Flow Capacity and Friction Loss for Schedule 40 Thermoplastic Pipe per 100ft

Gals. Per Minute	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)
		1/4" Pipe																						
1/2	1.73	4.90	2.12																					
3/4	2.59	10.38	4.50		1/2" Pipe			3/4" Pipe																
1	3.45	17.68	7.66	1.13	1.16	.50	1.26	1.03	.45		1" Pipe			1 1/4" Pipe										
2	6.90	63.82	27.66	2.25	4.19	1.82	3.16	5.60	2.43								1 1/2" Pipe							
5	17.26	348.29	150.93	5.64	22.88	9.92	4.42	10.44	4.52	1.93	1.69	0.73	1.1	0.43	0.19									
7				7.89	42.66	18.49	6.32	20.21	8.76	2.70	3.14	1.36	1.55	0.81	0.35	1.13	0.38	0.16		2" Pipe			2 1/2" Pipe	
10				11.27	82.59	35.79	9.48	42.82	18.56	3.86	6.08	2.63	2.21	1.57	0.68	1.62	0.73	0.32						
15		3" Pipe		16.91	175.01	75.84	12.64	72.95	31.61	5.79	12.89	5.59	3.31	3.32	1.44	2.42	1.55	0.67	1.46	0.45	0.2	1.02	0.19	0.08
20							15.80	110.29	47.80	7.72	21.96	9.52	4.42	5.65	2.45	3.23	2.64	1.14	1.95	0.77	0.33	1.38	0.33	0.14
25	1.10	.17	.07							9.64	33.20	14.39	5.52	8.55	3.71	4.04	4	1.73	2.44	1.17	0.51	1.71	0.49	0.21
30	1.32	0.24	0.1		4" Pipe					11.57	46.54	20.17	6.63	11.98	5.19	4.85	5.6	2.43	2.92	1.64	0.71	2.05	0.69	0.3
35	1.54	.32	.14							13.50	61.91	26.83	7.73	15.94	6.91	5.65	7.45	3.23	3.41	2.18	0.94	2.39	0.92	0.4
40	1.77	.41	.18	1.02	.11	.05				15.43	79.28	34.36	8.83	20.41	8.84	6.46	9.54	4.13	3.9	2.79	1.21	2.73	1.18	0.51
45	1.99	.51	.22	1.15	.13	.06							9.94	25.39	11	7.27	11.87	5.14	4.39	3.47	1.5	3.07	1.46	0.63
50	2.21	.61	.26	1.28	.16	.07							11.04	30.86	13.37	8.08	14.43	6.25	4.87	4.22	1.83	3.42	1.78	0.77
60	2.65	.86	.37	1.53	.23	.10							13.25	43.25	18.74	9.69	20.22	8.76	5.85	5.92	2.57	4.1	2.49	1.08
70	3.09	1.15	.50	1.79	.30	.13							15.46	57.54	24.94	11.31	26.9	11.66	6.82	7.87	3.41	4.78	3.32	1.44
75	3.31	1.30	.56	1.92	.34	.15		6" Pipe								12.12	30.57	13.25	7.31	8.94	3.87	5.12	3.77	1.63
80	3.53	1.47	.64	2.04	.39	.17										12.93	34.45	14.93	7.8	10.08	4.37	5.47	4.25	1.84
90	3.97	1.82	.79	2.30	.48	.21	1.01	.07	.03							14.54	42.85	18.57	8.77	12.53	5.43	6.15	5.28	2.29
100	4.41	2.22	.96	2.56	.59	.26	1.12	.08	.03							16.16	52.08	22.57	9.75	15.23	6.6	6.83	6.42	2.78
125	5.52	3.35	1.45	3.19	.89	.39	1.40	.12	.05		8" Pipe								12.18	23.03	9.98	8.54	9.7	4.2
150	6.62	4.70	2.04	3.83	1.24	.54	1.68	.17	.07										14.62	32.28	13.99	10.25	13.6	5.89
175	7.72	6.25	2.71	4.47	1.65	.72	1.97	.22	.10	1.13	.06	0.03		10" Pipe					17.06	42.95	18.61	11.96	18.09	7.84
200	8.83	8.00	3.47	5.11	2.12	.92	2.25	.29	0.13	1.3	0.08	0.03										13.67	23.17	10.04
250	11.03	12.10	5.24	6.39	3.20	1.39	2.81	.43	0.19	1.62	0.11	0.05	1.03	0.04	0.02		12" Pipe					17.08	35.03	15.18
300	13.24	16.96	7.35	7.67	4.49	1.95	3.37	.61	0.26	1.94	0.16	0.07	1.23	0.05	0.02									
350	15.45	22.56	9.78	8.94	5.97	2.59	3.93	.81	0.35	2.27	0.21	0.09	1.44	0.07	0.03	1.01	0.03	0.01						
400				10.22	7.64	3.31	4.49	1.03	0.45	2.59	0.27	0.12	1.64	0.09	0.04	1.16	0.04	0.02						
450				11.50	9.51	4.12	5.05	1.29	0.56	2.91	0.34	0.15	1.85	0.11	0.04	1.3	0.05	0.02						
500				12.78	11.54	5.01	5.61	1.56	0.68	3.24	0.41	0.18	2.05	0.14	0.06	1.44	0.06	0.03						
750				19.17	24.49	10.61	8.42	3.31	1.43	4.86	0.87	0.38	3.08	0.29	0.13	2.17	0.12	0.05						
1000							11.23	5.64	2.44	6.48	1.48	0.64	4.1	0.49	0.21	2.89	0.21	0.09						
1250							14.04	8.53	3.7	8.09	2.24	0.97	5.13	0.74	0.32	3.61	0.31	0.13						
1500							16.84	11.96	5.18	9.71	3.13	1.36	6.16	1.03	0.45	4.33	0.44	0.19						
2000										12.95	5.34	2.31	8.21	1.76	0.76	5.78	0.75	0.33						
2500										16.19	8.07	3.5	10.26	2.66	1.15	7.22	1.13	0.49						
3000													12.31	3.73	1.62	8.67	1.58	0.68						
3500													14.36	4.96	2.15	10.11	2.11	0.92						
4000													16.42	6.36	2.87	11.56	2.71	1.17						

