For example, the lift on a car tends to reduce the contac[illegible] between the wheels and the ground, causing reduction in traction and cornering It is desirable to reduce this lift.

9.4.1 Surface Pressure Distribution

The lift can be determ[illegible]ed from Eq. 9.2 if the distributions of pressure a[illegible] shear stress [illegible] and the [illegible]e body are known. As is indicated in Section 9.

TABLE 9.5 Values of N_i (Ref. 12). See Fig. 9.29

A. Plan view, front end			
N_A =	1	A-1	Approximately semicircular
	2	A-2	Well-rounded outer quarters
	3	A-3	Rounded corners without protuberances
	4	A-4	Rounded corners with protuberances
	5	A-5	Squared tapering-in corners
	6	A-6	Squared constant width front
B. Plan view, windshield			
N_B =	1	B-1	Full wraparound (approximately semicircular)
	2	B-2	Wraparound ends
	3	B-3	Bowed
	4	B-4	Flat
C. Plan view, roof			
N_C =	1	C-1	Well- or medium-tapered to rear
	2	C-2	Tapering to front and rear or approximately constant width
	3	C-3	Tapering to front (maximum width at rear)
D. Plan view, lower rear end			
N_C =	1	D-1	Well- or medium-tapered to rear
	2	D-2	Small taper to rear or constant width
	3	D-3	Outward taper (or flared-out fins)
E. Side elevation, front end			
N_E =	1	E-1	Low, rounded front, sloping up
	1	E-2	High, tapered, rounded hood
	2	E-3	Low, squared front, sloping up
	2	E-4	High, tapered, squared hood
	3	E-5	Medium-height, rounded front, sloping up
	4	E-6	Medium-height, squared front, sloping up
	4	E-7	High, rounded front, with horizontal hood
	5	E-8	High, squared front, with horizontal hood

$C_D = 0{,}16 + 0{,}0095 \sum_1^n N_i$

TABLE 9.5 (continued)

F. Side elevation, windshield peak			
N_F =	1	F-1	Rounded
	2	F-2	Squared (including flanges or gutters)
	3	F-3	Forward-projecting peak
G. Side elevation, rear roof/trunk			
N_G =	1	G-1	Fastback (roofline continuous to tail)
	2	G-2	Semifastback (with discontinuity in line to tail)
	3	G-3	Squared roof with trunk rear edge squared
	4	G-4	Rounded roof with rounded trunk
	4	G-5	Squared roof with short or no trunk
	5	G-6	Rounded roof with short or no trunk
H. Front elevation, cowl and fender cross section at windshield			
N_H =	1	H-1	Flush hood and fenders, well-rounded body sides
	2	H-2	High cowl, low fenders
	3	H-3	Hood flush with rounded-top fenders
	3	H-4	High cowl with rounded-top fenders
	4	H-5	Hood flush with square-edged fenders
	5	H-6	Depressed hood with high squared-edged fenders

components identified (i.e., front end, windshield, roof, rear end, front shield peak, rear roof/trunk, and cowl). The corresponding body compo are illustrated in Fig. 9.29.

As is indicated in Fig. 9.30, the drag coefficient for cars has decre continuously over the years. This reduction is a result of careful design c and the details (such as window moulding, rear view mirrors, etc.). Ar reduction in drag has been accomplished by a reduction of the projecte net result is a considerable increase in the gas mileage, especially at high

The effect of several important parameters (shape, Re, Ma, Fr, and ro the drag coefficient for various objects has been discussed in this sectio previously, drag coefficient information for a very wide range of objects in the literature. Some of this information is given in Figs. 9.31, 9.32, an variety of two- and three-dimensional, natural and man-made objects. F drag coefficient of unity is equivalent to the drag produced by the dynar

