UPP Piping Above Ground and Marina Installations

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The following factors need to be considered for above ground installations of piping:

- Temperature Variation
- Pipe layout, supports and constraints
- Potential mechanical or impact loading
- Chemical exposure
- UV radiation

Temperature Variation

Above-grade installations are exposed to greater temperature fluctuations compared to relatively stable buried installations. Irradiation by sunlight, seasonal changes, and day-to-night transitions can impose a significant effect on any piping material installed above the ground.

Changes in temperature cause dimensional change of any material. The amount of dimensional change for a given temperature change is dependent on the material characteristics.

Field experience has shown that flow within the pipe acts as a heat-sink and removes heat from the piping. However, calculations for UPP piping assumes the flow stream is static or even that there is no flow stream.

Table below gives some thermal linear expansion coefficients for commonly used materials

Piping Material	Coefficient of linear Thermal Expansion $\left(\frac{m}{m} \times °C\right)$ x 10^{-6}	Resultant Pipe expansion for 50m x 10°C (mm)
HDPE	220	110
PVC	52	26
Steel	13	6.5
Stainless Steel (316)	16	8
FRP	16	8
Copper	16	8

Table 1: Coefficient of Linear Expansion

HDPE is less stiff than metal piping and through its “stress-relaxation” capacity can result in considerably lower reaction loads for an equal temperature change. Even so,design and installation should always avoid or compensate for potentially adverse effects of temperature variation.

Situations that require special attention include:

- Limit excessive thrust or bending moments on fittings
- Limit excessive pipe sag
- Limit excessive stress at change of direction

Assessment of the axial expansion

The axial expansion ΔL due to thermal effect for a pipe that is free to expand without any axial constraint is given by the following equation:)

Equation (1) $\Delta L = \alpha \cdot L \cdot \Delta T$

Where α is the coefficient of linear thermal expansion (for PE it is in the range 160-220 x 10-6 (°C^{-1}))

L is the pipe length and ΔT is the temperature change.

As indicated above, pipe subjected to temperature variation will expand and contract in response to temperature variations. The designer has two options available to counteract this phenomenon.

a). The pipe may be anchored by some means that will control any change of physical dimensions; anchoring can take advantage of polyethylene’s unique stress relaxation properties to control movement and deflection mechanically.

b). The pipe may be installed in an unrestrained manner, thus allowing the pipe to move freely in response to temperature change.

Absorbing Thermal Expansion / Contraction

To absorb thermal expansion / contraction in piping installed above ground it is necessary to build in added flexibility. There are two ways that this may be done:

a) By the addition of offsets or expansion loops
b) By allowing controlled lateral deflection

Offsets and expansion loops are used primarily with piping that is supported periodically, such as by hangers.

Lateral deflection is employed with piping that has continuous support such as by racks or when installed on grade.

Offset and Expansion Loop Calculation

A compressive or tensile axial stress in a straight run of pipe may be relieved by transforming it to a bending stress at an offset. As illustrated by Figure 1, the offset length Lo1 acts as a cantilevered beam to the long pipe run L1. Under thermal expansion, length L1 increases by ΔL1, which forces offset Lo1 to bend, and therefore to absorb the expansion stresses. The length of the offset Lo1 needs to be sufficient so that the offset pipe transforms the axial thrust into a moderate bending stress.

In Figure 1, two offset legs Lo1 and Lo2 are shown, in this case each leg shall be dimensioned to its correspondent straight length, respectively L1 and L2.