Engineering Data

Flow Capacity and Friction Loss for Schedule 80 Thermoplastic Pipe per 100ft

Gals. Per Minute	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)	Velocity (Feet per Second)	Friction Head (Feet)	Friction Loss (PSI)
		1/4" Pipe																						
1/4	1.28	3.57	1.55		1/2" Pipe																			
1/2	2.57	12.88	5.58					3/4" Pipe																
3/4	3.85	27.29	11.83	1.11	1.31	.57					1" Pipe													
1	5.14	46.49	20.15	1.48	2.24	.97	.78	.48	.21					1 1/4" Pipe										
3	15.41	355.60	154.20	4.43	17.13	7.43	2.35	3.65	1.59	1.40	1.04	.45					1 1/2" Pipe							
5				7.38	44.12	19.12	3.92	9.45	4.10	2.33	9.45	1.16	1.30	.64	.28					2" Pipe				
7				10.33	82.27	35.65	5.48	17.62	7.64	3.26	4.98	2.16	1.82	1.20	.52	1.31	.54	.23					2 1/2" Pipe	
10		3" Pipe		14.76	159.26	69.02	7.84	34.11	14.78	4.66	9.65	4.18	2.59	2.32	1.01	1.87	1.05	.46	1.12	.30	.13			
15							11.75	72.27	31.32	6.99	20.44	8.86	3.89	4.91	2.13	2.81	2.23	.97	1.67	.63	.27	1.17	.26	.11
20	1.00	.15	.07				15.67	123.13	53.36	9.32	34.82	15.09	5.19	8.36	3.62	3.75	3.80	1.65	2.23	1.07	.46	1.56	.45	.20
25	1.24	.23	.10		4" Pipe					11.66	52.64	22.81	6.48	12.64	5.48	4.69	5.74	2.49	2.79	1.63	.71	1.92	.68	.29
30	1.49	.32	.14							13.99	78.78	31.97	7.78	17.71	7.67	5.62	8.04	3.48	3.35	2.28	.99	2.34	.95	.41
35	1.74	.43	.19	1.00	.11	.05				16.32	98.16	42.54	9.08	23.56	10.21	6.56	10.70	4.64	3.91	3.03	1.31	2.73	1.26	.55
40	1.99	.54	.23	1.14	.14	.06							10.37	30.17	13.07	7.50	13.71	5.94	4.46	3.88	1.68	3.12	1.62	.70
45	2.24	.68	.29	1.28	.17	.07							11.67	37.53	16.26	8.44	17.05	7.39	5.02	4.38	2.09	3.50	2.01	.87
50	2.49	.82	.36	1.42	.21	.09							12.97	45.62	19.77	9.37	20.72	8.98	5.58	5.87	2.54	3.89	2.45	1.06
60	2.99	1.15	.50	1.71	.30	.13							15.56	69.94	27.71	11.25	29.04	12.58	6.07	8.22	3.56	4.67	3.43	1.49
70	3.49	1.54	.67	1.99	.39	.17		6" Pipe								13.12	38.64	16.74	7.81	10.94	4.74	5.45	4.56	1.98
75	3.73	1.74	.75	2.14	.45	.20										14.06	43.90	19.02	8.37	12.43	5.39	5.84	5.18	2.24
80	3.98	1.97	.85	2.28	.51	.22	1.00	.07	.03							15.00	49.48	21.44	8.93	14.01	6.07	6.23	5.84	2.53
90	4.48	2.45	1.06	2.56	.63	.27	1.13	.63	.27							16.87	61.54	26.67	10.05	17.42	7.55	7.01	7.26	3.15
100	4.98	2.97	1.29	2.85	.76	.33	1.25	.10	.04		8" Pipe								11.16	21.18	9.18	7.79	8.83	3.83
125	6.22	4.49	1.95	3.56	1.16	.50	1.57	.16	.07										13.95	32.02	13.88	9.74	13.34	5.78
150	7.47	6.30	2.73	4.27	1.62	.70	1.88	.22	.10	1.07	.06	.03							16.74	44.88	19.45	11.68	18.70	8.10
175	8.71	8.38	3.63	4.99	2.16	.94	2.19	.29	.13	1.25	.07	.03		10" Pipe								13.63	24.88	10.78
200	9.96	10.73	4.65	5.70	2.76	1.20	2.51	.37	.16	1.43	.10	.04										15.58	31.86	13.81
250	12.45	16.22	7.03	7.12	4.17	1.81	3.13	.57	.25	1.78	.14	.06	1.13	.05	.02		12" Pipe							
300	14.94	22.74	9.85	8.55	5.85	2.54	3.76	.79	.34	2.14	.20	.09	1.36	.07	.03									
350	17.43	30.25	13.11	9.97	7.78	3.37	4.39	1.05	.46	2.50	.27	.12	1.59	.09	.04	1.12	.04	.02						
400				11.40	9.96	4.32	5.01	1.35	.59	2.85	.34	.15	1.81	.11	.05	1.28	.05	.02						
450				12.85	12.39	5.37	5.64	1.68	.73	3.21	.43	.19	2.04	.14	.06	1.44	.06	.03						
500				14.25	15.06	6.53	6.27	2.04	.88	3.57	.52	.23	2.27	.17	.07	1.60	.07	.03						
750				21.37	31.92	13.83	9.40	4.33	1.88	5.35	1.10	.48	3.40	.36	.16	2.40	.16	.07						
1000							12.53	7.37	3.19	7.14	1.87	.81	4.53	.62	.27	3.20	.27	.12						
1250							15.67	11.14	4.83	8.92	2.83	1.23	5.67	.94	.41	4.00	.40	.17						
1500										10.71	3.97	1.72	6.80	1.32	.57	4.81	.57	.25						
2000										14.27	6.76	2.93	9.07	2.24	.97	6.41	.96	.42						
2500										17.84	10.23	4.43	11.33	3.39	1.47	8.01	1.46	.63						
3000													13.60	4.74	2.06	9.45	1.96	.85						
3500													15.86	6.23	2.74	11.03	2.61	1.13						
4000																12.60	3.34	1.45						

