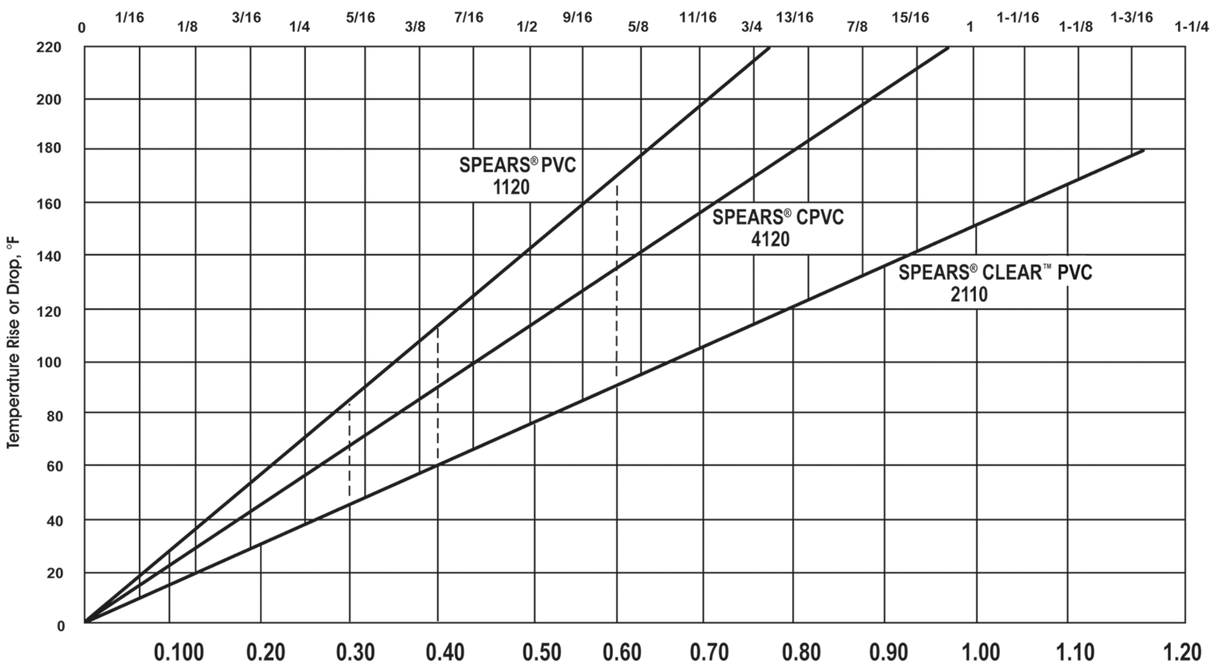
Thermal Expansion & Contraction

Piping systems expand and contract with changes in temperature. Thermoplastic piping expands and contracts more than metallic piping when subjected to temperature changes - as much as ten times that of steel. The effects of thermal expansion and contraction must be considered during the design phase, particularly for systems involving long runs, hot water lines, hot drain lines, and piping systems exposed to environmental temperature extremes. Installation versus working temperature or summer to winter extremes must be considered and addressed with appropriate system design to prevent damage to the piping system.

The degree of movement (change in length) generated as the result of temperature changes, must be calculated based on the type of piping material and the anticipated temperature changes of the system. The rate of expansion does not vary with pipe size. This movement must then be compensated for by the construction of appropriate sized expansion loops, offsets, bends or the installation of expansion joints. This absorbs the stresses generated, minimizing damage to the piping.

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

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



Change in Length (inches) of a 10' Length of Pipe

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

Calculating Linear Movement Caused by Thermal Expansion

The change in length caused by thermal expansion or contraction can be calculated as follows:

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

Where

ΔL = Expansion or contraction in inches
y = Coefficient of linear expansion of piping material selected
l = Length of piping run in feet
ΔT = (T1 - T2) temperature change °F

Where:

T1 = Maximum system temperature and
T2 = System temperature at installation or minimum system temperature

Coefficient of Linear Expansion (y) of Various Spears® Piping Products (in/in/°F) per ASTM D 696

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

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

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

Where:

ΔL = linear expansion or contraction in inches y = 2.9×10^{-5} in/in/°F

l = 100ft

ΔT = 41°F (73°F - 32°F)

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

ΔL = 1.43"

In this example the piping would expand approximately 1-1/2" in length over a 100 foot straight run once the operating temperature of 73°F was obtained.

