Engineering & Design Data

Hydraulic Shock

Hydraulic shock is the term used to describe the momentary pressure rise in a piping system which results when the liquid is started or stopped quickly. This pressure rise is caused by the momentum of the fluid; therefore, the pressure rise increases with the velocity of the liquid, the length of the system from the fluid source, or with an increase in the speed with which it is started or stopped. Examples of situations where hydraulic shock can occur are valves, which are opened or closed quickly, or pumps, which start with an empty discharge line. Hydraulic shock can even occur if a high speed wall of liquid (as from a starting pump) hits a sudden change of direction in the piping, such as an elbow. The pressure rise created by the hydraulic shock effect is added to whatever fluid pressure exists in the piping system and, although only momentary, this shock load can be enough to burst pipe and break fittings or valves.

A formula, which closely predicts hydraulic shock effects is:

$$p = v\left(\frac{SG-1}{2}C + C\right)$$

Where:

p = maximum surge pressure, psi

v = fluid velocity in feet per second

C = surge wave constant for water at 73°F

*SG = specific gravity of liquid (If SG is 1, then p = VC)

Example: A 2" PVC schedule 80 pipe carries a fluid with a specific gravity of 1.2 at a rate of 30 gpm and at a line pressure of 160 psi. What would the surge pressure be if a valve were suddenly closed?

From table 1: C = 23.9

$$p = (3.35)\left(\frac{(1.2-1)}{2}23.9 + 23.9\right)$$

$$p = (3.35)(26.3) = 88 \text{ psi}$$

Total line pressure = 88 + 160 = 248 psi

Schedule 80 2" PVC has a pressure rating of 400 psi at room temperature.

Therefore, 2" schedule 80 PVC pipe is acceptable for this application.

! NOTE The total pressure at any time in a pressure-type system (operating plus surge or water hammer) should not exceed 150 percent of the pressure rating of the system.

Table I - C-Surge Wave Constant

Pipe Size (in.)	PVC		CPVC	
	Sch. 40	Sch. 80	Sch. 40	Sch. 80
1/8	34.7	41.3	32.9	39.4
1/4	33.6	39.3	31.8	37.5
3/8	30.2	35.6	28.4	33.8
1/2	29.3	34.2	27.6	32.3
3/4	26.4	30.9	24.8	29.1
1	25.4	29.6	23.8	27.8
1-1/4	23.0	27.0	21.5	25.3
1-1/2	21.8	25.7	20.4	24.1
2	20.0	23.9	18.6	22.4
2-1/2	20.8	24.5	19.4	22.9
3	19.4	23.1	18.1	21.6
3-1/2	18.6	22.2	17.3	20.7
4	17.9	21.5	16.7	20.1
5	16.8	20.3	15.6	19.0
6	16.0	20.0	14.9	18.6
8	15.0	18.8	13.9	17.5
10	14.3	18.3	13.3	17.1
12	13.8	18.1	12.8	16.9
14	13.7	18.1	12.7	16.8
16	13.7	17.9	12.7	16.7
18	13.7	17.8	12.7	16.6
20	13.3	17.7	12.4	16.5
24	13.1	17.6	12.2	16.3

Proper design when laying out a piping system will eliminate the possibility of hydraulic shock damage.

The following suggestions will help in avoiding problems:

1. In a plastic piping system, a fluid velocity not exceeding 5 ft./sec. will minimize hydraulic shock effects, even with quickly closing valves, such as solenoid valves.
2. Using actuated valves which have a specific closing time will eliminate the possibility of someone inadvertently slamming a valve open or closed too quickly. With pneumatic and air-spring actuators, it may be necessary to place a valve in the air line to slow down the valve operation cycle.
3. If possible, when starting a pump, partially close the valve in the discharge line to minimize the volume of liquid, which is rapidly accelerating through the system. Once the pump is up to speed and the line completely full, the valve may be opened.
4. A check valve installed near a pump in the discharge line will keep the line full and help prevent excessive hydraulic shock during pump start-up.

Head Loss Characteristics

Head Loss Characteristics of Water Flow Through Rigid Plastic Pipe—Nomograph

The nomograph on the following page provides approximate values for a wide range of plastic pipe sizes. More precise values should be calculated from the Williams & Hazen formula. Experimental test value of C (a constant for inside pipe roughness) ranges from 155 to 165 for various types of plastic pipe. Use of a value of 150 will ensure conservative friction loss values. Since directional changes and restrictions contribute the most head loss, use of head loss data for comparable metal valves and fittings will provide conservative values when actual values for PVC and CPVC fittings and valves are not available.

Williams & Hazen formula.

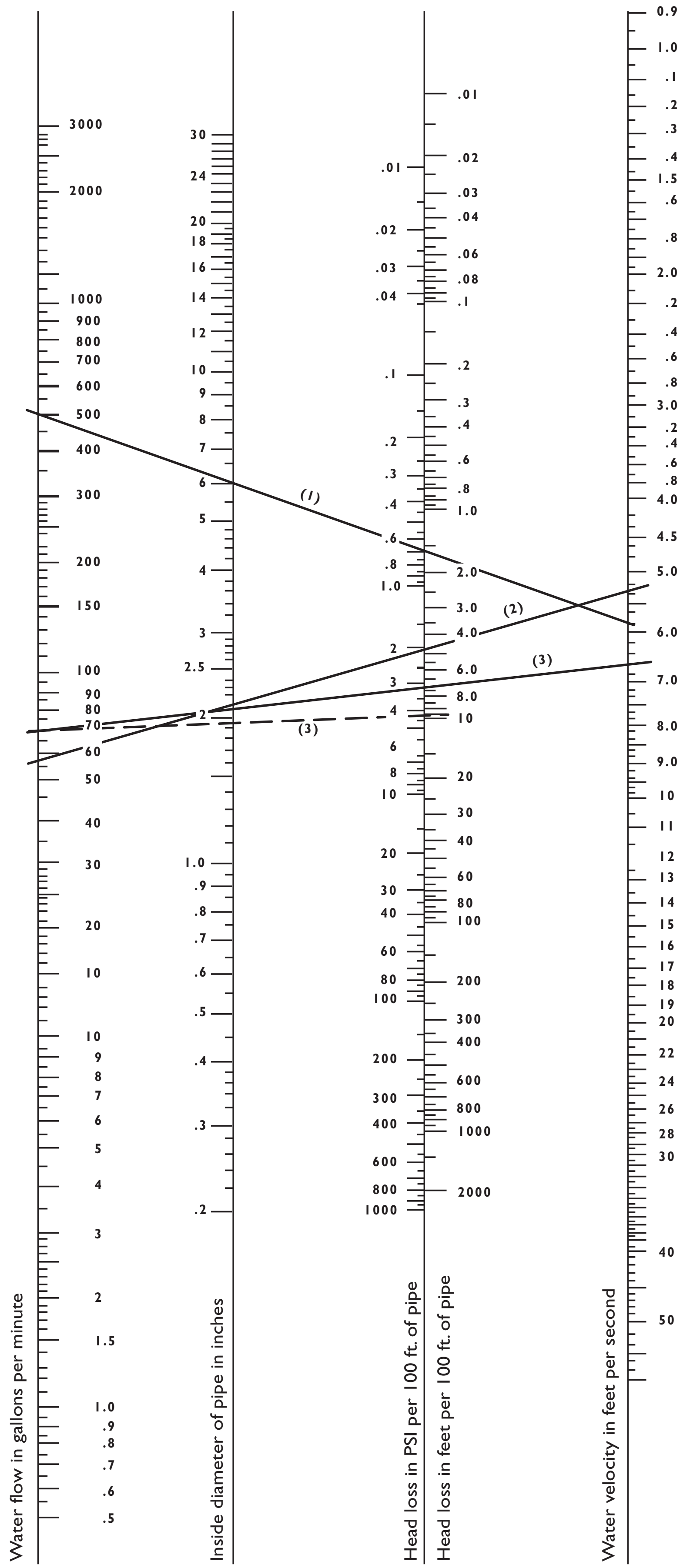
$$f = .2083 \times \left(\frac{100}{C}\right)^{1.852} \times \frac{G^{1.852}}{di^{4.8655}}$$

Where:

f = Friction head in feet of water per 100 feet
d = Inside diameter of pipe in inches
g = Flowing gallons per minute
C = Constant for inside roughness of the pipe
(C = 150 for thermoplastic pipe)

The nomograph is used by lining up values on the scales by means of a ruler or straight edge. Two independent variables must be set to obtain the other values. For example line (1) indicates that 500 gallons per minute may be obtained with a 6-inch inside diameter pipe at a head loss of about 0.65 pounds per square inch at a velocity of 6.0 feet per second. Line (2) indicates that a pipe with a 2.1 inch inside diameter will give a flow of about 60 gallons per minute at a loss in head of 2 pounds per square inch per 100 feet of pipe. Line (3) and dotted line (3) show that in going from a pipe 2.1-inch inside diameter to one of 2 inches inside diameter the head loss goes from 3 to 4 pounds per square inch in obtaining a flow of 70 gallons per minute. Flow velocities in excess of 5.0 feet per second are not recommended.

Nomograph courtesy of Plastics Pipe Institute, a division of The Society of The Plastics Industry.



Flow Velocity & Friction Loss

Friction Loss

Friction loss through PVC and CPVC pipe is most commonly obtained by the use of the Hazen-Williams equations as expressed below for water:

$$f = .2083 \times \left(\frac{100}{C}\right)^{1.852} \times \frac{G^{1.852}}{di^{4.8655}}$$

Where: f = friction head of feet of water per 100' for the specific pipe size and I.D.

C = a constant for internal pipe roughness. 150 is the commonly accepted value for PVC and CPVC pipe.

G = flow rate of gallons per minute (U.S. gallons).

di = inside diameter of pipe in inches.

Compared to other materials on construction for pipe, thermoplastic pipe smoothness remains relatively constant throughout its service life.

Water Velocities

Velocities for water in feet per second at different GPM's and pipe inside diameters can be calculated as follows:

$$V = .3208 \frac{G}{A}$$

Where: V = velocity in feet per second
G = gallons per minute
A = inside cross sectional area in square inches

⚠CAUTION GF Harvel does not recommend flow velocities in excess of five feet per second for closed-end systems, particularly in pipe sizes 6" and larger. Contact GF Harvel tech services for additional information.

Thrust Blocking

In addition to limiting velocities to 5'/sec., especially with larger diameters (6" and above), consideration should be given to stresses induced with intermittent pump operation, quick opening valves and back flow in elevated discharge lines. Use of bypass piping with electrically actuated time cycle valves or variable speed pumps and check valves on the discharge side are suggested with the higher GPM rates. Thrust blocking should be considered for directional changes and pump operations in buried lines 10" and above, particularly where fabricated fittings are utilized. Above grade installations 10" and above should have equivalent bracing to simulate thrust blocking at directional changes and for intermittent pump operations. Thrust blocking of directional changes and time cycle valves are also recommended for large diameter drain lines in installations such as large swimming pools and tanks. Use of appropriate pump vibration dampers are also recommended.

