TABLE 3.1 Roughness Heights, e, for Certain Common Pipe Materials

Pipe Material	e (mm)	e (ft)
Brass	0.0015	0.000005
Concrete		
Steel forms, smooth	0.18	0.0006
Good joints, average	0.36	0.0012
Rough, visible form marks	0.60	0.002
Copper	0.0015	0.000005
Corrugated metal (CMP)	45	0.15
Iron (common in older water lines, except ductile or DIP, which is widely used today)		
Asphalt lined	0.12	0.0004
Cast	0.26	0.00085
Ductile; DIP—cement mortar lined	0.12	0.0004
Galvanized	0.15	0.0005
Wrought	0.045	0.00015
Polyvinyl chloride (PVC)	0.0015	0.000005
Polyethylene, high density (HDPE)	0.0015	0.000005
Steel		
Enamel coated	0.0048	0.000016
Riveted	0.9 ~ 9.0	0.003–0.03
Seamless	0.004	0.000013
Commercial	0.045	0.00015

NOTE: $ln(u) = 2.3026 log(u)$

JAIN EQUATION

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon/D}{3.7} + 5.74\,\mathrm{Re}^{-0.9}\right) \implies f = \frac{1.325}{\left\{\ln\left(\frac{\varepsilon/D}{3.7} + 5.74\,\mathrm{Re}^{-0.9}\right)\right\}^2}$$

(Use if $5000 < \mathrm{Re} < 10^8$; $10^{-6} < \varepsilon/D < 10^{-2}$)

HAALAND EQUATION

$$\frac{1}{\sqrt{f}} = -1.8\log\left[\left(\frac{\varepsilon/D}{3.7}\right)^{1.11} + \frac{6.9}{\mathrm{Re}}\right] \qquad (4000 < \mathrm{Re} < 10^8)$$

SWAMEE-JAIN EQUATIONS

$$h_f = 1.07\frac{Q^2L}{gD^5}\left\{\ln\left[\frac{\varepsilon/D}{3.7} + 4.62\left(\frac{\nu D}{Q}\right)^{0.9}\right]\right\}^{-2}$$

$$Q = -0.965\sqrt{\frac{gD^5h_f}{L}}\,\ln\left[\frac{\varepsilon/D}{3.7} + \left(\frac{3.17\nu^2L}{gD^3h_f}\right)^{1/2}\right]$$

TABLE 1.3 Viscosities of Water and Air

	Water		Air	
Temperature (°C)	Viscosity (μ) N·sec/m²	Kinematic Viscosity (ν) m²/sec	Viscosity (μ) N·sec/m²	Kinematic Viscosity (ν) m²/sec
0	1.781×10^{-3}	1.785×10^{-6}	1.717×10^{-5}	1.329×10^{-5}
5	1.518×10^{-3}	1.519×10^{-6}	1.741×10^{-5}	1.371×10^{-5}
10	1.307×10^{-3}	1.306×10^{-6}	1.767×10^{-5}	1.417×10^{-5}
15	1.139×10^{-3}	1.139×10^{-6}	1.793×10^{-5}	1.463×10^{-5}
20	1.002×10^{-3}	1.003×10^{-6}	1.817×10^{-5}	1.509×10^{-5}
25	0.890×10^{-3}	0.893×10^{-6}	1.840×10^{-5}	1.555×10^{-5}
30	0.798×10^{-3}	0.800×10^{-6}	1.864×10^{-5}	1.601×10^{-5}
40	0.653×10^{-3}	0.658×10^{-6}	1.910×10^{-5}	1.695×10^{-5}
50	0.547×10^{-3}	0.553×10^{-6}	1.954×10^{-5}	1.794×10^{-5}
60	0.466×10^{-3}	0.474×10^{-6}	2.001×10^{-5}	1.886×10^{-5}
70	0.404×10^{-3}	0.413×10^{-6}	2.044×10^{-5}	1.986×10^{-5}
80	0.354×10^{-3}	0.364×10^{-6}	2.088×10^{-5}	2.087×10^{-5}
90	0.315×10^{-3}	0.326×10^{-6}	2.131×10^{-5}	2.193×10^{-5}
100	0.282×10^{-3}	0.294×10^{-6}	2.174×10^{-5}	2.302×10^{-5}

TABLE 1.2 Density and Specific Weight of Water

Temperature (°C)	Density (ρ, kg/m³)	Specific Weight (γ, N/m³)
0° (ice)	917	8,996
0° (water)	999	9,800
4°	1,000	9,810
10°	999	9,800
20°	998	9,790
30°	996	9,771
40°	992	9,732
50°	988	9,692
60°	983	9,643
70°	978	9,594
80°	972	9,535
90°	965	9,467
100°	958	9,398

