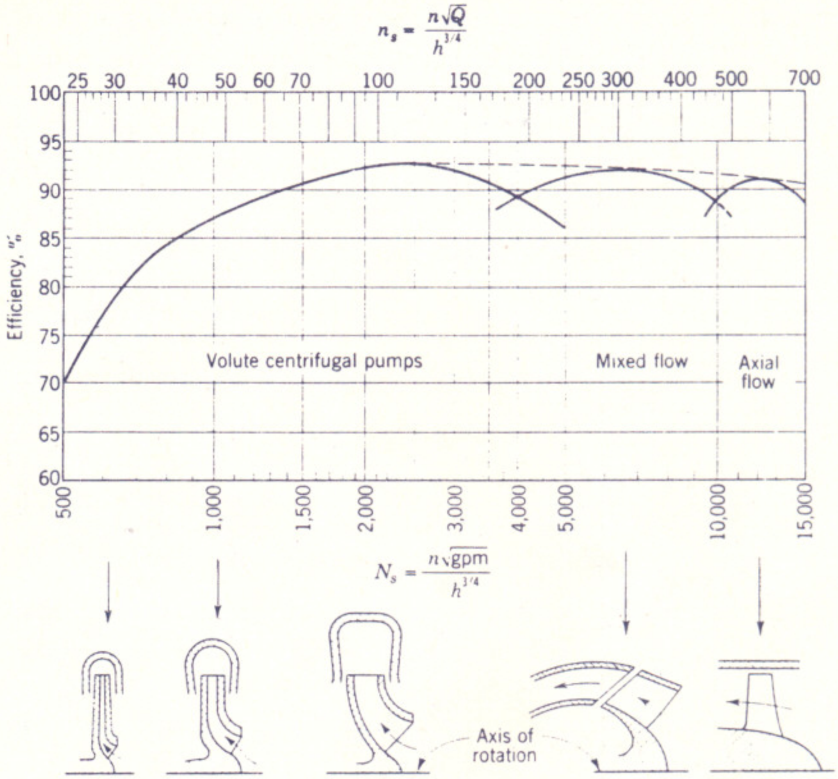


Fig. A-40

Optimum efficiency of water pumps as a function of specific speed.

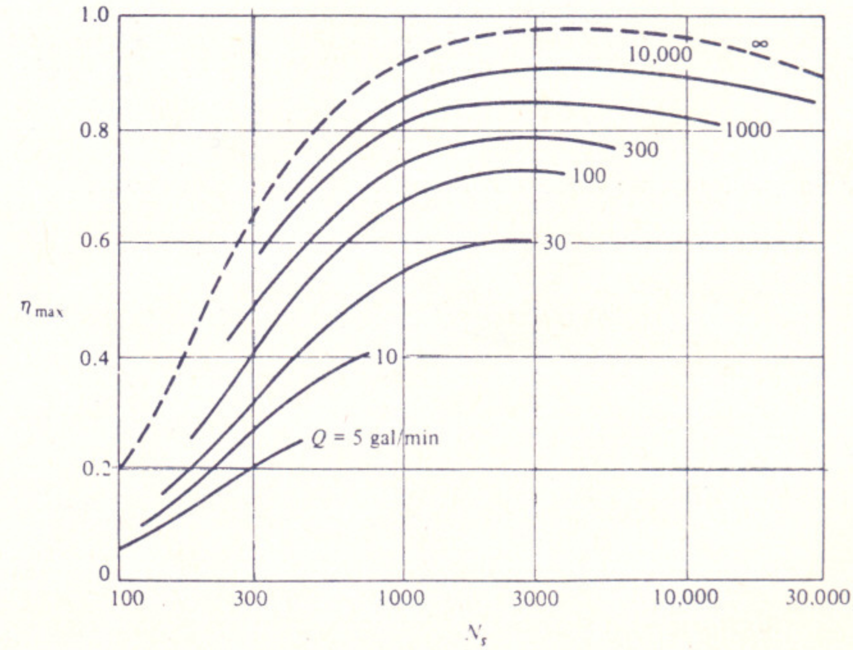


Fig. A-41

Optimum efficiency of pumps versus capacity and specific speed. (G. F. Wislicenus, *Fluid Mechanics of Turbomachinery*, 2d ed., McGraw-Hill, New York, 1965; I. J. Karassick et al., *Pump Handbook*, 2d ed., McGraw-Hill, New York, 1985.)

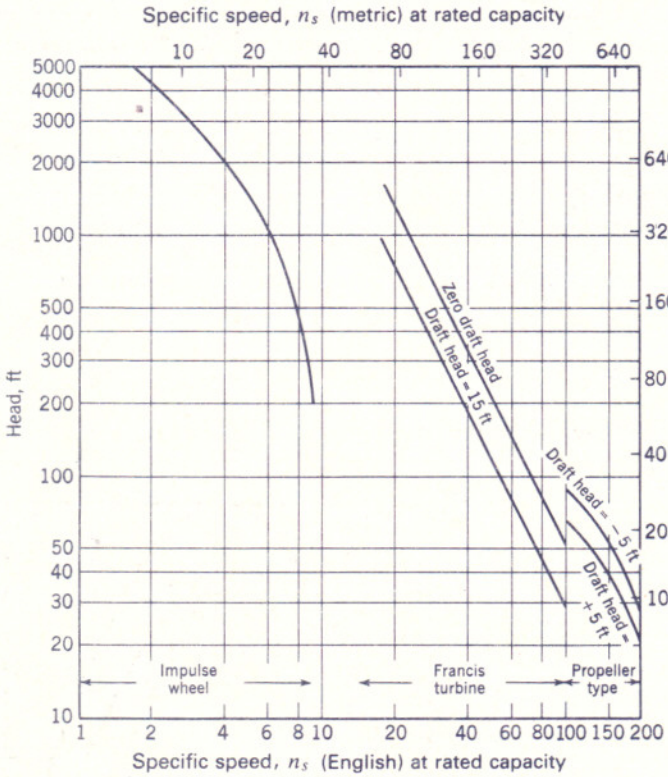


Fig. A-42

Recommended limits of specific speed for turbines under various effective heads at sea level with water temperature at 80 °F. (After Moody.)

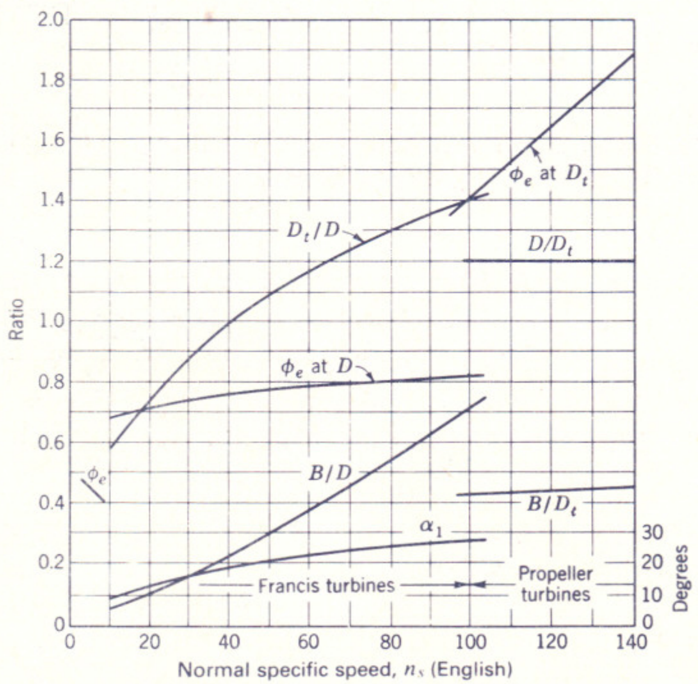


Fig. A-43

Characteristics of turbines as a function of specific speed.

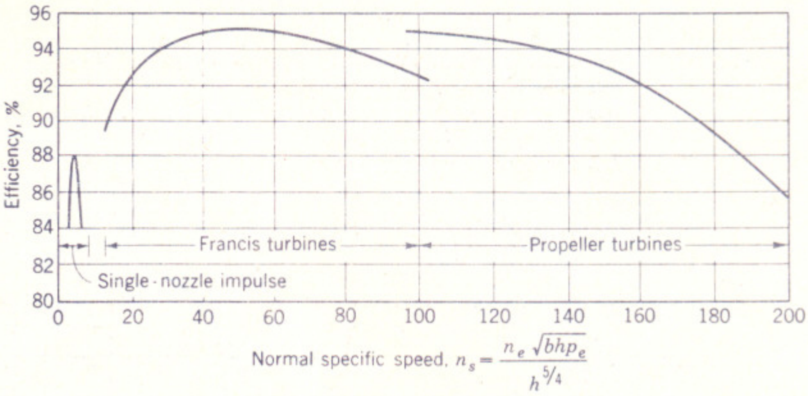


Fig. A-44

Optimum values of turbine efficiency.

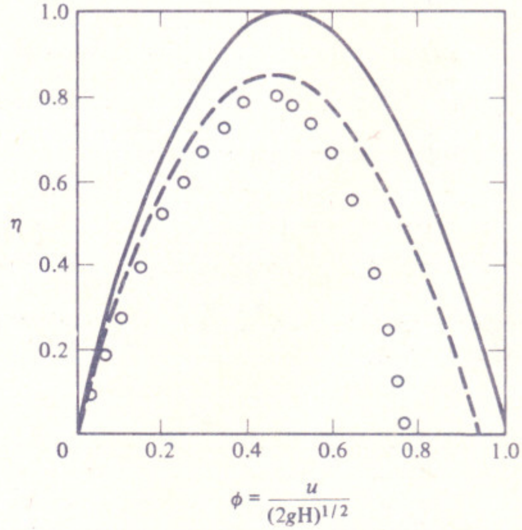


Fig. A-45

Efficiency of an impulse turbine: solid curve = ideal, $\beta = 180°$, $C_v = 1.0$; dashed curve = actual, $\beta = 160°$, $C_v = 0.94$; open circles = data, Pelton wheel, diameter = 2 ft.

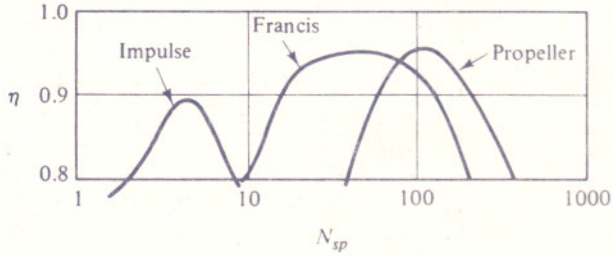


Fig. A-46

Optimum efficiency of turbine designs.

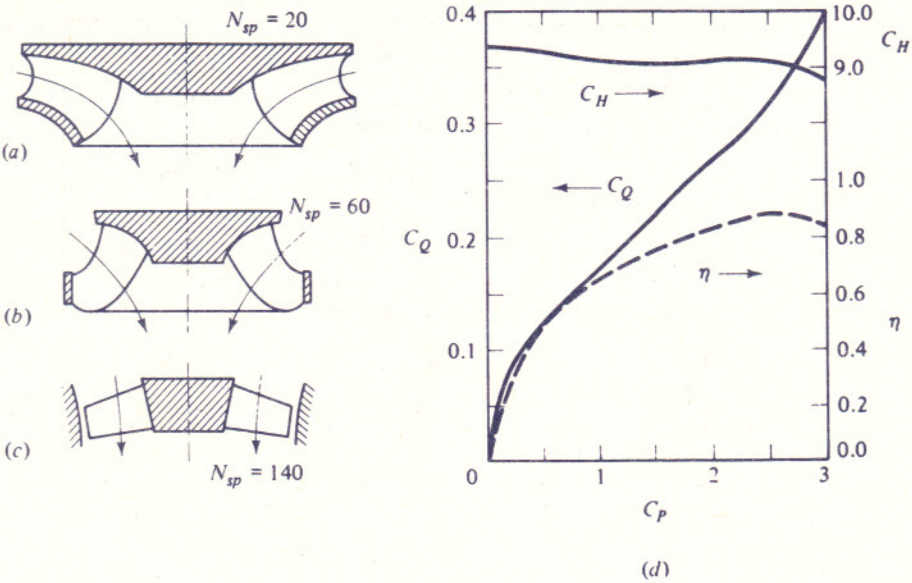


Fig. A-47

Reaction turbines: (*a*) Francis (radial type); (*b*) Francis (mixed-flow); (*c*) propeller (axial-flow); (*d*) performance curves for a Francis turbine, $n = 600$ r/min, $D = 2.25$ ft, $N_{sp} = 29$.

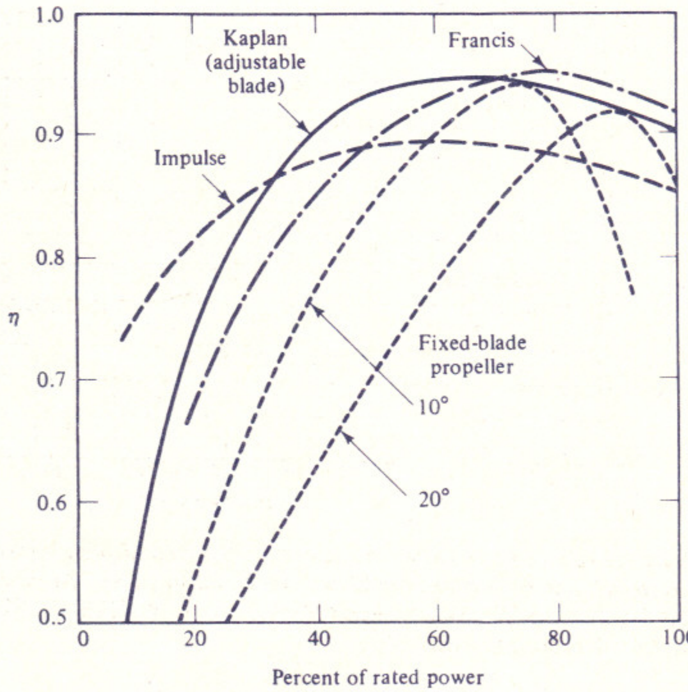


Fig. A-48

Efficiency versus power level for various turbine designs at constant speed and head.

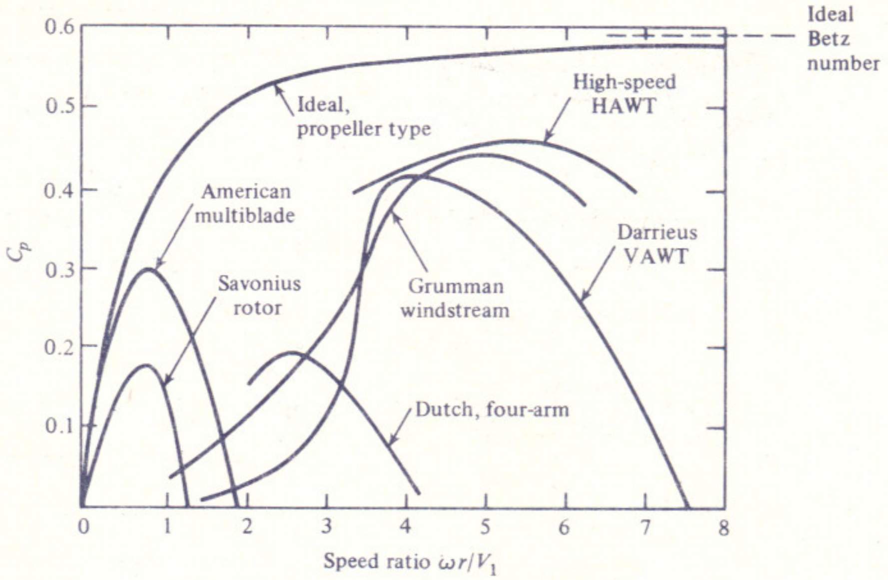


Fig. A-49

Estimated performance of various wind turbine designs as a function of blade-tip speed ratio. (Reprinted from *The Aeronautical Journal,* Vol. 85, No. 845, June 1981, by kind permission of The Royal Aeronautical Society.)

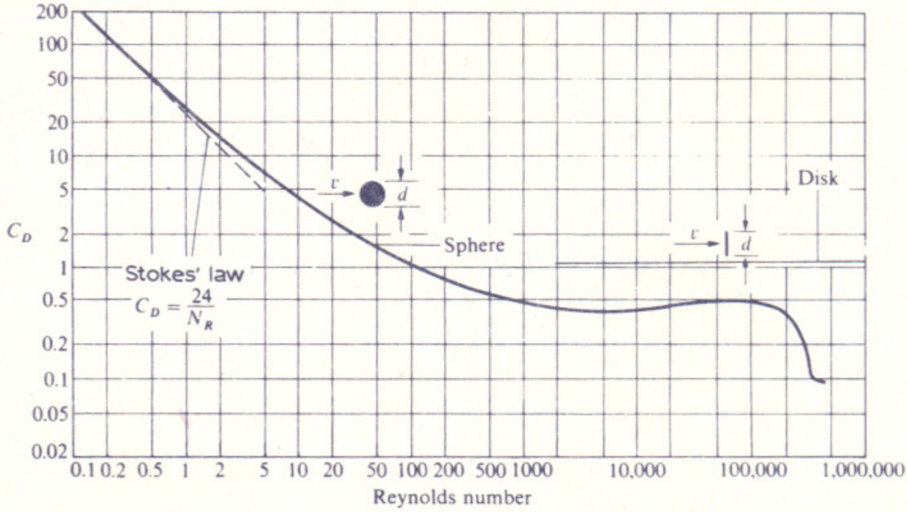


Fig. A-50

Drag coefficients for sphere and circular disk. Area in the drag relation is projected area normal to the stream. (Data adapted from "Das Widerstandsproblem," by F. Eisner, *Proc. 3d Intern. Congr. Appl. Mech.,* Stockholm, 1931.) Raymond C. Binder, *Fluid Mechanics,* 5e, © 1973, p. 132. Reprinted by permission of Prentice-Hall, Inc., Englewood Cliffs, N.J.