THRUST IN POUNDS FROM STATIC INTERNAL PRESSURE

Pipe Size (in.)	Socket Depth (in.)	For Plug, 60° Ell, Cap Tee	For 22.5° Ell	For 45° Ell	For 90° Ell	Joint Resist. To Thrust	90° Ell Safety Factor
6	6	7,170	2,800	5,480	10,140	37,464	3.7
8	6	11,240	4,380	8,590	15,890	48,774	3.1
10	8	16,280	6,350	12,440	23,020	81,054	3.5
12	8	23,040	8,990	17,600	32,580	102,141	3.1
14	9	26,610	10,380	20,330	37,630	115,752	3.1
16	10	34,910	13,620	26,670	49,360	150,798	3.1
18	12	44,290	17,270	33,840	62,630	203,577	3.3
20	12	43,410	16,540	32,400	59,970	226,194	3.8
24	14	61,040	23,810	46,640	86,310	316,500	3.7

Socket depths are from ASTM D 2672 for belled-end PVC pipe. Working pressures utilized for the tabulation above are for Schedule 80 2"- 18" sizes and SDR 160 psi for 20" and 24" sizes.

The calculation for thrusts due to static internal pressure is:

$$\text{Thrust} = \frac{((\text{Avg I.D.})^2 \pi)}{4} \bullet (\text{working pressure}) \bullet (x)$$

x = 1.0 for tees, 60° ells, plugs and caps, .390 for 22-1/2° bends, .764 for 45° ells, 1.414 for 90° ells

Joint Resistance to Thrust = (O.D.) (π) (socket depth) (300 psi)
300 psi = Minimum cement shear strength with good field cementing technique.

Friction Loss Through Fittings

Friction loss through fittings is expressed in equivalent feet of the same pipe size and schedule for the system flow rate. Schedule 40 head loss per 100' values are usually used for other wall thicknesses and standard iron pipe size O.D.s.

Average Friction Loss for PVC and CPVC Fittings in Equivalent Feet of Straight Run Pipe

	Size (in.)																	
Item	**1/2**	**3/4**	**1**	**1-1/4**	**1-1/2**	**2**	**2-1/2**	**3**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**24**
Tee Run	1.0	1.4	1.7	2.3	2.7	4.0	4.9	6.1	7.9	12.3	14.0	17.5	20.0	25.0	27.0	32.0	35.0	42.0
Tee Branch	3.8	4.9	6.0	7.3	8.4	12.0	14.7	16.4	22.0	32.7	49.0	57.0	67.0	78.0	88.0	107.0	118.0	137.0
90° Ell	1.5	2.0	2.5	3.8	4.0	5.7	6.9	7.9	11.4	16.7	21.0	26.0	32.0	37.0	43.0	53.0	58.0	67.0
45° Ell	0.8	1.1	1.4	1.8	2.1	2.6	3.1	4.0	5.1	8.0	10.6	13.5	15.5	18.0	20.0	23.0	25.0	30.0

Values 10" - 24": Approximate values from Nomograph.

Pressure Drop in Valves and Strainers

Pressure drop calculations can be made for valves and strainers for different fluids, flow rates, and sizes using the CV values and the following equation:

$$P = \frac{(G)^2 \text{ (specific gravity liquid)}}{(\text{CV Factor})^2}$$

Where: P = Pressure drop in PSI; feet of water $= \frac{\text{PSI}}{.4332}$

G = Gallons per minute

CV = Gallons per minute per 1 PSI pressure drop

CV Factors GPM

	Size (in.)										
Item	**1/4**	**3/8**	**1/2**	**3/4**	**1**	**1-1/4**	**1-1/2**	**2**	**2-1/2**	**3**	**4**
True Union Ball Valve	1.0	8.0	8.0	15.0	29.0	75.0	90.0	140.0	330.0	480.0	600.0
Single Entry Ball Valve	1.0	8.0	8.0	16.0	29.0	75.0	90.0	140.0	330.0	480.0	600.0
QIC Ball Valve	-	-	8.0	15.0	29.0	75.0	90.0	140.0	-	-	-
True Check Ball Valve	1.0	3.0	4.6	10.0	28.0	45.0	55.0	90.0	225.0	324.0	345.0
Y-Check Valve	-	-	5.0	6.0	12.5	40.0	40.0	65.0	130.0	160.0	250.0
3-Way Flanged Ball Valve	-	-	5.0	10.0	16.0	-	45.0	55.0	-	200.0	350.0
Needle Valve Full Open	5.0	7.5	8.0	-	-	-	-	-	-	-	-
Angle Valve	1.0	-	5.0	10.0	16.0	-	45.0	70.0	-	-	-
Y-Strainer (clean screen)	-	-	3.8	6.6	8.4	20.0	25.0	35.0	60.0	60.0	95.0
Simplex Basket Strainer (clean screen)	-	-	6.0	9.5	29.0	-	40.0	55.0	-	125.0	155.0
Duplex Basket Strainer (clean screen)	-	-	5.0	6.0	7.0	-	28.0	35.0	-	80.0	100.0

Schedule 40

Flow Rate (GPM)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)
	1/8"			1/4"			3/8"		
0.25	1.64	6.54	2.83	0.86	1.36	0.59	0.46	0.29	0.12
0.50	3.27	23.60	10.23	1.72	4.90	2.12	0.91	1.04	0.45
0.75	4.91	50.00	21.68	2.59	10.38	4.50	1.37	2.20	0.96
1	6.55	85.18	36.93	3.45	17.68	7.66	1.82	3.75	1.63
2	13.09	307.52	133.31	6.90	63.82	27.67	3.65	13.55	5.88
5				17.25	348.29	150.98	9.11	73.96	32.06
7							12.76	137.93	59.79
10									

Flow Rate (GPM)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Rate (GPM)
	1/2"			3/4"			1"			1-1/4"			1-1/2"			2"			2-1/2"			3"			
1	1.13	1.16	0.50	0.63	0.28	0.12	0.39	0.09	0.04	0.22	0.02	0.01	0.16	0.01	0.00	0.10	0.00	0.00	0.07	0.00	0.00	0.04	0.00	0.00	1
2	2.25	4.19	1.82	1.26	1.03	0.44	0.77	0.31	0.13	0.44	0.08	0.03	0.32	0.04	0.02	0.19	0.01	0.00	0.14	0.00	0.00	0.09	0.00	0.00	2
5	5.63	22.88	9.92	3.16	5.60	2.43	1.93	1.69	0.73	1.10	0.43	0.19	0.81	0.20	0.09	0.49	0.06	0.03	0.34	0.02	0.01	0.22	0.01	0.00	5
7	7.88	42.66	18.49	4.42	10.44	4.53	2.70	3.14	1.36	1.55	0.81	0.35	1.13	0.38	0.16	0.68	0.11	0.05	0.48	0.05	0.02	0.31	0.02	0.01	7
10	11.26	82.59	35.80	6.31	20.21	8.76	3.86	6.08	2.64	2.21	1.57	0.68	1.62	0.73	0.32	0.97	0.21	0.09	0.68	0.09	0.04	0.44	0.03	0.01	10
15	4"			9.47	42.82	18.56	5.78	12.89	5.59	3.31	3.32	1.44	2.42	1.55	0.67	1.46	0.45	0.20	1.02	0.19	0.08	0.66	0.07	0.03	15
20	0.51	0.03	0.01	12.63	72.95	31.63	7.71	21.96	9.52	4.42	5.65	2.45	3.23	2.64	1.15	1.95	0.77	0.34	1.37	0.33	0.14	0.88	0.11	0.05	20
25	0.64	0.05	0.02	5"			9.64	33.20	14.39	5.52	8.55	3.71	4.04	4.00	1.73	2.44	1.17	0.51	1.71	0.49	0.21	1.10	0.17	0.07	25
30	0.77	0.06	0.03	0.49	0.02	0.01	11.57	46.54	20.17	6.62	11.98	5.19	4.85	5.60	2.43	2.92	1.64	0.71	2.05	0.69	0.30	1.32	0.24	0.10	30
35	0.89	0.08	0.04	0.57	0.03	0.01				7.73	15.94	6.91	5.65	7.45	3.23	3.41	2.18	0.94	2.39	0.92	0.40	1.54	0.32	0.14	35
40	1.02	0.11	0.05	0.65	0.04	0.02				8.83	20.41	8.85	6.46	9.54	4.14	3.90	2.79	1.21	2.73	1.18	0.51	1.76	0.41	0.18	40
45	1.15	0.13	0.06	0.73	0.04	0.02	6"			9.94	25.39	11.00	7.27	11.87	5.15	4.39	3.47	1.51	3.07	1.46	0.63	1.99	0.51	0.22	45
50	1.28	0.16	0.07	0.81	0.05	0.02	0.56	0.02	0.01	11.04	30.86	13.38	8.08	14.43	6.25	4.87	4.22	1.83	3.41	1.78	0.77	2.21	0.61	0.27	50
60	1.53	0.23	0.10	0.97	0.08	0.03	0.67	0.03	0.01				9.69	20.22	8.77	5.85	5.92	2.56	4.10	2.49	1.08	2.65	0.86	0.37	60
70	1.79	0.30	0.13	1.14	0.10	0.04	0.79	0.04	0.02							6.82	7.87	3.41	4.78	3.32	1.44	3.09	1.15	0.50	70
75	1.92	0.34	0.15	1.22	0.11	0.05	0.84	0.05	0.02							7.31	8.94	3.88	5.12	3.77	1.63	3.31	1.30	0.56	75
80	2.04	0.39	0.17	1.30	0.13	0.06	0.90	0.05	0.02							7.80	10.08	4.37	5.46	4.25	1.84	3.53	1.47	0.64	80

NOTE GF Harvel recommends that Flow Velocities be maintained at or below 5 feet per second in large diameter piping systems (i.e. 6" diameter and larger) to minimize the potential for hydraulic shock. Refer to GF Harvel engineering section entitled "Hydraulic Shock" for additional information. Friction loss data based on utilizing mean wall dimensions to determine average ID; actual ID may vary.

