Standard Pipe Dimensions

Shown in inches

SCHED. 40 PLASTIC PIPE			
Nominal Pipe Size	Outside Diameter	Inside Diameter	Wall Thickness
½	0.840	.622	0.109
¾	1.050	.824	0.113
1	1.315	1.049	0.133
1 ¼	1.660	1.380	0.140
1 ½	1.900	1.610	0.145
2	2.375	2.067	0.154
2 ½	2.875	2.469	0.203
3	3.500	3.068	0.216
3 ½	4.000	3.548	0.226
4	4.500	4.026	0.237

SCHED. 80 PLASTIC PIPE			
Nominal Pipe Size	Outside Diameter	Inside Diameter	Wall Thickness
½	0.840	0.546	0.147
¾	1.050	0.742	0.154
1	1.315	0.957	0.179
1 ¼	1.600	1.278	0.191
1 ½	1.900	1.500	0.200
2	2.375	1.939	0.218
2 ½	2.875	2.323	0.276
3	3.500	2.900	0.300
4	4.500	3.826	0.337

FLEXIBLE POLYETHYLENE PIPE									
		SDR 15		SDR 11.5		SDR 9		SDR 7	
Nominal Pipe Size	Inside Diameter	Outside Diameter	Wall Thickness	Outside Diameter	Wall Thickness	Outside Diameter	Wall Thickness	Outside Diameter	Wall Thickness
½	0.622	0.742	0.060	0.742	0.060	0.760	0.069	0.800	0.089
¾	0.824	0.944	0.060	0.968	0.072	1.008	0.092	1.060	0.118
1	1.049	1.189	0.070	1.231	0.091	1.283	0.117	1.349	0.150
1 ¼	1.380	1.564	0.092	1.620	0.120	4.686	0.153	1.774	0.197
1 ½	1.610	1.824	0.107	1.890	0.140	7.968	0.179	2.070	0.230
2	2.067	2.343	0.138	2.427	0.180	2.527	0.230	2.657	0.295
2 ½	2.469	2.799	0.165	2.899	0.215				

COPPER WATER TUBE									
		DRAIN, WASTE & VENT		TYPE M		TYPE L		TYPE K	
Nominal Pipe Size	Outside Diameter	Inside Diameter	Wall Thickness	Inside Diameter	Wall Thickness	Inside Diameter	Wall Thickness	Inside Diameter	Wall Thickness
½	0.625			0.569	0.028	0.545	0.040	0.527	0.049
¾	0.875			0.811	0.032	0.785	0.045	0.745	0.065
1	1.125			1.055	0.035	1.025	0.050	0.995	0.065
1 ¼	1.375	1.295	0.040	1.291	0.042	1.265	0.055	1.245	0.065
1 ½	1.625	1.541	0.042	1.527	0.049	1.505	0.060	1.481	0.072
2	2.125	2.041	0.042	2.009	0.058	1.985	0.070	1.959	0.083
2 ½	2.625			2.495	0.065	2.465	0.080	2.435	0.095
3	3.125	3.035	0.045	2.981	0.072	2.945	0.090	2.907	0.109
4	4.125	4.009	0.058	3.953	0.095	3.905	0.110	3.857	0.134

Standard Pipe Dimensions

Shown in inches

CLASS 150 CAST IRON PIPE			
Nominal Pipe Size	Outside Diameter	Inside Diameter	Wall Thickness
3	3.96	3.32	0.32
4	4.80	4.10	0.35
6	6.90	6.14	0.38
8	9.05	8.23	0.41
10	11.10	10.22	0.44
12	13.20	12.24	0.48
14	15.30	14.28	0.51
16	17.40	16.32	0.54
18	19.50	18.34	0.58
20	21.60	20.36	0.62
24	25.80	24.34	0.73

CLASS 150 ASBESTOS -- CEMENT PIPE			
Nominal Pipe Size	Outside Diameter	Inside Diameter	Wall Thickness
3	4.10	3.00	0.550
4	5.07	4.00	0.535
5	6.18	5.00	0.590
6	7.17	5.85	0.660
8	9.37	7.85	0.760
10	11.92	10.00	0.960
12	14.18	12.00	1.090
14	16.48	14.00	1.240
16	18.72	16.00	1.360

SCHED. 40 STEEL PIPE			
Nominal Pipe Size	Outside Diameter	Inside Diameter	Wall Thickness
½	0.840	0.622	0.109
¾	1.050	0.824	0.113
1	1.315	1.049	0.133
1 ¼	1.660	1.380	0.140
1 ½	1.900	1.610	0.145
2	2.375	2.037	0.154
2 ½	2.875	2.469	0.203
3	3.500	3.068	0.216
3 ½	4.000	3.548	0.226
4	4.500	4.026	0.237

ALUMINUM PIPE			
Nominal Pipe Size	Outside Diameter	Inside Diameter	Wall Thickness
3	3.0	2.914	0.043
4	4.0	3.906	0.047
5	5.0	4.896	0.052
6	6.0	5.884	0.058
7	7.0	6.872	0.064
8	8.0	7.856	0.072
10	10.0	9.818	0.091

