APPENDIX E4

FRICTION LOSS FOR WATER IN FEET PER 100 FT OF PIPE

(Excerpted from Hydraulic Institute Engineering Data Handbook with permission.)

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe

4 in nominal		Steel-schedule 40 ID = 4.026 in $\varepsilon/D = 0.000447$			Asphalt-dipped cast iron ID = 4.00 in $\varepsilon/D = 0.00120$		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
0.0111	5	0.126	0.000247	0.00310	0.128	0.000253	0.00325
0.0223	10	0.252	0.000987	0.01017	0.255	0.00101	0.01080
0.0446	20	0.504	0.00395	0.0344	0.511	0.00405	0.03700
0.0668	30	0.756	0.00888	0.0702	0.766	0.00912	0.0770
0.0981	40	1.01	0.0158	0.118	1.02	0.0162	0.131
0.111	50	1.26	0.0247	0.176	1.28	0.0253	0.199
0.134	60	1.51	0.0355	0.245	1.53	0.0365	0.278
0.156	70	1.76	0.0484	0.325	1.79	0.0496	0.370
0.178	80	2.02	0.0632	0.415	2.04	0.0648	0.476
0.201	90	2.27	0.0800	0.515	2.30	0.0820	0.594
0.223	100	2.52	0.0987	0.624	2.55	0.101	0.725
0.245	110	2.77	0.119	0.744	2.81	0.123	0.869
0.267	120	3.02	0.142	0.877	3.06	0.146	1.03
0.290	130	3.28	0.167	1.017	3.32	0.171	1.19
0.312	140	3.53	0.193	1.165	3.57	0.199	1.38
0.334	150	3.78	0.222	1.32	3.83	0.228	1.58
0.356	160	4.03	0.253	1.49	4.08	0.259	1.78
0.379	170	4.28	0.285	1.67	4.34	0.293	2.00
0.401	180	4.54	0.320	1.86	4.60	0.328	2.24
0.423	190	4.79	0.356	2.06	4.85	0.366	2.49
0.446	200	5.04	0.395	2.27	5.11	0.406	2.74
0.490	220	5.54	0.478	2.72	5.62	0.490	3.28
0.535	240	6.05	0.569	3.21	6.13	0.583	3.88
0.579	260	6.55	0.667	3.74	6.64	0.685	4.54
0.624	280	7.06	0.774	4.30	7.15	0.794	5.25
0.668	300	7.56	0.888	4.89	7.66	0.912	6.03
0.713	320	8.06	1.01	5.51	8.17	1.04	6.87
0.758	340	8.57	1.14	6.19	8.68	1.17	7.75
0.802	360	9.07	1.28	6.92	9.19	1.31	8.68
0.847	380	9.58	1.43	7.68	9.70	1.46	9.66
0.891	400	10.1	1.58	8.47	10.2	1.62	10.7
0.936	420	10.6	1.74	9.30	10.7	1.79	11.7
0.980	440	11.1	1.91	10.2	11.2	1.96	12.8
1.025	460	11.6	2.09	11.1	11.7	2.14	14.0
1.069	480	12.1	2.27	12.0	12.3	2.33	15.3
1.114	500	12.6	2.47	13.0	12.8	2.53	16.6
1.225	550	13.9	2.99	15.7	14.0	3.06	19.9
1.337	600	15.1	3.55	18.6	15.3	3.65	23.6
1.448	650	16.4	4.17	21.7	16.6	4.28	27.7
1.560	700	17.6	4.84	25.0	17.9	4.96	32.1
1.671	750	18.9	5.55	28.6	19.1	5.70	36.7
1.782	800	20.2	6.32	32.4	20.4	6.48	41.6
1.894	850	21.4	7.13	36.5	21.7	7.32	46.8
2.005	900	22.7	8.00	40.8	23.0	8.20	52.3
2.117	950	23.9	8.91	45.3	24.3	9.14	58.1

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

4 in nominal		Steel-schedule 40 ID = 4.026 in ε/D = 0.000447			Asphalt-dipped cast iron ID = 4.00 in ε/D = 0.00120		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
2.228	1 000	25.2	9.87	50.2	25.5	10.1	64.2
2.451	1 100	27.7	11.9	60.5	28.1	12.3	78.2
2.674	1 200	30.2	14.2	72.0	30.6	14.6	92.8
2.896	1 300	32.8	16.7	84.3	33.2	17.1	108.2
3.119	1 400	35.3	19.3	97.6	35.7	19.9	126
3.342	1 500	37.8	22.2	112	38.3	22.8	144
3.565	1 600	40.3	25.3	127	40.8	25.9	164
3.788	1 700	42.8	28.5	143	43.4	29.3	185
4.010	1 800	45.4	32.0	160	46.0	32.8	207
4.233	1 900	47.9	35.6	178	48.5	36.6	230
4.456	2 000	50.4	39.5	196	51.1	40.5	255

6 in nominal		Steel-schedule 40 ID = 6.065 in ε/D = 0.000293			Asphalt-dipped cast iron ID = 6.00 in ε/D = 0.000800		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
0.0223	10	0.111	0.000192	0.00146	0.113	0.000200	0.00157
0.0446	20	0.222	0.000767	0.00487	0.227	0.000800	0.00523
0.0668	30	0.333	0.00172	0.00988	0.340	0.00180	0.01070
0.0891	40	0.444	0.00307	0.0164	0.454	0.00320	0.0179
0.111	50	0.555	0.00479	0.0244	0.567	0.00500	0.0268
0.134	60	0.666	0.00690	0.0337	0.681	0.00720	0.0374
0.156	70	0.777	0.00939	0.0445	0.794	0.00980	0.0496
0.178	80	0.888	0.0123	0.0564	0.908	0.0128	0.0635
0.201	90	0.999	0.0155	0.0698	1.02	0.0162	0.0789
0.223	100	1.11	0.0192	0.0843	1.13	0.0200	0.0958
0.267	120	1.33	0.0276	0.118	1.36	0.0288	0.130
0.312	140	1.55	0.0376	0.155	1.59	0.0392	0.178
0.356	160	1.78	0.0491	0.198	1.82	0.0512	0.229
0.401	180	2.00	0.0621	0.246	2.04	0.0648	0.282
0.446	200	2.22	0.0767	0.299	2.27	0.0800	0.346
0.490	220	2.44	0.0927	0.357	2.50	0.0968	0.415
0.535	240	2.66	0.110	0.419	2.72	0.115	0.490
0.579	260	2.89	0.130	0.487	2.95	0.135	0.570
0.624	280	3.11	0.150	0.560	3.18	0.157	0.655
0.668	300	3.33	0.172	0.637	3.40	0.180	0.745
0.713	320	3.55	0.196	0.719	3.63	0.205	0.846
0.758	340	3.78	0.222	0.806	3.86	0.231	0.952
0.802	360	4.00	0.240	0.898	4.08	0.259	1.06
0.847	380	4.22	0.277	0.993	4.31	0.289	1.18
0.891	400	4.44	0.307	1.09	4.54	0.320	1.30

