# SYSTEMS ENGINEERING DATA FOR THERMOPLASTIC PIPING

## INTRODUCTION

In the engineering of thermoplastic piping systems, it is necessary to have not only a working knowledge of piping design but also an awareness of a number of the unique properties of thermoplastics.

In addition to chemical resistance, important factors to be considered in designing piping systems employing thermoplastics are:

1. Pressure ratings.
2. Water hammer.
3. Temperature-Pressure relationships.
4. Friction-loss characteristics.
5. Dimensional and Weight data.

These factors are considered in detail in this section.

## PRESSURE RATINGS OF THERMOPLASTICS

### DETERMINING PRESSURE-STRESS-PIPE RELATIONSHIPS

### ISO EQUATION

Circumferential stress is the largest stress present in any pressurized piping system. It is this factor that determines the pressure that a section of pipe can withstand. The relation-ship of stress, pressure and pipe dimensions is described by the ISO (for International Standardization Organization) Equation. In various forms this equation is:

$$P = \frac{2S}{R-1} = \frac{2St}{D_0 - t} \qquad \frac{2S}{P} = \left(\frac{D_0}{t}\right) - 1$$

$$\frac{2S}{P} = R - 1 \qquad S = \frac{P(R-1)}{2}$$

**Where:**

P = Internal Pressure, psi
S = Circumferential Stress, psi
t = Wall thickness, in.
$D_0$ = Outside Pipe diameter, in.
R = $D_0/t$

### LONG-TERM STRENGTH

To determine the long-term strength of thermoplastic pipe, lengths of pipe are capped at both ends (see Figure 1) and subjected to various internal pressures, to produce circumferential stresses that will produce failure in from 10 to 10,000 hours. The test is run according to ASTMD 1598 — Standard Test for Time-to-Failure of Plastic Pipe Under Long-Term Hydrostatic Pressure.

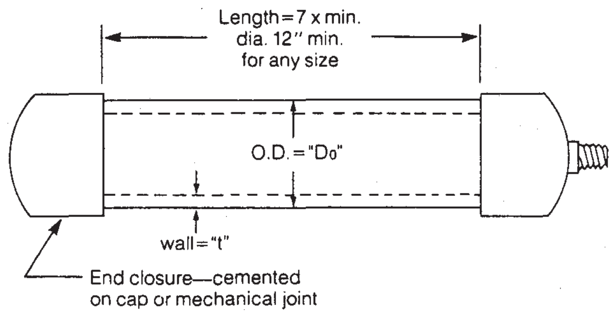
The resulting failure points are used in a statistical analysis (outlined in ASTM D-2837; see page 6 to determine the characteristic regression curve that represents the stress/ time-to-failure relationship for the particular thermoplastic pipe compound under test. This curve is represented by the equation: Log = a + b log S

**Where:**

a and b are constants describing the slope and intercept of the curve, and T and S are time-to-failure and stress, respectively.

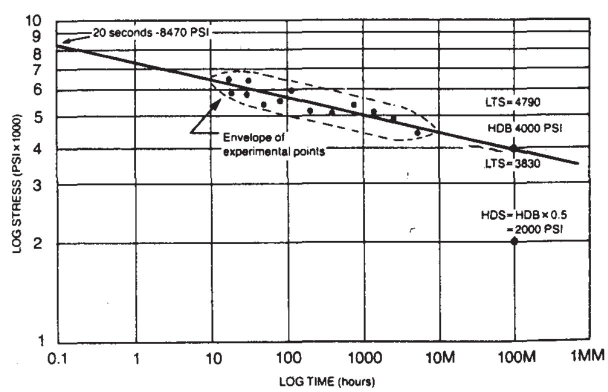
The regression curve may be plotted on a log-log paper, as shown in Figure 2, and extrapolated from 10,000 to 100,000 hours (11.4 years). The stress at 100,000 hours is known as the Long Term Hydrostatic Strength (LTHS) for that particular thermoplastic compound. From this (LTHS) the Hydrostatic Design Stress (HDS) is determined by applying the service factor multiplier, as described below.

### FIGURE 1
**LONG-TERM STRENGTH TEST PER ASTM D1 598**




Pipe test specimen per ASTM D 1598 for "Time-to-Failure of Plastic Pipe Under Long-Term Hydrostatic Pressure"

### FIGURE 2
**REGRESSION CURVE—STRESS/TIME-TO-FAILURE FOR PVC TYPE I**




### SERVICE FACTOR

The Plastics Pipe Institute (PPI) has determined that a service (design) factor of one-half the Hydrostatic Design Basis would provide an adequate safety margin for use with water to ensure useful plastic-pipe service for a long period of time. While not stated in the standards, it is generally understood within the industry that this "long period of time" is minimum of 50 years.

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Accordingly, the standards for plastic pipe, using the 0.5 service factor, required that the pressure rating of the pipe be based upon this Hydrostatic Design Stress, again calculated with the ISO equation.

While early experience indicated that this service factor, or multiplier, of 0.5 provided adequate safety for many if not most uses, some experts felt that a more conservative service factor of 0.4 would better compensate for water hammer pressure surges, as well as for slight manufacturing variations and damage suffered during installation.

The PPI has issued a policy statement officially recommending this 0.4 service factor. This is equivalent to recommending that the pressure rating of the pipe should equal 1.25 times the system design pressure for any particular installation. Based upon this policy, many thousands of miles of thermoplastic pipe have been installed in the United States without failure.

It is best to consider the actual surge conditions, as outlined later in this section. In addition, substantial reductions in working pressure are advisable when handling aggressive chemical solutions and in high-temperature service.

Numerical relationships for service factors and design stresses of PVC are shown in Table I-A below.

**SERVICE FACTORS AND HYDROSTATIC DESIGN STRESS (HDS)***

| SERVICE FACTOR | HDS |
|---|---|
| 0.5 | 2000 psi (13.8 MPa) |
| 0.4 | 1600 psi (11 MPa) |

*Material: PVC Type 1 & CPVC

## TEMPERATURE-PRESSURE AND MODULUS RELATIONSHIPS

**Temperature Derating.**

Pressure ratings for thermoplastic pipe are generally deter-mined in a water medium at room temperature (73°F). As the system temperature increases, the thermoplastic pipe becomes more ductile, increases in impact strength and decreases in tensile strength. The pressure ratings of thermoplastic pipe must therefore be decreased accordingly.

The effects of temperature have been exhaustively studied and correction (derating) factors developed for each thermoplastic piping compound. To determine the maximum operating pressure at any given temperature, multiply the pressure rating at ambient shown in Table 1by the temperature correction factor for that material shown in Table 2. Attention must also be given to the pressure rating of the joining technique i.e. Threaded system normally reduces pressure capabilities, substantially.

### TABLE 1

**MAXIMUM OPERATING PRESSURES (PSI) AT 73°F AMBIENT**
**BASED UPON A SERVICE FACTOR OF .5**

| NOMINAL SIZE | PVC & CPVC SCHEDULE 40 SOLVENT WELD | PVC & CPVC SCHEDULE 80 | | POLYPROPYLENE*(PP) | | | POLYVINYLIDENE FLUORIDE (PVDF) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | PROLINE SDR | | SUPER PROLINE SDR | | SCHEDULE 80 | |
| | | SOLVENT WELD | THREADED | PPRO-SEAL | 11 | 32 | 11 | 32 | SOCKET FUSION | THREADED |
| 1/4 | 780 | 1130 | — | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 3/8 | 620 | 920 | — | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 1/2 | 600 | 850 | 420 | 150 | 160 | 45 | 230 | N/A | 975 | 290 |
| 3/4 | 480 | 690 | 340 | 150 | 160 | 45 | 230 | N/A | 790 | 235 |
| 1 | 450 | 630 | 320 | 150 | 160 | 45 | 230 | N/A | 725 | 215 |
| 1-1/4 | 370 | 520 | 260 | N/A | 160 | 45 | 230 | N/A | 600 | 180 |
| 1-1/2 | 330 | 471 | 240 | 150 | 160 | 45 | 230 | N/A | 540 | 160 |
| 2 | 280 | 400 | 200 | 150 | 160 | 45 | 230 | N/A | 465 | 135 |
| 2-1/2 | 300 | 425 | 210** | N/A | 160 | 45 | N/A | 160 | N/A | N/R |
| 3 | 260 | 375 | 190** | N/A | 160 | 45 | N/A | 160 | 430 | N/R |
| 4 | 220 | 324 | 160** | N/A | 160 | 45 | N/A | 160 | 370 | N/R |
| 6 | 180 | 280 | N/R | N/A | 160 | 45 | N/A | 160 | N/A | N/R |
| 8 | 160 | 250 | N/R | N/A | 160 | 45 | N/A | 160 | N/A | N/A |
| 10 | 140 | 230 | N/R | N/A | 160 | 45 | N/A | 160 | N/A | N/A |
| 12 | 130 | 230 | N/R | N/A | 160 | 45 | N/A | 160 | N/A | N/A |

— = Data not available at printing; N/R = Not Recommended; N/A = Not Available (not manufactured)
* Threaded Polypropylene is not recommended for pressure applications and Fuseal drainage systems are not pressure rated.
**For threaded joints properly backwelded.
NOTE: The pressure ratings in this chart are based on water and are for pipe and fittings only. Systems that include valves, flanges, or other weaker items will require derating the entire system.

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**Table 2**

**TEMPERATURE CORRECTION FACTORS**

| OPERATING TEMPERATURES °F | FACTORS | | | | | |
|---|---|---|---|---|---|---|
| | | | POLYPROPYLENE | | POLYVINYLIDENE FLUORIDE | |
| | PVC | CPVC | PPRO-SEAL NATURAL | PROLINE | SUPER PROLINE | SCHEDULE 80 |
| 73 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 80 | .88 | .94 | .93 | | .95 | .93 |
| 90 | .75 | .86 | .83 | | .87 | .87 |
| 100 | .62 | .78 | .74 | .64 | .80 | .82 |
| 110 | .50 | .71 | .66 | | | .76 |
| 120 | .40 | .64 | .58 | | .68 | .71 |
| 130 | .30 | .57 | .51 | | | .65 |
| 140 | .22 | .50 | .40 | .40 | .58 | .61 |
| 150 | N/R | .43 | .38 | | | .57 |
| 160 | N/R | .37 | .35 | | .49 | .54 |
| 180 | N/R | .25 | .23 | .28 | .42 | .47 |
| 200 | N/R | .18 | .14 | .10 | .36 | .41 |
| 210 | N/R | .16 | .10 | N/R | | .38 |
| 220 | N/R | N/R | N/R | N/R | | .35 |
| 240 | N/R | N/R | N/R | N/R | .25 | |
| 250 | N/R | N/R | N/R | N/R | | .28 |
| 280 | N/R | N/R | N/R | N/R | .18 | .22 |

## FLANGED SYSTEMS

**FLANGED SYSTEMS**
Maximum pressure for any flanged system is 150 psi. At elevated temperatures the pressure capability of a flanged system must be derated as shown in Table 12.

Design Pressure - Pressure rating at 73°F x temperature correction factor.

**Table 3 - MAXIMUM OPERATING PRESSURE (PSI) FOR FLANGED SYSTEMS**

| OPERATING TEMPERATURE °F | PVC* | CPVC* | PP** | PVDF |
|---|---|---|---|---|
| 100 | 150 | 150 | 150 | 150 |
| 110 | 135 | 145 | 140 | 150 |
| 120 | 110 | 135 | 130 | 150 |
| 130 | 75 | 125 | 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 |
| 210 | N/R | 40 | N/R | 90 |
| 240 | N/R | N/R | N/R | 60 |
| 280 | N/R | N/R | N/R | 25 |

N/R = Not Recommended

* PVC and CPVC flanges sizes 2-1/2 through 3-/and 4-inch threaded must be backwelded for the above pressure capability to be applicable.

** Threaded PP flanges size 1/2 through 4 inch as well as the 6" back welded socket flange are not recommended for pressure applications (drainage only).



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# PRESSURE RATINGS

## PVC LARGE DIAMETER FABRICATED FITTINGS AT 73°F 10" THROUGH 24"

The following tables indicate the working pressure recommended by the manufacturer for large diameter PVC fabricated fittings. These fittings are not generally recommended for high pressure applications. Pressure capabilities are not necessarily the same as the rating of the pipe from which they are fabricated. Be sure pressure to temperature correction factors are considered when system design calls for temperatures above 73°F.

Water hammer and surge pressure are the two most critical elements in large-diameter design. Keeping velocities below 5 feet per second and working pressures to these guidelines will give years of trouble-free service.

### Table 4

**90° ELBOW**

| NOMINAL SIZE (IN.) | SCHEDULE 40 | | SCHEDULE 80 | |
|---|---|---|---|---|
| | WT. (LBS.) | PSI RTG | WT. (LBS.) | PSI RTG |
| 10 | 22 | 140 | 34 | 230 |
| 12 | 30 | 130 | 50 | 230 |
| 14 | 40 | 130 | 70 | 220 |
| 16 | 56 | 130 | 100 | 220 |
| 18 | 90 | 100 | 93 | 125 |
| 20 | 121 | 50 | 125 | 75 |
| 24 | 202 | 50 | 208 | 75 |

### Table 5

**COUPLING**

| NOMINAL SIZE (IN.) | SCHEDULE 40 | | SCHEDULE 80 | |
|---|---|---|---|---|
| | WT. (LBS.) | PSI RTG | WT. (LBS.) | PSI RTG |
| 10 | 9 | 140 | 15 | 230 |
| 12 | 15 | 130 | 23 | 230 |
| 14 | 19 | 130 | 33 | 220 |
| 16 | 29 | 130 | 54 | 220 |
| 18 | 33 | 100 | 53 | 160 |
| 20 | 45 | 50 | 74 | 75 |
| 24 | 77 | 50 | 110 | 75 |

### Table 6

**TEE**

| NOMINAL SIZE (IN.) | SCHEDULE 40 | | SCHEDULE 80 | |
|---|---|---|---|---|
| | WT. (LBS.) | PSI RTG | WT. (LBS.) | PSI RTG |
| 10 | 28 | 140 | 44 | 230 |
| 12 | 41 | 130 | 69 | 230 |
| 14 | 54 | 130 | 95 | 220 |
| 16 | 78 | 130 | 139 | 220 |
| 18 | 115 | 100 | 156 | 160 |
| 20 | 153 | 50 | 204 | 75 |
| 24 | 231 | 50 | 338 | 75 |

### Table 7

**45° ELBOW**

| NOMINAL SIZE (IN.) | SCHEDULE 40 | | SCHEDULE 80 | |
|---|---|---|---|---|
| | WT. (LBS.) | PSI RTG | WT. (LBS.) | PSI RTG |
| 10 | 15 | 140 | 24 | 230 |
| 12 | 21 | 130 | 36 | 230 |
| 14 | 30 | 130 | 52 | 220 |
| 16 | 42 | 130 | 75 | 220 |
| 18 | 47 | 100 | 71 | 160 |
| 20 | 62 | 50 | 95 | 75 |
| 24 | 103 | 50 | 159 | 75 |

### Table 8

**REDUCING TEE**

| NOMINAL SIZE (IN.) | SCHEDULE 40 | | SCHEDULE 80 | |
|---|---|---|---|---|
| | WT. (LBS.) | PSI RTG | WT. (LBS.) | PSI RTG |
| 10 x 8 | 23 | 140 | 32 | 230 |
| 10 x 6 | 21 | 140 | 30 | 230 |
| 10 x 4 | 18 | 140 | 28 | 230 |
| 12 x 10 | 32 | 130 | 55 | 220 |
| 12 x 8 | 30 | 130 | 49 | 220 |
| 12 x 6 | 26 | 130 | 47 | 220 |
| 12 x 4 | 24 | 130 | 45 | 220 |
| 14 x 12 | 46 | 100 | 70 | 160 |
| 14 x 10 | 39 | 100 | 66 | 160 |
| 14 x 8 | 36 | 100 | 59 | 160 |
| 16 x 14 | 68 | 100 | 118 | 160 |
| 16 x 12 | 61 | 100 | 105 | 160 |
| 16 x 10 | 54 | 100 | 90 | 160 |
| 16 x 8 | 49 | 100 | 82 | 160 |
| 18 x 16 | 82 | 100 | 132 | 160 |
| 18 x 14 | 73 | 100 | 116 | 160 |
| 20 x 18 | 104 | 75 | 160 | 100 |
| 20 x 16 | 98 | 75 | 156 | 100 |
| 24 x 20 | 162 | 50 | 251 | 75 |

# PRESSURE RATINGS

## PVC LARGE DIAMETER FABRICATED FITTINGS
## AT 73°F 10" THROUGH 24"

### Table 9
CONCENTRIC REDUCER

| NOMINAL SIZE (IN.) | SCHEDULE 40 | |
|---|---|---|
| | WT. (LBS.) | PSI RTG |
| 10 x 8 | 9 | 140 |
| 10 x 6 | 22 | 140 |
| 10 x 4 | 23 | 140 |
| 12 x 10 | 15 | 130 |
| 12 x 8 | 31 | 130 |
| 12 x 6 | 34 | 130 |
| 14 x1 2 | 23 | 130 |
| 14 x 10 | 36 | 130 |
| 16 x 14 | 32 | 130 |
| 16 x 12 | 54 | 130 |
| 18 x 16 | 46 | 100 |
| 20 x 18 | 45 | 100 |
| 24 x 20 | 87 | 100 |

