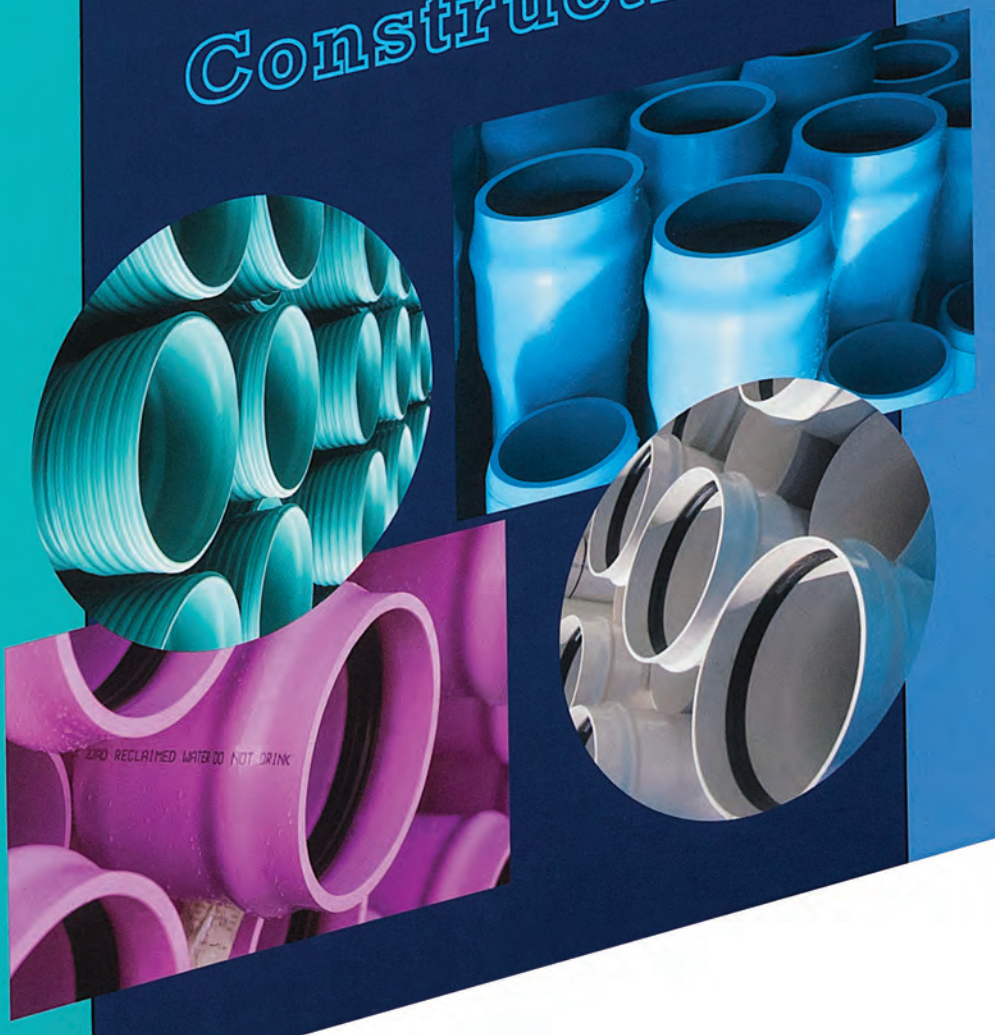
PVCPIPE association

FIFTH EDITION

Handbook of PVC Pipe Design and Construction



PVCPIPE association

FIFTH EDITION
Handbook of PVC
Pipe Design and Construction

CHAPTER 9

Hydraulics

Introduction to Hydraulics

•

Flow in PVC Pressure Pipes

•

Flow in PVC Nonpressure Pipe

Table of Contents

9.1 Notation

A = cross-sectional area of flow, ft^2

A_c = cross-sectional area of circle, $in.^2$

A_s = cross-sectional area of ellipse, $in.^2$

a = deflected pipe long semi-axis, in.

b = deflected pipe short semi-axis, in.

C = Hazen–Williams flow coefficient, dimensionless

d_i = pipe inside diameter, in.

D = pipe inside diameter, ft

D_i = pipe inside diameter, in.

f = friction loss, ft of H_2O/100 ft

f_D = Darcy friction factor, dimensionless

g = acceleration of gravity, ft/s^2

h_f = head loss, ft of H_2O

H = head loss, ft of H_2O/1,000 ft

H_1 = upstream pipe elevation, ft

H_2 = downstream pipe elevation, ft

ID = inside pipe diameter, in.

L = pipe length, ft

n = coefficient of roughness (Manning's equation and Kutter's formula), dimensionless

P_w = wetted perimeter, ft

P_1 = maximum pressure, psi

P_2 = minimum pressure, psi

Q or MGD = flow rate, gpm or ft^3/s or gpd

R_e = Reynolds number, dimensionless

R_H = hydraulic radius, ft

r_i = pipe inside radius, in.

S = hydraulic slope, ft/ft (pressure pipe)

s = hydraulic slope, ft/ft (non-pressure pipe)

S_E = slope of energy grade line, ft/ft

t = pipe wall thickness, in.

V = mean flow velocity, ft/s

ε = equivalent roughness, in. or ft (to match units of pipe inside diameter)

ν = kinematic viscosity of a fluid, ft^2/s

ΔX = horizontal pipe deflection, in.

ΔY = vertical pipe deflection, in.

9.2 Introduction to Hydraulics

9.2.1 Flow Theories and Equations

Many empirical formulas have been developed for solving the variety of problems related to flow in pipes. Equations developed by hydraulic engineers are used daily in the solution of problems encountered by water and sewer engineers. Relatively few specific problems in pipe hydraulics, such as laminar flow, can be solved entirely theoretically by mathematical means; rather, solutions to a majority of flow problems depend to some degree on experimentally determined coefficients. Thus, commonly used flow formulas have been developed through research by (among others) Fanning, Darcy, Chezy, Kutter, Scobey, Manning, Weisbach, Hazen, and Williams.

9.2.2 Hydraulic Radius

The *hydraulic radius* is used for hydraulic calculations for both pressure and nonpressure pipe. The hydraulic radius is obtained by dividing the cross-sectional area of the flow by the wetted perimeter of the pipe (i.e., the perimeter along which the flow is in contact with the pipe walls). The value of the hydraulic radius varies with the level of flow.

For the pressure pipe portion of this chapter, pipes will be assumed to be flowing full. For the nonpressure portion, pipes will be assumed to be flowing either full or half-full.

Equation 9.1

$$R_H = \frac{A}{P_w}$$

where:

R_H = hydraulic radius, ft

A = cross-sectional area of flow, ft^2

P_w = wetted perimeter of flow area, ft

For pipe flowing full,

$$A = \pi D_i^2/4$$
$$P_w = \pi D_i$$

where:

D_i = pipe inside diameter, ft

The hydraulic radius

$$R_H = \frac{A}{P_w} = \frac{\frac{\pi D_i^2}{4}}{\pi D_i} = \frac{D_i}{4}.$$

For pipe flowing half-full, both A and P_w are thus divided by 2, so $A = {}^1/_2\ (\pi\ D_i^2/4)$ and $P_w = {}^1/_2\ (\pi\ D_i)$.

Thus, hydraulic radius is given by:

$$R_H = \frac{A}{P_w} = \frac{\frac{1}{2}\pi\frac{D_i^2}{4}}{\frac{1}{2}\pi\ D_i} = \frac{D_i}{4}.$$

Therefore, for the design of all pressure pipe and nonpressure pipe, the hydraulic radius = $D_i/4$.

9.3 Flow in PVC Pressure Pipe

Hydraulic flow research and analysis has established that flow conditions in PVC pressure piping systems can be designed conservatively using the *Hazen–Williams* equation. Flow conditions also can be designed with more detailed analysis through the *Darcy–Weisbach* equation. These two formulas are covered in the next sections.

9.3.1 Hazen–Williams Flow Formula

The Hazen–Williams flow formula is most widely used in the calculation of pressure pipe conditions. Various forms of Hazen–Williams are given in Equations 9.2 through

9.9. Equations 9.2 through 9.5 are generic, while Equations 9.6 through 9.9 are specific to PVC pipe.

Equation 9.2

$$V = 1.318\,C R_H^{0.63} S^{0.54}$$

where:

V = mean flow velocity, ft/s
C = Hazen–Williams flow coefficient, dimensionless
S = hydraulic slope, ft/ft

Equation 9.3

$$Q = 0.442\,C D_i^{2.63} \left(\frac{P_1 - P_2}{L}\right)^{0.54}$$

where:

Q = flow rate, gpm
L = pipe length, ft
P_1 = maximum pressure, psi
P_2 = minimum pressure, psi

Equation 9.4

$$Q = 0.006756\,C D_i^{2.63}\, H^{0.54}$$

where:

H = head loss, ft of H_2O/1,000 ft

Friction loss (f) in hydraulic flow is derived through the following expression of the Hazen–Williams equation:

Equation 9.5

$$f = 0.2083\left(\frac{100}{C}\right)^{1.85} \frac{Q^{1.85}}{D_i^{4.86}}$$

where:

f = friction loss, ft of H_2O/100 ft

PVC pipe flow coefficients were discovered through the research and analysis of various individuals, including Neale, Price, Jeppson, and Bishop. The Hazen–Williams flow coefficient (or "C Factor") is commonly calculated as a range of values from 155 to 165 for both new and used PVC pipe. The coefficient has been established, conservatively, at C = 150 for gasketed PVC piping system design. Research has also established that the internal bead formed from the butt-fusion of PVC is adequately addressed with a C Factor of 150.

With C established at 150 for PVC pipe, Equations 9.2 through 9.5 can be simplified for PVC piping system design:

Equation 9.6

$$V = 197.7 R_H^{0.63} S^{0.54}$$

Equation 9.7

$$Q = 66.3 D_i^{2.63} \left(\frac{P_1 - P_2}{L} \right)^{0.54}$$

Equation 9.8

$$Q = 1.0134 D_i^{2.63} H^{0.54}$$

Equation 9.9

$$f = 0.0984 \frac{Q^{1.85}}{D_i^{4.86}}$$

Nomographs for solving flow characteristics are provided in Figs. 9.1 and 9.2; Table 9.1 shows some of these data in tabular form. Additionally, Tables 9.3, 9.4, and 9.5 were developed based on the Hazen–Williams formula with C Factor of 150 to provide flow capacity (gpm), friction loss (ft of H_2O/100 ft), and flow velocity (ft/s) for PVC pressure pipe products.

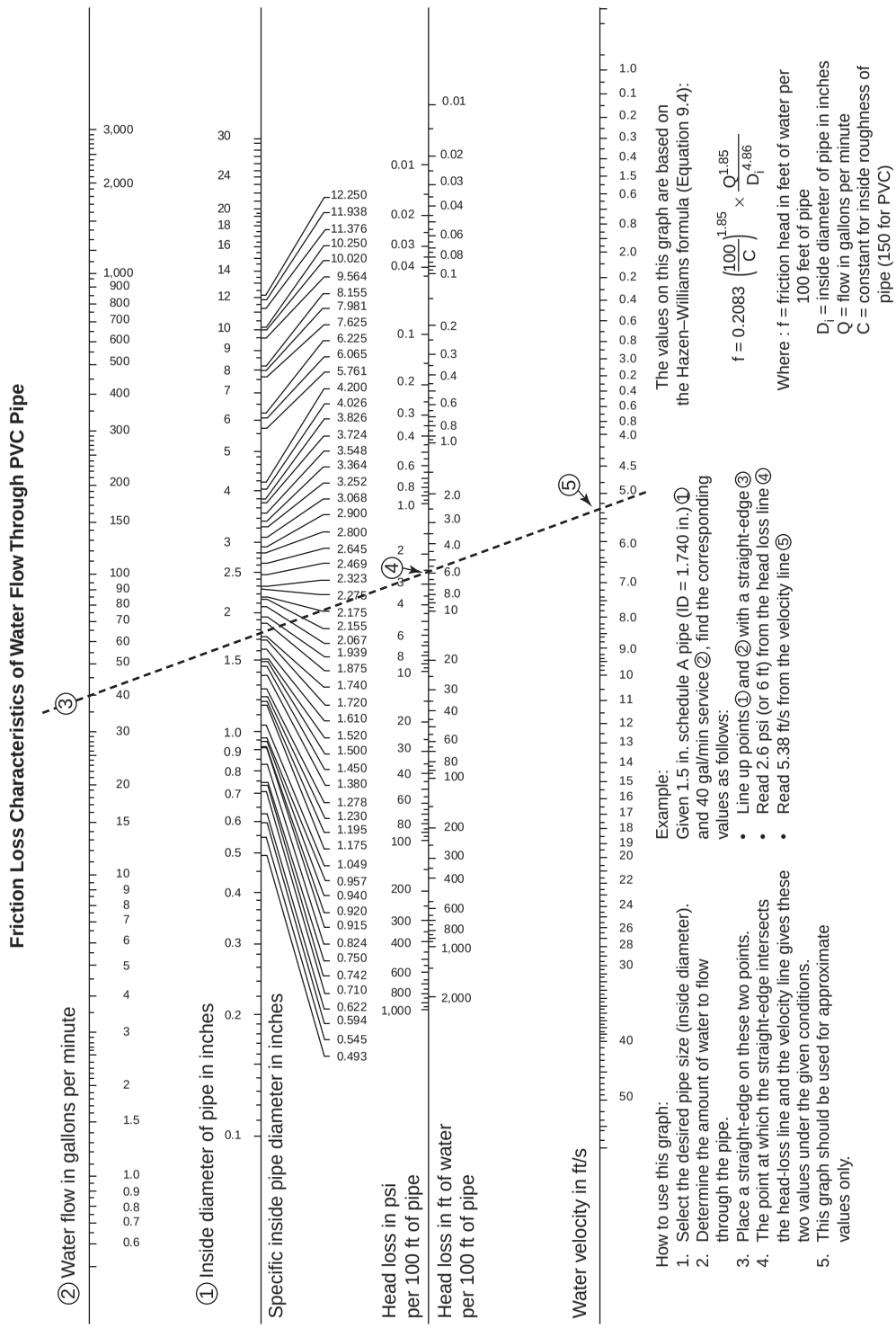
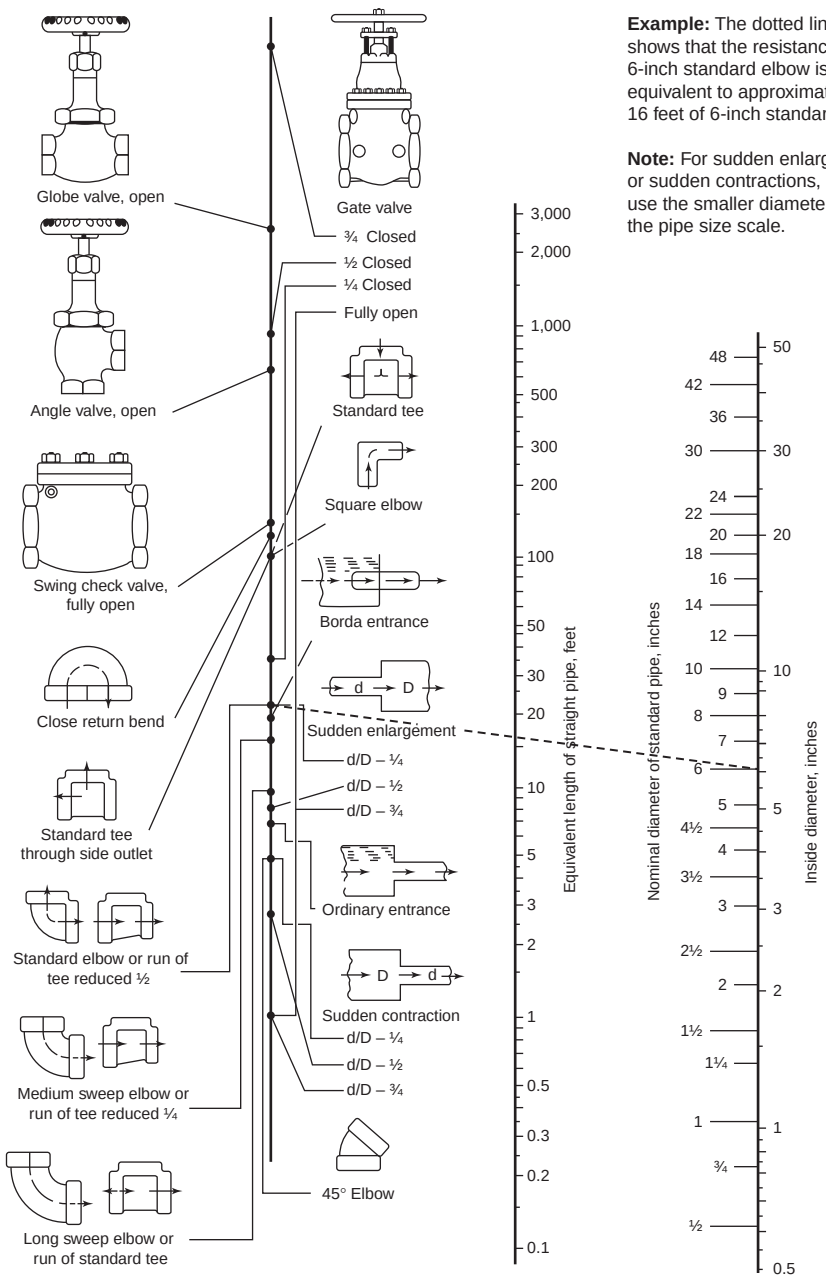


Fig. 9.1 Friction loss characteristics of water flow through PVC pipe.



Notes:
1. Head loss through check valves varies with type manufactured; consult manufacturer for correct values.
2. Data in above chart are satisfactory for most applications; for more detailed information consult fittings manufacturer.

Fig. 9.2 Resistance of valves and fittings to flow of fluids.

Table 9.1 Friction loss of water in pipe fittings in terms of equivalent length (L), feet of straight pipe

Pipe size, in.	Approx inside diam, in.	Friction factor	Gate Valve --- full open	90° Elbow	Long radius 90° or 45° std elbow	Std tee --- thru flow	Std tee --- branch flow	Close return bend	Swing check valve --- Full open	Angle valve --- Full open	Globe valve --- Full open	Butterfly valve	90° welding elbow		Miter bend	
													r/d = 1	r/d = 2	45°	90°
0.5	0.622	0.027	0.41	1.55	0.83	1.04	3.11	2.59	5.18	7.78	17.6					
0.75	0.824	0.025	0.55	2.06	1.10	1.37	4.12	3.43	6.86	10.3	23.3					
1	1.049	0.023	0.70	2.62	1.40	1.75	5.25	4.37	8.74	13.1	29.7	–	–	–	–	–
1.25	1.380	0.022	0.92	3.45	1.84	2.30	6.90	5.75	11.5	17.3	39.1					
1.5	1.610	0.021	1.07	4.03	2.15	2.68	8.05	6.71	13.4	20.1	45.6					
2	2.067	0.019	1.38	5.17	2.76	3.45	10.3	8.61	17.2	25.8	58.6	7.75	3.45	2.07	2.58	10.3
2.5	2.469	0.018	1.65	6.17	3.29	4.12	12.3	10.3	20.6	30.9	70.0	9.26	4.12	2.47	3.08	12.3
3	3.068	0.018	2.04	7.67	4.09	5.11	15.3	12.8	25.5	38.4	86.9	11.5	5.11	3.07	3.84	15.3
4	4.026	0.017	2.68	10.1	5.37	6.71	20.1	16.8	33.6	50.3	114	15.1	6.71	4.03	5.03	20.1
5	5.047	0.016	3.36	12.6	6.73	8.41	25.2	21.0	42.1	63.1	143	18.9	8.41	5.05	6.31	25.2
6	6.065	0.015	4.04	15.2	8.09	10.1	30.3	25.3	50.5	75.8	172	22.7	10.1	6.07	7.58	30.3
8	7.981	0.014	5.32	20.0	10.6	13.3	39.9	33.3	33.3	99.8	226	29.9	13.3	7.98	9.98	39.9
10	10.02	0.014	6.68	25.1	13.4	16.7	50.1	41.8	41.8	125	284	29.2	16.7	10.0	12.5	50.1
12	11.938	0.013	7.96	29.8	15.9	19.9	59.7	49.7	49.7	149	338	34.8	19.9	11.9	14.9	59.7
14	13.124	0.013	8.75	32.8	17.5	21.8	65.6	54.7	54.7	164	372	38.3	21.8	13.1	16.4	65.6
16	15.00	0.013	10.0	37.5	20.0	25.0	75.0	62.5	62.5	188	425	31.3	25.0	15.0	18.8	75.0
18	16.876	0.012	16.9	42.2	22.5	28.1	84.4	70.3	70.3	210	478	35.2	28.1	16.9	21.1	84.4
20	18.814	0.012	12.5	47.0	25.1	31.4	94.1	78.4	78.4	235	533	39.2	31.4	18.8	23.5	94.1
24	22.628	0.012	15.1	56.6	30.2	37.7	113	94.3	94.3	283	641	47.1	37.7	22.6	28.3	113
30	28	0.011	18.7	70	37.3	46.7	140	117	–	–	–	–	46.7	28	35	140
36	34	0.011	22.7	85	45.3	56.7	170	142					56.7	34	43	170
42	40	0.010	26.7	100	53.3	66.7	200	167	–	–	–	–	66.7	40	50	200
48	46	0.010	30.7	115	61.3	76.7	230	192					76.7	46	58	230
L/D			8	30	16	20	60	50	0.5 to 6 = 100 28 to 48 = 50	150	340	–	20	12	15	60

Calculated from data in Crane Co. – Technical Paper 410. $K = f\frac{L}{D}$, $f = \frac{KD}{L}$, $L = \frac{KD}{f}$, where D is inside pipe diameter in feet.