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

6 in nominal		Steel-schedule 40 ID = 6.065 in $\varepsilon/D = 0.000293$			Asphalt-dipped cast iron ID = 6.00 in $\varepsilon/D = 0.000800$		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
0.936	420	4.66	0.338	1.20	4.76	0.353	1.43
0.980	440	4.89	0.371	1.31	4.99	0.387	1.57
1.025	460	5.11	0.405	1.42	5.22	0.423	1.71
1.07	480	5.33	0.442	1.54	5.45	0.461	1.86
1.11	500	5.55	0.479	1.66	5.67	0.500	2.02
1.23	550	6.11	0.580	1.99	6.24	0.605	2.42
1.34	600	6.66	0.690	2.34	6.81	0.720	2.84
1.45	650	7.22	0.810	2.73	7.37	0.845	3.33
1.56	700	7.77	0.939	3.13	7.94	0.980	3.87
1.67	750	8.33	1.08	3.57	8.51	1.12	4.45
1.78	800	8.88	1.23	4.03	9.08	1.28	5.06
1.89	850	9.44	1.38	4.53	9.64	1.44	5.69
2.01	900	9.99	1.55	5.05	10.2	1.62	6.34
2.12	950	10.5	1.73	5.60	10.8	1.80	7.02
2.23	1 000	11.1	1.92	6.17	11.3	2.00	7.73
2.45	1 100	12.2	2.32	7.41	12.5	2.42	9.80
2.67	1 200	13.3	2.76	8.76	13.6	2.88	11.2
2.90	1 300	14.4	3.24	10.2	14.7	3.38	13.0
3.12	1 400	15.5	3.76	11.8	15.9	3.92	15.1
3.34	1 500	16.7	4.31	13.5	17.0	4.50	17.4
3.56	1 600	17.8	4.91	15.4	18.2	5.12	19.8
3.79	1 700	18.9	5.54	17.3	19.3	5.78	22.3
4.01	1 800	20.0	6.21	19.4	20.4	6.48	24.8
4.23	1 900	21.1	6.92	21.6	21.6	7.22	27.6
4.46	2 000	22.2	7.67	23.8	22.7	8.00	30.5
4.68	2 100	23.3	8.45	26.2	23.8	8.82	33.6
4.90	2 200	24.4	9.27	28.8	25.0	9.68	36.8
5.12	2 300	25.5	10.1	31.4	26.1	10.6	40.1
5.35	2 400	26.6	11.0	34.2	27.2	11.5	43.5
5.57	2 500	27.8	12.0	37.0	28.4	12.5	47.1
5.79	2 600	28.9	13.0	39.9	29.5	13.5	51.0
6.02	2 700	30.0	14.0	42.9	30.6	14.6	55.2
6.24	2 800	31.1	15.0	46.1	31.8	15.7	59.6
6.46	2 900	32.2	16.1	49.4	32.9	16.8	64.1
6.68	3 000	33.3	17.2	52.8	34.0	18.0	68.8
7.13	3 200	35.5	19.6	59.9	36.3	20.5	78.0
7.58	3 400	37.8	22.2	67.4	38.6	23.1	88.0
8.02	3 600	40.0	24.8	75.5	40.8	25.9	98.7
8.47	3 800	42.2	27.7	84.1	43.1	28.9	110
8.91	4 000	44.4	30.7	93.1	45.4	32.0	122

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

8 in nominal		Steel-schedule 40 ID = 7.981 in $\varepsilon/D = 0.000226$			Asphalt-dipped cast iron ID = 8.00 in $\varepsilon/D = 0.00060$		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
0.0223	10	0.0641	0.0000639	0.000401	0.0638	0.0000633	0.000399
0.0446	20	0.128	0.000256	0.001320	0.128	0.000253	0.001320
0.0668	30	0.192	0.000575	0.00266	0.191	0.000570	0.00269
0.0891	40	0.257	0.00102	0.00442	0.255	0.00101	0.00447
0.111	50	0.321	0.00160	0.00652	0.319	0.00158	0.00664
0.134	60	0.385	0.00230	0.00904	0.382	0.00228	0.00920
0.156	70	0.449	0.00313	0.01190	0.447	0.00310	0.01210
0.178	80	0.513	0.00409	0.0151	0.511	0.00405	0.0154
0.201	90	0.577	0.00518	0.0186	0.574	0.00513	0.0191
0.223	100	0.641	0.00639	0.0224	0.638	0.00633	0.0232
0.267	120	0.770	0.00920	0.0311	0.766	0.00911	0.0323
0.312	140	0.898	0.0125	0.0410	0.893	0.0124	0.0428
0.356	160	1.03	0.0164	0.0521	1.02	0.0162	0.0548
0.401	180	1.15	0.0207	0.0644	1.15	0.0205	0.0681
0.446	200	1.28	0.0256	0.0780	1.28	0.0253	0.0828
0.490	220	1.41	0.0309	0.0928	1.40	0.0306	0.0989
0.535	240	1.54	0.0368	0.1088	1.53	0.0365	0.1163
0.579	260	1.67	0.0432	0.1260	1.66	0.0428	0.135
0.624	280	1.80	0.0501	0.144	1.79	0.0496	0.155
0.668	300	1.92	0.0575	0.163	1.91	0.0570	0.176
0.713	320	2.05	0.0655	0.184	2.04	0.0648	0.198
0.758	340	2.18	0.0739	0.206	2.17	0.0732	0.222
0.802	360	2.31	0.0828	0.229	2.30	0.0820	0.248
0.847	380	2.44	0.0923	0.253	2.43	0.0914	0.275
0.891	400	2.57	0.102	0.279	2.55	0.101	0.304
1.003	450	2.89	0.129	0.348	2.87	0.128	0.380
1.11	500	3.21	0.160	0.424	3.19	0.158	0.464
1.23	550	3.53	0.193	0.507	3.51	0.191	0.557
1.34	600	3.85	0.230	0.597	3.83	0.228	0.658
1.45	650	4.17	0.271	0.694	4.15	0.267	0.767
1.56	700	4.49	0.313	0.797	4.47	0.310	0.884
1.67	750	4.81	0.360	0.907	4.79	0.356	1.01
1.78	800	5.13	0.409	1.02	5.11	0.405	1.14
1.89	850	5.45	0.462	1.147	5.42	0.457	1.29
2.01	900	5.77	0.518	1.27	5.74	0.513	1.44
2.12	950	6.09	0.577	1.41	6.06	0.571	1.60
2.23	1 000	6.41	0.639	1.56	6.38	0.633	1.76
2.45	1 100	7.05	0.773	1.87	7.02	0.766	2.14
2.67	1 200	7.70	0.920	2.20	7.66	0.911	2.53
2.90	1 300	8.34	1.08	2.56	8.30	1.07	2.94

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

8 in nominal		Steel-schedule 40 ID = 7.981 in $\varepsilon/D = 0.000226$			Asphalt-dipped cast iron ID = 8.00 in $\varepsilon/D = 0.00060$		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
3.12	1 400	8.98	1.25	2.95	8.93	1.24	3.40
3.34	1 500	9.62	1.44	3.37	9.57	1.42	3.91
3.56	1 600	10.3	1.64	3.82	10.2	1.62	4.45
3.79	1 700	10.9	1.85	4.29	10.8	1.83	5.00
4.01	1 800	11.5	2.07	4.79	11.5	2.05	5.58
4.23	1 900	12.2	2.31	5.31	12.1	2.29	6.19
4.46	2 000	12.8	2.56	5.86	12.8	2.53	6.84
4.90	2 200	14.1	3.09	7.02	14.0	3.06	8.26
5.35	2 400	15.4	3.68	8.31	15.3	3.65	9.80
5.79	2 600	16.7	4.32	9.70	16.6	4.28	11.47
6.24	2 800	18.0	5.01	11.20	17.9	4.96	13.3
6.68	3 000	19.2	5.75	12.8	19.1	5.70	15.2
7.13	3 200	20.5	6.55	14.5	20.4	6.48	17.3
7.58	3 400	21.8	7.39	16.4	21.7	7.32	19.5
8.02	3 600	23.1	8.28	18.4	23.0	8.20	21.9
8.47	3 800	24.4	9.23	20.5	24.3	9.14	24.4
8.91	4 000	25.7	10.2	22.6	25.5	10.1	27.0
10.03	4 500	28.9	12.9	28.5	28.7	12.8	34.0
11.1	5 000	32.1	16.0	35.1	31.9	15.8	42.0
12.3	5 550	35.3	19.3	42.5	35.1	19.1	51.0
13.4	6 000	38.5	23.0	50.5	38.3	22.8	60.5
14.5	6 500	41.7	27.0	59.1	41.5	26.7	71.0
15.6	7 000	44.9	31.3	68.3	44.7	31.0	82.0
16.7	7 500	48.1	36.0	78.1	47.9	35.6	94.0
17.8	8 000	51.3	40.9	88.6	51.1	40.5	107