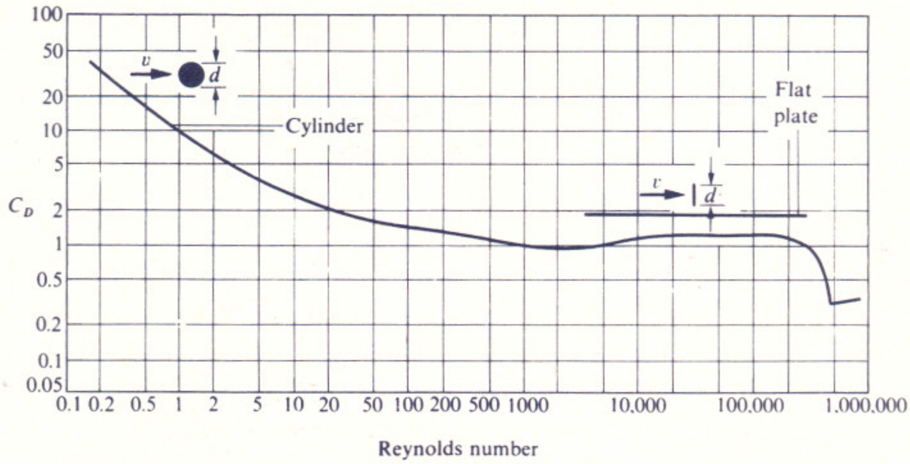


Fig. A-51

Drag coefficient for two-dimensional flow around a cylinder and a flat plate. Area in the drag relation is projected area normal to the stream. (Data adapted from "Das Widerstandsproblem," by F. Eisner, *Proc. 3d Intern. Congr. Appl. Mech.*, Stockholm, 1931.) Raymond C. Binder, *Fluid Mechanics*, 5e, © 1973, p. 134. Reprinted by permission of Prentice-Hall, Inc. Englewood Cliffs, N.J. 1973.

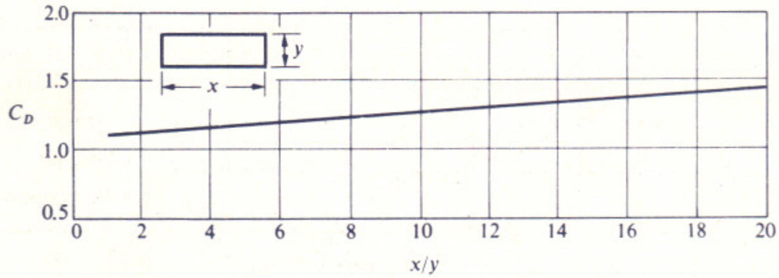


Fig. A-52

Drag coefficients for a flat plate of finite length normal to flow. Raymond C. Binder, *Fluid Mechanics*, 5e, © 1973, p. 135. Reprinted by permission of Prentice-Hall, Inc., Englewood Cliffs, N.J.

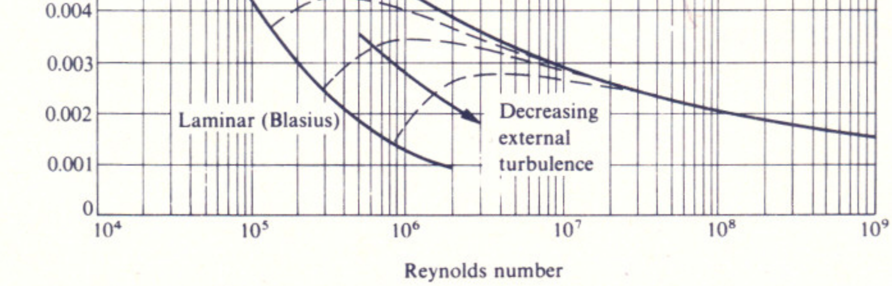


Fig. A-53

Skin-friction drag for smooth flat plates. T. v. Kármán, "Turbulence and Skin Friction," *J. Aeronaut. Sci.*, 1, no. 1 (January, 1934), © American Institute of Aeronautics and Astronautics, reprinted with permission.

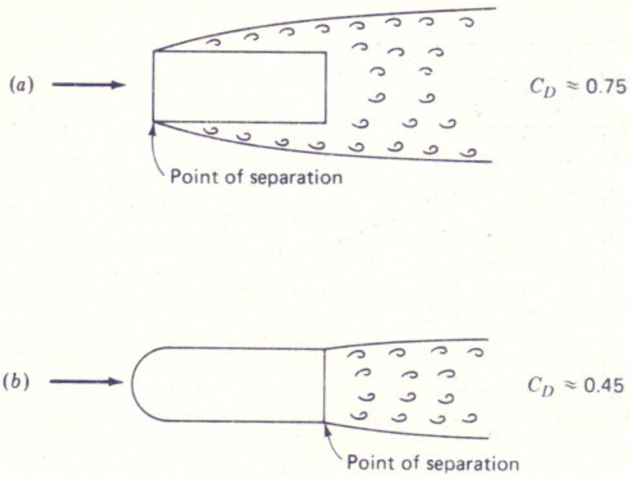


Fig. A-54

Plan view of flow about a motor vehicle (delivery van). (*a*) Blunt nose with separated flow along the entire side wall and a large drag coefficient $C_D = 0.75$. (*b*) Round nose with separation at the rear of the vehicle and smaller drag coefficient $C_D = 0.45$. (Adapted from H. Schlicting, *Boundary Layer Theory,* 4th ed., McGraw-Hill Book Co., New York, N.Y., 1960, p. 34).

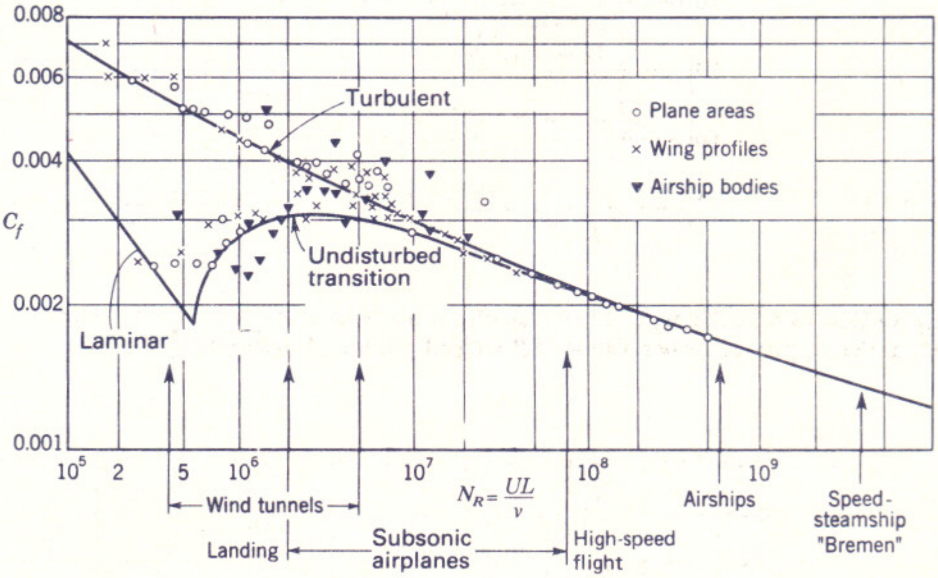


Fig. A-55

Drag coefficients for a smooth flat plate. (Adapted from *NACA Tech. Mem. 1218,* p. 117, 1949.)

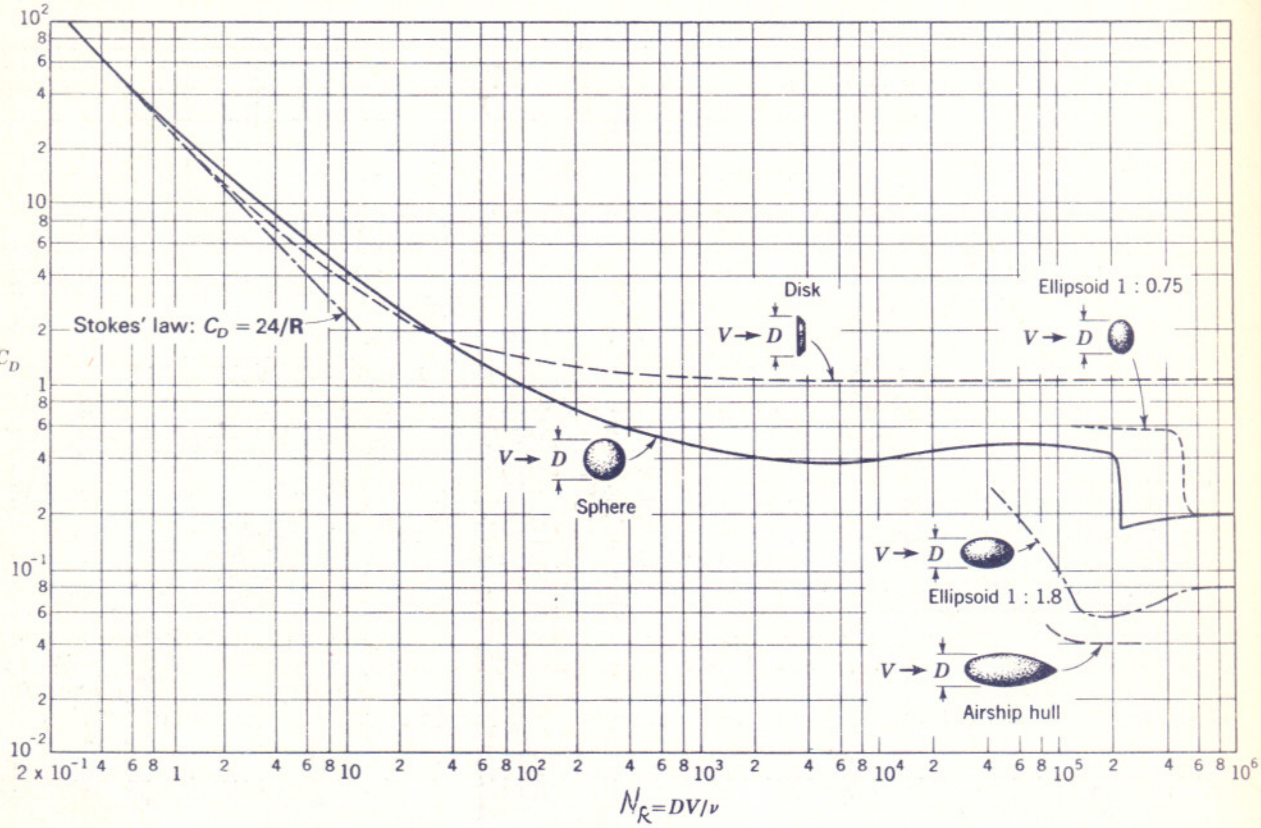


Fig. A-56

Drag coefficient for bodies of revolution. (Adapted from L. Prandtl, *Ergebnisse der aerodynamischen Versuchsanstalt zu Göttingen,* R. Oldenbourg, Munich and Berlin, 1923, p. 29; and F. Eisner, "Das Widerstandsproblem," *Proc. 3d Intern. Congr. Appl. Mech.*, 1930, p. 32.)

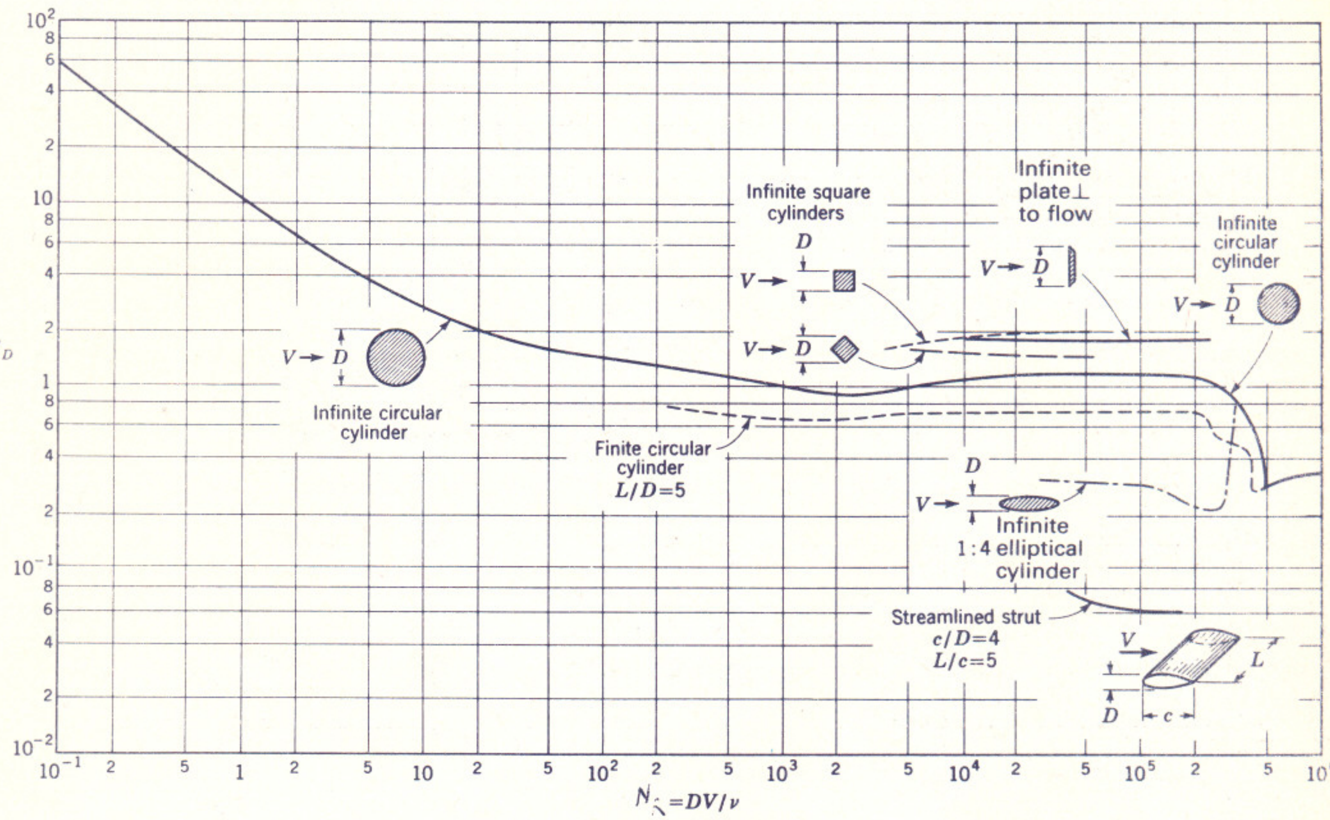


Fig. A-57

Drag coefficient for two-dimensional bodies. (Adapted from L. Prandtl, *Ergebnisse der aerodynamischen Versuchsanstalt zu Göttingen,* R. Oldenbourg, Munich and Berlin, 1923, p. 24; F. Eisner, "Das Widerstandsproblem," *Proc. 3d Intern. Congr. Appl. Mech.*, p. 32, 1930; A. F. Zahm, R. H. Smith, and G. C. Hill, "Point Drag and Total Drag of Navy Struts No. 1 Modified," *NACA Rept. 137,* p. 14, 1972; and W. F. Lindsey, "Drag of Cylinders of Simple Shapes," *NACA Rept. 619,* pp. 4–5, 1938.)

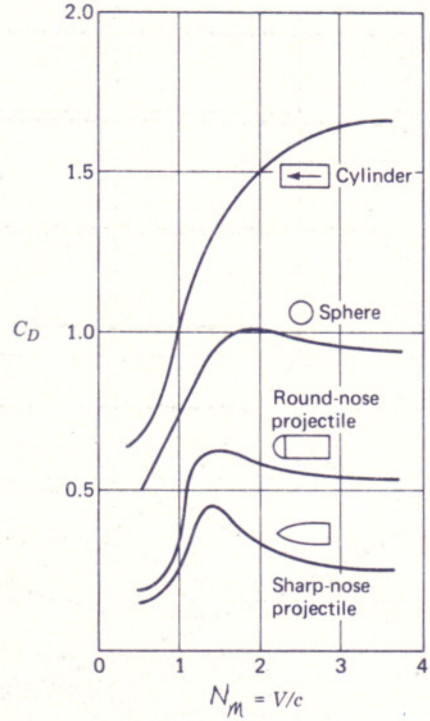


Fig. A-58

Drag coefficients as a function of Mach number.