9.3.2 Darcy–Weisbach Formula

In hydraulic design of PVC pressure water pipe, conditions are defined relative to pipe roughness ε/D_i, where ε is the equivalent roughness; and Reynolds number $R_e = VD/\nu$, where ν is the kinematic viscosity of the fluid. For water at 70 °F and at atmospheric pressure, kinematic viscosity is 1.052×10^{-5} ft^2/s. In this case, the Darcy–Weisbach formula provides a sound design basis. The most commonly used Darcy–Weisbach formula is given next:

Equation 9.10

$$h_f = f_D \frac{LV^2}{D\,2g}$$

where:

h_f = head loss, ft of H_2O
f_D = Darcy-Weisbach friction factor, dimensionless
L = pipe length, ft
D = pipe inside diameter, ft
V = mean flow velocity, ft/s
g = acceleration of gravity, 32.2 ft/s^2

Investigation and analysis by Neale and Jeppson established that the friction factor (f_D) for PVC pipe can be given as in the following equation for hydraulically smooth flow:

Equation 9.11

$$\frac{1}{\sqrt{f_D}} = 2\log\left(R_e\sqrt{f_D}\right) - 0.8$$

where:

R_e = Reynolds number, dimensionless

Calculations of friction factor f_D are obviously tedious. In common practice, the factor is found by referencing the Moody diagram (Fig. 9.4)), using equivalent roughness values from Table 9.2. Equation 9.12 gives the relationship between relative roughness ε/D_i and friction factor f_D:

Fig. 9.3 12-in. molded PVC fitting.

Equation 9.12

$$\frac{1}{\sqrt{f_D}} = 1.14 - 2\log\left(\frac{\varepsilon}{D_i} + \frac{9.35}{R_e\sqrt{f_D}}\right) \text{ for } R_e > 4{,}000$$

where:

ε = equivalent roughness, in.

At velocities above 5 ft/s (1.5 m/s), special consideration should be given to surge pressures that could damage system components. It should also be noted that high fluid velocity results in high head loss.

Table 9.2 Equivalent roughness (ε) for pipe products.

Material	ε	
	in.	cm
Concrete	0.01 to 0.1	0.02 to 0.2
Cast iron	0.0102	0.026
Galvanized iron	0.006	0.015
Asphalted cast iron	0.0048	0.012
Steel or wrought iron	0.0018	0.046
PVC	0.000084	0.00021

Note: The equivalent roughness values (ε) listed above must be divided by pipe inside diameter (D_i), expressed in the same units, to properly utilize the Moody diagram, Figure 9.4.

Source: *Analysis of Flow in Pipe Networks,* R.W. Jeppson, Ann Arbor Science, Ann Arbor, MI.

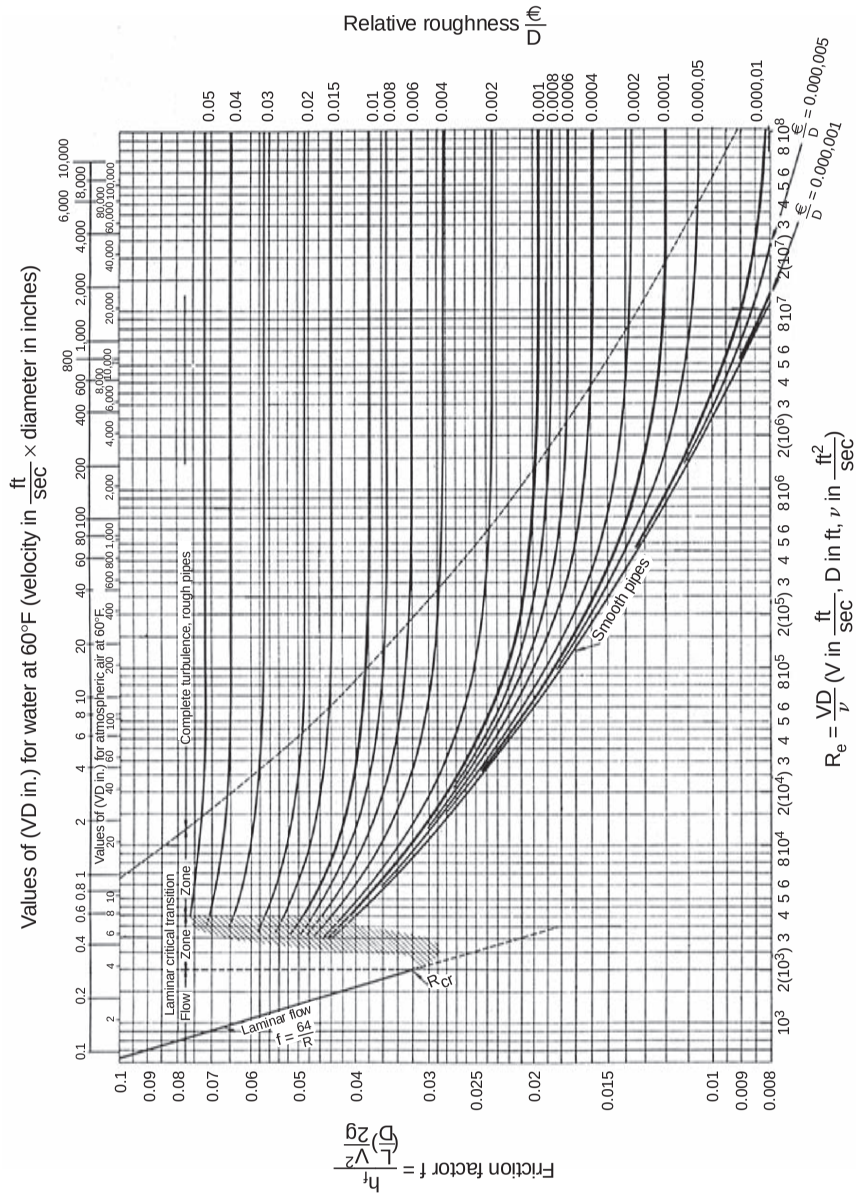


Fig. 9.4 Moody diagram: friction factor. Values of equivalent roughness (ε) for commercial pipes (new).

Source: American Society of Mechanical Engineers, New York, *Tansactions ASME*, Vol. 66 (1944) L. F. Moody.

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe

4 in. CIOD (AWWA C900)									
Flow, gpm	DR 25 Pressure class 165 psi			DR 18 Pressure class 235 psi			DR 14 Pressure class 305 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
25	0.530	0.0286	0.0124	0.571	0.0343	0.0148	0.617	0.0414	0.0179
40	0.849	0.0683	0.0296	0.914	0.0818	0.0354	0.987	0.0987	0.0427
55	1.17	0.123	0.0533	1.26	0.147	0.0638	1.36	0.178	0.0770
70	1.49	0.192	0.0833	1.60	0.230	0.0997	1.73	0.278	0.120
85	1.80	0.275	0.119	1.94	0.330	0.143	2.10	0.398	0.172
100	2.12	0.372	0.161	2.29	0.446	0.193	2.47	0.537	0.233
120	2.55	0.521	0.226	2.74	0.624	0.270	2.96	0.753	0.326
140	2.97	0.693	0.300	3.20	0.830	0.360	3.46	1.00	0.434
160	3.39	0.888	0.384	3.66	1.06	0.460	3.95	1.28	0.555
180	3.82	1.10	0.478	4.11	1.32	0.572	4.44	1.59	0.690
200	4.24	1.34	0.581	4.57	1.61	0.696	4.94	1.94	0.839
225	4.77	1.67	0.722	5.14	2.00	0.865	5.55	2.41	1.04
250	5.30	2.03	0.878	5.71	2.43	1.05	6.17	2.93	1.27
275	5.83	2.42	1.05	6.28	2.90	1.25	6.79	3.49	1.51
300	6.36	2.84	1.23	6.86	3.40	1.47	7.40	4.10	1.78
350	7.43	3.78	1.64	8.00	4.52	1.96	8.64	5.46	2.36
400	8.49	4.84	2.09	9.14	5.79	2.51	9.87	6.99	3.02
450	9.55	6.01	2.60	10.3	7.20	3.12	11.1	8.69	3.76

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

6 in. CIOD (AWWA C900)									
Flow, gpm	DR 25 Pressure class 165 psi			DR 18 Pressure class 235 psi			DR 14 Pressure class 305 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
50	0.513	0.0177	0.00766	0.551	0.0210	0.00911	0.595	0.0254	0.0110
75	0.770	0.0375	0.0162	0.827	0.0445	0.0193	0.893	0.0537	0.0232
100	1.03	0.0638	0.0276	1.10	0.0758	0.0328	1.19	0.0914	0.0396
125	1.28	0.0964	0.0417	1.38	0.115	0.0496	1.49	0.138	0.0598
150	1.54	0.135	0.0585	1.65	0.161	0.0695	1.79	0.194	0.0838
175	1.80	0.180	0.0778	1.93	0.213	0.0924	2.08	0.257	0.111
200	2.05	0.230	0.0996	2.20	0.273	0.118	2.38	0.330	0.143
250	2.57	0.348	0.150	2.76	0.413	0.179	2.98	0.498	0.216
300	3.08	0.487	0.211	3.31	0.579	0.251	3.57	0.698	0.302
350	3.59	0.648	0.280	3.86	0.770	0.333	4.17	0.928	0.402
400	4.11	0.829	0.359	4.41	0.985	0.427	4.76	1.19	0.514
450	4.62	1.03	0.446	4.96	1.23	0.531	5.36	1.48	0.640
500	5.13	1.25	0.543	5.51	1.49	0.645	5.95	1.80	0.777
600	6.16	1.76	0.760	6.61	2.09	0.903	7.14	2.52	1.09
700	7.19	2.33	1.01	7.72	2.77	1.20	8.33	3.35	1.45
800	8.22	2.99	1.29	8.82	3.55	1.54	9.53	4.28	1.85
900	9.24	3.72	1.61	9.92	4.42	1.91	10.7	5.33	2.31
1,000	10.3	4.52	1.96	11.0	5.37	2.32	11.9	6.47	2.80

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

8 in. CIOD (AWWA C900)									
Flow, gpm	DR 25 Pressure class 165 psi			DR 18 Pressure class 235 psi			DR 14 Pressure class 305 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
100	0.596	0.0170	0.00738	0.642	0.0204	0.00883	0.693	0.0246	0.0106
125	0.745	0.0257	0.0111	0.803	0.0308	0.0133	0.866	0.0371	0.0161
150	0.895	0.0361	0.0156	0.963	0.0432	0.0187	1.04	0.0520	0.0225
200	1.19	0.0614	0.0266	1.28	0.0735	0.0318	1.39	0.0885	0.0383
250	1.49	0.0928	0.0402	1.61	0.111	0.0481	1.73	0.134	0.0579
300	1.79	0.130	0.0563	1.93	0.156	0.0674	2.08	0.187	0.0812
350	2.09	0.173	0.0749	2.25	0.207	0.0896	2.43	0.249	0.108
400	2.39	0.221	0.0959	2.57	0.265	0.115	2.77	0.319	0.138
450	2.68	0.275	0.119	2.89	0.329	0.143	3.12	0.397	0.172
500	2.98	0.335	0.145	3.21	0.400	0.173	3.47	0.482	0.209
600	3.58	0.469	0.203	3.85	0.561	0.243	4.16	0.676	0.293
700	4.17	0.623	0.270	4.49	0.746	0.323	4.85	0.899	0.389
800	4.77	0.798	0.346	5.14	0.955	0.413	5.55	1.15	0.498
1,000	5.96	1.21	0.522	6.42	1.44	0.625	6.93	1.74	0.753
1,200	7.16	1.69	0.732	7.70	2.02	0.875	8.32	2.44	1.05
1,400	8.35	2.25	0.973	8.99	2.69	1.16	9.70	3.24	1.40
1,600	9.54	2.88	1.25	10.3	3.44	1.49	11.1	4.15	1.80
1,800	10.7	3.58	1.55	11.6	4.28	1.85	12.5	5.16	2.23

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

10 in. CIOD (AWWA C900)									
Flow, gpm	DR 25 Pressure class 165 psi			DR 18 Pressure class 235 psi			DR 14 Pressure class 305 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
150	0.594	0.0133	0.00578	0.640	0.0160	0.00692	0.691	0.0193	0.00834
200	0.792	0.0227	0.00984	0.853	0.0272	0.0118	0.922	0.0328	0.0142
250	0.990	0.0343	0.0149	1.07	0.0411	0.0178	1.15	0.0496	0.0215
300	1.19	0.0481	0.0208	1.28	0.0576	0.0249	1.38	0.0695	0.0301
350	1.39	0.0640	0.0277	1.49	0.0766	0.0332	1.61	0.0924	0.0400
400	1.58	0.0819	0.0355	1.71	0.0981	0.0425	1.84	0.118	0.0512
450	1.78	0.102	0.0441	1.92	0.122	0.0528	2.07	0.147	0.0637
500	1.98	0.124	0.0536	2.13	0.148	0.0642	2.30	0.179	0.0774
600	2.38	0.173	0.0751	2.56	0.208	0.0899	2.76	0.250	0.108
700	2.77	0.231	0.100	2.99	0.276	0.120	3.23	0.333	0.144
800	3.17	0.295	0.128	3.41	0.354	0.153	3.69	0.426	0.185
1,000	3.96	0.446	0.193	4.27	0.534	0.231	4.61	0.644	0.279
1,200	4.75	0.625	0.271	5.12	0.749	0.324	5.53	0.903	0.391
1,400	5.55	0.831	0.360	5.97	1.00	0.431	6.45	1.20	0.520
1,600	6.34	1.06	0.461	6.83	1.27	0.552	7.37	1.54	0.666
1,800	7.13	1.32	0.573	7.68	1.59	0.686	8.29	1.91	0.828
2,200	8.71	1.92	0.831	9.39	2.30	0.995	10.1	2.77	1.20
2,600	10.3	2.61	1.13	11.1	3.13	1.36	12.0	3.77	1.63

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

12 in. CIOD (AWWA C900)									
Flow, gpm	DR 25 Pressure class 165 psi			DR 18 Pressure class 235 psi			DR 14 Pressure class 305 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
200	0.560	0.00980	0.00424	0.602	0.0117	0.00506	0.652	0.0141	0.00613
250	0.700	0.0148	0.00641	0.753	0.0177	0.00764	0.815	0.0214	0.00926
300	0.841	0.0207	0.00898	0.904	0.0247	0.0107	0.978	0.0300	0.0130
350	0.981	0.0276	0.0119	1.05	0.0329	0.0142	1.14	0.0398	0.0173
400	1.12	0.0353	0.0153	1.20	0.0421	0.0182	1.30	0.0510	0.0221
500	1.40	0.0534	0.0231	1.51	0.0636	0.0276	1.63	0.0771	0.0334
600	1.68	0.0748	0.0324	1.81	0.0892	0.0386	1.96	0.108	0.0468
700	1.96	0.0994	0.0431	2.11	0.119	0.0514	2.28	0.144	0.0622
800	2.24	0.127	0.0551	2.41	0.152	0.0657	2.61	0.184	0.0796
1,000	2.80	0.192	0.0833	3.01	0.229	0.0993	3.26	0.278	0.120
1,200	3.36	0.270	0.117	3.61	0.321	0.139	3.91	0.389	0.169
1,400	3.92	0.358	0.155	4.22	0.428	0.185	4.56	0.518	0.224
1,600	4.48	0.459	0.199	4.82	0.547	0.237	5.22	0.663	0.287
2,000	5.60	0.694	0.300	6.02	0.827	0.358	6.52	1.00	0.434
2,400	6.72	0.972	0.421	7.23	1.16	0.502	7.82	1.40	0.608
2,800	7.85	1.29	0.560	8.43	1.54	0.667	9.13	1.87	0.808
3,200	8.97	1.65	0.716	9.64	1.97	0.854	10.4	2.39	1.03
3,600	10.1	2.06	0.891	10.8	2.45	1.06	11.7	2.97	1.29

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

14 in. CIOD (AWWA C905)									
Flow, gpm	DR 41 Pressure class 100 psi			DR 32.5 Pressure class 125 psi			DR 25 Pressure class 165 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
300	0.583	0.00851	0.00369	0.600	0.00914	0.00396	0.626	0.0101	0.00439
450	0.874	0.0180	0.00780	0.900	0.0193	0.00838	0.939	0.0214	0.00928
600	1.17	0.0307	0.0133	1.20	0.0329	0.0143	1.25	0.0365	0.0158
800	1.55	0.0522	0.0226	1.60	0.0561	0.0243	1.67	0.0622	0.0269
1,000	1.94	0.0789	0.0342	2.00	0.0847	0.0367	2.09	0.0939	0.0407
1,200	2.33	0.111	0.0479	2.40	0.119	0.0514	2.50	0.132	0.0570
1,400	2.72	0.147	0.0637	2.80	0.158	0.0684	2.92	0.175	0.0758
1,600	3.11	0.188	0.0815	3.20	0.202	0.0875	3.34	0.224	0.0970
1,800	3.50	0.234	0.101	3.60	0.251	0.109	3.75	0.279	0.121
2,000	3.88	0.285	0.123	4.00	0.305	0.132	4.17	0.339	0.147
2,200	4.27	0.339	0.147	4.40	0.364	0.158	4.59	0.404	0.175
2,600	5.05	0.462	0.200	5.20	0.496	0.215	5.42	0.550	0.238
3,000	5.83	0.603	0.261	6.00	0.647	0.280	6.26	0.717	0.310
3,400	6.60	0.759	0.329	6.80	0.815	0.353	7.09	0.904	0.391
3,800	7.38	0.933	0.404	7.60	1.00	0.434	7.93	1.11	0.481
4,200	8.16	1.12	0.486	8.40	1.21	0.522	8.76	1.34	0.579
4,600	8.93	1.33	0.575	9.20	1.43	0.618	9.60	1.58	0.685
5,000	9.71	1.55	0.671	10.0	1.66	0.721	10.4	1.84	0.799

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

14 in. CIOD (AWWA C905)									
Flow, gpm	DR 21 Pressure class 200 psi			DR 18 Pressure class 235 psi			DR 14 Pressure class 305 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
300	0.648	0.0110	0.00477	0.673	0.0121	0.00523	0.728	0.0146	0.00633
450	0.972	0.0233	0.0101	1.01	0.0256	0.0111	1.09	0.0310	0.0134
600	1.30	0.0397	0.0172	1.35	0.0436	0.0189	1.46	0.0527	0.0228
800	1.73	0.0676	0.0293	1.79	0.0742	0.0321	1.94	0.0898	0.0389
1,000	2.16	0.102	0.0442	2.24	0.112	0.0485	2.43	0.136	0.0587
1,200	2.59	0.143	0.0620	2.69	0.157	0.0680	2.91	0.190	0.0823
1,400	3.02	0.190	0.0824	3.14	0.209	0.0904	3.40	0.253	0.109
1,600	3.46	0.244	0.106	3.59	0.267	0.116	3.88	0.324	0.140
1,800	3.89	0.303	0.131	4.04	0.333	0.144	4.37	0.402	0.174
2,000	4.32	0.368	0.159	4.49	0.404	0.175	4.85	0.489	0.212
2,200	4.75	0.439	0.190	4.94	0.482	0.209	5.34	0.583	0.253
2,600	5.61	0.598	0.259	5.83	0.657	0.284	6.31	0.795	0.344
3,000	6.48	0.780	0.338	6.73	0.856	0.370	7.28	1.04	0.448
3,400	7.34	0.983	0.426	7.63	1.08	0.467	8.25	1.31	0.565
3,800	8.21	1.21	0.523	8.52	1.32	0.574	9.22	1.60	0.694
4,200	9.07	1.45	0.629	9.42	1.59	0.690	10.2	1.93	0.836
4,600	9.93	1.72	0.745	10.3	1.89	0.817	11.2	2.28	0.989
5,000	10.8	2.01	0.869	11.2	2.20	0.953	12.1	2.66	1.15

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

16 in. CIOD (AWWA C905)									
Flow, gpm	DR 41 Pressure class 100 psi			DR 32.5 Pressure class 125 psi			DR 25 Pressure class 165 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
350	0.526	0.00606	0.00262	0.541	0.00651	0.00282	0.565	0.00721	0.00312
500	0.751	0.0117	0.00508	0.773	0.0126	0.00545	0.807	0.0140	0.00604
650	0.976	0.0191	0.00825	1.01	0.0205	0.00886	1.05	0.0227	0.00982
800	1.20	0.0280	0.0121	1.24	0.0300	0.0130	1.29	0.0333	0.0144
1,000	1.50	0.0423	0.0183	1.55	0.0454	0.0197	1.61	0.0503	0.0218
1,200	1.80	0.0592	0.0256	1.86	0.0636	0.0275	1.94	0.0705	0.0305
1,400	2.10	0.0788	0.0341	2.17	0.0846	0.0366	2.26	0.0937	0.0406
1,800	2.70	0.125	0.0543	2.78	0.135	0.0583	2.90	0.149	0.0646
2,200	3.30	0.182	0.0787	3.40	0.195	0.0845	3.55	0.216	0.0937
2,600	3.90	0.248	0.107	4.02	0.266	0.115	4.19	0.295	0.128
3,000	4.51	0.323	0.140	4.64	0.346	0.150	4.84	0.384	0.166
3,500	5.26	0.429	0.186	5.41	0.461	0.200	5.65	0.511	0.221
4,000	6.01	0.549	0.238	6.19	0.590	0.255	6.45	0.654	0.283
4,500	6.76	0.683	0.296	6.96	0.733	0.318	7.26	0.813	0.352
5,000	7.51	0.830	0.359	7.73	0.891	0.386	8.07	0.988	0.428
5,500	8.26	0.990	0.429	8.51	1.06	0.460	8.87	1.18	0.510
6,000	9.01	1.16	0.504	9.28	1.25	0.541	9.68	1.38	0.599
6,500	9.76	1.35	0.584	10.1	1.45	0.627	10.5	1.60	0.695