10 in nominal		Steel-schedule 40 ID = 10.020 in $\varepsilon/D = 0.000180$			Asphalt-dipped cast iron ID = 10.00 in $\varepsilon/D = 0.000480$		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
0.0223	10	0.0407	0.0000257	0.000138	0.0409	0.0000259	0.000140
0.0446	20	0.0814	0.000103	0.000451	0.0817	0.000104	0.000460
0.0891	40	0.163	0.000412	0.00149	0.163	0.000415	0.00154
0.134	60	0.244	0.000926	0.00304	0.245	0.000934	0.00315
0.178	80	0.325	0.00165	0.00505	0.327	0.00166	0.00525
0.223	100	0.407	0.00257	0.00747	0.409	0.00259	0.00783
0.267	120	0.488	0.00370	0.0103	0.490	0.00373	0.01085
0.312	140	0.570	0.00504	0.0136	0.572	0.00508	0.0144
0.356	160	0.651	0.00659	0.0174	0.654	0.00664	0.0183
0.401	180	0.732	0.00834	0.0215	0.735	0.00840	0.0227

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

10 in nominal		Steel-schedule 40 ID = 10.020 in $\varepsilon/D = 0.000180$			Asphalt-dipped cast iron ID = 10.00 in $\varepsilon/D = 0.000480$		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
0.446	200	0.814	0.0103	0.0260	0.817	0.0104	0.0276
0.490	220	0.895	0.0125	0.0309	0.899	0.0126	0.0329
0.535	240	0.976	0.0148	0.0362	0.980	0.0149	0.0387
0.579	260	1.06	0.0174	0.0417	1.06	0.0175	0.0449
0.624	280	1.14	0.0202	0.0478	1.14	0.0203	0.0514
0.668	300	1.22	0.0232	0.0542	1.23	0.0233	0.0583
0.780	350	1.42	0.0315	0.0719	1.43	0.0318	0.0778
0.891	400	1.63	0.0412	0.0917	1.63	0.0415	0.0990
1.003	450	1.83	0.0521	0.114	1.84	0.0525	0.1235
1.11	500	2.03	0.0643	0.138	2.04	0.0648	0.151
1.23	550	2.24	0.0778	0.164	2.25	0.0785	0.181
1.34	600	2.44	0.0926	0.192	2.45	0.0934	0.214
1.45	650	2.64	0.109	0.224	2.66	0.110	0.250
1.56	700	2.85	0.126	0.256	2.86	0.127	0.288
1.67	750	3.05	0.145	0.291	3.06	0.146	0.328
1.78	800	3.25	0.165	0.328	3.27	0.166	0.370
1.89	850	3.46	0.186	0.368	3.47	0.187	0.415
2.01	900	3.66	0.208	0.410	3.68	0.210	0.462
2.12	950	3.87	0.232	0.455	3.88	0.234	0.512
2.23	1 000	4.07	0.257	0.500	4.09	0.259	0.565
2.45	1 100	4.48	0.311	0.600	4.49	0.314	0.680
2.67	1 200	4.88	0.370	0.703	4.90	0.373	0.805
2.90	1 300	5.29	0.435	0.818	5.31	0.438	0.945
3.12	1 400	5.70	0.504	0.940	5.72	0.508	1.09
3.34	1 500	6.10	0.579	1.07	6.13	0.584	1.25
3.56	1 600	6.51	0.659	1.21	6.54	0.664	1.42
3.79	1 700	6.92	0.743	1.36	6.94	0.749	1.60
4.01	1 800	7.32	0.834	1.52	7.35	0.840	1.78
4.23	1 900	7.73	0.929	1.68	7.76	0.936	1.97
4.46	2 000	8.14	1.03	1.86	8.17	1.04	2.17
4.90	2 200	8.95	1.25	2.23	8.99	1.26	2.64
5.35	2 400	9.76	1.48	2.64	9.80	1.49	3.12
5.79	2 600	10.6	1.74	3.08	10.6	1.75	3.63
6.24	2 800	11.4	2.02	3.56	11.4	2.03	4.18
6.68	3 000	12.2	2.32	4.06	12.3	2.33	4.79
7.13	3 200	13.0	2.63	4.59	13.1	2.66	5.47
7.58	3 400	13.8	2.97	5.16	13.9	3.00	6.18
8.02	3 600	14.6	3.33	5.76	14.7	3.36	6.91
8.47	3 800	15.5	3.71	6.40	15.5	3.74	7.68
8.91	4 000	16.3	4.12	7.07	16.3	4.15	8.50

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

10 in nominal		Steel-schedule 40 ID = 10.020 in $\varepsilon/D = 0.000180$			Asphalt-dipped cast iron ID = 10.00 in $\varepsilon/D = 0.000480$		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
10.03	4 500	18.3	5.21	8.88	18.4	5.25	10.7
11.1	5 000	20.3	6.43	10.9	20.4	6.48	13.2
12.3	5 500	22.4	7.78	13.2	22.5	7.85	15.9
13.4	6 000	24.4	9.26	15.6	24.5	9.34	18.9
14.5	6 500	26.4	10.9	18.3	26.6	11.0	22.2
15.6	7 000	28.5	12.6	21.1	28.6	12.7	25.8
16.7	7 500	30.5	14.5	24.3	30.0	14.6	29.6
17.8	8 000	32.5	16.5	27.5	32.7	16.6	33.6
18.9	8 500	34.6	18.6	30.9	34.7	18.7	37.8
20.1	9 000	36.6	20.8	34.6	36.8	21.0	42.2
21.2	9 500	38.7	23.2	38.5	38.8	23.4	46.9
22.3	10 000	40.7	25.7	42.6	40.9	25.9	51.8
12 in nominal		Steel-schedule 40 D = 11.938 in $\varepsilon/D = 0.000151$			Asphalt-dipped cast iron ID = 12.00 in $\varepsilon/D = 0.000400$		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
0.223	100	0.287	0.00128	0.00325	0.284	0.00125	0.00320
0.267	120	0.344	0.00184	0.00448	0.340	0.00180	0.00445
0.312	140	0.401	0.00250	0.00590	0.397	0.00245	0.00589
0.356	160	0.459	0.00327	0.00747	0.454	0.00320	0.00752
0.401	180	0.516	0.00414	0.00920	0.511	0.00405	0.00932
0.446	200	0.573	0.00511	0.0111	0.567	0.00500	0.01129
0.490	220	0.631	0.00618	0.0132	0.624	0.00605	0.0135
0.535	240	0.688	0.00735	0.0155	0.681	0.00720	0.0158
0.579	260	0.745	0.00863	0.0180	0.738	0.00845	0.0182
0.624	280	0.802	0.0100	0.0206	0.794	0.00980	0.0208
0.668	300	0.860	0.0115	0.0233	0.851	0.0113	0.0236
0.780	350	1.00	0.0156	0.0306	0.993	0.0153	0.0316
0.891	400	1.15	0.0204	0.0391	1.13	0.0200	0.0404
1.00	450	1.29	0.0259	0.0485	1.28	0.0253	0.0500
1.11	500	1.43	0.0319	0.0587	1.42	0.0313	0.0604
1.23	550	1.58	0.0386	0.0698	1.56	0.0378	0.0718
1.34	600	1.72	0.0460	0.0820	1.70	0.0450	0.0845
1.45	650	1.86	0.0539	0.0950	1.84	0.0528	0.0990
1.56	700	2.01	0.0626	0.109	1.99	0.0613	0.115
1.67	750	2.15	0.0718	0.124	2.13	0.0703	0.131
1.78	800	2.29	0.0817	0.140	2.27	0.0800	0.148
1.89	850	2.44	0.0922	0.156	2.41	0.0903	0.166
2.01	900	2.58	0.103	0.173	2.55	0.101	0.184
2.12	950	2.72	0.115	0.191	2.69	0.113	0.203
2.23	1 000	2.87	0.128	0.210	2.84	0.125	0.224

