



Hydraulic Design

Sizing CPVC Pipe.

A FlowGuard Gold® system will use the same size pipe that a copper system would for a typical residential installation. For systems using larger sizes, design should be based on fixture demand rates. A FlowGuard Gold® system, unlike systems utilizing insert fittings for joining the pipe, offers full-bore flow. This results in significantly reduced head loss.

Design Velocity.

The process for establishing a limiting or maximum flow velocity that is applicable to any piping material is not well defined. For some materials, there may be velocities that can create abrasion or erosion, but there is no evidence that this occurs with CPVC piping under any known operating conditions. An investigation of some CPVC systems revealed that velocities of 7 to 17 feet per second could be developed under maximum flow conditions.

A maximum design velocity of 10 feet per second is typically utilized for both hot water and cold water CTS CPVC systems (1/2" through 2") and for IPS CPVC hot and cold water distribution systems 4" and smaller. A design velocity of 5 feet per second is typically used for IPS CPVC water distribution systems larger than 4". This design velocity is based on both field experience and laboratory investigation. The CPVC design velocity is different from copper, which has a recommended maximum design velocity of 5 feet per second for hot water and 8 feet per second for cold water.

The system should be designed and installed utilizing good engineering practices. To avoid water hammer, quick closing valves are not recommended on 2" to 4" IPS water mains when the velocity exceeds 5 ft/sec. It is acceptable to have quick closing valves on the smaller branch lines.

Hazen-William C Factor.

Hydraulic calculations for sizing of FlowGuard Gold® pipe and fittings should be calculated using a Hazen-William C Factor of 150. While both copper and CPVC use a C Factor of 150 for new systems, as copper ages, the ID of the pipe is subject to pitting and scaling causing pressure loss to increase over time. Since a FlowGuard Gold® system is not subject to pitting or scaling, the C Factor will remain constant as the system ages.

Head-Loss Characteristics - Pipe.

The flow characteristics of water flowing through piping systems are affected by several factors including system configuration, pipe size and length, friction at the pipe and fitting surfaces, etc. These and other factors cause a reduction in pressure (head-loss, also expressed as pressure drop) over the length of the system. This section deals only with the head-losses that result from frictional forces in the various sizes of CPVC pipe and fittings.

The following formulas were used to calculate water velocities, head-losses and pressure drops as function of flow rates. The results are given in Tables 7 thru 10. Head-loss as a function of water velocity has also been calculated and can be found in Tables 11 thru 14.

The Hazen-William formula can be used to adequately describe these losses:

Head Loss Formula

$$H_f = 0.2083(100/C)^{1.852} \times F_r^{1.852} / d^{4.8655}$$

Velocity Formula

$$V_w = 0.4085F_r/d^2$$

- Where:
- H_f = Frictional head loss (feet of water per 100 feet)
 - C = Hazen-William factor (150 for CPVC)
 - F_r = Flow rate (gal/min.)
 - d = Inside diameter of pipe (inches)
 - V_w = Velocity of water (feet/second)
 - One foot of water = 0.4335 psi

(Table 7)

FlowGuard Gold® Pipe
SDR 11 (ASTM D 2846)

Frictional Losses At Different Flow Rates

Flow Rate GPM	1/2"			3/4"			1"		
	V _w	H _L	P _L	V _w	H _L	P _L	V _w	H _L	P _L
1	1.71	3.19	1.38	0.80	0.50	0.22	0.48	0.15	0.06
2	3.42	11.53	5.00	1.60	1.82	0.79	0.96	0.53	0.23
3	5.13	24.43	10.59	2.40	3.85	1.67	1.44	1.12	0.49
4	6.83	41.62	18.04	3.20	6.55	2.84	1.93	1.91	0.83
5	8.54	62.91	27.27	4.00	9.91	4.29	2.41	2.89	1.25
6	10.25	88.18	38.23	4.79	13.89	6.02	2.89	4.05	1.76
7	11.96	117.32	50.86	5.59	18.47	8.01	3.37	5.39	2.34
8	13.67	150.23	65.13	6.39	23.66	10.26	3.85	6.90	2.99
9	15.38	186.85	81.00	7.19	29.42	12.76	4.33	8.58	3.72
10	17.08	227.11	98.45	7.99	35.76	15.50	4.82	10.43	4.52
15				11.99	75.78	32.85	7.22	22.11	9.58
20				15.98	129.11	55.97	9.63	37.67	16.33
25							12.04	56.94	24.69
30							14.45	79.82	34.60
35							16.86	106.19	46.03

(Table 8)

FlowGuard Gold® Pipe
SDR 11 (ASTM D 2846)