### Table 10
BUSHING (SPIG x SOC)

| NOMINAL SIZE (IN.) | SCHEDULE 40 | |
|---|---|---|
| | WT. (LBS.) | PSI RTG |
| 10 x 8 | 11 | 140 |
| 10 x 6 | 16 | 140 |
| 10 x 4 | 20 | 140 |
| 12 x 10 | 15 | 130 |
| 12 x 8 | 26 | 130 |
| 12 x 6 | 31 | 130 |
| 14 x 12 | 24 | 100 |
| 16 x 14 | 22 | 100 |
| 16 x 12 | 46 | 100 |
| 16 x 10 | 61 | 100 |
| 16 x 8 | 72 | 100 |
| 18 x 16 | 30 | 100 |
| 20 x 18 | 33 | 100 |
| 24 x 20 | 55 | 100 |

### Table 11
EXTENDED BUSHING

| NOMINAL SIZE (IN.) | SCHEDULE 40 | |
|---|---|---|
| | WT. (LBS.) | PSI RTG |
| 10 x 8 | 11 | 140 |
| 12 x 10 | 19 | 130 |
| 14 x 12 | 28 | 130 |
| 16 x 14 | 38 | 130 |

### Table 12
MALE ADAPTOR

| NOMINAL SIZE (IN.) | SCHEDULE 40 | |
|---|---|---|
| | WT. (LBS.) | PSI RTG |
| 6 | 6 | 25 |
| 8 | 7 | 25 |
| 10 | 8 | 25 |
| 12 | 14 | 25 |

### Table 13
FEMALE ADAPTOR

| NOMINAL SIZE (IN.) | SCHEDULE 40 | |
|---|---|---|
| | WT. (LBS.) | PSI RTG |
| 6 | 6 | 25 |
| 8 | 7 | 25 |
| 10 | 8 | 25 |
| 12 | 14 | 25 |

# PRESSURE RATINGS

## PVC LARGE DIAMETER FABRICATED FITTINGS
## AT 73°F

### Table 14
CROSS

| NOMINAL SIZE (IN.) | SCHEDULE 40 | | SCHEDULE 80 | |
|---|---|---|---|---|
| | WT. (LBS.) | PSI RTG | WT. (LBS.) | PSI RTG |
| 3 | 2 | 240 | 5 | 260 |
| 4 | 3 | 220 | 7 | 240 |
| 6 | 13 | 160 | 22 | 240 |
| 8 | 22 | 160 | 30 | 240 |
| 10 | 38 | 140 | 62 | 230 |
| 12 | 58 | 130 | 95 | 230 |
| 14 | 74 | 130 | 129 | 220 |
| 16 | 107 | 130 | 190 | 220 |
| 18 | 117 | 100 | 185 | 160 |
| 20 | 158 | 50 | 247 | 75 |
| 24 | 267 | 50 | 413 | 75 |

### Table 15
FLANGE (BLIND)

| NOMINAL SIZE (IN.) | SCHEDULE 40 | | SCHEDULE 80 | |
|---|---|---|---|---|
| | WT. (LBS.) | PSI RTG | WT. (LBS.) | PSI RTG |
| 10 | 16 | 25 | 32 | 75 |
| 12 | 21 | 25 | 42 | 75 |
| 14 | 26 | 25 | 52 | 75 |
| 16 | 33 | 25 | 66 | 75 |
| 18 | 36 | 25 | 72 | 75 |
| 20 | 44 | 25 | 88 | 75 |
| 24 | 57 | 25 | 114 | 75 |

### Table 16
CAP

| NOMINAL SIZE (IN.) | SCHEDULE 40 | | SCHEDULE 80 | |
|---|---|---|---|---|
| | WT. (LBS.) | PSI RTG | WT. (LBS.) | PSI RTG |
| 10 | 5 | 140 | 14 | 230 |
| 12 | 7 | 130 | 17 | 230 |
| 14 | 23 | 130 | 35 | 220 |
| 16 | 32 | 130 | 49 | 220 |
| 18 | 38 | 100 | 54 | 160 |
| 20 | 49 | 50 | 69 | 75 |
| 24 | 74 | 50 | 108 | 75 |

### Table 17
IPS PIPE DIMENSION TABLE

| NOMINAL PIPE SIZE (IN.) | O.D. | SCHEDULE 40 | | SCHEDULE 80 | |
|---|---|---|---|---|---|
| | | AVERAGE I.D. | MINIMUM WALL | AVERAGE I.D. | MINIMUM WALL |
| 1 | 1.315 | 1.033 | .133 | .935 | .179 |
| 1-1/4 | 1.660 | 1.364 | .140 | 1.256 | .191 |
| 1-1/2 | 1.900 | 1.592 | .145 | 1.476 | .200 |
| 2 | 2.375 | 2.049 | .154 | 1.913 | .218 |
| 3 | 3.500 | 3.042 | .216 | 2.864 | .300 |
| 4 | 4.500 | 3.998 | .237 | 3.786 | .337 |
| 5 | 5.563 | 5.047 | .258 | 4.813 | .375 |
| 6 | 6.625 | 6.013 | .280 | 5.709 | .432 |
| 8 | 8.625 | 7.943 | .322 | 7.565 | .500 |
| 10 | 10.750 | 9.976 | .365 | 9.492 | .593 |
| 12 | 12.750 | 11.890 | .406 | 11.294 | .687 |
| 14 | 14.000 | 13.126 | .437 | 12.440 | .780 |
| 16 | 16.000 | 15.000 | .500 | 14.200 | .900 |
| CLASS 100 | | | | CLASS 160 | |
| 18 | 18.000 | 17.120 | .440 | 16.614 | .693 |
| 20 | 20.000 | 19.022 | .489 | 18.460 | .770 |
| 24 | 24.000 | 22.870 | .585 | 22.152 | .924 |



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# SYSTEMS ENGINEERING DATA

## FOR THERMOPLASTIC PIPING

### Table 18

MODULUS OF ELASTICITY (x10[illegible]) PSI VS. TEMPERATURE

| MATERIAL | TEMPERATURE, °F | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 73 | 90 | 110 | 140 | 170 | 200 | 210 | 250 | 280 |
| PVC | 4.20 | 3.85 | 3.40 | 3.00 | — | — | — | — | — |
| CPVC | 4.23 | 4.10 | 3.70 | 3.27 | 2.93 | 2.40 | 2.26 | — | — |
| PP Fuseal | 2.00 | 1.30 | .097 | .074 | 0.61 | 0.55 | 0.53 | — | — |
| PP Pressure | 1.50 | 1.34 | 1.18 | 0.96 | 0.77 | 0.59 | 0.53 | — | — |
| PVDF | 2.13 | 1.66 | 1.37 | 1.04 | 0.80 | 0.61 | 0.55 | 0.37 | 0.29 |

**EXTERNAL PRESSURES - COLLAPSE RATING**

Thermoplastic pipe is frequently specified for situations where uniform external pressures are applied to the pipe, such as in underwater applications. In these applications, the collapse rating of the pipe determines the maximum permissible pressure differential between external and internal pressures. The basic formulas for collapsing external pressure applied uniformly to a long pipe are:

1. For thick wall pipe where collapse is caused by compression and failure of the pipe material:

$$Pc = \frac{o}{2Do^2}(Do^2 - Di^2)$$

2. For thin wall pipe where collapse is caused by elastic instability of the pipe wall:

$$Pc = \frac{2cE}{1-v^2}\left(\frac{t}{Dm}\right)^3$$

**Where:**

Pc = Collapse Pressure (external minus internal pressure), psi
o = Compressive Strength, psi
E = Modulus of elasticity, psi
v = Poisson's Ratio
Do = Outside Pipe Diameter, in.
Dm = Mean Pipe Diameter, in.
Di = Inside Pipe Diameter, in.
t = Wall Thickness, in.
c = Out-of-Roundness Factor, Approximately 0.66

Choice of Formula - By using formula 2 on thick-wall pipe, an excessively large pressure will be obtained. It is therefore necessary to calculate, for a given pipe size, the collapse pressure using both formulas and use the lower value as a guide to safe working pressure. For short-term loading conditions, the values of E, o and v from the relative properties charts shown on pages 40-41 will yield reasonable results. See individual materials charts for short-term collapse pressures at 73°F. For long-term loading conditions, appropriate long-term data should be used.

**SHORT-TERM COLLAPSE PRESSURE**

Thermoplastic pipe is often used for suction lines or in applications where external pressures are applied to the pipe, such as in heat exchangers, or underwater loading conditions. The differential pressure rating of the pipe between the internal and external pressures is determined by derating collapse pressures of the pipe. The differential pressure rating of the pipe is determined by derating the short-term collapse pressures shown in Table 19.

Collapse pressures must be adjusted for temperatures other than for room temperature. The pressure temperature correction chart (Table 19) used to adjust pipe pressure ratings may be used for this purpose. (See note below table).

### Table 19

SHORT-TERM COLLAPSE PRESSURE IN PSI AT 73°F

| | 1/2 | 3/4 | 1 | 1-1/4 | 1-1/2 | 2 | 3 | 4 | 6 | 8 | 10 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SCHEDULE 40 PVC | 2095 | 1108 | 900 | 494 | 356 | 211 | 180 | 109 | 54 | 39 | 27 | 22 |
| SCHEDULE 80 PVC | 2772 | 2403 | 2258 | 1389 | 927 | 632 | 521 | 335 | 215 | 147 | 126 | 117 |
| SCHEDULE 80 CPVC - IPS | 2772 | 2403 | 2258 | 1389 | 927 | 632 | 521 | 335 | 215 | 147 | 126 | 117 |
| SCHEDULE 80 PRESSURE POLYPROPYLENE - IPS | 1011 | 876 | 823 | 612 | 412 | 278 | 229 | 147 | 94 | 65 | 55 | 51 |
| SCHEDULE 80 PVDF - IPS | 2936 | 1576 | 1206 | 680 | 464 | 309 | 255 | 164 | 105 | 72 | 61 | 57 |
| PROLINE PRO 150 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| PROLINE PRO 45 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |
| SUPER PROLINE | 202 | 99 | 92 | 44 | 41 | 22 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 |

NOTE: These are short-term ratings; long-term ratings should be reduced by 1/3 to 1/2 of the short-term ratings.

**Vacuum Service - All sizes of Schedule 80 thermoplastic pipe are suitable for vacuum service up to 140°F and 30 inches of mercury.** Solvent-cemented joints are recommended for vacuum applications when using PVC. Schedule 40 PVC will handle full vacuum up to 24" diameter.

Laboratory tests have been conducted on Schedule 80 PVC pipe to determine performance under vacuum at temperatures above recommended operating conditions. Pipe sizes under 6 inches show no deformation at temperatures to 170°F and 27 inches of mercury vacuum.

The 6 inch pipe showed slight deformation at 165°F, and 20 inches of mercury. Above this temperature, failure occurred due to thread deformation.



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# SYSTEMS ENGINEERING DATA

## FOR THERMOPLASTIC PIPING

### WATER HAMMER

Surge pressures due to water hammer are a major factor contributing to pipe failure in liquid transmission systems. A column of moving fluid within a pipeline, owing to its mass and velocity, contains stored energy. Since liquids are essentially incompressible, this energy cannot be absorbed by the fluid when a valve is suddenly closed. The result is a high momentary pressure surge, usually called water hammer. The five factors that determine the severity of water hammer are:

1. Velocity (The primary factor in excessive water hammer: see discussion of "Velocity " and "Safety Factor" on page 62).
2. Modulus of elasticity of material of which the pipe is made.
3. Inside diameter of pipe.
4. Wall thickness of pipe.
5. Valve closing time.

Maximum pressure surges caused by water hammer can be calculated by using the equation below. This surge pressure should be added to the existing line pressure to arrive at a maximum operating pressure figure.

$$Ps = V\left(\frac{Et\ 3960}{Et + 3 \times 10^5 Di}\right)^{1/2}$$

**Where:**

Ps = Surge Pressure. in psi
V = Liquid Velocity, in ft. per sec.
Di = Inside Diameter of Pipe, in.
E = Modulus of Elasticity of Pipe Material, psi
t = Wall Thickness of Pipe, in.

Calculated surge pressure, which assumes instantaneous valve closure, can be calculated for any material using the values for E (Modulus of Elasticity) found in the properties chart, pages 13-14. Here are the most commonly used surge pressure tables for IPS pipe sizes.

**Table 20 - SURGE PRESSURE, Ps IN PSI AT 73°F**

| WATER VELOCITY (FT/SEC) | NOMINAL PIPE SIZE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1/2 | 3/4 | 1 | 1-1/4 | 1-1/2 | 2 | 3 | 4 | 6 | 8 | 10 | 12 |
| **SCHEDULE 40 PVC & CPVC** | | | | | | | | | | | | |
| 1 | 27.9 | 25.3 | 24.4 | 22.2 | 21.1 | 19.3 | 18.9 | 17.4 | 15.5 | 14.6 | 13.9 | 13.4 |
| 2 | 55.8 | 50.6 | 48.8 | 44.4 | 42.2 | 38.6 | 37.8 | 34.8 | 31.0 | 29.2 | 27.8 | 26.8 |
| 3 | 83.7 | 75.9 | 73.2 | 66.6 | 63.3 | 57.9 | 56.7 | 52.2 | 46.5 | 43.8 | 41.7 | 40.2 |
| 4 | 111.6 | 101.2 | 97.6 | 88.8 | 84.4 | 77.2 | 75.6 | 69.6 | 62.0 | 58.4 | 55.6 | 53.6 |
| 5 | 139.5 | 126.5 | 122.0 | 111.0 | 105.5 | 96.5 | 94.5 | 87.0 | 77.5 | 73.0 | 69.5 | 67.0 |
| 6 | 167.4 | 151.8 | 146.4 | 133.2 | 126.6 | 115.8 | 113.4 | 104.4 | 93.0 | 87.6 | 83.4 | 80.4 |
| **SCHEDULE 80 PVC & CPVC** | | | | | | | | | | | | |
| 1 | 32.9 | 29.9 | 28.7 | 26.2 | 25.0 | 23.2 | 22.4 | 20.9 | 19.4 | 18.3 | 17.3 | 17.6 |
| 2 | 65.6 | 59.8 | 57.4 | 52.4 | 50.0 | 46.4 | 44.8 | 41.8 | 38.8 | 36.6 | 35.6 | 35.2 |
| 3 | 98.7 | 89.7 | 86.7 | 78.6 | 75.0 | 69.6 | 67.2 | 62.7 | 58.2 | 59.9 | 53.4 | 52.8 |
| 4 | 131.6 | 119.6 | 114.8 | 104.8 | 107.0 | 92.8 | 89.6 | 83.6 | 77.6 | 73.2 | 71.2 | 70.4 |
| 5 | 164.5 | 149.5 | 143.5 | 131.0 | 125.0 | 116.0 | 112.0 | 104.5 | 97.0 | 91.5 | 89.0 | 88.0 |
| 6 | 197.4 | 179.4 | 172.2 | 157.2 | 150.0 | 133.2 | 134.4 | 125.4 | 116.4 | 109.8 | 106.8 | 105.6 |
| **SCHEDULE 80 POYLPROPYLENE** | | | | | | | | | | | | |
| 1 | 23.5 | 20.9 | 20.0 | 18.1 | 17.1 | 15.9 | 15.2 | 14.1 | 13.1 | 12.2 | 11.9 | 11.8 |
| 2 | 47.0 | 41.8 | 40.0 | 36.2 | 34.2 | 31.6 | 30.4 | 28.2 | 26.2 | 24.4 | 23.8 | 23.6 |
| 3 | 70.5 | 62.7 | 60.0 | 54.3 | 51.3 | 47.4 | 45.6 | 42.3 | 39.3 | 36.6 | 35.7 | 35.4 |
| 4 | 94.0 | 83.6 | 80.0 | 72.4 | 68.4 | 63.2 | 60.8 | 56.4 | 52.4 | 48.8 | 47.6 | 47.2 |
| 5 | 117.5 | 104.5 | 100.0 | 90.5 | 85.5 | 79.0 | 76.0 | 70.5 | 65.5 | 61.0 | 59.5 | 59.0 |
| 6 | 141.0 | 125.4 | 120.0 | 108.6 | 102.6 | 94.8 | 91.2 | 84.6 | 78.6 | 73.2 | 71.4 | 70.8 |
| **SCHEDULE 80 PVDF** | | | | | | | | | | | | |
| 1 | 25.2 | 22.6 | 21.6 | 19.5 | 18.5 | 17.1 | 16.5 | 15.3 | 14.2 | 13.3 | 12.9 | 12.8 |
| 2 | 50.4 | 45.2 | 43.2 | 39.0 | 37.0 | 34.2 | 33.0 | 30.6 | 28.9 | 26.6 | 25.8 | 25.6 |
| 3 | 75.6 | 67.8 | 64.8 | 58.5 | 55.5 | 51.3 | 49.5 | 45.9 | 42.6 | 39.9 | 38.7 | 38.4 |
| 4 | 100.8 | 90.4 | 86.4 | 78.0 | 74.0 | 68.4 | 66.0 | 61.2 | 56.8 | 53.2 | 51.6 | 51.2 |
| 5 | 126.0 | 118.0 | 108.0 | 97.5 | 92.5 | 85.5 | 82.5 | 76.5 | 71.0 | 66.5 | 64.5 | 64.0 |
| 6 | 151.2 | 135.6 | 129.6 | 117.0 | 111.0 | 102.6 | 99.0 | 91.8 | 85.2 | 79.8 | 77.4 | 76.8 |
| **SUPER PROLINE** | | | | | | | | | | | | |
| 1 | 22.3 | 19.8 | 19.6 | 17.4 | 17.1 | 15.5 | 18.4 | 12.6 | 12.5 | 12.4 | 12.4 | 12.4 |
| 2 | 44.5 | 39.7 | 39.1 | 34.7 | 34.2 | 30.9 | 24.8 | 25.2 | 24.9 | 24.8 | 24.9 | 24.8 |
| 3 | 66.8 | 59.5 | 58.7 | 52.1 | 51.4 | 46.4 | 37.2 | 37.7 | 37.4 | 37.2 | 37.3 | 37.3 |
| 4 | 89.1 | 79.4 | 78.3 | 69.5 | 68.5 | 61.8 | 49.7 | 50.3 | 49.9 | 49.6 | 49.8 | 49.7 |
| 5 | 111.3 | 99.2 | 97.9 | 86.9 | 85.6 | 77.3 | 62.1 | 62.9 | 62.3 | 62.0 | 62.2 | 62.1 |
| 6 | 133.6 | 119.0 | 117.4 | 104.2 | 102.7 | 92.8 | 74.5 | 75.5 | 74.8 | 74.4 | 74.6 | 74.5 |
| **PROLINE PRO 150** | | | | | | | | | | | | |
| 1 | 15.3 | 14.1 | 12.9 | 12.6 | 12.8 | 12.8 | 12.7 | 12.7 | 12.8 | 12.7 | 12.7 | 12.7 |
| 2 | 30.7 | 28.2 | 25.9 | 25.3 | 25.6 | 25.6 | 25.5 | 25.4 | 25.5 | 25.5 | 25.5 | 25.5 |
| 3 | 46.0 | 42.3 | 38.8 | 37.9 | 38.4 | 38.4 | 38.2 | 38.2 | 38.3 | 38.2 | 38.2 | 38.2 |
| 4 | 61.4 | 56.4 | 51.8 | 50.5 | 51.2 | 51.2 | 51.0 | 50.9 | 51.0 | 50.9 | 51.0 | 50.9 |
| 5 | 76.7 | 70.5 | 64.7 | 63.2 | 64.0 | 64.0 | 63.7 | 63.6 | 63.8 | 63.7 | 63.7 | 63.7 |
| 6 | 92.1 | 84.6 | 77.6 | 75.8 | 76.8 | 76.8 | 76.5 | 76.3 | 76.5 | 76.4 | 76.5 | 76.4 |
| **PROLINE PRO 45** | | | | | | | | | | | | |
| 1 | - | - | - | - | - | 7.1 | 7.0 | 7.1 | 7.1 | 7.0 | 7.1 | 7.1 |
| 2 | - | - | - | - | - | 14.2 | 14.1 | 14.3 | 14.2 | 14.1 | 14.1 | 14.1 |
| 3 | - | - | - | - | - | 21.3 | 21.1 | 21.4 | 21.2 | 21.1 | 21.2 | 21.1 |
| 4 | - | - | - | - | - | 28.4 | 28.1 | 28.6 | 28.3 | 28.2 | 28.2 | 28.2 |
| 5 | - | - | - | - | - | 35.5 | 35.2 | 35.7 | 35.4 | 35.2 | 35.3 | 35.3 |
| 6 | - | - | - | - | - | 42.5 | 42.3 | 42.8 | 42.5 | 42.2 | 42.4 | 42.3 |