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

12 in nominal		Steel-schedule 40 D = 11.938 in ε/D = 0.000151			Asphalt-dipped cast iron ID = 12.00 in ε/D = 0.000400		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
2.45	1 100	3.15	0.154	0.251	3.12	0.151	0.272
2.67	1 200	3.44	0.184	0.296	3.40	0.180	0.321
2.90	1 300	3.73	0.216	0.344	3.69	0.211	0.372
3.12	1 400	4.01	0.250	0.395	3.97	0.245	0.428
3.34	1 500	4.30	0.287	0.450	4.26	0.281	0.488
3.56	1 600	4.59	0.327	0.509	4.54	0.320	0.552
3.79	1 700	4.87	0.369	0.572	4.82	0.361	0.621
4.01	1 800	5.16	0.414	0.636	5.11	0.405	0.695
4.23	1 900	5.45	0.461	0.704	5.39	0.451	0.774
4.46	2 000	5.73	0.511	0.776	5.67	0.500	0.858
4.90	2 200	6.31	0.618	0.930	6.24	0.605	1.03
5.35	2 400	6.88	0.735	1.093	6.81	0.720	1.22
5.79	2 600	7.45	0.863	1.28	7.38	0.845	1.43
6.24	2 800	8.03	1.00	1.47	7.94	0.980	1.65
6.68	3 000	8.60	1.15	1.68	8.51	1.13	1.88
7.13	3 200	9.17	1.31	1.90	9.08	1.28	2.13
7.58	3 400	9.75	1.48	2.13	9.65	1.45	2.41
8.02	3 600	10.3	1.65	2.37	10.2	1.62	2.70
8.47	3 800	10.9	1.84	2.63	10.8	1.81	3.00
8.91	4 000	11.5	2.04	2.92	11.3	2.00	3.31
10.03	4 500	12.9	2.59	3.65	12.8	2.53	4.18
11.1	5 000	14.3	3.19	4.47	14.2	3.13	5.13
12.3	5 500	15.8	3.86	5.38	15.6	3.78	6.17
13.4	6 000	17.2	4.60	6.39	17.0	4.50	7.30
14.5	6 500	18.6	5.39	7.47	18.4	5.28	8.55
15.6	7 000	20.1	6.26	8.63	19.9	6.13	9.92
16.7	7 500	21.5	7.18	9.88	21.3	7.03	11.4
17.8	8 000	22.9	8.17	11.20	22.7	8.00	13.0
18.9	8 500	24.4	9.22	12.6	24.1	9.04	14.7
20.1	9 000	25.8	10.3	14.1	25.5	10.1	16.4
21.2	9 500	27.2	11.5	15.7	26.9	11.3	18.2
22.3	10 000	28.7	12.8	17.4	28.4	12.5	20.2
24.5	11 000	31.5	15.4	21.0	31.2	15.1	24.2
26.7	12 000	34.4	18.3	24.8	34.0	18.0	28.8
29.0	13 000	37.3	21.6	28.9	36.9	21.1	34.0
31.2	14 000	40.1	25.0	33.5	39.7	24.5	39.7
33.4	15 000	43.0	28.7	38.4	42.6	28.1	45.7
35.6	16 000	45.9	32.7	43.7	45.4	32.0	51.8
37.9	17 000	48.7	36.9	49.2	48.2	36.1	58.2
40.1	18 000	51.6	41.4	55.2	51.1	40.5	65.0
42.3	19 000	54.5	46.1	61.5	53.9	45.1	72.1
44.6	20 000	57.3	51.1	68.1	56.7	50.0	79.8

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

16 in nominal		Steel-schedule 40 ID = 15.000 in ε/D = 0.000120			Asphalt-dipped cast iron ID = 16.00 in ε/D = 0.000300		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
0.668	300	0.545	0.00461	0.00769	0.479	0.00356	0.00581
0.891	400	0.726	0.00820	0.0129	0.638	0.00633	0.00980
1.114	500	0.908	0.0128	0.0193	0.798	0.00989	0.0148
1.34	600	1.09	0.0184	0.0269	0.957	0.0142	0.0207
1.56	700	1.27	0.0251	0.0356	1.12	0.0194	0.0276
1.78	800	1.45	0.0328	0.0454	1.28	0.0253	0.0354
2.01	900	1.63	0.0415	0.0563	1.44	0.0320	0.0441
2.23	1 000	1.82	0.0512	0.0683	1.60	0.0396	0.0537
2.67	1 200	2.18	0.0738	0.0953	1.91	0.0570	0.0760
3.12	1 400	2.54	0.1004	0.127	2.23	0.0775	0.101
3.56	1 600	2.90	0.131	0.163	2.55	0.101	0.130
4.01	1 800	3.27	0.166	0.203	2.87	0.128	0.163
4.46	2 000	3.63	0.205	0.248	3.19	0.158	0.200
5.57	2 500	4.54	0.320	0.377	3.99	0.247	0.307
6.68	3 000	5.45	0.461	0.535	4.79	0.356	0.435
7.80	3 500	6.35	0.627	0.718	5.58	0.485	0.584
8.91	4 000	7.26	0.820	0.921	6.38	0.633	0.754
10.02	4 500	8.17	1.04	1.15	7.18	0.801	0.948
11.1	5 000	9.08	1.28	1.41	7.98	0.989	1.17
13.4	6 000	10.9	1.84	2.01	9.57	1.42	1.66
15.6	7 000	12.7	2.51	2.69	11.2	1.94	2.26
17.8	8 000	14.5	3.28	3.49	12.8	2.53	2.96
20.1	9 000	16.3	4.15	4.38	14.4	3.20	3.73
22.3	10 000	18.2	5.12	5.38	16.0	3.96	4.57
24.5	11 000	20.0	6.20	6.49	17.6	4.79	5.50
26.7	12 000	21.8	7.38	7.69	19.1	5.70	6.52
29.0	13 000	23.6	8.66	8.99	20.7	6.69	7.63
31.2	14 000	25.4	10.04	10.4	22.3	7.75	8.81
33.4	15 000	27.2	11.5	11.9	23.9	8.90	10.1
35.6	16 000	29.0	13.1	13.5	25.5	10.1	11.5
37.9	17 000	30.9	14.8	15.3	27.1	11.4	13.0
40.1	18 000	32.7	16.6	17.2	28.7	12.8	14.6
42.3	19 000	34.5	18.5	19.2	30.3	14.3	16.3
44.6	20 000	36.3	20.5	21.2	31.9	15.8	18.1
49.0	22 000	39.9	24.8	25.5	35.1	19.1	21.8
53.5	24 000	43.6	29.5	30.2	38.3	22.8	25.9
57.9	26 000	47.2	34.6	35.4	41.5	26.7	30.4
62.4	28 000	50.8	40.2	41.0	44.7	31.0	35.3
66.8	30 000	54.5	46.1	47.0	47.9	35.6	40.5
71.3	32 000	58.1	52.4	53.5	51.1	40.5	46.0
75.8	34 000	61.7	59.2	60.2	54.3	45.7	51.9
80.2	36 000	65.4	66.4	67.2	57.4	51.3	58.1
84.7	38 000	69.0	74.0	75.0	60.6	57.1	64.7
89.1	40 000	72.6	82.0	83.0	63.8	63.3	71.7
93.6	42 000	76.2	90.4	91.5	67.0	69.8	79.1
98.0	44 000	79.9	99.2	101	70.2	76.6	86.9
102.5	46 000	83.5	108.4	110	73.4	83.7	95.0
107	48 000	87.1	118	118	76.6	91.2	103
111	50 000	90.8	128	128	79.8	98.9	112