Temperature Rating of Fabco Products

Since the strength of plastic pipe is sensitive to temperature, the identical test method is used to determine the material strength at elevated temperature levels. The correction factor for each temperature is the ratio of strength at that temperature level to the basic strength at 73° F. Because the hoop stress is directly proportional to the internal pressure, which created that pipe stress, the correction factors may be used for the temperature correction of pressure as well as stress. For pipe and fitting applications above 73° F, refer to the table below for the Temperature Correction Factors. To determine the maximum non-shock pressure rating at an elevated temperature, simply multiply the base pressure rating obtained from the table in the preceding column by the correction factor from the table below. The allowable pressure will be the same as the base pressure for all temperatures below 73° F.

TEMPERATURE CORRECTION FACTORS

OPERATING TEMPERATURE (ºF)	FACTORS			
	PVC	CPVC	PP	PVDF
70	1.00	1.00	1.00	1.00
80	0.90	0.96	0.97	0.95
90	0.75	0.92	0.91	0.87
100	0.62	0.85	0.85	0.80
110	0.50	0.77	0.80	0.75
115	0.45	0.74	0.77	0.71
120	0.40	0.70	0.75	0.68
125	0.35	0.66	0.71	0.66
130	0.30	0.62	0.68	0.62
140	0.22	0.55	0.65	0.58
150	N.R.	0.47	0.57	0.52
160	N.R.	0.40	0.50	0.49
170	N.R.	0.32	0.26	0.45
180	N.R.	0.25	*	0.42
200	N.R.	0.18	N.R.	0.36
210	N.R.	0.15	N.R.	0.33
240	N.R.	N.R.	N.R.	0.25
280	N.R.	N.R.	N.R.	0.18

** Recommended for intermittent drainage pressure not exceeding 20 psi.*
N.R. = Not Recommended.

Pressure Rating of Fabco Products

The pressure carrying capability of any pipe at a given temperature is a function of the material strength from which the pipe is made and the geometry of the pipe as defined by its diameter and wall thickness. The following expression, commonly known as the ISO equation, is used in thermoplastic pipe specifications to relate these factors:

$$P = 2S / (Do/t - 1)$$

where: P = maximum pressure rating, psi
S = maximum hydraulic design stress (max. working strength), psi
Do = average outside pipe diameter, in.
t = minimum wall thickness, in.

The allowable design stress, which is the tensile stress in the hoop direction of the pipe, is derived for each material in accordance with ASTM D 2837, Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials, at 73° F. The pressure ratings below were calculated from the basic Hydraulic Design Stress for each of the materials.

Pipe and Fittings

In order to determine the pressure rating for a product system, first find the plastic material and schedule of pipe and fittings in the heading of the Maximum Non-Shock Operating Pressure table below. Then, locate the selected joining method in the subheading of the table and go down the column to the value across from a particular pipe size, listed in the far left column. This will be the maximum non-shock operating pressure at 73° F for the defined product system.