Frictional Losses At Different Flow Rates

Flow Rate GPM	1 1/4"			1 1/2"			2"		
	V _w	H _L	P _L	V _w	H _L	P _L	V _w	H _L	P _L
5	1.61	1.09	0.47	1.16	0.49	0.21	0.68	0.13	0.06
10	3.23	3.94	1.71	2.31	1.75	0.76	1.35	0.49	0.21
15	4.84	8.35	3.62	3.47	3.71	1.61	2.03	1.03	0.45
20	6.46	14.23	6.17	4.63	6.33	2.74	2.70	1.76	0.76
25	8.07	21.51	9.33	5.78	9.56	4.15	3.38	2.66	1.15
30	9.68	30.15	13.07	6.94	13.40	5.81	4.05	3.73	1.62
35	11.30	40.11	17.39	8.09	17.83	7.73	4.73	4.96	2.15
40	12.91	51.37	22.27	9.25	22.83	9.90	5.40	6.35	2.75
45	14.52	63.89	27.70	10.41	28.40	12.31	6.08	7.89	3.42
50	16.14	77.66	33.66	11.56	34.52	14.96	6.75	9.60	4.16
55	17.75	92.65	40.16	12.72	41.18	17.85	7.43	11.45	4.96
60				13.88	48.38	20.97	8.10	13.45	5.83
70				16.19	64.37	27.90	9.46	17.89	7.76
80							10.81	22.91	9.93
90							12.16	28.50	12.35
100							13.51	34.64	15.02
125							16.89	52.37	22.70

V_w = Velocity of water (feet/second)
H_L = Frictional head loss (feet of water per 100 feet)
P_L = Pressure Loss (psi per 100 feet)

(Table 9)

Corzan® Pipe
Schedule 80 (ASTM F 441)

Frictional Losses At Different Flow Rates

Flow Rate GPM	2 1/2"			3"			4"		
	V _w	H _L	P _L	V _w	H _L	P _L	V _w	H _L	P _L
25	1.95	0.68	0.29	1.25	0.23	0.10	0.71	0.06	0.03
50	3.90	2.45	1.06	2.49	0.82	0.36	1.42	0.21	0.09
75	5.85	5.19	2.25	3.74	1.74	0.76	2.14	0.45	0.19
100	7.80	8.85	3.83	4.98	2.97	1.29	2.85	0.76	0.33
125	9.75	13.37	5.80	6.23	4.49	1.95	3.56	1.16	0.50
150	11.69	18.74	8.12	7.47	6.30	2.73	4.27	1.62	0.70
175	13.64	24.94	10.81	8.72	8.38	3.63	4.99	2.16	0.93
200	15.59	31.93	13.84	9.96	10.73	4.65	5.70	2.76	1.20
225	17.54	39.71	17.22	11.21	13.35	5.79	6.41	3.43	1.49
250				12.45	16.22	7.03	7.12	4.17	1.81
300				14.94	22.74	9.86	8.55	5.85	2.54
350				17.43	30.25	13.12	9.97	7.78	3.37
400							11.40	9.96	4.32
500							14.25	15.06	6.53
600							17.10	21.11	9.15

(Table 10)

Corzan® Pipe
Schedule 80 (ASTM F 441)

Frictional Losses At Different Flow Rates

Flow Rate GPM	6"			8"			10"		
	V _w	H _L	P _L	V _w	H _L	P _L	V _w	H _L	P _L
100	1.25	0.10	0.04	0.71	0.03	0.01	0.45	0.01	0.00
200	2.51	0.37	0.16	1.43	0.10	0.04	0.91	0.03	0.01
300	3.76	0.79	0.34	2.14	0.20	0.09	1.36	0.07	0.03
400	5.01	1.35	0.59	2.86	0.34	0.15	1.81	0.11	0.05
500	6.27	2.04	0.89	3.57	0.52	0.23	2.27	0.17	0.07
600	7.52	2.86	1.24	4.28	0.73	0.32	2.72	0.24	0.10
700	8.77	3.81	1.65	5.00	0.97	0.42	3.17	0.32	0.14
800	10.03	4.88	2.11	5.71	1.24	0.54	3.63	0.41	0.18
900	11.28	6.06	2.63	6.42	1.54	0.67	4.08	0.51	0.22
1000	12.53	7.37	3.20	7.14	1.87	0.81	4.53	0.62	0.27
1250	15.67	11.14	4.83	8.92	2.83	1.23	5.67	0.94	0.41
1500				10.71	3.97	1.72	6.80	1.32	0.57
1750				12.49	5.28	2.29	7.93	1.75	0.76
2000				14.28	6.76	2.93	9.07	2.24	0.97
2250				16.06	8.41	3.65	10.20	2.79	1.21
2500							11.33	3.39	1.47
3000							13.60	4.75	2.06
3500							15.87	6.32	2.74

(Table 11)

**FlowGuard Gold® Pipe
SDR 11 (ASTM D 2846)**

Frictional Losses At Different Water Velocities

V _w	1/2"			3/4"			1"		
	F _R	H _L	P _L	F _R	H _L	P _L	F _R	H _L	P _L
2	1.17	4.28	1.85	2.50	2.75	1.19	4.15	2.05	0.89
4	2.34	15.44	6.69	5.01	9.93	4.30	8.31	7.40	3.21
6	3.51	32.71	14.18	7.51	21.04	9.12	12.46	15.68	6.80
8	4.68	55.72	24.16	10.01	35.84	15.54	16.61	26.71	11.58
10	5.85	84.24	36.52	12.51	54.18	23.49	20.76	40.38	17.50