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Schedule 40

Flow Rate (GPM)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Rate (GPM)
		4"			5"			6"									2"			2-1/2"			3"		
90	2.30	0.48	0.21	1.46	0.16	0.07	1.01	0.07	0.03		8"					8.77	12.53	5.43	6.15	5.28	2.29	3.97	1.82	0.79	90
100	2.55	0.59	0.25	1.62	0.19	0.08	1.12	0.08	0.03	0.65	0.02	0.01				9.74	15.23	6.60	6.83	6.42	2.78	4.41	2.22	0.96	100
125	3.19	0.89	0.38	2.03	0.29	0.13	1.40	0.12	0.05	0.81	0.03	0.01				12.18	23.03	9.98	8.54	9.70	4.21	5.52	3.35	1.45	125
150	3.83	1.24	0.54	2.43	0.41	0.18	1.68	0.17	0.07	0.97	0.04	0.02							10.24	13.60	5.90	6.62	4.70	2.04	150
175	4.47	1.65	0.72	2.84	0.55	0.24	1.96	0.22	0.10	1.13	0.06	0.03		10"								7.72	6.25	2.71	175
200	5.11	2.12	0.92	3.25	0.70	0.30	2.25	0.29	0.12	1.29	0.08	0.03	0.82	0.02	0.01							8.82	8.00	3.47	200
250	6.39	3.20	1.39	4.06	1.06	0.46	2.81	0.43	0.19	1.62	0.11	0.05	1.03	0.04	0.02							11.03	12.10	5.24	250
300	7.66	4.49	1.95	4.87	1.49	0.65	3.37	0.61	0.26	1.94	0.16	0.07	1.23	0.05	0.02		12"								300
350	8.94	5.97	2.59	5.68	1.98	0.86	3.93	0.81	0.35	2.27	0.21	0.09	1.44	0.07	0.03	1.01	0.03	0.01		14"			16"		350
400	10.22	7.64	3.31	6.49	2.54	1.10	4.49	1.03	0.45	2.59	0.27	0.12	1.64	0.09	0.04	1.16	0.04	0.02	0.96	0.02	0.01	0.73	0.01	0.01	400
450				7.30	3.15	1.37	5.05	1.29	0.56	2.91	0.34	0.15	1.85	0.11	0.05	1.30	0.05	0.02	1.08	0.03	0.01	0.82	0.02	0.01	450
500		18"		8.11	3.83	1.66	5.61	1.56	0.68	3.24	0.41	0.18	2.05	0.14	0.06	1.44	0.06	0.02	1.19	0.04	0.02	0.91	0.02	0.01	500
750	1.08	0.02	0.01		20"					4.85	0.87	0.38	3.08	0.29	0.12	2.17	0.12	0.05	1.79	0.08	0.03	1.37	0.04	0.02	750
1,000	1.45	0.04	0.02	1.16	0.02	0.01				6.47	1.48	0.64	4.10	0.49	0.21	2.89	0.21	0.09	2.39	0.13	0.06	1.83	0.07	0.03	1,000
1,250	1.81	0.06	0.03	1.45	0.03	0.01		24"					5.13	0.74	0.32	3.61	0.31	0.14	2.99	0.20	0.09	2.29	0.10	0.04	1,250
1,500	2.17	0.08	0.04	1.74	0.05	0.02	1.21	0.02	0.01				6.15	1.03	0.45	4.33	0.44	0.19	3.58	0.28	0.12	2.74	0.14	0.06	1,500
2,000	2.89	0.14	0.06	2.32	0.08	0.04	1.61	0.03	0.01							5.78	0.75	0.33	4.78	0.47	0.20	3.66	0.25	0.11	2,000
2,500	3.61	0.21	0.09	2.91	0.12	0.05	2.01	0.05	0.02							7.22	1.13	0.49	5.97	0.71	0.31	4.57	0.37	0.16	2,500
3,000	4.34	0.29	0.13	3.49	0.17	0.08	2.41	0.07	0.03										7.17	1.00	0.43	5.49	0.52	0.23	3,000
3,500	5.06	0.39	0.17	4.07	0.23	0.10	2.81	0.09	0.04													6.40	0.70	0.30	3,500
4,000	5.78	0.50	0.22	4.65	0.30	0.13	3.21	0.12	0.05																4,000
4,500	6.50	0.62	0.27	5.23	0.37	0.16	3.62	0.15	0.06																4,500
5,000				5.81	0.45	0.19	4.02	0.18	0.08																5,000
5,500				6.39	0.53	0.23	4.42	0.22	0.09																5,500
6,000				6.97	0.63	0.27	4.82	0.25	0.11																6,000
7,000							5.62	0.34	0.15																7,000
7,500							6.03	0.39	0.17																7,500
8,000							6.43	0.43	0.19																8,000
8,500							6.83	0.49	0.21																8,500

NOTE GF Harvel recommends that Flow Velocities be maintained at or below 5 feet per second in large diameter piping systems (i.e. 6" diameter and larger) to minimize the potential for hydraulic shock. Refer to GF Harvel engineering section entitled "Hydraulic Shock" for additional information. Friction loss data based on utilizing mean wall dimensions to determine average ID; actual ID may vary.

Schedule 80

Flow Rate (GPM)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)
	1/8"			1/4"			3/8"		
0.25	2.67	21.47	9.31	1.29	3.57	1.55	0.63	0.63	0.27
0.50	5.35	77.52	33.60	2.59	12.88	5.58	1.25	2.27	0.98
0.75	8.02	164.25	71.20	3.88	27.29	11.83	1.88	4.80	2.08
1	10.69	279.84	121.31	5.17	46.49	20.15	2.51	8.18	3.55
2	21.39	1010.21	437.93	10.35	167.84	72.76	5.01	29.54	12.81
5				25.87	915.95	397.07	12.53	161.23	69.89
7							17.54	300.66	130.34
10									

Flow Rate (GPM)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Rate (GPM)
	1/2"			3/4"			1"			1-1/4"			1-1/2"			2"			2-1/2"			3"			
1	1.48	2.24	0.97	0.78	0.48	0.21	0.47	0.14	0.06	0.26	0.03	0.01	0.19	0.01	0.01	0.11	0.00	0.00	0.08	0.00	0.00	0.05	0.00	0.00	1
2	2.96	8.08	3.50	1.56	1.73	0.75	0.93	0.49	0.21	0.52	0.12	0.05	0.38	0.05	0.02	0.22	0.02	0.01	0.16	0.01	0.00	0.10	0.00	0.00	2
5	7.39	44.12	19.12	3.91	9.45	4.10	2.33	2.67	1.16	1.30	0.64	0.28	0.96	0.29	0.13	0.56	0.08	0.04	0.39	0.03	0.01	0.25	0.01	0.01	5
7	10.35	82.27	35.66	5.48	17.62	7.64	3.26	4.98	2.16	1.81	1.20	0.52	1.34	0.54	0.24	0.78	0.15	0.07	0.55	0.06	0.03	0.35	0.02	0.01	7
10	14.78	159.26	69.04	7.82	34.11	14.79	4.66	9.65	4.18	2.59	2.32	1.00	1.92	1.05	0.46	1.12	0.30	0.13	0.78	0.12	0.05	0.50	0.04	0.02	10
15	4"			11.74	72.27	31.33	6.99	20.44	8.86	3.89	4.91	2.13	2.87	2.23	0.97	1.67	0.63	0.27	1.17	0.26	0.11	0.75	0.09	0.04	15
20	0.57	0.04	0.02	15.65	123.13	53.38	9.33	34.82	15.09	5.18	8.36	3.62	3.83	3.80	1.65	2.23	1.07	0.47	1.56	0.45	0.19	1.00	0.15	0.07	20
25	0.71	0.06	0.03	5"			11.66	52.64	22.82	6.48	12.64	5.48	4.79	5.74	2.49	2.79	1.63	0.70	1.95	0.68	0.29	1.24	0.23	0.10	25
30	0.85	0.08	0.04	0.54	0.03	0.01	13.99	73.78	31.98	7.77	17.71	7.68	5.75	8.04	3.49	3.35	2.28	0.99	2.34	0.95	0.41	1.49	0.32	0.14	30
35	1.00	0.11	0.05	0.63	0.04	0.02	16.32	98.16	42.55	9.07	23.56	10.21	6.71	10.70	4.64	3.91	3.03	1.31	2.73	1.26	0.55	1.74	0.43	0.18	35
40	1.14	0.14	0.06	0.72	0.05	0.02	18.65	125.70	54.49	10.37	30.17	13.08	7.66	13.71	5.94	4.46	3.88	1.68	3.11	1.62	0.70	1.99	0.54	0.24	40
45	1.28	0.17	0.08	0.81	0.06	0.02	6"			11.66	37.53	16.27	8.62	17.05	7.39	5.02	4.83	2.09	3.50	2.01	0.87	2.24	0.68	0.29	45
50	1.42	0.21	0.09	0.90	0.07	0.03	0.63	0.03	0.01	12.96	45.62	19.77	9.58	20.72	8.98	5.58	5.87	2.54	3.89	2.45	1.06	2.49	0.82	0.36	50
60	1.71	0.30	0.13	1.08	0.10	0.04	0.75	0.04	0.02	15.55	63.94	27.72	11.50	29.04	12.59	6.69	8.22	3.56	4.67	3.43	1.49	2.99	1.15	0.50	60
70	1.99	0.39	0.17	1.26	0.13	0.06	0.88	0.05	0.02	18.14	85.06	36.87	13.41	38.64	16.75	7.81	10.94	4.74	5.45	4.56	1.98	3.48	1.54	0.67	70
75	2.14	0.45	0.19	1.35	0.15	0.06	0.94	0.06	0.03	19.43	96.66	41.90	14.37	43.90	19.03	8.37	12.43	5.39	5.84	5.18	2.25	3.73	1.74	0.76	75
80	2.28	0.51	0.22	1.44	0.16	0.07	1.00	0.07	0.03	20.73	108.93	47.22	15.33	49.48	21.45	8.93	14.01	6.07	6.23	5.84	2.53	3.98	1.97	0.85	80

NOTE GF Harvel recommends that Flow Velocities be maintained at or below 5 feet per second in large diameter piping systems (i.e. 6" diameter and larger) to minimize the potential for hydraulic shock. Refer to GF Harvel engineering section entitled "Hydraulic Shock" for additional information. Friction loss data based on utilizing mean wall dimensions to determine average ID; actual ID may vary.