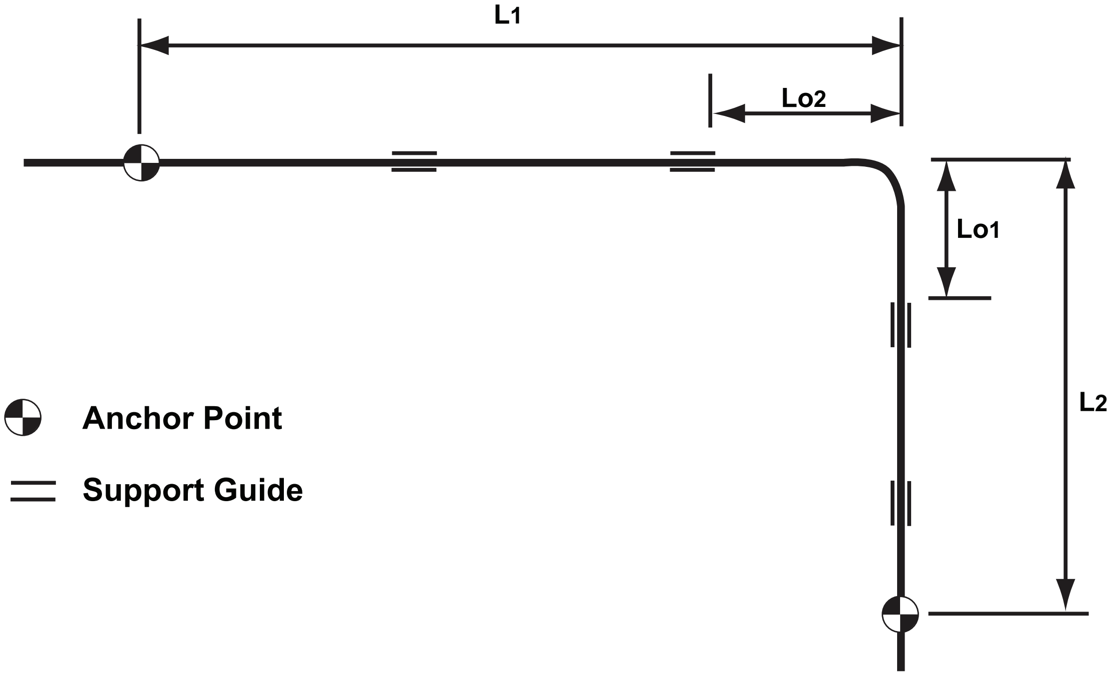


Figure 1: Offset Calculation Diagram

The minimum length of the offset L_o that will safely absorb the thermal load in long straight length of pipe L is given by the following equation:

$$L_o = \sqrt{\frac{3}{20} \cdot D \cdot \alpha \cdot L \cdot \Delta T}$$

Where:

L_o = Minimum length of offset leg (m)

D = Pipe OD (mm)*

α = Coefficient of linear thermal expansion (1/°C)

L = straight length of pipe from the first anchor point (m)

ΔT = Anticipated maximum change in temperature (°C)

The minimum offset length Lo may be distributed as segments of a loop or other geometries as illustrated in Fig. 2 and Fig. 3 below

* Note: When using double wall piping, use the secondary pipe OD

Example.
Let's assume in Fig. 1 an HDPE piping subjected to a max ΔT of 50°C in the following configuration:

L1= 6 (m)

L2 =4 (m)

D= 63 (mm)

α = 220 x 10-6 (from Table 1)

$$L_{o1} = \sqrt{\frac{3}{20} \cdot D \cdot \alpha \cdot L_1 \cdot \Delta T} \qquad L_{o2} = \sqrt{\frac{3}{20} \cdot D \cdot \alpha \cdot L_2 \cdot \Delta T}$$

$$L_{o1} = \sqrt{\frac{3}{20} \cdot 63 \cdot 220 \cdot 10^{-6} \cdot 6 \cdot 50} = 0.79 \text{ (m)} \qquad L_{o2} = \sqrt{\frac{3}{20} \cdot 63 \cdot 220 \cdot 10^{-6} \cdot 4 \cdot 50} = 0.64 \text{ (m)}$$

The minimum offset length Lo may be distributed as segments of a loop or other geometries as illustrated in Fig. 2 and Fig. 3 below