MAX. NON-SHOCK OPERATING PRESSURE (PSI) AT 73ºF

	SCHEDULE 40 PVC & CPVC	SCHEDULE 80 PVC & CPVC	
NOM. PIPE SIZE	SOCKET END	SOCKET END	THREADED END
1/2	600	850	420
3/4	480	690	340
1	450	630	320
1 1/4	370	520	260
1 1/2	330	470	240
2	280	400	200
2 1/2	300	420	210
3	260	370	190
4	220	320	160
6	180	280	N.R.
8	160	250	N.R.
10	140	230	N.R.
12	130	230	N.R.

	SCHEDULE 80 POLYPROPYLENE		SCHEDULE 80 PVDF	
NOM. PIPE SIZE	THERMO SEAL JOINT	THREADED	THERMO SEAL JOINT	THREADED
1/2	410	20	580	290
3/4	330	20	470	230
1	310	20	430	210
1 1/4	260	20	—	—
1 1/2	230	20	326	160
2	200	20	270	140
2 1/2	—	—	—	—
3	190	20	250	N.R.
4	160	20	220	N.R
6	140	N.R.	190	N.R.

N.R. = Not Recommended.

1. For more severe service, an additional correction factor may be required.
2. 8" CPVC Tee, 90° ELL and 45° ELL rated at 1/2 of value shown. Pressure rating of 175 psi can be obtained by factory overwrapping with glass and polyester. Consult Customer Service for delivery information.
3. Recommended for intermittent drainage pressure not exceeding 20 psi.

Valves, Unions, and Flanges

The maximum pressure rating for valves, flanges, and unions, regardless of size, is 150 psi at 73° F. As with all other thermoplastic piping components, the maximum non-shock operating pressure is related to temperature. Above 100° F refer to the chart below.

MAXIMUM NON-SHOCK OPERATING PRESSURE (PSI) VS. TEMPERATURE

TEMPERATURE (° F)	PVC	CPVC	PP	PVDF
100	150	150	150	150
110	135	140	140	150
120	110	130	130	150
130	75	120	118	150
140	50	110	105	150
150	N.R.	100	93	140
160	N.R.	90	80	133
170	N.R.	80	70	125
180	N.R.	70	50	115
190	N.R.	60	N.R.	106
200	N.R.	50	N.R.	97
250	N.R.	N.R.	N.R.	50
280	N.R.	N.R.	N.R.	25

N.R. = Not Recommended.

Fabco Products in Vacuum or Collapse Loading Situations

Thermoplastic pipe is often used in applications where the pressure on the outside of the pipe exceeds the pressure inside. Suction or vacuum lines and buried pipe are examples of this type of service. As a matter of practical application, gauges indicate the pressure differential above or below atmospheric pressure. However, scientists and engineers frequently express pressure on an absolute scale where zero equals a theoretically perfect vacuum and standard atmospheric pressure equals 14.6959 psia.

Solvent cemented or thermo-sealed joints are particularly recommended for vacuum service. In PVC, CPVC, PP, or PVDF vacuum systems, mechanical devices such as valves and transition joints at equipment will generally represent a greater intrusion problem than the thermoplastic piping system will. Experience indicates that PVC vacuum systems can be evacuated to pressures as low as 5 microns with continuous pumping. However, when the system is shut off, the pressure will rise and stabilize around 10,000 microns or approximately 10 mm of Mercury at 73° F. The following chart lists the allowable collapse loading for plastic pipe at 73° F. It shows how much greater the external pressure may be than the internal pressure. (Thus, a pipe with 100 psi internal pressure can withstand 100 psi more external pressure than a pipe with zero psi internal pressure.) For temperatures other than 73° F, multiply the values in the chart by the correction factors listed in the temperature correction table on the preceding page. The chart also applies to a vacuum. The external pressure is generally atmospheric pressure, or 0.0 psig, while the internal pressure is normally identified as a vacuum or negative gauge pressure. However, this negative value will never exceed −14.7 psig. Therefore, if the allowable pressure listed in the chart (after temperature correction) is greater than the difference for internal-to-external pressure, the plastic system is viable.

PIPE SIZE	SCH. 40 PVC	SCH. 80 PVC	SCH. 80 CPVC	SCH. 80 PP	SCH. 80 PVDF
1/2	450	575	575	230	391
3/4	285	499	499	200	339
1	245	469	469	188	319
1 1/4	160	340	340	136	—
1 1/2	120	270	270	108	183
2	75	190	190	76	129
2 1/2	100	220	220	—	—
3	70	155	155	62	105
4	45	115	115	46	78
6	25	80	80	32	54
8	16	50	50	—	—
10	12	43	—	—	—
12	9	39	—	—	—

Pressure Losses in a Piping System

Piping Calculations

As a fluid flows through a piping system, it will experience a headloss depending on, among other factors, fluid velocity, pipe wall smoothness and internal pipe surface area. The Tables on pages 9 and 10 give Friction Loss and Velocity data for Schedule 40 and Schedule 80 thermoplastic pipe based on the Williams and Hazen formula.

$$H=0.2083 \times (100/C)1.852 \times (q1.852/d4.8655)$$

Where: H = Friction Head Loss in Feet of Water/100 Feet of Pipe

C = Surface Roughness Constant (150 for all thermoplastic pipe)

q = Fluid Flow (gallons/min.)

d = Inside Diameter of Pipe

Fittings and valves, due to their more complex configurations, contribute significant friction losses in a piping system. A common method of expressing the losses experienced in fittings is to relate them to pipe in terms of equivalent pipe length. This is the length of pipe required to give the same friction loss as a fitting of the same size. Tables are available for the tabulation of the equivalent pipe length in feet for the various sizes of a number of common fittings. By using this Table and the Friction Loss Tables, the total friction loss in a plastic piping system can be calculated for any fluid velocity.