Schedule 80

Flow Rate (GPM)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100ft.)	Flow Rate (GPM)
		4"			**5"**			**6"**						**1-1/2"**			**2"**			**2-1/2"**			**3"**		
90	2.56	0.63	0.27	1.62	0.20	0.09	1.13	0.09	0.04				17.24	61.54	26.68	10.04	17.42	7.55	7.01	7.26	3.15	4.48	2.45	1.06	90
100	2.85	0.76	0.33	1.80	0.25	0.11	1.25	0.10	0.04		**8"**		19.16	74.80	32.42	11.16	21.18	9.18	7.79	8.83	3.83	4.98	2.97	1.29	100
125	3.56	1.16	0.50	2.24	0.38	0.16	1.57	0.16	0.07	0.89	0.04	0.02	23.95	113.07	49.02	13.95	32.02	13.88	9.73	13.34	5.78	6.22	4.49	1.95	125
150	4.27	1.62	0.70	2.69	0.53	0.23	1.88	0.22	0.10	1.07	0.06	0.02	28.74	158.49	68.71	16.74	44.88	19.45	11.68	18.70	8.11	7.47	6.30	2.73	150
175	4.98	2.16	0.93	3.14	0.70	0.30	2.19	0.29	0.13	1.25	0.07	0.03		**10"**		19.53	59.70	25.88	13.63	24.88	10.79	8.71	8.38	3.63	175
200	5.70	2.76	1.20	3.59	0.90	0.39	2.51	0.37	0.16	1.43	0.10	0.04	0.91	0.03	0.01	22.32	76.45	33.14	15.57	31.86	13.81	9.96	10.73	4.65	200
250	7.12	4.17	1.81	4.49	1.36	0.59	3.13	0.57	0.25	1.78	0.14	0.06	1.13	0.05	0.02	27.90	115.58	50.10	19.47	48.17	20.88	12.44	16.22	7.03	250
300	8.55	5.85	2.54	5.39	1.90	0.83	3.76	0.79	0.34	2.14	0.20	0.09	1.36	0.07	0.03		**12"**		23.36	67.52	29.27	14.93	22.74	9.86	300
350	9.97	7.78	3.37	6.29	2.53	1.10	4.38	1.05	0.46	2.50	0.27	0.12	1.59	0.09	0.04	1.12	0.04	0.02		**14"**			**16"**		350
400	11.39	9.96	4.32	7.18	3.24	1.41	5.01	1.35	0.59	2.85	0.34	0.15	1.81	0.11	0.05	1.28	0.05	0.02	1.06	0.03	0.01	0.81	0.02	0.01	400
450	12.82	12.39	5.37	8.08	4.04	1.75	5.64	1.68	0.73	3.21	0.43	0.19	2.04	0.14	0.06	1.44	0.06	0.03	1.19	0.04	0.02	0.91	0.02	0.01	450
500		**18"**		8.98	4.90	2.13	6.26	2.04	0.89	3.57	0.52	0.23	2.27	0.17	0.07	1.60	0.07	0.03	1.33	0.05	0.02	1.01	0.02	0.01	500
750	1.19	0.03	0.01		**20"**					5.35	1.10	0.48	3.40	0.36	0.16	2.40	0.16	0.07	1.99	0.10	0.04	1.52	0.05	0.02	750
1,000	1.59	0.05	0.02	1.29	0.03	0.01				7.13	1.87	0.81	4.53	0.62	0.27	3.20	0.27	0.12	2.65	0.17	0.07	2.02	0.09	0.04	1,000
1,250	1.99	0.07	0.03	1.61	0.04	0.02		**24"**					5.66	0.94	0.41	4.00	0.40	0.17	3.31	0.25	0.11	2.53	0.13	0.06	1,250
1,500	2.39	0.10	0.04	1.93	0.06	0.03	1.34	0.03	0.01				6.80	1.32	0.57	4.80	0.57	0.24	3.98	0.36	0.15	3.03	0.18	0.08	1,500
2,000	3.18	0.18	0.08	2.57	0.10	0.05	1.78	0.04	0.02							6.40	0.96	0.42	5.30	0.61	0.26	4.04	0.31	0.14	2,000
2,500	3.98	0.27	0.12	3.22	0.16	0.07	2.23	0.06	0.03										6.63	0.92	0.40	5.05	0.48	0.21	2,500
3,000	4.78	0.37	0.16	3.86	0.22	0.10	2.67	0.09	0.04										7.95	1.29	0.56	6.06	0.67	0.29	3,000
3,500	5.57	0.50	0.22	4.50	0.30	0.13	3.12	0.12	0.05													7.07	0.89	0.38	3,500
4,000	6.37	0.64	0.28	5.15	0.38	0.16	3.56	0.15	0.07																4,000
4,500	7.16	0.79	0.34	5.79	0.47	0.20	4.01	0.19	0.08																4,500
5,000				6.43	0.57	0.25	4.45	0.23	0.10																5,000
5,500				7.08	0.68	0.30	4.90	0.28	0.12																5,500
6,000				7.72	0.80	0.35	5.34	0.33	0.14																6,000
7,000							6.23	0.44	0.19																7,000
7,500							6.68	0.49	0.21																7,500
8,000							7.12	0.56	0.24																8,000
8,500							7.57	0.62	0.27																8,500

NOTE GF Harvel recommends that Flow Velocities be maintained at or below 5 feet per second in large diameter piping systems (i.e. 6" diameter and larger) to minimize the potential for hydraulic shock. Refer to GF Harvel engineering section entitled "Hydraulic Shock" for additional information. Friction loss data based on utilizing mean wall dimensions to determine average ID; actual ID may vary.

Schedule 120

Flow Rate (GPM)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Flow Rate (GPM)
		1/2"			3/4"			1"			1-1/4"			1-1/2"			2"			2-1/2"			3"		
1	1.77	3.50	1.52	0.86	0.60	0.26	0.51	0.17	0.07	0.28	0.04	0.02	0.20	0.02	0.01	0.12	0.00	0.00	0.08	0.00	0.00	0.05	0.00	0.00	1
2	3.54	12.62	5.47	1.72	2.16	0.94	1.03	0.62	0.27	0.56	0.14	0.06	0.40	0.06	0.03	0.24	0.02	0.01	0.16	0.01	0.00	0.11	0.00	0.00	2
5	8.86	68.86	29.85	4.29	11.78	5.11	2.57	3.40	1.47	1.41	0.78	0.34	1.01	0.35	0.15	0.60	0.10	0.04	0.41	0.04	0.02	0.27	0.01	0.01	5
7	12.41	128.41	55.67	6.00	21.97	9.52	3.60	6.33	2.75	1.97	1.46	0.63	1.41	0.65	0.28	0.84	0.18	0.08	0.57	0.07	0.03	0.38	0.03	0.01	7
10	17.72	248.59	107.76	8.58	42.53	18.43	5.15	12.26	5.31	2.82	2.83	1.23	2.02	1.26	0.54	1.20	0.36	0.15	0.82	0.14	0.06	0.54	0.05	0.02	10
15		4"		12.87	90.11	39.06	7.72	25.98	11.26	4.23	6.00	2.60	3.03	2.66	1.15	1.80	0.75	0.33	1.22	0.29	0.13	0.81	0.11	0.05	15
20	0.64	0.05	0.02	17.16	153.52	66.55	10.30	44.25	19.18	5.64	10.23	4.43	4.04	4.54	1.97	2.40	1.28	0.56	1.63	0.50	0.22	1.07	0.18	0.08	20
25	0.80	0.08	0.03				12.87	66.90	29.00	7.05	15.46	6.70	5.04	6.86	2.97	3.00	1.94	0.84	2.04	0.76	0.33	1.34	0.27	0.12	25
30	0.96	0.11	0.05				15.45	93.77	40.65	8.46	21.67	9.39	6.05	9.61	4.17	3.60	2.72	1.18	2.45	1.06	0.46	1.61	0.38	0.17	30
35	1.12	0.14	0.06				18.02	124.75	54.08	9.87	28.83	12.50	7.06	12.79	5.54	4.20	3.61	1.57	2.85	1.41	0.61	1.88	0.51	0.22	35
40	1.28	0.19	0.08				20.60	159.75	69.25	11.28	36.92	16.01	8.07	16.37	7.10	4.80	4.63	2.01	3.26	1.80	0.78	2.15	0.65	0.28	40
45	1.44	0.23	0.10		6"					12.69	45.92	19.91	9.08	20.37	8.83	5.40	5.76	2.50	3.67	2.24	0.97	2.42	0.81	0.35	45
50	1.60	0.28	0.12	0.69	0.04	0.02				14.09	55.82	24.20	10.09	24.75	10.73	6.00	7.00	3.03	4.08	2.73	1.18	2.69	0.99	0.43	50
60	1.92	0.39	0.17	0.83	0.05	0.02				16.91	78.24	33.92	12.11	34.70	15.04	7.20	9.81	4.25	4.89	3.82	1.66	3.22	1.39	0.60	60
70	2.24	0.52	0.23	0.97	0.07	0.03				19.73	104.09	45.12	14.12	46.16	20.01	8.40	13.05	5.66	5.71	5.09	2.21	3.76	1.84	0.80	70
75	2.40	0.59	0.26	1.04	0.08	0.03				21.14	118.27	51.27	15.13	52.45	22.74	9.00	14.82	6.43	6.11	5.78	2.51	4.03	2.10	0.91	75
80	2.56	0.67	0.29	1.11	0.09	0.04				22.55	133.29	57.78	16.14	59.11	25.62	9.60	16.71	7.24	6.52	6.51	2.82	4.30	2.36	1.02	80
90	2.88	0.83	0.36	1.25	0.11	0.05				25.37	165.78	71.87	18.16	73.52	31.87	10.81	20.78	9.01	7.34	8.10	3.51	4.84	2.94	1.27	90
100	3.20	1.01	0.44	1.38	0.13	0.06		8"					20.18	89.36	38.74	12.01	25.26	10.95	8.15	9.85	4.27	5.37	3.57	1.55	100
125	4.00	1.53	0.66	1.73	0.20	0.09	0.99	0.05	0.02				25.22	135.09	58.56	15.01	38.18	16.55	10.19	14.89	6.45	6.72	5.40	2.34	125
150	4.80	2.14	0.93	2.08	0.28	0.12	1.19	0.07	0.03				30.26	189.35	82.08	18.01	53.52	23.20	12.23	20.87	9.05	8.06	7.57	3.28	150
175	5.60	2.85	1.24	2.42	0.37	0.16	1.38	0.10	0.04							21.01	71.20	30.86	14.27	27.76	12.04	9.40	10.07	4.36	175
200	6.40	3.65	1.58	2.77	0.48	0.21	1.58	0.12	0.05							24.01	91.17	39.52	16.30	35.55	15.41	10.75	12.89	5.59	200
250	8.00	5.52	2.39	3.46	0.72	0.31	1.98	0.18	0.08							30.01	137.83	59.75	20.38	53.75	23.30	13.43	19.49	8.45	250
300	9.60	7.74	3.36	4.15	1.01	0.44	2.37	0.26	0.11										24.46	75.34	32.66	16.12	27.32	11.84	300
350	11.20	10.30	4.46	4.84	1.34	0.58	2.77	0.34	0.15																350
400	12.80	13.19	5.72	5.54	1.72	0.74	3.16	0.44	0.19																400

NOTE GF Harvel recommends that Flow Velocities be maintained at or below 5 feet per second in large diameter piping systems (i.e. 6" diameter and larger) to minimize the potential for hydraulic shock. Refer to GF Harvel engineering section entitled "Hydraulic Shock" for additional information. Friction loss data based on utilizing mean wall dimensions to determine average ID; actual ID may vary.

Schedule 120

Flow Rate (GPM)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Flow Rate (GPM)
		4"			6"			8"																	
450	14.40	16.40	7.11	6.23	2.14	0.93	3.56	0.55	0.24																450
500				6.92	2.60	1.13	3.95	0.67	0.29																500
750				10.38	5.50	2.38	5.93	1.14	0.61																750
1,000				13.84	9.37	4.06	7.91	2.40	1.04																1,000
1,250							9.88	3.63	1.57																1,250
1,500							11.86	5.09	2.21																1,500
2,000							15.81	8.67	3.76																2,000
2,500																									2,500
3,000																									3,000
3,500																									3,500
4,000																									4,000
4,500																									4,500
5,000																									5,000
5,500																									5,500
6,000																									6,000
7,000																									7,000
7,500																									7,500
8,000																									8,000
8,500																									8,500

NOTE GF Harvel recommends that Flow Velocities be maintained at or below 5 feet per second in large diameter piping systems (i.e. 6" diameter and larger) to minimize the potential for hydraulic shock. Refer to GF Harvel engineering section entitled "Hydraulic Shock" for additional information. Friction loss data based on utilizing mean wall dimensions to determine average ID; actual ID may vary.