NOTE: For sizes larger than 12", call your Corr Tech representative.

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# SYSTEMS ENGINEERING DATA

## FOR THERMOPLASTIC PIPING

**WATER HAMMER (continued)**

However, to keep water hammer pressures within reasonable limits, it is common practice to design valves for closure times considerably greater than 2L/C.

$$T_c > \frac{2L}{C}$$

**Where:** $T_c$ = Valve Closure time, sec.
L = Length of Pipe run, ft.
C = Sonic Velocity of the Pressure Wave = 4720 ft. sec.

Another formula which closely predicts water hammer effects is: $p = a \frac{w}{144g}$

Which is based on the elastic wave theory. In this text, we have further simplified the equation to:

$$p = Cv$$

**Where:** p = maximum surge pressure, psi
v = fluid velocity in feet per second
C = surge wave constant for water at 73°F

It should be noted that the surge pressure (water hammer) calculated here is a maximum pressure rise for any fluid velocity, such as would be expected from the instant closing of a valve. It would therefore yield a somewhat conservative figure for use with slow closing actuated valves, etc.

For fluids heavier than water, the following correction should be made to the surge wave constant C.

$$C^1 = \frac{(S.G. -1)\,C + C}{2}$$

**Where:** $C^1$ = Corrected Surge Wave Constant
S.G. = Specific Gravity or Liquid

For example, for a liquid with a specific gravity of 1.2 in 2" Schedule 80 PVC pipe, from Table 43 = 24.2

$$C^1 = \frac{(1.2 - 1)}{2}(24.2) + 24.2$$

$$C^1 = 2.42 + 24.2$$

$$C^1 = 26.6$$

**Table 21 - Surge Wave Correction for Specific Gravity**

| PIPE SIZE (IN.) | PVC | | CPVC | | POLY-PROPYLENE | KYNAR (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 | |
| 4 | 17.8 | 21.8 | 18.8 | 22.9 | 15.4 | |
| 6 | 15.7 | 20.2 | 16.8 | 21.3 | | |
| 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 | | |

**Proper design when laying out a piping system will eliminate the possibility of water hammer damage.**
The following suggestions will help in avoiding problems:

1) In a plastic piping system, a fluid velocity not exceeding 5ft/sec. will minimize water hammer 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 water hammer during pump start-up.

### VELOCITY

Thermoplastic piping systems have been installed that have successfully handled water velocities in excess of 10 ft/sec. Thermoplastic pipe is not subject to erosion caused by high velocities and turbulent flow, and in this respect is superior to metal piping systems, particularly where corrosive or chemically aggressive fluids are involved. The Plastics Pipe Institute has issued the following policy statement on water velocity: The maximum safe water velocity in a thermoplastic piping system depends on the specific details of the system and the operating conditions. **In general, 5 feet per second is considered to be safe.** Higher velocities may be used in cases where the operating characteristics of valves and pumps are known so that sudden changes in flow velocity can be controlled. The total pressure in the system at any time (operating plus surge or water hammer) should not exceed 150 percent of the pressure rating of the system.

### SAFETY FACTOR

As the duration of pressure surges due to water hammer is extremely short - seconds, or more likely, fractions of a second - in determining the safety factor the maximum fiber stress due to total internal pressure must be compared to some very short-term strength value. Referring to Figure 2, shown on page15, it will be seen that the failure stress for very short time periods is very high when compared to the hydrostatic design stress. The calculation of safety factor may thus be based very conservatively on the 20-second strength value given in Figure 2, shown on page 15 - 8470 psi for PVC Type 1.

A sample calculation is shown below, based upon the listed criteria:

Pipe = 1-1/4" Schedule 80 PVC
O.D. = 1.660: Wall = 0.191
HDS = 2000 psi

The calculated surge pressure for 1-1/4" Schedule 80 PVC pipe at a velocity of 1 ft/sec is 26.2 psi/ft/sec.

# CARRYING CAPACITY & FRICTION LOSS

## TABLE 22

### CARRYING CAPACITY AND FRICTION LOSS FOR SCHEDULE 80 THERMOPLASTIC PIPE

(Independent variables: Gallons per minute and nominal pipe size O.D.

Dependent variables: Velocity, friction head and pressure drop per 100 feet of pipe, interior smooth .)

| GALLONS PER MINUTE | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1/2 IN. | | | 3/4 IN. | | | 1 IN. | | | 1-1/4 IN. | | | 1-1/2 IN. | | | 2 IN. | | | 2-1/2 IN. | | | 3 IN. | | |
| 1 | 1.48 | 4.02 | 1.74 | 0.74 | 0.86 | 0.37 | | | | | | | | | | | | | | | | | | |
| 2 | 2.95 | 8.03 | 3.48 | 1.57 | 1.72 | 0.74 | 0.94 | 0.88 | 0.38 | 0.52 | 0.21 | 0.09 | 0.38 | 0.10 | 0.041 | | | | | | | | | |
| 5 | 7.39 | 45.23 | 19.59 | 3.92 | 9.67 | 4.19 | 2.34 | 2.75 | 1.19 | 1.30 | 0.66 | 0.29 | 0.94 | 0.30 | 0.126 | 0.56 | 0.10 | 0.040 | 0.39 | 0.05 | 0.022 | 0.25 | 0.02 | 0.009 |
| 7 | 10.34 | 83.07 | 35.97 | 5.49 | 17.76 | 7.69 | 3.28 | 5.04 | 2.19 | 1.82 | 1.21 | 0.53 | 1.32 | 0.55 | 0.24 | 0.78 | 0.15 | 0.065 | 0.54 | 0.07 | 0.032 | 0.35 | 0.028 | 0.012 |
| 10 | | | | 7.84 | 33.84 | 14.65 | 4.68 | 9.61 | 4.16 | 2.60 | 2.30 | 1.00 | 1.88 | 1.04 | 0.45 | 1.12 | 0.29 | 0.13 | 0.78 | 0.12 | 0.052 | 0.50 | 0.04 | 0.017 |
| | 4 IN. | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | | | | 11.76 | 71.70 | 31.05 | 7.01 | 20.36 | 8.82 | 3.90 | 4.87 | 2.11 | 2.81 | 2.20 | 0.95 | 1.68 | 0.62 | 0.27 | 1.17 | 0.26 | 0.11 | 0.75 | 0.09 | 0.039 |
| 20 | 0.57 | 0.04 | 0.017 | | | | 9.35 | 34.68 | 15.02 | 5.20 | 8.30 | 3.59 | 3.75 | 3.75 | 1.62 | 2.23 | 1.06 | 0.46 | 1.56 | 0.44 | 0.19 | 1.00 | 0.15 | 0.065 |
| | | | | 5 IN. | | | | | | | | | | | | | | | | | | | | |
| 25 | 0.72 | 0.06 | 0.026 | | | | 11.69 | 52.43 | 22.70 | 6.50 | 12.55 | 5.43 | 4.69 | 5.67 | 2.46 | 2.79 | 1.60 | 0.69 | 1.95 | 0.67 | 0.29 | 1.25 | 0.22 | 0.095 |
| 30 | 0.86 | 0.08 | 0.035 | 0.54 | 0.03 | 0.013 | 14.03 | 73.48 | 31.82 | 7.80 | 17.59 | 7.62 | 5.63 | 7.95 | 3.44 | 3.35 | 2.25 | 0.97 | 2.34 | 0.94 | 0.41 | 1.49 | 0.31 | 0.13 |
| 35 | 1.00 | 0.11 | 0.048 | 0.63 | 0.04 | 0.017 | | | | 9.10 | 23.40 | 10.13 | 6.57 | 10.58 | 4.58 | 3.91 | 2.99 | 1.29 | 2.73 | 1.25 | 0.54 | 1.74 | 0.42 | 0.18 |
| 40 | 1.15 | 0.14 | 0.061 | 0.72 | 0.04 | 0.017 | | | | 10.40 | 29.97 | 12.98 | 7.50 | 13.55 | 5.87 | 4.47 | 3.83 | 1.66 | 3.12 | 1.60 | 0.69 | 1.99 | 0.54 | 0.23 |
| | | | | | | | 6 IN. | | | | | | | | | | | | | | | | | |
| 45 | 1.29 | 0.17 | 0.074 | 0.81 | 0.06 | 0.026 | | | | 11.70 | 37.27 | 16.14 | 8.44 | 16.85 | 7.30 | 5.03 | 4.76 | 2.07 | 3.51 | 1.99 | 0.86 | 2.24 | 0.67 | 0.29 |
| 50 | 1.43 | 0.21 | 0.091 | 0.90 | 0.07 | 0.030 | 0.63 | 0.03 | 0.013 | 13.00 | 45.30 | 19.61 | 9.38 | 20.48 | 8.87 | 5.58 | 5.79 | 2.51 | 3.90 | 2.42 | 1.05 | 2.49 | 0.81 | 0.35 |
| 60 | 1.72 | 0.30 | 0.13 | 1.08 | 0.10 | 0.043 | 0.75 | 0.04 | 0.017 | | | | 11.26 | 28.70 | 12.43 | 6.70 | 8.12 | 3.52 | 4.68 | 3.39 | 1.47 | 2.99 | 1.14 | 0.49 |
| 70 | 2.01 | 0.39 | 0.17 | 1.26 | 0.13 | 0.056 | 0.88 | 0.05 | 0.022 | | | | | | | 7.82 | 10.80 | 4.68 | 5.46 | 4.51 | 1.95 | 3.49 | 1.51 | 0.65 |
| 75 | 2.15 | 0.45 | 0.19 | 1.35 | 0.14 | 0.061 | 0.94 | 0.06 | 0.026 | | | | | | | 8.38 | 12.27 | 5.31 | 5.85 | 5.12 | 2.22 | 3.74 | 1.72 | 0.74 |
| 80 | 2.29 | 0.50 | 0.22 | 1.44 | 0.16 | 0.069 | 1.00 | 0.07 | 0.030 | | | | | | | 8.93 | 13.83 | 5.99 | 6.24 | 5.77 | 2.50 | 3.99 | 1.94 | 0.84 |
| 90 | 2.58 | 0.63 | 0.27 | 1.62 | 0.20 | 0.087 | 1.13 | 0.08 | 0.035 | | | | | | | 10.05 | 17.20 | 7.45 | 7.02 | 7.18 | 3.11 | 4.48 | 2.41 | 1.04 |
| | | | | | | | | | | 8 IN. | | | | | | | | | | | | | | |
| 100 | 2.87 | 0.76 | 0.33 | 1.80 | 0.24 | 0.10 | 1.25 | 0.10 | 0.043 | | | | | | | 11.17 | 20.90 | 9.05 | 7.80 | 8.72 | 3.78 | 4.98 | 2.93 | 1.27 |
| 125 | 3.59 | 1.16 | 0.50 | 2.25 | 0.37 | 0.16 | 1.57 | 0.16 | 0.068 | 0.90 | 0.045 | 0.019 | | | | | | | 9.75 | 13.21 | 5.72 | 6.23 | 4.43 | 1.92 |
| 150 | 4.30 | 1.61 | 0.70 | 2.70 | 0.52 | 0.23 | 1.88 | 0.22 | 0.095 | 1.07 | 0.05 | 0.022 | | | | | | | 11.70 | 18.48 | 8.00 | 7.47 | 6.20 | 2.68 |
| | | | | | | | | | | | | | 10 IN. | | | | | | | | | | | |
| 175 | 5.02 | 2.15 | 0.93 | 3.15 | 0.69 | 0.30 | 2.20 | 0.29 | 0.12 | 1.25 | 0.075 | 0.033 | | | | | | | | | | 8.72 | 8.26 | 3.58 |
| 200 | 5.73 | 2.75 | 1.19 | 3.60 | 0.88 | 0.38 | 2.51 | 0.37 | 0.16 | 1.43 | 0.09 | 0.039 | 0.90 | 0.036 | 0.015 | | | | | | | 9.97 | 10.57 | 4.58 |
| 250 | 7.16 | 4.16 | 1.81 | 4.50 | 1.34 | 0.58 | 3.14 | 0.56 | 0.24 | 1.79 | 0.14 | 0.61 | 1.14 | 0.045 | 0.02 | | | | | | | 12.46 | 16.00 | 6.93 |
| | | | | | | | | | | | | | | | | 12 IN. | | | | | | | | |
| 300 | 8.60 | 5.83 | 2.52 | 5.40 | 1.87 | 0.81 | 3.76 | 0.78 | 0.34 | 2.14 | 0.20 | 0.087 | 1.36 | 0.07 | 0.03 | | | | | | | | | |
| 350 | 10.03 | 7.76 | 3.36 | 6.30 | 2.49 | 1.08 | 4.39 | 1.04 | 0.45 | 2.50 | 0.27 | 0.12 | 1.59 | 0.085 | 0.037 | 1.12 | 0.037 | 0.016 | | | | | | |
| 400 | 11.47 | 9.93 | 4.30 | 7.19 | 3.19 | 1.38 | 5.02 | 1.33 | 0.58 | 2.86 | 0.34 | 0.15 | 1.81 | 0.11 | 0.048 | 1.28 | 0.05 | 0.022 | | | | | | |
| 450 | | | | 8.09 | 3.97 | 1.72 | 5.64 | 1.65 | 0.71 | 3.21 | 0.42 | 0.18 | 2.04 | 0.14 | 0.061 | 1.44 | 0.06 | 0.026 | | | | | | |
| 500 | | | | 8.99 | 4.82 | 2.09 | 6.27 | 2.00 | 0.87 | 3.57 | 0.51 | 0.22 | 2.27 | 0.17 | 0.074 | 1.60 | 0.07 | 0.030 | | | | | | |
| 750 | | | | | | | 9.40 | 4.25 | 1.84 | 5.36 | 1.08 | 0.47 | 3.40 | 0.36 | 0.16 | 2.40 | 0.15 | 0.065 | | | | | | |
| 1000 | | | | | | | 12.54 | 7.23 | 3.13 | 7.14 | 1.84 | 0.80 | 4.54 | 0.61 | 0.26 | 3.20 | 0.26 | 0.11 | | | | | | |
| 1250 | | | | | | | | | | 8.93 | 2.78 | 1.20 | 5.67 | 0.92 | 0.40 | 4.01 | 0.40 | 0.17 | | | | | | |
| 1500 | | | | | | | | | | 10.71 | 3.89 | 1.68 | 6.80 | 1.29 | 0.56 | 4.81 | 0.55 | 0.24 | | | | | | |
| 2000 | | | | | | | | | | | | | 9.07 | 2.19 | 0.95 | 6.41 | 0.94 | 0.41 | | | | | | |
| 2500 | | | | | | | | | | | | | 11.34 | 3.33 | 1.44 | 8.01 | 1.42 | 0.62 | | | | | | |
| 3000 | | | | | | | | | | | | | | | | 9.61 | 1.99 | 0.86 | | | | | | |
| 3500 | | | | | | | | | | | | | | | | 11.21 | 2.65 | 1.15 | | | | | | |
| 4000 | | | | | | | | | | | | | | | | 12.82 | 3.41 | 1.48 | | | | | | |