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

18 in nominal		Steel-schedule 40 ID = 16.876 in $\varepsilon/D = 0.000107$			Asphalt-dipped cast iron ID = 18.00 in $\varepsilon/D = 0.000267$		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
0.668	300	0.430	0.00288	0.00437	0.378	0.00222	0.00328
0.891	400	0.574	0.00512	0.00730	0.504	0.00359	0.00554
1.114	500	0.717	0.00799	0.0109	0.630	0.00618	0.00832
1.34	600	0.861	0.0115	0.0152	0.756	0.00889	0.01162
1.56	700	1.00	0.0157	0.0201	0.883	0.0121	0.0154
1.78	800	1.15	0.0205	0.0256	1.01	0.0158	0.0197
2.01	900	1.29	0.0259	0.0318	1.13	0.0200	0.0245
2.23	1 000	1.43	0.0320	0.0386	1.26	0.0247	0.0298
2.67	1 200	1.72	0.0460	0.0541	1.51	0.0356	0.0420
3.12	1 400	2.01	0.0627	0.0719	1.77	0.0484	0.0560
3.56	1 600	2.30	0.0819	0.092	2.02	0.0632	0.0728
4.01	1 800	2.58	0.1036	0.114	2.27	0.0800	0.0910
4.46	2 000	2.87	0.128	0.139	2.52	0.0988	0.110
5.57	2 500	3.59	0.200	0.211	3.15	0.154	0.170
6.68	3 000	4.30	0.288	0.297	3.78	0.222	0.240
7.80	3 500	5.02	0.392	0.397	4.41	0.303	0.320
8.91	4 000	5.74	0.512	0.511	5.04	0.395	0.415
10.02	4 500	6.45	0.647	0.639	5.67	0.500	0.525
11.1	5 000	7.17	0.799	0.781	6.30	0.618	0.645
13.4	6 000	8.61	1.15	1.11	7.56	0.889	0.920
15.6	7 000	10.0	1.57	1.49	8.83	1.21	1.24
17.8	8 000	11.5	2.05	1.93	10.09	1.58	1.61
20.1	9 000	12.9	2.59	2.42	11.3	2.00	2.02
22.3	10 000	14.3	3.20	2.97	12.6	2.47	2.48
26.7	12 000	17.2	4.60	4.21	15.1	3.56	3.56
31.2	14 000	20.1	6.27	5.69	17.7	4.84	4.85
35.6	16 000	22.9	8.19	7.41	20.2	6.32	6.34
40.1	18 000	25.8	10.36	9.33	22.7	8.00	8.02
44.6	20 000	28.7	12.8	11.5	25.2	9.88	9.88
49.0	22 000	31.6	15.5	13.9	27.7	12.0	11.90
53.5	24 000	34.4	18.4	16.5	30.3	14.2	14.10
57.9	26 000	37.3	21.6	19.2	32.8	16.7	16.50
62.4	28 000	40.2	25.1	22.2	35.3	19.4	19.1
66.8	30 000	43.0	28.8	25.5	37.8	22.9	21.9
71.3	32 000	45.9	32.7	29.0	40.3	25.3	24.9
75.8	34 000	48.8	37.0	32.8	42.9	28.6	28.1
80.2	36 000	51.6	41.4	36.8	45.4	32.0	31.5
84.7	38 000	54.5	46.2	40.8	47.9	35.7	35.1
89.1	40 000	57.4	51.2	45.0	50.4	39.5	38.9
93.6	42 000	60.2	56.4	49.7	53.0	43.6	42.9
98	44 000	63.1	61.9	54.5	55.5	47.8	47.0
102	46 000	66.0	67.7	59.5	58.0	52.3	51.3
107	48 000	68.9	73.7	64.8	60.5	56.9	55.8
111	50 000	71.7	79.9	70.2	63.0	61.8	60.5
123	55 000	78.9	96.7	84.8	69.3	74.7	73.0
134	60 000	86.1	115	101	75.6	88.9	86.7
145	65 000	93.2	135	118	82.0	104.4	101.8
156	70 000	100.4	157	136	88.3	121	118

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

20 in nominal		Steel-schedule 40 ID = 18.812 in ε/D = 0.0000957			Asphalt-dipped cast iron ID = 20.00 in ε/D = 0.000240		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
0.668	300	0.346	0.00186	0.00258	0.306	0.00146	0.00197
0.891	400	0.462	0.00331	0.00432	0.408	0.00259	0.00332
1.114	500	0.577	0.00517	0.00645	0.511	0.00405	0.00496
1.34	600	0.692	0.00745	0.00897	0.613	0.00583	0.00691
1.56	700	0.808	0.0101	0.01186	0.715	0.00794	0.00918
1.78	800	0.923	0.0132	0.0152	0.817	0.0104	0.0117
2.01	900	1.039	0.0168	0.0188	0.919	0.0131	0.0146
2.23	1 000	1.15	0.0207	0.0227	1.02	0.0162	0.0177
2.67	1 200	1.38	0.0298	0.0318	1.23	0.0233	0.0249
3.12	1 400	1.62	0.0406	0.0422	1.43	0.0318	0.0332
3.56	1 600	1.85	0.0530	0.0538	1.63	0.0415	0.0427
4.01	1 800	2.08	0.0671	0.0669	1.84	0.0525	0.0533
4.46	2 000	2.31	0.0828	0.0812	2.04	0.0648	0.0650
5.57	2 500	2.89	0.129	0.123	2.55	0.1013	0.0998
6.68	3 000	3.46	0.186	0.174	3.06	0.146	0.140
7.80	3 500	4.04	0.254	0.232	3.57	0.198	0.188
8.91	4 000	4.62	0.331	0.298	4.08	0.259	0.243
10.02	4 500	5.19	0.419	0.372	4.59	0.328	0.306
11.1	5 000	5.77	0.517	0.455	5.11	0.405	0.376
13.4	6 000	6.92	0.745	0.645	6.13	0.583	0.533
15.6	7 000	8.08	1.014	0.862	7.15	0.794	0.721
17.8	8 000	9.23	1.32	1.11	8.17	1.04	0.935
20.1	9 000	10.39	1.68	1.39	9.19	1.31	1.18
22.3	10 000	11.5	2.07	1.70	10.2	1.62	1.45
26.7	12 000	13.8	2.98	2.44	12.3	2.33	2.07
31.2	14 000	16.2	4.06	3.29	14.3	3.18	2.80
35.6	16 000	18.5	5.30	4.26	16.3	4.15	3.66
40.1	18 000	20.8	6.71	5.35	18.4	5.25	4.62
44.6	20 000	23.1	8.28	6.56	20.4	6.48	5.67
49.0	22 000	25.4	10.02	7.91	22.5	7.84	6.85
53.5	24 000	27.7	11.9	9.39	24.5	9.33	8.13
57.9	26 000	30.0	14.0	11.0	26.5	10.95	9.54
62.4	28 000	32.3	16.2	12.7	28.6	12.7	11.1
66.8	30 000	34.6	18.6	14.6	30.6	14.6	12.7
71.3	32 000	36.9	21.2	16.6	32.7	16.6	14.4
75.8	34 000	39.2	23.9	18.7	34.7	18.7	16.3
80.2	36 000	41.5	26.8	20.9	36.8	21.0	18.2
84.7	38 000	43.9	29.9	23.2	38.8	23.4	20.2
89.1	40 000	46.2	33.1	25.7	40.8	25.9	22.4
93.6	42 000	48.5	36.5	28.4	42.9	28.6	24.7
98	44 000	50.8	40.1	31.3	44.9	31.4	27.1
102	46 000	53.1	43.8	34.2	47.0	34.3	29.7
107	48 000	55.4	47.7	37.1	49.0	37.3	32.4
111	50 000	57.7	51.7	40.0	51.1	40.5	35.2
123	55 000	63.5	62.6	48.3	56.2	49.0	4