For example, suppose we wanted to determine the pressure loss across a 2" Schedule 40, 90° elbow, at 75 gpm. From the lower table we find the equivalent length of a 2" 90° elbow to be 5.5 feet of pipe. From the Schedule 40 Pipe Table we find the friction loss to be 3.87 psi per 100 feet of pipe when the flow rate is 75 gpm. Therefore, the solution is as follows:

5.5 Feet/90° Elbow x 3.87 psi/100 Feet
= 0.21 psi Pressure Drop/90° Elbow

which is the pressure drop across a 2" Schedule 40 elbow. But, what if it were a 2" Schedule 80 elbow, and we wanted to know the friction head loss? The solution is similar, except we look for the friction head in the Schedule 80 Pipe Table and find it to be 12.43 feet per 100 feet of pipe when the flow rate is 75 gpm. The solution follows:

5.5 Feet/90° Elbow x 12.43 Feet/100 Feet
= 0.68 Feet Friction Head/90° Elbow

which is the friction head loss across a 2" Schedule 80 elbow.

For a copy of the tables mentioned in this section, please contact customer service.

Valve Calculations

As an aid to system design, liquid sizing constants (Cv values) are shown for valves where applicable. These values are defined as the flow rate through the valve required to produce a pressure drop of 1 psi. To determine the pressure drop for a given condition the following formula may be used:

$$P=(Q^2 S.G.)/(Cv^2)$$

Where: P = Pressure drop across the valve in psi

Q = Flow through the valve in gpm

S.G. = Specific gravity of the liquid (Water=1.0)

Cv = Flow coefficient

See the solution of the following example problem. For Cv values for specific valves, contact customer service or consult the manufacturers catalog.

EXAMPLE:

Find the pressure drop across a 1 1/2" PVC ball check valve with a water flow rate of 50 gpm. The Cv is 56.

$P=(50^2 \times 1.0)/56^2$

$P=(50/56)^2$

$P=0.797$ psi

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 highspeed 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.

Proper design when laying out a piping system will limit 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. (Flow is normally expressed in GALLONS PER MINUTE—GPM. To determine the fluid velocity in any segment of piping the following formula may be used:

$$V=(0.4085xGPM)/Di2$$

Where: v = fluid velocity in feet per second

Di = inside diameter

GPM = rate of flow in gallons per minute

Flow Capacity Tables are available for the fluid velocities resulting from specific flow rates in Schedule 40 and Schedule 80 pipes. The upper threshold rate of flow for any pipe may be determined by substituting 5 ft./sec. Fluid velocity in the above formula and solving for GPM. Upper Threshold Rate of Flow (GPM) = 12.24 Di2

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 air-to-air and air-to-spring actuators, it will probably be necessary to place a flow control valve in the air line to slow down the valve operation cycle, particularly on valve sizes greater than 1 1/2".
3. If possible, when starting a pump, partially close the valve in the discharge line to minimize the volume of liquid that 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. Before initial start-up the discharge line should be vented of all air. Air trapped in the piping will substantially reduce the capability of plastic pipe withstanding shock loading.

Shock Surge Wave

Providing all air is removed from an affected system, a formula based on theory may closely predict hydraulic shock effect.

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: c = 24.2 v = 3.35

p = (3.35) (26.6) = 90 psi

Total line pressure = 90 + 160 = 250 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.

SURGE WAVE CONSTANT(C)

PIPE	PVC		CPVC		PP	PVDF
	SCH.40	SCH.80	SCH.40	SCH.80	SCH.80	SCH.80
1/4	31.3	34.7	33.2	37.3	—	—
3/8	29.3	32.7	31.0	34.7	—	—
1/2	28.7	31.7	30.3	33.7	25.9	28.3
3/4	26.3	29.8	27.8	31.6	23.1	25.2
1	25.7	29.2	27.0	30.7	21.7	24.0
1 1/4	23.2	27.0	24.5	28.6	19.8	—
1 1/2	22.0	25.8	23.2	27.3	18.8	20.6
2	20.2	24.2	21.3	25.3	17.3	19.0
2 1/2	21.1	24.7	22.2	26.0	—	—
3	19.5	23.2	20.6	24.5	16.6	18.3
4	17.8	21.8	18.8	22.9	15.4	17.0
6	15.7	20.2	16.8	21.3	14.2	15.8
8	14.8	18.8	15.8	19.8		
10	14.0	18.3	15.1	19.3		
12	13.7	18.0	14.7	19.2		
14	13.4	17.9	14.4	19.2		

CAUTION: The removal of all air from the system in order for the surge wave analysis method to be valid was pointed out at the beginning of this segment. However, this can be easier said than done. Over reliance on this method of analysis is not encouraged. Our experience suggests that the best approach to assure a successful installation is for the design to focus on strategic placements of air vents and the maintenance of fluid velocity near or below the threshold limit of 5 ft./sec.