# CARRYING CAPACITY & FRICTION LOSS

## TABLE 23

### CARRYING CAPACITY AND FRICTION LOSS FOR SCHEDULE 40 THERMOPLASTIC PIPE

**(Independent variables: Gallons per minute and nominal pipe size O. D.**
**Dependent variables: Velocity, friction head and pressure drop per 100 feet of pipe, interior smooth .)**

| GALLONS PER MINUTE | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1/2 IN. | | | 3/4 IN. | | | 1 IN. | | | 1-1/4 IN. | | | 1-1/2 IN. | | | 2 IN. | | | 2-1/2 IN. | | | 3 IN. | | |
| 1 | 1.13 | 2.08 | 0.90 | 0.63 | 0.51 | 0.22 | | | | | | | | | | | | | | | | | | |
| 2 | 2.26 | 4.16 | 1.80 | 1.26 | 1.02 | 0.44 | 0.77 | 0.55 | 0.24 | 0.44 | 0.14 | 0.06 | 0.33 | 0.07 | 0.03 | | | | | | | | | |
| 5 | 5.64 | 23.44 | 10.45 | 3.16 | 5.73 | 2.48 | 1.93 | 1.72 | 0.75 | 1.11 | 0.44 | 0.19 | 0.81 | 0.22 | 0.09 | 0.49 | 0.066 | 0.029 | 0.30 | 0.038 | 0.016 | 0.22 | 0.015 | 0.007 |
| 7 | 7.90 | 43.06 | 13.64 | 4.43 | 10.52 | 4.56 | 2.72 | 3.17 | 1.37 | 1.55 | 0.81 | 0.35 | 1.13 | 0.38 | 0.17 | 0.69 | 0.11 | 0.048 | 0.49 | 0.051 | 0.023 | 0.31 | 0.021 | 0.009 |
| 10 | 11.28 | 82.02 | 35.51 | 6.32 | 20.04 | 8.68 | 3.86 | 6.02 | 2.61 | 2.21 | 1.55 | 0.67 | 1.62 | 0.72 | 0.31 | 0.98 | 0.21 | 0.091 | 0.68 | 0.09 | 0.039 | 0.44 | 0.03 | 0.013 |
| 15 | 4 IN. | | | 9.48 | 42.46 | 18.39 | 5.79 | 12.77 | 5.53 | 3.31 | 3.28 | 1.42 | 2.42 | 1.53 | 0.66 | 1.46 | 0.45 | 0.19 | 1.03 | 0.19 | 0.082 | 0.66 | 0.07 | 0.030 |
| 20 | 0.51 | 0.03 | 0.013 | 12.65 | 72.34 | 31.32 | 7.72 | 21.75 | 9.42 | 4.42 | 5.59 | 2.42 | 3.23 | 2.61 | 1.13 | 1.95 | 0.76 | 0.33 | 1.37 | 0.32 | 0.14 | 0.88 | 0.11 | 0.048 |
| 25 | 0.64 | 0.04 | 0.017 | 5 IN. | | | 9.65 | 32.88 | 14.22 | 5.52 | 8.45 | 3.66 | 4.04 | 3.95 | 1.71 | 2.44 | 1.15 | 0.50 | 1.71 | 0.49 | 0.21 | 1.10 | 0.17 | 0.074 |
| 30 | 0.77 | 0.06 | 0.026 | 0.49 | 0.02 | 0.009 | 11.58 | 46.08 | 19.95 | 6.63 | 11.85 | 5.13 | 4.85 | 5.53 | 2.39 | 2.93 | 1.62 | 0.70 | 2.05 | 0.68 | 0.29 | 1.33 | 0.23 | 0.10 |
| 35 | 0.89 | 0.08 | 0.035 | 0.57 | 0.03 | 0.013 | | | | 7.73 | 15.76 | 6.82 | 5.66 | 7.36 | 3.19 | 3.41 | 2.15 | 0.93 | 2.39 | 0.91 | 0.39 | 1.55 | 0.31 | 0.13 |
| 40 | 1.02 | 0.11 | 0.046 | 0.65 | 0.03 | 0.013 | | | | 8.84 | 20.18 | 8.74 | 6.47 | 9.43 | 4.08 | 3.90 | 2.75 | 1.19 | 2.73 | 1.16 | 0.50 | 1.77 | 0.40 | 0.17 |
| 45 | 1.15 | 0.13 | 0.056 | 0.73 | 0.04 | 0.017 | 6 IN. | | | 9.94 | 25.10 | 10.87 | 7.27 | 11.73 | 5.08 | 4.39 | 3.43 | 1.49 | 3.08 | 1.44 | 0.62 | 1.99 | 0.50 | 0.22 |
| 50 | 1.28 | 0.16 | 0.069 | 0.81 | 0.05 | 0.022 | 0.56 | 0.02 | 0.009 | 11.05 | 30.51 | 13.21 | 8.08 | 14.25 | 6.17 | 4.88 | 4.16 | 1.80 | 3.42 | 1.75 | 0.76 | 2.21 | 0.60 | 0.26 |
| 60 | 1.53 | 0.22 | 0.095 | 0.97 | 0.07 | 0.030 | 0.67 | 0.03 | 0.013 | | | | 9.70 | 19.98 | 8.65 | 5.85 | 5.84 | 2.53 | 4.10 | 2.46 | 1.07 | 2.65 | 0.85 | 0.37 |
| 70 | 1.79 | 0.30 | 0.13 | 1.14 | 0.10 | 0.043 | 0.79 | 0.04 | 0.017 | | | | | | | 6.83 | 7.76 | 3.36 | 4.79 | 3.27 | 1.42 | 3.09 | 1.13 | 0.49 |
| 75 | 1.92 | 0.34 | 0.15 | 1.22 | 0.11 | 0.048 | 0.84 | 0.05 | 0.022 | | | | | | | 7.32 | 8.82 | 3.82 | 5.13 | 3.71 | 1.61 | 3.31 | 1.28 | 0.55 |
| 80 | 2.05 | 0.38 | 0.16 | 1.30 | 0.13 | 0.056 | 0.90 | 0.05 | 0.022 | 8 IN. | | | | | | 7.80 | 9.94 | 4.30 | 5.47 | 4.19 | 1.81 | 3.53 | 1.44 | 0.62 |
| 90 | 2.30 | 0.47 | 0.20 | 1.46 | 0.16 | 0.069 | 1.01 | 0.06 | 0.026 | | | | | | | 8.78 | 12.37 | 5.36 | 6.15 | 5.21 | 2.26 | 3.98 | 1.80 | 0.78 |
| 100 | 2.56 | 0.58 | 0.25 | 1.62 | 0.19 | 0.082 | 1.12 | 0.08 | 0.035 | 0.65 | 0.03 | 0.012 | | | | 9.75 | 15.03 | 6.51 | 6.84 | 6.33 | 2.74 | 4.42 | 2.18 | 0.94 |
| 125 | 3.20 | 0.88 | 0.38 | 2.03 | 0.29 | 0.125 | 1.41 | 0.12 | 0.052 | 0.81 | 0.035 | 0.015 | | | | | | | 8.55 | 9.58 | 4.15 | 5.52 | 3.31 | 1.43 |
| 150 | 3.84 | 1.22 | 0.53 | 2.44 | 0.40 | 0.17 | 1.69 | 0.16 | 0.069 | 0.97 | 0.04 | 0.017 | 10 IN. | | | | | | 10.26 | 13.41 | 5.81 | 6.63 | 4.63 | 2.00 |
| 175 | 4.48 | 1.63 | 0.71 | 2.84 | 0.54 | 0.235 | 1.97 | 0.22 | 0.096 | 1.14 | 0.055 | 0.024 | | | | | | | | | | 7.73 | 6.16 | 2.67 |
| 200 | 5.11 | 2.08 | 0.90 | 3.25 | 0.69 | 0.30 | 2.25 | 0.28 | 0.12 | 1.30 | 0.07 | 0.030 | 0.82 | 0.027 | 0.012 | | | | | | | 8.83 | 7.88 | 3.41 |
| 250 | 6.40 | 3.15 | 1.36 | 4.06 | 1.05 | 0.45 | 2.81 | 0.43 | 0.19 | 1.63 | 0.11 | 0.048 | 1.03 | 0.035 | 0.015 | 12 IN. | | | | | | 11.04 | 11.93 | 5.17 |
| 300 | 7.67 | 4.41 | 1.91 | 4.87 | 1.46 | 0.63 | 3.37 | 0.60 | 0.26 | 1.94 | 0.16 | 0.069 | 1.23 | 0.05 | 0.022 | | | | | | | | | |
| 350 | 8.95 | 5.87 | 2.55 | 5.69 | 1.95 | 0.85 | 3.94 | 0.79 | 0.34 | 2.27 | 0.21 | 0.091 | 1.44 | 0.065 | 0.028 | 1.01 | 0.027 | 0.012 | | | | | | |
| 400 | 10.23 | 7.52 | 3.26 | 6.50 | 2.49 | 1.08 | 4.49 | 1.01 | 0.44 | 2.59 | 0.27 | 0.12 | 1.64 | 0.09 | 0.039 | 1.16 | 0.04 | 0.017 | | | | | | |
| 450 | | | | 7.31 | 3.09 | 1.34 | 5.06 | 1.26 | 0.55 | 2.92 | 0.33 | 0.14 | 1.85 | 0.11 | 0.048 | 1.30 | 0.05 | 0.022 | | | | | | |
| 500 | | | | 8.12 | 3.76 | 1.63 | 5.62 | 1.53 | 0.66 | 3.24 | 0.40 | 0.17 | 2.05 | 0.13 | 0.056 | 1.45 | 0.06 | 0.026 | | | | | | |
| 750 | | | | | | | 8.43 | 3.25 | 1.41 | 4.86 | 0.85 | 0.37 | 3.08 | 0.28 | 0.12 | 2.17 | 0.12 | 0.052 | | | | | | |
| 1000 | | | | | | | 11.24 | 5.54 | 2.40 | 6.48 | 1.45 | 0.63 | 4.11 | 0.48 | 0.21 | 2.89 | 0.20 | 0.087 | | | | | | |
| 1250 | | | | | | | | | | 8.11 | 2.20 | 0.95 | 5.14 | 0.73 | 0.32 | 3.62 | 0.31 | 0.13 | | | | | | |
| 1500 | | | | | | | | | | 9.72 | 3.07 | 1.33 | 6.16 | 1.01 | 0.44 | 4.34 | 0.43 | 0.19 | | | | | | |
| 2000 | | | | | | | | | | | | | 8.21 | 1.72 | 0.74 | 5.78 | 0.73 | 0.32 | | | | | | |
| 2500 | | | | | | | | | | | | | 10.27 | 2.61 | 1.13 | 7.23 | 1.11 | 0.49 | | | | | | |
| 3000 | | | | | | | | | | | | | | | | 8.68 | 1.55 | 0.67 | | | | | | |
| 3500 | | | | | | | | | | | | | | | | 10.12 | 2.07 | 0.90 | | | | | | |
| 4000 | | | | | | | | | | | | | | | | 11.07 | 2.66 | 1.15 | | | | | | |

