

### EXPANSION AND CONTRACTION OF PLASTIC PIPE

#### CALCULATING STRESS

Plastics, like other piping materials, undergo dimensional changes as a result of temperature variations above and below the installation temperature. If movement resulting from these dimensional changes is restricted by adjacent equipment or by a vessel to which the pipe may be rigidly attached, the resultant stresses and forces may cause damage to such items or even to the pipe itself. In a special case, where compensation is not provided for these dimensional changes and where the piping system is rigidly held or restricted at both ends, an estimate of the magnitude of the resultant stresses can be obtained with the following formula. This formula relates the temperature differential to the temperature dependent modulus (see table 1) and the expansion coefficient for the particular plastic material.

$$S = EC (T_1 - T_2)$$

S = Stress (psi)

E = Modulus of Elasticity (psi)

(see table below for specific values at various temperatures)

C = Coefficient of Expansion (in/in/°F x 10<sup>-5</sup>)

T<sub>1</sub>-T<sub>2</sub> = Temperature differential between the installation temperature and the maximum or minimum system temperature.

TABLE 1

Temperature vs. Modulus (x105) psi

|      | Temperature °F |      |      |      |      |      |     |
|------|----------------|------|------|------|------|------|-----|
|      | 73             | 90   | 100  | 140  | 180  | 210  | 250 |
| PVC  | 4.20           | 3.75 | 3.60 | 270  | N/A  | N/A  | N/A |
| CPVC | 4.23           | 4.00 | 3.85 | 3.25 | 2.69 | 2.20 | N/A |
| PP   | 1.79           | 1.25 | 1.15 | .72  | .50  | N/A  | N/A |
| PVDF | 2.19           | 1.88 | 1.74 | 1.32 | 1.12 | .81  | .59 |

N/A = Not Applicable

The magnitude of the resultant longitudinal forces can be determined by multiplying the stress times the plastic cross sectional area.

#### Example 1

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

$$S = EC (T_1 - T_2)$$

$$S = EC (100 - 70)$$

$$S = (3.60 \times 105) \times (3.0 \times 10^{-5})(30)$$

$$S = 324 \text{ psi}$$

The magnitude of the resultant longitudinal forces:

$$F = S \times A$$

F = FORCE (lbs)

S = STRESS (psi)

A = CROSS SECTIONAL AREA (in<sup>2</sup>)

2" Sch. 80 PVC Pipe has:

$$OD = 2.375"$$

$$ID = 1.934"$$

$$\text{Cross sectional area (A)} = ((OD/2)^2 - (ID/2)^2) \times 3.14 = 1.48 \text{ in.}^2$$

$$F = SA$$

$$F = 324 \times 1.48$$

$$F = 479 \text{ lbs.}$$

#### CALCULATING DIMENSIONAL CHANGE

The extent of expansion or contraction is dependent upon the piping material of construction and its coefficient of linear expansion which, for convenience, is listed below for several materials in units of inches of expansion per 10°F temperature change per 100 feet of pipe.

TABLE 2

Expansion Coefficient

| Material | Y - in/10°F/100ft. |
|----------|--------------------|
| PVC      | .360               |
| CPVC     | .456               |
| PP       | .600               |
| PVDF     | .948               |

The degree of thermal expansion or contraction is also dependent upon the system temperature differential as well as the length of pipe run between changes in direction and it can be calculated using the following formula.

$$\Delta L = Y(T_1 - T_2) / 10 \times L / 100$$

ΔL = dimensional change due to thermal expansion or contraction (in.)

Y = expansion coefficient (see table 2) (in/10°F/100ft)

(T<sub>1</sub>-T<sub>2</sub>) = temperature differential between the installation temperature and the maximum or minimum system temperature, whichever provides the greatest differential (°F)

L = length of pipe run between changes in direction (ft)

#### EXAMPLE 1

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

$$\Delta L = .360((120 - 75) / 10) \times (200 / 100) = .360 \times 4.5 \times 2.0 = 3.24 \text{ inches}$$

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

Normally, piping systems are designed with sufficient directional changes which provide inherent flexibility to compensate for expansion and contraction. However, when this is not the case or when there is reasonable doubt as to the adequate flexibility of the system, expansion loops or expansion joints should be designed into the system. If an expansion loop (which is fabricated with 90° elbows and straight pipe as depicted in fig. 1) is to be used, the leg length (R) should be determined by using the following formula to insure that it is of sufficient length to absorb expansion and contraction movement without damage.