SDR 21

Flow Rate (GPM)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Flow Rate (GPM)
		1/2"			3/4"			1"			1-1/4"			1-1/2"			2"			2-1/2"			3"		
1				0.49	0.16	0.07	0.30	0.05	0.02	0.19	0.01	0.01	0.14	0.01	0.00	0.09	0.00	0.00	0.06	0.00	0.00	0.04	0.00	0.00	1
2				0.99	0.56	0.24	0.60	0.17	0.07	0.37	0.05	0.02	0.28	0.03	0.01	0.18	0.01	0.00	0.12	0.00	0.00	0.08	0.00	0.00	2
5				2.46	3.06	1.33	1.49	0.91	0.39	0.93	0.29	0.12	0.71	0.15	0.06	0.45	0.05	0.02	0.31	0.02	0.01	0.21	0.01	0.00	5
7				3.45	5.71	2.48	2.09	1.69	0.73	1.30	0.53	0.23	0.99	0.27	0.12	0.63	0.09	0.04	0.43	0.04	0.02	0.29	0.01	0.01	7
10				4.93	11.06	4.80	2.99	3.27	1.42	1.86	1.03	0.45	1.41	0.53	0.23	0.90	0.18	0.08	0.61	0.07	0.03	0.41	0.03	0.01	10
15		4"		7.39	23.44	10.16	4.48	6.93	3.00	2.79	2.18	0.95	2.12	1.12	0.49	1.35	0.37	0.16	0.92	0.15	0.06	0.62	0.06	0.02	15
20	0.50	0.03	0.01	9.86	39.94	17.31	5.97	11.81	5.12	3.72	3.72	1.61	2.83	1.91	0.83	1.80	0.64	0.28	1.23	0.25	0.11	0.83	0.10	0.04	20
25	0.62	0.04	0.02		5"		7.47	17.85	7.74	4.65	5.63	2.44	3.53	2.89	1.25	2.25	0.97	0.42	1.53	0.38	0.16	1.03	0.14	0.06	25
30	0.75	0.06	0.03	0.49	0.02	0.01	8.96	25.02	10.85	5.58	7.89	3.42	4.24	4.05	1.75	2.70	1.35	0.59	1.84	0.53	0.23	1.24	0.20	0.09	30
35	0.87	0.08	0.03	0.57	0.03	0.01	10.45	33.28	14.43	6.51	10.49	4.55	4.94	5.38	2.33	3.15	1.80	0.78	2.15	0.71	0.31	1.44	0.27	0.12	35
40	1.00	0.10	0.04	0.65	0.04	0.02				7.43	13.44	5.83	5.65	6.89	2.99	3.60	2.31	1.00	2.45	0.90	0.39	1.65	0.34	0.15	40
45	1.12	0.13	0.05	0.73	0.04	0.02		6"		8.36	16.71	7.25	6.36	8.57	3.72	4.05	2.87	1.24	2.76	1.12	0.49	1.86	0.43	0.19	45
50	1.25	0.15	0.07	0.82	0.05	0.02	0.58	0.02	0.01	9.29	20.31	8.81	7.06	10.42	4.52	4.50	3.49	1.51	3.06	1.37	0.59	2.06	0.52	0.23	50
60	1.50	0.21	0.09	0.98	0.08	0.03	0.69	0.03	0.01				8.48	14.60	6.33	5.41	4.89	2.12	3.68	1.91	0.83	2.48	0.73	0.32	60
70	1.75	0.29	0.12	1.14	0.10	0.04	0.81	0.04	0.02				9.89	19.43	8.42	6.31	6.50	2.82	4.29	2.55	1.10	2.89	0.97	0.42	70
75	1.87	0.32	0.14	1.22	0.12	0.05	0.86	0.05	0.02				10.59	22.08	9.57	6.76	7.39	3.20	4.60	2.89	1.25	3.09	1.10	0.48	75
80	2.00	0.37	0.16	1.31	0.13	0.06	0.92	0.06	0.02							7.21	8.32	3.61	4.90	3.26	1.41	3.30	1.25	0.54	80
90	2.24	0.46	0.20	1.47	0.16	0.07	1.04	0.07	0.03		8"					8.11	10.35	4.49	5.52	4.06	1.76	3.71	1.55	0.67	90
100	2.49	0.55	0.24	1.63	0.20	0.09	1.15	0.08	0.04	0.68	0.02	0.01				9.01	12.58	5.46	6.13	4.93	2.14	4.13	1.88	0.82	100
125	3.12	0.84	0.36	2.04	0.30	0.13	1.44	0.13	0.06	0.85	0.04	0.02							7.66	7.46	3.23	5.16	2.85	1.23	125
150	3.74	1.17	0.51	2.45	0.42	0.18	1.73	0.18	0.08	1.02	0.05	0.02							9.19	10.45	4.53	6.19	3.99	1.73	150
175	4.36	1.56	0.68	2.86	0.56	0.24	2.01	0.24	0.10	1.19	0.07	0.03							10.73	13.90	6.03	7.22	5.31	2.30	175
200	4.99	2.00	0.87	3.26	0.71	0.31	2.30	0.30	0.13	1.36	0.08	0.04										8.25	6.80	2.95	200
250	6.24	3.02	1.31	4.08	1.08	0.47	2.88	0.46	0.20	1.70	0.13	0.06										10.31	10.27	4.45	250
300	7.48	4.23	1.84	4.90	1.51	0.65	3.45	0.65	0.28	2.04	0.18	0.08													300
350	8.73	5.63	2.44	5.71	2.01	0.87	4.03	0.86	0.37	2.38	0.24	0.10													350
400	9.98	7.21	3.13	6.53	2.57	1.12	4.61	1.10	0.48	2.71	0.30	0.13													400

NOTE GF Harvel recommends that Flow Velocities be maintained at or below 5 feet per second in large diameter piping systems (i.e. 6" diameter and larger) to minimize the potential for hydraulic shock. Refer to GF Harvel engineering section entitled "Hydraulic Shock" for additional information. Friction loss data based on utilizing mean wall dimensions to determine average ID; actual ID may vary.

SDR 21

Flow Rate (GPM)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Flow Rate (GPM)
		4"			5"			6"			8"														
450	11.22	8.97	3.89	7.35	3.20	1.39	5.18	1.37	0.59	3.05	0.38	0.16													450
500				8.16	3.89	1.69	5.76	1.66	0.72	3.39	0.46	0.20													500
750							8.64	3.52	1.53	5.09	0.97	0.42													750
1,000										6.79	1.66	0.72													1,000
1,250										8.48	2.51	1.09													1,250
1,500																									1,500
2,000																									2,000
2,500																									2,500
3,000																									3,000
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8,500																									8,500

NOTE GF Harvel recommends that Flow Velocities be maintained at or below 5 feet per second in large diameter piping systems (i.e. 6" diameter and larger) to minimize the potential for hydraulic shock. Refer to GF Harvel engineering section entitled "Hydraulic Shock" for additional information. Friction loss data based on utilizing mean wall dimensions to determine average ID; actual ID may vary.

SDR 26

Flow Rate (GPM)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/ 100ft.)	Flow Rate (GPM)
		1/2"			**3/4"**			**1"**			**1-1/4"**			**1-1/2"**			**2"**			**2-1/2"**			**3"**		
1							0.30	0.04	0.02	0.18	0.01	0.01	0.14	0.01	0.00	0.09	0.00	0.00	0.06	0.00	0.00	0.04	0.00	0.00	1
2							0.59	0.16	0.07	0.36	0.05	0.02	0.27	0.02	0.01	0.17	0.01	0.00	0.12	0.00	0.00	0.08	0.00	0.00	2
5							1.48	0.88	0.38	0.89	0.26	0.11	0.68	0.13	0.06	0.43	0.04	0.02	0.29	0.02	0.01	0.20	0.01	0.00	5
7							2.07	1.65	0.71	1.25	0.48	0.21	0.95	0.25	0.11	0.61	0.08	0.04	0.41	0.03	0.01	0.28	0.01	0.01	7
10							2.96	3.19	1.38	1.79	0.94	0.41	1.36	0.48	0.21	0.86	0.16	0.07	0.59	0.06	0.03	0.40	0.02	0.01	10
15		**4"**					4.44	6.76	2.93	2.68	1.98	0.86	2.04	1.02	0.44	1.30	0.34	0.15	0.88	0.13	0.06	0.59	0.05	0.02	15
20	0.48	0.03	0.01				5.91	11.52	4.99	3.57	3.38	1.46	2.72	1.73	0.75	1.73	0.58	0.25	1.18	0.23	0.10	0.79	0.09	0.04	20
25	0.60	0.04	0.02		**5"**		7.39	17.41	7.55	4.47	5.10	2.21	3.40	2.62	1.14	2.16	0.87	0.38	1.47	0.34	0.15	0.99	0.13	0.06	25
30	0.72	0.05	0.02	0.47	0.02	0.01	8.87	24.40	10.58	5.36	7.15	3.10	4.07	3.67	1.59	2.59	1.23	0.53	1.76	0.48	0.21	1.19	0.18	0.08	30
35	0.84	0.07	0.03	0.55	0.03	0.01	10.35	32.46	14.07	6.25	9.52	4.13	4.75	4.89	2.12	3.03	1.63	0.71	2.06	0.64	0.28	1.39	0.24	0.11	35
40	0.96	0.09	0.04	0.63	0.03	0.01	11.83	41.57	18.02	7.14	12.19	5.28	5.43	6.26	2.71	3.46	2.09	0.90	2.35	0.82	0.35	1.58	0.31	0.14	40
45	1.08	0.11	0.05	0.70	0.04	0.02		**6"**		8.04	15.16	6.57	6.11	7.78	3.37	3.89	2.60	1.13	2.65	1.02	0.44	1.78	0.39	0.17	45
50	1.19	0.14	0.06	0.78	0.05	0.02	0.55	0.02	0.01	8.93	18.43	7.99	6.79	9.46	4.10	4.32	3.16	1.37	2.94	1.24	0.54	1.98	0.47	0.20	50
60	1.43	0.19	0.08	0.94	0.07	0.03	0.66	0.03	0.01	10.72	25.83	11.20	8.15	13.26	5.75	5.19	4.42	1.92	3.53	1.73	0.75	2.38	0.66	0.29	60
70	1.67	0.26	0.11	1.10	0.09	0.04	0.77	0.04	0.02				9.51	17.64	7.65	6.05	5.88	2.55	4.12	2.30	1.00	2.77	0.88	0.38	70
75	1.79	0.29	0.13	1.17	0.10	0.05	0.83	0.04	0.02				10.19	20.05	8.69	6.49	6.69	2.90	4.41	2.62	1.13	2.97	1.00	0.43	75
80	1.91	0.33	0.14	1.25	0.12	0.05	0.88	0.05	0.02				10.87	22.59	9.79	6.92	7.54	3.27	4.70	2.95	1.28	3.17	1.13	0.49	80
90	2.15	0.41	0.18	1.41	0.15	0.06	0.99	0.06	0.03		**8"**		12.22	28.10	12.18	7.78	9.37	4.06	5.29	3.67	1.59	3.57	1.40	0.61	90
100	2.39	0.50	0.22	1.56	0.18	0.08	1.10	0.08	0.03	0.65	0.02	0.01	13.58	34.16	14.81	8.65	11.39	4.94	5.88	4.46	1.93	3.96	1.71	0.74	100
125	2.99	0.75	0.33	1.96	0.27	0.12	1.38	0.11	0.05	0.81	0.03	0.01				10.81	17.22	7.47	7.35	6.74	2.92	4.95	2.58	1.12	125
150	3.58	1.06	0.46	2.35	0.38	0.16	1.65	0.16	0.07	0.98	0.04	0.02							8.82	9.45	4.10	5.94	3.62	1.57	150
175	4.18	1.41	0.61	2.74	0.50	0.22	1.93	0.21	0.09	1.14	0.06	0.03		**10"**					10.29	12.57	5.45	6.93	4.81	2.09	175
200	4.78	1.80	0.78	3.13	0.64	0.28	2.21	0.27	0.12	1.30	0.08	0.03	0.84	0.03	0.01							7.92	6.16	2.67	200
250	5.97	2.72	1.18	3.91	0.97	0.42	2.76	0.42	0.18	1.63	0.11	0.05	1.05	0.04	0.02							9.91	9.31	4.04	250