(Table 12)

**FlowGuard Gold® Pipe
SDR 11 (ASTM D 2846)**

Frictional Losses At Different Water Velocities

V _w	1 1/4"			1 1/2"			2"		
	F _R	H _L	P _L	F _R	H _L	P _L	F _R	H _L	P _L
2	6.2	1.62	0.70	8.6	1.34	0.58	14.8	0.98	0.42
4	12.4	5.86	2.54	17.3	4.83	2.09	29.6	3.54	1.53
6	18.6	12.43	5.39	25.9	10.24	4.44	44.4	7.49	3.25
8	24.8	21.17	9.18	34.6	17.45	7.56	59.2	12.77	5.53
10	31.0	32.01	13.87	43.2	26.37	11.43	74.0	19.30	8.37

(Table 13)

**Corzan® Pipe
Schedule 80 (ASTM F 441)**

Frictional Losses At Different Water Velocities

V _w	2 1/2"			3"			4"		
	F _R	H _L	P _L	F _R	H _L	P _L	F _R	H _L	P _L
2	26	0.71	0.31	40	0.55	0.24	70	0.40	0.17
4	51	2.57	1.11	80	1.98	0.86	140	1.43	0.62
6	77	5.45	2.36	120	4.20	1.82	211	3.04	1.32
8	103	9.28	4.02	161	7.15	3.10	281	5.17	2.24
10	128	14.03	6.08	201	10.81	4.69	351	7.82	3.39

(Table 14)

**Corzan® Pipe
Schedule 80 (ASTM F 441)**

Frictional Losses At Different Water Velocities

V _w	6"			8"			10"		
	F _R	H _L	P _L	F _R	H _L	P _L	F _R	H _L	P _L
2	160	0.25	0.11	280	0.18	0.08	441	0.14	0.06
4	319	0.89	0.39	560	0.64	0.28	882	0.49	0.21
6	479	1.88	0.82	841	1.36	0.59	1323	1.04	0.45
8	638	3.21	1.39	1121	2.31	1.00	1764	1.78	0.77
10	798	4.85	2.10	1401	3.50	1.52	2206	2.69	1.17

V_w = Velocity of water (feet/second)F_R = Flow Rate (gal/min.)H_L = Frictional head loss (feet of water per 100 feet)P_L = Pressure Loss (psi per 100 feet)

Head Loss Characteristics - Valves and Fittings. In addition to head losses that result from frictional forces in the pipe, losses also occur when water flows through valves, fittings, etc. in the system. These losses are difficult to calculate due to the complex internal configuration of the various fittings. Generally, loss values are determined for each fitting configuration by experimental tests and are expressed in equivalent length of straight pipe. Typical equivalent length values for valves and fittings can be found in Tables 15 and 16.

(Table 15)

**Friction Loss in FlowGuard Gold® CTS
Valves and Fittings in Terms of Equivalent
Length (L) – Feet of Straight Pipe ^{Note 1}**

Nominal Pipe Size	Gate Valve Full Open	Globe Valve Full Open	Angle Valve Full Open	Swing Check Valve Full Open	90° Elbow	Long Radius 90° or 45° Standard Elbow	Standard Tee Through Flow	Standard Flow Branch Flow
1/2"	0.41	17.6	7.78	5.18	1.55	0.83	1.04	3 . 1 1
3/4"	0.55	23.3	10.3	6.86	2.06	1.10	1.37	4 . 1 2
1"	0.70	29.7	13.1	8.74	2.62	1.40	1.75	5 . 2 5
1 1/4"	0.92	39.1	17.3	11.5	3.45	1.84	2.30	6 . 9 0
1 1/2"	1.07	45.6	20.1	13.4	4.03	2.15	2.68	8 . 0 5
2"	1.38	58.6	25.8	17.2	5.17	2.76	3.45	10.30

(Table 16)

**Friction Loss in Corzan® IPS
Valves and Fittings in Terms of Equivalent
Length (L) – Feet of Straight Pipe ^{Note 1}**

Nominal Pipe Size	Gate Valve Full Open	Globe Valve Full Open	Angle Valve Full Open	Swing Check Valve Full Open	90° Elbow	Long Radius 90° or 45° Standard Elbow	Standard Tee Through Flow	Standard Flow Branch Flow
2 1/2"	1.65	70.0	30.9	20.6	6.1	3.3	4.1	12.2
3"	2.04	86.9	38.4	25.5	7.6	4.1	5.1	15.2
4"	2.68	114.0	50.3	33.6	10.0	5.3	6.7	20.0
6"	Note 2	Note 2	Note 2	Note 2	15.1	8.0	10.1	30.2
8"	Note 2	Note 2	Note 2	Note 2	19.9	10.6	13.2	39.7
10"	Note 2	Note 2	Note 2	Note 2	24.9	13.3	16.6	49.9

Notes: 1) The BOCA National Plumbing Code

2) See data published by valve manufacturer