# PROLINE-POLYPROPYLENE 150 FLOW RATES

## TABLE 24

| GALLONS PER MINUTE | 1/2 IN. VELOCITY FEET PER SECOND | 1/2 IN. FRICTION HEAD FEET | 1/2 IN. FRICTION LOSS POUNDS PER SQUARE INCH | 3/4 IN. VELOCITY FEET PER SECOND | 3/4 IN. FRICTION HEAD FEET | 3/4 IN. FRICTION LOSS POUNDS PER SQUARE INCH | 1 IN. VELOCITY FEET PER SECOND | 1 IN. FRICTION HEAD FEET | 1 IN. FRICTION LOSS POUNDS PER SQUARE INCH | 1-1/4 IN. VELOCITY FEET PER SECOND | 1-1/4 IN. FRICTION HEAD FEET | 1-1/4 IN. FRICTION LOSS POUNDS PER SQUARE INCH | 1-1/2 IN. VELOCITY FEET PER SECOND | 1-1/2 IN. FRICTION HEAD FEET | 1-1/2 IN. FRICTION LOSS POUNDS PER SQUARE INCH | 2 IN. VELOCITY FEET PER SECOND | 2 IN. FRICTION HEAD FEET | 2 IN. FRICTION LOSS POUNDS PER SQUARE INCH | 2-1/2 IN. VELOCITY FEET PER SECOND | 2-1/2 IN. FRICTION HEAD FEET | 2-1/2 IN. FRICTION LOSS POUNDS PER SQUARE INCH | 3 IN. VELOCITY FEET PER SECOND | 3 IN. FRICTION HEAD FEET | 3 IN. FRICTION LOSS POUNDS PER SQUARE INCH | 4 IN. VELOCITY FEET PER SECOND | 4 IN. FRICTION HEAD FEET | 4 IN. FRICTION LOSS POUNDS PER SQUARE INCH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.17 | 1.27 | .55 | .68 | .35 | .15 | .39 | .09 | .04 | .24 | .02 | .01 | | | | | | | | | | | | | | | |
| 2 | 2.34 | 4.60 | 1.99 | 1.37 | 1.25 | .54 | .78 | .32 | .14 | .49 | .09 | .04 | .32 | .05 | .02 | | | | | | | | | | | | |
| 5 | 5.84 | 25.04 | 10.84 | 3.42 | 6.81 | 2.96 | 1.95 | 1.73 | .75 | 1.22 | .55 | .24 | .79 | .18 | .08 | .50 | .07 | .03 | .35 | .02 | .01 | .24 | .02 | .01 | | | |
| 7 | 8.16 | 46.69 | 20.21 | 4.79 | 12.73 | 5.51 | 2.72 | 3.21 | 1.39 | 1.71 | 1.04 | .45 | 1.11 | .37 | .16 | .70 | .12 | .05 | .49 | .05 | .02 | .34 | .05 | .02 | | | |
| 10 | 11.70 | 90.37 | 39.12 | 6.85 | 24.62 | 10.66 | 3.89 | 6.24 | 2.70 | 2.45 | 2.01 | .87 | 1.58 | .69 | .30 | 1.00 | .23 | .10 | .70 | .09 | .04 | .49 | .07 | .03 | | | |
| | 6 IN. | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | | | | 10.30 | 52.18 | 22.59 | 5.84 | 13.21 | 5.72 | 3.67 | 4.27 | 1.85 | 2.37 | 1.48 | .64 | 1.49 | .49 | .21 | 1.05 | .21 | .09 | .73 | .14 | .06 | .49 | .02 | .01 |
| 20 | | | | | | | 7.78 | 22.50 | 9.74 | 4.90 | 7.28 | 3.15 | 3.16 | 2.52 | 1.09 | 1.99 | .83 | .36 | 1.41 | .35 | .15 | .97 | .23 | .10 | .65 | .05 | .02 |
| 25 | | | | | | | 9.73 | 34.00 | 14.72 | 6.12 | 11.02 | 4.77 | 3.95 | 3.79 | 1.64 | 2.49 | 1.25 | .54 | 1.76 | .53 | .23 | 1.22 | .30 | .13 | .81 | .07 | .03 |
| 30 | | | | | | | 11.70 | 47.66 | 20.63 | 7.34 | 15.43 | 6.68 | 4.74 | 5.31 | 2.30 | 2.99 | 1.73 | .75 | 2.11 | .74 | .32 | 1.46 | .38 | .17 | .98 | .12 | .05 |
| 35 | .54 | .02 | .01 | | | | | | | 8.57 | 20.54 | 8.89 | 5.53 | 7.09 | 3.07 | 3.49 | 2.31 | 1.00 | 2.46 | .99 | .43 | 1.70 | .53 | .23 | 1.14 | .14 | .06 |
| | | | | 8 IN. | | | | | | | | | | | | | | | | | | | | | | | |
| 40 | .62 | .05 | .02 | | | | | | | 9.79 | 26.29 | 11.38 | 6.32 | 9.06 | 3.92 | 3.98 | 2.93 | 1.27 | 2.81 | 1.27 | .55 | 1.94 | .65 | .28 | 1.30 | .18 | .08 |
| 45 | .69 | .06 | .02 | | | | | | | 11.00 | 32.71 | 14.16 | 7.11 | 11.27 | 4.88 | 4.48 | 3.67 | 1.59 | 3.16 | 1.57 | .68 | 2.19 | .79 | .34 | 1.46 | .23 | .10 |
| 50 | .77 | .07 | .03 | | | | | | | | | | 7.90 | 13.70 | 5.93 | 4.98 | 4.46 | 1.93 | 3.52 | 1.92 | .83 | 2.43 | 1.09 | .47 | 1.63 | .30 | .13 |
| 60 | .92 | .07 | .03 | .59 | .02 | .01 | | | | | | | 9.48 | 18.20 | 8.31 | 5.98 | 6.26 | 2.71 | 4.22 | 2.68 | 1.16 | 2.92 | 1.46 | .63 | 1.95 | .42 | .18 |
| 70 | 1.08 | .09 | .04 | .69 | .05 | .02 | | | | | | | 11.10 | 25.64 | 11.10 | 6.97 | 8.32 | 3.60 | 4.92 | 3.56 | 1.54 | 3.40 | 1.87 | .81 | 2.28 | .55 | .24 |
| | | | | | | | 10 IN. | | | | | | | | | | | | | | | | | | | | |
| 80 | 1.23 | .12 | .05 | .79 | .05 | .02 | | | | | | | | | | 7.97 | 10.65 | 4.61 | 5.62 | 4.55 | 1.97 | 3.89 | 2.31 | 1.00 | 2.60 | .69 | .30 |
| 90 | 1.39 | .14 | .06 | .89 | .07 | .03 | | | | | | | | | | 8.96 | 13.24 | 5.73 | 6.33 | 5.68 | 2.46 | 4.38 | 2.82 | 1.22 | 2.93 | .88 | .38 |
| 100 | 1.54 | .16 | .07 | .98 | .07 | .03 | | | | | | | | | | 9.96 | 16.10 | 6.97 | 7.03 | 6.91 | 2.99 | 4.86 | 4.25 | 1.84 | 3.25 | 1.06 | .46 |
| 125 | 1.92 | .25 | .11 | 1.23 | .09 | .04 | .79 | .02 | .01 | | | | | | | 12.50 | 24.26 | 10.50 | 8.79 | 10.44 | 4.52 | 6.08 | 5.91 | 2.56 | 4.06 | 1.59 | .69 |
| | | | | | | | | | | 12 IN. | | | 14 IN. | | | | | | | | | | | | | | |
| 150 | 2.31 | .37 | .16 | 1.48 | .12 | .05 | .96 | .05 | .02 | | | | | | | | | | 10.60 | 14.62 | 6.33 | 7.29 | 7.92 | 3.43 | 4.88 | 2.24 | .97 |
| 175 | 2.69 | .49 | .21 | 1.72 | .16 | .07 | 1.10 | .05 | .02 | | | | | | | | | | | | | 8.51 | 10.14 | 4.39 | 5.69 | 2.98 | 1.29 |
| 200 | 3.08 | .62 | .27 | 1.97 | .21 | .09 | 1.26 | .07 | .03 | | | | | | | | | | | | | 9.72 | 15.34 | 6.64 | 6.50 | 3.81 | 1.65 |
| 250 | 3.85 | .92 | .40 | 2.46 | .30 | .13 | 1.58 | .12 | .06 | .99 | .02 | .01 | | | | | | | | | | 12.20 | 21.51 | 9.31 | 8.13 | 5.75 | 2.49 |
| 300 | 4.62 | 1.32 | .57 | 2.95 | .44 | .19 | 1.89 | .14 | .06 | 1.19 | .05 | .02 | .94 | .03 | .01 | | | | | | | | | | 9.75 | 8.09 | 3.50 |
| | | | | | | | | | | | | | | | | 16 IN. | | | 18 IN. | | | | | | | | |
| 350 | 5.39 | 1.73 | .75 | 3.44 | .80 | .26 | 2.21 | .21 | .09 | 1.39 | .07 | .03 | 1.09 | .06 | .02 | | | | | | | | | | 11.40 | 10.72 | 4.64 |
| 400 | 6.16 | 2.24 | .97 | 3.94 | .74 | .32 | 2.52 | .25 | .11 | 1.59 | .07 | .03 | 1.25 | .05 | .02 | | | | | | | | | | | | |
| 450 | 6.93 | 2.27 | 1.20 | 4.43 | .92 | .40 | 2.84 | .32 | .14 | 1.78 | .09 | .04 | 1.40 | .07 | .03 | 1.11 | .02 | .01 | | | | | | | | | |
| 500 | 7.69 | 3.37 | 1.46 | 4.92 | 1.13 | .49 | 3.15 | .37 | .16 | 1.98 | .12 | .06 | 1.56 | .07 | .03 | 1.23 | .05 | .02 | | | | | | | | | |
| 600 | 9.23 | 4.71 | 2.04 | 5.90 | 1.59 | .69 | 3.78 | .53 | .23 | 2.38 | .16 | .07 | 1.87 | .09 | .04 | 1.48 | .06 | .02 | 1.17 | .02 | .01 | | | | | | |
| 700 | 10.80 | 6.28 | 2.72 | 6.89 | 2.13 | .92 | 4.41 | .72 | .31 | 2.78 | .23 | .10 | 2.19 | .14 | .06 | 1.72 | .07 | .03 | 1.36 | .05 | .02 | | | | | | |
| 800 | | | | 7.87 | 2.70 | 1.17 | 5.04 | .92 | .40 | 3.17 | .30 | .13 | 2.50 | .16 | .07 | 1.97 | .09 | .04 | 1.55 | .05 | .02 | | | | | | |
| 900 | | | | 8.85 | 3.37 | 1.46 | 5.67 | 1.13 | .49 | 3.57 | .37 | .16 | 2.81 | .21 | .09 | 2.21 | .12 | .05 | 1.75 | .07 | .03 | | | | | | |
| 1000 | | | | 9.84 | 4.11 | 1.78 | 6.30 | 1.39 | .60 | 3.97 | .44 | .19 | 3.12 | .25 | .11 | 2.45 | .14 | .06 | 1.94 | .07 | .03 | | | | | | |
| 2000 | | | | | | | 12.60 | 5.01 | 2.17 | 7.93 | 1.62 | .70 | 6.24 | .90 | .39 | 4.92 | .51 | .22 | 3.89 | .30 | .13 | | | | | | |
| 2500 | | | | | | | | | | 9.92 | 2.47 | 1.07 | 7.80 | 1.36 | .59 | 6.15 | .76 | .33 | 4.86 | .44 | .19 | | | | | | |
| 500 | | | | | | | | | | | | | | | | 12.30 | 2.77 | 1.20 | 9.72 | 1.57 | .68 | | | | | | |
| 7500 | | | | | | | | | | | | | | | | | | | 14.60 | 3.30 | 1.43 | | | | | | |

CORR TECH INCORPORATED

# PROLINE-POLYPROPYLENE 45 FLOW RATES

## TABLE 25

V = Velocity, Feet per Second; FH = Friction Head, Feet; FL = Friction Loss, Pounds per Square Inch

| Gallons per Minute | 2 IN. Velocity Feet per Second | 2 IN. Friction Head Feet | 2 IN. Friction Loss Pounds per Square Inch | 2-1/2 IN. Velocity Feet per Second | 2-1/2 IN. Friction Head Feet | 2-1/2 IN. Friction Loss Pounds per Square Inch | 3 IN. Velocity Feet per Second | 3 IN. Friction Head Feet | 3 IN. Friction Loss Pounds per Square Inch | 4 IN. Velocity Feet per Second | 4 IN. Friction Head Feet | 4 IN. Friction Loss Pounds per Square Inch | 6 IN. Velocity Feet per Second | 6 IN. Friction Head Feet | 6 IN. Friction Loss Pounds per Square Inch | 8 IN. Velocity Feet per Second | 8 IN. Friction Head Feet | 8 IN. Friction Loss Pounds per Square Inch | 10 IN. Velocity Feet per Second | 10 IN. Friction Head Feet | 10 IN. Friction Loss Pounds per Square Inch | 12 IN. Velocity Feet per Second | 12 IN. Friction Head Feet | 12 IN. Friction Loss Pounds per Square Inch | 14 IN. Velocity Feet per Second | 14 IN. Friction Head Feet | 14 IN. Friction Loss Pounds per Square Inch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | .38 | .02 | .01 | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | .53 | .07 | .03 | .37 | .02 | .01 | | | | | | | | | | | | | | | | | | | | | |
| 10 | .76 | .12 | .06 | .53 | .05 | .02 | .37 | .02 | .01 | | | | | | | | | | | | | | | | | | |
| 15 | 1.13 | .23 | .10 | .80 | .12 | .05 | .55 | .05 | .02 | | | | | | | | | | | | | | | | | | |
| 20 | 1.51 | .42 | .18 | 1.07 | .18 | .08 | .74 | .07 | .03 | .50 | .02 | .01 | | | | | | | | | | | | | | | |
| 25 | 1.89 | .62 | .27 | 1.34 | .28 | .12 | .92 | .12 | .05 | .62 | .05 | .02 | | | | | | | | | | | | | | | |
| 30 | 2.27 | .88 | .38 | 1.60 | .37 | .16 | 1.11 | .14 | .06 | .74 | .07 | .03 | | | | | | | | | | | | | | | |
| 35 | 2.64 | 1.18 | .51 | 1.87 | .51 | .22 | 1.29 | .21 | .09 | .87 | .07 | .03 | | | | | | | | | | | | | | | |
| 40 | 3.02 | 1.50 | .65 | 2.14 | .65 | .28 | 1.48 | .25 | .11 | .99 | .09 | .04 | | | | | | | | | | | | | | | |
| 45 | 3.40 | 1.87 | .81 | 2.40 | .81 | .35 | 1.66 | .32 | .14 | 1.12 | .12 | .05 | | | | | | | | | | | | | | | |
| 50 | 3.78 | 2.29 | .99 | 2.67 | .97 | .42 | 1.84 | .39 | .17 | 1.24 | .14 | .06 | | | | | | | | | | | | | | | |
| 60 | 4.53 | 3.19 | 1.38 | 3.20 | 1.36 | .59 | 2.22 | .55 | .24 | 1.49 | .21 | .09 | .70 | .02 | .01 | | | | | | | | | | | | |
| 70 | 5.29 | 4.25 | 1.84 | 3.74 | 1.82 | .79 | 2.59 | .74 | .32 | 1.74 | .28 | .12 | .82 | .05 | .02 | | | | | | | | | | | | |
| 80 | 6.04 | 5.43 | 2.35 | 4.27 | 2.38 | 1.03 | 2.96 | .95 | .41 | 1.99 | .37 | .16 | .94 | .07 | .03 | | | | | | | | | | | | |
| 90 | 6.80 | 6.77 | 2.93 | 4.80 | 2.91 | 1.26 | 3.33 | 1.20 | .52 | 2.23 | .44 | .19 | 1.05 | .07 | .03 | | | | | | | | | | | | |
| 100 | 7.55 | 8.22 | 3.56 | 5.34 | 3.53 | 1.53 | 3.69 | 1.43 | .62 | 2.48 | .55 | .24 | 1.17 | .09 | .04 | | | | | | | | | | | | |
| 125 | 9.44 | 12.43 | 5.38 | 6.68 | 5.41 | 2.34 | 4.62 | 2.17 | .94 | 3.10 | .83 | .36 | 1.46 | .14 | .06 | .93 | .02 | .01 | | | | | | | | | |
| 150 | 11.30 | | | 8.01 | 7.48 | 3.24 | 5.54 | 3.07 | 1.33 | 3.72 | 1.16 | .50 | 1.76 | .18 | .08 | 1.12 | .07 | .03 | | | | | | | | | |
| 175 | | | | 9.35 | 9.96 | 4.31 | 6.47 | 4.07 | 1.76 | 4.34 | 1.55 | .67 | 2.05 | .25 | .11 | 1.31 | .07 | .03 | .84 | .02 | .01 | | | | | | |
| 200 | | | | 10.68 | 12.77 | 5.53 | 7.39 | 5.22 | 2.26 | 4.96 | 1.99 | .86 | 2.34 | .32 | .14 | 1.50 | .07 | .03 | .96 | .05 | .02 | | | | | | |
| 250 | | | | | | | 9.24 | 7.88 | 3.41 | 6.20 | 2.98 | 1.29 | 2.93 | .49 | .21 | 1.87 | .12 | .05 | 1.20 | .05 | .02 | | | | | | |
| 300 | | | | | | | 11.08 | 11.04 | 4.78 | 7.44 | 4.18 | 1.81 | 3.51 | .67 | .29 | 2.24 | .16 | .07 | 1.44 | .07 | .03 | | | | | | |
| 350 | | | | | | | | | | 8.68 | 5.59 | 2.42 | 4.10 | .90 | .39 | 2.62 | .23 | .10 | 1.68 | .09 | .04 | 1.06 | .02 | .01 | | | |
| 400 | | | | | | | | | | 9.93 | 7.14 | 3.09 | 4.68 | 1.16 | .50 | 2.99 | .30 | .13 | 1.92 | .14 | .06 | 1.21 | .05 | .02 | | | |
| 450 | | | | | | | | | | 11.17 | 8.87 | 3.84 | 5.27 | 1.43 | .62 | 3.37 | .37 | .16 | 2.16 | .16 | .07 | 1.38 | .05 | .02 | 1.07 | .02 | |

| Gallons per Minute | 16 IN. Velocity Feet per Second | 16 IN. Friction Head Feet | 16 IN. Friction Loss Pounds per Square Inch | 18 IN. Velocity Feet per Second | 18 IN. Friction Head Feet | 18 IN. Friction Loss Pounds per Square Inch | 20 IN. Velocity Feet per Second | 20 IN. Friction Head Feet | 20 IN. Friction Loss Pounds per Square Inch | 24 IN. Velocity Feet per Second | 24 IN. Friction Head Feet | 24 IN. Friction Loss Pounds per Square Inch | 6 IN. Velocity Feet per Second | 6 IN. Friction Head Feet | 6 IN. Friction Loss Pounds per Square Inch | 8 IN. Velocity Feet per Second | 8 IN. Friction Head Feet | 8 IN. Friction Loss Pounds per Square Inch | 10 IN. Velocity Feet per Second | 10 IN. Friction Head Feet | 10 IN. Friction Loss Pounds per Square Inch | 12 IN. Velocity Feet per Second | 12 IN. Friction Head Feet | 12 IN. Friction Loss Pounds per Square Inch | 14 IN. Velocity Feet per Second | 14 IN. Friction Head Feet | 14 IN. Friction Loss Pounds per Square Inch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 500 | | | | | | | | | | | | | 5.85 | 1.73 | .75 | 3.74 | .44 | .19 | 2.40 | .21 | .09 | 1.51 | .07 | .03 | 1.19 | .05 | |
| 600 | 1.12 | .02 | .01 | | | | | | | | | | 7.02 | 2.43 | 1.05 | 4.49 | .60 | .26 | 2.87 | .28 | .12 | 1.81 | .09 | .04 | 1.43 | .05 | |
| 700 | 1.31 | .05 | .02 | | | | | | | | | | 8.19 | 3.23 | 1.40 | 5.24 | .83 | .36 | 3.35 | .35 | .15 | 2.11 | .12 | .05 | 1.66 | .07 | |
| 800 | 1.50 | .06 | .02 | | | | | | | | | | 9.36 | 4.13 | 1.79 | 5.98 | 1.04 | .45 | 3.83 | .46 | .20 | 2.41 | .14 | .06 | 1.90 | .09 | |
| 900 | 1.68 | .07 | .03 | 1.30 | .02 | .01 | | | | | | | 10.53 | 5.15 | 2.23 | 6.73 | 1.29 | .56 | 4.31 | .60 | .26 | 2.71 | .18 | .08 | 2.14 | .12 | |
| 1000 | 1.87 | .07 | .03 | 1.48 | .05 | .02 | 1.20 | .02 | .01 | | | | 11.70 | 6.26 | 2.71 | 7.48 | 1.67 | .68 | 4.79 | .72 | .31 | 3.02 | .23 | .10 | 2.38 | .14 | |
| 2000 | 3.74 | .25 | .11 | 2.96 | .14 | .06 | 2.39 | .09 | .04 | 1.51 | .02 | .01 | | | | 14.96 | 5.71 | 2.47 | 9.58 | 2.56 | 1.11 | 6.03 | .83 | .36 | 4.75 | .46 | |
| 2500 | 4.67 | .39 | .17 | 3.69 | .23 | .10 | 2.99 | .14 | .06 | 1.89 | .05 | .02 | | | | | | | 11.96 | 3.88 | 1.68 | 7.54 | 1.27 | .55 | 5.94 | .72 | |
| 5000 | 9.35 | 1.41 | .61 | 7.39 | .81 | .35 | 5.98 | .49 | .21 | 3.77 | .16 | .07 | | | | | | | | | | | | | 11.88 | 2.54 | |
| 7500 | 14.00 | .69 | .30 | 11.00 | 1.71 | .74 | 8.97 | 1.02 | .44 | 5.66 | .32 | .14 | | | | | | | | | | | | | | | |
| 10000 | | | | 14.80 | 2.91 | 1.26 | 12.00 | 1.73 | .76 | 7.55 | .55 | .24 | | | | | | | | | | | | | | | |