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SDR 26

Flow Rate (GPM)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Friction Flow Velocity (ft/sec.)	Friction Loss (Ft.Water 100ft.)	Loss (psi/100ft.)	Flow Rate (GPM)
		4"			**5"**			**6"**			**8"**			**10"**										**3"**		
300	7.17	3.81	1.65	4.69	1.36	0.59	3.31	0.58	0.25	1.95	0.16	0.07	1.26	0.06	0.02		**12"**					11.89	13.06	5.66	300
350	8.36	5.07	2.20	5.48	1.81	0.79	3.86	0.77	0.34	2.28	0.21	0.09	1.47	0.07	0.03	1.04	0.03	0.01		**14"**			**16"**		350
400	9.56	6.50	2.82	6.26	2.32	1.01	4.41	0.99	0.43	2.60	0.27	0.12	1.68	0.09	0.04	1.19	0.04	0.02	0.99	0.03	0.01	0.76	0.01	0.01	400
450	10.75	8.08	3.50	7.04	2.89	1.25	4.96	1.23	0.53	2.93	0.34	0.15	1.88	0.12	0.05	1.34	0.05	0.02	1.11	0.03	0.01	0.85	0.02	0.01	450
500		**18"**		7.82	3.51	1.52	5.52	1.50	0.65	3.25	0.41	0.18	2.09	0.14	0.06	1.49	0.06	0.03	1.23	0.04	0.02	0.95	0.02	0.01	500
750	1.12	0.02	0.01		**20"**		8.27	3.17	1.38	4.88	0.88	0.38	3.14	0.30	0.13	2.23	0.13	0.06	1.85	0.08	0.04	1.42	0.04	0.02	750
1,000	1.49	0.04	0.02	1.21	0.03	0.01	11.03	5.41	2.34	6.51	1.50	0.65	4.19	0.51	0.22	2.98	0.22	0.10	2.47	0.14	0.06	1.89	0.07	0.03	1,000
1,250	1.87	0.06	0.03	1.51	0.04	0.02		**24"**		8.13	2.26	0.98	5.23	0.78	0.34	3.72	0.34	0.15	3.09	0.21	0.09	2.36	0.11	0.05	1,250
1,500	2.24	0.09	0.04	1.81	0.05	0.02	1.26	0.02	0.01	9.76	3.17	1.38	6.28	1.09	0.47	4.47	0.47	0.21	3.70	0.30	0.13	2.84	0.16	0.07	1,500
2,000	2.99	0.15	0.07	2.42	0.09	0.04	1.68	0.04	0.02				8.38	1.85	0.80	5.95	0.81	0.35	4.94	0.51	0.22	3.78	0.27	0.12	2,000
2,500	3.73	0.23	0.10	3.02	0.14	0.06	2.10	0.06	0.02							7.44	1.22	0.53	6.17	0.77	0.34	4.73	0.40	0.18	2,500
3,000	4.48	0.32	0.14	3.63	0.19	0.08	2.52	0.08	0.03										7.41	1.08	0.47	5.67	0.57	0.25	3,000
3,500	5.23	0.42	0.18	4.23	0.25	0.11	2.94	0.10	0.05													6.62	0.75	0.33	3,500
4,000	5.97	0.54	0.24	4.84	0.33	0.14	3.36	0.13	0.06																4,000
4,500	6.72	0.68	0.29	5.44	0.41	0.18	3.78	0.17	0.07																4,500
5,000				6.05	0.49	0.21	4.20	0.20	0.09																5,000
5,500				6.65	0.59	0.25	4.62	0.24	0.10																5,500
6,000				7.26	0.69	0.30	5.04	0.28	0.12																6,000
7,000							5.88	0.38	0.16																7,000
7,500							6.30	0.43	0.19																7,500
8,000							6.72	0.48	0.21																8,000
8,500							7.14	0.54	0.24																8,500

NOTE GF Harvel recommends that Flow Velocities be maintained at or below 5 feet per second in large diameter piping systems (i.e. 6" diameter and larger) to minimize the potential for hydraulic shock. Refer to GF Harvel engineering section entitled "Hydraulic Shock" for additional information. Friction loss data based on utilizing mean wall dimensions to determine average ID; actual ID may vary.

SDR 41

Flow Rate (GPM)	Flow Velocity (ft./sec.)	Friction Loss (Ft.Water/ 100ft.)	Friction Loss (psi/ 100 ft.)	Flow Velocity (ft./sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100 ft.)	Flow Velocity (ft./sec.)	Friction Loss (Ft.Water 100ft.)	Friction Loss (psi/ 100 ft.)	Flow Rate (GPM)
		18"			20"			24"		
750	1.05	0.02	0.01							750
1,000	1.40	0.04	0.02							1,000
1,250	1.75	0.05	0.02	1.42	0.03	0.01				1,250
1,500	2.10	0.08	0.03	1.70	0.05	0.02	1.18	0.02	0.01	1,500
2,000	2.81	0.13	0.06	2.27	0.08	0.03	1.58	0.03	0.01	2,000
2,500	3.51	0.20	0.08	2.84	0.12	0.05	1.97	0.05	0.02	2,500
3,000	4.21	0.27	0.12	3.41	0.16	0.07	2.37	0.07	0.03	3,000
3,500	4.91	0.36	0.16	3.98	0.22	0.09	2.76	0.09	0.04	3,500
4,000	5.61	0.47	0.20	4.55	0.28	0.12	3.16	0.12	0.05	4,000
4,500	6.31	0.58	0.25	5.11	0.35	0.15	3.55	0.14	0.06	4,500
5,000				5.68	0.42	0.18	3.95	0.17	0.08	5,000
5,500				6.25	0.50	0.22	4.34	0.21	0.09	5,500
6,000				6.82	0.59	0.26	4.73	0.24	0.11	6,000
7,000							5.52	0.32	0.14	7,000
7,500							5.92	0.37	0.16	7,500
8,000							6.31	0.42	0.18	8,000
8,500							6.71	0.47	0.20	8,500

NOTE GF Harvel recommends that Flow Velocities be maintained at or below 5 feet per second in large diameter piping systems (i.e. 6" diameter and larger) to minimize the potential for hydraulic shock. Refer to GF Harvel engineering section entitled "Hydraulic Shock" for additional information. Friction loss data based on utilizing mean wall dimensions to determine average ID; actual ID may vary.

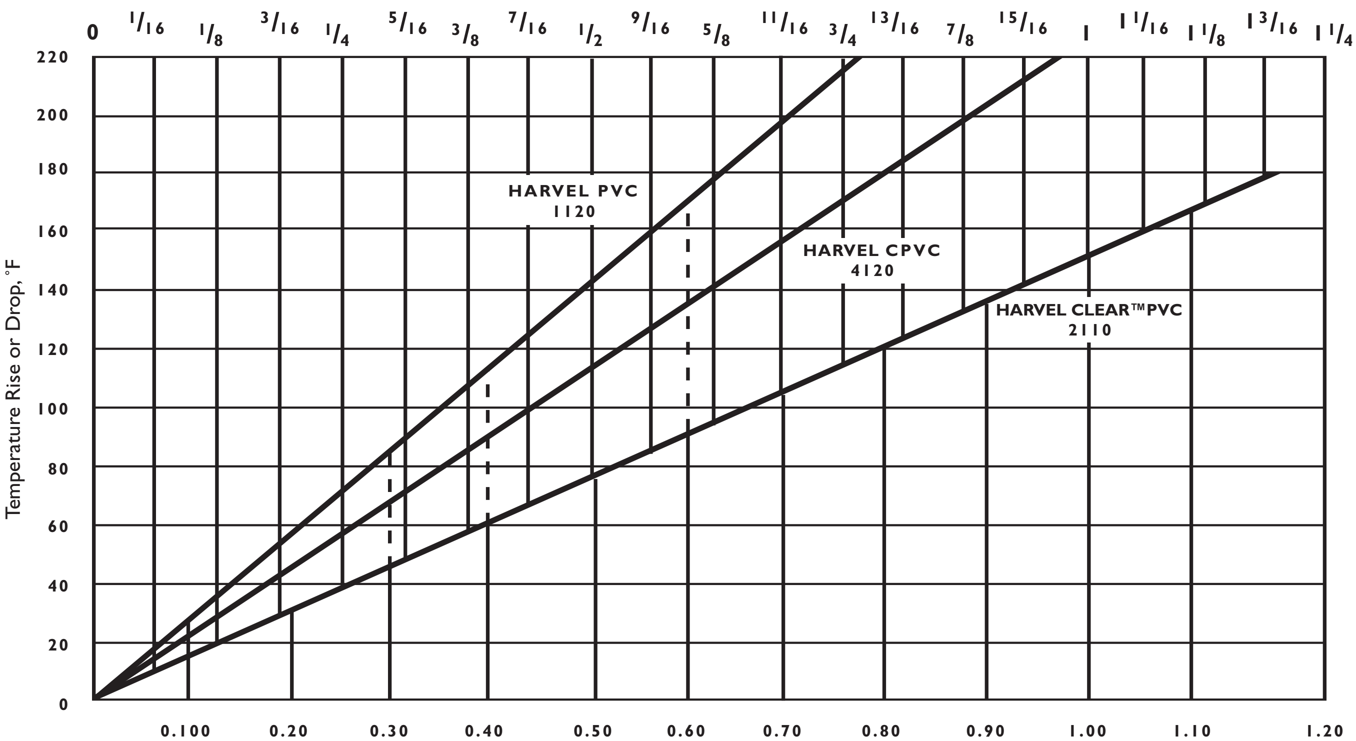
Thermal Expansion & Contraction

All piping systems expand and contract with changes in temperature. Thermoplastic piping expands and contracts more than metallic piping when subjected to temperature changes. This issue must be addressed with appropriate system design to prevent damage to the piping system. The degree of movement (change in length) generated as the result of temperature changes, must be calculated based on the type of piping material and the anticipated temperature changes of the system. The rate of expansion does not vary with pipe size. In many cases this movement must then be compensated for by the construction of appropriate sized expansion loops, offsets, bends or the installation of expansion joints.