Pressure Loss From Friction/Velocity of Flow – Schedule 40 PVC

Loss per 100 ft of pipe (1120, 1220) C=150

Nominal Size	1/2"		3/4"		1"		1 1/4"		1 1/2"		2"		2 1/2"		3"		Nominal Size
Pipe ID	0.622		0.824		1.049		1.380		1.610		2.067		2.469		3.068		Pipe ID
Pipe OD	0.840		1.050		1.315		1.660		1.900		2.375		2.875		3.500		Pipe OD
Wall Thick	0.109		0.113		0.133		0.140		0.145		0.154		0.203		0.216		Wall Thick
Flow GPM	Velocity FPS	PSI LOSS	Velocity FPS	PSI LOSS	Velocity FPS	PSI LOSS	Velocity FPS	PSI LOSS	Velocity FPS	PSI LOSS	Velocity FPS	PSI LOSS	Velocity FPS	PSI LOSS	Velocity FPS	PSI LOSS	Flow GPM
1	1.05	0.43	0.60	0.11	0.37	0.03	0.21	0.01	0.16	0.00							1
2	2.11	1.55	1.20	0.39	0.74	0.12	0.43	0.03	0.31	0.02	0.19	0.00					2
3	3.16	3.28	1.80	0.84	1.11	0.25	0.64	0.07	0.47	0.03	0.29	0.01	0.20	0.00			3
4	4.22	5.59	2.40	1.42	1.48	0.44	0.86	0.12	0.63	0.05	0.38	0.02	0.27	0.01			4
5	5.27	8.45	3.00	2.15	1.85	0.66	1.07	0.17	0.79	0.08	0.48	0.02	0.33	0.01	0.22	0.00	5
6	6.33	11.85	3.61	3.02	2.22	0.93	1.29	0.25	0.94	0.12	0.57	0.03	0.40	0.01	0.26	0.01	6
7	7.38	15.75	4.21	4.01	2.60	1.24	1.50	0.33	1.10	0.15	0.67	0.05	0.47	0.02	0.30	0.01	7
8	8.44	20.18	4.81	5.14	2.97	1.59	1.71	0.42	1.26	0.20	0.76	0.06	0.54	0.02	0.35	0.01	8
9	9.49	25.10	5.41	6.39	3.34	1.97	1.93	0.52	1.42	0.25	0.86	0.07	0.60	0.03	0.39	0.01	9
10	10.55	30.51	6.01	7.77	3.71	2.40	2.14	0.63	1.57	0.30	0.95	0.09	0.67	0.04	0.43	0.01	10
11	11.60	36.40	6.61	9.26	4.08	2.86	2.36	0.75	1.73	0.36	1.05	0.11	0.74	0.04	0.48	0.02	11
12	12.65	42.77	7.21	10.88	4.45	3.36	2.57	0.89	1.89	0.42	1.15	0.12	0.80	0.05	0.52	0.02	12
13	13.71	49.60	7.81	12.62	4.82	3.90	2.79	1.03	2.05	0.48	1.24	0.14	0.87	0.06	0.56	0.02	13
14	14.76	56.90	8.41	14.48	5.19	4.47	3.00	1.18	2.20	0.56	1.34	0.16	0.94	0.07	0.61	0.02	14
15	15.82	64.65	9.01	16.45	5.56	5.08	3.21	1.34	2.36	0.63	1.43	0.19	1.00	0.08	0.65	0.03	15
16	16.87	72.86	9.61	18.54	5.93	5.73	3.43	1.51	2.52	0.71	1.53	0.21	1.07	0.09	0.69	0.03	16
17	17.93	81.52	10.22	20.75	6.30	6.41	3.64	1.69	2.68	0.80	1.62	0.24	1.14	0.10	0.74	0.03	17
18	18.98	90.62	10.82	23.06	6.67	7.12	3.86	1.88	2.83	0.89	1.72	0.25	1.20	0.11	0.78	0.04	18
19			11.42	25.49	7.04	7.87	4.07	2.07	2.99	0.98	1.81	0.29	1.27	0.12	0.82	0.04	19
20			12.02	28.03	7.42	8.66	4.28	2.28	3.15	1.08	1.91	0.32	1.34	0.13	0.87	0.05	20
22			13.22	33.44	8.16	10.33	4.71	2.72	3.46	1.28	2.10	0.38	1.47	0.16	0.95	0.06	22
24			14.42	39.29	8.90	12.14	5.14	3.20	3.78	1.51	2.29	0.45	1.61	0.19	1.04	0.07	24
25			15.02	42.36	9.27	13.09	5.36	3.45	3.94	1.63	2.39	0.48	1.67	0.20	1.08	0.07	25
26			15.62	45.57	9.64	14.08	5.57	3.71	4.09	1.75	2.48	0.52	1.74	0.22	1.13	0.08	26