# SUPER/PROLINE - PVDF FLOW RATES

## TABLE 26

| GALLONS PER MINUTE | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH | VELOCITY FEET PER SECOND | FRICTION HEAD FEET | FRICTION LOSS POUNDS PER SQUARE INCH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1/2 IN. | | | 3/4 IN. | | | 1 IN. | | | 1-1/4 IN. | | | 1-1/2 IN. | | | 2 IN. | | | 2-1/2 IN. | | | 3 IN. | | | 4 IN. | | |
| 1 | 1.00 | .88 | .38 | .58 | .23 | .10 | .36 | .07 | .03 | .21 | .02 | .01 | | | | | | | | | | | | | | | |
| 2 | 2.00 | 3.14 | 1.36 | 1.17 | .85 | .37 | .71 | .25 | .11 | .42 | .07 | .03 | .27 | .02 | .01 | | | | | | | | | | | | |
| 5 | 5.00 | 17.14 | 7.42 | 2.92 | 4.64 | 2.01 | 1.78 | 1.39 | .60 | 1.06 | .39 | .17 | .67 | .14 | .06 | .41 | .06 | .02 | | | | | | | | | |
| 7 | 7.00 | 31.88 | 13.80 | 4.09 | 8.64 | 3.74 | 2.49 | 2.58 | 1.11 | 1.49 | .74 | .32 | .94 | .23 | .10 | .57 | .07 | .03 | .38 | .02 | .01 | | | | | | |
| 10 | 10.00 | 61.91 | 26.80 | 5.84 | 16.72 | 7.24 | 3.55 | 4.99 | 2.16 | 2.12 | 1.43 | .62 | 1.35 | .46 | .20 | .81 | .14 | .06 | .54 | .05 | .02 | .40 | .02 | .01 | | | |
| 15 | | | | 8.76 | 35.34 | 15.30 | 5.33 | 10.56 | 4.57 | 3.19 | 3.03 | 1.31 | 2.02 | .99 | .43 | 1.22 | .30 | .13 | .81 | .12 | .05 | .60 | .05 | .02 | | | |
| 20 | | | | 11.70 | 60.29 | 26.10 | 7.10 | 17.99 | 7.79 | 4.25 | 5.17 | 2.24 | 2.69 | 1.71 | .74 | 1.62 | .49 | .21 | 1.07 | .18 | .08 | .79 | .09 | .04 | .50 | .02 | .01 |
| 25 | | | | | | | 8.88 | 27.28 | 11.80 | 5.31 | 7.78 | 3.37 | 3.37 | 2.58 | 1.11 | 2.03 | .74 | .32 | 1.34 | .28 | .12 | .99 | .14 | .06 | .62 | .05 | .02 |
| 30 | | | | | | | 10.70 | 38.12 | 16.50 | 6.37 | 10.93 | 4.73 | 4.04 | 3.60 | 1.56 | 2.43 | 1.04 | .45 | 1.61 | .39 | .17 | 1.19 | .18 | .08 | .74 | .07 | .03 |
| 35 | | | | | | | | | | 7.43 | 14.55 | 6.30 | 4.71 | 4.80 | 2.08 | 2.84 | 1.39 | .60 | 1.88 | .51 | .22 | 1.39 | .25 | .11 | .87 | .07 | .03 |
| | | 16 IN. | | | | | | | | | | | | | | | | | | | | | | | | | |
| 40 | | | | | | | | | | 8.50 | 18.62 | 8.06 | 5.38 | 6.14 | 2.66 | 3.24 | 1.80 | .78 | 2.15 | .67 | .29 | 1.59 | .32 | .14 | .99 | .09 | .04 |
| 45 | | | | | | | | | | 9.56 | 23.10 | 10.00 | 6.06 | 7.65 | 3.31 | 3.65 | 2.22 | .96 | 2.42 | .83 | .36 | 1.79 | .39 | .17 | 1.12 | .12 | .05 |
| 50 | .59 | .02 | .01 | | | | | | | 10.62 | 28.18 | 12.20 | 6.73 | 9.29 | 4.02 | 4.05 | 2.70 | 1.17 | 2.69 | .99 | .43 | 1.99 | .49 | .21 | 1.24 | .14 | .06 |
| 60 | .70 | .05 | .02 | | | | | | | | | | 8.08 | 13.01 | 5.63 | 4.86 | 3.79 | 1.64 | 3.22 | 1.39 | .60 | 2.38 | .67 | .29 | 1.49 | .21 | .09 |
| 70 | .82 | .05 | .02 | | | | | | | | | | 9.42 | 17.30 | 7.49 | 5.67 | 5.04 | 2.18 | 3.76 | 1.85 | .80 | 2.78 | .90 | .39 | 1.74 | .28 | .12 |
| | | | | | 18 IN. | | | 10 IN. | | | | | | | | | | | | | | | | | | | |
| 80 | .94 | .07 | .03 | | | | | | | | | | 10.80 | 22.18 | 9.60 | 6.48 | 6.44 | 2.79 | 4.30 | 2.38 | 1.03 | 3.18 | 1.13 | .49 | 1.99 | .37 | .16 |
| 90 | 1.05 | .07 | .03 | | | | | | | | | | | | | 7.29 | 8.02 | 3.47 | 4.83 | 2.96 | 1.28 | 3.57 | 1.41 | .61 | 2.23 | .44 | .19 |
| 100 | 1.17 | .08 | .04 | .75 | .02 | .01 | | | | | | | | | | 8.10 | 9.75 | 4.22 | 5.37 | 3.58 | 1.55 | 4.96 | 1.71 | .74 | 2.48 | .55 | .24 |
| 125 | 1.46 | .14 | .06 | .93 | .05 | .02 | | | | | | | | | | 10.13 | 14.74 | 6.38 | 6.71 | 5.43 | 2.35 | 5.96 | 2.61 | 1.13 | 3.10 | .83 | .36 |
| 150 | 1.76 | .18 | .08 | 1.12 | .07 | .03 | | | | | | | | | | | | | 8.06 | 7.60 | 3.29 | 6.95 | 3.65 | 1.58 | 3.72 | 1.16 | .50 |
| | | | | | | | | | | | 12 IN. | | | | | | | | | | | | | | | | |
| 175 | 2.05 | .23 | .10 | 1.31 | .07 | .03 | .96 | .02 | .01 | | | | | | | | | | 9.40 | 10.09 | 4.37 | 7.94 | 4.85 | 2.10 | 4.34 | 1.96 | .85 |
| 200 | 2.34 | .32 | .14 | 1.50 | .09 | .04 | 1.20 | .05 | .02 | | | | | | | | | | 10.70 | 12.94 | 5.60 | 9.93 | 6.19 | 2.68 | 4.96 | 2.98 | 1.29 |
| 250 | 2.93 | .49 | .21 | 1.87 | .16 | .07 | 1.44 | .07 | .03 | | | | | | | | | | | | | 11.90 | 20.93 | 9.06 | 6.20 | 4.18 | 1.81 |
| 300 | 3.51 | .67 | .29 | 2.24 | .23 | .10 | 1.68 | .09 | .04 | | | | | | | | | | | | | | | | 7.44 | 5.57 | 2.41 |
| 350 | 4.10 | .90 | .39 | 2.62 | .30 | .13 | 1.92 | .14 | .06 | 1.06 | .02 | .01 | | | | | | | | | | | | | 8.68 | 7.14 | 3.09 |
| 400 | 4.68 | 1.13 | .49 | 2.99 | .37 | .16 | 2.16 | .16 | .07 | 1.21 | .05 | .02 | | | | | | | | | | | | | 9.93 | 8.87 | 3.84 |
| 450 | 5.27 | 1.41 | .61 | 3.37 | .46 | .20 | 2.40 | .18 | .08 | 1.36 | .05 | .02 | | | | | | | | | | | | | 11.20 | 10.79 | 4.67 |
| 500 | 5.85 | 1.73 | .75 | 3.74 | .58 | .25 | 2.67 | .28 | .12 | 1.51 | .07 | .03 | | | | | | | | | | | | | | | |
| 600 | 7.02 | 2.43 | 1.05 | 4.49 | .81 | .35 | 3.35 | .37 | .16 | 1.81 | .07 | .03 | | | | | | | | | | | | | | | |
| 700 | 8.19 | 3.23 | 1.40 | 5.24 | 1.09 | .47 | 3.83 | .46 | .20 | 2.11 | .12 | .05 | | | | | | | | | | | | | | | |
| 800 | 9.36 | 4.13 | 1.79 | 5.98 | 1.39 | .60 | 4.31 | .60 | .26 | 2.41 | .14 | .06 | | | | | | | | | | | | | | | |
| 900 | 10.50 | 5.15 | 2.23 | 6.73 | 1.73 | .75 | 4.79 | .72 | .31 | 2.71 | .18 | .08 | | | | | | | | | | | | | | | |
| 1000 | | | | 7.48 | 2.10 | .91 | 9.58 | 2.56 | 1.11 | 3.02 | .23 | .10 | | | | | | | | | | | | | | | |
| 2000 | | | | 15.00 | 7.60 | 3.29 | 12.00 | 3.88 | 1.68 | 6.03 | .83 | .36 | | | | | | | | | | | | | | | |
| 2500 | | | | | | | | | | 7.54 | 1.27 | .55 | | | | | | | | | | | | | | | |
| 5000 | | | | | | | | | | 15.10 | 4.55 | 1.97 | | | | | | | | | | | | | | | |

# CARRYING CAPACITY & FRICTION LOSS

## TABLE 27

### EQUIVALENT LENGTH OF THERMOPLASTIC PIPE IN FEET

| | | | | ¼" | ½" | ¾" | 1" | 1¼" | 1½" | 2" | 2½" | 3" | 4" | 6" | 8" | 10" | 12" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GLOBE VALVES | Conventional | With no obstruction in flat, bevel, or plug type seat | Fully Open | 10.3 | 17.6 | 23.3 | 29.7 | 39.1 | 45.6 | 58.6 | 69.95 | 86.9 | 114.1 | 171.8 | 226.1 | 283.9 | 338.2 |
| | | With wing or pin guided disc | Fully Open | 13.7 | 23.3 | 30.9 | 39.3 | 51.8 | 60.4 | 77.5 | 92.6 | 115.1 | 151.0 | 227.4 | 298.3 | 375.8 | 447.7 |
| | Y-Pattern | (No obstruction in flat, bevel or plug type seat) —With stem 60 degrees from run of pipe line | Fully Open | 5.3 | 9.1 | 12.0 | 15.3 | 20.1 | 23.5 | 30.1 | 36.0 | 44.7 | 58.7 | 88.4 | 116.4 | 146.1 | 174.1 |
| | | —With stem 45 degrees from run of pipe line | Fully Open | 4.4 | 7.5 | 10.0 | 12.7 | 16.7 | 19.5 | 25.0 | 29.8 | 37.1 | 48.6 | 73.3 | 96.4 | 121.1 | 144.3 |
| ANGLE VALVES | Conventional | With no obstruction in flat, bevel, plug type seat | Fully Open | 4.4 | 7.5 | 10.0 | 12.7 | 16.7 | 19.5 | 25.0 | 29.8 | 37.1 | 48.6 | 73.3 | 96.4 | 121.1 | 144.3 |
| | | With wing or pin guided disc | Fully Open | 6.1 | 10.4 | 13.7 | 17.5 | 23.0 | 26.8 | 34.5 | 41.2 | 51.1 | 67.1 | 101.1 | 133.0 | 167.0 | 199.0 |
| GATE VALVES | Conventional Wedge Disc, Dbl Disc, or Plug Disc | | Fully Open | 0.4 | 0.7 | 0.9 | 1.1 | 1.5 | 1.7 | 2.2 | 2.7 | 3.3 | 4.4 | 6.6 | 8.6 | 10.9 | 12.9 |
| | | | Three-Quarters Open | 1.1 | 1.8 | 2.4 | 3.1 | 4.0 | 4.7 | 6.0 | 7.2 | 8.9 | 11.7 | 17.7 | 23.3 | 29.2 | 34.8 |
| | | | One-Half Open | 4.9 | 8.3 | 11.0 | 14.0 | 18.4 | 21.5 | 27.6 | 32.9 | 40.9 | 53.7 | 80.9 | 106.4 | 133.6 | 159.2 |
| | | | One-Quarter Open | 27.3 | 45.7 | 61.8 | 78.7 | 103.5 | 120.8 | 155.0 | 185.2 | 230.1 | 302.0 | 454.9 | 598.6 | 751.5 | 895.4 |
| BALL VALVES | Full Port Design | | Fully Open | Same as an equivalent of Sch. 80 Pipe | | | | | | | | | | | | | |
| FITTINGS | 90° Standard Elbow | | | 0.9 | 1.6 | 2.1 | 2.6 | 3.5 | 4.0 | 5.5 | 6.2 | 7.7 | 10.1 | 15.2 | 20.0 | 25.1 | 29.8 |
| | 45° Standard Elbow | | | 0.5 | 0.8 | 1.1 | 1.4 | 1.8 | 2.1 | 2.8 | 3.3 | 4.1 | 5.4 | 8.1 | 10.6 | 13.4 | 15.9 |
| | 90° Long Radius Elbow | | | 0.6 | 1.0 | 1.4 | 1.7 | 2.3 | 2.7 | 4.3 | 5.1 | 6.3 | 8.3 | 12.5 | 16.5 | 20.7 | 24.7 |
| | 90° Street Elbow | | | 1.5 | 2.6 | 3.4 | 4.4 | 5.8 | 6.7 | 8.6 | 10.3 | 12.8 | 16.8 | 25.3 | 33.3 | 41.8 | 49.78 |
| | 45° Street Elbow | | | 0.8 | 1.3 | 1.8 | 2.3 | 3.0 | 3.5 | 4.5 | 5.4 | 6.6 | 8.7 | 13.1 | 17.3 | 21.7 | 25.9 |
| | Square Corner Elbow | | | 1.7 | 3.0 | 3.9 | 5.0 | 6.5 | 7.6 | 9.8 | 11.7 | 14.6 | 19.1 | 28.8 | 37.9 | 47.6 | 56.7 |
| | Standard Tee | With Flow through run | | 0.6 | 1.0 | 1.4 | 1.7 | 2.3 | 2.7 | 4.3 | 5.1 | 6.3 | 8.3 | 12.5 | 16.5 | 20.7 | 24.7 |
| | | With Flow through branch | | 1.8 | 4.0 | 5.1 | 6.0 | 6.9 | 8.1 | 12 | 14.3 | 16.3 | 22.1 | 32.2 | 39.9 | 50.1 | 59.7 |

# SYSTEMS ENGINEERING DATA
## FOR THERMOPLASTIC PIPING

Water Velocity = 5 feet per second
Static Pressure in System = 300 psi
Total System Pressure = Static Pressure + Surge Pressure:

$$
\begin{aligned}
Pt &= P \times Ps \\
&= 300 + 5 \times 26.2 \\
&= 431.0 \text{ psi}
\end{aligned}
$$

Maximum circumferential stress is calculated from a variation of the ISO Equation:

$$S = \frac{Pt\,(Do\text{-}t)}{2t} = \frac{431(1.660\text{-}.191)}{2x.191} = 1657.4$$

$$\text{Safety Factor} = \frac{\text{20 second strength}}{\text{Maximum stress}} = \frac{8470}{1657} = 5.11$$

Table 28 gives the results of safety factor calculations based upon service factors of 0.5 and 0.4 for the 1-1/4" PVC Schedule 80 pipe of the example shown above using the full pressure rating calculated from the listed hydrostatic design-stress.