These configurations will absorb the stresses generated from the movement, thereby minimizing damage to the piping. The effects of thermal expansion and contraction must be considered during the design phase, particularly for systems involving long runs, hot water lines, hot drain lines, and piping systems exposed to environmental temperature extremes (i.e. summer to winter).

The following chart depicts the amount of linear movement (change in length, inches) experienced in a 10ft length of pipe when exposed to various temperature changes.

Highly important is the change in length of plastic pipe with temperature variation. This fact should always be considered when installing pipe lines and allowances made accordingly.



NOTE The data furnished herein is based on information furnished by manufacturers of the raw material. This information may be considered as a basis for recommendation, but not as a guarantee. Materials should be tested under actual service to determine suitability for a particular purpose.

Engineering & Design Data

Calculating Linear Movement Caused by Thermal Expansion

The rate of movement (change in length) caused by thermal expansion or contraction can be calculated as follows:

$\Delta L = 12yl(\Delta T)$

Where:
ΔL = expansion or contraction in inches
y = Coefficient of linear expansion of piping material selected
l = length of piping run in feet
$\Delta T = (T_1 - T_2)$ temperature change °F

Where:
T_1 = maximum service temperature of system and
T_2 = temperature at time of installation (or difference between lowest system temperature and maximum system temperature – whichever is greatest)

Coefficient of Linear Expansion (y) of Various GF Harvel Piping Products (in/in/°F) per ASTM D696

Pipe Material	y
GF Harvel PVC Pressure Pipe (all schedules & SDR's) and PVC Duct	2.9×10^{-5}
GF Harvel CPVC Schedule 40 & Schedule 80 Pressure Pipe	3.7×10^{-5}
GF Harvel CPVC Duct	3.9×10^{-5}
GF Harvel CTS CPVC Plumbing Pipe	3.2×10^{-5}
GF Harvel Clear PVC Schedule 40 & Schedule 80 Pipe	4.1×10^{-5}
GF Harvel LXT UPW Pipe	3.9×10^{-5}

Note: Refer to appropriate physical Properties Tables for additional detailed information

Example 1: Calculate the change in length for a 100 foot straight run of 2" Schedule 80 PVC pipe operating at a temperature of 73°F; installed at 32°F.

$\Delta L = 12yl(\Delta T)$

Where:
ΔL = linear expansion or contraction in inches
y = 2.9×10^{-5} in/in/°F
l = 100ft
ΔT = 41°F (73°F – 32°F)

ΔL = 12 in/ft x 0.000029 in/in/ft x 100ft x 41°F

ΔL = 1.43"

In this example the piping would expand approximately 1½" in length over a 100 ft straight run once the operating temperature of 73°F was obtained.

Example 2: 100 foot straight run of 2" Schedule 80 CPVC pipe operating temperature 180°F; installed at 80°F

$\Delta L = 12yl(\Delta T)$

Where:
ΔL = linear expansion or contraction in inches
y = 3.7×10^{-5} in/in/°F
l = 100ft
ΔT = 100°F (180°F-80°F)

ΔL = 12 in/ft x 0.000037 in/in/ft x 100ft x 100°F

ΔL = 4.44"

In this example the piping would expand approximately 4.5" in length over a 100 ft straight run once the operating temperature of 180°F was obtained.

Compensating for Movement Caused by Thermal Expansion/Contraction

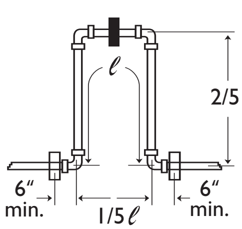
In most piping applications the effects of thermal expansion/contraction are usually absorbed by the system at changes of direction in the piping. However, long, straight runs of piping are more susceptible to experiencing measurable movement with changes in temperature. As with other piping materials, the installation of an expansion joints, expansion loops or offsets is required on long, straight runs. This will allow the piping system to absorb the forces generated by expansion/contraction without damage.

Once the change in length (ΔL) has been determined, the length of an offset, expansion loop, or bend required to compensate for this change can be calculated as follows:

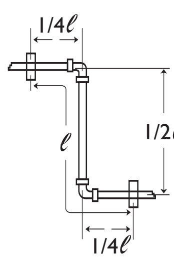
$$\ell = \sqrt{\frac{3ED(\Delta L)}{2S}}$$

Where:
ℓ = Length of expansion loop in inches
E = Modulus of elasticity
D = Average outside diameter of pipe
ΔL = Change in length of pipe due to temperature change
S = Working stress at max. temperature

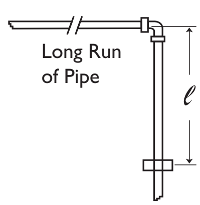
Loop



Offset



Bend
(Change of Direction)



Hangers or guides should only be placed in the loop, offset, or change of direction as indicated above, and must not compress or restrict the pipe from axial movement. Piping supports should restrict lateral movement and should direct axial movement into the expansion loop configuration. Do not restrain "change in direction" configurations by butting up against joists, studs, walls or other structures. Use only solvent-cemented connections on straight pipe lengths in combination with 90° elbows to construct the expansion loop, offset or bend. The use of threaded components to construct the loop configuration is not recommended. Expansion loops, offsets, and bends should be installed as nearly as possible at the midpoint between anchors. Concentrated loads such as valves should not be installed in the developed length. Calculated support guide spacing distances for offsets and bends must not exceed recommended hanger support spacing for the maximum anticipated temperature. If that occurs, the distance between anchors will have to be reduced until the support guide spacing distance is equal to or less than the maximum recommended support spacing distance for the appropriate pipe size at the temperature used.

Example: 2" Schedule 80 CPVC pipe operating temperature 180°F; installed at 80°F where ΔL = 4.08"

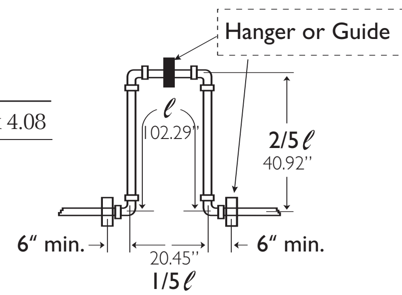
$$\ell = \sqrt{\frac{3ED(\Delta L)}{2S}}$$

$$\ell = \sqrt{\frac{3 \times 360{,}000 \times 2.375 \times 4.08}{2 \times 500}}$$

ℓ = 102.29"

2/5 ℓ = 40.92"

1/5 ℓ = 20.46"



Engineering & Design Data

Thermal Stress

Compressive stress is generated in piping that is restrained from expanding in cases where the effects of thermal expansion are not addressed. This induced stress can damage the piping system leading to premature failure, and in some cases also cause damage to hangers and supports or other structural members. The amount of compressive stress generated is dependent on the pipe materials coefficient of thermal expansion and its tensile modulus and can be determined by the following equation:

S = EyΔT

Where:
S = stress induced in the pipe
E = Modulus of Elasticity at maximum system temperature
y = Coefficient of thermal expansion
ΔT = total temperature change of the system

Maximum Allowable Working (Fiber) Stress and Tensile Modulus at Various Temperatures

	Temp (°F)	Maximum Allowable Working (Fiber) Stress, psi	Tensile Modulus of Elasticity, psi
PVC	73	2,000	400,000
	80	1,760	396,000
	90	1,500	375,000
	100	1,240	354,000
	110	1,020	333,000
	120	800	312,000
	130	620	291,000
	140	440	270,000
CPVC	73	2,000	364,000
	90	1,820	349,000
	100	1,640	339,000
	110	1,500	328,000
	120	1,300	316,000
	140	1,000	290,000
	160	750	262,000
	180	500	214,000
	200	400	135,000

The stress induced into the pipe as a result of thermal influences must not exceed the maximum allowable working stress of the pipe material. The maximum allowable working stress (fiber stress) is dependent on the temperature the pipe is exposed to. Increases in temperature will reduce the allowable stress as shown the table below.

Example: 100 foot straight run of 2" Schedule 80 CPVC pipe operating temperature 180˚F; installed at 80˚F:

ΔL = 12yl(ΔT)

Where:
ΔL = linear expansion or contraction in inches
y = 3.7 x 10^{-5} in/in/˚F
l = 100ft
ΔT = 100˚F (180˚F – 80˚F)
ΔL = 12 in/ft x 0.000037 in/in/ft x 100ft x 100˚F
ΔL = 4.44"

In this example the piping would expand approximately 4.5" in length over a 100 ft straight run

Stress generated from this expansion if no allowances are made to compensate for it:

S = EyΔT

Where:
S = stress induced in the pipe
E = Modulus of Elasticity at 180˚F = 214,000
y = Coefficient of thermal expansion = 3.7 x 10^{-5} in./in./˚F
ΔT = total temperature change of the system = 100˚F
S = 214,000 x 0.000037 x 100
S = 792 psi

From chart at left, maximum allowable stress for CPVC at 180˚F is 500 psi; in this example the stress generated from this expansion in a restrained piping system exceeds the maximum allowable stress and will result in failure of the piping.

Negative Pressure Applications

CRITICAL COLLAPSE PRESSURE is the maximum allowable pressure that can be applied externally to pipe, and is directly related to the wall thickness of the pipe selected. Examples of external pressure conditions can occur: when buried pipe is subjected to soil loads; underwater applications; vacuum service; and pipe installed on pump suction lines. The actual external load being applied to the pipe is the difference between the external pressure and the internal pressure which counteract each other. As a result, a pressurized pipe can withstand a greater external load than an empty pipe.