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

20 in nominal		Steel-schedule 40 ID = 18.812 in ε/D = 0.0000957			Asphalt-dipped cast iron ID = 20.00 in ε/D = 0.000240		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
134	60 000	69.2	74.5	57.4	61.3	58.3	50.4
145	65 000	75.0	87.4	67.2	66.4	68.5	59.0
156	70 000	80.8	101.4	77.8	71.5	79.4	68.4
167	75 000	86.6	116	89.3	76.6	91.1	78.6
178	80 000	92.3	132	102	81.7	103.7	89.5
189	85 000	98.1	150	115	86.8	117	101
201	90 000	103.9	168	129	91.9	131	113
212	95 000	109.6	187	143	97.0	146	126
223	100 000	115.4	207	158	102.1	162	139
24 in nominal		Steel-schedule 40 ID = 22.624 in ε/D = 0.0000796			Asphalt-dipped cast iron ID = 24.00 in ε/D = 0.000200		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
0.668	300	0.239	0.000891	0.00107	0.213	0.000703	0.000821
0.891	400	0.319	0.00158	0.00178	0.284	0.00125	0.00137
1.114	500	0.399	0.00247	0.00267	0.355	0.00195	0.00205
1.34	600	0.479	0.00356	0.00371	0.426	0.00281	0.00284
1.56	700	0.559	0.00485	0.00490	0.496	0.00383	0.00376
1.78	800	0.638	0.00633	0.00621	0.567	0.00500	0.00480
2.01	900	0.716	0.00801	0.00767	0.638	0.00633	0.00597
2.23	1 000	0.798	0.00989	0.00928	0.709	0.00782	0.00724
2.67	1 200	0.958	0.0142	0.0129	0.851	0.01126	0.0102
3.12	1 400	1.12	0.0194	0.0171	0.993	0.0153	0.0135
3.56	1 600	1.28	0.0253	0.0219	1.135	0.0200	0.0173
4.01	1 800	1.44	0.0321	0.0272	1.276	0.0253	0.0216
4.46	2 000	1.60	0.0396	0.0330	1.42	0.0313	0.0262
5.57	2 500	1.99	0.0618	0.0499	1.77	0.0489	0.0398
6.68	3 000	2.39	0.0891	0.0700	2.13	0.0703	0.0563
7.80	3 500	2.79	0.121	0.0934	2.48	0.0957	0.0759
8.91	4 000	3.19	0.158	0.120	2.84	0.125	0.098
10.02	4 500	3.59	0.200	0.149	3.19	0.158	0.122
11.1	5 000	3.99	0.247	0.181	3.55	0.195	0.149
13.4	6 000	4.79	0.356	0.257	4.26	0.281	0.211
15.6	7 000	5.59	0.485	0.343	4.96	0.383	0.284
17.8	8 000	6.38	0.633	0.441	5.67	0.500	0.368
20.1	9 000	7.18	0.801	0.551	6.38	0.633	0.464
22.3	10 000	7.98	0.989	0.671	7.09	0.782	0.571
26.7	12 000	9.58	1.42	0.959	8.51	1.126	0.816
31.2	14 000	11.2	1.94	1.29	9.93	1.53	1.11
35.6	16 000	12.8	2.53	1.67	11.35	2.00	1.43
40.1	18 000	14.4	3.21	2.10	12.76	2.53	1.80
44.6	20 000	16.0	3.96	2.58	14.2	3.13	2.21
49.0	22 000	17.6	4.79	3.10	15.6	3.78	2.67

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

24 in nominal		Steel-schedule 40 ID = 22.624 in ε/D = 0.0000796			Asphalt-dipped cast iron ID = 24.00 in ε/D = 0.000200		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
53.5	24 000	19.2	5.70	3.67	17.0	4.50	3.16
57.9	26 000	20.7	6.69	4.29	18.4	5.28	3.71
62.4	28 000	22.3	7.76	4.96	19.9	6.13	4.32
66.8	30 000	23.9	8.91	5.68	21.3	7.03	4.97
71.3	32 000	25.5	10.13	6.42	22.7	8.00	5.65
75.8	34 000	27.1	11.4	7.22	24.1	9.04	6.35
80.2	36 000	28.7	12.8	8.08	25.5	10.13	7.10
84.7	38 000	30.3	14.3	9.00	26.9	11.3	7.90
89.1	40 000	31.9	15.8	9.98	28.4	12.5	8.75
93.6	42 000	33.5	17.5	11.0	29.8	13.8	9.63
98.0	44 000	35.1	19.2	12.1	31.2	15.1	10.5
102	46 000	36.7	20.9	13.2	32.6	16.5	11.5
107	48 000	38.3	22.8	14.3	34.0	18.0	12.5
111	50 000	39.9	24.7	15.5	35.5	19.5	13.6
123	55 000	43.9	29.9	18.7	39.0	23.6	16.4
134	60 000	47.9	35.6	22.3	42.6	28.1	19.5
145	65 000	51.9	41.8	26.2	46.1	33.0	22.9
156	70 000	55.9	48.5	30.4	49.6	38.3	26.5
167	75 000	59.8	55.7	34.8	53.2	44.0	30.5
178	80 000	63.8	63.3	39.4	56.7	50.0	34.7
189	85 000	67.8	71.5	44.4	60.3	56.5	39.2
201	90 000	71.8	80.1	49.7	63.8	63.3	43.9
212	95 000	75.8	89.3	55.5	67.4	70.5	48.9
223	100 000	79.8	98.9	61.5	70.9	78.2	54.2
245	110 000	87.8	120	74.0	78.0	94.6	65.5
267	120 000	95.8	142	88.0	85.1	113	78.0
290	130 000	103.7	167	103	92.2	132	91.5
312	140 000	112	194	119	99.3	153	106
334	150 000	120	223	137	106	200	121

30 in nominal		Steel-schedule 40 ID = 29.000 in ε/D = 0.0000621			Asphalt-dipped cast iron ID = 30.00 in ε/D = 0.000160		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
0.891	400	0.194	0.000587	0.000540	0.182	0.000512	0.000466
1.114	500	0.243	0.000917	0.000805	0.227	0.000800	0.000695
1.34	600	0.291	0.00132	0.001115	0.272	0.00115	0.000964
1.56	700	0.340	0.00180	0.00147	0.318	0.00157	0.00128
1.78	800	0.389	0.00235	0.00187	0.363	0.00205	0.00163
2.01	900	0.437	0.00297	0.00231	0.408	0.00259	0.00202
2.23	1 000	0.486	0.00367	0.00280	0.454	0.00320	0.00244
2.67	1 200	0.583	0.00528	0.00390	0.545	0.00461	0.00343
3.12	1 400	0.680	0.00719	0.00514	0.635	0.00627	0.00452
3.56	1 600	0.777	0.00939	0.00652	0.726	0.00819	0.00577

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

30 in nominal		Steel-schedule 40 ID = 29.000 in $\varepsilon/D = 0.0000621$			Asphalt-dipped cast iron ID = 30.00 in $\varepsilon/D = 0.000160$		
Discharge				h_f feet per 100 ft of pipe			h_f feet per 100 ft of pipe
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)		V (ft/s)	$V^2/2g$ (ft)	
4.01	1 800	0.874	0.0119	0.00814	0.817	0.0104	0.00720
4.46	2 000	0.971	0.0147	0.00986	0.908	0.0128	0.00876
5.57	2 500	1.21	0.0229	0.0148	1.13	0.0200	0.0132
6.68	3 000	1.46	0.0330	0.0206	1.36	0.0288	0.0186
7.80	3 500	1.70	0.0449	0.0276	1.59	0.0392	0.0248
8.91	4 000	1.94	0.0587	0.0354	1.82	0.0512	0.0320
10.02	4 500	2.19	0.0742	0.0440	2.04	0.0648	0.0400
11.14	5 000	2.43	0.0917	0.0535	2.27	0.0800	0.0488
13.4	6 000	2.91	0.132	0.0750	2.72	0.115	0.0690
15.6	7 000	3.40	0.180	0.100	3.18	0.157	0.0923
17.8	8 000	3.89	0.235	0.129	3.63	0.205	0.119
20.1	9 000	4.37	0.297	0.161	4.08	0.259	0.149
22.3	10 000	4.86	0.367	0.196	4.54	0.320	0.183
26.7	12 000	5.83	0.528	0.277	5.45	0.461	0.260
31.2	14 000	6.80	0.719	0.371	6.35	0.627	0.351
35.6	16 000	7.77	0.939	0.478	7.26	0.819	0.455
40.1	18 000	8.74	1.19	0.598	8.17	1.04	0.572
44.6	20 000	9.71	1.47	0.732	9.08	1.28	0.703
55.7	25 000	12.1	2.29	1.13	11.3	2.00	1.09
66.8	30 000	14.6	3.30	1.61	13.6	2.88	1.57
78.0	35 000	17.0	4.49	2.17	15.9	3.92	2.13
89.1	40 000	19.4	5.87	2.83	18.2	5.12	2.77
100	45 000	21.9	7.42	3.56	20.4	6.48	3.50
111	50 000	24.3	9.17	4.38	22.7	8.00	4.30
134	60 000	29.1	13.2	6.23	27.2	11.5	6.19
156	70 000	34.0	18.0	8.43	31.8	15.7	8.39
178	80 000	38.9	23.5	11.0	36.3	20.5	10.9
201	90 000	43.7	29.7	13.8	40.8	25.9	13.8
223	100 000	48.6	36.7	17.0	45.4	32.0	17.0
245	110 000	53.4	44.4	20.6	49.9	38.7	20.5
267	120 000	58.3	52.8	24.5	54.5	46.1	24.4
290	130 000	63.1	62.0	28.7	59.0	54.1	28.6
312	140 000	68.0	71.9	33.3	63.5	62.7	33.1
334	150 000	72.9	82.5	38.2	68.1	72.0	38.0
356	160 000	77.7	93.9	43.3	72.6	81.9	43.2
379	170 000	82.6	106	48.8	77.2	92.5	48.7
401	180 000	87.4	119	54.7	81.7	104	54.7
423	190 000	92.3	132	60.8	86.2	116	61.0
446	200 000	97.1	147	67.1	90.8	128	67.6
468	210 000	102	162	73.8	95.3	141	74.5
490	220 000	107	177	81.0	99.8	155	81.7
512	230 000	112	194	88.6	104	169	89.2
535	240 000	117	211	96.7	109	184	97.0
557	250 000	121	229	106	113	200	105