28			16.83	52.27	10.38	16.15	6.00	4.25	4.41	2.01	2.67	0.60	1.87	0.25	1.21	0.09	28
30			18.03	59.40	11.12	18.35	6.43	4.83	4.72	2.28	2.86	0.68	2.01	0.28	1.30	0.10	30
32			19.23	66.94	11.86	20.68	6.86	5.44	5.04	2.57	3.06	0.76	2.14	0.32	1.39	0.11	32
34					12.61	23.13	7.28	6.09	5.35	2.88	3.25	0.85	2.28	0.36	1.47	0.12	34
35					12.98	24.41	7.50	6.43	5.51	3.04	3.34	0.90	2.34	0.38	1.52	0.13	35
36					13.35	25.72	7.71	6.77	5.67	3.20	3.44	0.95	2.41	0.40	1.56	0.14	36
38					14.09	28.43	8.14	7.48	5.98	3.54	3.63	1.05	2.54	0.44	1.65	0.15	38
40					14.83	31.28	8.57	8.23	6.30	3.89	3.82	1.15	2.68	0.49	1.73	0.17	40
42					15.57	34.22	9.00	9.01	6.61	4.25	4.01	1.26	2.81	0.53	1.82	0.18	42
44					16.31	37.29	9.43	9.82	6.93	4.64	4.20	1.37	2.94	0.58	1.91	0.20	44
45					16.68	38.88	9.64	10.24	7.08	4.83	4.30	1.43	3.01	0.60	1.95	0.21	45
46					17.06	40.49	9.86	10.66	7.24	5.04	4.39	1.49	3.08	0.63	1.99	0.22	46
48					17.80	43.81	10.28	11.54	7.56	5.45	4.58	1.62	3.21	0.68	2.08	0.24	48
50					18.54	47.26	10.71	12.44	7.87	5.88	4.77	1.74	3.35	0.73	2.17	0.25	50
55							11.78	14.84	8.66	7.01	5.25	2.06	3.68	0.86	2.38	0.30	55
60							12.85	17.44	9.44	8.24	5.73	2.44	4.02	1.03	2.60	0.36	60
65							13.93	20.29	10.23	9.55	6.21	2.83	4.35	1.19	2.82	0.41	65
70							15.00	23.20	11.02	10.95	6.68	3.25	4.69	1.37	3.03	0.48	70
75							16.07	26.36	11.81	12.45	7.16	3.69	5.02	1.55	3.25	0.54	75
80							17.14	29.71	12.58	14.03	7.64	4.16	5.35	1.75	3.47	0.61	80
85							18.21	33.24	13.38	15.70	8.12	4.65	5.69	1.96	3.68	0.68	85
90							19.28	36.95	14.17	17.45	8.59	5.17	6.02	2.18	3.90	0.76	90
95									14.95	19.29	9.07	5.72	6.36	2.41	4.12	0.84	95
100									15.74	21.21	9.55	6.29	6.69	2.65	4.33	0.92	100
110									17.31	25.31	10.50	7.50	7.36	3.16	4.77	1.10	110
120									18.89	29.74	11.46	8.82	8.03	3.71	5.20	1.29	120
130											12.41	10.22	8.70	4.31	5.63	1.50	130
140											13.37	11.73	9.37	4.94	6.07	1.72	140
150											14.32	13.33	10.04	5.61	6.50	1.95	150
160											15.28	15.02	10.71	6.33	6.94	2.20	160
170											16.23	16.80	11.38	7.08	7.37	2.46	170
180											17.19	18.68	12.05	7.87	7.80	2.73	180
190											18.14	20.65	12.72	8.70	8.24	3.02	190
200											19.10	22.70	13.39	9.56	8.67	3.32	200
225													15.06	11.89	9.75	4.13	225
250													16.73	14.48	10.84	5.02	250
275													18.41	17.25	11.92	5.99	275
300															13.00	7.04	300
325	Shaded area represents velocities over 5 FPS.														14.09	8.17	325
350	Use with caution where water hammer is a concern.														15.17	9.37	350
375															16.25	10.64	375
400															17.34	12.00	400