TABLE 3.6 Values of K_v for Common Hydraulic Valves

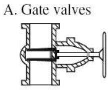
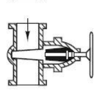
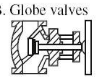
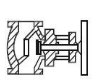
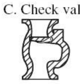
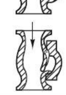
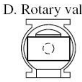
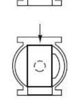
A. Gate valves		
	Closed	$K_v = 0.15$ (fully open)
	Open	
B. Globe valves		
	Closed	$K_v = 10.0$ (fully open)
	Open	
C. Check valves		
	Closed Hinge (swing type)	Swing type: $K_v = 2.5$ (fully open) Ball type: $K_v = 70.0$ (fully open) Lift type: $K_v = 12.0$ (fully open)
	Open	
D. Rotary valves		
	Closed	$K_v = 10.0$ (fully open)
	Open	

TABLE 3.2 Hazen-Williams Coefficient, C_{HW}, for Different Types of Pipes

Pipe Materials	C_{HW}
Brass	130–140
Cast iron (common in older water lines)	
New, unlined	130
10-year-old	107–113
20-year-old	89–100
30-year-old	75–90
40-year-old	64–83
Concrete or concrete lined	
Smooth	140
Average	120
Rough	100
Copper	130–140
Ductile iron (cement mortar lined)	140
Glass	140
High-density polyethylene (HDPE)	150
Plastic	130–150
Polyvinyl chloride (PVC)	150
Steel	
Commercial	140–150
Riveted	90–110
Welded (seamless)	100
Vitrified clay	110

TABLE 3.3 Manning's Roughness Coefficient, *n*, for Pipe Flows

Type of Pipe	Manning's *n*	
	Min.	Max.
Brass	0.009	0.013
Cast iron	0.011	0.015
Cement mortar surfaces	0.011	0.015
Cement rubble surfaces	0.017	0.030
Clay drainage tile	0.011	0.017
Concrete, precast	0.011	0.015
Copper	0.009	0.013
Corrugated metal (CMP)	0.020	0.024
Ductile iron (cement mortar lined)	0.011	0.013
Glass	0.009	0.013
High-density polyethylene (HDPE)	0.009	0.011
Polyvinyl chloride (PVC)	0.009	0.011
Steel, commercial	0.010	0.012
Steel, riveted	0.017	0.020
Vitrified sewer pipe	0.010	0.017
Wrought iron	0.012	0.017

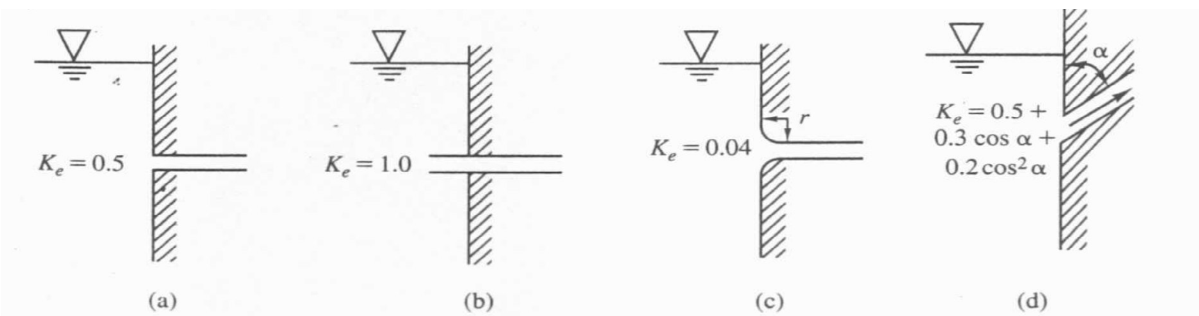


Figure 3.12 Coefficient K_e for pipe entrances

Darcy-Weisbach Equation

Hf = $\frac{fLV^2}{2gD}$ R= $\frac{fL}{2gDA^2}$

$$DQ = \frac{-\sum HL}{2\sum (HL/Q)}$$

Hazen Williams Equation

Q= $BCA(Rh)^{0.63} S^{0.54}$

B= 1.318 in British System, B= 0.85 in SI

R= $\left[\frac{L}{C^{1.85} D^{4.87}} x \frac{7.88}{B^{1.85}}\right]$

$$DQ = \frac{-\sum HL}{1.85\sum (HL/Q)}$$

Manning's Equation

Q= $\frac{AB}{n}(Rh)^{2/3} S^{1/2}$,

B=1 in SI, B=1.49 in British Systems

R= $\left[\frac{10.29}{B^2} x \frac{L.n^2}{D^{5.33}}\right]$

$$DQ = \frac{-\sum HL}{2\sum (HL/Q)}$$

$Re\ (Nr) = \frac{V.D}{\nu}$, 1meter=39.37in

$\frac{1}{\sqrt{f}} = 2.\log\left(3.7\frac{D}{\varepsilon}\right)$ if 0.08 ε < δ <1.7 ε