Expansion and Thermal Contraction of Plastic Pipe

Calculating Dimensional Change

All materials undergo dimensional change as a result of temperature variation above or below the installation temperature. The extent of expansion or contraction is dependent upon the coefficient of linear expansion for the piping material. These coefficients are listed below for the essential industrial plastic piping materials in the more conventional form of inches of dimensional change, per ° F of temperature change, per inch of length. They are also presented in a more convenient form to use. Namely, the units are inches of dimensional change, per 10° F temperature change, per 100 feet of pipe.

EXPANSION COEFFICIENT

MATERIAL	C(IN/IN/°Fx10^{-5})	Y(IN/10°F/100 FT)
PVC	3.0	.360
CPVC	3.8	.456
PP	5.0	.600
PVDF	7.9	.948

The formula for calculating thermally induced dimensional change, utilizing the convenient coefficient (Y), is dependent upon the temperature change to which the system may be exposed – between the installation temperature and the greater differential to maximum or minimum temperature – as well as, the length of pipe run between directional changes or anchors points.

Also, a handy chart is presented below, which approximates the dimensional change based on temperature change vs. pipe length.

L=Yx(T1-T2)/10 X L/100

L = Dimensional change due to thermal expansion or contraction(in)
Y = Expansion coefficient (See table above) (in/10°/100 ft)
(T1-T2) = Temperature differential between the installation temperature and the maximum or minimum system temperature, whichever provides the greatest differential (° F).
L = Length of pipe run between changes in direction (ft.)

EXAMPLE 1:

How much expansion can be expected in a 200 foot straight run of 3 inch PVC pipe that will be installed at 75° F when the piping system will be operated at a maximum of 120° F and a minimum of 40° F?

L=(120-75)/10x200/100=0.360x4.50x2.0=3.24 in.

TEMP	LENGTH OF PIPE TO CLOSEST ANCHOR POINT (FT.)									
T(°F)	10'	20'	30'	40'	50'	60'	70'	80'	90'	100'
10°	0.04	0.07	0.11	0.14	0.18	0.22	0.25	0.29	0.32	0.36
20°	0.07	0.14	0.22	0.29	0.36	0.43	0.50	0.58	0.65	0.72
30°	0.11	0.22	0.32	0.43	0.54	0.65	0.76	0.86	0.97	1.08
40°	0.14	0.29	0.43	0.58	0.72	0.86	1.00	1.15	1.30	1.44
50°	0.18	0.36	0.54	0.72	0.90	1.08	1.26	1.44	1.62	1.80
60°	0.22	0.43	0.65	0.86	1.08	1.30	1.51	1.73	1.94	2.16
70°	0.25	0.50	0.76	1.01	1.26	1.51	1.76	2.02	2.27	2.52
80°	0.29	0.58	0.86	1.15	1.44	1.73	2.02	2.30	2.59	2.88
90°	0.32	0.65	0.97	1.30	1.62	1.94	2.27	2.59	2.92	3.24
100°	0.36	0.72	1.08	1.44	1.80	2.16	2.52	2.88	3.24	3.60
110°	0.40	0.79	1.19	1.58	1.98	2.38	2.77	3.17	3.56	3.96
120°	0.43	0.86	1.30	1.73	2.16	2.59	3.02	3.46	3.89	4.32

Note: Temperature change (T) from installation to the greater of maximum or minimum limits.

To determine the expansion or contraction for pipe of a material other than PVC, multiply the change in length given for PVC in the table above by 1.2667 for the change in CPVC, by 1.6667 for the change in PP, or by 2.6333 for the change in PVDF.

Calculating Stress

If movement resulting from thermal changes is restricted by the piping support system or the equipment to which it is attached, the resultant forces may damage the attached equipment or the pipe itself. Therefore, pipes should always be anchored independently at those attachments. If the piping system is rigidly held or restricted at both ends when no compensation has been made for thermally induced growth or shrinkage of the pipe, the resultant stress can be calculated with the following formula.

St = EC (T1-T2)
St = Stress (psi)
E = Modulus of Elasticity (psi) (See table below for specific values at various temperatures)
C = Coefficient of Expansion (in/in/ ° F x 105)
(see physical property chart on for values)
(T1-T2) = Temperature change (° F) between the installation temperature and the maximum or minimum system temperature, whichever provides the greatest differential.

MODULUS OF ELASTICITY

	73°F	90°F	100°F	140°F	180°F	210°F	250°F
PVC	4.20	3.75	3.60	2.70	N/A	N/A	N/A
CPVC	4.23	4.00	3.85	3.25	2.69	2.20	N/A
PP	1.79	1.25	1.15	.72	.50	N/A	N/A
PVDF	2.19	1.88	1.74	1.32	1.12	.81	.59

N/A - Not Applicable

The magnitude of the resulting longitudinal force can be determined by multiplying the thermally induced stress by the cross sectional area of the plastic pipe.

F = St x A
F = FORCE (lbs)
St = STRESS (psi)
A = CROSS SECTIONAL AREA (in²)

EXAMPLE 2:

What would be the amount of force developed in 2" Schedule 80 PVC pipe with the pipe rigidly held and restricted at both ends? Assume the temperature extremes are from 70° F to 100° F.