Pressure Loss From Friction/Velocity of Flow -Polyethylene (PE) Pipe

Loss per 100 ft of pipe C=140 SDR 7, 9, 11.5, 15

Nominal Size / Pipe ID / Flow GPM	1/2" 0.622 Velocity FPS	1/2" PSI LOSS	3/4" 0.824 Velocity FPS	3/4" PSI LOSS	1" 1.049 Velocity FPS	1" PSI LOSS	1-1/4" 1.380 Velocity FPS	1-1/4" PSI LOSS	1-1/2" 1.610 Velocity FPS	1-1/2" PSI LOSS	2" 2.067 Velocity FPS	2" PSI LOSS	Nominal Size / Pipe ID / Flow GPM
1	1.05	0.49	0.60	0.12	0.37	0.04	0.21	0.01	0.16	0.00	0.10	0.00	1
2	2.11	1.76	1.20	0.45	0.74	0.14	0.43	0.04	0.31	0.02	0.19	0.01	2
3	3.16	3.73	1.80	0.95	1.11	0.29	0.64	0.08	0.47	0.04	0.29	0.01	3
4	4.22	6.35	2.40	1.62	1.48	0.50	0.86	0.13	0.63	0.06	0.38	0.02	4
5	5.27	9.60	3.00	2.44	1.85	0.76	1.07	0.20	0.79	0.09	0.48	0.03	5
6	6.33	13.46	3.61	3.43	2.22	1.06	1.29	0.28	0.94	0.13	0.57	0.04	6
7	7.38	17.91	4.21	4.56	2.60	1.41	1.50	0.37	1.10	0.18	0.67	0.05	7
8	8.44	22.93	4.81	5.84	2.97	1.80	1.71	0.47	1.26	0.22	0.76	0.07	8
9	9.49	28.52	5.41	7.26	3.34	2.24	1.93	0.59	1.42	0.28	0.86	0.08	9
10	10.55	34.67	6.01	8.82	3.71	2.73	2.14	0.72	1.57	0.34	0.95	0.10	10
11	11.60	41.36	6.61	10.53	4.08	3.25	2.36	0.86	1.73	0.40	1.05	0.12	11
12	12.65	48.60	7.21	12.37	4.45	3.82	2.57	1.01	1.89	0.48	1.15	0.14	12
13	13.71	56.36	7.81	14.34	4.82	4.43	2.79	1.17	2.05	0.55	1.24	0.16	13
14	14.76	64.65	8.41	16.45	5.19	5.08	3.00	1.34	2.20	0.63	1.34	0.19	14
15	15.82	73.47	9.01	18.70	5.56	5.78	3.21	1.52	2.36	0.72	1.43	0.21	15
16	16.87	82.79	9.61	21.07	5.93	6.51	3.43	1.71	2.52	0.81	1.53	0.24	16
17	17.93	92.63	10.22	23.57	6.30	7.28	3.64	1.92	2.68	0.91	1.62	0.27	17
18	18.98	103.0	10.82	26.21	6.67	8.10	3.86	2.13	2.83	1.01	1.72	0.30	18
19			11.42	28.97	7.04	8.95	4.07	2.36	2.99	1.11	1.81	0.33	19
20			12.02	31.85	7.42	9.84	4.28	2.59	3.15	1.22	1.91	0.36	20
22			13.22	38.00	8.16	11.74	4.71	3.09	3.46	1.46	2.10	0.43	22
24			14.42	44.65	8.90	13.79	5.14	3.63	3.78	1.72	2.29	0.51	24
25			15.02	48.15	9.27	14.87	5.36	3.92	3.94	1.85	2.39	0.55	25
26			15.62	51.78	9.64	16.00	5.57	4.21	4.09	1.99	2.48	0.59	26
28			16.83	59.40	10.38	18.35	6.00	4.83	4.41	2.28	2.67	0.68	28
30			18.03	67.50	11.12	20.85	6.43	5.49	4.72	2.59	2.86	0.77	30
32			19.23	76.06	11.86	23.50	6.86	6.19	5.04	2.92	3.06	0.87	32
34					12.61	26.29	7.28	6.92	5.35	3.27	3.25	0.97	34
35					12.98	27.74	7.50	7.30	5.51	3.45	3.34	1.02	35
36					13.35	29.22	7.71	7.69	5.67	3.63	3.44	1.08	36
38					14.09	32.30	8.14	8.50	5.98	4.02	3.63	1.19	38
40					14.83	35.52	8.57	9.35	6.30	4.42	3.82	1.31	40
42					15.57	38.89	9.00	10.24	6.61	4.83	4.01	1.43	42
44					16.31	42.38	9.43	11.16	6.93	5.27	4.20	1.56	44
45					16.68	44.16	9.64	11.63	7.08	5.49	4.30	1.63	45
46					17.06	46.01	9.86	12.12	7.24	5.72	4.39	1.70	46
48					17.80	49.79	10.28	13.11	7.56	6.19	4.58	1.84	48
50					18.54	53.70	10.71	14.14	7.87	6.68	4.77	1.98	50
55							11.78	16.87	8.66	7.97	5.25	2.36	55
60							12.85	19.82	9.44	9.36	5.73	2.77	60
65							13.93	22.98	10.23	10.86	6.21	3.22	65
70							15.00	26.36	11.02	12.45	6.68	3.69	70
75							16.07	29.96	11.81	14.15	7.16	4.19	75
80							17.14	33.76	12.59	15.95	7.64	4.73	80
85							18.21	37.77	13.38	17.84	8.12	5.29	85
90							19.28	41.99	14.17	19.83	8.59	5.88	90
95									14.95	21.92	9.07	6.50	95
100									15.74	24.11	9.55	7.15	100
110									17.31	28.76	10.50	8.53	110
120									18.89	33.79	11.46	10.02	120
130											12.41	11.62	130
140											13.37	13.33	140
150											14.32	15.14	150
160											15.28	17.07	160
170											16.23	19.09	170
180											17.19	21.23	180
190											18.14	23.46	190
200											19.10	25.80	200

Shaded area represents velocities over 5 FPS.
Use with caution where water hammer is a concern.

Approximate Pressure Losses Through Pipe Fittings and Manual Valves

Listed in equivalent feet of pipe

PIPE FITTINGS			
Pipe Size	Standard Elbow Or Tee Reduced by ½	Long Sweep Elbow Or Standard Tee	Side Outlet Or Standard Tee
½	0.9	0.4	1.8
¾	1.2	0.6	2.5
1	1.7	0.8	3.4
1 ¼	2.4	1.2	4.8
1 ½	3.0	1.4	5.8
2	4.0	2.0	7.9
2 ½	5.0	2.5	9.9
3	6.7	3.3	13.1
4	9.2	4.5	18.3
5	12.2	6.0	24.3
6	15.3	7.6	30.5
8	21.7	10.7	43.1
10	28.7	14.1	56.9

MANUAL VALVES			
Valve Size	Gate Valves	Angle Valves	Globe Valves
½	0.3	1.2	2.7
¾	0.5	1.7	3.8
1	0.6	2.3	5.1
1 ¼	0.9	3.2	7.2
1 ½	1.1	4.0	8.7
2	1.5	5.4	11.9
2 ½	1.9	6.7	14.9
3	2.5	8.9	19.7
4	3.4	12.4	27.5
5	4.6	16.5	36.6
6	5.7	20.6	45.0
8	8.1	29.2	64.8
10	10.7	38.5	85.6

To use these charts:

1. Find the type of fittings for manual valves along the top of the chart.
2. Find the size along the left of the chart.
3. The value at the intersection is the equivalent feet of pipe value.
4. Go to the appropriate pipe sizing chart and find the loss per 100 ft for the flow through the fitting or manual valve.
5. Multiply the loss per 100 ft by the equivalent feet of pipe value, then divide by 100.