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

16 in. CIOD (AWWA C905)									
Flow, gpm	DR 21 Pressure class 200 psi			DR 18 Pressure class 235 psi			DR 14 Pressure class 305 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
350	0.585	0.00786	0.00340	0.607	0.00861	0.00373	0.656	0.0104	0.00450
500	0.836	0.0152	0.00659	0.868	0.0167	0.00721	0.937	0.0201	0.00870
650	1.09	0.0247	0.0107	1.13	0.0271	0.0117	1.22	0.0326	0.0141
800	1.34	0.0363	0.0157	1.39	0.0397	0.0172	1.50	0.0479	0.0207
1,000	1.67	0.0548	0.0237	1.74	0.0600	0.0260	1.87	0.0724	0.0314
1,200	2.01	0.0768	0.0333	2.08	0.0841	0.0364	2.25	0.101	0.0439
1,400	2.34	0.102	0.0442	2.43	0.112	0.0485	2.62	0.135	0.0584
1,800	3.01	0.163	0.0704	3.12	0.178	0.0771	3.37	0.215	0.0930
2,200	3.68	0.236	0.102	3.82	0.258	0.112	4.12	0.311	0.135
2,600	4.35	0.321	0.139	4.51	0.352	0.152	4.87	0.424	0.184
3,000	5.01	0.418	0.181	5.21	0.458	0.198	5.62	0.553	0.239
3,500	5.85	0.557	0.241	6.07	0.610	0.264	6.56	0.735	0.318
4,000	6.69	0.713	0.309	6.94	0.780	0.338	7.50	0.941	0.407
4,500	7.52	0.886	0.384	7.81	0.970	0.420	8.43	1.17	0.507
5,000	8.36	1.08	0.466	8.68	1.18	0.511	9.37	1.42	0.616
5,500	9.19	1.28	0.556	9.54	1.41	0.609	10.3	1.70	0.734
6,000	10.0	1.51	0.653	10.4	1.65	0.715	11.2	1.99	0.863
6,500	10.9	1.75	0.757	11.3	1.92	0.830	12.2	2.31	1.00

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

18 in. CIOD (AWWA C905)									
Flow, gpm	DR 51 Pressure class 80 psi			DR 41 Pressure class 100 psi			DR 32.5 Pressure class 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
500	0.585	0.00640	0.00277	0.598	0.00674	0.00292	0.615	0.00722	0.00313
800	0.936	0.0153	0.00661	0.957	0.0161	0.00696	0.984	0.0172	0.00746
1,100	1.29	0.0275	0.0119	1.32	0.0290	0.0126	1.35	0.0311	0.0134
1,400	1.64	0.0430	0.0186	1.67	0.0453	0.0196	1.72	0.0485	0.0210
1,800	2.11	0.0684	0.0296	2.15	0.0721	0.0312	2.21	0.0772	0.0334
2,200	2.58	0.0992	0.0429	2.63	0.105	0.0453	2.71	0.112	0.0485
2,600	3.04	0.135	0.585	3.11	0.142	0.0616	3.20	0.153	0.0660
3,000	3.51	0.176	0.0762	3.59	0.186	0.0803	3.69	0.199	0.0860
3,500	4.10	0.234	0.101	4.19	0.247	0.107	4.31	0.264	0.114
4,000	4.68	0.300	0.130	4.78	0.316	0.137	4.92	0.338	0.147
4,500	5.27	0.373	0.161	5.38	0.393	0.170	5.54	0.421	0.182
5,000	5.85	0.453	0.196	5.98	0.477	0.207	6.15	0.511	0.221
5,500	6.44	0.540	0.234	6.58	0.569	0.247	6.77	0.610	0.264
6,000	6.44	0.635	0.275	7.18	0.669	0.290	7.38	0.716	0.310
6,500	7.61	0.736	0.319	7.77	0.775	0.336	8.00	0.831	0.360
7,000	8.19	0.844	0.366	8.37	0.889	0.385	8.61	0.953	0.413
7,500	8.78	0.959	0.415	8.97	1.01	0.438	9.23	1.08	0.469
8,000	9.36	1.08	0.468	9.57	1.14	0.493	9.84	1.22	0.528

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

18 in. CIOD (AWWA C905)									
Flow, gpm	DR 25 Pressure class 165 psi			DR 21 Pressure class 200 psi			DR 18 Pressure class 235 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
500	0.642	0.00800	0.00346	0.665	0.00874	0.00378	0.691	0.00958	0.00415
800	1.03	0.0191	0.00826	1.06	0.0208	0.00902	1.11	0.0229	0.00990
1,100	1.41	0.0344	0.0149	1.46	0.0376	0.0163	1.52	0.0412	0.0178
1,400	1.80	0.0537	0.0233	1.86	0.0587	0.0254	1.93	0.0644	0.0279
1,800	2.31	0.0856	0.0370	2.39	0.0934	0.0405	2.49	0.102	0.0444
2,200	2.82	0.124	0.0537	2.93	0.135	0.0586	3.04	0.149	0.0643
2,600	3.34	0.169	0.0732	3.46	0.184	0.0799	3.59	0.202	0.0876
3,000	3.85	0.220	0.0953	3.99	0.240	0.104	4.15	0.264	0.114
3,500	4.49	0.293	0.127	4.66	0.320	0.138	4.84	0.351	0.152
4,000	5.13	0.375	0.162	5.32	0.409	0.177	5.53	0.449	0.194
4,500	5.77	0.466	0.202	5.99	0.509	0.220	6.22	0.558	0.242
5,000	6.42	0.566	0.245	6.65	0.618	0.268	6.91	0.678	0.294
5,500	7.06	0.676	0.293	7.32	0.738	0.319	7.60	0.809	0.350
6,000	7.70	0.794	0.344	7.98	0.867	0.375	8.29	0.950	0.412
6,500	8.34	0.920	0.398	8.65	1.00	0.435	8.98	1.10	0.477
7,000	8.98	1.06	0.457	9.31	1.15	0.499	9.67	1.26	0.547
7,500	9.62	1.20	0.519	9.98	1.31	0.567	10.4	1.44	0.622
8,000	10.3	1.35	0.585	10.6	1.48	0.639	11.1	1.62	0.701

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

18 in. CIOD (AWWA C905)			
Flow, gpm	DR 14 Pressure class 305 psi		
	Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft
500	0.746	0.0116	0.00500
800	1.19	0.0276	0.0119
1,100	1.64	0.0497	0.0215
1,400	2.09	0.0776	0.0336
1,800	2.69	0.124	0.0535
2,200	3.28	0.179	0.0776
2,600	3.88	0.244	0.106
3,000	4.48	0.318	0.138
3,500	5.22	0.423	0.183
4,000	5.97	0.541	0.234
4,500	6.72	0.673	0.291
5,000	7.46	0.818	0.354
5,500	8.21	0.976	0.422
6,000	8.96	1.15	0.496
6,500	9.70	1.33	0.575
7,000	10.4	1.52	0.660
7,500	11.2	1.73	0.750
8,000	11.9	1.95	0.845

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

20 in. CIOD (AWWA C905)									
Flow, gpm	DR 51 Pressure class 80 psi			DR 41 Pressure class 100 psi			DR 32.5 Pressure class 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
600	0.573	0.00546	0.00236	0.585	0.00575	0.00249	0.602	0.00616	0.00267
1,000	0.954	0.0140	0.00608	0.975	0.0148	0.00640	1.00	0.0159	0.00686
1,400	1.34	0.0262	0.0113	1.36	0.0276	0.0119	1.40	0.0295	0.0128
1,800	1.72	0.0417	0.0180	1.75	0.0439	0.0190	1.81	0.0470	0.0204
2,200	2.10	0.0604	0.0261	2.14	0.0636	0.0275	2.21	0.0682	0.0295
2,600	2.48	0.0822	0.0356	2.53	0.0866	0.0375	2.61	0.0928	0.0402
3,000	2.86	0.107	0.0464	2.92	0.113	0.0489	3.01	0.121	0.0524
3,500	3.34	0.143	0.0617	3.41	0.150	0.0650	3.51	0.161	0.0697
4,000	3.82	0.182	0.0790	3.90	0.192	0.0832	4.01	0.206	0.0892
4,500	4.29	0.227	0.0982	4.39	0.239	0.103	4.51	0.256	0.111
5,000	4.77	0.276	0.119	4.87	0.290	0.126	5.02	0.311	0.135
5,500	5.25	0.329	0.142	5.36	0.346	0.150	5.52	0.371	0.161
6,000	5.73	0.386	0.167	5.85	0.407	0.176	6.02	0.436	0.189
6,500	6.20	0.448	0.194	6.34	0.472	0.204	6.52	0.506	0.219
7,000	6.68	0.514	0.222	6.82	0.541	0.234	7.02	0.580	0.251
8,000	7.63	0.658	0.285	7.80	0.693	0.300	8.02	0.743	0.322
9,000	8.59	0.818	0.354	8.77	0.862	0.373	9.03	0.923	0.400
10,000	9.54	0.994	0.430	9.75	1.05	0.453	10.0	1.12	0.486

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

20 in. CIOD (AWWA C905)									
Flow, gpm	DR 25 Pressure class 165 psi			DR 21 Pressure class 200 psi			DR 18 Pressure class 235 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
600	0.628	0.00682	0.00295	0.650	0.00744	0.00322	0.675	0.00815	0.00353
1,000	1.05	0.0176	0.00760	1.08	0.0191	0.00829	1.13	0.0210	0.00908
1,400	1.46	0.0327	0.0142	1.52	0.0357	0.0155	1.58	0.0391	0.0169
1,800	1.88	0.0521	0.0225	1.95	0.0568	0.0246	2.03	0.0622	0.0269
2,200	2.30	0.0755	0.0327	2.39	0.0823	0.0357	2.48	0.0902	0.0390
2,600	2.72	0.103	0.0445	2.82	0.112	0.0486	2.93	0.123	0.0532
3,000	3.14	0.134	0.0580	3.25	0.146	0.0633	3.38	0.160	0.0693
3,500	3.66	0.178	0.0772	3.79	0.194	0.0842	3.94	0.213	0.0922
4,000	4.18	0.228	0.0988	4.34	0.249	0.108	4.50	0.273	0.118
4,500	4.71	0.284	0.123	4.88	0.309	0.134	5.06	0.339	0.147
5,000	5.23	0.345	0.149	5.42	0.376	0.163	5.63	0.412	0.178
5,500	5.75	0.411	0.178	5.96	0.449	0.194	6.19	0.491	0.213
6,000	6.28	0.483	0.209	6.50	0.527	0.228	6.75	0.577	0.250
6,500	6.80	0.560	0.243	7.05	0.611	0.265	7.32	0.669	0.290
7,000	7.32	0.642	0.278	7.59	0.701	0.303	7.88	0.767	0.332
8,000	8.37	0.822	0.356	8.67	0.897	0.388	9.00	0.982	0.425
9,000	9.41	1.02	0.443	9.76	1.12	0.483	10.1	1.22	0.529
10,000	10.5	1.24	0.538	10.8	1.36	0.587	11.3	1.48	0.643

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

24 in. CIOD (AWWA C905)									
Flow, gpm	DR 51 Pressure class 80 psi			DR 41 Pressure class 100 psi			DR 32.5 Pressure class 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
800	0.535	0.00391	0.00169	0.546	0.00412	0.00178	0.562	0.00442	0.00191
1,200	0.802	0.00829	0.00359	0.819	0.00872	0.00378	0.843	0.00936	0.00405
1,600	1.07	0.0141	0.00611	1.09	0.0149	0.00643	1.12	0.0159	0.00690
2,000	1.34	0.0213	0.00923	1.37	0.0224	0.00972	1.41	0.0241	0.0104
2,600	1.74	0.0346	0.0150	1.78	0.0365	0.0158	1.83	0.0391	0.0169
3,200	2.14	0.0509	0.0220	2.19	0.0536	0.0232	2.25	0.0574	0.0249
3,800	2.54	0.0699	0.0303	2.59	0.0736	0.0319	2.67	0.0789	0.0342
4,600	3.08	0.100	0.0431	3.14	0.105	0.0454	3.23	0.112	0.0487
5,400	3.61	0.134	0.0580	3.69	0.141	0.0610	3.80	0.151	0.0655
6,200	4.14	0.173	0.0749	4.23	0.182	0.0788	4.36	0.195	0.0845
7,000	4.68	0.216	0.0937	4.78	0.228	0.0987	4.92	0.244	0.106
8,000	5.35	0.277	0.120	5.46	0.292	0.126	5.62	0.313	0.135
9,000	6.02	0.345	0.149	6.15	0.363	0.157	6.33	0.389	0.168
10,000	6.69	0.419	0.181	6.83	0.441	0.191	7.03	0.473	0.205
11,000	7.35	0.499	0.216	7.51	0.526	0.228	7.73	0.564	0.244
12,000	8.02	0.587	0.254	8.19	0.618	0.267	8.43	0.662	0.287
13,500	9.03	0.730	0.316	9.22	0.768	0.333	9.49	0.824	0.357
15,000	10.0	0.887	0.384	10.2	0.933	0.404	10.5	1.00	0.433

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

24 in. CIOD (AWWA C905)									
Flow, gpm	DR 25 Pressure class 165 psi			DR 21 Pressure class 200 psi			DR 18 Pressure class 235 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
800	0.587	0.00490	0.00212	0.608	0.00534	0.00231	0.631	0.00586	0.00254
1,200	0.880	0.0104	0.00449	0.912	0.0113	0.00489	0.947	0.0124	0.00537
1,600	1.17	0.0177	0.00765	1.22	0.0192	0.00833	1.26	0.0211	0.00915
2,000	1.47	0.0267	0.0116	1.52	0.0291	0.0126	1.58	0.0319	0.0138
2,600	1.91	0.0434	0.0188	1.98	0.0473	0.0205	2.05	0.0519	0.0225
3,200	2.35	0.0637	0.0276	2.43	0.0694	0.0300	2.53	0.0761	0.0330
3,800	2.79	0.0876	0.0379	2.89	0.0954	0.0413	3.00	0.105	0.0453
4,600	3.37	0.125	0.0540	3.49	0.136	0.0588	3.63	0.149	0.0645
5,400	3.96	0.168	0.0726	4.10	0.183	0.0791	4.26	0.200	0.0868
6,200	4.55	0.217	0.0938	4.71	0.236	0.102	4.89	0.259	0.112
7,000	5.13	0.271	0.117	5.32	0.295	0.128	5.52	0.324	0.140
8,000	5.87	0.347	0.150	6.08	0.378	0.164	6.31	0.415	0.180
9,000	6.60	0.432	0.187	6.84	0.470	0.203	7.10	0.516	0.223
10,000	7.33	0.525	0.227	7.60	0.571	0.247	7.89	0.627	0.271
11,000	8.07	0.626	0.271	8.36	0.681	0.295	8.68	0.748	0.324
12,000	8.80	0.735	0.318	9.12	0.800	0.346	9.47	0.878	0.380
13,500	9.90	0.914	0.396	10.3	1.00	0.431	10.7	1.09	0.473
15,000	11.0	1.11	0.481	11.4	1.21	0.524	11.8	1.33	0.575

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

30 in. CIOD (AWWA C905)									
Flow, gpm	DR 51 Pressure class 80 psi			DR 41 Pressure class 100 psi			DR 32.5 Pressure class 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
1,200	0.522	0.00291	0.00126	0.533	0.00306	0.00133	0.548	0.00329	0.00142
1,800	0.782	0.00616	0.00267	0.799	0.00649	0.00281	0.823	0.00696	0.00301
2,400	1.04	0.0105	0.00454	1.07	0.0110	0.00478	1.10	0.0119	0.00513
3,200	1.39	0.0179	0.00774	1.42	0.0188	0.00814	1.46	0.0202	0.00874
4,000	1.74	0.0270	0.0117	1.78	0.0284	0.0123	1.83	0.0305	0.0132
5,000	2.17	0.0408	0.0177	2.22	0.0429	0.0186	2.29	0.0461	0.0200
6,000	2.61	0.0572	0.0248	2.66	0.0602	0.0260	2.74	0.0646	0.0280
7,000	3.04	0.0760	0.0329	3.11	0.0800	0.0346	3.20	0.0859	0.0372
8,000	3.48	0.0973	0.0421	3.55	0.102	0.0444	3.66	0.110	0.0476
9,000	3.91	0.121	0.0524	3.99	0.127	0.0551	4.11	0.137	0.0592
10,000	4.35	0.147	0.0637	4.44	0.155	0.0670	4.57	0.166	0.0719
12,000	5.22	0.206	0.0892	5.33	0.217	0.0939	5.48	0.233	0.101
14,000	6.09	0.274	0.119	6.21	0.288	0.125	6.40	0.310	0.134
16,000	6.95	0.351	0.152	7.10	0.369	0.160	7.31	0.396	0.172
18,000	7.82	0.436	0.189	7.99	0.459	0.199	8.23	0.493	0.213
20,000	8.69	0.530	0.230	8.88	0.558	0.242	9.14	0.599	0.259
22,000	9.56	0.632	0.274	9.77	0.666	0.288	10.1	0.715	0.309
24,000	10.4	0.743	0.322	10.7	0.782	0.339	11.0	0.839	0.363

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

30 in. CIOD (AWWA C905)									
Flow, gpm	DR 25 Pressure class 165 psi			DR 21 Pressure class 200 psi			DR 18 Pressure class 235 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
1,200	0.572	0.00364	0.00158	0.593	0.00397	0.00172	0.616	0.00436	0.00189
1,800	0.858	0.00771	0.00334	0.889	0.00841	0.00364	0.923	0.00922	0.00399
2,400	1.14	0.0131	0.00568	1.19	0.0143	0.00620	1.23	0.0157	0.00680
3,200	1.53	0.0223	0.00968	1.58	0.0244	0.0106	1.64	0.0267	0.0116
4,000	1.91	0.0338	0.0146	1.98	0.0368	0.0160	2.05	0.0404	0.0175
5,000	2.38	0.0510	0.0221	2.47	0.0557	0.0241	2.57	0.0610	0.0264
6,000	2.86	0.0715	0.0310	2.96	0.0780	0.0338	3.08	0.0855	0.0370
7,000	3.34	0.0951	0.0412	3.46	0.104	0.0449	3.59	0.114	0.0493
8,000	3.81	0.122	0.0527	3.95	0.133	0.0575	4.10	0.146	0.0631
9,000	4.29	0.151	0.0656	4.45	0.165	0.0715	4.62	0.181	0.0784
10,000	4.77	0.184	0.0797	4.94	0.201	0.0869	5.13	0.220	0.0953
12,000	5.72	0.258	0.112	5.93	0.281	0.122	6.16	0.308	0.134
14,000	6.67	0.343	0.148	6.92	0.374	0.162	7.18	0.410	0.178
16,000	7.63	0.439	0.190	7.90	0.479	0.207	8.21	0.525	0.227
18,000	8.58	0.546	0.236	8.89	0.595	0.258	9.23	0.653	0.283
20,000	9.53	0.663	0.287	9.88	0.724	0.313	10.3	0.793	0.344
22,000	10.5	0.791	0.343	10.9	0.863	0.374	11.3	0.946	0.410
24,000	11.4	0.929	0.402	11.9	1.01	0.439	12.3	1.11	0.481

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

36 in. CIOD (AWWA C905)									
Flow, gpm	DR 51 Pressure class 80 psi			DR 41 Pressure class 100 psi			DR 32.5 Pressure class 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
2,000	0.607	0.00313	0.00135	0.620	0.00329	0.00143	0.638	0.00353	0.00153
3,500	1.06	0.00880	0.00381	1.08	0.00927	0.00402	1.12	0.00995	0.00431
5,000	1.52	0.0170	0.00737	1.55	0.0179	0.00777	1.60	0.0192	0.00833
7,000	2.12	0.0317	0.0137	2.17	0.0334	0.0145	2.23	0.0359	0.0155
9,000	2.73	0.0505	0.0219	2.79	0.0532	0.0230	2.87	0.0571	0.0247
11,000	3.34	0.0732	0.0317	3.41	0.0771	0.0334	3.51	0.0827	0.0358
13,000	3.94	0.0998	0.0432	4.03	0.105	0.0455	4.15	0.113	0.0488
15,000	4.55	0.130	0.0563	4.65	0.137	0.0593	4.79	0.147	0.0636
17,000	5.16	0.164	0.0710	5.27	0.173	0.0747	5.42	0.185	0.0802
19,000	5.76	0.201	0.0872	5.89	0.212	0.0918	6.06	0.227	0.0985
21,000	6.37	0.242	0.105	6.51	0.255	0.110	6.70	0.274	0.118
23,000	6.98	0.287	0.124	7.13	0.302	0.131	7.34	0.324	0.140
25,000	7.58	0.334	0.145	7.75	0.352	0.153	7.98	0.378	0.164
27,000	8.19	0.386	0.167	8.37	0.406	0.176	8.61	0.436	0.189
29,000	8.80	0.440	0.191	8.99	0.464	0.201	9.25	0.497	0.215
31,000	9.41	0.498	0.216	9.61	0.524	0.227	9.89	0.563	0.244
33,000	10.0	0.559	0.242	10.2	0.589	0.255	10.5	0.632	0.273
35,000	10.6	0.623	0.270	10.8	0.656	0.284	11.2	0.704	0.305