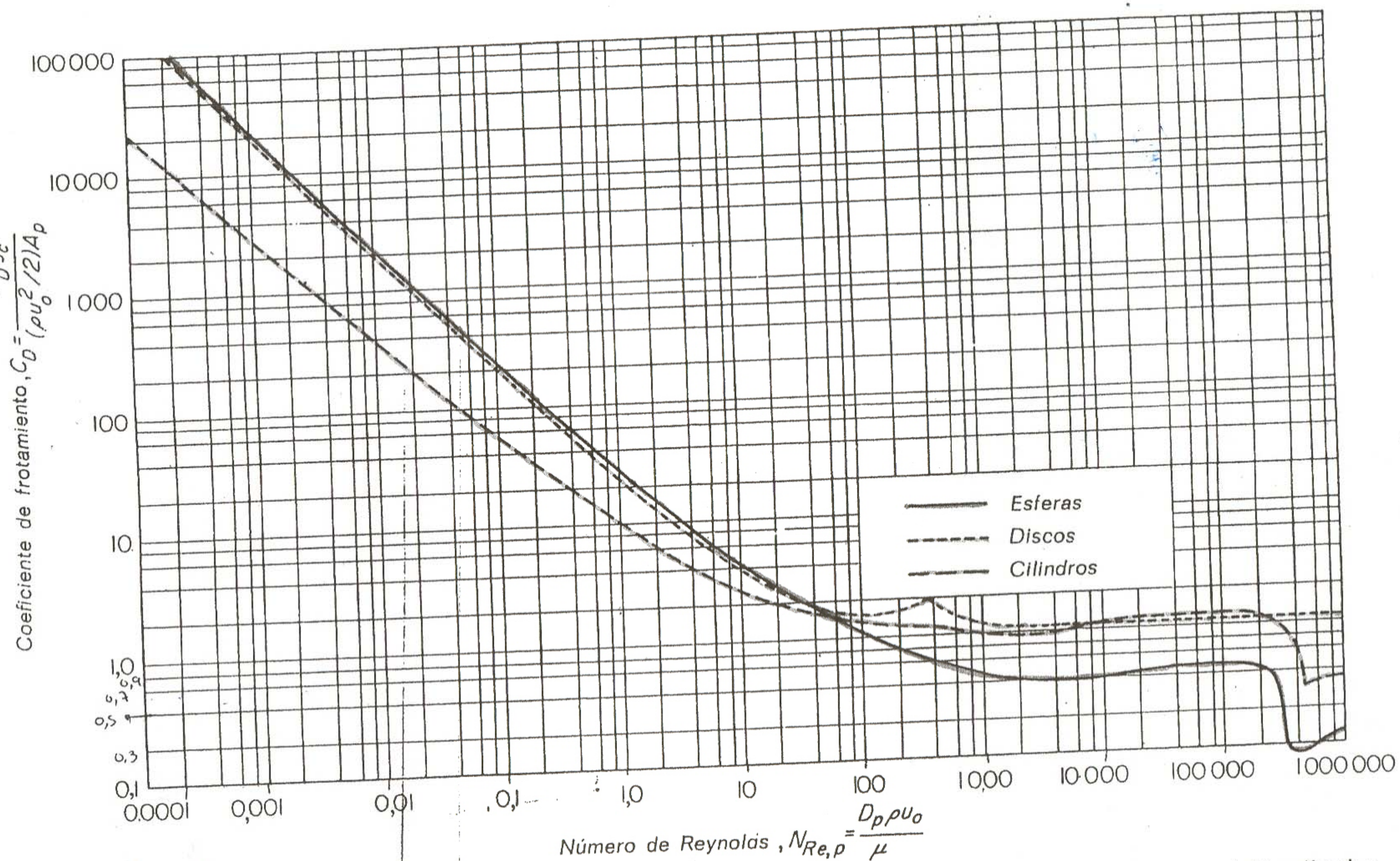


Fig. 7-3. Coeficientes de frotamiento para esferas, discos y cilindros. (Con autorización del «Chemical Engineers' Handbook», 4.ª ed., por J. H. Perry, 1963. McGraw-Hill Book Company.)