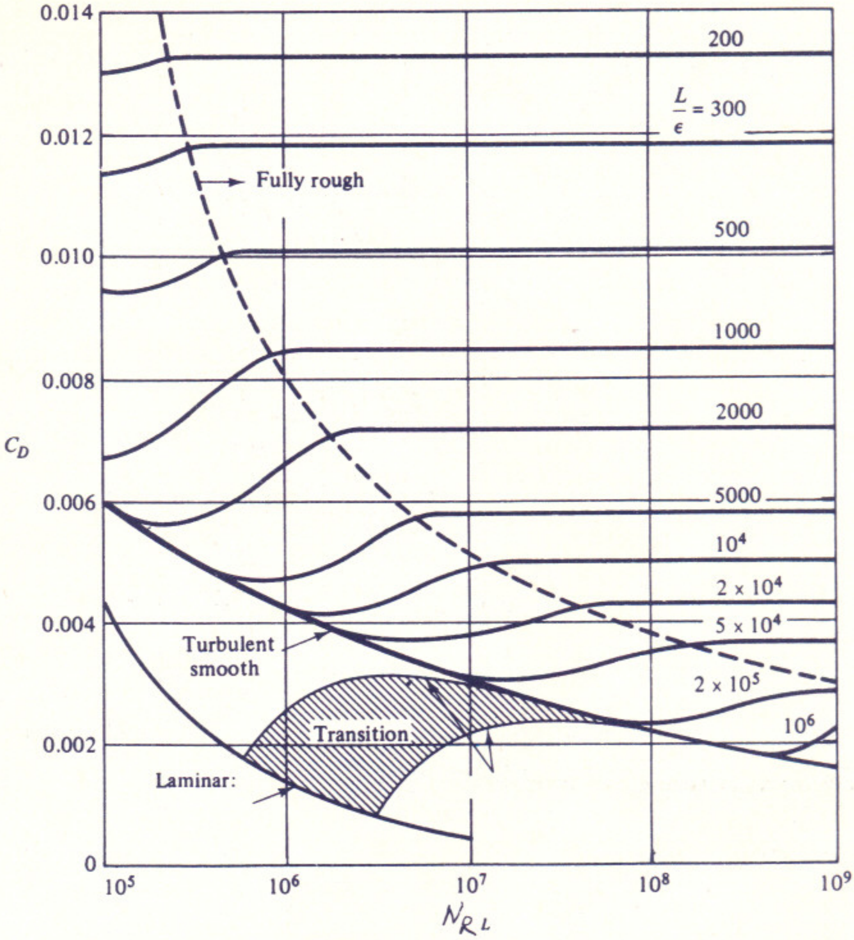
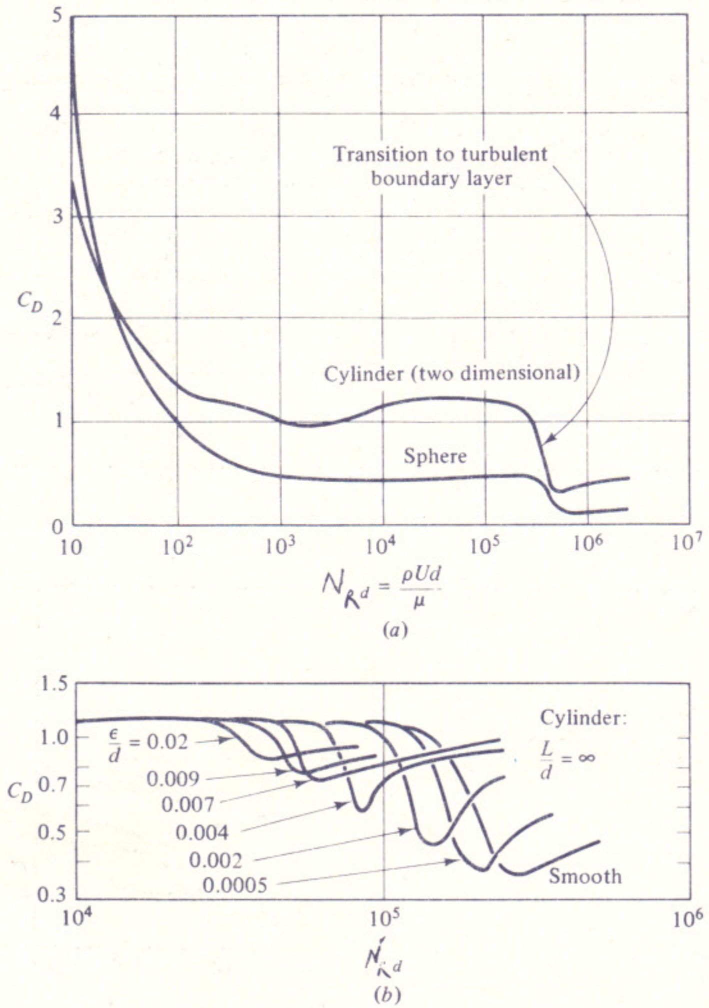


Fig. A-59

Drag coefficient of laminar and turbulent boundary layer on smooth and rough flat plates.



Cylinder length effect

($10^4 < N_R < 10^5$)

L/d	C_D
∞	1.20
40	0.98
20	0.91
10	0.82
5	0.74
3	0.72
2	0.68
1	0.64

Fig. A-60

The proof of practical dimensional analysis: drag coefficients of a cylinder and sphere: (*a*) drag coefficient of a smooth cylinder and sphere (data from many sources); (*b*) increased roughness causes earlier transition to a turbulent boundary layer.

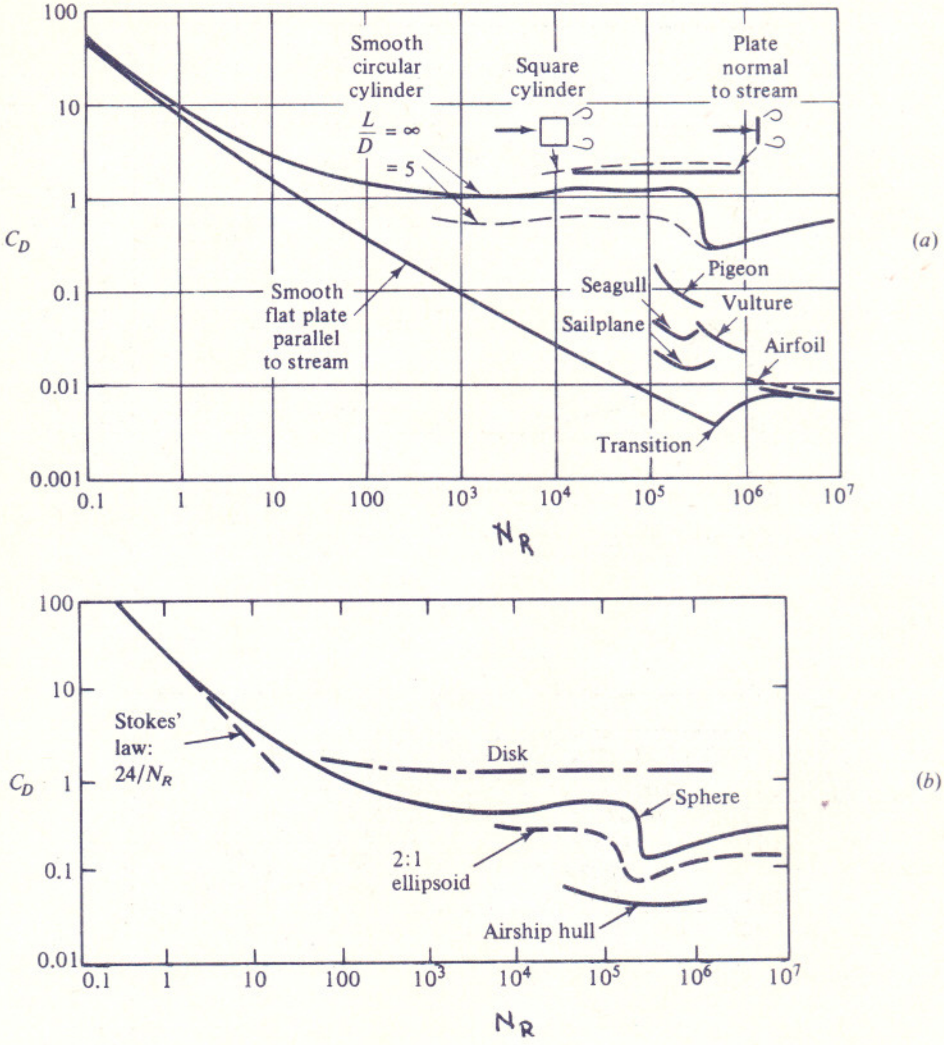
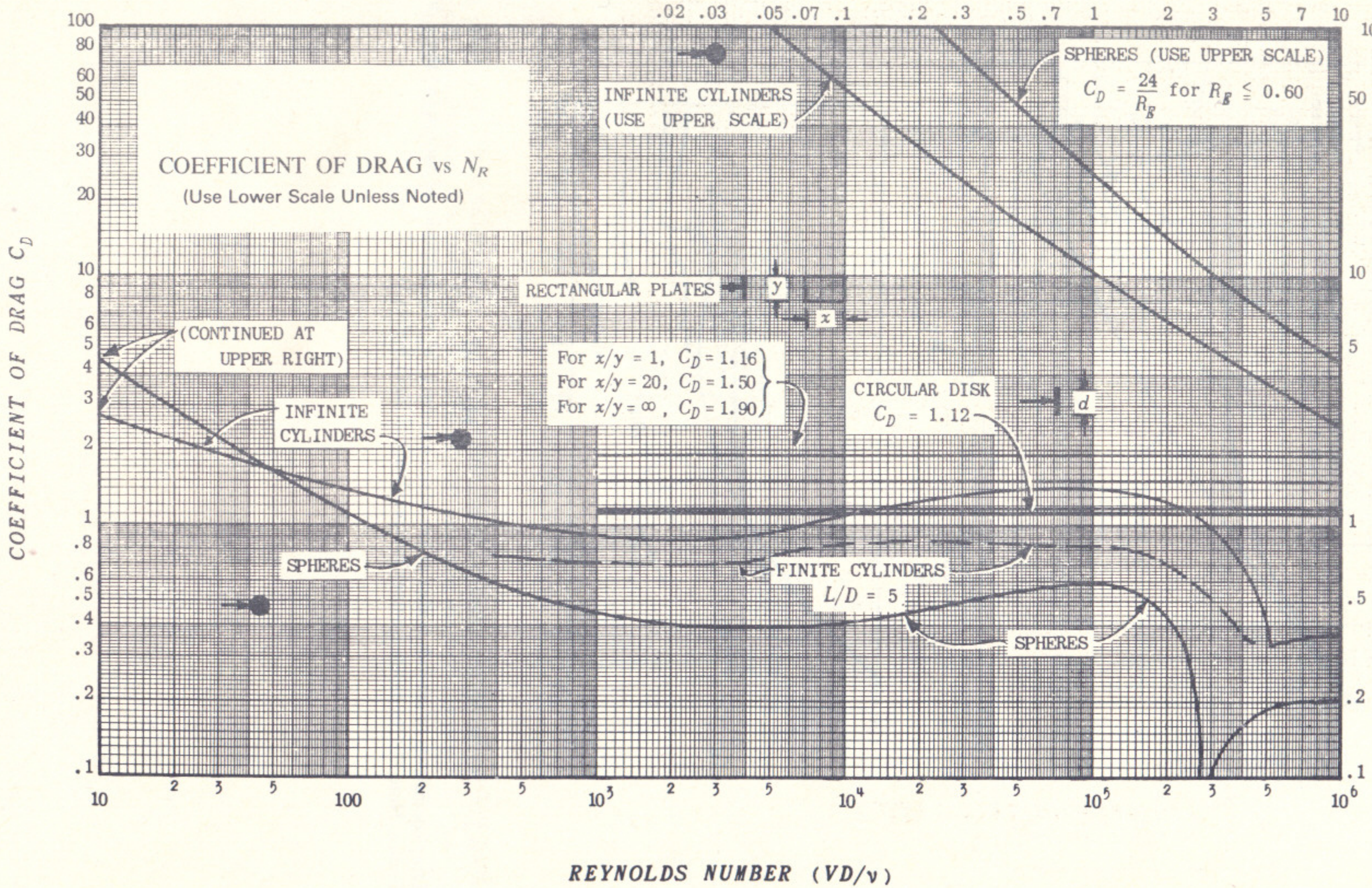


Fig. A-61

Drag coefficients of smooth bodies at low Mach numbers: (*a*) two-dimensional bodies; (*b*) three-dimensional bodies. Note the Reynolds-number independence of blunt bodies at high N_R.



COEFFICIENT OF DRAG vs N_R
(Use Lower Scale Unless Noted)
INFINITE CYLINDERS (USE UPPER SCALE)
SPHERES (USE UPPER SCALE)
$C_D = \frac{24}{R_E}$ for $R_E \leq 0.60$
RECTANGULAR PLATES
y
x
(CONTINUED AT UPPER RIGHT)
For $x/y = 1$, $C_D = 1.16$
For $x/y = 20$, $C_D = 1.50$
For $x/y = \infty$, $C_D = 1.90$
CIRCULAR DISK
$C_D = 1.12$
d
INFINITE CYLINDERS
SPHERES
FINITE CYLINDERS
$L/D = 5$
SPHERES
COEFFICIENT OF DRAG C_D
REYNOLDS NUMBER (VD/ν)
.02 .03 .05 .07 .1 .2 .3 .5 .7 1 2 3 5 7 10
10 2 3 5 100 2 3 5 10^3 2 3 5 10^4 2 3 5 10^5 2 3 5 10^6
100 80 60 50 40 30 20 10 8 6 5 4 3 2 1 .8 .6 .5 .4 .3 .2 .1

Fig. A-62

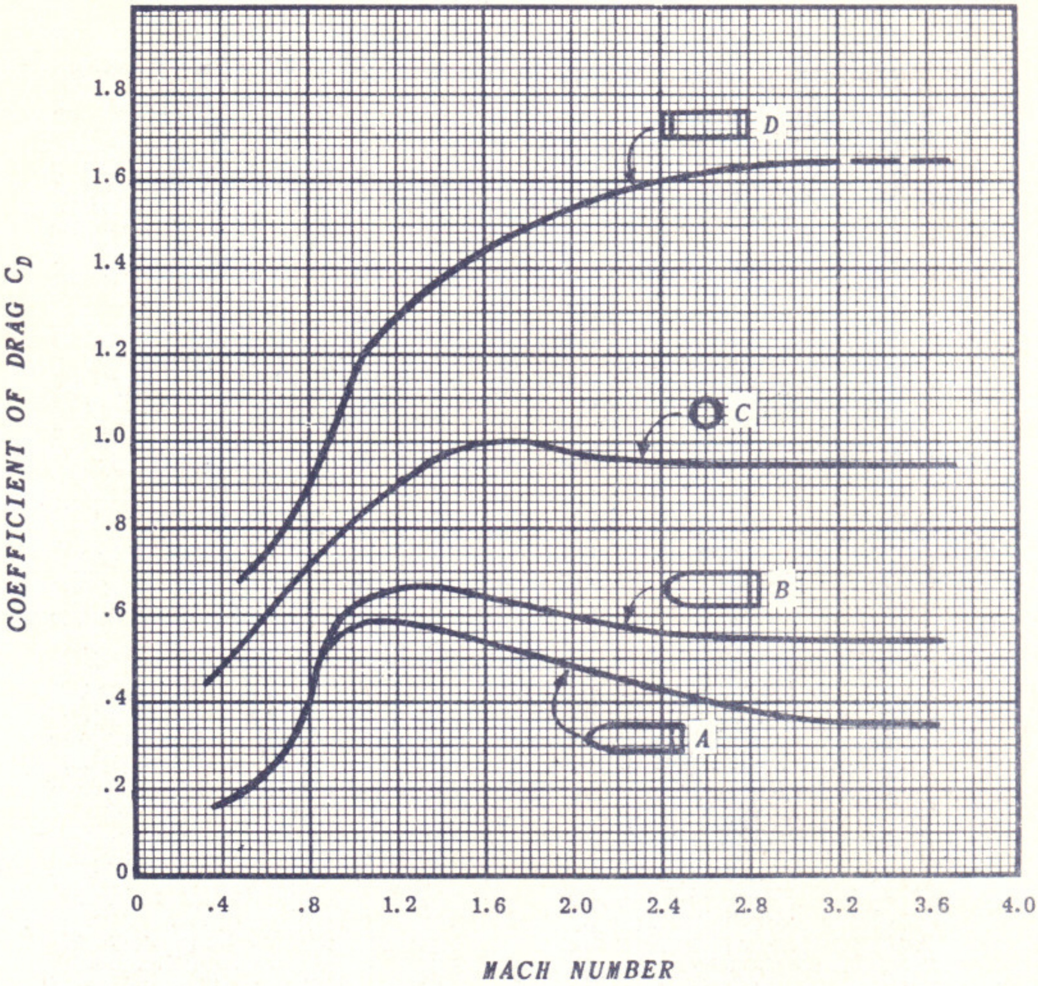


Fig. A-63

Drag coefficients at supersonic velocities.

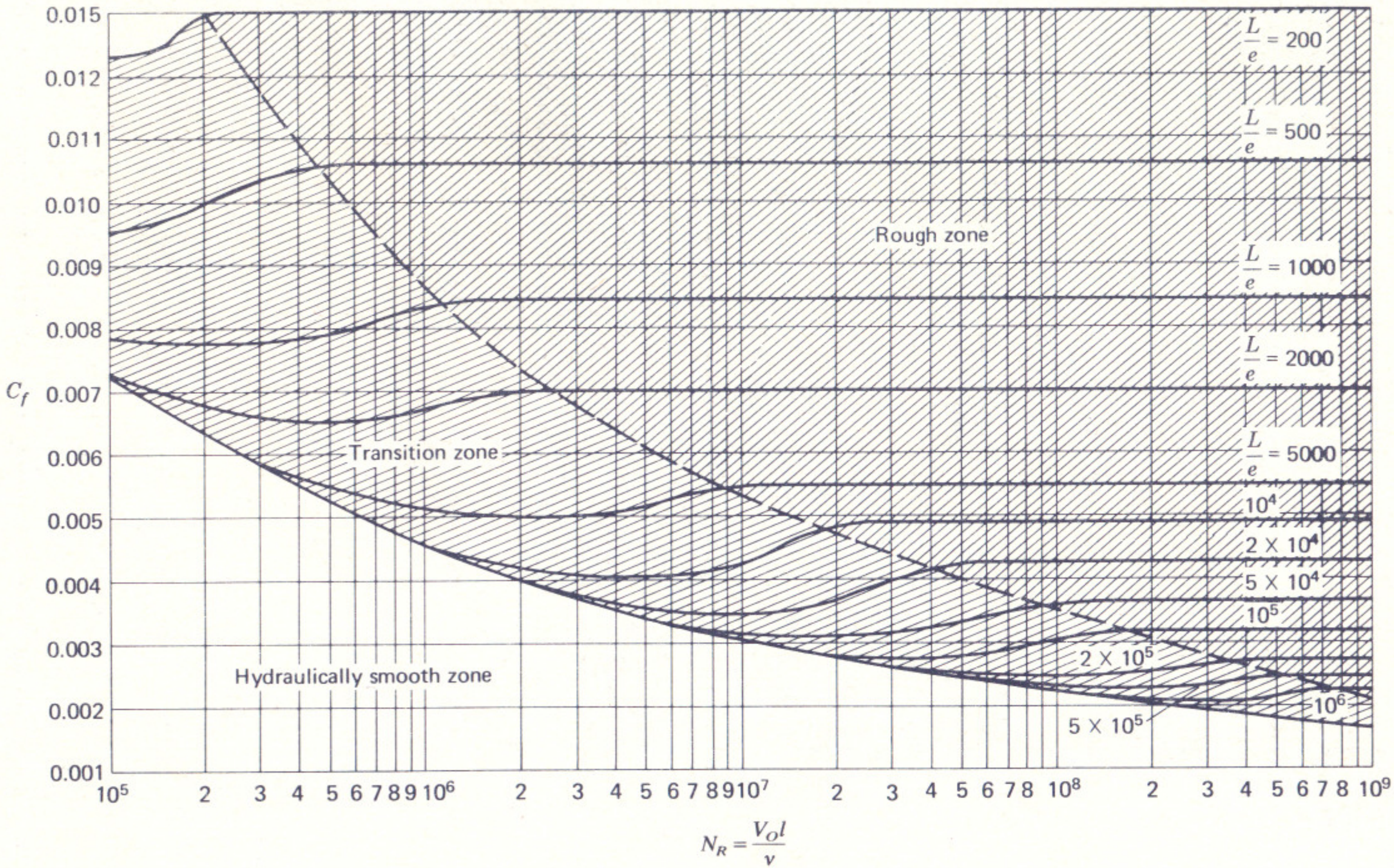


Fig. A-64

Three zones of flow for a rough plate.