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

36 in. CIOD (AWWA C905)									
Flow, gpm	DR 25 Pressure class 165 psi			DR 21 Pressure class 200 psi			DR 18 Pressure class 235 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
2,000	0.666	0.00391	0.00170	0.690	0.00427	0.00185	0.716	0.00468	0.00203
3,500	1.16	0.0110	0.00477	1.21	0.0120	0.00521	1.25	0.0132	0.00570
5,000	1.66	0.0213	0.00923	1.72	0.0233	0.0101	1.79	0.0255	0.011
7,000	2.33	0.0397	0.0172	2.41	0.0433	0.0188	2.51	0.0475	0.021
9,000	3.00	0.0633	0.0274	3.10	0.0690	0.0299	3.22	0.0756	0.033
11,000	3.66	0.0917	0.0397	3.79	0.100	0.0433	3.94	0.110	0.047
13,000	4.33	0.125	0.0541	4.48	0.136	0.0590	4.66	0.149	0.065
15,000	4.99	0.163	0.0705	5.17	0.178	0.0769	5.37	0.194	0.084
17,000	5.66	0.205	0.0888	5.86	0.224	0.0969	6.09	0.245	0.106
19,000	6.32	0.252	0.109	6.55	0.275	0.119	6.80	0.301	0.130
21,000	6.99	0.303	0.131	7.24	0.331	0.143	7.52	0.362	0.157
23,000	7.65	0.359	0.155	7.93	0.391	0.169	8.24	0.429	0.186
25,000	8.32	0.419	0.181	8.62	0.457	0.198	8.95	0.500	0.217
27,000	8.99	0.483	0.209	9.31	0.527	0.228	9.67	0.577	0.250
29,000	9.65	0.551	0.239	10.0	0.601	0.260	10.4	0.658	0.285
31,000	10.3	0.623	0.270	10.7	0.680	0.294	11.1	0.745	0.323
33,000	11.0	0.700	0.303	11.4	0.763	0.331	11.8	0.836	0.362
35,000	11.6	0.780	0.338	12.1	0.851	0.369	12.5	0.932	0.404

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

42 in. CIOD (AWWA C905)									
Flow, gpm	DR 51 Pressure class 80 psi			DR 41 Pressure class 100 psi			DR 32.5 Pressure class 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
2,500	0.562	0.00228	0.000987	0.574	0.00240	0.00104	0.591	0.00257	0.00111
4,000	0.899	0.00544	0.00235	0.918	0.00573	0.00248	0.945	0.00614	0.00266
5,500	1.24	0.00980	0.00424	1.26	0.0103	0.00447	1.30	0.0111	0.00479
7,000	1.57	0.0153	0.00663	1.61	0.0161	0.00698	1.65	0.0173	0.00748
9,500	2.14	0.0269	0.0117	2.18	0.0284	0.0123	2.24	0.0304	0.0132
12,000	2.70	0.0415	0.0180	2.76	0.0437	0.0189	2.84	0.0468	0.0203
14,500	3.26	0.0589	0.0255	3.33	0.0620	0.0269	3.43	0.0665	0.0288
17,000	3.82	0.0791	0.0342	3.90	0.0832	0.0360	4.02	0.0892	0.0386
20,000	4.50	0.107	0.0462	4.59	0.112	0.0487	4.73	0.121	0.0522
23,000	5.17	0.138	0.0599	5.28	0.146	0.0630	5.43	0.156	0.0676
26,000	5.84	0.173	0.0751	5.97	0.183	0.0791	6.14	0.196	0.0848
29,000	6.52	0.212	0.0919	6.66	0.224	0.0968	6.85	0.240	0.104
32,000	7.19	0.255	0.110	7.35	0.268	0.116	7.56	0.288	0.125
35,000	7.87	0.301	0.130	8.04	0.317	0.137	8.27	0.339	0.147
38,000	8.54	0.350	0.152	8.72	0.369	0.160	8.98	0.395	0.171
42,000	9.44	0.421	0.182	9.64	0.444	0.192	9.92	0.476	0.206
46,000	10.3	0.499	0.216	10.6	0.525	0.227	10.9	0.563	0.244
50,000	11.2	0.582	0.252	11.5	0.612	0.265	11.8	0.657	0.284

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

42 in. CIOD (AWWA C905)			
Flow, gpm	DR 25 Pressure class 165 psi		
	Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft
2,500	0.616	0.00285	0.00123
4,000	0.986	0.00680	0.00295
5,500	1.36	0.0123	0.00531
7,000	1.73	0.0192	0.00829
9,500	2.34	0.0337	0.0146
12,000	2.96	0.0519	0.0225
14,500	3.57	0.0737	0.0319
17,000	4.19	0.0989	0.0428
20,000	4.93	0.134	0.0578
23,000	5.67	0.173	0.0749
26,000	6.41	0.217	0.0940
29,000	7.15	0.266	0.115
32,000	7.89	0.319	0.138
35,000	8.63	0.376	0.163
38,000	9.37	0.438	0.190
42,000	10.4	0.527	0.228
46,000	11.3	0.624	0.270
50,000	12.3	0.728	0.315

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

48 in. CIOD (AWWA C905)									
Flow, gpm	DR 51 Pressure class 80 psi			DR 41 Pressure class 100 psi			DR 32.5 Pressure class 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
3,000	0.517	0.00168	0.000726	0.529	0.00177	0.000765	0.544	0.00189	0.000820
5,000	0.862	0.00432	0.00187	0.881	0.00455	0.00197	0.906	0.00487	0.00211
8,000	1.38	0.0103	0.00446	1.41	0.0108	0.00470	1.45	0.0116	0.00503
11,000	1.90	0.0186	0.00804	1.94	0.0196	0.00847	1.99	0.0210	0.00907
14,000	2.41	0.0290	0.0126	2.47	0.0306	0.0132	2.54	0.0327	0.0142
17,000	2.93	0.0415	0.0180	3.00	0.0438	0.0189	3.08	0.0469	0.0203
20,000	3.45	0.0561	0.0243	3.52	0.0591	0.0256	3.63	0.0633	0.0274
23,000	3.97	0.0726	0.0315	4.05	0.0765	0.0331	4.17	0.0820	0.0355
26,000	4.48	0.0911	0.0395	4.58	0.0960	0.0416	4.71	0.103	0.0446
29,000	5.00	0.112	0.0483	5.11	0.118	0.0509	5.26	0.126	0.0545
32,000	5.52	0.134	0.0579	5.64	0.141	0.0611	5.80	0.151	0.0654
36,000	6.21	0.166	0.0721	6.34	0.175	0.0759	6.53	0.188	0.0813
40,000	6.90	0.202	0.0876	7.05	0.213	0.0923	7.25	0.228	0.0989
44,000	7.59	0.241	0.104	7.75	0.254	0.110	7.98	0.272	0.118
48,000	8.28	0.283	0.123	8.46	0.299	0.129	8.70	0.320	0.139
52,000	8.97	0.329	0.142	9.16	0.346	0.150	9.43	0.371	0.161
56,000	9.66	0.377	0.163	9.87	0.397	0.172	10.2	0.425	0.184
60,000	10.3	0.428	0.185	10.6	0.451	0.195	10.9	0.483	0.209

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.3 Flow friction loss, AWWA C900 and C905 CIOD PVC pipe (*continued*)

48 in. CIOD (AWWA C905)			
Flow, gpm	DR 25 Pressure class 165 psi		
	Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft
3,000	0.568	0.00210	0.000909
5,000	0.946	0.00540	0.00234
8,000	1.51	0.0129	0.00558
11,000	2.08	0.0232	0.0101
14,000	2.65	0.0363	0.0157
17,000	3.22	0.0520	0.0225
20,000	3.78	0.0702	0.0304
23,000	4.35	0.0910	0.0394
26,000	4.92	0.114	0.0494
29,000	5.49	0.140	0.0605
32,000	6.05	0.168	0.0726
36,000	6.81	0.208	0.0902
40,000	7.57	0.253	0.110
44,000	8.32	0.302	0.131
48,000	9.08	0.355	0.154
52,000	9.84	0.411	0.178
56,000	10.6	0.472	0.204
60,000	11.4	0.536	0.232

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe

3 in. IPS (ASTM D2241)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
15	0.557	0.0433	0.0188	0.573	0.0464	0.0201	0.593	0.0506	0.0219
20	0.742	0.0738	0.0319	0.764	0.0791	0.0342	0.791	0.0861	0.0373
25	0.928	0.111	0.0483	0.955	0.120	0.0517	0.989	0.130	0.0564
30	1.11	0.156	0.0676	1.15	0.167	0.0725	1.19	0.182	0.0790
40	1.48	0.266	0.115	1.53	0.285	0.123	1.58	0.311	0.134
50	1.86	0.402	0.174	1.91	0.431	0.187	1.98	0.469	0.203
60	2.23	0.563	0.244	2.29	0.604	0.261	2.37	0.658	0.285
70	2.60	0.749	0.324	2.67	0.803	0.348	2.77	0.875	0.379
80	2.97	0.959	0.415	3.06	1.03	0.445	3.17	1.12	0.485
90	3.34	1.19	0.516	3.44	1.28	0.553	3.56	1.39	0.603
100	3.71	1.45	0.627	3.82	1.55	0.672	3.96	1.69	0.733
120	4.45	2.03	0.879	4.58	2.18	0.942	4.75	2.37	1.03
140	5.20	2.70	1.17	5.35	2.89	1.25	5.54	3.15	1.37
160	5.94	3.46	1.50	6.11	3.71	1.60	6.33	4.04	1.75
180	6.68	4.30	1.86	6.88	4.61	2.00	7.12	5.02	2.17
200	7.42	5.22	2.26	7.64	5.60	2.42	7.91	6.10	2.64
220	8.17	6.23	2.70	8.40	6.68	2.89	8.70	7.27	3.15
240	8.91	7.32	3.17	9.17	7.84	3.40	9.50	8.55	3.70

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

3 in. IPS (ASTM D2241)									
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi			DR 13.5 Pressure rated 315 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
15	0.619	0.0561	0.0243	0.653	0.0639	0.0277	0.705	0.0768	0.0332
20	0.826	0.0956	0.0414	0.871	0.109	0.0471	0.939	0.131	0.0566
25	1.03	0.144	0.0625	1.09	0.164	0.0712	1.17	0.198	0.0855
30	1.24	0.202	0.0876	1.31	0.230	0.100	1.41	0.277	0.120
40	1.65	0.345	0.149	1.74	0.392	0.170	1.88	0.471	0.204
50	2.06	0.521	0.225	2.18	0.593	0.257	2.35	0.712	0.308
60	2.48	0.729	0.316	2.61	0.831	0.360	2.82	1.00	0.432
70	2.89	0.970	0.420	3.05	1.11	0.478	3.29	1.33	0.575
80	3.30	1.24	0.538	3.49	1.41	0.613	3.76	1.70	0.736
90	3.72	1.54	0.669	3.92	1.76	0.762	4.23	2.11	0.915
100	4.13	1.88	0.813	4.36	2.14	0.926	4.70	2.57	1.11
120	4.96	2.63	1.14	5.23	3.00	1.30	5.64	3.60	1.56
140	5.78	3.50	1.51	6.10	3.98	1.72	6.58	4.78	2.07
160	6.61	4.48	1.94	6.97	5.10	2.21	7.52	6.12	2.65
180	7.43	5.57	2.41	7.84	6.34	2.75	8.45	7.61	3.30
200	8.26	6.77	2.93	8.71	7.71	3.34	9.39	9.25	4.01
220	9.08	8.07	3.49	9.58	9.19	3.98	10.3	11.0	4.78
240	9.91	9.48	4.11	10.5	10.8	4.68	11.3	13.0	5.61

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

4 in. IPS (ASTM D2241)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
25	0.561	0.0329	0.0142	0.578	0.0352	0.0153	0.598	0.0384	0.0166
40	0.898	0.0784	0.0339	0.924	0.0841	0.0364	0.957	0.0916	0.0396
55	1.23	0.141	0.0612	1.27	0.152	0.0656	1.32	0.165	0.0715
70	1.57	0.221	0.0956	1.62	0.237	0.102	1.68	0.258	0.112
85	1.91	0.316	0.137	1.96	0.339	0.147	2.03	0.369	0.160
100	2.25	0.427	0.185	2.31	0.458	0.198	2.39	0.499	0.216
125	2.81	0.645	0.279	2.89	0.692	0.300	2.99	0.754	0.326
150	3.37	0.904	0.391	3.47	0.969	0.420	3.59	1.06	0.457
175	3.93	1.20	0.521	4.04	1.29	0.558	4.19	1.40	0.608
200	4.49	1.54	0.667	4.62	1.65	0.715	4.79	1.80	0.779
225	5.05	1.91	0.829	5.20	2.05	0.889	5.39	2.24	0.968
250	5.61	2.33	1.01	5.78	2.49	1.08	5.98	2.72	1.18
275	6.17	2.77	1.20	6.35	2.98	1.29	6.58	3.24	1.40
300	6.74	3.26	1.41	6.93	3.49	1.51	7.18	3.81	1.65
325	7.30	3.78	1.64	7.51	4.05	1.75	7.78	4.41	1.91
350	7.86	4.33	1.88	8.09	4.65	2.01	8.38	5.06	2.19
375	8.42	4.92	2.13	8.67	5.28	2.29	8.98	5.75	2.49
400	8.98	5.55	2.40	9.24	5.95	2.58	9.57	6.48	2.81

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

4 in. IPS (ASTM D2241)									
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi			DR 13.5 Pressure rated 315 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
25	0.624	0.0426	0.0184	0.659	0.0485	0.0210	0.710	0.0582	0.0252
40	1.00	0.102	0.0440	1.05	0.116	0.0501	1.14	0.139	0.0602
55	1.37	0.183	0.0793	1.45	0.209	0.0903	1.56	0.250	0.108
70	1.75	0.286	0.124	1.84	0.326	0.141	1.99	0.391	0.169
85	2.12	0.410	0.177	2.24	0.467	0.202	2.42	0.560	0.243
100	2.50	0.553	0.240	2.64	0.630	0.273	2.84	0.757	0.328
125	3.12	0.836	0.362	3.29	0.952	0.412	3.55	1.14	0.495
150	3.75	1.17	0.507	3.95	1.33	0.578	4.26	1.60	0.694
175	4.37	1.56	0.675	4.61	1.77	0.768	4.97	2.13	0.923
200	5.00	1.99	0.864	5.27	2.27	0.984	5.68	2.73	1.18
225	5.62	2.48	1.07	5.93	2.83	1.22	6.39	3.39	1.47
250	6.24	3.01	1.31	6.59	3.43	1.49	7.10	4.12	1.78
275	6.87	3.60	1.56	7.25	4.10	1.77	7.81	4.92	2.13
300	7.49	4.22	1.83	7.91	4.81	2.08	8.52	5.78	2.50
325	8.12	4.90	2.12	8.57	5.58	2.42	9.23	6.70	2.90
350	8.74	5.62	2.43	9.22	6.40	2.77	9.94	7.68	3.33
375	9.37	6.38	2.76	9.88	7.27	3.15	10.7	8.73	3.78
400	10.0	7.19	3.11	10.5	8.19	3.55	11.4	9.83	4.26

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

5 in. IPS (ASTM D2241)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
40	0.588	0.0280	0.0121	0.605	0.0300	0.0130	0.626	0.0327	0.0141
55	0.808	0.0504	0.0218	0.832	0.0541	0.0234	0.861	0.0589	0.0255
70	1.03	0.0788	0.0341	1.06	0.0845	0.0366	1.10	0.0920	0.0398
85	1.25	0.113	0.0488	1.29	0.121	0.0524	1.33	0.132	0.0570
100	1.47	0.152	0.0660	1.51	0.163	0.0707	1.57	0.178	0.0771
125	1.84	0.230	0.100	1.89	0.247	0.107	1.96	0.269	0.116
150	2.20	0.323	0.140	2.27	0.346	0.150	2.35	0.377	0.163
175	2.57	0.429	0.186	2.65	0.460	0.199	2.74	0.501	0.217
200	2.94	0.549	0.238	3.02	0.589	0.255	3.13	0.642	0.278
225	3.31	0.683	0.296	3.40	0.732	0.317	3.52	0.798	0.345
250	3.67	0.830	0.359	3.78	0.890	0.385	3.92	0.969	0.420
300	4.41	1.16	0.504	4.54	1.25	0.540	4.70	1.36	0.588
350	5.14	1.55	0.670	5.29	1.66	0.718	5.48	1.81	0.782
400	5.88	1.98	0.857	6.05	2.12	0.919	6.26	2.31	1.00
450	6.61	2.46	1.07	6.80	2.64	1.14	7.05	2.88	1.25
500	7.35	2.99	1.30	7.56	3.21	1.39	7.83	3.49	1.51
550	8.08	3.57	1.55	8.32	3.83	1.66	8.61	4.17	1.80
600	8.82	4.19	1.82	9.07	4.50	1.95	9.40	4.90	2.12

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

5 in. IPS (ASTM D2241)									
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi			DR 13.5 Pressure rated 315 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
40	0.654	0.0362	0.0157	0.690	0.0413	0.0179	0.744	0.0496	0.0215
55	0.899	0.0653	0.0283	0.948	0.0744	0.0322	1.02	0.0893	0.0387
70	1.14	0.102	0.0442	1.21	0.116	0.0503	1.30	0.140	0.0604
85	1.39	0.146	0.0633	1.47	0.166	0.0721	1.58	0.200	0.0866
100	1.63	0.197	0.0855	1.72	0.225	0.0974	1.86	0.270	0.117
125	2.04	0.298	0.129	2.16	0.340	0.147	2.32	0.408	0.177
150	2.45	0.418	0.181	2.59	0.476	0.206	2.79	0.572	0.248
175	2.86	0.556	0.241	3.02	0.633	0.274	3.25	0.760	0.329
200	3.27	0.712	0.308	3.45	0.811	0.351	3.72	0.973	0.421
225	3.68	0.885	0.383	3.88	1.01	0.436	4.18	1.21	0.524
250	4.09	1.08	0.466	4.31	1.22	0.530	4.65	1.47	0.637
300	4.90	1.51	0.652	5.17	1.72	0.743	5.58	2.06	0.892
350	5.72	2.00	0.868	6.04	2.28	0.988	6.51	2.74	1.19
400	6.54	2.57	1.11	6.90	2.92	1.27	7.44	3.51	1.52
450	7.36	3.19	1.38	7.76	3.63	1.57	8.37	4.36	1.89
500	8.17	3.88	1.68	8.62	4.42	1.91	9.30	5.30	2.30
550	8.99	4.62	2.00	9.48	5.27	2.28	10.2	6.32	2.74
600	9.81	5.43	2.35	10.3	6.19	2.68	11.2	7.43	3.22

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

6 in. IPS (ASTM D2241)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
50	0.518	0.0181	0.00783	0.533	0.0194	0.00839	0.552	0.0211	0.00914
75	0.777	0.0383	0.0166	0.800	0.0410	0.0178	0.828	0.0447	0.0194
100	1.04	0.0652	0.0282	1.07	0.0699	0.0303	1.10	0.0761	0.0330
125	1.29	0.0985	0.0426	1.33	0.106	0.0457	1.38	0.115	0.0498
150	1.55	0.138	0.0598	1.60	0.148	0.0641	1.66	0.161	0.0698
175	1.81	0.184	0.0795	1.87	0.197	0.0852	1.93	0.214	0.0928
200	2.07	0.235	0.102	2.13	0.252	0.109	2.21	0.274	0.119
225	2.33	0.292	0.127	2.40	0.313	0.136	2.48	0.341	0.148
250	2.59	0.355	0.154	2.67	0.381	0.165	2.76	0.415	0.180
300	3.11	0.497	0.215	3.20	0.533	0.231	3.31	0.581	0.252
350	3.63	0.662	0.286	3.73	0.709	0.307	3.87	0.773	0.335
400	4.14	0.847	0.367	4.26	0.908	0.393	4.42	0.989	0.428
450	4.66	1.05	0.456	4.80	1.13	0.489	4.97	1.23	0.533
500	5.18	1.28	0.554	5.33	1.37	0.594	5.52	1.50	0.647
600	6.22	1.79	0.777	6.40	1.92	0.833	6.63	2.09	0.907
700	7.25	2.39	1.03	7.46	2.56	1.11	7.73	2.79	1.21
800	8.29	3.05	1.32	8.53	3.27	1.42	8.83	3.57	1.54
900	9.32	3.80	1.64	9.59	4.07	1.76	9.94	4.44	1.92