In each case, the hydrostatic design basis = 4000 psi, and the water velocity = 5 feet per second.

Comparing safety factor for this 1-1/4" Schedule 80 pipe at different service factors, it is instructive to note that changing from a service factor of 0.5 to a more conservative 0.4 increases the safety factor only by 16%.

$$100 \times \left(1 - \frac{3.38}{4.03}\right) = 16\%$$

In the same way, changing the service factor from 0.4 to 0.35 increases the safety factor only by 9%. Changing the service factor from 0.5 to 0.35 increases the safety factor by 24%. From these comparisons it is obvious that little is to be gained in safety from surge pressures by fairly large changes in the hydrostatic design stress resulting from choice of more conservative service factors.

### Table 28
**SAFETY FACTORS VS. SERVICE FACTORS - PVC TYPE 1 THERMOPLASTIC PIPE**

| PIPE CLASS | SERVICE FACTOR | HDS PSI | PRESSURE RATING PSI | SURGE PRESSURE AT 5 FT/SEC | MAXIMUM PRESSURE PSI | MAXIMUM STRESS PSI | SAFETY FACTOR |
|---|---|---|---|---|---|---|---|
| 1-1/4" Sch. 80 | 0.5 | 2000 | 520 | 131.0 | 651.0 | 2503.5 | 3.38 |
| 1-1/4" Sch. 80 | 0.4 | 1600 | 416 | 131.0 | 547.0 | 2103.5 | 4.03 |

Pressure rating values are for PVC pipe, and for most sizes are calculated from the experimentally determined long-term strength of PVC extrusion compounds. Because molding compounds may differ in long term strength and elevated temperature properties from pipe compounds, piping systems consisting of extruded pipe and molded fittings may have lower pressure ratings than those shown here, particularly at the higher temperatures. Caution should be exercised in design operating above 100°F.

## FRICTION LOSS CHARACTERISTICS OF WATER THROUGH PLASTIC PIPE, FITTINGS AND VALVES

**INTRODUCTION**
A major advantage of thermoplastic pipe is its exceptionally smooth inside surface area, which reduces friction loss compared to other materials.

Friction loss in plastic pipe remains constant over extended periods of time, in contrast to some other materials where the value of the Hazen and Williams C factor (constant for inside roughness) decreases with time. As a result, the flow capacity of thermoplastics is greater under fully turbulent flow conditions like those encountered in water service.

**C FACTORS**
Tests made both with new pipe and pipe that had been in service revealed C factor values for plastic pipe between 160 and 165. Thus, the factor of 150 recommended for water in the equation below is on the conservative side. On the other hand, the C factor for metallic pipe varies from 65 to 125, depending upon age and interior roughening. The obvious benefit is that with plastic systems it is often possible to use a smaller diameter pipe and still obtain the same or even lower friction losses.

The most significant losses occur as a result of the length of pipe and fittings and depend on the following factors.

1. Flow velocity of the fluid.
2. The type of fluid being transmitted, especially its viscosity.
3. Diameter of the pipe.
4. Surface roughness of interior of the pipe.
5. The length of the pipeline.

**Hazen and Williams Formula**
The head losses resulting from various water flow rates in plastic piping may be calculated by means of the Hazen and Williams formula:

$$f = 0.2083\left(\frac{100}{C}\right)^{1.852} \times \frac{q^{1.852}}{Di^{4.8655}}$$

$$= .0983\,\frac{q^{1.852}}{Di^{4.8655}} \quad \text{for } C = 150$$

$$P = .4335f$$

**Where:**

f = Friction Head in ft. of Water per 100 ft of Pipe
P = Pressure Loss in psi per 100 ft. of Pipe
Di = Inside Diameter of Pipe, in.
q = Flow Rate in U.S. gal/min
C = Constant for Inside Roughness (C equals 150 thermoplastics)

# SYSTEMS ENGINEERING DATA
## FOR THERMOPLASTIC PIPING

### FLOW OF FLUIDS AND HEAD LOSS CALCULATIONS

Tables, flow charts, or a monograph may be used to assist in the design of a piping system depending upon the accuracy desired. In computing the internal pressure for a specified flow rate, changes in static head loss due to restrictions (valves, orifices, etc.) as well as flow head loss must be considered.

The formula in Table 29 can be used to determine the head loss due to flow if the fluid viscosity and density and flow rate are known. The head loss in feet of fluid is given by:

$$h = :186 \frac{fLV}{d^2}$$

f, the friction factor, is a function of the Reynolds number, a dimensionless parameter which indicates the degree of turbulence.

The Reynolds number is defined as: $f = \frac{dVW}{12U}$

Figure 7 below shows the relationship between the friction factor, and the Reynolds number, R. It is seen that three distinct flow zones exist. In the laminar flow zone, from Reynolds numbers 0 to 2000, the friction factor is given by the equation:

$$f = \frac{64}{R}$$

Substituting this in the equation for the head loss, the formula for laminar flow becomes:

$$h = \frac{143\ ULV}{Wd^2}$$

Flow in the critical zone, Reynolds numbers 2000 to 4000, is unstable and a surging type of flow exists. Pipe lines should be designed to avoid operation in the critical zone since head losses cannot be calculated accurately in this zone. In addition, the unstable flow results in pressure surges and water hammer which may be excessively high. In the transition zone, the degree of turbulence increases as the Reynolds number increases. However, due to the smooth inside surface of plastic pipe, complete turbu-lence rarely exists. Most pipe systems are designed to operate in the transition zone.

**TABLE 29**

**FORMULAS FOR HEAD LOSS CALCULATIONS**

$$R = \frac{dVw}{12\ u}$$

$$R = \frac{3160\ G}{kd}$$

$$R = \frac{2220B}{kd}$$

$$R = 22{,}735 \frac{Qw}{zd}$$

When R = 4000:

$$h = .186 \frac{fLV^2}{d}$$

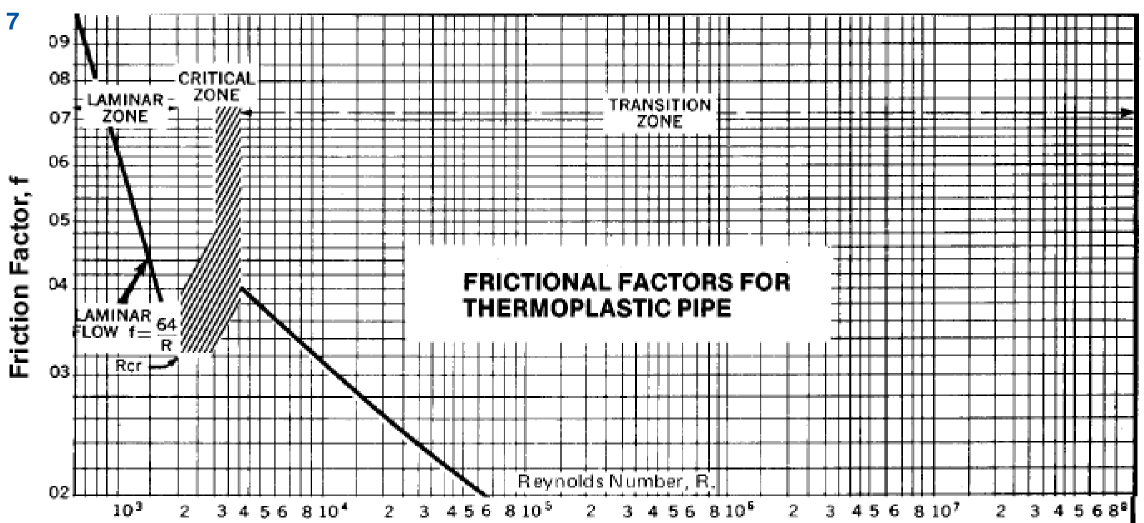
$$h = .0311 \frac{fLG^2}{d^5}$$

$$P = \frac{fLB^2\ W}{9450d^2}$$

$$P = 43.5 \frac{fLQ^2\ W}{d^5}$$

| SYMBOL | QUANTITY | UNITS |
|---|---|---|
| B | flow rate | barrels/hour |
| d | inside diameter | inches |
| f | friction factor | dimensionless |
| G | flow rate | gallons/minute |
| h | head loss | feet of fluid |
| k | kinematic viscosity | centistokes |
| L | length of pipe | feet |
| P | pressure drop | $lbs/in^2$ |
| Q | flow rate | $ft^3$/sec. |
| R | Reynolds number | dimensionless |
| u | absolute viscosity | lb/ft-sec. |
| V | velocity | ft./sec. |
| w | density | $lbs/ft^3$ |
| z | absolute viscosity | centipoises |

**Fig. 7**




## MANNING EQUATION

The Manning roughness factor is another equation used to determine friction loss in hydraulic flow. Like the Hazen-Williams C factor, the Manning "n" factor is an empirical number that defines the interior wall smoothness of a pipe. PVC pipe has an "n" value that ranges from 0.008 to 0.012 from laboratory testing. Comparing with cast iron with a range of 0.011 to 0.015, PVC is at least 37.5 percent more efficient, or another way to express this would be to have equal flow with the PVC pipe size being one-third smaller than the cast iron. The following table gives the range of "n" value for various piping materials.

**TABLE 30**

| PIPE MATERIAL | "n" RANGE |
|---|---|
| CAST IRON | 0.011-0.015 |
| WROUGHT IRON (BLACK) | 0.012-0.015 |
| WROUGHT IRON (GALVANIZED) | 0.013-0.017 |
| SMOOTH BRASS | 0.009-0.013 |
| GLASS | 0.009-0.013 |
| RIVETED AND SPIRAL STEEL | 0.013-0.017 |
| CLAY DRAINAGE TILE | 0.011-0.017 |
| CONCRETE | 0.012-0.016 |
| CONCRETE LINED | 0.012-0.018 |
| CONCRETE-RUBBLE SURFACE | 0.017-0.030 |
| PVC | 0.008-0.012 |
| WOOD | 0.010-0.013 |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# SYSTEMS ENGINEERING DATA
## FOR THERMOPLASTIC PIPING

**COMPENSATING FOR THERMAL EXPANSION**
Thermoplastics exhibit a relatively high coefficient of thermal expansion (see Relative Properties Chart page 13 and 14)—as much as ten times that of steel. When designing plastic piping systems, expansion of long runs must be considered. Installation temperature versus working temperature or summer to winter extremes must be considered.

One area where extreme temperature variations can occur is in a polypropylene drain application. Temperature in waste systems depends on quantity and temperature of the waste liquids discharged into the system. In general, the quantities of wastes discharged through waste systems from laboratories in educational institutions will be relatively small (a few gallons at a time), while industrial laboratories and processing systems may discharge large quantities of very hot or very cold water.

There are several methods of controlling or compensating for thermal expansion of piping systems: taking advantage of off-sets and change of direction in the piping and expansion joints.

1. Offsets—Most piping systems have occasional changes in direction which will allow the thermally induced length changes to be taken up in offsets of the pipe beyond the bends. Where this method is employed, the pipe must be able to float except at anchor points.

2. Expansion Joints—Expansion joints for pressure applications are generally expensive.

The expansion loops and offset tables as shown on following pages have been generated for elevated temperatures as noted beneath the table. If the change in temperature and working temperatures are lower than those used to derive expansion loop and offset tables, the figures will be conservative. These tables can be generated for any temperature and expansion by using the following equations and the modulus of elasticity and working stress at the given temperature.

Assume the pipe to be a cantilevered beam. Deflection of a cantilevered beam is $\Delta L$.

$$\Delta L = \frac{Pl^3}{3EI}$$

Where:
- P = Force Causing the Pipe to Deflect
- $l$ = Length of Pipe that is Deflected, in.
- E = Modulus of Elasticity at System Temperature, psi
- I = Moment of Inertia
- e = Coefficient of Thermal Expansion, in./in. °F
- $\Delta T$ = Change of Temperature, °F
- $\Delta L$ = Change in Length = $12e(\Delta T)$, in.
- L = Length of Straight Pipe Run, ft.

Maximum stress equation:

$$S = \frac{Mc}{I}$$

Where:
- S = Working Stress at the System Temperature, psi
- M = Bending Moment, lb. ft. = $Pl$
- c = Pipe O.D./2, in.
- I = Moment of Inertia

By substituting in maximum stress equation:

$$S = \frac{PlD}{2I}$$

Rearranging:

$$P = \frac{2SI}{lD}$$

Rearranging deflection equation:

$$P = \frac{3EI(\Delta L)}{l^3}$$

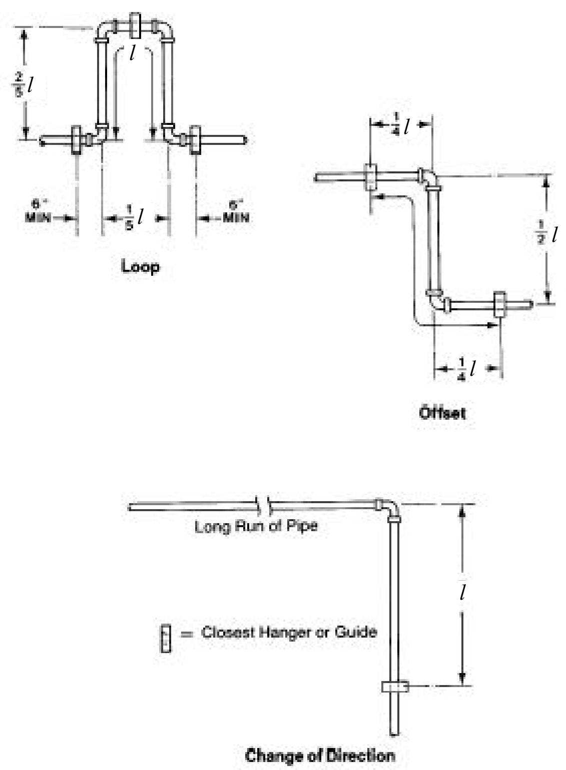
Equating both equations:

$$\frac{2SI}{lD} = \frac{3EI(\Delta L)}{l^3}$$

Solving for loop length $l$:

$$l = \left(\frac{3ED(\Delta L)}{2S}\right)^{1/2}$$

**FIGURE 4**
Expansion Loop and Offset Configurations for Thermoplastics.



# SYSTEMS ENGINEERING DATA

## FOR THERMOPLASTIC PIPING

**THERMAL EXPANSION COMPENSATION**

The change in length of Thermoplastic pipe with temperature variation should always be considered when installing pipe lines and provisions made to compensate for this change in length. The following tables have been prepared to assist you in determining this expansion.