St = EC (T1 – T2)
St = EC (100 – 70)
St = (3.60 x 105) x (3.0 x 10-5) (30)
St = 324 psi

The Outside and Inside Diameters of the pipe are used for calculating the Cross Sectional Area (A) as follows: (See the Pipe Reference Table for the pipe diameters and cross sectional area for specific sizes of schedule 80 Pipes.)

$$A=\pi/4(OD^2-ID^2)=3.1416/4(2.375^2-1.913^2)$$

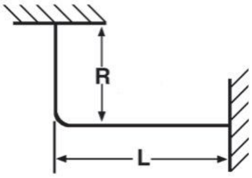
$$=1.556 \text{ in}^2$$

The force exerted by the 2" pipe, which has been restrained, is simply the compressive stress multiplied over the cross sectional area of that pipe.

F = St x A
F = 324 psi x 1.556 in.2
F = 504 lbs.

Managing Expansion/Contraction in System Design

Stresses and forces which result from thermal expansion and contraction can be reduced or eliminated by providing for flexibility in the piping system through frequent changes in direction or introduction of loops as graphically depicted on this page.



Normally, piping systems are designed with sufficient directional changes, which provide inherent flexibility, to compensate for expansion and contraction. To determine if adequate flexibility exists in leg (R) (see Fig. 1) to accommodate the expected expansion and contraction in the adjacent leg(L) use the following formula:

$$R = 2.877\sqrt{D\,L} \text{ SINGLE OFFSET FORMULA}$$

Where: R = Length of opposite leg to be flexed (ft.)
D = Actual outside diameter of pipe (in.)
L = Dimensional change in adjacent leg due to thermal expansion or contraction (in.)

Keep in mind the fact that both pipe legs will expand and contract. Therefore, the shortest leg must be selected for the adequacy test when analyzing inherent flexibility in naturally occurring offsets.

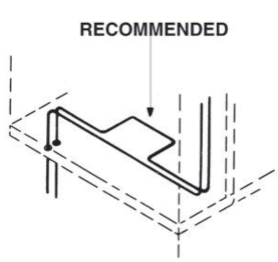
EXAMPLE 3:
What would the minimum length of a right angle leg need to be in order to compensate for the expansion if it were located at the unanchored end of the 200 ft. run of pipe in Example 1 from the previous page?

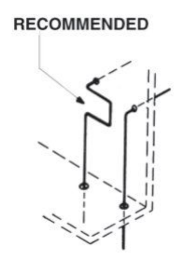
$$R = 2.877\sqrt{3.500 \times 3.24} = 9.69 \text{ ft.}$$

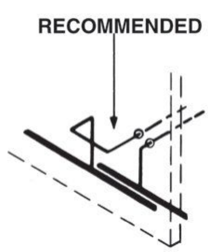
Flexibility must be designed into a piping system, through the introduction of flexural offsets, in the following situations:

1. Where straight runs of pipe are long.
2. Where the ends of a straight run are restricted from movement.
3. Where the system is restrained at branches and/or turns.

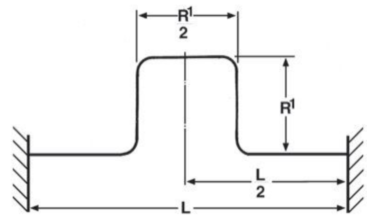
Several examples of methods for providing flexibility in these situations are graphically presented below. In each case, rigid supports or restraints should not be placed on a flexible leg of an expansion loop, offset or bend.







An expansion loop (which is fabricated with 90° elbows and straight pipe as depicted in Fig. above) is simply a double offset designed into an otherwise straight run of pipe.



The length for each of the two loop legs (R'), required to accommodate the expected expansion and contraction in the pipe run (L), may be determined by modification of the SINGLE OFFSET FORMULA to produce a LOOP FORMULA, as shown below:

$$R' = 2.041\sqrt{D\,L} \text{ LOOP FORMULA}$$

EXAMPLE 4:
How long should the expansion loop legs be in order to compensate for the expansion in Example 1 from the previous page?

$$R' = 2.041\sqrt{3.500 \times 3.24} = 6.87 \text{ ft.}$$

Minimum Cold Bending Radius

The formulae above for Single Offset and Loop bends of pipe, which are designed to accommodate expansion or contraction in the pipe, are derived from the fundamental equation for a cantilevered beam – in this case a pipe fixed at one end. A formula can be derived from the same equation for calculating the minimum cold bending radius for any thermoplastic pipe diameter.

$$RB = DO\,(0.6999\,E/SB - 0.5)$$

Where: RB = Minimum Cold Bend Radius (in.)
DO = Outside Pipe Diameter (in.)
E * = Modulus of Elasticity @ Maximum Operating Temperature (psi)
SB * = Maximum Allowable Bending Stress @ Maximum Operating Temperature (psi)

*The three formulae on this page provide for the maximum bend in pipe while the pipe operates at maximum long-term internal pressure, creating maximum allowable hydrostatic design stress (tensile stress in the hoop direction). Accordingly, the maximum allowable bending stress will be one half the basic hydraulic design stress at 73° F with correction to the maximum operating temperature. The modulus of elasticity, corrected for temperature may be found in the table in the second column of the preceding page.