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

6 in. IPS (ASTM D2241)									
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi			DR 13.5 Pressure rated 315 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
50	0.576	0.0234	0.0101	0.608	0.0267	0.0116	0.655	0.0320	0.0139
75	0.864	0.0496	0.0215	0.912	0.0565	0.0245	0.983	0.0678	0.0294
100	1.15	0.0845	0.0366	1.22	0.0962	0.0417	1.31	0.116	0.0500
125	1.44	0.128	0.0553	1.52	0.145	0.0629	1.64	0.175	0.0756
150	1.73	0.179	0.0774	1.82	0.204	0.0882	1.97	0.245	0.106
175	2.02	0.238	0.103	2.13	0.271	0.117	2.29	0.325	0.141
200	2.30	0.304	0.132	2.43	0.347	0.150	2.62	0.416	0.180
225	2.59	0.379	0.164	2.74	0.431	0.187	2.95	0.518	0.224
250	2.88	0.460	0.199	3.04	0.524	0.227	3.28	0.629	0.272
300	3.46	0.645	0.279	3.65	0.734	0.318	3.93	0.882	0.382
350	4.03	0.857	0.371	4.26	0.977	0.423	4.59	1.17	0.508
400	4.61	1.10	0.475	4.86	1.25	0.541	5.24	1.50	0.650
450	5.19	1.36	0.591	5.47	1.55	0.673	5.90	1.87	0.808
500	5.76	1.66	0.718	6.08	1.89	0.818	6.55	2.27	0.982
600	6.91	2.32	1.01	7.30	2.65	1.15	7.87	3.18	1.38
700	8.07	3.09	1.34	8.51	3.52	1.52	9.18	4.23	1.83
800	9.22	3.96	1.71	9.73	4.51	1.95	10.5	5.41	2.34
900	10.4	4.92	2.13	10.9	5.60	2.43	11.8	6.73	2.91

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

8 in. IPS (ASTM D2241)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
90	0.550	0.0149	0.00644	0.566	0.0160	0.00691	0.586	0.0174	0.00753
120	0.733	0.0253	0.0110	0.755	0.0272	0.0118	0.782	0.0296	0.0128
150	0.917	0.0383	0.0166	0.943	0.0411	0.0178	0.977	0.0447	0.0194
200	1.22	0.0652	0.0282	1.26	0.0699	0.0303	1.30	0.0761	0.0330
250	1.53	0.0985	0.0427	1.57	0.106	0.0457	1.63	0.115	0.0498
300	1.83	0.138	0.0598	1.89	0.148	0.0641	1.95	0.161	0.0698
350	2.14	0.184	0.0795	2.20	0.197	0.0852	2.28	0.214	0.0928
400	2.44	0.235	0.102	2.52	0.252	0.109	2.61	0.274	0.119
500	3.06	0.355	0.154	3.14	0.381	0.165	3.26	0.415	0.180
600	3.67	0.498	0.215	3.77	0.534	0.231	3.91	0.581	0.252
700	4.28	0.662	0.287	4.40	0.710	0.307	4.56	0.773	0.335
800	4.89	0.847	0.367	5.03	0.908	0.393	5.21	0.990	0.428
900	5.50	1.05	0.456	5.66	1.13	0.489	5.86	1.23	0.533
1,000	6.11	1.28	0.554	6.29	1.37	0.594	6.52	1.50	0.647
1,100	6.72	1.53	0.661	6.92	1.64	0.709	7.17	1.78	0.772
1,200	7.33	1.79	0.777	7.55	1.92	0.833	7.82	2.10	0.907
1,400	8.56	2.39	1.03	8.81	2.56	1.11	9.12	2.79	1.21
1,600	9.78	3.05	1.32	10.1	3.27	1.42	10.4	3.57	1.54

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

8 in. IPS (ASTM D2241)						
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
90	0.612	0.0193	0.00834	0.646	0.0220	0.00952
120	0.816	0.0328	0.0142	0.861	0.0374	0.0162
150	1.02	0.0496	0.0215	1.08	0.0566	0.0245
200	1.36	0.0844	0.0365	1.44	0.0963	0.0417
250	1.70	0.128	0.0552	1.79	0.146	0.0630
300	2.04	0.179	0.0774	2.15	0.204	0.0883
350	2.38	0.238	0.103	2.51	0.271	0.117
400	2.72	0.304	0.132	2.87	0.347	0.150
500	3.40	0.460	0.199	3.59	0.525	0.227
600	4.08	0.644	0.279	4.31	0.735	0.318
700	4.76	0.857	0.371	5.02	0.978	0.423
800	5.44	1.10	0.475	5.74	1.25	0.542
900	6.12	1.36	0.591	6.46	1.56	0.674
1,000	6.80	1.66	0.718	7.18	1.89	0.819
1,100	7.48	1.98	0.856	7.89	2.26	0.977
1,200	8.16	2.32	1.01	8.61	2.65	1.15
1,400	9.52	3.09	1.34	10.0	3.52	1.53
1,600	10.9	3.95	1.71	11.5	4.51	1.95

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

10 in. IPS (ASTM D2241)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
150	0.590	0.0131	0.00568	0.607	0.0141	0.00610	0.629	0.0153	0.00664
200	0.787	0.0224	0.00968	0.810	0.0240	0.0104	0.839	0.0261	0.0113
250	0.984	0.0338	0.0146	1.01	0.0362	0.0157	1.05	0.0395	0.0171
300	1.18	0.0473	0.0205	1.21	0.0507	0.0220	1.26	0.0553	0.0239
400	1.57	0.0806	0.0349	1.62	0.0864	0.0374	1.68	0.0941	0.0408
500	1.97	0.122	0.0527	2.02	0.131	0.0565	2.10	0.142	0.0616
600	2.36	0.171	0.0739	2.43	0.183	0.0792	2.52	0.199	0.0863
700	2.75	0.227	0.0982	2.83	0.243	0.105	2.94	0.265	0.115
800	3.15	0.290	0.126	3.24	0.311	0.135	3.36	0.339	0.147
900	3.54	0.361	0.156	3.64	0.387	0.168	3.77	0.422	0.183
1,000	3.93	0.439	0.190	4.05	0.471	0.204	4.19	0.513	0.222
1,200	4.72	0.615	0.266	4.86	0.659	0.286	5.03	0.718	0.311
1,400	5.51	0.818	0.354	5.67	0.877	0.380	5.87	0.955	0.414
1,600	6.29	1.05	0.453	6.48	1.12	0.486	6.71	1.22	0.530
1,800	7.08	1.30	0.564	7.29	1.40	0.605	7.55	1.52	0.659
2,000	7.87	1.58	0.685	8.10	1.70	0.735	8.39	1.85	0.800
2,200	8.66	1.89	0.817	8.91	2.02	0.876	9.23	2.20	0.955
2,500	9.84	2.39	1.04	10.1	2.56	1.11	10.5	2.79	1.21

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

10 in. IPS (ASTM D2241)						
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
150	0.656	0.0170	0.00736	0.693	0.0194	0.00839
200	0.875	0.0289	0.0125	0.924	0.0330	0.0143
250	1.09	0.0437	0.0189	1.15	0.0499	0.0216
300	1.31	0.0613	0.0265	1.39	0.0698	0.0302
400	1.75	0.104	0.0452	1.85	0.119	0.0515
500	2.19	0.158	0.0683	2.31	0.180	0.0778
600	2.63	0.221	0.0956	2.77	0.252	0.109
700	3.06	0.294	0.127	3.23	0.335	0.145
800	3.50	0.376	0.163	3.69	0.429	0.186
900	3.94	0.468	0.202	4.16	0.533	0.231
1,000	4.38	0.568	0.246	4.62	0.648	0.281
1,200	5.25	0.796	0.345	5.54	0.908	0.393
1,400	6.13	1.06	0.459	6.47	1.21	0.523
1,600	7.00	1.36	0.587	7.39	1.55	0.669
1,800	7.88	1.69	0.730	8.31	1.92	0.832
2,000	8.75	2.05	0.887	9.24	2.34	1.01
2,200	9.63	2.44	1.06	10.2	2.79	1.21
2,500	10.9	3.10	1.34	11.5	3.53	1.53

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

12 in. IPS (ASTM D2241)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
200	0.559	0.00975	0.00422	0.576	0.0105	0.00453	0.596	0.0114	0.00493
300	0.839	0.0207	0.00894	0.864	0.0221	0.00959	0.894	0.0241	0.0104
400	1.12	0.0352	0.0152	1.15	0.0377	0.0163	1.19	0.0411	0.0178
500	1.40	0.0531	0.0230	1.44	0.0570	0.0247	1.49	0.0621	0.0269
600	1.68	0.0744	0.0322	1.73	0.0798	0.0346	1.79	0.0870	0.0377
700	1.96	0.0990	0.0429	2.01	0.106	0.0460	2.09	0.116	0.0501
800	2.24	0.127	0.0549	2.30	0.136	0.0589	2.39	0.148	0.0641
900	2.52	0.158	0.0683	2.59	0.169	0.0732	2.68	0.184	0.0797
1,000	2.80	0.192	0.0829	2.88	0.205	0.0889	2.98	0.224	0.0969
1,200	3.36	0.268	0.116	3.45	0.288	0.125	3.58	0.313	0.136
1,400	3.92	0.357	0.155	4.03	0.383	0.166	4.17	0.417	0.181
1,600	4.47	0.457	0.198	4.61	0.490	0.212	4.77	0.534	0.231
1,800	5.03	0.568	0.246	5.18	0.609	0.264	5.37	0.664	0.287
2,000	5.59	0.691	0.299	5.76	0.740	0.321	5.96	0.807	0.349
2,400	6.71	0.968	0.419	6.91	1.04	0.449	7.16	1.13	0.489
2,800	7.83	1.29	0.557	8.06	1.38	0.597	8.35	1.50	0.651
3,200	8.95	1.65	0.713	9.21	1.77	0.765	9.54	1.92	0.833
3,600	10.1	2.05	0.887	10.4	2.20	0.951	10.7	2.39	1.04

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

12 in. IPS (ASTM D2241)						
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
200	0.622	0.0126	0.00547	0.657	0.0144	0.00623
300	0.933	0.0267	0.0116	0.985	0.0305	0.0132
400	1.24	0.0455	0.0197	1.31	0.0519	0.0225
500	1.56	0.0688	0.0298	1.64	0.0784	0.0340
600	1.87	0.0964	0.0417	1.97	0.110	0.0476
700	2.18	0.128	0.0555	2.30	0.146	0.0633
800	2.49	0.164	0.0711	2.63	0.187	0.0810
900	2.80	0.204	0.0884	2.95	0.233	0.101
1,000	3.11	0.248	0.107	3.28	0.283	0.122
1,200	3.73	0.347	0.150	3.94	0.396	0.172
1,400	4.35	0.462	0.200	4.60	0.527	0.228
1,600	4.98	0.592	0.256	5.25	0.674	0.292
1,800	5.60	0.736	0.319	5.91	0.839	0.363
2,000	6.22	0.894	0.387	6.57	1.02	0.441
2,400	7.46	1.25	0.542	7.88	1.43	0.618
2,800	8.71	1.67	0.721	9.19	1.90	0.822
3,200	10.0	2.13	0.923	10.5	2.43	1.05
3,600	11.2	2.65	1.15	11.8	3.02	1.31

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

14 in. IPS (ASTM D2241 and AWWA C905)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
250	0.580	0.00936	0.00405	0.597	0.0100	0.00434	0.618	0.0109	0.00473
300	0.696	0.0131	0.00568	0.716	0.0140	0.00608	0.742	0.0153	0.00663
350	0.812	0.0174	0.00755	0.835	0.0187	0.00809	0.866	0.0204	0.00882
400	0.928	0.0223	0.00966	0.955	0.0239	0.0104	0.989	0.0261	0.0113
500	1.16	0.0337	0.0146	1.19	0.0361	0.0156	1.24	0.0394	0.0171
600	1.39	0.0473	0.0205	1.43	0.0506	0.0219	1.48	0.0552	0.0239
700	1.62	0.0628	0.0272	1.67	0.0674	0.0292	1.73	0.0734	0.0318
800	1.86	0.0805	0.0348	1.91	0.0862	0.0373	1.98	0.0940	0.0407
1,000	2.32	0.122	0.0526	2.39	0.130	0.0564	2.47	0.142	0.0615
1,200	2.78	0.170	0.0738	2.86	0.183	0.0790	2.97	0.199	0.0862
1,400	3.25	0.227	0.0981	3.34	0.243	0.105	3.46	0.265	0.115
1,600	3.71	0.290	0.126	3.82	0.311	0.135	3.96	0.339	0.147
2,000	4.64	0.438	0.190	4.77	0.470	0.203	4.95	0.512	0.222
2,400	5.57	0.614	0.266	5.73	0.658	0.285	5.93	0.717	0.311
2,800	6.50	0.817	0.354	6.68	0.875	0.379	6.92	0.954	0.413
3,200	7.42	1.05	0.453	7.64	1.12	0.485	7.91	1.22	0.529
3,700	8.58	1.37	0.592	8.83	1.47	0.635	9.15	1.60	0.692
4,200	9.74	1.73	0.749	10.0	1.85	0.802	10.4	2.02	0.875

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

14 in. IPS (ASTM D2241 and AWWA C905)						
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
250	0.645	0.0121	0.00525	0.681	0.0138	0.00598
300	0.774	0.0170	0.00735	0.817	0.0193	0.00837
350	0.903	0.0226	0.00978	0.953	0.0257	0.0111
400	1.03	0.0289	0.0125	1.09	0.0329	0.0143
500	1.29	0.0437	0.0189	1.36	0.0498	0.0215
600	1.55	0.0612	0.0265	1.63	0.0697	0.0302
700	1.81	0.0814	0.0352	1.91	0.0927	0.0401
800	2.06	0.104	0.0451	2.18	0.119	0.0514
1,000	2.58	0.157	0.0682	2.72	0.179	0.0777
1,200	3.10	0.221	0.0955	3.27	0.251	0.109
1,400	3.61	0.293	0.127	3.81	0.334	0.145
1,600	4.13	0.376	0.163	4.36	0.428	0.185
2,000	5.16	0.568	0.246	5.44	0.647	0.280
2,400	6.19	0.795	0.344	6.53	0.906	0.392
2,800	7.22	1.06	0.458	7.62	1.21	0.522
3,200	8.26	1.35	0.586	8.71	1.54	0.668
3,700	9.55	1.77	0.767	10.1	2.02	0.874
4,200	10.8	2.24	0.970	11.4	2.55	1.10

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

16 in. IPS (ASTM D2241 and AWWA C905)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
300	0.533	0.00685	0.00297	0.548	0.00735	0.00318	0.568	0.00800	0.00346
400	0.710	0.0117	0.00505	0.731	0.0125	0.00542	0.757	0.0136	0.00590
500	0.888	0.0176	0.00763	0.914	0.0189	0.00818	0.947	0.0206	0.00891
600	1.07	0.0247	0.0107	1.10	0.0265	0.0115	1.14	0.0288	0.0125
700	1.24	0.0328	0.0142	1.28	0.0352	0.0152	1.33	0.0384	0.0166
800	1.42	0.0420	0.0182	1.46	0.0451	0.0195	1.51	0.0491	0.0213
1,000	1.78	0.0635	0.0275	1.83	0.0681	0.0295	1.89	0.0742	0.0321
1,300	2.31	0.103	0.0447	2.38	0.111	0.0479	2.46	0.121	0.0522
1,600	2.84	0.152	0.0656	2.92	0.163	0.0704	3.03	0.177	0.0767
1,900	3.37	0.208	0.0902	3.47	0.223	0.0967	3.60	0.243	0.105
2,200	3.91	0.273	0.118	4.02	0.293	0.127	4.17	0.319	0.138
2,500	4.44	0.346	0.150	4.57	0.371	0.161	4.73	0.404	0.175
3,000	5.33	0.485	0.210	5.48	0.520	0.225	5.68	0.566	0.245
3,500	6.22	0.645	0.279	6.40	0.692	0.299	6.63	0.753	0.326
4,000	7.10	0.826	0.358	7.31	0.885	0.383	7.57	0.965	0.418
4,500	7.99	1.03	0.445	8.23	1.10	0.477	8.52	1.20	0.519
5,000	8.88	1.25	0.540	9.14	1.34	0.579	9.47	1.46	0.631
5,500	9.77	1.49	0.644	10.1	1.60	0.691	10.4	1.74	0.753

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

16 in. IPS (ASTM D2241 and AWWA C905)						
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
300	0.593	0.00888	0.00384	0.625	0.0101	0.00438
400	0.790	0.0151	0.00654	0.834	0.0172	0.00745
500	0.988	0.0228	0.00989	1.04	0.0260	0.0113
600	1.19	0.0320	0.0139	1.25	0.0364	0.0158
700	1.38	0.0426	0.0184	1.46	0.0485	0.0210
800	1.58	0.0545	0.0236	1.67	0.0621	0.0269
1,000	1.98	0.0823	0.0357	2.08	0.0938	0.0406
1,300	2.57	0.134	0.0579	2.71	0.152	0.0660
1,600	3.16	0.196	0.0851	3.34	0.224	0.0969
1,900	3.75	0.270	0.117	3.96	0.307	0.133
2,200	4.35	0.354	0.153	4.59	0.403	0.175
2,500	4.94	0.449	0.194	5.21	0.511	0.221
3,000	5.93	0.628	0.272	6.25	0.716	0.310
3,500	6.92	0.836	0.362	7.30	0.952	0.412
4,000	7.90	1.07	0.463	8.34	1.22	0.528
4,500	8.89	1.33	0.576	9.38	1.52	0.656
5,000	9.88	1.62	0.700	10.4	1.84	0.797
5,500	10.9	1.93	0.835	11.5	2.20	0.951

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

18 in. IPS (ASTM D2241 and AWWA C905)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
400	0.561	0.00658	0.00285	0.578	0.00706	0.00306	0.598	0.00769	0.00333
600	0.842	0.0139	0.00603	0.867	0.0149	0.00647	0.898	0.0163	0.00705
800	1.12	0.0237	0.0103	1.16	0.0254	0.0110	1.20	0.0277	0.0120
1,000	1.40	0.0358	0.0155	1.44	0.0384	0.0166	1.50	0.0419	0.0181
1,200	1.68	0.0502	0.0217	1.73	0.0539	0.0233	1.80	0.0587	0.0254
1,400	1.96	0.0668	0.0289	2.02	0.0716	0.0310	2.09	0.0780	0.0338
1,800	2.53	0.106	0.0460	2.60	0.114	0.0494	2.69	0.124	0.0538
2,200	3.09	0.154	0.0667	3.18	0.165	0.0716	3.29	0.180	0.0780
2,600	3.65	0.210	0.0909	3.75	0.225	0.0975	3.89	0.245	0.106
3,000	4.21	0.274	0.118	4.33	0.293	0.127	4.49	0.320	0.138
3,500	4.91	0.364	0.158	5.05	0.390	0.169	5.24	0.425	0.184
4,000	5.61	0.466	0.202	5.78	0.500	0.216	5.98	0.544	0.236
4,500	6.31	0.579	0.251	6.50	0.621	0.269	6.73	0.677	0.293
5,000	7.02	0.704	0.305	7.22	0.755	0.327	7.48	0.822	0.356
5,500	7.72	0.840	0.364	7.94	0.900	0.390	8.23	0.981	0.425
6,000	8.42	0.986	0.427	8.67	1.06	0.458	8.98	1.15	0.499
6,500	9.12	1.14	0.495	9.39	1.23	0.531	9.72	1.34	0.578
7,000	9.82	1.31	0.568	10.1	1.41	0.609	10.5	1.53	0.663

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

18 in. IPS (ASTM D2241 and AWWA C905)						
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
400	0.624	0.00853	0.00369	0.659	0.00971	0.00421
600	0.937	0.0181	0.00782	0.988	0.0206	0.00890
800	1.25	0.0307	0.0133	1.32	0.0350	0.0152
1,000	1.56	0.0465	0.0201	1.65	0.0529	0.0229
1,200	1.87	0.0651	0.0282	1.98	0.0741	0.0321
1,400	2.19	0.0866	0.0375	2.31	0.0986	0.0427
1,800	2.81	0.138	0.0597	2.96	0.157	0.0680
2,200	3.43	0.200	0.0865	3.62	0.228	0.0985
2,600	4.06	0.272	0.118	4.28	0.310	0.134
3,000	4.68	0.355	0.154	4.94	0.404	0.175
3,500	5.46	0.472	0.204	5.76	0.537	0.233
4,000	6.24	0.604	0.261	6.59	0.688	0.298
4,500	7.03	0.751	0.325	7.41	0.855	0.370
5,000	7.81	0.912	0.395	8.24	1.04	0.450
5,500	8.59	1.09	0.471	9.06	1.24	0.537
6,000	9.37	1.28	0.553	9.88	1.46	0.630
6,500	10.1	1.48	0.642	10.7	1.69	0.731
7,000	10.9	1.70	0.736	11.5	1.94	0.838