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

36 in ID				Steel $\varepsilon/D = 0.0000500$	Cast iron $\varepsilon/D = 0.000133$
Discharge					
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)	h_f feet per 100 ft of pipe	h_f feet per 100 ft of pipe
2.23	1 000	0.315	0.00154	0.000988	0.00101
2.67	1 200	0.378	0.00222	0.00137	0.00140
3.12	1 400	0.441	0.00303	0.00181	0.00186
3.56	1 600	0.504	0.00395	0.00231	0.00237
4.01	1 800	0.567	0.00500	0.00285	0.00295
4.46	2 000	0.630	0.00618	0.00344	0.00357
5.57	2 500	0.788	0.00965	0.00517	0.00538
6.68	3 000	0.946	0.0139	0.00721	0.00751
7.80	3 500	1.103	0.0189	0.00957	0.0101
8.91	4 000	1.26	0.0247	0.0122	0.0129
10.02	4 500	1.41	0.0313	0.0152	0.0161
11.14	5 000	1.58	0.0386	0.0185	0.0196
13.4	6 000	1.89	0.0556	0.0260	0.0276
15.6	7 000	2.21	0.0756	0.0345	0.0369
17.8	8 000	2.52	0.0988	0.0442	0.0475
20.1	9 000	2.84	0.125	0.0551	0.0593
22.3	10 000	3.15	0.154	0.0670	0.0724
26.7	12 000	3.78	0.222	0.0942	0.103
31.2	14 000	4.41	0.303	0.126	0.139
35.6	16 000	5.04	0.395	0.162	0.180
40.1	18 000	5.67	0.500	0.203	0.227
44.6	20 000	6.30	0.618	0.248	0.279
55.7	25 000	7.88	0.965	0.378	0.430
66.8	30 000	9.46	1.39	0.540	0.617
78.0	35 000	11.03	1.89	0.724	0.832
89.1	40 000	12.6	2.47	0.941	1.08
100	45 000	14.1	3.13	1.18	1.36
111	50 000	15.8	3.86	1.45	1.68
134	60 000	18.9	5.56	2.07	2.40
156	70 000	22.1	7.56	2.81	3.25
178	80 000	25.2	9.88	3.66	4.23
201	90 000	28.4	12.5	4.59	5.34
223	100 000	31.5	15.4	5.64	6.58
267	120 000	37.8	22.2	8.05	9.50
312	140 000	44.1	30.3	10.9	12.9
356	160 000	50.4	39.5	14.2	16.8
401	180 000	56.7	50.0	17.9	21.3
446	200 000	63.0	61.8	22.1	26.3
557	250 000	78.8	96.5	34.4	41.0
668	300 000	94.6	139	49.4	58.8
780	350 000	110	189	67.0	80.0
891	400 000	126	247	87.3	105

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

42 in ID				Steel $\varepsilon/D = 0.0000429$	Cast iron $\varepsilon/D = 0.000114$
Discharge					
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)	h_f feet per 100 ft of pipe	h_f feet per 100 ft of pipe
2.23	1 000	0.232	0.000833	0.000471	0.000481
3.34	1 500	0.347	0.00187	0.000977	0.000997
4.46	2 000	0.463	0.00333	0.00164	0.00168
5.57	2 500	0.579	0.00521	0.00246	0.00252
6.68	3 000	0.695	0.00750	0.00343	0.00353
7.80	3 500	0.811	0.0102	0.00454	0.00470
8.91	4 000	0.926	0.0133	0.00580	0.00602
10.02	4 500	1.042	0.0169	0.00720	0.00750
11.14	5 000	1.16	0.0208	0.00874	0.00915
13.4	6 000	1.39	0.0300	0.0122	0.0128
15.6	7 000	1.62	0.0408	0.0162	0.0172
17.8	8 000	1.85	0.0533	0.0208	0.0222
20.1	9 000	2.08	0.0675	0.0258	0.0276
22.3	10 000	2.32	0.0833	0.0314	0.0337
26.7	12 000	2.78	0.120	0.0441	0.0477
31.2	14 000	3.24	0.163	0.0591	0.0641
35.6	16 000	3.71	0.213	0.0758	0.0829
40.1	18 000	4.17	0.270	0.0944	0.104
44.6	20 000	4.63	0.333	0.115	0.127
55.7	25 000	5.79	0.521	0.176	0.196
66.8	30 000	6.95	0.750	0.250	0.279
78.0	35 000	8.11	1.02	0.334	0.377
89.1	40 000	9.26	1.33	0.433	0.490
100	45 000	10.42	1.69	0.545	0.619
111	50 000	11.6	2.08	0.668	0.760
134	60 000	13.9	3.00	0.946	1.09
156	70 000	16.2	4.08	1.27	1.48
178	80 000	18.5	5.33	1.66	1.92
201	90 000	20.8	6.75	2.08	2.42
223	100 000	23.2	8.33	2.57	2.98
267	120 000	27.8	12.0	3.67	4.30
312	140 000	32.4	16.3	4.98	5.82
356	160 000	37.1	21.3	6.46	7.58
401	180 000	41.7	27.0	8.12	9.58
446	200 000	46.3	33.3	10.00	11.8
557	250 000	57.9	52.1	15.6	18.4
668	300 000	69.5	75.0	22.3	26.5
780	350 000	81.1	102	30.4	36.1
891	400 000	92.6	133	39.6	47.2
1002	450 000	104.2	169	50.1	59.7
1114	500 000	116	208	67.7	73.6