Table C3 Frictional Loss, psi / 100 ft, of PVC Plastic Pipe - Sched. 40

Notes: Hazen Williams Coefficient (C) = 150, a =inside area, OD = outside diameter, ID = inside diameter, use caution with vel. over 5 ft / sec.

Size (in)	0.75		1.00		1.25		1.50		2.00		2.50		3.00		Size (in)
a (sq in)	0.53		0.86		1.49		2.03		3.35		4.79		7.39		a (sq in)
OD (in)	1.050		1.315		1.660		1.900		2.375		2.875		3.500		OD (in)
ID (in)	0.824		1.049		1.380		1.610		2.067		2.469		3.068		ID (in)
FLOW	velocity	loss	velocity	loss	velocity	loss	velocity	loss	velocity	loss	velocity	loss	velocity	loss	FLOW
gal/min	ft/s	psi	ft/s	psi	ft/s	psi	ft/s	psi	ft/s	psi	ft/s	psi	ft/s	psi	gal/min
1	0.6	0.11	0.4	0.03	0.2	0.01	0.2	0.00							1
2	1.2	0.39	0.7	0.12	0.4	0.03	0.3	0.02	0.2	0.00					2
3	1.8	0.83	1.1	0.26	0.6	0.07	0.5	0.03	0.3	0.01	0.2	0.00			3
4	2.4	1.42	1.5	0.44	0.9	0.12	0.6	0.05	0.4	0.02	0.3	0.01			4
5	3.0	2.15	1.9	0.66	1.1	0.17	0.8	0.08	0.5	0.02	0.3	0.01			5
6	3.6	3.01	2.2	0.93	1.3	0.25	0.9	0.12	0.6	0.03	0.4	0.01	0.3	0.01	6
7	4.2	4.01	2.6	1.24	1.5	0.33	1.1	0.15	0.7	0.05	0.5	0.02	0.3	0.01	7
8	4.8	5.14	3.0	1.59	1.7	0.42	1.3	0.20	0.8	0.06	0.5	0.02	0.3	0.01	8
9	5.4	6.39	3.3	1.97	1.9	0.52	1.4	0.25	0.9	0.07	0.6	0.03	0.4	0.01	9
10	6.0	7.76	3.7	2.40	2.1	0.63	1.6	0.30	1.0	0.09	0.7	0.04	0.4	0.01	10
11	6.6	9.26	4.1	2.86	2.4	0.75	1.7	0.36	1.1	0.11	0.7	0.04	0.5	0.02	11
12	7.2	10.88	4.4	3.36	2.6	0.89	1.9	0.42	1.1	0.12	0.8	0.05	0.5	0.02	12
14	8.4	14.48	5.2	4.47	3.0	1.18	2.2	0.56	1.3	0.16	0.9	0.07	0.6	0.02	14
16	9.6	18.54	5.9	5.73	3.4	1.51	2.5	0.71	1.5	0.21	1.1	0.09	0.7	0.03	16
18	10.8	23.06	6.7	7.12	3.9	1.88	2.8	0.89	1.7	0.26	1.2	0.11	0.8	0.04	18
20	12.0	28.03	7.4	8.66	4.3	2.28	3.1	1.08	1.9	0.32	1.3	0.13	0.9	0.05	20
22	13.2	33.44	8.2	10.33	4.7	2.72	3.5	1.28	2.1	0.38	1.5	0.16	1.0	0.06	22
24	14.4	39.28	8.9	12.13	5.1	3.19	3.8	1.51	2.3	0.45	1.6	0.19	1.0	0.07	24
26	15.6	45.56	9.6	14.07	5.6	3.71	4.1	1.75	2.5	0.52	1.7	0.22	1.1	0.08	26
28	16.8	52.26	10.4	16.14	6.0	4.25	4.4	2.01	2.7	0.60	1.9	0.25	1.2	0.09	28
30			11.1	18.34	6.4	4.83	4.7	2.28	2.9	0.68	2.0	0.28	1.3	0.10	30
35			13.0	24.40	7.5	6.43	5.5	3.03	3.3	0.90	2.3	0.38	1.5	0.13	35
40			14.8	31.25	8.6	8.23	6.3	3.89	3.8	1.15	2.7	0.49	1.7	0.17	40
45			16.7	38.87	9.6	10.23	7.1	4.83	4.3	1.43	3.0	0.60	2.0	0.21	45
50					10.7	12.44	7.9	5.88	4.8	1.74	3.3	0.73	2.2	0.25	50
55					11.8	14.84	8.7	7.01	5.3	2.08	3.7	0.88	2.4	0.30	55
60					12.9	17.44	9.4	8.24	5.7	2.44	4.0	1.03	2.6	0.36	60
65					13.9	20.22	10.2	9.55	6.2	2.83	4.4	1.19	2.8	0.41	65
70					15.0	23.20	11.0	10.96	6.7	3.25	4.7	1.37	3.0	0.48	70
75					16.1	26.36	11.8	12.45	7.2	3.69	5.0	1.55	3.3	0.54	75
80							12.6	14.03	7.6	4.16	5.4	1.75	3.5	0.61	80
85							13.4	15.70	8.1	4.65	5.7	1.96	3.7	0.68	85
90							14.2	17.45	8.6	5.17	6.0	2.18	3.9	0.76	90
95							15.0	19.29	9.1	5.72	6.4	2.41	4.1	0.84	95
100							15.7	21.21	9.5	6.29	6.7	2.65	4.3	0.92	100
110									10.5	7.50	7.4	3.16	4.8	1.10	110
120									11.5	8.81	8.0	3.71	5.2	1.29	120
130									12.4	10.22	8.7	4.30	5.6	1.50	130
140									13.4	11.73	9.4	4.94	6.1	1.72	140
150									14.3	13.32	10.0	5.61	6.5	1.95	150
160									15.3	15.02	10.7	6.32	6.9	2.20	160
170									16.2	16.80	11.4	7.08	7.4	2.46	170
180											12.0	7.87	7.8	2.73	180
190											12.7	8.69	8.2	3.02	190
200											13.4	9.56	8.7	3.32	200
225											15.1	11.89	9.8	4.13	225
250											16.7	14.45	10.8	5.02	250
275													11.9	5.99	275
300													13.0	7.04	300
325													14.1	8.16	325
350													15.2	9.37	350
375													16.3	10.64	375
400															400
425															425
450															450