**TABLE 31 - THERMAL EXPANSION ΔL(in.) — PVC Type 1**

| TEMP. CHANGE ΔT°F | LENGTH OF RUN IN FEET | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 30 | .11 | .22 | .32 | .43 | .54 | .65 | .76 | .86 | .97 | 1.08 |
| 40 | .14 | .29 | .43 | .58 | .72 | .86 | 1.01 | 1.15 | 1.30 | 1.44 |
| 50 | .18 | .36 | .54 | .72 | .90 | 1.08 | 1.26 | 1.40 | 1.62 | 1.80 |
| 60 | .22 | .43 | .65 | .86 | 1.08 | 1.30 | 1.51 | 1.73 | 1.94 | 2.16 |
| 70 | .25 | .50 | .76 | 1.01 | 1.26 | 1.51 | 1.76 | 2.02 | 2.27 | 2.52 |
| 80 | .29 | .58 | .86 | 1.15 | 1.44 | 1.73 | 2.02 | 2.30 | 2.59 | 2.88 |
| 90 | .32 | .65 | .97 | 1.30 | 1.62 | 1.94 | 2.27 | 2.59 | 2.92 | 3.24 |
| 100 | .36 | .72 | 1.03 | 1.44 | 1.80 | 2.16 | 2.52 | 2.88 | 3.24 | 3.60 |

**Example:** Highest temperature expected— 120°F
Lowest temperature expected— 50°F
Total Change (ΔT) 70°F
Length of run—40 feet
From 70°F row on PVC chart read 1.01 in. length change (ΔL)
NOTE: Table is based on: $\Delta L = 12eL(\Delta T)$

Where: e = Coefficient of Thermal Expansion
= $3.0 \times 10^{-5}$ in./in.°F
L = Length of Run
ΔT = Temperature Change

**TABLE 32 - THERMAL EXPANSION ΔL(in.) — CPVC Schd. 80**

| TEMP. CHANGE ΔT°F | LENGTH OF RUN IN FEET | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 20 | .09 | .18 | .27 | .36 | .46 | .55 | .64 | .73 | .82 | .91 |
| 30 | .14 | .27 | .41 | .55 | .68 | .82 | .96 | 1.09 | 1.23 | 1.37 |
| 40 | .18 | .36 | .55 | .73 | .91 | 1.09 | 1.28 | 1.46 | 1.64 | 1.82 |
| 50 | .23 | .46 | .68 | .91 | 1.14 | 1.37 | 1.60 | 1.82 | 2.05 | 2.28 |
| 60 | .27 | .55 | .82 | 1.09 | 1.37 | 1.64 | 1.92 | 2.19 | 2.46 | 2.74 |
| 70 | .32 | .64 | .96 | 1.28 | 1.60 | 1.92 | 2.23 | 2.55 | 2.87 | 3.19 |
| 80 | .36 | .73 | 1.09 | 1.46 | 1.82 | 2.19 | 2.55 | 2.92 | 3.28 | 3.65 |
| 90 | .41 | .82 | 1.23 | 1.64 | 2.05 | 2.46 | 2.87 | 3.28 | 3.69 | 4.10 |
| 100 | .46 | .91 | 1.37 | 1.82 | 2.28 | 2.74 | 3.19 | 3.65 | 4.10 | 4.56 |

**TABLE 33 - THERMAL EXPANSION ΔL(in.) — Copoly. Poly.**

| TEMP. CHANGE ΔT°F | LENGTH OF RUN IN FEET | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 20 | .15 | .29 | .44 | .59 | .73 | .88 | 1.02 | 1.17 | 1.32 | 1.46 |
| 30 | .22 | .44 | .66 | .88 | 1.10 | 1.32 | 1.54 | 1.76 | 1.98 | 2.20 |
| 40 | .29 | .59 | .88 | 1.17 | 1.46 | 1.76 | 2.05 | 2.34 | 2.64 | 2.93 |
| 50 | .37 | .73 | 1.10 | 1.46 | 1.83 | 2.20 | 2.56 | 2.93 | 3.29 | 3.66 |
| 60 | .44 | .88 | 1.32 | 1.76 | 2.20 | 2.64 | 3.07 | 3.51 | 3.95 | 4.39 |
| 70 | .51 | 1.02 | 1.54 | 2.05 | 2.56 | 3.07 | 3.59 | 4.10 | 4.61 | 5.12 |
| 80 | .59 | 1.17 | 1.76 | 2.34 | 2.93 | 3.51 | 4.10 | 4.68 | 5.27 | 5.86 |
| 90 | .66 | 1.32 | 1.98 | 2.69 | 3.29 | 3.95 | 4.61 | 5.27 | 5.93 | 6.59 |
| 100 | .73 | 1.46 | 2.20 | 2.93 | 3.66 | 4.39 | 5.12 | 5.86 | 6.59 | 7.32 |

**TABLE 34 - THERMAL EXPANSION ΔL(in.) — PVDF Schedule 80 and Pur-Flo**

| TEMP. CHANGE ΔT°F | LENGTH OF RUN IN FEET | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 20 | .19 | .38 | .58 | .77 | .96 | 1.15 | 1.34 | 1.54 | 1.73 | 1.92 |
| 40 | .38 | .77 | 1.15 | 1.54 | 1.92 | 2.30 | 2.69 | 3.07 | 3.46 | 3.84 |
| 50 | .48 | .96 | 1.44 | 1.92 | 2.40 | 2.88 | 3.36 | 3.84 | 4.32 | 4.80 |
| 60 | .58 | 1.15 | 1.73 | 2.30 | 2.88 | 3.46 | 4.03 | 4.61 | 5.18 | 5.76 |
| 70 | .67 | 1.34 | 2.02 | 2.69 | 3.36 | 4.03 | 4.70 | 5.38 | 6.05 | 6.72 |
| 80 | .77 | 1.54 | 2.30 | 3.07 | 3.84 | 4.61 | 5.38 | 6.14 | 6.91 | 7.68 |
| 90 | .86 | 1.73 | 2.59 | 3.46 | 4.32 | 5.18 | 6.05 | 6.91 | 7.78 | 8.64 |
| 100 | .96 | 1.92 | 2.88 | 3.84 | 4.80 | 5.76 | 6.72 | 7.68 | 8.64 | 9.60 |

The following expansion loop and offset lengths have been calculated based on stress and modulus of elasticities at the temperature shown below each chart. To calculate the proper length of loop at other temperatures the following formula may be used:

$$l \sqrt{\frac{3E\,(O.D.)\,\Delta L}{2S}}$$

Where:
ΔT = Temperature Change in °F
S = Thermal Stress, psi = e(ΔT)E
E = Modulus of Elasticity (found in relative properties chart on pages 482 and 483)
ΔL = Length Change in inches at ΔT (see tables above)
$l$ = Total Length of Loop or Offset

**TABLE 35 - EXPANSION LOOPS AND OFFSET LENGTHS, PVC Type 1, Schedule 40 and 80**

| NOM. PIPE SIZE | AVERAGE O.D. | LENGTH OF RUN IN FEET | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| | | LENGTH OF LOOP "$l$" IN INCHES | | | | | | | | | |
| 1/2 | .840 | 11 | 15 | 19 | 22 | 24 | 27 | 29 | 31 | 32 | 34 |
| 3/4 | 1.050 | 12 | 17 | 21 | 24 | 27 | 30 | 32 | 34 | 36 | 38 |
| 1 | 1.315 | 14 | 19 | 23 | 27 | 30 | 33 | 36 | 38 | 41 | 43 |
| 1¼ | 1.660 | 15 | 22 | 26 | 30 | 34 | 37 | 40 | 43 | 46 | 48 |
| 1½ | 1.900 | 16 | 23 | 28 | 33 | 36 | 40 | 43 | 46 | 49 | 51 |
| 2 | 2.375 | 18 | 26 | 32 | 36 | 41 | 45 | 48 | 52 | 55 | 58 |
| 3 | 3.500 | 22 | 31 | 38 | 44 | 49 | 54 | 58 | 63 | 66 | 70 |
| 4 | 4.500 | 25 | 35 | 43 | 50 | 56 | 61 | 66 | 71 | 75 | 79 |
| 6 | 6.625 | 30 | 43 | 53 | 61 | 68 | 74 | 80 | 86 | 91 | 96 |
| 8 | 8.625 | 35 | 49 | 60 | 69 | 78 | 85 | 92 | 98 | 104 | 110 |
| 10 | 10.750 | 39 | 55 | 67 | 77 | 87 | 96 | 102 | 110 | 116 | 122 |
| 12 | 12.750 | 42 | 60 | 73 | 84 | 94 | 103 | 112 | 119 | 126 | 133 |

NOTE: Table based on stress and modulus of elasticity at 130°F.
ΔT = 50°F
S = 600 psi
E = $3.1 \times 10^5$ psi

# SYSTEMS ENGINEERING DATA
## FOR THERMOPLASTIC PIPING

**TABLE 36**

**EXPANSION LOOPS AND OFFSET LENGTHS, CPVC Schedule 80**

| NOM. PIPE SIZE | AVERAGE O.D. | LENGTH OF RUN IN FEET | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| | | LENGTH OF LOOP "l" IN INCHES | | | | | | | | | |
| 1/2 | .840 | 15 | 21 | 26 | 30 | 33 | 37 | 39 | 42 | 45 | 47 |
| 3/4 | 1.050 | 17 | 22 | 27 | 31 | 34 | 38 | 40 | 43 | 46 | 48 |
| 1 | 1.315 | 19 | 26 | 32 | 37 | 42 | 46 | 49 | 53 | 56 | 59 |
| 1¼ | 1.660 | 21 | 30 | 36 | 42 | 47 | 52 | 56 | 59 | 63 | 67 |
| 1½ | 1.900 | 23 | 32 | 39 | 45 | 50 | 55 | 59 | 64 | 67 | 71 |
| 2 | 2.375 | 25 | 35 | 43 | 50 | 56 | 62 | 67 | 71 | 75 | 80 |
| 3 | 3.500 | 31 | 43 | 53 | 61 | 68 | 75 | 81 | 86 | 91 | 97 |
| 4 | 4.500 | 35 | 49 | 60 | 69 | 77 | 85 | 92 | 98 | 103 | 109 |
| 6 | 6.625 | 42 | 59 | 73 | 84 | 94 | 103 | 111 | 119 | 125 | 133 |
| 8 | 8.625 | 48 | 67 | 83 | 96 | 107 | 118 | 127 | 135 | 143 | 152 |
| 10 | 10.750 | 54 | 75 | 93 | 107 | 119 | 131 | 142 | 151 | 160 | 169 |
| 12 | 12.750 | 59 | 82 | 101 | 116 | 130 | 143 | 154 | 164 | 174 | 184 |

NOTE: Table based on stress and modulus of elasticity at 160°F.
$\Delta T = 100°F$
$S = 750$ psi
$E = 2.91 \times 10^5$ psi

**TABLE 38**

**EXPANSION LOOPS AND OFFSET LENGTHS, PVDF Schedule 80**

| NOM. PIPE SIZE | AVERAGE O.D. | LENGTH OF RUN IN FEET | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| | | LENGTH OF LOOP "l" IN INCHES | | | | | | | | | |
| 1/2 | .840 | 10 | 15 | 18 | 20 | 23 | 25 | 27 | 29 | 31 | 32 |
| 3/4 | 1.050 | 11 | 16 | 20 | 23 | 26 | 28 | 30 | 32 | 34 | 36 |
| 1 | 1.315 | 13 | 18 | 22 | 26 | 29 | 31 | 34 | 36 | 38 | 40 |
| 1¼ | 1.660 | 14 | 20 | 25 | 29 | 32 | 35 | 38 | 41 | 43 | 45 |
| 1½ | 1.900 | 15 | 22 | 27 | 31 | 34 | 38 | 41 | 44 | 46 | 49 |
| 2 | 2.375 | 17 | 24 | 30 | 34 | 38 | 42 | 46 | 49 | 52 | 54 |

NOTE: Table based on stress and modulus of elasticity at 180°F.
$\Delta T = 100°F$
$S = 1080$ psi
$E = 1.04 \times 10^5$ psi

**TABLE 37**

**EXPANSION LOOPS AND OFFSET LENGTHS**

| COPOLYMER POLYPROPYLENE | | LENGTH OF RUN IN FEET | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NOM. PIPE SIZE | AVERAGE O.D. | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| | | LENGTH OF LOOP "l" IN INCHES | | | | | | | | | |
| 1/2 | .840 | 18 | 25 | 31 | 36 | 40 | 44 | 47 | 50 | 54 | 57 |
| 3/4 | 1.050 | 20 | 28 | 35 | 40 | 45 | 49 | 53 | 56 | 60 | 63 |
| 1 | 1.315 | 22 | 32 | 39 | 45 | 50 | 55 | 59 | 63 | 67 | 71 |
| 1¼ | 1.660 | 25 | 35 | 43 | 50 | 56 | 62 | 66 | 71 | 75 | 79 |
| 1½ | 1.900 | 27 | 38 | 46 | 54 | 60 | 66 | 71 | 76 | 81 | 85 |
| 2 | 2.375 | 30 | 42 | 52 | 60 | 67 | 74 | 79 | 85 | 90 | 95 |
| 3 | 3.500 | 36 | 52 | 63 | 73 | 81 | 89 | 96 | 103 | 109 | 115 |
| 4 | 4.500 | 41 | 58 | 71 | 83 | 92 | 101 | 109 | 117 | 124 | 131 |
| 6 | 6.625 | 50 | 71 | 87 | 100 | 112 | 123 | 132 | 142 | 151 | 159 |
| 8 | 8.625 | 57 | 81 | 99 | 114 | 128 | 140 | 151 | 162 | 172 | 181 |
| 10 | 10.750 | 64 | 90 | 111 | 128 | 143 | 156 | 169 | 181 | 192 | 202 |
| 12 | 12.750 | 69 | 98 | 121 | 139 | 155 | 170 | 184 | 197 | 209 | 220 |

NOTE: Table based on stress and modulus of elasticity at 160°F.
$\Delta T = 100°F$
$S = 240$ psi
$E = .83 \times 10^5$ lb./in.$^2$



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# SYSTEMS ENGINEERING DATA
## FOR THERMOPLASTIC PIPING

These tables are based on:

*F* = As = restraining force, lbs.
A = Cross sectional wall area, in.$^2$
S = e($\Delta$T)E*
e = Coefficient of liner expansion*
E = Modulus of elasticity*
$\Delta$T = Temperature change, °F

*All values are available from relative properties chart on pages 482 and 483

**TABLE 39**

**RESTRAINT FORCE "F" (LB.)—PVC Type 1 Schedule 40 and 80.**

| | SCHEDULE 40 PVC | | | SCHEDULE 80 PVC | | |
|---|---|---|---|---|---|---|
| PIPE SIZE | CROSS SECTIONAL WALL AREA (IN²) | ΔT = 50°F S = 630 PSI | ΔT = 100°F S = 1260 PSI | CROSS SECTIONAL WALL AREA (IN²) | ΔT = 50°F S = 630 PSI | ΔT = 100°F S = 1260 PSI |
| 1/2 | .250 | 155 | 310 | .320 | 200 | 400 |
| 3/4 | .333 | 210 | 420 | .434 | 275 | 550 |
| 1 | .494 | 310 | 620 | .639 | 405 | 810 |
| 1¼ | .669 | 420 | 840 | .882 | 555 | 1,110 |
| 1½ | .800 | 505 | 1,010 | 1.068 | 675 | 1,350 |
| 2 | 1.075 | 675 | 1,350 | 1.477 | 930 | 1,860 |
| 3 | 2.229 | 1,405 | 2,810 | 3.016 | 1,900 | 3,800 |
| 4 | 3.174 | 2,000 | 4,000 | 4.407 | 2,775 | 5,550 |
| 6 | 5.581 | 3,515 | 7,030 | 8.405 | 5,295 | 10,590 |
| 8 | 8.399 | 5,290 | 10,580 | 12.763 | 8,040 | 16,080 |
| 10 | 11.908 | 7,500 | 15,000 | 18.922 | 11,920 | 23,840 |
| 12 | 15.745 | 9,920 | 19,840 | 26.035 | 16,400 | 32,800 |

**TABLE 40**

**RESTRAINT FORCE "F" (LB.), CPVC Schedule 80**

| PIPE SIZE | CROSS SECTIONAL WALL AREA (IN.²) | ΔT = 50°F S = 805 PSI | ΔT = 100°F S = 1610 PSI |
|---|---|---|---|
| 1/2 | .320 | 260 | 520 |
| 3/4 | .434 | 350 | 700 |
| 1 | .639 | 515 | 1,030 |
| 1¼ | .882 | 710 | 1,420 |
| 1½ | 1.068 | 860 | 1,720 |
| 2 | 1.477 | 1,190 | 2,380 |
| 3 | 3.016 | 2,430 | 4,860 |
| 4 | 4.407 | 3,550 | 7,100 |
| 6 | 8.405 | 6,765 | 13,530 |
| 8 | 12.763 | 10,275 | 20,550 |
| 10 | 18.922 | 15,230 | 30,460 |
| 12 | 26.035 | 20,960 | 41,920 |

**TABLE 41**

**RESTRAINT FORCE "F" (LB.), Copolymer Polypropylene Schedule 80**

| PIPE SIZE | CROSS SECTIONAL WALL AREA (IN.²) | ΔT = 50°F S = 550 PSI | ΔT = 100°F S = 1110 PSI |
|---|---|---|---|
| 1/2 | .320 | 147 | 294 |
| 3/4 | .434 | 199 | 398 |
| 1 | .639 | 293 | 586 |
| 1¼ | .882 | 404 | 808 |
| 1½ | 1.068 | 489 | 978 |
| 2 | 1.477 | 663 | 1,325 |
| 3 | 3.016 | 1,381 | 2,762 |
| 4 | 4.407 | 2,018 | 4,036 |
| 6 | 8.405 | 3,899 | 7,698 |
| 8 | 12.763 | 5,895 | 11,690 |
| 10 | 18.922 | 8,666 | 17,332 |
| 12 | 26.035 | 11,929 | 23,848 |

**TABLE 42**

**RESTRAINT FORCE "F" (LB.), PVDF Schedule 80**

| PIPE SIZE | CROSS SECTIONAL WALL AREA (IN.²) | ΔT = 50°F S = 850 PSI | ΔT = 100°F S = 1700 PSI |
|---|---|---|---|
| 1/2 | .320 | 270 | 540 |
| 3/4 | .434 | 370 | 740 |
| 1 | .639 | 540 | 1,080 |
| 1¼ | .882 | 750 | 1,500 |
| 1½ | 1.068 | 905 | 1,810 |
| 2 | 1.477 | 1,255 | 2,510 |
| 3 | 3.016 | 2,565 | 5,130 |
| 4 | 4.407 | 3,745 | 7,490 |

**TABLE 43**

**RESTRAINT FORCE "F" (LB.), PVDF**

| PIPE SIZE | CROSS SECTIONAL WALL AREA (IN.²) | ΔT = 50°F S = 850 PSI | ΔT = 100°F S = 1700 PSI |
|---|---|---|---|
| ½ | 0.167 | 142 | 284 |
| ¾ | 0.213 | 180 | 360 |
| 1 | 0.346 | 294 | 588 |
| 1½ | 0.681 | 579 | 1158 |
| 2 | 0.876 | 745 | 1490 |
| 3 | 1.791 | 1522 | 3044 |
| 4 | 2.706 | 2300 | 4600 |



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