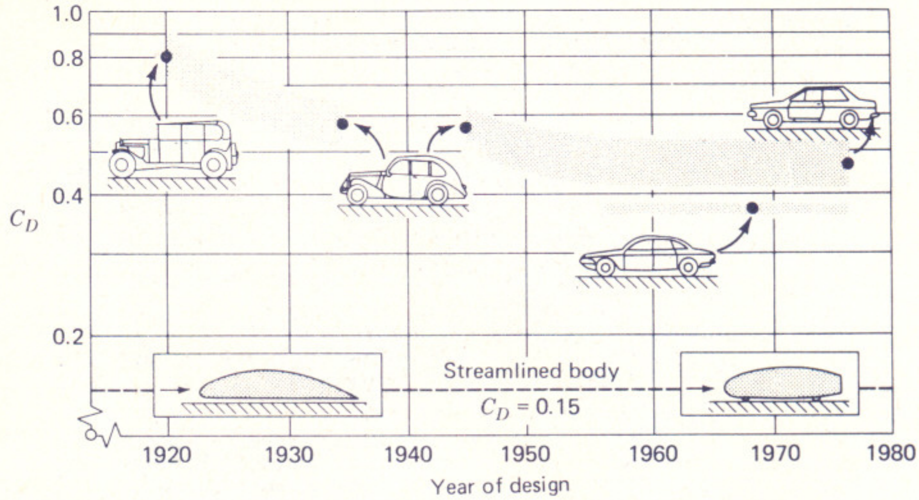


Fig. A-65

Time history of the aerodynamic drag of cars in comparison with streamlined bodies. (From W. H. Hucho, L. J. Janssen, and H. J. Emmelmann, *The Optimisation of Body Details—A Method For Reducing the Aerodynamic Drag of Road Vehicles*, SAE 760185, 1976.)

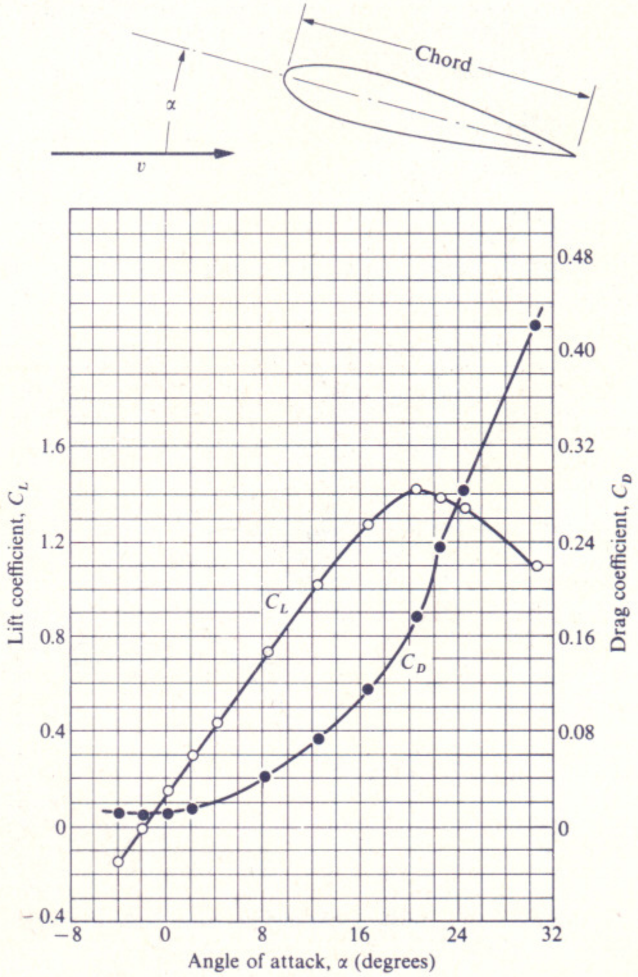


Fig. A-66

Lift and drag coefficients plotted against angle of attack for N.A.C.A. 2418 airfoil. Reynolds number = 3 060 000. (*NACA. Tech. Rept. No. 669.*)

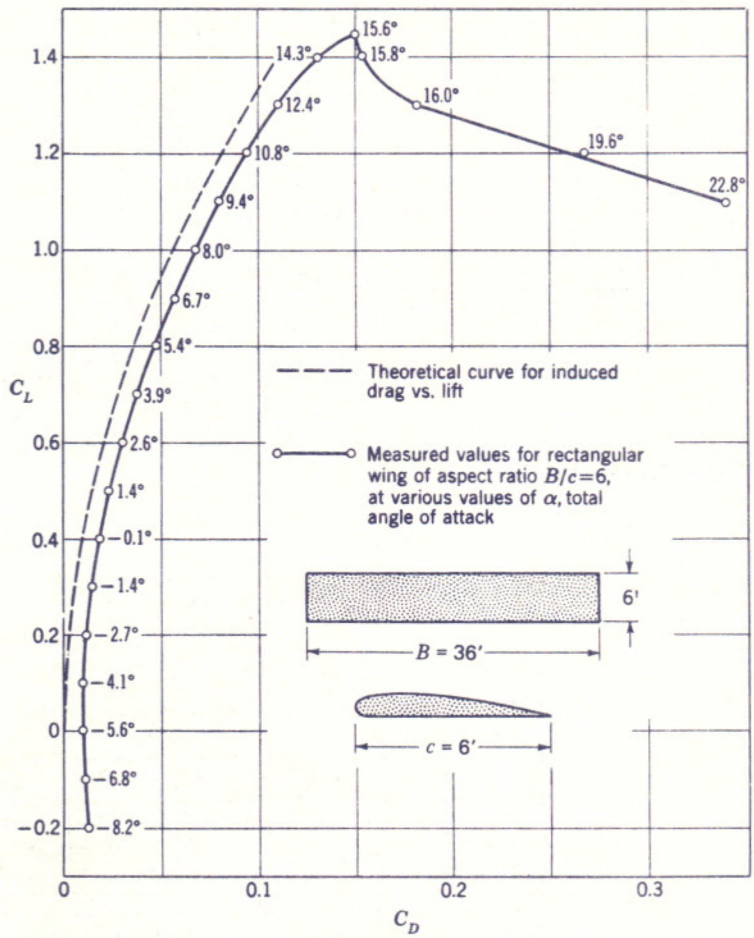


Fig. A-67

Polar diagram for rectangular Clark Y airfoil of 6-ft chord by 36-ft span. (Data from A. Silverstein, *NACA Rept. 502,* p. 15, 1934.)

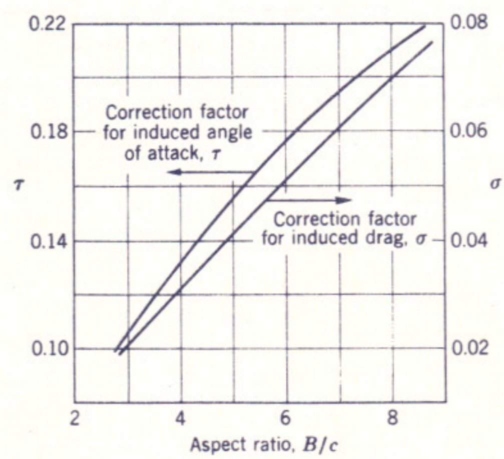


Fig. A-68

Correction factors for transforming rectangular airfoils from finite to infinite aspect ratio. (From A. Silverstein, *NACA Rept. 502*, Fig. 7, 1934.)

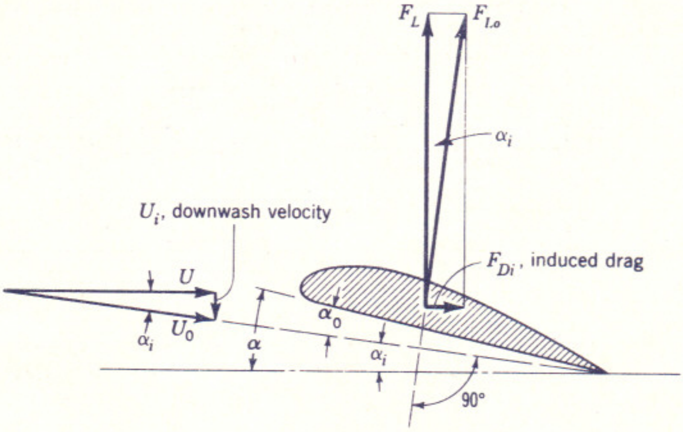


Fig. A-69

Definition sketch for induced drag.

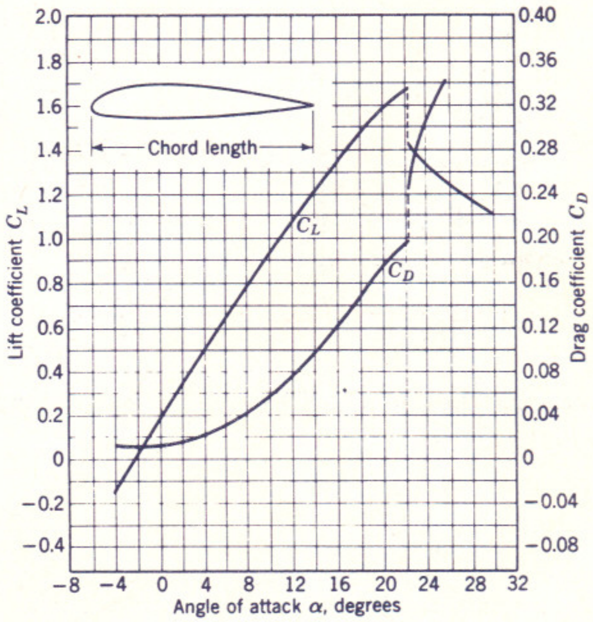


Fig. A-70

Typical lift and drag coefficients for an airfoil; C_L and C_D based on maximum projected wing area.

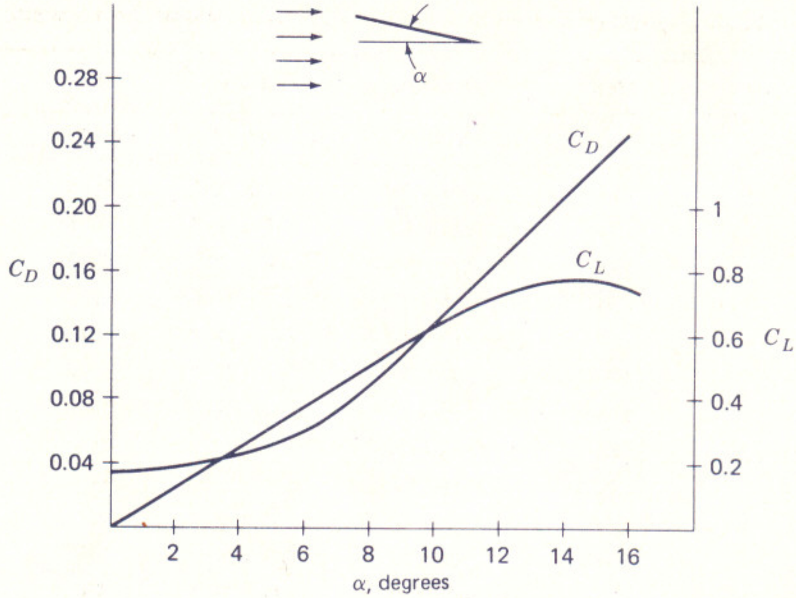


Fig. A-71

Coefficients of lift and drag for a flat plate at varying inclination α.

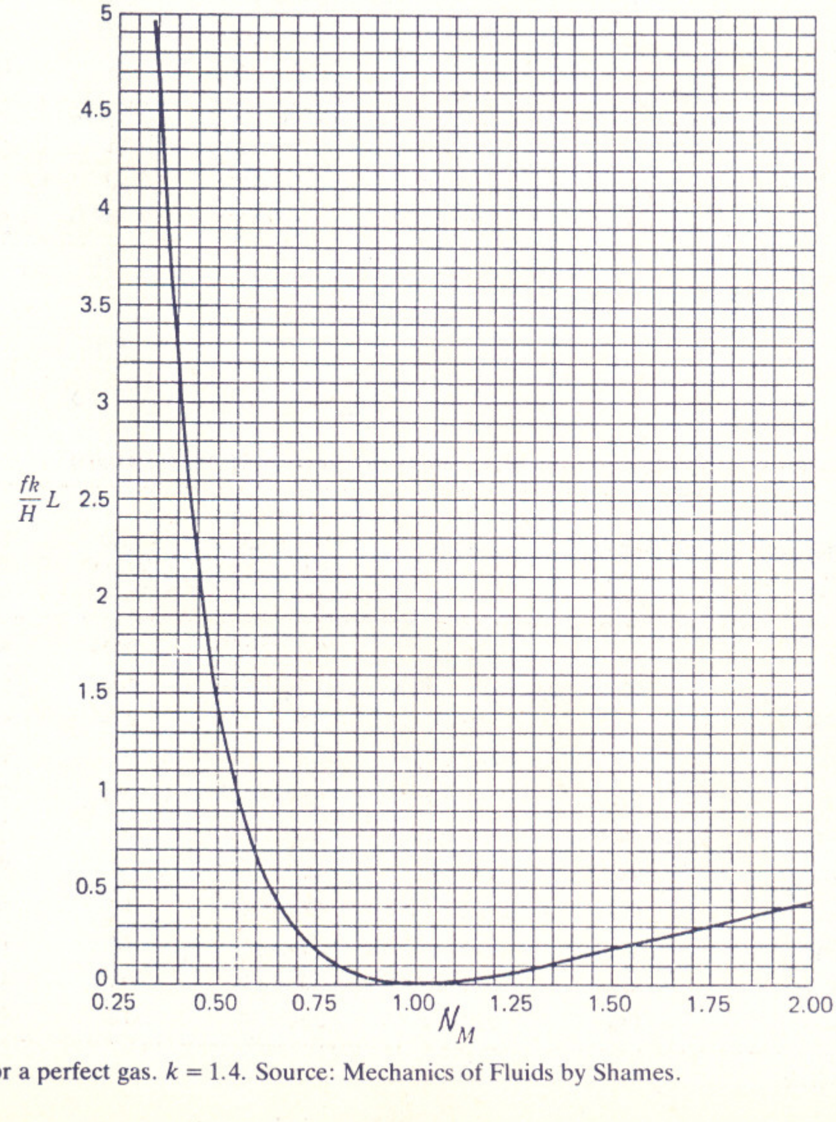


Fig. A-72

Friction curve for a perfect gas. $k = 1.4$. Source: Mechanics of Fluids by Shames.

TABLE A-1 Approximate physical properties of water (English Gravitational Unit System)

Temperature (°F)	Specific (or unit) weight, γ (lb/ft^3)	Mass density, ρ (slugs/ft^3)	Dynamic viscosity, μ (lb-s/ft^2)	Kinematic viscosity, ν (ft^2/s)	Vapor pressure, p_v (lb/ft^2)	Surface tension,† σ (lb/ft)	Bulk modulus of elasticity, K (lb/in^2)
32	62.4	1.94	3.66×10^{-5}	1.89×10^{-5}	12.8	0.00518	293,000
40	62.4	1.94	3.23×10^{-5}	1.67×10^{-5}	18.5	0.00514	294,000
50	62.4	1.94	2.72×10^{-5}	1.40×10^{-5}	25.7	0.00509	305,000
60	62.4	1.94	2.35×10^{-5}	1.21×10^{-5}	36.5	0.00504	311,000
70	62.3	1.93	2.04×10^{-5}	1.05×10^{-5}	52.2	0.00500	320,000
80	62.2	1.93	1.77×10^{-5}	9.15×10^{-6}	73.5	0.00492	322,000
90	62.1	1.93	1.60×10^{-5}	8.29×10^{-6}	101	0.00486	323,000
100	62.0	1.93	1.42×10^{-5}	7.37×10^{-6}	135	0.00480	327,000
110	61.9	1.92	1.26×10^{-5}	6.55×10^{-6}	189	0.00473	331,000
120	61.7	1.92	1.14×10^{-5}	5.94×10^{-6}	251	0.00465	333,000
130	61.5	1.91	1.05×10^{-5}	5.49×10^{-6}	322	0.00460	334,000
140	61.4	1.91	9.60×10^{-6}	5.03×10^{-6}	416	0.00454	330,000
150	61.2	1.90	8.90×10^{-6}	4.68×10^{-6}	545	0.00447	328,000
160	61.0	1.90	8.30×10^{-6}	4.38×10^{-6}	693	0.00441	326,000
170	60.8	1.89	7.70×10^{-6}	4.07×10^{-6}	875	0.00433	322,000
180	60.6	1.88	7.23×10^{-6}	3.84×10^{-6}	1086	0.00426	318,000
190	60.4	1.88	6.80×10^{-6}	3.62×10^{-6}	1358	0.00419	313,000
200	60.1	1.87	6.25×10^{-6}	3.35×10^{-6}	1671	0.00412	308,000
210	59.9	1.86	5.95×10^{-6}	3.20×10^{-6}	2042	0.00405	301,000
212	59.8	1.86	5.89×10^{-6}	3.17×10^{-6}	2116	0.00404	300,000

† In contact with air.