3.4 Minor Losses

Water flowing in a straight pipe under pressure at a constant velocity produces a constant friction loss. A change in the velocity or direction of flow creates additional losses. Such losses are classified as minor, as they are a small percentage of the total loss in relatively long pipelines; a pipeline with a length in excess of 500 diameters is usually classified as "long". Minor losses become important when small diameter pipes and high velocities are considered in the total piping and appurtenances relating to a pumping station. Minor losses are produced by flow through bends, fittings, valves and openings such as fire hydrants and in and out of reservoirs.

The loss of head h_m (ft or m) due to change in pipe alignment or an appurtenance can be expressed as follows:

$$h_m = K \frac{(V^2)}{(2g)} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

in which K is the dimensionless minor loss coefficient through the pipeline fitting or appurtenance and V, as previously defined, is the mean velocity in the pipe under consideration: The expression $V^2/2g$ is termed the velocity head. Many studies and tests have been conducted to determine the approximate value of minor loss coefficient for various fittings and appurtenances.

The equivalent length of pipe is the number of feet of straight pipe which will cause the same pressure drop as the flow through the fitting or appurtenance. The relationship between pipe diameter (d, D) and pipe length (l) within the hydraulic formulas allows the minor losses to be stated in terms of the equivalent length in pipe diameters rather than the minor loss coefficient (K). Examples of the value of K lent lengths in pipe diameters for various fittings and appurtena common practice are as follows:

Table 4 - LOSSES IN PIPE FITTINGS AND APPURTENANCES

Description of Pipe Fitting or Appurtenance	Minor Loss Coefficient (K)	Loss in Equivalent Length in Pipe Diameters (d)
Gate Valve		
3/4 Closed	24.0	900
1/2 Closed	5.6	160
1/4 Closed	1.2	35
Full Open	0.2	13
Angle Valve Open	2.5	170
Globe Valve Open	10.0	340
Swing Check Valve	0.6 - 2.5	80
Elbows		
90° Standard	0.7	32
90° Long Radius	0.6	20
45° Standard	0.5	16
Tee Flow Through Run	1.8	20
Sudden Contraction *		
d/D = 1/4	0.4	15
= 1/2	0.3	12
= 3/4	0.2	7
Sudden Enlargement *		
d/D = 1/4	0.9	32
= 1/2	0.6	20
= 3/4	0.2	7
Flow From Storage Tank		
Pipe Projecting Into Tank	0.78	
Pipe Flush With Tank Wall	0.5	
Slightly Rounded Entrance	0.23	
Well Rounded Entrance	0.04	
Flow Into Storage Tank		
All Conditions	1.0	