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

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

Where:

ΔL = Linear expansion or contraction in inches

y = 3.2×10^{-5} in/in/°F

l = 100 ft

ΔT = 100°F (180°F - 80°F)

ΔL = 12 in/ft x 0.000032 in/in/°F x 100ft x 100°F

ΔL = 3.84"

In this example the piping would expand approximately 4" in length over a 100 foot straight run once the operating temperature of 180°F was obtained.

Compensating for Movement Caused by Thermal Expansion/Contraction

Thermal expansion/ contraction are usually absorbed by the system at changes of direction. Long, straight runs are more susceptible to measurable movement with changes in temperature and the installation of expansion joints, expansion loops or offsets is required. This will allow the system to absorb expansion/contraction forces without damage.

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

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

Where:

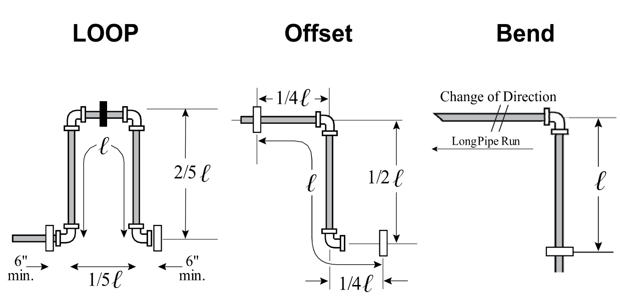
ℓ = Length of expansion loop in inches

E = Modulus of elasticity

D = Average outside diameter of pipe

ΔL = Change in length of pipe due to temperature change

S = Working stress at max. temperature



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

Example: 2" Schedule 80 CPVC pipe operating temperature 180°F; installed at 80°F where ΔL = 3.84"

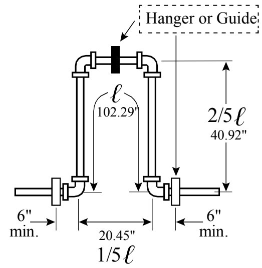
$$\ell = \sqrt{\frac{3ED\,(\Delta L)}{2S}}$$

$$\ell = \sqrt{\frac{3 \times 214{,}000 \times 2.375 \times 3.84}{2 \times 500}}$$

$\ell = 76.51"$

$2/5\ \ell = 30.60"$

$1/5\ \ell = 15.30"$



Thermal Stress

Compressive stress in piping restrained from expanding can damage the piping system and in some cases damage hangers and supports. The amount of stress generated is dependent on the pipe material's coefficient of thermal expansion and its tensile modulus using the following equation:

$S = Ey\Delta T$

Where

S = Stress induced in the pipe

E = Modulus of Elasticity at maximum system temperature y = Coefficient of thermal expansion

ΔT = Total temperature change of the system

The stress induced must not exceed the pipe material maximum allowable working stress (fiber stress). Increases in temperature will reduce the allowable stress as shown the table.

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

ΔL = 12 yl (ΔT) Where:

ΔL = Linear expansion or contraction in inches

$y = 3.2 \times 10^{-5}$ in/in/°F

l = 100ft

ΔT = 100°F (180°F - 80°F)

ΔL = 12 in/ft x 0.000032 in/in/°F x 100 foot x 100°F

ΔL = 3.84"

The piping would expand approximately 4" in length in a 100 ft straight run

The equation for determining induced stress can then be used:

$S = Ey\Delta T$

Where:

S = Stress induced in the pipe

E = Modulus of Elasticity at 180°F = 214,000

y = Coefficient of thermal expansion = 3.2×10^{-5} in./in./°F

ΔT = Total temperature change of the system = 100°F

S = 214,000 x .000032 x 100

S = 685 psi

From chart, maximum allowable stress for CPVC at 180°F is 500 psi; Stress generated from this expansion in a restrained piping system exceeds the maximum allowable stress and will result in failure of the piping, unless compensation is made for thermal expansion.

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

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