TABLE A-2 Approximate physical properties of water (International System of Units)

Temperature (°C)	Specific (or unit) weight, γ (kN/m^3)	Mass density, ρ (kg/m^3)	Dynamic Viscosity, μ (Pa · s)	Kinematic Viscosity, ν (m^2/s)	Vapor Pressure (kPa)	Surface Tension,† σ (N/m)	Bulk modulus of elasticity, K (GPa)
0	9.81	1000	1.75×10^{-3}	1.75×10^{-6}	0.611	0.0756	2.02
10	9.81	1000	1.30×10^{-3}	1.30×10^{-6}	1.23	0.0742	2.10
20	9.79	998	1.02×10^{-3}	1.02×10^{-6}	2.34	0.0728	2.18
30	9.77	996	8.00×10^{-4}	8.03×10^{-7}	4.24	0.0712	2.25
40	9.73	992	6.51×10^{-4}	6.56×10^{-7}	7.38	0.0696	2.28
50	9.69	988	5.41×10^{-4}	5.48×10^{-7}	12.3	0.0679	2.29
60	9.65	984	4.60×10^{-4}	4.67×10^{-7}	19.9	0.0662	2.28
70	9.59	978	4.02×10^{-4}	4.11×10^{-7}	31.2	0.0644	2.25
80	9.53	971	3.50×10^{-4}	3.60×10^{-7}	47.4	0.0626	2.20
90	9.47	965	3.11×10^{-4}	3.22×10^{-7}	70.1	0.0608	2.14
100	9.40	958	2.82×10^{-4}	2.94×10^{-7}	101.3	0.0589	2.07

† In contact with air.

TABLE A-3 Approximate physical properties of some common liquids at 1 atmosphere pressure and 20 °C (68 °F)

Liquid	Specific (or unit) weight, γ		Mass density, ρ		Specific gravity	Dynamic viscosity, μ		Vapor pressure		Surface tension,† σ	
	(lb/ft^3)	(kN/m^3)	($slugs/ft^3$)	(kg/m^3)		($lb\text{-}s/ft^2$)	($Pa \cdot s$)	(lb/ft^2)	(kPa)	(lb/ft)	(N/m)
Ammonia	51.7	8.13	1.61	829	0.83	4.60×10^{-6}	2.20×10^{-4}	19,000	910	0.00146	0.0213
Benzene	54.8	8.62	1.70	879	0.88	1.36×10^{-5}	6.51×10^{-4}	210	10.1	0.00198	0.0289
Carbon tetrachloride	99.1	15.57	3.08	1,588	1.59	2.02×10^{-5}	9.67×10^{-4}	250	12.0	0.00185	0.0270
Ethanol	49.2	7.73	1.53	788	0.79	2.51×10^{-5}	1.20×10^{-3}	120	5.75	0.00156	0.0228
Gasoline	44.9	7.05	1.40	719	0.72	6.10×10^{-6}	2.92×10^{-4}	1,150	55.1		
Glycerin	78.5	12.34	2.44	1,258	1.26	3.11×10^{-2}	1.49	0.0003	0.000014	0.00434	0.0633
Kerosine	51.1	8.03	1.59	819	0.82	4.00×10^{-5}	1.92×10^{-3}	65	3.11	0.00190	0.0277
Mercury	847.3	133.1	26.34	13,570	13.6	3.25×10^{-5}	1.56×10^{-3}	0.000023	0.0000011	0.0352	0.514
Methanol	49.2	7.73	1.53	788	0.79	1.25×10^{-5}	5.98×10^{-4}	280	13.4	0.00155	0.0226
SAE 10 Oil	54.2	8.52	1.68	869	0.87	1.70×10^{-3}	8.14×10^{-2}	....	....	0.00250	0.0365
SAE 30 Oil	55.4	8.71	1.72	888	0.89	9.20×10^{-3}	4.40×10^{-1}	....	....	0.00240	0.0350
Water	62.3	9.79	1.94	998	1.00	2.09×10^{-5}	1.02×10^{-3}	48	2.34	0.00500	0.0728
Seawater	64.2	10.08	2.00	1,028	1.03	2.23×10^{-5}	1.07×10^{-3}	48	2.34	0.00500	0.0728

† In contact with air.

TABLE A-4 Approximate physical properties of air at standard atmospheric pressure (English Gravitational Unit System)

Temperature (°F)	Specific (or unit) weight, γ (lb/ft³)	Mass density, ρ (slugs/ft³)	Dynamic viscosity, μ (lb-s/ft²)	Kinematic viscosity, ν (ft²/s)
32	0.0808	0.00251	3.59×10^{-7}	1.43×10^{-4}
40	0.0794	0.00247	3.62×10^{-7}	1.46×10^{-4}
50	0.0779	0.00242	3.68×10^{-7}	1.52×10^{-4}
60	0.0763	0.00237	3.74×10^{-7}	1.58×10^{-4}
70	0.0750	0.00233	3.82×10^{-7}	1.64×10^{-4}
80	0.0735	0.00228	3.85×10^{-7}	1.69×10^{-4}
90	0.0723	0.00224	3.90×10^{-7}	1.74×10^{-4}
100	0.0709	0.00220	3.96×10^{-7}	1.80×10^{-4}
110	0.0696	0.00218	4.02×10^{-7}	1.84×10^{-4}
120	0.0684	0.00215	4.07×10^{-7}	1.89×10^{-4}
130	0.0674	0.00210	4.10×10^{-7}	1.95×10^{-4}
140	0.0663	0.00206	4.14×10^{-7}	2.01×10^{-4}
150	0.0652	0.00202	4.18×10^{-7}	2.06×10^{-4}
160	0.0641	0.00199	4.22×10^{-7}	2.12×10^{-4}
170	0.0631	0.00196	4.28×10^{-7}	2.18×10^{-4}
180	0.0621	0.00193	4.34×10^{-7}	2.25×10^{-4}
190	0.0612	0.00190	4.42×10^{-7}	2.32×10^{-4}
200	0.0602	0.00187	4.49×10^{-7}	2.40×10^{-4}
210	0.0594	0.00184	4.57×10^{-7}	2.48×10^{-4}
212	0.0592	0.00184	4.58×10^{-7}	2.50×10^{-4}

TABLE A-5 Approximate physical properties of air at standard atmospheric pressure (International System of Units)

Temperature (°C)	Specific (or unit) weight, γ (N/m³)	Mass density, ρ (kg/m³)	Dynamic viscosity, μ (Pa · s)	Kinematic viscosity, ν (m²/s)
0	12.7	1.29	1.72×10^{-5}	1.33×10^{-5}
10	12.2	1.25	1.77×10^{-5}	1.42×10^{-5}
20	11.8	1.20	1.81×10^{-5}	1.51×10^{-5}
30	11.4	1.16	1.86×10^{-5}	1.60×10^{-5}
40	11.0	1.13	1.91×10^{-5}	1.69×10^{-5}
50	10.7	1.09	1.95×10^{-5}	1.79×10^{-5}
60	10.4	1.06	1.99×10^{-5}	1.89×10^{-5}
70	10.1	1.03	2.04×10^{-5}	1.99×10^{-5}
80	9.80	1.00	2.09×10^{-5}	2.09×10^{-5}
90	9.53	0.972	2.13×10^{-5}	2.19×10^{-5}
100	9.28	0.946	2.17×10^{-5}	2.30×10^{-5}

TABLE A-6 Approximate physical properties of some common gases at 1 atmosphere pressure and 30 °C (68 °F)

	Specific (or unit) weight, γ		Mass density, ρ		Dynamic viscosity (μ)		Gas constant (**R**)			
Gas	(lb/ft^3)	(N/m^3)	(slugs/ft^3)	(kg/m^3)	(lb-s/ft^2)	(kPa · s)	(ft/°R)	(m/k)	(lb-ft/slug-°R)	(J/kg · K)
Air	0.0752	11.8	0.00234	1.20	3.78×10^{-7}	1.81×10^{-8}	53.3	29.3	1 716	287
Carbon dioxide	0.115	18.1	0.00357	1.84	3.10×10^{-7}	1.48×10^{-8}	35.1	19.3	1 130	189
Helium	0.0104	1.63	0.000323	0.166	4.11×10^{-7}	1.97×10^{-8}	385.7	212.0	12 420	2079
Hydrogen	0.00522	0.823	0.000162	0.0839	1.89×10^{-7}	9.05×10^{-9}	765.5	420.8	24 649	4127
Methane	0.0416	6.53	0.00129	0.666	2.80×10^{-7}	1.34×10^{-8}	96.2	52.9	3 098	519
Nitrogen	0.0726	11.4	0.00225	1.16	3.68×10^{-7}	1.76×10^{-8}	55.1	30.3	1 774	297
Oxygen	0.0830	13.0	0.00258	1.33	4.18×10^{-7}	2.00×10^{-8}	48.2	26.5	1 552	260

	Specific heat ratio (k)	Specific heat (c_p)		Specific heat (c_v)		Molecular weight (M)
Gas	Dimensionless ratio c_p/c_v	lb-ft/slug-°R	J/kg · K	lb-ft/slug-°R	J/kg · K	
Air	1.40	6 000	1 003	4 285	716	29.00
Carbon dioxide	1.30	5 132	858	4 009	670	44.00
Helium	1.66	31 230	5 220	18 810	3 143	4.00
Hydrogen	1.41	86 390	14 450	61 710	10 330	2.02
Methane	1.32	13 400	2 250	10 300	1 730	16.00
Nitrogen	1.40	6 210	1 040	4 437	743	28.00
Oxygen	1.40	5 437	909	3 883	649	32.00

TABLE A-7 The ICAO standard atmosphere in English units

Elevation above sea level, ft	Temp, °F	Absolute pressure, psia	Specific weight γ, lb/ft^3	Density ρ, slugs/ft^3	Viscosity $\mu \times 10^7$, lb·s/ft^2
0	59.0	14.70	0.07648	0.002377	3.737
5,000	41.2	12.24	0.06587	0.002048	3.637
10,000	23.4	10.11	0.05643	0.001756	3.534
15,000	5.6	8.30	0.04807	0.001496	3.430
20,000	−12.3	6.76	0.04070	0.001267	3.325
25,000	−30.1	5.46	0.03422	0.001066	3.217
30,000	−47.8	4.37	0.02858	0.000891	3.107
35,000	−65.6	3.47	0.02367	0.000738	2.995
40,000	−69.7	2.73	0.01882	0.000587	2.969
45,000	−69.7	2.15	0.01481	0.000462	2.969
50,000	−69.7	1.69	0.01165	0.000364	2.969
60,000	−69.7	1.05	0.00722	0.000226	2.969
70,000	−69.7	0.65	0.00447	0.000140	2.969
80,000	−69.7	0.40	0.00277	0.000087	2.969
90,000	−57.2	0.25	0.00168	0.000053	3.048
100,000	−40.9	0.16	0.00102	0.000032	3.150

TABLE A-8 The ICAO standard atmosphere in SI units

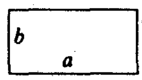
Elevation above sea level, km	Temp, °C	Absolute pressure, kPa, abs	Specific weight γ, N/m^3	Density ρ, kg/m^3	Viscosity $\mu \times 10^5$, $Pa \cdot s$
0	15.0	101.33	12.01	1.225	1.79
2	2.0	79.50	9.86	1.007	1.73
4	−4.5	60.12	8.02	0.909	1.66
6	−24.0	47.22	6.46	0.660	1.60
8	−36.9	35.65	5.14	0.526	1.53
10	−49.9	26.50	4.04	0.414	1.46
12	−56.5	19.40	3.05	0.312	1.42
14	−56.5	14.20	2.22	0.228	1.42
16	−56.5	10.35	1.62	0.166	1.42
18	−56.5	7.57	1.19	0.122	1.42
20	−56.5	5.53	0.87	0.089	1.42
25	−51.6	2.64	0.41	0.042	1.45
30	−40.2	1.20	0.18	0.018	1.51

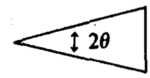
TABLE A-9 Typical wall roughness values for commercial conduits

	Roughness (ε)	
Material (new)	ft	m
Riveted steel	0.003–0.03	0.0009–0.009
Concrete	0.001–0.01	0.0003–0.003
Wood stave	0.0006–0.003	0.0002–0.0009
Cast iron	0.00085	0.00026
Galvanized iron	0.0005	0.00015
Asphalted cast iron	0.0004	0.0001
Commercial steel or wrought iron	0.00015	0.000046
Drawn brass or copper tubing	0.000005	0.0000015
Glass and plastic	"smooth"	"smooth"

From: Lewis F. Moody, "Friction Factors for Pipe Flow," *ASME Trans.*, vol. 66, pp. 671–684, 1944.

TABLE A-10 Laminar friction constants fN_R for rectangular and triangular ducts





Rectangular		Isosceles triangle	
b/a	fN_{RD_h}	θ, deg	fN_{RD_h}
0.0	96.00	0	48.0
0.05	89.91	10	51.6
0.1	84.68	20	52.9
0.125	82.34	30	53.3
0.167	78.81	40	52.9
0.25	72.93	50	52.0
0.4	65.47	60	51.1
0.5	62.19	70	49.5
0.75	57.89	80	48.3
1.0	56.91	90	48.0

TABLE A-11 Resistance coefficients $K = \dfrac{h_m}{v^2/2g}$ for open valves, elbows, and trees

Nominal diameter, in	Screwed				Flanged				
	$\frac{1}{2}$	1	2	4	1	2	4	8	20
Valves (fully open):									
Globe	14	8.2	6.9	5.7	13	8.5	6.0	5.8	5.5
Gate	0.30	0.24	0.16	0.11	0.80	0.35	0.16	0.07	0.03
Swing check	5.1	2.9	2.1	2.0	2.0	2.0	2.0	2.0	2.0
Angle	9.0	4.7	2.0	1.0	4.5	2.4	2.0	2.0	2.0
Elbows:									
45° regular	0.39	0.32	0.30	0.29					
45° long radius					0.21	0.20	0.19	0.16	0.14
90° regular	2.0	1.5	0.95	0.64	0.50	0.39	0.30	0.26	0.21
90° long radius	1.0	0.72	0.41	0.23	0.40	0.30	0.19	0.15	0.10
180° regular	2.0	1.5	0.95	0.64	0.41	0.35	0.30	0.25	0.20
180° long radius					0.40	0.30	0.21	0.15	0.10
Tees:									
Line flow	0.90	0.90	0.90	0.90	0.24	0.19	0.14	0.10	0.07
Branch flow	2.4	1.8	1.4	1.1	1.0	0.80	0.64	0.58	0.41

TABLE A-12 Increased losses of partially open valves

	Ratio K/K(open condition)	
Condition	Gate value	Globe value
Open	1.0	1.0
Closed, 25%	3.0–5.0	1.5–2.0
50%	12–22	2.0–3.0
75%	70–120	6.0–8.0

TABLE A-13 Values of n in Manning's formula

Prepared by R. E. Horton and others

	n	
Nature of surface	Min	Max
Neat cement surface	0.010	0.013
Wood-stave pipe	0.010	0.013
Plank flumes, planed	0.010	0.014
Vitrified sewer pipe	0.010	0.017
Metal flumes, smooth	0.011	0.015
Concrete, precast	0.011	0.013
Cement mortar surfaces	0.011	0.015
Plank flumes, unplaned	0.011	0.015
Common-clay drainage tile	0.011	0.017
Concrete, monolithic	0.012	0.016
Brick with cement mortar	0.012	0.017
Cast iron—new	0.013	0.017
Cement rubble surfaces	0.017	0.030
Riveted steel	0.017	0.020
Corrugated metal pipe	0.021	0.025
Canals and ditches, smooth earth	0.017	0.025
Metal flumes, corrugated	0.022	0.030
Canals:		
Dredged in earth, smooth	0.025	0.033
In rock cuts smooth	0.025	0.035
Rough beds and weeds on sides	0.025	0.040
Rock cuts, jagged and irregular	0.035	0.045
Natural streams:		
Smoothest	0.025	0.033
Roughest	0.045	0.060
Very weedy	0.075	0.150

TABLE A-14 Typical values of the Hazen-Williams Coefficient, C

Extremely smooth and straight pipes	140
New steel or cast iron	130
Wood; concrete	120
New riveted steel; vitrified	110
Old cast iron	100
Very old and corroded cast iron	80