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

48 in ID				Steel $\varepsilon/D = 0.0000375$	Cast iron $\varepsilon/D = 0.000100$
Discharge					
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)	h_f feet per 100 ft of pipe	h_f feet per 100 ft of pipe
3.34	1 500	0.266	0.00110	0.000508	0.000521
4.46	2 000	0.355	0.00195	0.000855	0.000883
5.57	2 500	0.443	0.00305	0.00129	0.00133
6.68	3 000	0.532	0.00440	0.00180	0.00185
7.80	3 500	0.621	0.00598	0.00238	0.00245
8.91	4 000	0.709	0.00782	0.00304	0.00314
10.02	4 500	0.798	0.00989	0.00378	0.00391
11.14	5 000	0.887	0.01221	0.00458	0.00474
13.4	6 000	1.064	0.0176	0.00636	0.00667
15.6	7 000	1.24	0.0239	0.00844	0.00890
17.8	8 000	1.42	0.0313	0.0108	0.0114
20.1	9 000	1.60	0.0396	0.0134	0.0142
22.3	10 000	1.77	0.0489	0.0163	0.0173
26.7	12 000	2.13	0.0703	0.0229	0.0244
31.2	14 000	2.48	0.0957	0.0305	0.0327
35.6	16 000	2.84	0.125	0.0391	0.0422
40.1	18 000	3.19	0.158	0.0488	0.0529
44.6	20 000	3.55	0.195	0.0598	0.0648
55.7	25 000	4.43	0.305	0.0910	0.0996
66.8	30 000	5.32	0.440	0.128	0.142
78.0	35 000	6.21	0.598	0.172	0.192
89.1	40 000	7.09	0.782	0.222	0.248
100.2	45 000	7.98	0.989	0.278	0.314
111.4	50 000	8.87	1.221	0.341	0.384
134	60 000	10.64	1.76	0.484	0.548
156	70 000	12.4	2.39	0.652	0.742
178	80 000	14.2	3.13	0.849	0.968
201	90 000	16.0	3.96	1.06	1.22
223	100 000	17.7	4.89	1.30	1.50
267	120 000	21.3	7.03	1.87	2.15
312	140 000	24.8	9.57	2.51	2.92
356	160 000	28.4	12.5	3.26	3.81
401	180 000	31.9	15.8	4.11	4.83
446	200 000	35.5	19.5	5.05	5.97
557	250 000	44.3	30.5	7.88	9.28
668	300 000	53.2	44.0	11.3	13.4
780	350 000	62.1	59.8	15.3	18.2
891	400 000	70.9	78.2	20.0	23.7
1002	450 000	79.8	98.9	25.2	29.9
1114	500 000	88.7	122.1	31.1	36.8
1225	550 000	97.5	148	37.6	44.5
1337	600 000	106.4	176	44.7	53.0

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

60 in ID				Steel $\varepsilon/D = 0.0000300$	Cast iron $\varepsilon/D = 0.000800$
Discharge					
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)	h_f feet per 100 ft of pipe	h_f feet per 100 ft of pipe
4.46	2 000	0.227	0.000800	0.000293	0.000298
5.57	2 500	0.284	0.00125	0.000440	0.000446
6.68	3 000	0.340	0.00180	0.000612	0.000621
7.80	3 500	0.397	0.00245	0.000810	0.000824
8.91	4 000	0.454	0.00320	0.00103	0.00105
10.02	4 500	0.511	0.00405	0.00128	0.00131
11.14	5 000	0.567	0.00500	0.00155	0.00159
13.4	6 000	0.681	0.00720	0.00216	0.00223
15.6	7 000	0.794	0.00980	0.00285	0.00297
17.8	8 000	0.908	0.0128	0.00365	0.00382
20.1	9 000	1.021	0.0162	0.00454	0.00476
22.3	10 000	1.13	0.0200	0.00550	0.00579
26.7	12 000	1.36	0.0288	0.00766	0.00815
31.2	14 000	1.59	0.0392	0.0102	0.0108
35.6	16 000	1.82	0.0512	0.0131	0.0140
40.1	18 000	2.04	0.0648	0.0163	0.0174
44.6	20 000	2.27	0.0800	0.0198	0.0212
55.7	25 000	2.84	0.125	0.0301	0.0325
66.8	30 000	3.40	0.180	0.0424	0.0460
78.0	35 000	3.97	0.245	0.0567	0.0618
89.1	40 000	4.54	0.320	0.0730	0.0800
100.2	45 000	5.11	0.405	0.0916	0.100
111.4	50 000	5.67	0.500	0.112	0.124
134	60 000	6.81	0.720	0.158	0.176
156	70 000	7.94	0.980	0.213	0.237
178	80 000	9.08	1.28	0.275	0.307
201	90 000	10.21	1.62	0.344	0.387
223	100 000	11.3	2.00	0.420	0.478
267	120 000	13.6	2.88	0.600	0.688
312	140 000	15.9	3.92	0.806	0.930
356	160 000	18.2	5.12	1.04	1.20
401	180 000	20.4	6.48	1.32	1.52
446	200 000	22.7	8.00	1.62	1.87
557	250 000	28.4	12.5	2.52	2.92
668	300 000	34.0	18.0	3.60	4.20
780	350 000	39.7	24.5	4.88	5.71
891	400 000	45.4	32.0	6.34	7.42
1002	450 000	51.1	40.5	8.01	9.40
1114	500 000	56.7	50.0	9.87	11.6
1225	550 000	62.4	60.5	11.9	14.0
1337	600 000	68.1	72.0	14.1	16.7
1448	650 000	73.8	84.5	16.6	19.6
1560	700 000	79.4	98.0	19.2	22.7
1671	750 000	85.1	112.6	22.0	26.0
1782	800 000	90.8	128	25.0	29.6

TABLE E4.1 Friction Loss for Water in Feet per 100 Ft of Pipe (*Continued*)

84 in ID				Steel $\varepsilon/D = 0.0000214$	Cast iron $\varepsilon/D = 0.000571$
Discharge					
ft^3/s	gal/min	V (ft/s)	$V^2/2g$ (ft)	h_f feet per 100 ft of pipe	h_f feet per 100 ft of pipe
6.68	3 000	0.174	0.000469	0.000121	0.000122
8.91	4 000	0.232	0.000833	0.000203	0.000206
11.14	5 000	0.289	0.00130	0.000306	0.000309
13.4	6 000	0.347	0.00188	0.000425	0.000432
15.6	7 000	0.405	0.00255	0.000562	0.000573
17.8	8 000	0.463	0.00333	0.000717	0.000731
20.1	9 000	0.521	0.00422	0.000891	0.000910
22.3	10 000	0.579	0.00521	0.00108	0.00110
26.7	12 000	0.695	0.00750	0.00150	0.00154
31.2	14 000	0.811	0.01021	0.00199	0.00205
35.6	16 000	0.926	0.0133	0.00255	0.00262
40.1	18 000	1.042	0.0169	0.00316	0.00327
44.6	20 000	1.16	0.0208	0.00384	0.00400
55.7	25 000	1.45	0.0326	0.00579	0.00606
66.8	30 000	1.74	0.0469	0.00810	0.00858
78.0	35 000	2.03	0.0638	0.0108	0.0115
89.1	40 000	2.32	0.0833	0.0139	0.0148
100.2	45 000	2.61	0.105	0.0174	0.0185
111.4	50 000	2.89	0.130	0.0212	0.0226
134	60 000	3.47	0.180	0.0298	0.0321
156	70 000	4.05	0.255	0.0398	0.0431
178	80 000	4.63	0.333	0.0513	0.0558
201	90 000	5.21	0.422	0.0640	0.0700
223	100 000	5.79	0.521	0.0781	0.0866
267	120 000	6.95	0.750	0.111	0.122
312	140 000	8.11	1.021	0.149	0.166
356	160 000	9.26	1.33	0.193	0.216
401	180 000	10.42	1.69	0.242	0.272
446	200 000	11.6	2.08	0.297	0.334
557	250 000	14.5	3.26	0.458	0.516
668	300 000	17.4	4.69	0.649	0.740
780	350 000	20.3	6.38	0.880	1.00
891	400 000	23.2	8.33	1.14	1.30
1002	450 000	26.1	10.5	1.44	1.65
1114	500 000	28.9	13.0	1.78	2.04
1225	550 000	31.8	15.8	2.14	2.47
1337	600 000	34.7	18.0	2.54	2.94
1448	650 000	37.6	22.0	2.97	3.45
1560	700 000	40.5	25.5	3.43	4.00
1671	750 000	43.4	29.3	3.93	4.58
1782	800 000	46.3	33.3	4.47	5.20
1894	850 000	49.2	37.6	5.04	5.87
2005	900 000	52.1	42.2	5.64	6.58
2117	950 000	55.0	47.0	6.29	7.32
2228	1 000 000	57.9	52.1	6.95	8.10

Note: No allowance has been made for age, differences in diameter, or any abnormal condition of interior surface. Any factor of safety must be estimated from the local conditions and the requirements of each particular installation.

Source: Friction loss, h_f, is derived from Darcy-Weisbach equations. (*Hydraulic Institute Engineering Data Book,* Table IIIB-4).