Critical Collapse Pressure Rating of GF Harvel PVC and CPVC Piping in PSI (and Inches of Water) – Based @ 73°F with No Safety Factor

Size(in.)	Duct	SDR 41	SDR 26	SDR 21	SCH 40	SCH 80	SCH 120
2	N/A	17* (470)	74* (2,048)	126* (3,487)	316 (8,746)	939 (25,989)	1309 (36,230)
2-1/2	N/A	17* (470)	74* (2,048)	126* (3,487)	451 (12,483)	975 (26,986)	1309 (36,230)
3	N/A	17* (470)	74* (2,048)	126* (3,487)	307 (8,497)	722 (19,983)	1128 (31,221)
3-1/2	N/A	17* (470)	74* (2,048)	126* (3,487)	217 (6,006)	578 (15,998)	N/A
4	N/A	17* (470)	74* (2,048)	126* (3,487)	190 (5,259)	451 (12,482)	1128 (31,221)
5	N/A	17* (470)	74* (2,048)	126* (3,487)	117 (3,238)	361 (10,000)	N/A
6	N/A	17* (470)	74* (2,048)	126* (3,487)	90 (2,491)	343 (9,493)	722 (19,983)
6 x 1/8	5.2 (144)	N/A	N/A	N/A	N/A	N/A	N/A
6 x 3/16	0.7 (426)	N/A	N/A	N/A	N/A	N/A	N/A
8	10.0 (193)	17* (470)	74* (2,048)	126* (3,487)	58 (1,605)	235 (6,504)	N/A
10	5.4 (100)	17* (470)	74* (2,048)	126* (3,487)	49 (1,605)	217 (6,504)	N/A
12	3.0 (60)	17* (470)	74* (2,048)	126* (3,487)	42 (1,162)	199 (5,508)	N/A
14	2.5 (45)	17* (470)	74* (2,048)	126* (3,487)	40 (1,107)	194 (5,369)	N/A
16	1.6 (30)	17* (470)	74* (2,048)	126* (3,487)	40 (1,107)	181 (5,010)	N/A
18	1.0 (26)	17* (470)	74* (2,048)	126* (3,487)	33 (913)	162 (4,484)	N/A
20	1.3 (28)	17* (470)	74* (2,048)	126* (3,487)	28 (775)	157 (4,346)	N/A
24	1.0 (20)	17* (470)	74* (2,048)	126* (3,487)	25 (692)	150 (4,152)	N/A

* SDR Series Pipe maintains the same collapse ratings for all sizes due to the wall thickness/O.D. ratio.

Georg Fischer Harvel LLC recommends the use of solvent-cemented connections when using PVC/CPVC piping in vacuum service applications. Threaded connections are not recommended due to the greater potential for leakage when used in negative pressure applications.

1 psi = 2.036 inches of mercury

De-Rating Factors

PVC Pipe

Temp (°F)	Working De-Rating Factor
73	1.00
80	0.88
90	0.75
100	0.62
110	0.51
120	0.40
130	0.31
140	0.22

CPVC Pipe

Temp (°F)	Working De-Rating Factor
73	1.00
110	0.72
120	0.65
130	0.57
140	0.50
150	0.42
160	0.40
170	0.29
180	0.25
200	0.20

Appropriate temperature de-rating factors must be applied at temperatures other than 73°F based on the material selected.

Multiply the collapse pressure rating of the selected pipe at 73°F, by the appropriate de-rating factor to determine the collapse pressure rating of the pipe at the elevated temperature chosen.

Temperature Limitations

PVC

Georg Fischer Harvel LLC PVC piping products are manufactured from a Type I, Grade I PVC compound with a Cell Classification of 12454 per ASTM D1784. GF Harvel PVC Schedule 40 and Schedule 80 pipe is manufactured in strict compliance to ASTM D1785 using this material, and consistently meets or exceeds the requirements of this standard with regard to materials, workmanship, dimensions, sustained pressure, burst pressure, flattening resistance and extrusion quality.

The maximum operating temperature for PVC pipe produced to these standards is 140˚F. As with all thermoplastic materials, an increase in temperature results in an increase in impact strength and a decrease in tensile strength and pipe stiffness, which reduces the pressure rating. The mechanical properties of PVC pipe manufactured to the above referenced standards are routinely tested and recorded at 73˚F based on testing per applicable ASTM material test standards. Appropriate temperature de-rating factors must be applied when working at elevated temperatures to determine maximum allowable pressure. The following temperature de-rating factors are to be applied to the working pressure ratings stated for the products at 73˚F when operating at elevated temperatures:

Multiply the working pressure rating of the selected pipe at 73˚F, by the appropriate de-rating factor to determine the maximum working pressure rating of the pipe at the elevated temperature chosen.

Temp (°F)	Working De-Rating Factor
73	1.00
80	0.88
90	0.75
100	0.62
110	0.51
120	0.40
130	0.31
140	0.22

EX: 10" PVC SCHEDULE 80 @ 120°F = ?
230 psi x 0.40 = 92 psi max. @ 120°F

THE MAXIMUM SERVICE TEMPERATURE FOR PVC IS 140°F.

Solvent cemented joints should be utilized when working at or near maximum temperatures. GF Harvel Plastics does not recommend the use of PVC for threaded connections at temperatures above 110˚F; use flanged joints, unions, or roll grooved couplings where disassembly is necessary at elevated temperatures.

It is a documented fact that as temperatures fall below 73˚F, tensile strength and pipe stiffness values increase thereby increasing the pipes pressure bearing capability and resistance to bending deflection. However, as with most materials impact resistance and ductility decrease at colder temperatures. In addition, a drop in temperature will cause the piping to contract, which must be addressed with proper system design. Due to PVC's coefficient of thermal expansion, a 20-foot length of pipe will contract approximately 3/4" when cooled from 95˚F to -5˚F.

Since pressure bearing capacity is not reduced with a decrease in temperature, PVC pipe is suitable for use at colder temperatures provided the fluid medium is protected from freezing, consideration is given to the effects of expansion and contraction, and additional care and attention are given during handling, installation and operation of the system to prevent physical damage caused by impact or other mechanical forces.

It should be noted that Georg Fischer Harvel LLC routinely conducts drop impact testing on our PVC piping products at 73˚F as well as 32˚F. The impact resistance of PVC pipe at 32˚F vs. 73˚F is dependent on the pipe diameter as well as the wall thickness of the product. To our knowledge, definitive testing has not been conducted to establish an accurate ratio of the actual reduction in impact strength on the entire range of sizes/dimensions of PVC piping at lower temperatures.

CPVC

Georg Fischer Harvel LLC CPVC piping products are manufactured from a Type IV, Grade I CPVC compound with a Cell Classification of 23447 per ASTM D1784. GF Harvel CPVC Schedule 40 and Schedule 80 pipe is manufactured in strict compliance to ASTM F441 using this material, and consistently meets or exceeds the requirements of this standard with regard to materials, workmanship, dimensions, sustained pressure, burst pressure, flattening resistance and extrusion quality.

The maximum operating temperature for CPVC pipe produced to these standards is 200˚F. As with all thermoplastic materials, an increase in temperature results in an increase in impact strength and a decrease in tensile strength and pipe stiffness, which reduces the pressure rating. The mechanical properties of CPVC pipe manufactured to the above-referenced standards are routinely tested and recorded at 73˚F based on testing per applicable ASTM material test standards. Appropriate temperature de-rating factors must be applied when working at elevated temperatures to determine maximum allowable pressure. The following temperature de-rating factors are to be applied to the working pressure ratings stated for the products at 73˚F when operating at elevated temperatures:

Multiply the working pressure rating of the selected pipe at 73˚F, by the appropriate de-rating factor to determine the maximum working pressure rating of the pipe at the elevated temperature chosen.

Temp (°F)	Working De-Rating Factor
73-80	1.00
90	0.91
100	0.82
110	0.72
120	0.65
130	0.57
140	0.50
150	0.42
160	0.40
170	0.29
180	0.25
200	0.20

EX: 10" CPVC SCHEDULE 80 @ 120°F = 230 psi x 0.65 = 149.5 psi max. @ 120°F

THE MAXIMUM SERVICE TEMPERATURE FOR CPVC IS 200°F.

Solvent-cemented joints should be utilized when working at or near maximum temperatures. GF Harvel Plastics does not recommend the use of CPVC for threaded connections at temperatures above 150°F; use flanged joints, unions, or roll grooved couplings where disassembly is necessary at elevated temperatures.

It is a documented fact that as temperatures fall below 73°F, tensile strength and pipe stiffness values increase thereby increasing the pipes pressure bearing capability and resistance to bending deflection. However, as with most materials impact resistance and ductility decrease at colder temperatures. In addition, a drop in temperature will cause the piping to contract, which must be addressed with proper system design. Due to CPVC's coefficient of thermal expansion, a 20-foot length of pipe will contract approximately 7/8" when cooled from 95°F to -5°F.

Since pressure bearing capacity is not reduced with a decrease in temperature, CPVC pipe is suitable for use at colder temperatures provided the fluid medium is protected from freezing, consideration is given to the effects of expansion and contraction, and additional care and attention are given during handling, installation and operation of the system to prevent physical damage caused by impact or other mechanical forces.

An accurate ratio of the actual reduction in impact strength on specific sizes/dimensions of CPVC piping at lower temperatures has not yet been determined with physical testing due to the numerous variables involved. However, preliminary drop impact testing that has been conducted on limited sizes reveals a reduction in drop impact strength of approximately 60% on pipe that was tested at 32°F compared to the same size of pipe tested at 73°F. The impact resistance of CPVC pipe at 32°F vs. 73°F is dependent on the pipe diameter as well as the wall thickness of the product.

Weatherability

Testing and past field experience studies have concluded that when conventional Type I, Grade I (Cell Classification 12454) rigid PVC pipe is exposed to UV radiation from sunlight the following conditions have been noted:

- The effects of exposure to UV radiation results in a color change to the product, slight increase in tensile strength, slight increase in modulus of tensile elasticity, and a slight decrease in impact strength.
- UV degradation occurs only in the plastic material directly exposed to UV radiation and to extremely shallow penetration depths (frequently less than 0.001 inch).
- UV degradation does not continue when exposure to UV is terminated.
- UV radiation will not penetrate even thin shields such as paint coatings, clothing or wrapping.

Based on these studies, Georg Fischer Harvel LLC recommends that PVC and CPVC piping products (i.e. pipe, duct and shapes) exposed to the direct effects of UV radiation be painted with a light colored acrylic or latex paint that is chemically compatible with the PVC/CPVC products. Compatibility information should be confirmed with the paint manufacturer. The use of oil-based paints is not recommended.

When painted the effects of exposure to sunlight are significantly reduced, however, consideration should be given to the effects of expansion/contraction of the system caused by heat absorption in outdoor applications. The use of a light colored, reflective paint coating will reduce this affect, however, the system must also be designed and installed in such a manner to reduce the effects of movement due to thermal expansion. Information concerning expansion and contraction, proper hanger support spacing and other design criteria can be found in this engineering and installation guide.

It should be noted that GF Harvel's standard formulation of PVC compound (H707) used in the manufacture of our rigid PVC pipe and duct contains ≳1-1/2% of Titanium Dioxide (TiO2), a natural UV inhibitor. GF Harvel's CPVC compounds used in the manufacture of rigid CPVC pipe and duct contains at least 2% Titanium Dioxide (TiO2). GF Harvel's conventional Clear PVC piping products do not contain UV inhibitors and should not be exposed to UV radiation.