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

20 in. IPS (ASTM D2241 and AWWA C905)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
500	0.568	0.00596	0.00258	0.585	0.00639	0.00277	0.606	0.00696	0.00301
800	0.909	0.0142	0.00616	0.936	0.0152	0.00660	0.969	0.0166	0.00719
1,100	1.25	0.0256	0.0111	1.29	0.0275	0.0119	1.33	0.0299	0.0130
1,400	1.59	0.0400	0.0173	1.64	0.0429	0.0186	1.70	0.0468	0.0202
1,700	1.93	0.0573	0.0248	1.99	0.0615	0.0266	2.06	0.0670	0.0290
2,000	2.27	0.0774	0.0335	2.34	0.0830	0.0360	2.42	0.0905	0.0392
2,500	2.84	0.117	0.0507	2.92	0.125	0.0543	3.03	0.137	0.0592
3,000	3.41	0.164	0.0710	3.51	0.176	0.0761	3.64	0.192	0.0829
3,500	3.98	0.218	0.0944	4.09	0.234	0.101	4.24	0.255	0.110
4,000	4.55	0.279	0.121	4.68	0.299	0.130	4.85	0.326	0.141
4,500	5.11	0.347	0.150	5.26	0.372	0.161	5.45	0.405	0.176
5,000	5.68	0.422	0.183	5.85	0.452	0.196	6.06	0.493	0.213
5,500	6.25	0.503	0.218	6.43	0.540	0.234	6.66	0.588	0.254
6,000	6.82	0.591	0.256	7.02	0.634	0.274	7.27	0.690	0.299
6,500	7.39	0.685	0.297	7.60	0.735	0.318	7.88	0.801	0.347
7,000	7.96	0.786	0.340	8.19	0.843	0.365	8.48	0.918	0.398
7,500	8.52	0.893	0.387	8.77	0.958	0.415	9.09	1.04	0.452
8,000	9.09	1.01	0.436	9.36	1.08	0.467	9.69	1.18	0.509

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

20 in. IPS (ASTM D2241 and AWWA C905)						
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
500	0.632	0.00772	0.00334	0.667	0.00879	0.00381
800	1.01	0.0184	0.00798	1.07	0.0210	0.00909
1,100	1.39	0.0332	0.0144	1.47	0.0378	0.0164
1,400	1.77	0.0519	0.0225	1.87	0.0591	0.0256
1,700	2.15	0.0743	0.0322	2.27	0.0846	0.0366
2,000	2.53	0.100	0.0435	2.67	0.114	0.0495
2,500	3.16	0.152	0.0657	3.34	0.173	0.0748
3,000	3.79	0.212	0.0920	4.00	0.242	0.105
3,500	4.43	0.283	0.122	4.67	0.322	0.139
4,000	5.06	0.362	0.157	5.34	0.412	0.178
4,500	5.69	0.450	0.195	6.00	0.512	0.222
5,000	6.32	0.547	0.237	6.67	0.623	0.270
5,500	6.96	0.652	0.282	7.34	0.743	0.322
6,000	7.59	0.766	0.332	8.00	0.872	0.378
6,500	8.22	0.888	0.385	8.67	1.01	0.438
7,000	8.85	1.02	0.441	9.34	1.16	0.502
7,500	9.48	1.16	0.501	10.0	1.32	0.571
8,000	10.1	1.30	0.565	10.7	1.49	0.643

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

24 in. IPS (ASTM D2241 and AWWA C905)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
700	0.553	0.00458	0.00198	0.569	0.00491	0.00213	0.589	0.00535	0.00232
1,100	0.868	0.0106	0.00457	0.894	0.0113	0.00490	0.926	0.0123	0.00534
1,500	1.18	0.0187	0.00812	1.22	0.0201	0.00871	1.26	0.0219	0.00948
2,000	1.58	0.0319	0.0138	1.62	0.0342	0.0148	1.68	0.0373	0.0161
2,500	1.97	0.0482	0.0209	2.03	0.0517	0.0224	2.10	0.0563	0.0244
3,000	2.37	0.0676	0.0293	2.44	0.0725	0.0314	2.52	0.0790	0.0342
3,500	2.76	0.0899	0.0389	2.84	0.0964	0.0417	2.95	0.105	0.0455
4,000	3.16	0.115	0.0498	3.25	0.123	0.0534	3.37	0.134	0.0582
4,500	3.55	0.143	0.0620	3.66	0.153	0.0664	3.79	0.167	0.0724
5,000	3.95	0.174	0.0753	4.06	0.186	0.0807	4.21	0.203	0.0880
5,500	4.34	0.207	0.0898	4.47	0.222	0.0963	4.63	0.242	0.105
6,000	4.74	0.244	0.106	4.87	0.261	0.113	5.05	0.285	0.123
7,000	5.53	0.324	0.140	5.69	0.348	0.150	5.89	0.379	0.164
8,000	6.31	0.415	0.180	6.50	0.445	0.193	6.73	0.485	0.210
9,000	7.10	0.516	0.223	7.31	0.553	0.240	7.57	0.603	0.261
10,000	7.89	0.627	0.271	8.12	0.672	0.291	8.41	0.732	0.317
11,000	8.68	0.748	0.324	8.94	0.802	0.347	9.26	0.874	0.378
12,000	9.47	0.878	0.380	9.75	0.942	0.408	10.1	1.03	0.444

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

24 in. IPS (ASTM D2241 and AWWA C905)						
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
700	0.615	0.00593	0.00257	0.649	0.00676	0.00293
1,100	0.966	0.0137	0.00593	1.02	0.0156	0.00675
1,500	1.32	0.0243	0.0105	1.39	0.0277	0.0120
2,000	1.76	0.0414	0.0179	1.85	0.0471	0.0204
2,500	2.20	0.0625	0.0271	2.32	0.0712	0.0308
3,000	2.63	0.0876	0.0379	2.78	0.100	0.0432
3,500	3.07	0.116	0.0504	3.24	0.133	0.0575
4,000	3.51	0.149	0.0646	3.71	0.170	0.0736
4,500	3.95	0.185	0.0803	4.17	0.211	0.0915
5,000	4.39	0.225	0.0976	4.63	0.257	0.111
5,500	4.83	0.269	0.116	5.10	0.306	0.133
6,000	5.27	0.316	0.137	5.56	0.360	0.156
7,000	6.15	0.420	0.182	6.49	0.478	0.207
8,000	7.03	0.538	0.233	7.41	0.612	0.265
9,000	7.90	0.669	0.289	8.34	0.761	0.330
10,000	8.78	0.812	0.352	9.27	0.925	0.401
11,000	9.66	0.969	0.420	10.2	1.10	0.478
12,000	10.5	1.14	0.493	11.1	1.30	0.561

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

30 in. IPS (ASTM D2241 and AWWA C905)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
1,000	0.505	0.00299	0.00130	0.520	0.00321	0.00139	0.539	0.00350	0.00151
1,500	0.758	0.00634	0.00274	0.780	0.00680	0.00294	0.808	0.00740	0.00321
2,000	1.01	0.0108	0.00467	1.04	0.0116	0.00501	1.08	0.0126	0.00546
2,500	1.26	0.0163	0.00706	1.30	0.0175	0.00757	1.35	0.0191	0.00825
3,000	1.52	0.0229	0.00989	1.56	0.0245	0.0106	1.62	0.0267	0.0116
3,800	1.92	0.0354	0.0153	1.98	0.0379	0.0164	2.05	0.0413	0.0179
4,600	2.32	0.0504	0.0218	2.39	0.0540	0.0234	2.48	0.0589	0.0255
5,400	2.73	0.0678	0.0294	2.81	0.0727	0.0315	2.91	0.0792	0.0343
6,200	3.13	0.0875	0.0379	3.22	0.0939	0.0406	3.34	0.102	0.0443
7,000	3.54	0.110	0.0474	3.64	0.117	0.0509	3.77	0.128	0.0554
8,500	4.29	0.157	0.0679	4.42	0.168	0.0729	4.58	0.183	0.0794
10,000	5.05	0.212	0.0918	5.20	0.227	0.0984	5.39	0.248	0.107
11,500	5.81	0.274	0.119	5.98	0.294	0.127	6.19	0.321	0.139
13,000	6.57	0.344	0.149	6.76	0.369	0.160	7.00	0.402	0.174
14,500	7.33	0.421	0.183	7.54	0.452	0.196	7.81	0.492	0.213
16,000	8.08	0.506	0.219	8.32	0.542	0.235	8.62	0.591	0.256
18,000	9.09	0.629	0.272	9.36	0.674	0.292	9.69	0.734	0.318
20,000	10.1	0.764	0.331	10.4	0.819	0.355	10.8	0.893	0.386

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

30 in. IPS (ASTM D2241 and AWWA C905)						
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
1,000	0.562	0.00388	0.00168	0.593	0.00442	0.00191
1,500	0.843	0.00821	0.00356	0.889	0.00936	0.00405
2,000	1.12	0.0140	0.00605	1.19	0.0159	0.00690
2,500	1.40	0.0211	0.00915	1.48	0.0241	0.0104
3,000	1.69	0.0296	0.0128	1.78	0.0337	0.0146
3,800	2.14	0.0458	0.0199	2.25	0.0522	0.0226
4,600	2.59	0.0653	0.0283	2.73	0.0744	0.0322
5,400	3.03	0.0878	0.0380	3.20	0.100	0.0433
6,200	3.48	0.113	0.0491	3.68	0.129	0.0559
7,000	3.93	0.142	0.0615	4.15	0.162	0.0700
8,500	4.78	0.203	0.0880	5.04	0.232	0.100
10,000	5.62	0.275	0.119	5.93	0.313	0.135
11,500	6.46	0.356	0.154	6.82	0.405	0.175
13,000	7.31	0.446	0.193	7.71	0.508	0.220
14,500	8.15	0.546	0.236	8.60	0.622	0.269
16,000	8.99	0.655	0.284	9.49	0.746	0.323
18,000	10.1	0.815	0.353	10.7	0.928	0.402
20,000	11.2	0.990	0.429	11.9	1.13	0.488

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

36 in. IPS (ASTM D2241 and AWWA C905)									
Flow, gpm	DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi			DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
1,500	0.526	0.00261	0.00113	0.542	0.00280	0.00121	0.561	0.00305	0.00132
2,000	0.702	0.00445	0.00193	0.722	0.00477	0.00207	0.748	0.00520	0.00225
2,500	0.877	0.00672	0.00291	0.903	0.00721	0.00312	0.935	0.00785	0.00340
3,000	1.05	0.00942	0.00408	1.08	0.0101	0.00437	1.12	0.0110	0.00476
4,000	1.40	0.0160	0.00695	1.44	0.0172	0.00745	1.50	0.0187	0.00811
5,000	1.75	0.0242	0.0105	1.81	0.0260	0.0113	1.87	0.0283	0.0123
6,000	2.10	0.0340	0.0147	2.17	0.0364	0.0158	2.24	0.0397	0.0172
7,000	2.46	0.0452	0.0196	2.53	0.0484	0.0210	2.62	0.0528	0.0228
8,000	2.81	0.0578	0.0250	2.89	0.0620	0.0269	2.99	0.0675	0.0292
9,000	3.16	0.0719	0.0311	3.25	0.0771	0.0334	3.37	0.0840	0.0364
10,000	3.51	0.0874	0.0378	3.61	0.0937	0.0406	3.74	0.102	0.0442
12,000	4.21	0.122	0.0530	4.33	0.131	0.0568	4.49	0.143	0.0619
14,000	4.91	0.163	0.0705	5.05	0.175	0.0756	5.24	0.190	0.0824
16,000	5.61	0.208	0.0903	5.78	0.224	0.0968	5.98	0.244	0.105
18,000	6.31	0.259	0.112	6.50	0.278	0.120	6.73	0.303	0.131
20,000	7.02	0.315	0.136	7.22	0.338	0.146	7.48	0.368	0.159
24,000	8.42	0.441	0.191	8.67	0.473	0.205	8.98	0.516	0.223
28,000	9.82	0.587	0.254	10.1	0.629	0.273	10.5	0.686	0.297

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.4 Flow friction loss, ASTM D2241 and AWWA C905 IPS OD PVC pipe (*continued*)

36 in. IPS (ASTM D2241 and AWWA C905)						
Flow, gpm	DR 21 Pressure rated 200 psi			DR 17 Pressure rated 250 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
1,500	0.585	0.00339	0.00147	0.618	0.00386	0.00167
2,000	0.781	0.00577	0.00250	0.824	0.00657	0.00284
2,500	0.976	0.00871	0.00377	1.03	0.00992	0.00430
3,000	1.17	0.0122	0.00529	1.24	0.0139	0.00602
4,000	1.56	0.0208	0.00900	1.65	0.0237	0.0103
5,000	1.95	0.0314	0.0136	2.06	0.0358	0.0155
6,000	2.34	0.0440	0.0191	2.47	0.0501	0.0217
7,000	2.73	0.0585	0.0253	2.88	0.0667	0.0289
8,000	3.12	0.0749	0.0324	3.29	0.0854	0.0370
9,000	3.51	0.0932	0.0403	3.71	0.106	0.0460
10,000	3.90	0.113	0.0490	4.12	0.129	0.0558
12,000	4.68	0.159	0.0687	4.94	0.181	0.0782
14,000	5.46	0.211	0.0914	5.76	0.240	0.104
16,000	6.24	0.270	0.117	6.59	0.308	0.133
18,000	7.03	0.336	0.145	7.41	0.383	0.166
20,000	7.81	0.408	0.177	8.24	0.465	0.201
24,000	9.37	0.572	0.248	9.88	0.651	0.282
28,000	10.9	0.761	0.329	11.5	0.866	0.375

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe

6 in. PIP (ASTM D2241)									
Flow, gpm	DR 51 Pressure rated 80 psi			DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
50	0.590	0.0248	0.0108	0.603	0.0262	0.0113	0.621	0.0281	0.0121
75	0.885	0.0526	0.0228	0.905	0.0554	0.0240	0.931	0.0594	0.0257
100	1.18	0.0896	0.0388	1.21	0.0943	0.0408	1.24	0.101	0.0438
125	1.48	0.135	0.0586	1.51	0.143	0.0617	1.55	0.153	0.0662
150	1.77	0.190	0.0821	1.81	0.200	0.0865	1.86	0.214	0.0927
175	2.07	0.252	0.109	2.11	0.266	0.115	2.17	0.285	0.123
200	2.36	0.323	0.140	2.41	0.340	0.147	2.48	0.365	0.158
225	2.66	0.401	0.174	2.71	0.423	0.183	2.79	0.453	0.196
250	2.95	0.488	0.211	3.02	0.514	0.222	3.10	0.551	0.239
300	3.54	0.684	0.296	3.62	0.720	0.312	3.72	0.772	0.334
350	4.13	0.909	0.394	4.22	0.957	0.415	4.34	1.03	0.445
400	4.72	1.16	0.504	4.82	1.23	0.531	4.96	1.31	0.569
450	5.31	1.45	0.627	5.43	1.52	0.660	5.59	1.63	0.708
500	5.90	1.76	0.762	6.03	1.85	0.802	6.21	1.99	0.860
600	7.08	2.46	1.07	7.24	2.59	1.12	7.45	2.78	1.20
700	8.26	3.28	1.42	8.44	3.45	1.49	8.69	3.70	1.60
800	9.45	4.20	1.82	9.65	4.42	1.91	9.93	4.74	2.05
900	10.6	5.22	2.26	10.9	5.49	2.38	11.2	5.89	2.55

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe (*continued*)

8 in. PIP (ASTM D2241)									
Flow, gpm	DR 51 Pressure rated 80 psi			DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
75	0.501	0.0132	0.00572	0.512	0.0139	0.00602	0.527	0.0149	0.00646
100	0.668	0.0225	0.00973	0.683	0.0237	0.0103	0.703	0.0254	0.0110
125	0.836	0.0340	0.0147	0.854	0.0358	0.0155	0.878	0.0384	0.0166
150	1.00	0.0476	0.0206	1.02	0.0501	0.0217	1.05	0.0537	0.0233
200	1.34	0.0810	0.0351	1.37	0.0853	0.0370	1.41	0.0915	0.0396
250	1.67	0.122	0.0530	1.71	0.129	0.0558	1.76	0.138	0.0599
300	2.01	0.172	0.0743	2.05	0.181	0.0782	2.11	0.194	0.0839
350	2.34	0.228	0.0988	2.39	0.240	0.104	2.46	0.258	0.112
400	2.67	0.292	0.127	2.73	0.308	0.133	2.81	0.330	0.143
500	3.34	0.441	0.191	3.41	0.465	0.201	3.51	0.498	0.216
600	4.01	0.619	0.268	4.10	0.651	0.282	4.22	0.698	0.302
700	4.68	0.823	0.356	4.78	0.866	0.375	4.92	0.929	0.402
800	5.35	1.05	0.456	5.46	1.11	0.480	5.62	1.19	0.515
900	6.02	1.31	0.567	6.15	1.38	0.597	6.32	1.48	0.640
1,000	6.68	1.59	0.689	6.83	1.68	0.726	7.03	1.80	0.778
1,200	8.02	2.23	0.966	8.19	2.35	1.02	8.43	2.52	1.09
1,400	9.36	2.97	1.28	9.56	3.12	1.35	9.84	3.35	1.45
1,600	10.7	3.80	1.64	10.9	4.00	1.73	11.2	4.29	1.86

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe (*continued*)

10 in. PIP (ASTM D2241)									
Flow, gpm	DR 51 Pressure rated 80 psi			DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
125	0.535	0.0115	0.00497	0.546	0.0121	0.00524	0.562	0.0130	0.00561
150	0.642	0.0161	0.00697	0.656	0.0169	0.00734	0.675	0.0182	0.00787
175	0.749	0.0214	0.00927	0.765	0.0225	0.00976	0.787	0.0242	0.0105
200	0.856	0.0274	0.0119	0.874	0.0289	0.0125	0.899	0.0309	0.0134
250	1.07	0.0414	0.0179	1.09	0.0436	0.0189	1.12	0.0467	0.0202
300	1.28	0.0580	0.0251	1.31	0.0611	0.0264	1.35	0.0655	0.0284
350	1.50	0.0772	0.0334	1.53	0.0812	0.0352	1.57	0.0871	0.0377
400	1.71	0.0988	0.0428	1.75	0.104	0.0450	1.80	0.112	0.0483
500	2.14	0.149	0.0646	2.19	0.157	0.0681	2.25	0.169	0.0730
600	2.57	0.209	0.0905	2.62	0.220	0.0954	2.70	0.236	0.102
700	2.99	0.278	0.120	3.06	0.293	0.127	3.15	0.314	0.136
800	3.42	0.356	0.154	3.50	0.375	0.162	3.60	0.402	0.174
1,100	4.71	0.642	0.278	4.81	0.676	0.293	4.95	0.725	0.314
1,400	5.99	1.00	0.434	6.12	1.06	0.457	6.30	1.13	0.490
1,700	7.27	1.44	0.622	7.43	1.51	0.655	7.65	1.62	0.702
2,000	8.56	1.94	0.840	8.74	2.04	0.884	8.99	2.19	0.948
2,300	9.84	2.51	1.09	10.1	2.65	1.15	10.3	2.84	1.23
2,600	11.1	3.15	1.36	11.4	3.32	1.44	11.7	3.56	1.54

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe (*continued*)

12 in. PIP (ASTM D2241)									
Flow, gpm	DR 51 Pressure rated 80 psi			DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
200	0.594	0.0113	0.00489	0.607	0.0119	0.00515	0.625	0.0128	0.00552
300	0.891	0.0239	0.0104	0.910	0.0252	0.0109	0.937	0.0270	0.0117
400	1.19	0.0407	0.0176	1.21	0.0429	0.0186	1.25	0.0460	0.0199
500	1.49	0.0615	0.0266	1.52	0.0648	0.0281	1.56	0.0695	0.0301
600	1.78	0.0862	0.0373	1.82	0.0908	0.0393	1.87	0.0973	0.0422
700	2.08	0.115	0.0496	2.12	0.121	0.0523	2.19	0.129	0.0561
800	2.38	0.147	0.0636	2.43	0.155	0.0669	2.50	0.166	0.0718
1,000	2.97	0.222	0.0960	3.03	0.234	0.101	3.12	0.250	0.108
1,200	3.57	0.311	0.135	3.64	0.327	0.142	3.75	0.351	0.152
1,400	4.16	0.413	0.179	4.25	0.435	0.188	4.37	0.467	0.202
1,700	5.05	0.592	0.256	5.16	0.623	0.270	5.31	0.668	0.289
2,000	5.94	0.800	0.346	6.07	0.842	0.365	6.25	0.903	0.391
2,300	6.83	1.04	0.448	6.98	1.09	0.472	7.18	1.17	0.506
2,600	7.72	1.30	0.563	7.89	1.37	0.592	8.12	1.47	0.635
2,900	8.62	1.59	0.689	8.80	1.67	0.725	9.06	1.80	0.777
3,200	9.51	1.91	0.826	9.71	2.01	0.870	10.0	2.15	0.933
3,500	10.4	2.25	0.975	10.6	2.37	1.03	10.9	2.54	1.10
3,800	11.3	2.62	1.14	11.5	2.76	1.20	11.9	2.96	1.28

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe (*continued*)

15 in. PIP (ASTM D2241)									
Flow, gpm	DR 51 Pressure rated 80 psi			DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
300	0.570	0.00809	0.00350	0.583	0.00851	0.00369	0.600	0.00913	0.00395
450	0.856	0.0171	0.00741	0.874	0.0180	0.00781	0.899	0.0193	0.00837
600	1.14	0.0291	0.0126	1.17	0.0307	0.0133	1.20	0.0329	0.0143
800	1.52	0.0496	0.0215	1.55	0.0523	0.0226	1.60	0.0560	0.0243
1,000	1.90	0.0750	0.0325	1.94	0.0790	0.0342	2.00	0.0847	0.0367
1,200	2.28	0.105	0.0455	2.33	0.111	0.0479	2.40	0.119	0.0514
1,500	2.85	0.159	0.0687	2.91	0.167	0.0724	3.00	0.179	0.0776
1,800	3.42	0.222	0.0963	3.50	0.234	0.101	3.60	0.251	0.109
2,100	3.99	0.296	0.128	4.08	0.312	0.135	4.20	0.334	0.145
2,400	4.56	0.379	0.164	4.66	0.399	0.173	4.80	0.428	0.185
2,800	5.32	0.504	0.218	5.44	0.531	0.230	5.60	0.569	0.246
3,200	6.08	0.645	0.279	6.22	0.679	0.294	6.40	0.728	0.315
3,600	6.85	0.802	0.347	6.99	0.845	0.366	7.20	0.906	0.392
4,000	7.61	0.975	0.422	7.77	1.03	0.444	8.00	1.10	0.477
4,400	8.37	1.16	0.503	8.55	1.22	0.530	8.80	1.31	0.568
4,800	9.13	1.37	0.591	9.32	1.44	0.623	9.59	1.54	0.668
5,200	9.89	1.58	0.686	10.1	1.67	0.722	10.4	1.79	0.774
5,600	10.6	1.82	0.786	10.9	1.91	0.828	11.2	2.05	0.888