$$R = 1.44 \sqrt{D \Delta L}$$

R = expansion loop leg length (ft)

D = nominal outside diameter of pipe (in)

ΔL = dimensional change due to thermal expansion or contraction (in)

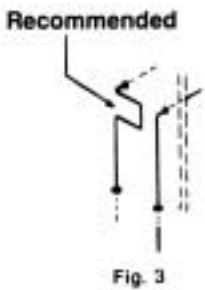
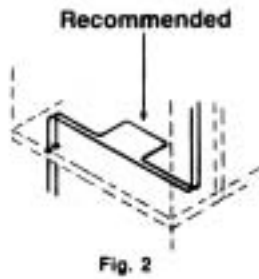
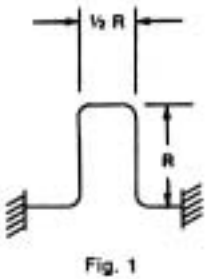
**EXPANSION AND CONTRACTION OF PLASTIC PIPE**

**EXAMPLE 2**

How long should the expansion loop legs be in order to compensate for the expansion in Example 1.

$$R = 1.44 \sqrt{3.500 \times 3.24} = 1.44 \sqrt{11.34} = 4.85 \text{ ft.}$$

Flexibility, through the introduction of flexural off-sets, must be inserted into a piping system design in situations where straight runs of pipe are long or the ends of a straight run are restricted from movement and also in situations where the system is restrained. Several examples of methods for inserting flexibility in these situations are graphically presented below. In each case, rigid supports or restraints should not be placed within the leg length of an expansion loop, off-set or bend.



**PVC AND CPVC PIPE IN COLLAPSE LOADING SITUATIONS**

Thermoplastic pipe is often used in applications where the pressure on the outside of the pipe exceeds the pressure inside. Suction or vacuum lines and buried pipe are examples of this type of service.

The following chart lists the allowable collapse loading for PVC & CPVC pipe at 73°F. This is the difference between external and internal pressure. (Therefore, a pipe with 100 psi internal pressure can withstand 100 psi more external pressure than a pipe with 0 psi internal pressure.) For temperatures other than 73°F, multiply the values in Table 3 by the correction factors listed in the temperature correction Table 4.

When working with vacuum applications, the following conversion factors may be useful.

- 1 Standard Atmosphere = 14.676 psia
- 1 Inch of Mercury = 0.4914 psi
- 1 Inch of Mercury = 25.4 mm of mercury
- 1 mm of Mercury = 1000 microns

It is recommended that solvent cemented joints be used whenever PVC and CPVC are used in vacuum service.

Experience indicates that PVC vacuum systems can be evacuated to pressures as low as 5 microns with continuous pumping.

However, when the system is shut off, the pressure will rise and stabilize around 10,000 microns or approximately 10 mm of Mercury at 73°F.

**TABLE 3**  
Collapse Rating, psi

| Pipe Size | PVC Sch. 40 | PVC Sch. 80 | CPVC Sch. 80 |
|-----------|-------------|-------------|--------------|
| 1/2"      | 450         | 575         | 575          |
| 3/4"      | 285         | 499         | 499          |
| 1"        | 245         | 469         | 469          |
| 1-1/4"    | 160         | 340         | 340          |
| 1-1/2"    | 120         | 270         | 270          |
| 2"        | 75          | 190         | 190          |
| 2-1/2"    | 100         | 220         | 220          |
| 3"        | 70          | 155         | 155          |
| 4"        | 45          | 115         | 115          |
| 6"        | 25          | 80          | 80           |
| 8"        | 16          | 50          | 50           |
| 10"       | 12          | 43          | —            |
| 12"       | 9           | 39          | —            |

**TABLE 4**  
Temperature Correction Factors, PVC and CPVC

| Operating Temp (°F) | PVC Factor | CPVC Factor |
|---------------------|------------|-------------|
| 70                  | 1.00       | 1.00        |
| 80                  | 0.90       | 0.96        |
| 90                  | 0.75       | 0.92        |
| 100                 | 0.62       | 0.85        |
| 110                 | 0.50       | 0.77        |
| 120                 | 0.40       | 0.70        |
| 130                 | 0.30       | 0.62        |
| 140                 | 0.22       | 0.55        |
| 150                 | N.R.       | 0.47        |
| 160                 | N.R.       | 0.40        |
| 170                 | N.R.       | 0.32        |
| 180                 | N.R.       | 0.25        |
| 200                 | N.R.       | 0.18        |
| 210                 | N.R.       | 0.15        |

N.R. = not recommended