TABLE A-15 Values of C from the Kutter formula

Slope S	n	Hydraulic Radius R in Feet														
		0.2	0.3	0.4	0.6	0.8	1.0	1.5	2.0	2.5	3.0	4.0	6.0	8.0	10.0	15.0
.00005	.010	87	98	109	123	133	140	154	164	172	177	187	199	207	213	220
	.012	68	78	88	98	107	113	126	135	142	148	157	168	176	182	189
	.015	52	58	66	76	83	89	99	107	113	118	126	138	145	150	159
	.017	43	50	57	65	72	77	86	93	98	103	112	122	129	134	142
	.020	35	41	45	53	59	64	72	80	84	88	95	105	111	116	125
	.025	26	30	35	41	45	49	57	62	66	70	78	85	92	96	104
	.030	22	25	28	33	37	40	47	51	55	58	65	74	78	84	90
.0001	.010	98	108	118	131	140	147	158	167	173	178	186	196	202	206	212
	.012	76	86	95	105	113	119	130	138	144	148	155	165	170	174	180
	.015	57	64	72	81	88	92	103	109	114	118	125	134	140	143	150
	.017	48	55	62	70	75	80	88	95	99	104	111	118	125	128	135
	.020	38	45	50	57	63	67	75	81	85	88	95	102	107	111	118
	.025	28	34	38	43	48	51	59	64	67	70	77	84	89	93	98
	.030	23	27	30	35	39	42	48	52	55	59	64	72	75	80	85
.0002	.010	105	115	125	137	145	150	162	169	174	178	185	193	198	202	206
	.012	83	92	100	110	117	123	133	139	144	148	154	162	167	170	175
	.015	61	69	76	84	91	96	105	110	114	118	124	132	137	140	145
	.017	52	59	65	73	78	83	90	97	100	104	110	117	122	125	130
	.020	42	48	53	60	65	68	76	82	85	88	94	100	105	108	113
	.025	30	35	40	45	50	54	60	65	68	70	76	83	86	90	95
	.030	25	28	32	37	40	43	49	53	56	59	63	69	74	77	82
.0004	.010	110	121	128	140	148	153	164	171	174	178	184	192	197	193	203
	.012	87	95	103	113	120	125	134	141	145	149	153	161	165	168	172
	.015	64	73	78	87	93	98	106	112	115	118	123	130	134	137	142
	.017	54	62	68	75	80	84	92	98	101	104	110	116	120	123	128
	.020	43	50	55	61	67	70	77	83	86	88	94	99	104	106	110
	.025	32	37	42	47	51	55	60	65	68	70	75	82	85	88	92
	.030	26	30	33	38	41	44	50	54	57	59	63	68	73	75	80
.001	.010	113	124	132	143	150	155	165	172	175	178	184	190	195	197	201
	.012	88	97	105	115	121	127	135	142	145	149	154	160	164	167	171
	.015	66	75	80	88	94	98	107	112	116	119	123	130	133	135	141
	.017	55	63	68	76	81	85	92	98	102	105	110	115	119	122	127
	.020	45	51	56	62	68	71	78	84	87	89	93	98	103	105	109
	.025	33	38	43	48	52	55	61	65	68	70	75	81	84	87	91
	.030	27	30	34	38	42	45	50	54	57	59	63	68	72	74	78
.01	.010	114	125	133	143	151	156	165	172	175	178	184	190	194	196	200
	.012	89	99	106	116	122	128	136	142	145	149	154	159	163	166	170
	.015	67	76	81	89	95	99	107	113	116	119	123	129	133	135	140
	.017	56	64	69	77	82	86	93	99	103	105	109	115	118	121	126
	.020	46	52	57	63	68	72	78	84	87	89	93	98	102	105	108
	.025	34	39	44	49	52	56	62	65	68	70	75	80	83	86	90
	.030	27	31	35	39	43	45	51	55	58	59	63	67	71	73	77

TABLE A-16 One-dimensional isentropic relations†

N_M	A/A^*	p/p_0	ρ/ρ_0	T/T_0	N_M	A/A^*	p/p_0	ρ/ρ_0	T/T_0
0.00	....	1.000	1.000	1.000	1.10	1.01	0.468	0.582	0.805
0.01	57.87	0.9999	0.9999	0.9999	1.12	1.01	0.457	0.571	0.799
0.02	28.94	0.9997	0.9999	0.9999	1.14	1.02	0.445	0.561	0.794
0.04	14.48	0.999	0.999	0.9996	1.16	1.02	0.434	0.551	0.788
0.06	9.67	0.997	0.998	0.999	1.18	1.02	0.423	0.541	0.782
0.08	7.26	0.996	0.997	0.999	1.20	1.03	0.412	0.531	0.776
0.10	5.82	0.993	0.995	0.998	1.22	1.04	0.402	0.521	0.771
0.12	4.86	0.990	0.993	0.997	1.24	1.04	0.391	0.512	0.765
0.14	4.18	0.986	0.990	0.996	1.26	1.05	0.381	0.502	0.759
0.16	3.67	0.982	0.987	0.995	1.28	1.06	0.371	0.492	0.753
0.18	3.28	0.978	0.984	0.994	1.30	1.07	0.361	0.483	0.747
0.20	2.96	0.973	0.980	0.992	1.32	1.08	0.351	0.474	0.742
0.22	2.71	0.967	0.976	0.990	1.34	1.08	0.342	0.464	0.736
0.24	2.50	0.961	0.972	0.989	1.36	1.09	0.332	0.455	0.730
0.26	2.32	0.954	0.967	0.987	1.38	1.10	0.323	0.446	0.724
0.28	2.17	0.947	0.962	0.985	1.40	1.11	0.314	0.437	0.718
0.30	2.04	0.939	0.956	0.982	1.42	1.13	0.305	0.429	0.713
0.32	1.92	0.932	0.951	0.980	1.44	1.14	0.297	0.420	0.707
0.34	1.82	0.923	0.944	0.977	1.46	1.15	0.289	0.412	0.701
0.36	1.74	0.914	0.938	0.975	1.48	1.16	0.280	0.403	0.695
0.38	1.66	0.905	0.931	0.972	1.50	1.18	0.272	0.395	0.690
0.40	1.59	0.896	0.924	0.969	1.52	1.19	0.265	0.387	0.684
0.42	1.53	0.886	0.917	0.966	1.54	1.20	0.257	0.379	0.678
0.44	1.47	0.876	0.909	0.963	1.56	1.22	0.250	0.371	0.672
0.46	1.42	0.865	0.902	0.959	1.58	1.23	0.242	0.363	0.667
0.48	1.38	0.854	0.893	0.956	1.60	1.25	0.235	0.356	0.661
0.50	1.34	0.843	0.885	0.952	1.62	1.27	0.228	0.348	0.656
0.52	1.30	0.832	0.877	0.949	1.64	1.28	0.222	0.341	0.650
0.54	1.27	0.820	0.868	0.945	1.66	1.30	0.215	0.334	0.645
0.56	1.24	0.808	0.859	0.941	1.68	1.32	0.209	0.327	0.639
0.58	1.21	0.796	0.850	0.937	1.70	1.34	0.203	0.320	0.634
0.60	1.19	0.784	0.840	0.933	1.72	1.36	0.197	0.313	0.628
0.62	1.17	0.772	0.831	0.929	1.74	1.38	0.191	0.306	0.623
0.64	1.16	0.759	0.821	0.924	1.76	1.40	0.185	0.300	0.617
0.66	1.13	0.747	0.812	0.920	1.78	1.42	0.179	0.293	0.612
0.68	1.12	0.734	0.802	0.915	1.80	1.44	0.174	0.287	0.607
0.70	1.09	0.721	0.792	0.911	1.82	1.46	0.169	0.281	0.602
0.72	1.08	0.708	0.781	0.906	1.84	1.48	0.164	0.275	0.596
0.74	1.07	0.695	0.771	0.901	1.86	1.51	0.159	0.269	0.591
0.76	1.06	0.682	0.761	0.896	1.88	1.53	0.154	0.263	0.586
0.78	1.05	0.669	0.750	0.891	1.90	1.56	0.149	0.257	0.581
0.80	1.04	0.656	0.740	0.886	1.92	1.58	0.145	0.251	0.576
0.82	1.03	0.643	0.729	0.881	1.94	1.61	0.140	0.246	0.571
0.84	1.02	0.630	0.719	0.876	1.96	1.63	0.136	0.240	0.566
0.86	1.02	0.617	0.708	0.871	1.98	1.66	0.132	0.235	0.561
0.88	1.01	0.604	0.698	0.865	2.00	1.69	0.128	0.230	0.556
0.90	1.01	0.591	0.687	0.860	2.02	1.72	0.124	0.225	0.551
0.92	1.01	0.578	0.676	0.855	2.04	1.75	0.120	0.220	0.546
0.94	1.00	0.566	0.666	0.850	2.06	1.78	0.116	0.215	0.541
0.96	1.00	0.553	0.655	0.844	2.08	1.81	0.113	0.210	0.536
0.98	1.00	0.541	0.645	0.839	2.10	1.84	0.109	0.206	0.531
1.00	1.00	0.528	0.632	0.833	2.12	1.87	0.106	0.201	0.526
1.02	1.00	0.516	0.623	0.828	2.14	1.90	0.103	0.197	0.522
1.04	1.00	0.504	0.613	0.822	2.16	1.94	0.100	0.192	0.517
1.06	1.00	0.492	0.602	0.817	2.18	1.97	0.097	0.188	0.513
1.08	1.01	0.480	0.592	0.810	2.20	2.01	0.094	0.184	0.508

TABLE A-16 One-dimensional isentropic relations (*continued*)

N_M	A/A^*	p/p_0	ρ/ρ_0	T/T_0	N_M	A/A^*	p/p_0	ρ/ρ_0	T/T_0
2.22	2.04	0.091	0.180	0.504	2.74	3.31	0.040	0.101	0.400
2.24	2.08	0.088	0.176	0.499	2.76	3.37	0.039	0.099	0.396
2.26	2.12	0.085	0.172	0.495	2.78	3.43	0.038	0.097	0.393
2.28	2.15	0.083	0.168	0.490	2.80	3.50	0.037	0.095	0.389
2.30	2.19	0.080	0.165	0.486	2.82	3.57	0.036	0.093	0.386
2.32	2.23	0.078	0.161	0.482	2.84	3.64	0.035	0.091	0.383
2.34	2.27	0.075	0.157	0.477	2.86	3.71	0.034	0.089	0.379
2.36	2.32	0.073	0.154	0.473	2.88	3.78	0.033	0.087	0.376
2.38	2.36	0.071	0.150	0.469	2.90	3.85	0.032	0.085	0.373
2.40	2.40	0.068	0.147	0.465	2.92	3.92	0.031	0.083	0.370
2.42	2.45	0.066	0.144	0.461	2.94	4.00	0.030	0.081	0.366
2.44	2.49	0.064	0.141	0.456	2.96	4.08	0.029	0.080	0.363
2.46	2.54	0.062	0.138	0.452	2.98	4.15	0.028	0.078	0.360
2.48	2.59	0.060	0.135	0.448	3.00	4.23	0.027	0.076	0.357
2.50	2.64	0.059	0.132	0.444	3.10	4.66	0.023	0.0685	0.342
2.52	2.69	0.057	0.129	0.441	3.20	5.12	0.020	0.062	0.328
2.54	2.74	0.055	0.126	0.437	3.3	5.63	0.0175	0.0555	0.315
2.56	2.79	0.053	0.123	0.433	3.4	6.18	0.015	0.050	0.302
2.58	2.84	0.052	0.121	0.429	3.5	6.79	0.013	0.045	0.290
2.60	2.90	0.050	0.118	0.425	3.6	7.45	0.0114	0.041	0.278
2.62	2.95	0.049	0.115	0.421	3.7	8.17	0.0099	0.037	0.2675
2.64	3.01	0.047	0.113	0.418	3.8	8.95	0.0086	0.0335	0.257
2.66	3.06	0.046	0.110	0.414	3.9	9.80	0.0075	0.030	0.247
2.68	3.12	0.044	0.108	0.410	4.0	10.72	0.0066	0.028	0.238
2.70	3.18	0.043	0.106	0.407					
2.72	3.24	0.042	0.103	0.403					

†For a perfect gas with constant specific heat, $k = 1.4$

TABLE A-17 One-dimensional normal-shock relations†

N_{M1}	N_{M2}	$\frac{p_2}{p_1}$	$\frac{T_2}{T_1}$	$\frac{(p_0)_2}{(p_0)_1}$
1.00	1.000	1.000	1.000	1.000
1.02	0.980	1.047	1.013	1.000
1.04	0.962	1.095	1.026	1.000
1.06	0.944	1.144	1.039	1.000
1.08	0.928	1.194	1.052	0.999
1.10	0.912	1.245	1.065	0.999
1.12	0.896	1.297	1.078	0.998
1.14	0.882	1.350	1.090	0.997
1.16	0.868	1.403	1.103	0.996
1.18	0.855	1.458	1.115	0.995
1.20	0.842	1.513	1.128	0.993
1.22	0.830	1.570	1.140	0.991
1.24	0.818	1.627	1.153	0.988
1.26	0.807	1.686	1.166	0.986
1.28	0.796	1.745	1.178	0.983
1.30	0.786	1.805	1.191	0.979
1.32	0.776	1.866	1.204	0.976
1.34	0.766	1.928	1.216	0.972
1.36	0.757	1.991	1.229	0.968
1.38	0.748	2.055	1.242	0.963
1.40	0.740	2.120	1.255	0.958
1.42	0.731	2.186	1.268	0.953
1.44	0.723	2.253	1.281	0.948
1.46	0.716	2.320	1.294	0.942
1.48	0.708	2.389	1.307	0.936
1.50	0.701	2.458	1.320	0.930
1.52	0.694	2.529	1.334	0.923
1.54	0.687	2.600	1.347	0.917
1.56	0.681	2.673	1.361	0.910
1.58	0.675	2.746	1.374	0.903
1.60	0.668	2.820	1.388	0.895
1.62	0.663	2.895	1.402	0.888
1.64	0.657	2.971	1.416	0.880
1.66	0.651	3.048	1.430	0.872
1.68	0.646	3.126	1.444	0.864
1.70	0.641	3.205	1.458	0.856
1.72	0.635	3.285	1.473	0.847
1.74	0.631	3.366	1.487	0.839
1.76	0.626	3.447	1.502	0.830
1.78	0.621	3.530	1.517	0.821
1.80	0.617	3.613	1.532	0.813
1.82	0.612	3.698	1.547	0.804
1.84	0.608	3.783	1.562	0.795
1.86	0.604	3.869	1.577	0.786
1.88	0.600	3.957	1.592	0.777
1.90	0.596	4.045	1.608	0.767
1.92	0.592	4.134	1.624	0.758
1.94	0.588	4.224	1.639	0.749
1.96	0.584	4.315	1.655	0.740
1.98	0.581	4.407	1.671	0.730
2.00	0.577	4.500	1.688	0.721
2.02	0.574	4.594	1.704	0.711
2.04	0.571	4.689	1.720	0.702
2.06	0.567	4.784	1.737	0.693
2.08	0.564	4.881	1.754	0.683
2.10	0.561	4.978	1.770	0.674
2.12	0.558	5.077	1.787	0.665
2.14	0.555	5.176	1.805	0.656
2.16	0.553	5.277	1.822	0.646
2.18	0.550	5.378	1.839	0.637
2.20	0.547	5.480	1.857	0.628
2.22	0.544	5.583	1.875	0.619
2.24	0.542	5.687	1.892	0.610
2.26	0.539	5.792	1.910	0.601
2.28	0.537	5.898	1.929	0.592
2.30	0.534	6.005	1.947	0.583
2.32	0.532	6.113	1.965	0.575
2.34	0.530	6.222	1.984	0.566
2.36	0.527	6.331	2.003	0.557
2.38	0.525	6.442	2.021	0.549
2.40	0.523	6.553	2.040	0.540
2.42	0.521	6.666	2.060	0.532
2.44	0.519	6.779	2.079	0.523
2.46	0.517	6.894	2.098	0.515
2.48	0.515	7.009	2.118	0.507
2.50	0.513	7.125	2.138	0.499
2.52	0.511	7.242	2.157	0.491
2.54	0.509	7.360	2.177	0.483
2.56	0.507	7.479	2.198	0.475
2.58	0.506	7.599	2.218	0.468
2.60	0.504	7.720	2.238	0.460
2.62	0.502	7.842	2.260	0.453
2.64	0.500	7.965	2.280	0.445
2.66	0.499	8.088	2.301	0.438
2.68	0.497	8.213	2.322	0.431
2.70	0.496	8.338	2.343	0.424
2.72	0.494	8.465	2.364	0.417
2.74	0.493	8.592	2.396	0.410
2.76	0.491	8.721	2.407	0.403
2.78	0.490	8.850	2.429	0.396
2.80	0.488	8.980	2.451	0.389
2.82	0.487	9.111	2.473	0.383
2.84	0.485	9.243	2.496	0.376
2.86	0.484	9.376	2.518	0.370
2.88	0.483	9.510	2.541	0.364
2.90	0.481	9.645	2.563	0.358
2.92	0.480	9.781	2.586	0.352
2.94	0.479	9.918	2.609	0.346
2.96	0.478	10.055	2.632	0.340
2.98	0.476	10.194	2.656	0.334
3.00	0.475	10.333	2.679	0.328

†For a perfect gas with $k = 1.4$.

TABLE A-18 Some expansion factors *Y* for compressible flow through flow-nozzles and venturi meters

p_2/p_1	k	Ratio of Diameters (d_2/d_1)				
		0.30	0.40	0.50	0.60	0.70
0.95	1.40	0.973	0.972	0.971	0.968	0.962
	1.30	.970	.970	.968	.965	.959
	1.20	.968	.967	.966	.963	.956
0.90	1.40	0.944	0.943	0.941	0.935	0.925
	1.30	.940	.939	.936	.931	.918
	1.20	.935	.933	.931	.925	.912
0.85	1.40	0.915	0.914	0.910	0.902	0.887
	1.30	.910	.907	.904	.896	.880
	1.20	.902	.900	.896	.887	.870
0.80	1.40	0.886	0.884	0.880	0.868	0.850
	1.30	.876	.873	.869	.857	.839
	1.20	.866	.864	.859	.848	.829
0.75	1.40	0.856	0.853	0.846	0.836	0.814
	1.30	.844	.841	.836	.823	.802
	1.20	.820	.818	.812	.798	.776
0.70	1.40	0.824	0.820	0.815	0.800	0.778
	1.30	.812	.808	.802	.788	.763
	1.20	.794	.791	.784	.770	.745

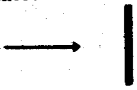
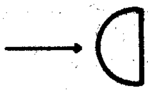
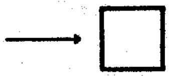
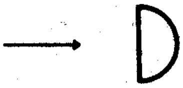
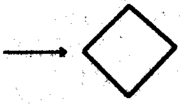
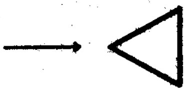
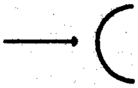
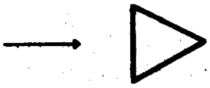
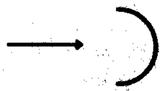
For $p_2/p_1 = 1.00$, $Y = 1.00$.