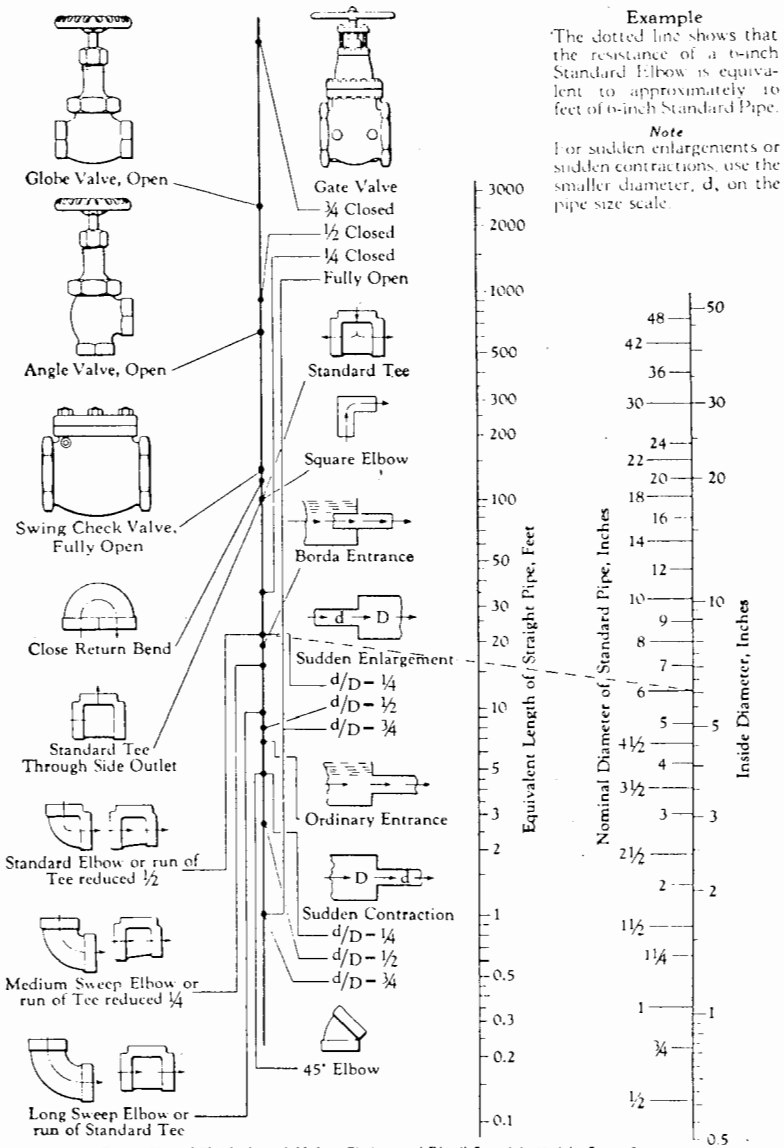
* For Contractions and Enlargements, coefficients are applied to the conditions in the smaller diameter pipe.

The nomograph shown in Figure 4 has been developed to estimate the equivalent length of straight pipe for each pipe size. The equivalent length for the valve or fitting is then added to the pipe length and loss calculated on the flow through the total equivalent length of pipe.

The waterworks industry now makes use of various types of valves for sectionalizing main lines or for control purposes. Each has distinctive interior contours which has an effect on fluid flow. Flow rate and loss of head charts have been prepared by the various manufacturers for the following sizes and types of valves:

	Size (in.)
Gate Valve	6-30
Butterfly Valve	6-48
Check Valve	6-30
Globe Valve Pattern	6-36
Angle Valve Pattern	6-36
Full Pattern Plug	6-16
Short Pattern Plug	6-12
Venturi Pattern Plug	6-36

Water meters in common usage in the waterworks field for small diameter pipelines are positive displacement type, turbine type and velocity or current meter type or a combination of two of the three for compound meters. Larger diameter pipelines and related larger flows can be monitored by pressure differential meters such as a venturi tube, orifice assembly or magnetic flow meters which monitor the flow with no obstruction within the tube. Pressure differential or magnetic types of flow meter installations cause small friction losses. However, small diameter meters with internal moving parts may be the source of considerable amounts of head loss in the piping system, particularly if the meter size has been reduced from the supply main size.



From "Flow of Fluids through Valves, Fittings and Pipe." Copyright 1942 by Crane Company.

FIGURE 4
FLOW OF WATER THROUGH VALVES & FITTINGS

The nomograph shown in Figure 4 has been developed to estimate the equivalent length of straight pipe for each pipe size. The equivalent length for the valve or fitting is then added to the pipe length and loss calculated on the flow through the total equivalent length of pipe.