EXAMPLE 5:
What would be the minimum cold radius bend, which the installer could place at the anchored end of the 200 ft. straight run of pipe in Examples 1 and 3, when the maximum operating temperature is 100° F instead of 140°F?

$$RB = 3.500\,(0.6999 \times 360{,}000/\ 1/2 \times 2000 \times 0.62 - 0.5) = 1{,}420.8 \text{ in. or } 118.4 \text{ ft}$$

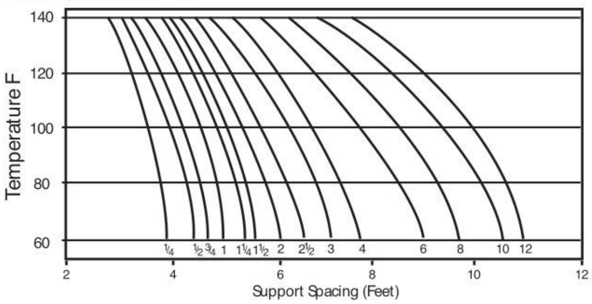
Pipe Support Spacing

Correct supporting of a piping system is essential to prevent excessive bending stress and to limit pipe "sag" to an acceptable amount. Horizontal pipe should be supported on uniform centers, which are determined for pipe size, schedule, temperature, loading and material. Point support must not be used for thermoplastic piping and, in general, the wider the bearing surface of the support the better. Supports should not be clamped in such a way that will restrain the axial movement of pipe that will normally occur due to thermal expansion and contraction. Concentrated loads in a piping system, such as valves must be separately supported.

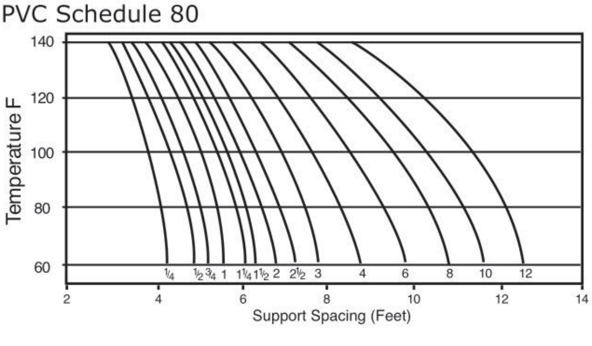
The graphs on this page give recommended support spacing for Chemtrol thermoplastic piping materials at various temperatures. The data is based on fluids with a specific gravity of 1.0 and permits a sag of less than 0.1" between supports. For heavier fluids, the support spacing from the graphs should be multiplied by the correct factor in the table below.

SPECIFIC GRAVITY	1.0	1.1	1.2	1.4	1.6	2.0	2.5
CORRECTION FACTOR	1.0	.98	.96	.93	.90	.85	.80

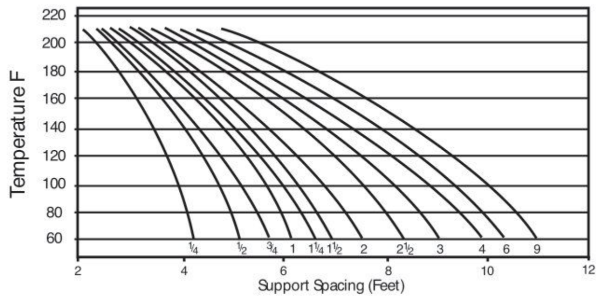
PVC Schedule 40



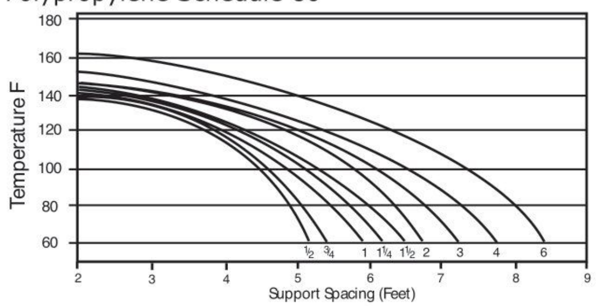
PVC Schedule 80



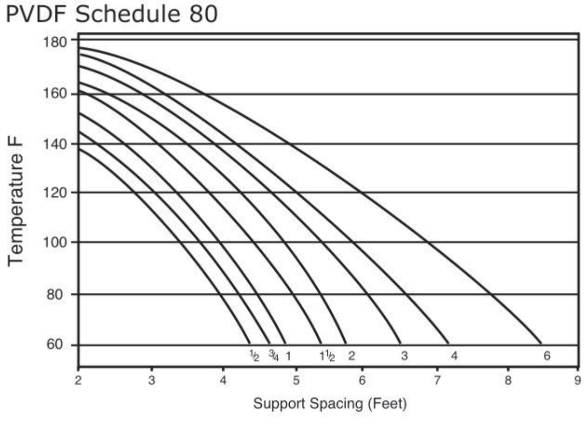
CPVC Schedule 80



Polypropylene Schedule 80



PVDF Schedule 80



The above data is for uninsulated lines. For insulated lines, reduce spans to 70% of graph values. For spans of less than 2 feet, continuous support should be used.