TABLE A-19 Discharge coefficients for vertical sharp-edged circular orifices
For Water at 60 °F Discharging into Air at Same Temperature

Head in Feet	Orifice Diameter in Inches					
	0.25	0.50	0.75	1.00	2.00	4.00
0.8	0.647	0.627	0.616	0.609	0.603	0.601
1.4	.635	.619	.610	.605	.601	.600
2.0	.629	.615	.607	.603	.600	.599
4.0	.621	.609	.603	.600	.598	.597
6.0	.617	.607	.601	.599	.597	.596
8.0	.614	.605	.600	.598	.596	.595
10.0	.613	.604	.600	.597	.596	.595
12.0	.612	.603	.599	.597	.595	.595
14.0	.611	.603	.598	.596	.595	.594
16.0	.610	.602	.598	.596	.595	.594
20.0	.609	.602	.598	.596	.595	.594
25.0	.608	.601	.597	.596	.594	.594
30.0	.607	.600	.597	.595	.594	.594
40.0	.606	.600	.596	.595	.594	.593
50.0	.605	.599	.596	.595	.594	.593
60.0	.605	.599	.596	.594	.593	.593

Source: F. W. Medaugh and G. D. Johnson, Civil Engr., July 1940, p. 424.

TABLE A-20 Drag of two-dimensional bodies at $N_R \geq 10^4$

Shape	C_D based on frontal area	Shape	C_D based on frontal area
Plate:		**Half-cylinder:**	
	2.0		1.2
Square cylinder:			
	2.1		1.7
		Equilateral triangle:	
	1.6		1.6
Half tube:			
	1.2		2.0
	2.3		

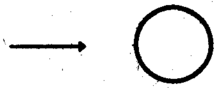
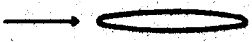
Elliptical cylinder:		Laminar	Turbulent
1:1		1.2	0.3
2:1		0.6	0.2
4:1		0.35	0.15
8:1		0.25	0.1

TABLE A-21 Drag of three-dimensional bodies at $N_R \geq 10^4$

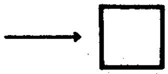
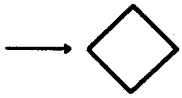
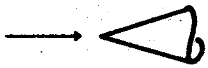
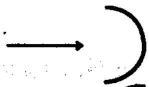
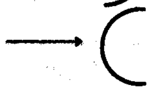
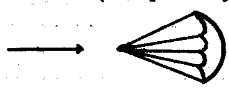
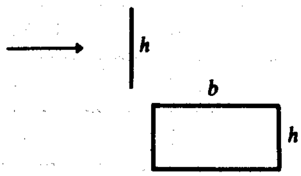
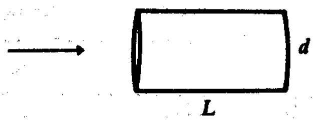
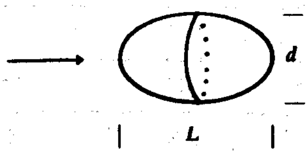
Body	Ratio	C_D based on frontal area	
Cube:			
		1.07	
		0.81	
60° cone:			
		0.5	
Disk:			
		1.17	
Cup:			
		1.4	
		0.4	
Parachute (low porosity):			
		1.2	
Rectangular plate:			
	b/h 1	1.18	
	5	1.2	
	10	1.3	
	20	1.5	
	∞	2.0	
Flat-faced cylinder:			
	L/d 0.5	1.15	
	1	0.90	
	2	0.85	
	4	0.87	
	8	0.99	
Ellipsoid:		Laminar	Turbulent
	L/d 0.75	0.5	0.2
	1	0.47	0.2
	2	0.27	0.13
	4	0.25	0.1
	8	0.2	0.08

TABLE A-22 Drag coefficients for three-dimensional bodies

Shape	C_D	Shape	C_D Laminar flow	C_D Turbulent flow
Disc	1.17	Sphere:	0.47	0.27
60° cone	0.49	Ellipsoidal body of revolution:		
Cube	1.05	2:1	0.27	0.06
	0.80	4:1	0.20	0.06
Hollow cup	0.38	8:1	0.25	0.13
	1.42			
Solid hemisphere	0.38			
	1.17			

TABLE A-23 Typical drag coefficients for various cylinders in two-dimensional flow

Body shape		C_D	Reynolds number
Circular cylinder		1.2	10^4 to 1.5×10^5
Elliptical cylinder	2:1	0.6	4×10^4
		0.46	10^5
	4:1	0.32	2.5×10^4 to 10^5
	8:1	0.29	2.5×10^4
		0.20	2×10^5
Square cylinder		2.0	3.5×10^4
		1.6	10^4 to 10^5
Triangular cylinders	120°	2.0	10^4
	120°	1.72	10^4
	90°	2.15	10^4
	90°	1.60	10^4
	60°	2.20	10^4
	60°	1.39	10^4
	30	1.8	10^5
	30°	1.0	10^5
Semitubular		2.3	4×10^4
		1.12	4×10^4

From W. F. Lindsey, *NACA Tech. Rep. 619,* 1938.

TABLE A-24 Adiabatic frictional flow in a constant-area duct for $\gamma = 1.4$

N_M	$\bar{f}L^*/D$	p/p^*	T/T^*	$\rho^*/\rho = V/V^*$	p_0/p_0^*
0.0	∞	∞	1.2000	0.0	∞
0.02	1778.4500	54.7701	1.1999	0.0219	28.9421
0.04	440.3520	27.3817	1.1996	0.0438	14.4815
0.06	193.0310	18.2508	1.1991	0.0657	9.6659
0.08	106.7180	13.6843	1.1985	0.0876	7.2616
0.1	66.9216	10.9435	1.1976	0.1094	5.8218
0.12	45.4080	9.1156	1.1966	0.1313	4.8643
0.14	32.5113	7.8093	1.1953	0.1531	4.1824
0.16	24.1978	6.8291	1.1939	0.1748	3.6727
0.18	18.5427	6.0662	1.1923	0.1965	3.2779
0.2	14.5333	5.4554	1.1905	0.2182	2.9635
0.22	11.5961	4.9554	1.1885	0.2398	2.7076
0.24	9.3865	4.5383	1.1863	0.2614	2.4956
0.26	7.6876	4.1851	1.1840	0.2829	2.3173
0.28	6.3572	3.8820	1.1815	0.3043	2.1656
0.3	5.2993	3.6191	1.1788	0.3257	2.0351
0.32	4.4467	3.3887	1.1759	0.3470	1.9219
0.34	3.7520	3.1853	1.1729	0.3682	1.8229
0.36	3.1801	3.0042	1.1697	0.3893	1.7358
0.38	2.7054	2.8420	1.1663	0.4104	1.6587
0.4	2.3085	2.6958	1.1628	0.4313	1.5901
0.42	1.9744	2.5634	1.1591	0.4522	1.5289
0.44	1.6915	2.4428	1.1553	0.4729	1.4740
0.46	1.4509	2.3326	1.1513	0.4936	1.4246
0.48	1.2453	2.2313	1.1471	0.5141	1.3801
0.5	1.0691	2.1381	1.1429	0.5345	1.3398
0.52	0.9174	2.0519	1.1384	0.5548	1.3034
0.54	0.7866	1.9719	1.1339	0.5750	1.2703
0.56	0.6736	1.8975	1.1292	0.5951	1.2403
0.58	0.5757	1.8282	1.1244	0.6150	1.2130
0.6	0.4908	1.7634	1.1194	0.6348	1.1882
0.62	0.4172	1.7026	1.1143	0.6545	1.1656
0.64	0.3533	1.6456	1.1091	0.6740	1.1451
0.66	0.2979	1.5919	1.1038	0.6934	1.1265
0.68	0.2498	1.5413	1.0984	0.7127	1.1097
0.7	0.2081	1.4935	1.0929	0.7318	1.0944
0.72	0.1721	1.4482	1.0873	0.7508	1.0806
0.74	0.1411	1.4054	1.0815	0.7696	1.0681
0.76	0.1145	1.3647	1.0757	0.7883	1.0570
0.78	0.0917	1.3261	1.0698	0.8068	1.0471
0.8	0.0723	1.2893	1.0638	0.8251	1.0382
0.82	0.0559	1.2542	1.0578	0.8433	1.0305
0.84	0.0423	1.2208	1.0516	0.8614	1.0237
0.86	0.0310	1.1889	1.0454	0.8793	1.0179
0.88	0.0218	1.1583	1.0391	0.8970	1.0129

Source: Fluid Mechanics by White

TABLE A-24 (*Cont.*)

N_M	$\bar{f}L^*/D$	p/p^*	T/T^*	$\rho^*/\rho = V/V^*$	p_0/p_0^*
0.9	0.0145	1.1291	1.0327	0.9146	1.0089
0.92	0.0089	1.1011	1.0263	0.9320	1.0056
0.94	0.0048	1.0743	1.0198	0.9493	1.0031
0.96	0.0021	1.0485	1.0132	0.9663	1.0014
0.98	0.0005	1.0238	1.0066	0.9833	1.0003
1.0	0.0000	1.0000	1.0000	1.0000	1.0000
1.02	0.0005	0.9771	0.9933	1.0166	1.0003
1.04	0.0018	0.9551	0.9866	1.0330	1.0013
1.06	0.0038	0.9338	0.9798	1.0492	1.0029
1.08	0.0066	0.9133	0.9730	1.0653	1.0051
1.1	0.0099	0.8936	0.9662	1.0812	1.0079
1.12	0.0138	0.8745	0.9593	1.0970	1.0113
1.14	0.0182	0.8561	0.9524	1.1126	1.0153
1.16	0.0230	0.8383	0.9455	1.1280	1.0198
1.18	0.0281	0.8210	0.9386	1.1432	1.0248
1.2	0.0336	0.8044	0.9317	1.1583	1.0304
1.22	0.0394	0.7882	0.9247	1.1732	1.0366
1.24	0.0455	0.7726	0.9178	1.1879	1.0432
1.26	0.0517	0.7574	0.9108	1.2025	1.0504
1.28	0.0582	0.7427	0.9038	1.2169	1.0581
1.3	0.0648	0.7285	0.8969	1.2311	1.0663
1.32	0.0716	0.7147	0.8899	1.2452	1.0750
1.34	0.0785	0.7012	0.8829	1.2591	1.0842
1.36	0.0855	0.6882	0.8760	1.2729	1.0940
1.38	0.0926	0.6755	0.8690	1.2864	1.1042
1.4	0.0997	0.6632	0.8621	1.2999	1.1149
1.42	0.1069	0.6512	0.8551	1.3131	1.1262
1.44	0.1142	0.6396	0.8482	1.3262	1.1379
1.46	0.1215	0.6282	0.8413	1.3392	1.1501
1.48	0.1288	0.6172	0.8344	1.3520	1.1629
1.5	0.1361	0.6065	0.8276	1.3646	1.1762
1.52	0.1433	0.5960	0.8207	1.3770	1.1899
1.54	0.1506	0.5858	0.8139	1.3894	1.2042
1.56	0.1579	0.5759	0.8071	1.4015	1.2190
1.58	0.1651	0.5662	0.8004	1.4135	1.2344
1.6	0.1724	0.5568	0.7937	1.4254	1.2502
1.62	0.1795	0.5476	0.7869	1.4371	1.2666
1.64	0.1867	0.5386	0.7803	1.4487	1.2836
1.66	0.1938	0.5299	0.7736	1.4601	1.3010
1.68	0.2008	0.5213	0.7670	1.4713	1.3190
1.7	0.2078	0.5130	0.7605	1.4825	1.3376
1.72	0.2147	0.5048	0.7539	1.4935	1.3567
1.74	0.2216	0.4969	0.7474	1.5043	1.3764
1.76	0.2284	0.4891	0.7410	1.5150	1.3967
1.78	0.2352	0.4815	0.7345	1.5256	1.4175

TABLE A-24 (*Contd.*) **Adiabatic frictional flow in a constant-area duct for $\gamma = 1.4$**

N_M	$\bar{f}L^*/D$	p/p^*	T/T^*	$\rho^*/\rho = V/V^*$	p_0/p_0^*
1.8	0.2419	0.4741	0.7282	1.5360	1.4390
1.82	0.2485	0.4668	0.7218	1.5463	1.4610
1.84	0.2551	0.4597	0.7155	1.5564	1.4836
1.86	0.2616	0.4528	0.7093	1.5664	1.5069
1.88	0.2680	0.4460	0.7030	1.5763	1.5308
1.9	0.2743	0.4394	0.6969	1.5861	1.5553
1.92	0.2806	0.4329	0.6907	1.5957	1.5804
1.94	0.2868	0.4265	0.6847	1.6052	1.6062
1.96	0.2929	0.4203	0.6786	1.6146	1.6326
1.98	0.2990	0.4142	0.6726	1.6239	1.6597
2.0	0.3050	0.4082	0.6667	1.6330	1.6875
2.02	0.3109	0.4024	0.6608	1.6420	1.7160
2.04	0.3168	0.3967	0.6549	1.6509	1.7451
2.06	0.3225	0.3911	0.6491	1.6597	1.7750
2.08	0.3282	0.3856	0.6433	1.6683	1.8056
2.1	0.3339	0.3802	0.6376	1.6769	1.8369
2.12	0.3394	0.3750	0.6320	1.6853	1.8690
2.14	0.3449	0.3698	0.6263	1.6936	1.9018
2.16	0.3503	0.3648	0.6208	1.7018	1.9354
2.18	0.3556	0.3598	0.6152	1.7099	1.9698
2.2	0.3609	0.3549	0.6098	1.7179	2.0050
2.22	0.3661	0.3502	0.6043	1.7258	2.0409
2.24	0.3712	0.3455	0.5989	1.7336	2.0777
2.26	0.3763	0.3409	0.5936	1.7412	2.1153
2.28	0.3813	0.3364	0.5883	1.7488	2.1538
2.3	0.3862	0.3320	0.5831	1.7563	2.1931
2.32	0.3911	0.3277	0.5779	1.7637	2.2333
2.34	0.3959	0.3234	0.5728	1.7709	2.2744
2.36	0.4006	0.3193	0.5677	1.7781	2.3164
2.38	0.4053	0.3152	0.5626	1.7852	2.3593
2.4	0.4099	0.3111	0.5576	1.7922	2.4031
2.42	0.4144	0.3072	0.5527	1.7991	2.4479
2.44	0.4189	0.3033	0.5478	1.8059	2.4936
2.46	0.4233	0.2995	0.5429	1.8126	2.5403
2.48	0.4277	0.2958	0.5381	1.8192	2.5880
2.5	0.4320	0.2921	0.5333	1.8257	2.6367
2.52	0.4362	0.2885	0.5286	1.8322	2.6865
2.54	0.4404	0.2850	0.5239	1.8386	2.7372
2.56	0.4445	0.2815	0.5193	1.8448	2.7891
2.58	0.4486	0.2781	0.5147	1.8510	2.8420
2.6	0.4526	0.2747	0.5102	1.8571	2.8960
2.62	0.4565	0.2714	0.5057	1.8632	2.9511
2.64	0.4604	0.2682	0.5013	1.8691	3.0073
2.66	0.4643	0.2650	0.4969	1.8750	3.0647
2.68	0.4681	0.2619	0.4925	1.8808	3.1233

TABLE A-24 (*Cont.*)

N_M	$\bar{f}L^*/D$	p/p^*	T/T^*	$\rho^*/\rho = V/V^*$	p_0/p_0^*
2.7	0.4718	0.2588	0.4882	1.8865	3.1830
2.72	0.4755	0.2558	0.4839	1.8922	3.2440
2.74	0.4791	0.2528	0.4797	1.8978	3.3061
2.76	0.4827	0.2498	0.4755	1.9033	3.3695
2.78	0.4863	0.2470	0.4714	1.9087	3.4342
2.8	0.4898	0.2441	0.4673	1.9140	3.5001
2.82	0.4932	0.2414	0.4632	1.9193	3.5674
2.84	0.4966	0.2386	0.4592	1.9246	3.6359
2.86	0.5000	0.2359	0.4552	1.9297	3.7058
2.88	0.5033	0.2333	0.4513	1.9348	3.7771
2.9	0.5065	0.2307	0.4474	1.9398	3.8498
2.92	0.5097	0.2281	0.4436	1.9448	3.9238
2.94	0.5129	0.2256	0.4398	1.9497	3.9993
2.96	0.5160	0.2231	0.4360	1.9545	4.0763
2.98	0.5191	0.2206	0.4323	1.9593	4.1547
3.0	0.5222	0.2182	0.4286	1.9640	4.2346
3.02	0.5252	0.2158	0.4249	1.9686	4.3160
3.04	0.5281	0.2135	0.4213	1.9732	4.3989
3.06	0.5310	0.2112	0.4177	1.9777	4.4835
3.08	0.5339	0.2090	0.4142	1.9822	4.5696
3.1	0.5368	0.2067	0.4107	1.9866	4.6573
3.12	0.5396	0.2045	0.4072	1.9910	4.7467
3.14	0.5424	0.2024	0.4038	1.9953	4.8377
3.16	0.5451	0.2002	0.4004	1.9995	4.9304
3.18	0.5478	0.1981	0.3970	2.0037	5.0248
3.2	0.5504	0.1961	0.3937	2.0079	5.1210
3.22	0.5531	0.1940	0.3904	2.0120	5.2189
3.24	0.5557	0.1920	0.3872	2.0160	5.3186
3.26	0.5582	0.1901	0.3839	2.0200	5.4201
3.28	0.5607	0.1881	0.3807	2.0239	5.5234
3.3	0.5632	0.1862	0.3776	2.0278	5.6286
3.32	0.5657	0.1843	0.3745	2.0317	5.7358
3.34	0.5681	0.1825	0.3714	2.0355	5.8448
3.36	0.5705	0.1806	0.3683	2.0392	5.9558
3.38	0.5729	0.1788	0.3653	2.0429	6.0687
3.4	0.5752	0.1770	0.3623	2.0466	6.1837
3.42	0.5775	0.1753	0.3594	2.0502	6.3007
3.44	0.5798	0.1736	0.3564	2.0537	6.4198
3.46	0.5820	0.1718	0.3535	2.0573	6.5409
3.48	0.5842	0.1702	0.3507	2.0607	6.6642
3.5	0.5864	0.1685	0.3478	2.0642	6.7896
3.52	0.5886	0.1669	0.3450	2.0676	6.9172
3.54	0.5907	0.1653	0.3422	2.0709	7.0471
3.56	0.5928	0.1637	0.3395	2.0743	7.1791
3.58	0.5949	0.1621	0.3368	2.0775	7.3135