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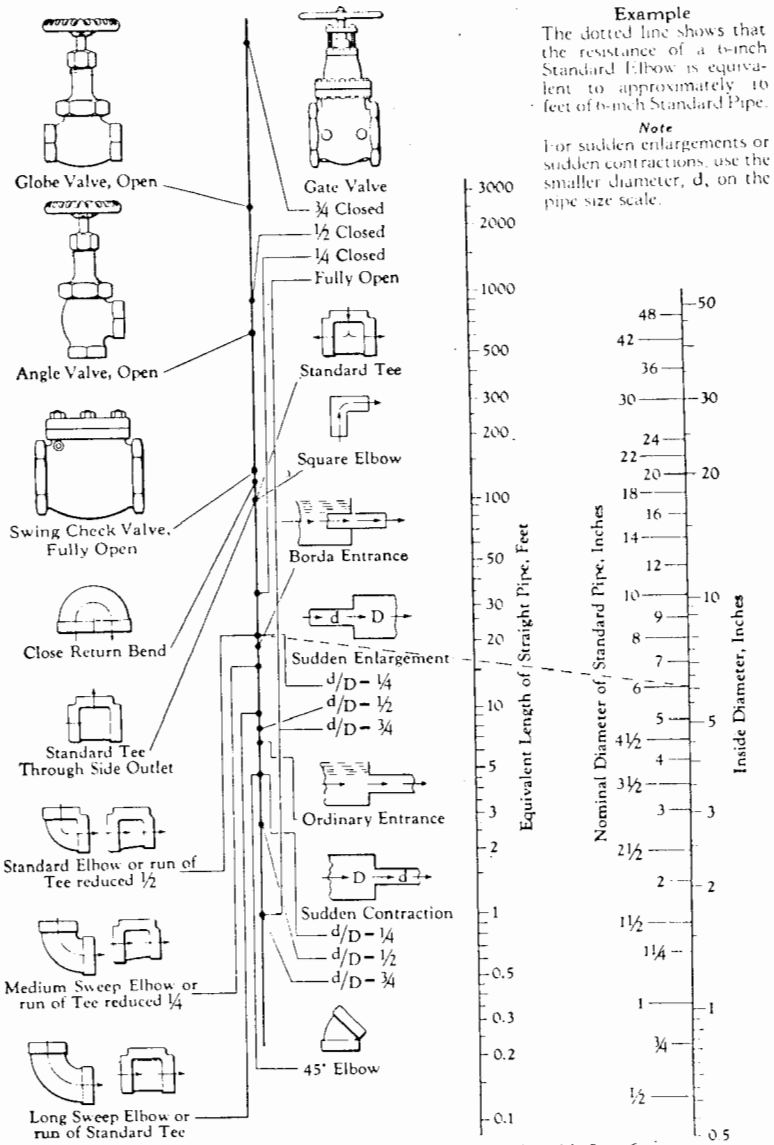

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FIGURE 4
FLOW OF WATER THROUGH VALVES & FITTINGS

Pump Rating. Pumps are usually rated at a certain capacity in gallons per minute (gpm) for a given head in feet of fluid flowing. The rating may be controlled by the pump design or by the size of the driver.

Water Horsepower. The water horsepower WHP is the product of the total head developed by the pump and the flow rate. Since one WHP equals 550 ft lb/sec, the equation form is:

$$WHP = \frac{wQH_p}{550} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where w is the specific weight of water (62.4 lb/ft^3), Q is the volumetric flow rate in cfs, H_p is the head, ft of water. In subsequent parts of this section the symbol H without the subscript will be used for the head developed by the pump. The water horsepower is more useful for water systems when the discharge rate is expressed in gpm:

$$WHP = \frac{wQH}{550} = \frac{(gpm)}{(449.6)} \times \frac{(62.4)H}{(550)} = \frac{(gpm)H}{3960} \quad \ldots (6)$$

Pump Efficiency. The efficiency of a pump is a direct measure of its hydraulic and mechanical performance and is defined as the ratio of energy output of the pump to the energy input applied to the pump shaft by the motor. The energy output of the pump is the water horsepower (WHP), as previously defined, and the energy input is the brake horsepower (BHP). The efficiency e expressed as a percentage, is as follows

$$e = \frac{WHP}{BHP} \times 100 \quad \ldots\ldots\ldots\ldots (7)$$

Suction Lift. The value of the suction lift (i.e., the height to which water may be lifted on the suction side of a pumping unit) is sometimes limited by physical factors; it is physically impossible to have negative gage pressure on the suction side of a pump whose magnitude is greater than barometric pressure. In most cases a pump will not function properly unless the absolute

pressure on the pump suction is well above the vapor pressure. Therefore, the height to which a pump will lift water from the suction well will be controlled by the barometric pressure, the temperature, and the vapor pressure of the liquid.

The maximum suction lifts for water pumps with different suction temperatures at a constant barometric pressure is given in the following tabulation.

TABLE 5

VARIATION OF SUCTION LIFT WITH TEMPERATURE FOR WATER WHEN BAROMETRIC PRESSURE IS 29.92 IN. (760 mm) of MERCURY

Temperature (°F)	Temperature (°C)	Specific Weight (lb/ft^3)	Specific Weight (kg/m^3)	Water Barometer (ft)	Water Barometer (m)	Absolute Pressure at Which Water Boils (ft)	Absolute Pressure at Which Water Boils (m)	Ideal Suction Lift (ft)	Ideal Suction Lift (m)
60	15.6	62.4	998.4	34.0	10.36	0.6	0.18	33.4	10.18
100	37.8	62.0	992.8	34.2	10.42	2.2	0.67	32.0	9.75
140	60.0	61.4	983.0	34.4	10.49	6.8	2.07	27.6	8.41
160	71.1	61.0	976.8	34.5	10.52	11.2	3.41	23.3	7.10
180	82.2	60.6	970.1	34.7	10.58	18.0	5.49	16.7	5.09
190	87.8	60.4	962.4	35.0	10.67	22.3	6.80	12.7	3.87
210	98.9	59.8	958.2	35.4	10.79	35.4	10.79	0.0	0.0

The maximum suction lift at different altitudes is given in the tabulation below. These are values for the ideal lift. The practical value will be less because friction losses in the suction pipe, losses in elbows and foot valve, and the suction velocity head will reduce the permissible suction lift. It is good design practice to place the pump close to, or below the intake surface of the fluid whenever possible, otherwise a practical value for the design suction lift equal to two-thirds of the ideal is used.

Each operable pumping system has a hydraulic head on the suction side of the pump which is termed Available NPSH i.e, net positive suction head. For satisfactory operation, the Available NPSH must exceed the NPSH