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe (*continued*)

15 in. PIP (ASTM D2241)						
Flow, gpm	DR 26 Pressure rated 160 psi			DR 21 Pressure rated 200 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
300	0.621	0.00994	0.00431	0.648	0.0110	0.00478
450	0.932	0.0211	0.00912	0.972	0.0234	0.0101
600	1.24	0.0359	0.0155	1.30	0.0398	0.0172
800	1.66	0.0610	0.0264	1.73	0.0677	0.0293
1,000	2.07	0.0922	0.0399	2.16	0.102	0.0443
1,200	2.48	0.129	0.0560	2.59	0.143	0.0621
1,500	3.11	0.195	0.0846	3.24	0.217	0.0938
1,800	3.73	0.274	0.118	3.89	0.304	0.131
2,000	4.14	0.333	0.144	4.32	0.369	0.160
2,400	4.97	0.466	0.202	5.19	0.517	0.224
2,800	5.80	0.620	0.268	6.05	0.687	0.298
3,200	6.63	0.793	0.344	6.91	0.880	0.381
3,600	7.45	0.986	0.427	7.78	1.09	0.474
4,000	8.28	1.20	0.519	8.64	1.33	0.576
4,400	9.11	1.43	0.619	9.51	1.59	0.687
4,800	9.94	1.68	0.727	10.4	1.86	0.807
5,200	10.8	1.95	0.843	11.2	2.16	0.936
5,600	11.6	2.23	0.967	12.1	2.48	1.07

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe (*continued*)

18 in. PIP (ASTM D2241)									
Flow, gpm	DR 51 Pressure rated 80 psi			DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
400	0.509	0.00519	0.00225	0.520	0.00547	0.00237	0.535	0.00586	0.00254
700	0.891	0.0146	0.00633	0.910	0.0154	0.00666	0.937	0.0165	0.00715
1,000	1.27	0.0283	0.0122	1.30	0.0298	0.0129	1.34	0.0319	0.0138
1,300	1.65	0.0459	0.0199	1.69	0.0484	0.0209	1.74	0.0519	0.0225
1,700	2.16	0.0755	0.0327	2.21	0.0795	0.0344	2.27	0.0852	0.0369
2,100	2.67	0.112	0.0483	2.73	0.117	0.0509	2.81	0.126	0.0545
2,500	3.18	0.154	0.0667	3.25	0.162	0.0702	3.34	0.174	0.0753
3,000	3.82	0.216	0.0934	3.90	0.227	0.0984	4.01	0.244	0.106
3,500	4.45	0.287	0.124	4.55	0.302	0.131	4.68	0.324	0.140
4,000	5.09	0.367	0.159	5.20	0.387	0.168	5.35	0.415	0.180
4,500	5.73	0.457	0.198	5.85	0.481	0.208	6.02	0.516	0.223
5,000	6.36	0.555	0.240	6.50	0.585	0.253	6.69	0.627	0.271
5,500	7.00	0.662	0.287	7.15	0.697	0.302	7.36	0.748	0.324
6,000	7.64	0.778	0.337	7.80	0.819	0.355	8.03	0.878	0.380
6,600	8.40	0.928	0.402	8.58	0.977	0.423	8.83	1.05	0.454
7,200	9.16	1.09	0.472	9.36	1.15	0.497	9.63	1.23	0.533
7,800	9.93	1.26	0.547	10.1	1.33	0.576	10.4	1.43	0.618
8,400	10.7	1.45	0.628	10.9	1.53	0.661	11.2	1.64	0.709

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe (*continued*)

18 in. PIP (ASTM D2241)			
Flow, gpm	DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft
400	0.554	0.00638	0.00276
700	0.970	0.0180	0.00778
1,000	1.39	0.0348	0.0151
1,300	1.80	0.0565	0.0245
1,700	2.36	0.0928	0.0402
2,100	2.91	0.137	0.0594
2,500	3.46	0.189	0.0820
3,000	4.16	0.265	0.115
3,500	4.85	0.353	0.153
4,000	5.54	0.452	0.196
4,500	6.24	0.562	0.243
5,000	6.93	0.683	0.296
5,500	7.62	0.815	0.353
6,000	8.32	0.957	0.414
6,600	9.15	1.14	0.494
7,200	9.98	1.34	0.581
7,800	10.8	1.55	0.673
8,400	11.6	1.78	0.772

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe (*continued*)

21 in. PIP (ASTM D2241)									
Flow, gpm	DR 51 Pressure rated 80 psi			DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
600	0.549	0.00494	0.00214	0.561	0.00520	0.00225	0.578	0.00558	0.00241
1,000	0.916	0.0127	0.00550	0.935	0.0134	0.00579	0.963	0.0143	0.00621
1,500	1.37	0.0269	0.0116	1.40	0.0283	0.0123	1.44	0.0304	0.0132
2,000	1.83	0.0458	0.0198	1.87	0.0482	0.0209	1.93	0.0517	0.0224
2,500	2.29	0.0692	0.0300	2.34	0.0729	0.0316	2.41	0.0781	0.0338
3,000	2.75	0.0970	0.0420	2.81	0.102	0.0442	2.89	0.109	0.0474
3,500	3.20	0.129	0.0558	3.27	0.136	0.0588	3.37	0.146	0.0631
4,000	3.66	0.165	0.0715	3.74	0.174	0.0753	3.85	0.186	0.0807
4,500	4.12	0.205	0.0889	4.21	0.216	0.0936	4.33	0.232	0.100
5,000	4.58	0.249	0.108	4.68	0.263	0.114	4.81	0.282	0.122
5,800	5.31	0.328	0.142	5.43	0.346	0.150	5.58	0.371	0.161
6,600	6.04	0.417	0.181	6.17	0.439	0.190	6.35	0.471	0.204
7,400	6.78	0.515	0.223	6.92	0.543	0.235	7.12	0.582	0.252
8,200	7.51	0.623	0.270	7.67	0.656	0.284	7.89	0.703	0.305
9,000	8.24	0.740	0.320	8.42	0.779	0.337	8.66	0.836	0.362
10,000	9.16	0.899	0.389	9.35	0.947	0.410	9.63	1.02	0.440
11,000	10.1	1.07	0.465	10.3	1.13	0.489	10.6	1.21	0.525
12,000	11.0	1.26	0.546	11.2	1.33	0.575	11.6	1.42	0.616

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe (*continued*)

21 in. PIP (ASTM D2241)			
Flow, gpm	DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft
600	0.598	0.00607	0.00263
1,000	1.00	0.0156	0.00677
1,500	1.50	0.0331	0.0143
2,000	1.99	0.0563	0.0244
2,500	2.49	0.0851	0.0369
3,000	2.99	0.119	0.0516
3,500	3.49	0.159	0.0687
4,000	3.99	0.203	0.0879
4,500	4.49	0.253	0.109
5,000	4.99	0.307	0.133
5,800	5.78	0.404	0.175
6,600	6.58	0.513	0.222
7,400	7.38	0.634	0.274
8,200	8.18	0.766	0.332
9,000	8.97	0.910	0.394
10,000	10.0	1.11	0.479
11,000	11.0	1.32	0.571
12,000	12.0	1.55	0.671

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe (*continued*)

24 in. PIP (ASTM D2241)									
Flow, gpm	DR 51 Pressure rated 80 psi			DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
800	0.579	0.00474	0.00205	0.591	0.00499	0.00216	0.608	0.00536	0.00232
1,200	0.868	0.0100	0.00435	0.887	0.0106	0.00458	0.913	0.0113	0.00491
1,600	1.16	0.0171	0.00740	1.18	0.0180	0.00780	1.22	0.0193	0.00836
2,000	1.45	0.0258	0.0112	1.48	0.0272	0.0118	1.52	0.0292	0.0126
2,500	1.81	0.0390	0.0169	1.85	0.0411	0.0178	1.90	0.0441	0.0191
3,000	2.17	0.0547	0.0237	2.22	0.0576	0.0249	2.28	0.0618	0.0267
4,000	2.89	0.0931	0.0403	2.96	0.0981	0.0425	3.04	0.105	0.0455
5,000	3.62	0.141	0.0609	3.70	0.148	0.0642	3.80	0.159	0.0688
6,000	4.34	0.197	0.0854	4.43	0.208	0.0899	4.56	0.223	0.0964
7,000	5.06	0.262	0.114	5.17	0.276	0.120	5.32	0.296	0.128
8,000	5.79	0.336	0.145	5.91	0.354	0.153	6.08	0.379	0.164
9,000	6.51	0.418	0.181	6.65	0.440	0.190	6.85	0.471	0.204
10,000	7.24	0.507	0.220	7.39	0.534	0.231	7.61	0.573	0.248
11,000	7.96	0.605	0.262	8.13	0.637	0.276	8.37	0.683	0.296
12,000	8.68	0.711	0.308	8.87	0.749	0.324	9.13	0.803	0.348
13,000	9.41	0.824	0.357	9.61	0.868	0.376	9.89	0.931	0.403
14,000	10.1	0.945	0.409	10.3	1.00	0.431	10.6	1.07	0.462
15,000	10.9	1.07	0.465	11.1	1.13	0.490	11.4	1.21	0.525

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe (*continued*)

24 in. PIP (ASTM D2241)			
Flow, gpm	DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft
800	0.630	0.00583	0.00253
1,200	0.945	0.0124	0.00535
16,000	12.61	1.4888	0.64467
16,400	12.92	1.5584	0.6748
16,900	13.31	1.6475	0.7134
17,400	13.71	1.7388	0.7529
18,400	14.50	1.928	0.8349
19,400	15.28	2.126	0.9208
20,400	16.07	2.334	1.010
21,400	16.86	2.550	1.104
22,400	17.65	2.775	1.201
23,400	18.44	3.008	1.302
24,400	19.22	3.250	1.407
25,400	20.01	3.501	1.516
26,400	20.80	3.760	1.628
27,400	21.6	4.03	1.744
28,400	22.4	4.30	1.864
29,400	23.2	4.59	1.987

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe (*continued*)

27 in. PIP (ASTM D2241)									
Flow, gpm	DR 51 Pressure rated 80 psi			DR 41 Pressure rated 100 psi			DR 32.5 Pressure rated 125 psi		
	Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop		Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft		ft H_2O/100 ft	psi/100 ft
1,000	0.570	0.00401	0.00174	0.582	0.00422	0.00183	0.599	0.00453	0.00196
1,500	0.854	0.00849	0.00367	0.873	0.00894	0.00387	0.898	0.00958	0.00415
2,000	1.14	0.0145	0.00626	1.16	0.0152	0.00659	1.20	0.0163	0.00707
2,500	1.42	0.0218	0.00945	1.45	0.0230	0.0100	1.50	0.0247	0.0107
3,000	1.71	0.0306	0.0132	1.75	0.0322	0.0140	1.80	0.0345	0.0150
3,500	1.99	0.0407	0.0176	2.04	0.0428	0.0186	2.10	0.0459	0.0199
4,000	2.28	0.0521	0.0226	2.33	0.0549	0.0238	2.40	0.0588	0.0255
5,000	2.85	0.0787	0.0341	2.91	0.0829	0.0359	2.99	0.0889	0.0385
6,000	3.42	0.110	0.0478	3.49	0.116	0.0503	3.59	0.125	0.0539
7,000	3.99	0.147	0.0635	4.07	0.154	0.0669	4.19	0.166	0.0717
8,000	4.56	0.188	0.0813	4.66	0.198	0.0856	4.79	0.212	0.0918
9,000	5.13	0.234	0.101	5.24	0.246	0.106	5.39	0.264	0.114
10,000	5.70	0.284	0.123	5.82	0.299	0.129	5.99	0.320	0.139
11,000	6.27	0.338	0.147	6.40	0.356	0.154	6.59	0.382	0.165
12,000	6.84	0.398	0.172	6.98	0.419	0.181	7.19	0.449	0.194
14,000	7.97	0.529	0.229	8.15	0.557	0.241	8.38	0.597	0.259
16,000	9.11	0.677	0.293	9.31	0.713	0.309	9.58	0.764	0.331
18,000	10.3	0.842	0.365	10.5	0.886	0.384	10.8	0.951	0.412

Notes:

1. Table is based on Equations 9.2 through 9.5, using C = 150.
2. Friction-loss values are based on average $D_i = D_o - (2 \times 106\% \times t_{min}) = D_o - (2.12 \times t_{min})$, where:
   D_i = pipe inside diameter, in.
   D_o = pipe outside diameter, in.
   t_{min} = minimum wall thickness, in.

Table 9.5 Flow friction loss, ASTM D2241 PIP PVC pipe (*continued*)

27 in. PIP (ASTM D2241)			
Flow, gpm	DR 26 Pressure rated 160 psi		
	Velocity, ft/s	Pressure drop	
		ft H_2O/100 ft	psi/100 ft
1,000	0.620	0.00493	0.00213
1,500	0.930	0.0104	0.00452
2,000	1.24	0.0178	0.00770
2,500	1.55	0.0269	0.0116
3,000	1.86	0.0376	0.0163
3,500	2.17	0.0500	0.0217
4,000	2.48	0.0641	0.0277
5,000	3.10	0.0968	0.0419
6,000	3.72	0.136	0.0587
7,000	4.34	0.180	0.0781
8,000	4.96	0.231	0.100
9,000	5.58	0.287	0.124
10,000	6.20	0.349	0.151
11,000	6.82	0.416	0.180
12,000	7.44	0.489	0.212
14,000	8.68	0.650	0.282
16,000	9.92	0.833	0.361
18,000	11.2	1.04	0.448

9.4 Flow in PVC Nonpressure Pipe

Hydraulic flow research has shown that flow conditions in PVC gravity sewer pipes can be designed conservatively using *Manning's formula*. Although *Kutter's formula* had been used since the early 1900s for open-channel flow, the equation was unwieldy and difficult to use. Due to its relative simplicity, Manning's formula has become the preferred design method.

Equation 9.13

Kutter's formula

$$V = \left[\frac{\frac{1.81}{n} + 41.67 + \frac{0.0028}{S_E}}{1 + \frac{n}{\sqrt{R_H}}\left(41.67 + \frac{0.0028}{S_E}\right)} \right] \sqrt{R_H S_E}$$

where:

V = mean flow velocity, ft/s
R_H = hydraulic radius, ft (see section 9.2.2) = $D_i/4$
n = coefficient of roughness, dimensionless
S_E = slope of energy grade line, ft/ft

Like water, sewage will seek its own level when introduced into a pipe with a sloping invert, which induces movement of the sewage (this movement is known as "gravity flow"). For simplification in solving the problem of sewer design, it is necessary to assume "steady" flow conditions even though most sewers operate with constantly fluctuating flow rate. Also, as long as the surface of the sewage is permitted to expand or contract, it is considered "open channel" flow. If open channel flow is not the condition, then a sewer is said to be "flowing full under head" or "flowing full under internal pressure."

Manning's equation is based on the above assumptions of steady flow and open channel flow for computing discharge of a sewer line. In this equation, the coefficient of roughness (n) is determined by research and analysis; it represents the interior surface characteristics of the pipe. The coefficient of roughness (often called "Manning's n factor") helps determine frictional losses in Manning's equation: the greater the losses, the higher the value of "n".

Equation 9.14

Manning's equation

$$V = \frac{1.486}{n} R_H^{2/3} s^{1/2}$$

where:

V = mean flow velocity, ft/s
n = coefficient of roughness, dimensionless
R_H = hydraulic radius, ft
s = hydraulic slope, ft/ft = $(H_1 - H_2)/L$
L = pipe length, ft
H_1 = upstream pipe elevation, ft
H_2 = downstream pipe elevation, ft

Slope (s) is equal in most cases to slope of the invert and slope of the flowing surface.

The value for "n" has been experimentally determined for all common sewer piping materials. The value can be as low as 0.007 under laboratory conditions, in which clean water is used, or higher than 0.015 under less favorable conditions and with rough-surfaced pipe. Historically, most engineers have selected roughness coefficient "n" to be 0.013 for all sewer products that were available before the advent of PVC sewer pipe.

There is no basis for using a single-value approach for "n." Such an approach fails to recognize the sizeable variation in "n" values for different pipe materials in sewers operating at or near a flow velocity of 2 ft/s. Both laboratory research and field studies support the variability of "n" values as a function of pipe material, number of joints, and close tolerance quality of each joint.

The most prevalent error made with respect to minimum slope criteria occurs as a result of using an average flow velocity calculated from a wide range of velocity measurements. Use of an average value is not recommended because "n" values vary with flow conditions:

- High flow velocities—As velocities increase, the associated "n" value will decrease because high velocities will keep solids suspended and will minimize slime growth.
- Low flow velocities—As velocities decrease, solids will settle and slime will become thicker and more irregular.

This means that the parameters used for determining minimum slopes for sewers should be based on data obtained under similar velocity conditions, i.e., flow velocities no greater than 2.5 ft/s.

No published technical study has ever reported an "n" value as high as 0.013 for a PVC sewer pipeline operating at the recommended minimum velocities, either in-service or in the laboratory. Studies in the laboratory, and more importantly, in actual use, have found the value of "n" for PVC to range from 0.007 to 0.011. These relatively low values can be attributed to:

- the nonporous, smooth surface of PVC pipe;
- the low profile gap at the joints;
- the longer laying lengths available in PVC pipe, resulting in fewer joints;
- the chemical and abrasion resistance of PVC.

PVC pipe's long lengths result in fewer joints than are necessary for competitive products. This causes reduced friction losses for PVC pipe and a lower value for the coefficient of roughness "n". The Uni-Bell PVC Pipe Association recommends the use of Manning's "n" = 0.009 for hydraulic design of PVC sewer pipe.

The following example demonstrates how Manning's equation is used in the design of a PVC gravity sewer system.

Example 9.1

Calculate the velocity and quantity of flow for 8-in. PVC sewer pipe (ASTM D3034 DR 35) flowing half-full with an invert slope of 4 ft per 1,000 ft.

Solution:

Data from the given information and the product dimensions found in ASTM D3034 SDR 35:

$$D_o = 8.400 \text{ in.}, \qquad t = 0.240 \text{ in.}$$

$$D_i = D_o - 2t(1.06) = 7.891 \text{ in.}$$

$$D_i = \frac{7.891 \text{ in.}}{12} = 0.658 \text{ ft}$$

Solving both ways:

Full pipe cross-sectional area $= \dfrac{\pi D_i^2}{4}$

Half-full pipe cross-sectional area $= \dfrac{1}{2}\left(\dfrac{\pi D_i^2}{4}\right)$

Wetted perimeter $= \pi D_i$ for full flow, ½ πD_i for half-full flow.

$$R_H = \frac{D_i}{4} = \frac{0.658\,\text{ft}}{4} = 0.165\,\text{ft}, \qquad s = \frac{4\,\text{ft}}{1{,}000\,\text{ft}} = 0.004, \qquad n = 0.009 \text{ for PVC pipe,}$$

$$V = \frac{1.486}{0.009}(0.165^{2/3})(0.004^{1/2}) = 165.1(0.301)(0.063) = 3.1 \text{ ft/s velocity.}$$

Next, the calculation of volume flow rate:

Equation 9.15

$$Q = VA$$

where:

Q = volume flow rate, ft^3/s

V = mean flow velocity, ft/s

A = cross sectional area of flow, ft^2

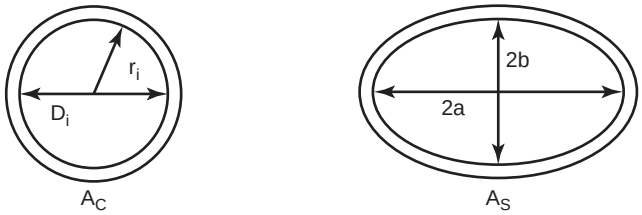


Fig. 9.5 Pipe cross-sectional area.

$$A = \frac{1}{2}\frac{\pi D_i^2}{4} = \pi\frac{0.658^2}{8} = 0.170\ \text{ft}^2$$

$$Q = 3.1\ \text{ft/s} \times 0.170\ \text{ft}^2 = 0.53\ \text{ft}^3\text{/s} = 343{,}000\ \text{gal/day}$$

It is recommended that flow velocity in sanitary sewer lines not be less than 2 ft/s (0.6 m/s) for self-cleansing action in the lines. Some authorities may require 2.5 ft/s (0.8 m/s) minimum velocity, particularly for storm sewers. At velocities above 10 ft/s (3 m/s) special consideration should be given to energy dissipation and erosion prevention. Where slopes exceed 40%, pipe anchorage should be considered. To allow for future growth or unanticipated flows, it is customary to size sanitary collection sewers to flow one-half full at maximum design inflow.