TABLE A-24 (*Cont.*) **Adiabatic frictional flow in a constant-area duct for $\gamma = 1.4$**

N_M	$\bar{f}L^*/D$	p/p^*	T/T^*	$\rho^*/\rho = V/V^*$	p_0/p_0^*
3.6	0.5970	0.1606	0.3341	2.0808	7.4501
3.62	0.05990	0.1590	0.3314	2.0840	7.5891
3.64	0.6010	0.1575	0.3288	2.0871	7.7305
3.66	0.6030	0.1560	0.3262	2.0903	7.8742
3.68	0.6049	0.1546	0.3236	2.0933	8.0204
3.7	0.6068	0.1531	0.3210	2.0964	8.1691
3.72	0.6087	0.1517	0.3185	2.0994	8.3202
3.74	0.6106	0.1503	0.3160	2.1024	8.4739
3.76	0.6125	0.1489	0.3135	2.1053	8.6302
3.78	0.6143	0.1475	0.3111	2.1082	8.7891
3.8	0.6161	0.1462	0.3086	2.1111	8.9506
3.82	0.6179	0.1449	0.3062	2.1140	9.1148
3.84	0.6197	0.1436	0.3039	2.1168	9.2817
3.86	0.6214	0.1423	0.3015	2.1195	9.4513
3.88	0.6231	0.1410	0.2992	2.1223	9.6237
3.9	0.6248	0.1397	0.2969	2.1250	9.7990
3.92	0.6265	0.1385	0.2946	2.1277	9.9771
3.94	0.6282	0.1372	0.2923	2.1303	10.1581
3.96	0.6298	0.1360	0.2901	2.1329	10.3420
3.98	0.6315	0.1348	0.2879	2.1355	10.5289
4.0	0.6331	0.1336	0.2857	2.1381	10.7188

TABLE A-25 Frictionless duct flow with heat transfer for $\gamma = 1.4$

N_M	T_0/T_0^*	p/p^*	T/T^*	$\rho^*/\rho = V/V^*$	p_0/p_0^*
0.0	0.0	2.4000	0.0	0.0	1.2679
0.02	0.0019	2.3987	0.0023	0.0010	1.2675
0.04	0.0076	2.3946	0.0092	0.0038	1.2665
0.06	0.0171	2.3880	0.0205	0.0086	1.2647
0.08	0.0302	2.3787	0.0362	0.0152	1.2623
0.1	0.0468	2.3669	0.0560	0.0237	1.2591
0.12	0.0666	2.3526	0.0797	0.0339	1.2554
0.14	0.0895	2.3359	0.1069	0.0458	1.2510
0.16	0.1151	2.3170	0.1374	0.0593	1.2461
0.18	0.1432	2.2959	0.1708	0.0744	1.2406
0.2	0.1736	2.2727	0.2066	0.0909	1.2346
0.22	0.2057	2.2477	0.2445	0.1088	1.2281
0.24	0.2395	2.2209	0.2841	0.1279	1.2213
0.26	0.2745	2.1925	0.3250	0.1482	1.2140
0.28	0.3104	2.1626	0.3667	0.1696	1.2064
0.3	0.3469	2.1314	0.4089	0.1918	1.1985
0.32	0.3837	2.0991	0.4512	0.2149	1.1904
0.34	0.4206	2.0657	0.4933	0.2388	1.1822
0.36	0.4572	2.0314	0.5348	0.2633	1.1737
0.38	0.4935	1.9964	0.5755	0.2883	1.1652
0.4	0.5290	1.9608	0.6151	0.3137	1.1566
0.42	0.5638	1.9247	0.6535	0.3395	1.1480
0.44	0.5975	1.8882	0.6903	0.3656	1.1394
0.46	0.6301	1.8515	0.7254	0.3918	1.1308
0.48	0.6614	1.8147	0.7587	0.4181	1.1224
0.5	0.6914	1.7778	0.7901	0.4444	1.1141
0.52	0.7199	1.7409	0.8196	0.4708	1.1059
0.54	0.7470	1.7043	0.8469	0.4970	1.0979
0.56	0.7725	1.6678	0.8723	0.5230	1.0901
0.58	0.7965	1.6316	0.8955	0.5489	1.0826
0.6	0.8189	1.5957	0.9167	0.5745	1.0753
0.62	0.8398	1.5603	0.9358	0.5998	1.0682
0.64	0.8592	1.5253	0.9530	0.6248	1.0615
0.66	0.8771	1.4908	0.9682	0.6494	1.0550
0.68	0.8935	1.4569	0.9814	0.6737	1.0489
0.7	0.9085	1.4235	0.9929	0.6975	1.0431
0.72	0.9221	1.3907	1.0026	0.7209	1.0376
0.74	0.9344	1.3585	1.0106	0.7439	1.0325
0.76	0.9455	1.3270	1.0171	0.7665	1.0278
0.78	0.9553	1.2961	1.0220	0.7885	1.0234
0.8	0.9639	1.2658	1.0255	0.8101	1.0193
0.82	0.9715	1.2362	1.0276	0.8313	1.0157
0.84	0.9781	1.2073	1.0285	0.8519	1.0124
0.86	0.9836	1.1791	1.0283	0.8721	1.0095
0.88	0.9883	1.1515	1.0269	0.8918	1.0070

TABLE A-25 (*Cont.*) **Frictionless duct flow with heat transfer for $\gamma = 1.4$**

N_M	T_0/T_0^*	p/p^*	T/T^*	$\rho^*/\rho = V/V^*$	p_0/p_0^*
0.9	0.9921	1.1246	1.0245	0.9110	1.0049
0.92	0.9951	1.0984	1.0212	0.9297	1.0031
0.94	0.9973	1.0728	1.0170	0.9480	1.0017
0.96	0.9988	1.0479	1.0121	0.9658	1.0008
0.98	0.9997	1.0236	1.0064	0.9831	1.0002
1.0	1.0000	1.0000	1.0000	1.0000	1.0000
1.02	0.9997	0.9770	0.9930	1.0164	1.0002
1.04	0.9989	0.9546	0.9855	1.0325	1.0008
1.06	0.9977	0.9327	0.9776	1.0480	1.0017
1.08	0.9960	0.9115	0.9691	1.0632	1.0031
1.1	0.9939	0.8909	0.9603	1.0780	1.0049
1.12	0.9915	0.8708	0.9512	1.0923	1.0070
1.14	0.9887	0.8512	0.9417	1.1063	1.0095
1.16	0.9856	0.8322	0.9320	1.1198	1.0124
1.18	0.9823	0.8137	0.9220	1.1330	1.0157
1.2	0.9787	0.7958	0.9118	1.1459	1.0194
1.22	0.9749	0.7783	0.9015	1.1584	1.0235
1.24	0.9709	0.7613	0.8911	1.1705	1.0279
1.26	0.9668	0.7447	0.8805	1.1823	1.0328
1.28	0.9624	0.7287	0.8699	1.1938	1.0380
1.3	0.9580	0.7130	0.8592	1.2050	1.0437
1.32	0.9534	0.6978	0.8484	1.2159	1.0497
1.34	0.9487	0.6830	0.8377	1.2264	1.0561
1.36	0.9440	0.6686	0.8269	1.2367	1.0629
1.38	0.9391	0.6546	0.8161	1.2467	1.0701
1.4	0.9343	0.6410	0.8054	1.2564	1.0777
1.42	0.9293	0.6278	0.7947	1.2659	1.0856
1.44	0.9243	0.6149	0.7840	1.2751	1.0940
1.46	0.9193	0.6024	0.7735	1.2840	1.1028
1.48	0.9143	0.5902	0.7629	1.2927	1.1120
1.5	0.9093	0.5783	0.7525	1.3012	1.1215
1.52	0.9042	0.5668	0.7422	1.3095	1.1315
1.54	0.8992	0.5555	0.7319	1.3175	1.1419
1.56	0.8942	0.5446	0.7217	1.3253	1.1527
1.58	0.8892	0.5339	0.7117	1.3329	1.1640
1.6	0.8842	0.5236	0.7017	1.3403	1.1756
1.62	0.8792	0.5135	0.6919	1.3475	1.1877
1.64	0.8743	0.5036	0.6822	1.3546	1.2002
1.66	0.8694	0.4940	0.6726	1.3614	1.2131
1.68	0.8645	0.4847	0.6631	1.3681	1.2264
1.7	0.8597	0.4756	0.6538	1.3746	1.2402
1.72	0.8549	0.4668	0.6445	1.3809	1.2545
1.74	0.8502	0.4581	0.6355	1.3870	1.2692
1.76	0.8455	0.4497	0.6265	1.3931	1.2843
1.78	0.8409	0.4415	0.6176	1.3989	1.2999

TABLE A-25 (*Cont.*)

N_M	T_0/T_0^*	p/p^*	T/T^*	$\rho^*/\rho = V/V^*$	p_0/p_0^*
1.8	0.8363	0.4335	0.6089	1.4046	1.3159
1.82	0.8317	0.4257	0.6004	1.4102	1.3324
1.84	0.8273	0.4181	0.5919	1.4156	1.3494
1.86	0.8228	0.4107	0.5836	1.4209	1.3669
1.88	0.8185	0.4035	0.5754	1.4261	1.3849
1.9	0.8141	0.3964	0.5673	1.4311	1.4033
1.92	0.8099	0.3895	0.5594	1.4360	1.4222
1.94	0.8057	0.3828	0.5516	1.4408	1.4417
1.96	0.8015	0.3763	0.5439	1.4455	1.4616
1.98	0.7974	0.3699	0.5364	1.4501	1.4821
2.0	0.7934	0.3636	0.5289	1.4545	1.5031
2.02	0.7894	0.3575	0.5216	1.4589	1.5246
2.04	0.7855	0.3516	0.5144	1.4632	1.5467
2.06	0.7816	0.3458	0.5074	1.4673	1.5693
2.08	0.7778	0.3401	0.5004	1.4714	1.5924
2.1	0.7741	0.3345	0.4936	1.4753	1.6162
2.12	0.7704	0.3291	0.4868	1.4792	1.6404
2.14	0.7667	0.3238	0.4802	1.4830	1.6653
2.16	0.7631	0.3186	0.4737	1.4867	1.6908
2.18	0.7596	0.3136	0.4673	1.4903	1.7168
2.2	0.7561	0.3086	0.4611	1.4938	1.7434
2.22	0.7527	0.3038	0.4549	1.4973	1.7707
2.24	0.7493	0.2991	0.4488	1.5007	1.7986
2.26	0.7460	0.2945	0.4428	1.5040	1.8271
2.28	0.7428	0.2899	0.4370	1.5072	1.8562
2.3	0.7395	0.2855	0.4312	1.5104	1.8860
2.32	0.7364	0.2812	0.4256	1.5134	1.9165
2.34	0.7333	0.2769	0.4200	1.5165	1.9476
2.36	0.7302	0.2728	0.4145	1.5194	1.9794
2.38	0.7272	0.2688	0.4091	1.5223	2.0119
2.4	0.7242	0.2648	0.4038	1.5252	2.0451
2.42	0.7213	0.2609	0.3986	1.5279	2.0789
2.44	0.7184	0.2571	0.3935	1.5306	2.1136
2.46	0.7156	0.2534	0.3885	1.5333	2.1489
2.48	0.7128	0.2497	0.3836	1.5359	2.1850
2.5	0.7101	0.2462	0.3787	1.5385	2.2218
2.52	0.7074	0.2427	0.3739	1.5410	2.2594
2.54	0.7047	0.2392	0.3692	1.5434	2.2978
2.56	0.7021	0.2359	0.3646	1.5458	2.3370
2.58	0.6995	0.2326	0.3601	1.5482	2.3770
2.6	0.6970	0.2294	0.3556	1.5505	2.4177
2.62	0.6945	0.2262	0.3512	1.5527	2.4593
2.64	0.6921	0.2231	0.3469	1.5549	2.5018
2.66	0.6896	0.2201	0.3427	1.5571	2.5451
2.68	0.6873	0.2171	0.3385	1.5592	2.5892

TABLE A-25 (*Cont.*) **Frictionless duct flow with heat transfer for $\gamma = 1.4$**

N_M	T_0/T_0^*	p/p^*	T/T^*	$\rho^*/\rho = V/V^*$	p_0/p_0^*
2.7	0.6849	0.2142	0.3344	1.5613	2.6343
2.72	0.6826	0.2113	0.3304	1.5634	2.6802
2.74	0.6804	0.2085	0.3264	1.5654	2.7270
2.76	0.6781	0.2058	0.3225	1.5673	2.7748
2.78	0.6760	0.2030	0.3186	1.5693	2.8235
2.8	0.6738	0.2004	0.3149	1.5711	2.8731
2.82	0.6717	0.1978	0.3111	1.5730	2.9237
2.84	0.6696	0.1953	0.3075	1.5748	2.9752
2.86	0.6675	0.1927	0.3039	1.5766	3.0278
2.88	0.6655	0.1903	0.3004	1.5784	3.0813
2.9	0.6635	0.1879	0.2969	1.5801	3.1359
2.92	0.6615	0.1855	0.2934	1.5818	3.1914
2.94	0.6596	0.1832	0.2901	1.5834	3.2481
2.96	0.6577	0.1809	0.2868	1.5851	3.3058
2.98	0.6558	0.1787	0.2835	1.5867	3.3646
3.0	0.6540	0.1765	0.2803	1.5882	3.4245
3.02	0.6522	0.1743	0.2771	1.5898	3.4854
3.04	0.6504	0.1722	0.2740	1.5913	3.5476
3.06	0.6486	0.1701	0.2709	1.5928	3.6108
3.08	0.6469	0.1681	0.2679	1.5942	3.6752
3.1	0.6452	0.1660	0.2650	1.5957	3.7408
3.12	0.6435	0.1641	0.2620	1.5971	3.8076
3.14	0.6418	0.1621	0.2592	1.5985	3.8756
3.16	0.6402	0.1602	0.2563	1.5998	3.9449
3.18	0.6386	0.1583	0.2535	1.6012	4.0154
3.2	0.6370	0.1565	0.2508	1.6025	4.0871
3.22	0.6354	0.1547	0.2481	1.6038	4.1602
3.24	0.6339	0.1529	0.2454	1.6051	4.2345
3.26	0.6324	0.1511	0.2428	1.6063	4.3101
3.28	0.6309	0.1494	0.2402	1.6076	4.3871
3.3	0.6294	0.1477	0.2377	1.6088	4.4655
3.32	0.6280	0.1461	0.2352	1.6100	4.5452
3.34	0.6265	0.1444	0.2327	1.6111	4.6263

TABLE A-25 (*Cont.*)

N_M	T_0/T_0^*	p/p^*	T/T^*	$\rho^*/\rho = V/V^*$	p_0/p_0^*
3.36	0.6251	0.1428	0.2303	1.6123	4.7089
3.38	0.6237	0.1412	0.2279	1.6134	4.7929
3.4	0.6224	0.1397	0.2255	1.6145	4.8783
3.42	0.6210	0.1381	0.2232	1.6156	4.9652
3.44	0.6197	0.1366	0.2209	1.6167	5.0536
3.46	0.6184	0.1351	0.2186	1.6178	5.1435
3.48	0.6171	0.1337	0.2164	1.6188	5.2350
3.5	0.6158	0.1322	0.2142	1.6198	5.3280
3.52	0.6145	0.1308	0.2120	1.6208	5.4226
3.54	0.6133	0.1294	0.2099	1.6218	5.5188
3.56	0.6121	0.1280	0.2078	1.6228	5.6167
3.58	0.6109	0.1267	0.2057	1.6238	5.7162
3.6	0.6097	0.1254	0.2037	1.6247	5.8173
3.62	0.6085	0.1241	0.2017	1.6257	5.9201
3.64	0.6074	0.1228	0.1997	1.6266	6.0247
3.66	0.6062	0.1215	0.1977	1.6275	6.1310
3.68	0.6051	0.1202	0.1958	1.6284	6.2390
3.7	0.6040	0.1190	0.1939	1.6293	6.3488
3.72	0.6029	0.1178	0.1920	1.6301	6.4605
3.74	0.6018	0.1166	0.1902	1.6310	6.5739
3.76	0.6008	0.1154	0.1884	1.6318	6.6893
3.78	0.5997	0.1143	0.1866	1.6327	6.8065
3.8	0.5987	0.1131	0.1848	1.6335	6.9256
3.82	0.5977	0.1120	0.1830	1.6343	7.0466
3.84	0.5967	0.1109	0.1813	1.6351	7.1696
3.86	0.5957	0.1098	0.1796	1.6359	7.2945
3.88	0.5947	0.1087	0.1779	1.6366	7.4215
3.9	0.5937	0.1077	0.1763	1.6374	7.5505
3.92	0.5928	0.1066	0.1746	1.6381	7.6816
3.94	0.5918	0.1056	0.1730	1.6389	7.8147
3.96	0.5909	0.1046	0.1714	1.6396	7.9499
3.98	0.5900	0.1036	0.1699	1.6403	8.0873
4.0	0.5891	0.1026	0.1683	1.6410	8.2269

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Note: Numbers following index entries refer to *problem numbers*, not page numbers.

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