TABLE 3.5 Values of the Coefficient K_c for Sudden Contraction

Velocity in Smaller Pipe (m/sec)	Sudden Contraction Coefficients, K_c (Ratio of Smaller to Larger Pipe Diameters, D_2/D_1)									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	0.49	0.49	0.48	0.45	0.42	0.38	0.28	0.18	0.07	0.03
2	0.48	0.48	0.47	0.44	0.41	0.37	0.28	0.18	0.09	0.04
3	0.47	0.46	0.45	0.43	0.40	0.36	0.28	0.18	0.10	0.04
6	0.44	0.43	0.42	0.40	0.37	0.33	0.27	0.19	0.11	0.05
12	0.38	0.36	0.35	0.33	0.31	0.29	0.25	0.20	0.13	0.06

1 m = 3.281 ft 1 cm= 3.937 x10^{-1} in

$Q = CdA_1\sqrt{2g(\frac{\Delta P}{\gamma})}$ $Cd = \frac{1}{\sqrt{(\frac{A1}{A2})^2-1}}$ $Q = CvCdA_1\sqrt{2g(\frac{\Delta P}{\gamma})}$ $yc = \sqrt[3]{\frac{q^2}{g}}$

$$Q = CdA\sqrt{2g(\frac{Po}{\gamma} - \frac{P1}{\gamma})}$$

$Power = \frac{\gamma QH}{efficiency}$ $N_F = \frac{V}{\sqrt{gy}}$

$Q = CLH^{3/2}$ $C = 3.22 + 0.40\frac{H}{P}$ in British Units, $C = 1.78 + 0.22\frac{H}{P}$ in SI units

$Q = 3.33(L - 0.2H)H^{3/2}$ in British Units, $Q = 1.84(L - 0.2H)H^{3/2}$ in SI units

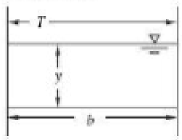
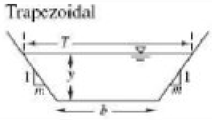
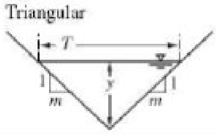
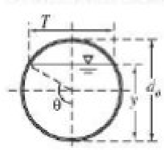
$Q = C(tan\frac{\theta}{2})H^{5/2}$

TABLE 6.3 Characteristics of Water Surface Profile Curves

Channel	Symbol	Type	Slope	Depth	Curve
Mild	M	1	$S_0 > 0$	$y > y_n > y_c$	M-1
Mild	M	2	$S_0 > 0$	$y_n > y > y_c$	M-2
Mild	M	3	$S_0 > 0$	$y_n > y_c > y$	M-3
Critical	C	1	$S_0 > 0$	$y > y_n = y_c$	C-1
Critical	C	3	$S_0 > 0$	$y_n = y_c > y$	C-3
Steep	S	1	$S_0 > 0$	$y > y_c > y_n$	S-1
Steep	S	2	$S_0 > 0$	$y_c > y > y_n$	S-2
Steep	S	3	$S_0 > 0$	$y_c > y_n > y$	S-3
Horizontal	H	2	$S_0 = 0$	$y > y_c$	H-2
Horizontal	H	3	$S_0 = 0$	$y_c > y$	H-3
Adverse	A	2	$S_0 < 0$	$y > y_c$	A-2
Adverse	A	3	$S_0 < 0$	$y_c > y$	A-3

Table 6.1 **Cross-Sectional Relationships for Open-Channel Flow**

TABLE 6.1 Cross-Sectional Relationships for Open-Channel Flow

Section Type	Area (A)	Wetted perimeter (P)	Hydraulic Radius (R_h)	Top Width (T)	Hydraulic Depth (D)
Rectangular 	by	$b + 2y$	$\frac{by}{b + 2y}$	b	y
Trapezoidal 	$(b + my)y$	$b + 2y\sqrt{1 + m^2}$	$\frac{(b + my)y}{b + 2y\sqrt{1 + m^2}}$	$b + 2my$	$\frac{(b + my)y}{b + 2my}$
Triangular 	my^2	$2y\sqrt{1 + m^2}$	$\frac{my}{2\sqrt{1 + m^2}}$	$2my$	$\frac{y}{2}$
Circular (θ is in radians) 	$\frac{1}{8}(2\theta - \sin 2\theta)d_0^2$	θd_0	$\frac{1}{4}\left(1 - \frac{\sin 2\theta}{2\theta}\right)d_0$	$(\sin\theta)d_0$ or $2\sqrt{y(d_0 - y)}$	$\frac{1}{8}\left(\frac{2\theta - \sin 2\theta}{\sin\theta}\right)d_0$

Source: V. T. Chow, *Open Channel Hydraulics* (New York: McGraw-Hill, 1959).