As flexible pipe is deflected, its cross-sectional area is slightly reduced. The elliptical cross-sectional area (A_s) after pipe ovalization will be only slightly less than the undeflected circular cross-sectional area (A_c) (Fig. 9.5).

Equation 9.16

$$A_c = \frac{\pi D_i^2}{4} = \pi r_i^2$$

Equation 9.17

$$A_s = \pi ab$$

where:

A_c = circle cross-sectional area, in.^{2}
A_s = ellipse cross-sectional area, in.^{2}
D_i = pipe inside diameter, in.
r_i = pipe inside radius, in.
a = deflected pipe long semi-axis, in.
b = deflected pipe short semi-axis, in.

For deflections less than 10%, the dimensions of the deflected elliptical shape are calculated using Spangler's relationship from Chapter 7:

Equation 9.18

$$\Delta X = 0.913\,\Delta Y$$

The vertical dimension of the ellipse is given by:

Equation 9.19

$$b = r_i\,(1 - \Delta Y/D_i)$$

And the horizontal dimension is:

Equation 9.20

$$a = r_i(1 + 0.913\Delta Y/D_i)$$

where:

ΔX = horizontal pipe deflection, in.

ΔY = vertical pipe deflection, in.

The resulting reductions in flow area for 5.0% and 7.5% vertical deflection are given in Table 9.6.

Reduction in flow volume is a function not only of reduced flow area, but also of reduced hydraulic radius. Calculations are simplified by assuming that the wetted circumference is not changed (i.e., the inside circumference of the ellipse is the same as the inside circumference of the circle). This means that the percent reduction in the hydraulic radius is the same as the percent reduction in flow area above. The reductions in flow volumes for 5.0% and 7.5% vertical deflection are also given in Table 9.6.

Table 9.6 Reduction in circular cross-sectional area and flow of deflected PVC pipe

Deflection (%)	% Reduction in internal cross-sectional area from circular to elliptical shape	% Reduction in flow
5.0	0.66%	1.10%
7.5	1.17%	1.94%

All sewers should be designed and constructed to give mean velocities of no less than 2.0 ft/s (0.61 m/s) when flowing full, based on Manning's equation using an appropriate "n" value. Table 9.7 lists the minimum slope values needed to maintain a 2.0-ft/s full flow velocity and corresponding flow capacities for PVC sewer pipe.

Table 9.8 provides velocities and flow rates for 4-in. through 60-in. PVC sewer pipe for the following conditions:

- Pipe products with pipe stiffness = 46 psi
- Slopes from 0.1% to 1.0% (at increments of 0.1%)
- Depth of flow = 100%
- Manning's "n" = 0.009

Table 9.7 Minimum slopes needed to maintain 2.0-ft/s full flow velocity, PVC sewer pipe

Pipe size, in.	n = 0.009	
	s, ft/100 ft	Q, 1,000 gpd
4	0.41	111
6	0.24	247
8	0.16	442
10	0.12	691
12	0.10	978
15	0.07	1,470
18	0.056	2,190
21	0.045	3,050
24	0.038	3,850
27	0.033	4,900
30	0.028	6,100
33	0.025	7,400
36	0.022	8,830
39	0.020	10,400
42	0.018	12,100
45	0.016	13,900
48	0.015	15,800

Table 9.8 PVC Sewer pipe—flow rates

Manning's n = 0.009		**Pipe stiffness = 46 psi**			**Depth of flow = 100%**		
Pipe size = 4 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	0.988	0.0845	54.5	0.1	0.975	0.0818	52.8
0.2	1.40	0.119	77.1	0.2	1.38	0.116	74.6
0.3	1.71	0.146	94.4	0.3	1.69	0.142	91.4
0.4	1.98	0.169	109	0.4	1.95	0.164	106
0.5	2.21	0.189	122	0.5	2.18	0.183	118
0.6	2.42	0.207	134	0.6	2.39	0.200	129
0.7	2.61	0.224	144	0.7	2.58	0.216	140
0.8	2.79	0.239	154	0.8	2.76	0.231	149
0.9	2.96	0.253	164	0.9	2.93	0.245	158
1.0	3.12	0.267	172	1.0	3.08	0.259	167
Pipe size = 6 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	1.29	0.244	157	0.1	1.27	0.236	152
0.2	1.82	0.345	223	0.2	1.80	0.334	215
0.3	2.23	0.423	273	0.3	2.20	0.409	264
0.4	2.58	0.488	315	0.4	2.54	0.472	305
0.5	2.88	0.546	352	0.5	2.84	0.528	341
0.6	3.16	0.598	386	0.6	3.11	0.578	373
0.7	3.41	0.646	416	0.7	3.36	0.625	403
0.8	3.64	0.690	445	0.8	3.60	0.668	431
0.9	3.86	0.732	472	0.9	3.81	0.708	457
1.0	4.07	0.772	498	1.0	4.02	0.747	482

Table 9.8 PVC Sewer pipe—flow rates (*continued*)

Manning's n = 0.009		**Pipe stiffness = 46 psi**			**Depth of flow = 100%**		
Pipe size = 8 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	1.56	0.532	343	0.1	1.54	0.514	332
0.2	2.21	0.752	485	0.2	2.18	0.728	469
0.3	2.71	0.921	594	0.3	2.68	0.891	575
0.4	3.13	1.06	686	0.4	3.09	1.03	664
0.5	3.50	1.19	767	0.5	3.45	1.15	742
0.6	3.83	1.30	840	0.6	3.78	1.26	813
0.7	4.14	1.41	907	0.7	4.09	1.36	878
0.8	4.43	1.50	970	0.8	4.37	1.46	939
0.9	4.69	1.59	1030	0.9	4.63	1.54	1000
1.0	4.95	1.68	1080	1.0	4.88	1.63	1050
Pipe size = 10 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	1.82	0.964	622	0.1	1.79	0.933	602
0.2	2.57	1.36	879	0.2	2.53	1.32	851
0.3	3.15	1.67	1080	0.3	3.10	1.62	1040
0.4	3.63	1.93	1240	0.4	3.58	1.87	1200
0.5	4.06	2.16	1390	0.5	4.01	2.09	1350
0.6	4.45	2.36	1520	0.6	4.39	2.28	1470
0.7	4.80	2.55	1640	0.7	4.74	2.47	1590
0.8	5.14	2.73	1760	0.8	5.07	2.64	1700
0.9	5.45	2.89	1870	0.9	5.38	2.80	1810
1.0	5.74	3.05	1970	1.0	5.67	2.95	1900

Table 9.8 PVC Sewer pipe—flow rates (*continued*)

Manning's n = 0.009		**Pipe stiffness = 46 psi**			**Depth of flow = 100%**		
Pipe size = 12 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	2.04	1.53	988	0.1	2.01	1.48	957
0.2	2.88	2.17	1400	0.2	2.85	2.10	1350
0.3	3.53	2.65	1710	0.3	3.49	2.57	1660
0.4	4.08	3.06	1980	0.4	4.03	2.97	1910
0.5	4.56	3.43	2210	0.5	4.50	3.32	2140
0.6	5.00	3.75	2420	0.6	4.93	3.63	2340
0.7	5.40	4.05	2620	0.7	5.33	3.92	2530
0.8	5.77	4.33	2800	0.8	5.69	4.19	2710
0.9	6.12	4.60	2970	0.9	6.04	4.45	2870
1.0	6.45	4.85	3130	1.0	6.37	4.69	3030
Pipe size = 15 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	2.33	2.63	1700	0.1	2.30	2.55	1640
0.2	3.30	3.72	2400	0.2	3.26	3.60	2320
0.3	4.04	4.56	2940	0.3	3.99	4.41	2840
0.4	4.67	5.26	3390	0.4	4.61	5.09	3280
0.5	5.22	5.88	3790	0.5	5.15	5.69	3670
0.6	5.72	6.44	4160	0.6	5.64	6.24	4020
0.7	6.18	6.96	4490	0.7	6.10	6.74	4350
0.8	6.60	7.44	4800	0.8	6.52	7.20	4650
0.9	7.00	7.89	5090	0.9	6.91	7.64	4930
1.0	7.38	8.32	5370	1.0	7.29	8.05	5190

Table 9.8 PVC Sewer pipe—flow rates (*continued*)

Manning's n = 0.009		**Pipe stiffness = 46 psi**			**Depth of flow = 100%**		
Pipe size = 18 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	2.68	4.54	2930	0.1	2.64	4.40	2840
0.2	3.79	6.43	4150	0.2	3.74	6.22	4010
0.3	4.64	7.87	5080	0.3	4.58	7.62	4910
0.4	5.35	9.09	5860	0.4	5.28	8.80	5670
0.5	5.98	10.2	6550	0.5	5.91	9.83	6340
0.6	6.56	11.1	7180	0.6	6.47	10.8	6950
0.7	7.08	12.0	7760	0.7	6.99	11.6	7510
0.8	7.57	12.9	8290	0.8	7.47	12.4	8020
0.9	8.03	13.6	8790	0.9	7.93	13.2	8510
1.0	8.46	14.4	9270	1.0	8.35	13.9	8970
Pipe size = 21 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	2.99	7.05	4550	0.1	2.95	6.82	4400
0.2	4.22	9.97	6430	0.2	4.17	9.65	6220
0.3	5.17	12.2	7880	0.3	5.11	11.8	7620
0.4	5.97	14.1	9090	0.4	5.90	13.6	8800
0.5	6.68	15.8	10200	0.5	6.59	15.3	9840
0.6	7.32	17.3	11100	0.6	7.22	16.7	10800
0.7	7.90	18.6	12000	0.7	7.80	18.1	11600
0.8	8.45	19.9	12900	0.8	8.34	19.3	12400
0.9	8.96	21.1	13600	0.9	8.84	20.5	13200
1.0	9.45	22.3	14400	1.0	9.32	21.6	13900

Table 9.8 PVC Sewer pipe—flow rates (*continued*)

Manning's n = 0.009		**Pipe stiffness = 46 psi**			**Depth of flow = 100%**		
Pipe size = 24 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	3.23	9.65	6230	0.1	3.19	9.34	6030
0.2	4.57	13.6	8810	0.2	4.51	13.2	8520
0.3	5.60	16.7	10800	0.3	5.52	16.2	10400
0.4	6.46	19.3	12500	0.4	6.38	18.7	12100
0.5	7.23	21.6	13900	0.5	7.13	20.9	13500
0.6	7.92	23.6	15300	0.6	7.81	22.9	14800
0.7	8.55	25.5	16500	0.7	8.44	24.7	15900
0.8	9.14	27.3	17600	0.8	9.02	26.4	17000
0.9	9.69	29.0	18700	0.9	9.57	28.0	18100
1.0	10.2	30.5	19700	1.0	10.1	29.5	19100
Pipe size = 27 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	3.50	13.3	8560	0.1	3.45	12.8	8290
0.2	4.95	18.8	12100	0.2	4.88	18.2	11700
0.3	6.06	23.0	14800	0.3	5.98	22.3	14400
0.4	7.00	26.6	17100	0.4	6.91	25.7	16600
0.5	7.83	29.7	19200	0.5	7.72	28.7	18500
0.6	8.57	32.5	21000	0.6	8.46	31.5	20300
0.7	9.26	35.1	22700	0.7	9.14	34.0	21900
0.8	9.90	37.6	24200	0.8	9.77	36.3	23400
0.9	10.5	39.8	25700	0.9	10.4	38.5	24900
1.0	11.1	42.0	27100	1.0	10.9	40.6	26200

Table 9.8 PVC Sewer pipe—flow rates (*continued*)

Manning's n = 0.009		**Pipe stiffness = 46 psi**			**Depth of flow = 100%**		
Pipe size = 30 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	3.83	19.0	12300	0.1	3.78	18.4	11900
0.2	5.42	26.9	17400	0.2	5.35	26.1	16800
0.3	6.63	33.0	21300	0.3	6.55	31.9	20600
0.4	7.66	38.1	24600	0.4	7.56	36.9	23800
0.5	8.56	42.6	27500	0.5	8.45	41.2	26600
0.6	9.38	46.6	30100	0.6	9.26	45.1	29100
0.7	10.1	50.4	32500	0.7	10.0	48.8	31500
0.8	10.8	53.9	34700	0.8	10.7	52.1	33600
0.9	11.5	57.1	36900	0.9	11.3	55.3	35700
1.0	12.1	60.2	38800	1.0	12.0	58.3	37600
Pipe size = 33 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	4.02	23.2	15000	0.1	3.97	19.4	12500
0.2	5.69	32.8	21100	0.2	5.62	27.4	17700
0.3	6.97	40.1	25900	0.3	6.88	33.5	21600
0.4	8.05	46.3	29900	0.4	7.94	38.7	25000
0.5	9.00	51.8	33400	0.5	8.88	43.3	27900
0.6	9.85	56.8	36600	0.6	9.73	47.4	30600
0.7	10.6	61.3	39600	0.7	10.5	51.2	33000
0.8	11.4	65.5	42300	0.8	11.2	54.8	35300
0.9	12.1	69.5	44900	0.9	11.9	58.1	37500
1.0	12.7	73.3	47300	1.0	12.6	61.2	39500

Table 9.8 PVC Sewer pipe—flow rates (*continued*)

Manning's n = 0.009		**Pipe stiffness = 46 psi**			**Depth of flow = 100%**		
Pipe size = 36 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	4.32	30.7	19800	0.1	4.26	29.8	19200
0.2	6.11	43.5	28100	0.2	6.03	42.1	27200
0.3	7.48	53.3	34400	0.3	7.38	51.5	33300
0.4	8.64	61.5	39700	0.4	8.52	59.5	38400
0.5	9.65	68.8	44400	0.5	9.53	66.5	42900
0.6	10.6	75.3	48600	0.6	10.4	72.9	47000
0.7	11.4	81.4	52500	0.7	11.3	78.7	50800
0.8	12.2	87.0	56100	0.8	12.1	84.2	54300
0.9	13.0	92.2	59500	0.9	12.8	89.3	57600
1.0	13.7	97.2	62700	1.0	13.5	94.1	60700
Pipe size = 39 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	4.50	36.4	23500	0.1	4.45	35.2	22700
0.2	6.37	51.5	33200	0.2	6.29	49.8	32200
0.3	7.80	63.1	40700	0.3	7.70	61.0	39400
0.4	9.01	72.8	47000	0.4	8.89	70.5	45500
0.5	10.1	81.4	52500	0.5	9.94	78.8	50800
0.6	11.0	89.2	57500	0.6	10.9	86.3	55700
0.7	11.9	96.3	62100	0.7	11.8	93.2	60200
0.8	12.7	103	66400	0.8	12.6	99.7	64300
0.9	13.5	109	70500	0.9	13.3	106	68200
1.0	14.2	115	74300	1.0	14.1	111	71900

Table 9.8 PVC Sewer pipe—flow rates (*continued*)

Manning's n = 0.009		**Pipe stiffness = 46 psi**			**Depth of flow = 100%**			
Pipe size = 42 in.								
Pipe deflection = 0%					Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,			Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day				ft^3/s	1000 gal/day
0.1	4.77	45.9	29600		0.1	4.71	44.4	28600
0.2	6.75	64.9	41900		0.2	6.66	62.8	40500
0.3	8.27	79.5	51300		0.3	8.16	76.9	49600
0.4	9.54	91.7	59200		0.4	9.42	88.8	57300
0.5	10.7	103	66200		0.5	10.5	99.3	64000
0.6	11.7	112	72500		0.6	11.5	109	70200
0.7	12.6	121	78300		0.7	12.5	117	75800
0.8	13.5	130	83700		0.8	13.3	126	81000
0.9	14.3	138	88800		0.9	14.1	133	85900
1.0	15.1	145	93600		1.0	14.9	140	90600
Pipe size = 45 in.								
Pipe deflection = 0%					Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,			Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day				ft^3/s	1000 gal/day
0.1	4.96	53.6	34600		0.1	4.90	51.9	33500
0.2	7.02	75.8	48900		0.2	6.92	73.3	47300
0.3	8.59	92.8	59900		0.3	8.48	89.8	57900
0.4	9.92	107	69100		0.4	9.79	104	66900
0.5	11.1	120	77300		0.5	10.9	116	74800
0.6	12.2	131	84700		0.6	12.0	127	81900
0.7	13.1	142	91500		0.7	13.0	137	88500
0.8	14.0	152	97800		0.8	13.8	147	94600
0.9	14.9	161	104000		0.9	14.7	156	100000
1.0	15.7	169	109000		1.0	15.5	164	106000

Table 9.8 PVC Sewer pipe—flow rates (*continued*)

Manning's n = 0.009		**Pipe stiffness = 46 psi**			**Depth of flow = 100%**		
Pipe size = 48 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	5.21	65.3	42100	0.1	5.14	63.2	40800
0.2	7.37	92.4	59600	0.2	7.28	89.4	57700
0.3	9.03	113	73000	0.3	8.91	109	70600
0.4	10.4	131	84300	0.4	10.3	126	81600
0.5	11.7	146	94200	0.5	11.5	141	91200
0.6	12.8	160	103000	0.6	12.6	155	100000
0.7	13.8	173	111000	0.7	13.6	167	108000
0.8	14.7	185	119000	0.8	14.6	179	115000
0.9	15.6	196	126000	0.9	15.4	190	122000
1.0	16.5	207	133000	1.0	16.3	200	129000
Pipe size = 54 in.							
Pipe deflection = 0%				Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,		Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day			ft^3/s	1000 gal/day
0.1	5.61	87.6	56500	0.1	5.54	84.8	54700
0.2	7.93	124	79900	0.2	7.83	120	77300
0.3	9.72	152	97800	0.3	9.59	147	94700
0.4	11.2	175	113000	0.4	11.07	170	109000
0.5	12.5	196	126000	0.5	12.38	190	122000
0.6	13.7	214	138000	0.6	13.56	208	134000
0.7	14.8	232	149000	0.7	14.65	224	145000
0.8	15.9	248	160000	0.8	15.66	240	155000
0.9	16.8	263	169000	0.9	16.61	254	164000
1.0	17.7	277	179000	1.0	17.51	268	173000

Table 9.8 PVC Sewer pipe—flow rates (*continued*)

Manning's n = 0.009		**Pipe stiffness = 46 psi**			**Depth of flow = 100%**			
Pipe size = 60 in.								
Pipe deflection = 0%					Pipe deflection = 7.5%			
Slope, ft/100 ft	Velocity, ft/s	Flow rate,			Slope, ft/100 ft	Velocity, ft/s	Flow rate,	
		ft^3/s	1000 gal/day				ft^3/s	1000 gal/day
0.1	6.02	116	75000		0.1	5.94	113	72600
0.2	8.52	164	106000		0.2	8.41	159	103000
0.3	10.4	201	130000		0.3	10.3	195	126000
0.4	12.0	233	150000		0.4	11.9	225	145000
0.5	13.5	260	168000		0.5	13.3	252	162000
0.6	14.7	285	184000		0.6	14.6	276	178000
0.7	15.9	308	198000		0.7	15.7	298	192000
0.8	17.0	329	212000		0.8	16.8	318	205000
0.9	18.1	349	225000		0.9	17.8	338	218000
1.0	19.0	368	237000		1.0	18.8	356	230000

9.5 Sources

Bishop, R.R., Jeppson, R.W., *Hydraulic Characteristics of PVC Pipe in Sanitary Sewers*. Utah State University, Logan, UT (1975).

Design and Construction of Sanitary and Storm Sewers, ASCE Manual and Report on Engineering Practice No. 37 (WPCF Manual of Practice No. 9). American Society of Civil Engineers and the Water Pollution Control Federation, New York, NY (1974).

Flow of Fluids Through Valves, Fittings and Pipe. Technical Paper No. 410, 12th Printing, Crane Co., Chicago, IL (1972).

Jeppson, R.W., *Analysis of Flow in Pipe Networks*. Ann Arbor Science Publishing Inc., Ann Arbor, MI (1977).

Kern, R., How to compute pipe size. *Chemical Engineering* (Jan. 1975).

Liu, H., Manning's coefficient for smooth pipes. *ASCE Journal of Sanitary Engineers*, Div. Proc. 98SA2, 353 (1972).

Neale, L.C., Price, R.E., Flow characteristics of PVC sewer pipe. *ASCE Journal of Sanitary Engineers*, Div. Proc. 90 SA3, 109 (1964).

Perry, J.H., *Chemical Engineer's Handbook, 3rd ed.* McGraw-Hill, New York, NY (1950).

Pipe Friction Manual, 3rd ed. Hydraulic Institute, New York, NY (1961).

Pomeroy, R.D., Flow velocities in smalls. *Journal WPCF* (Sept. 1967).

PVC Pipe—Technology Serving the Water Industry. Uni-Bell PVC Pipe Association, Dallas, TX (1984).

Streeter, V.L., *Fluid Mechanics, 9th ed.* McGraw-Hill College, New York (1958).

Symons, G.E., Design and Selection: Valves, Hydrants, and Fittings, Manual of Practice Number Four, *Water and Wastes Engineering*. Dun-Donnelley Publishing Corp., New York, NY (1968).

Symons, G.E., Water Systems Pipes and Piping, Manual of Practice Number Two, *Water and Wastes Engineering*. Dun-Donnelley Publishing Corp., New York, NY (1967).

Symons, G.E., Wastewater Systems—Pipes and Piping Manual of Practice Number Three, *Water and Wastes Engineering*. Dun-Donnelley Publishing Corp., New York, NY (1967).

Water Flow Characteristics of Thermoplastic Pipe, PPI Technical Report, PPI-TR14. Plastics Pipe Institute, New York, NY (1971).