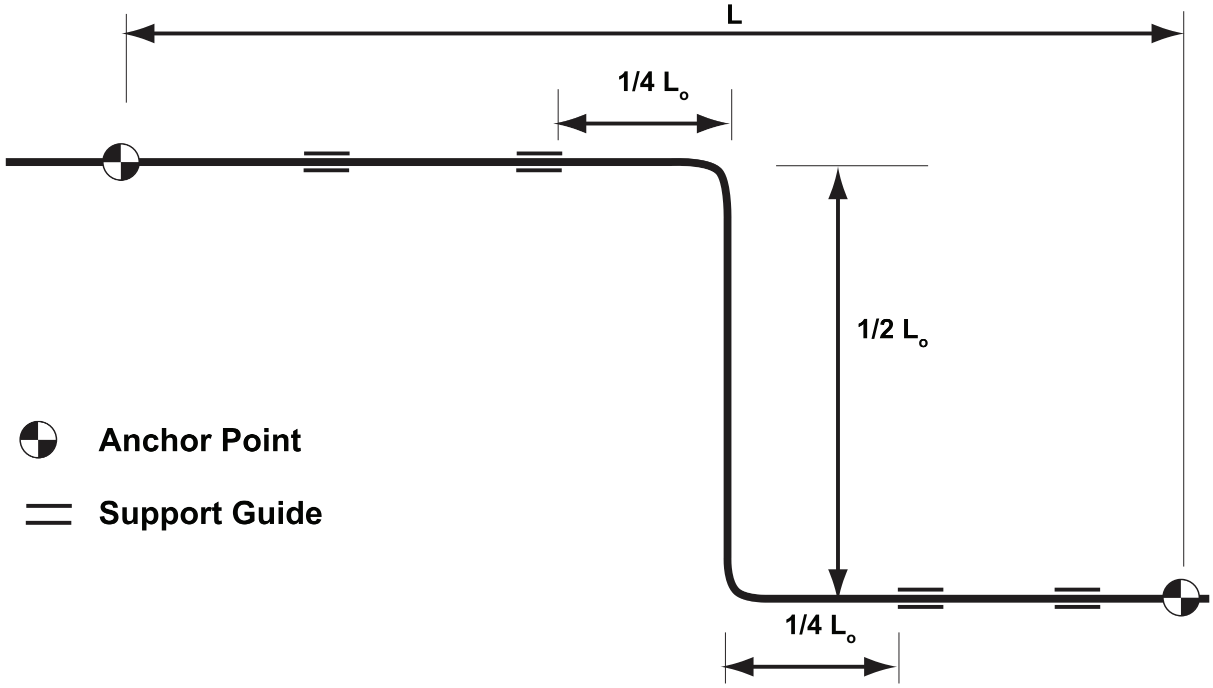


Figure 2:

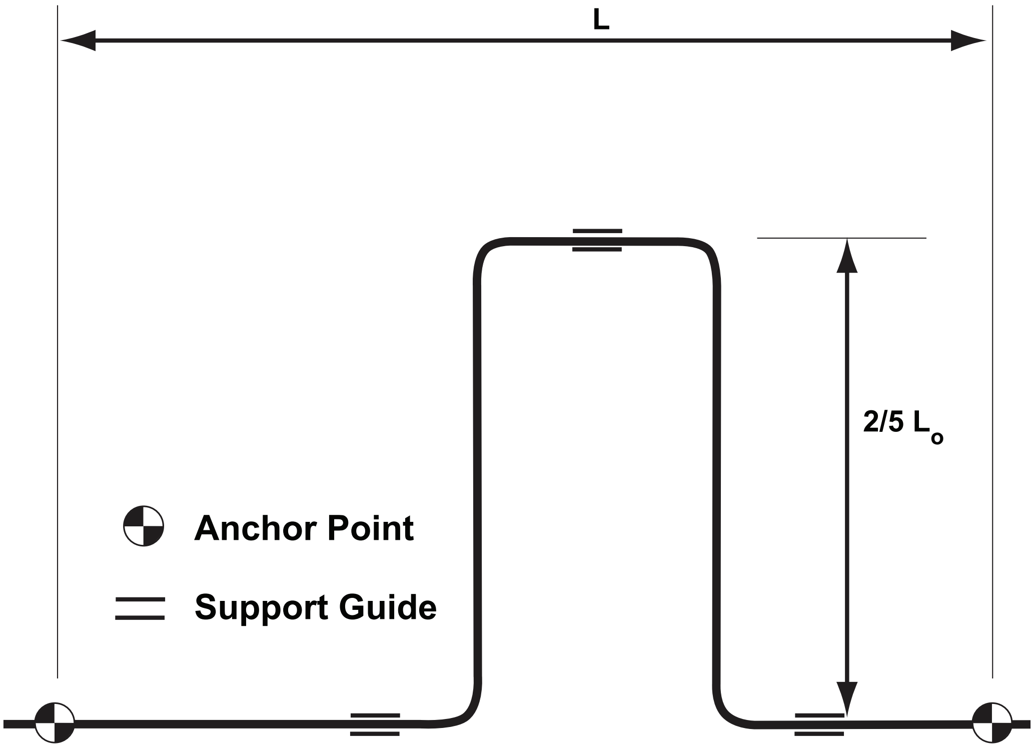
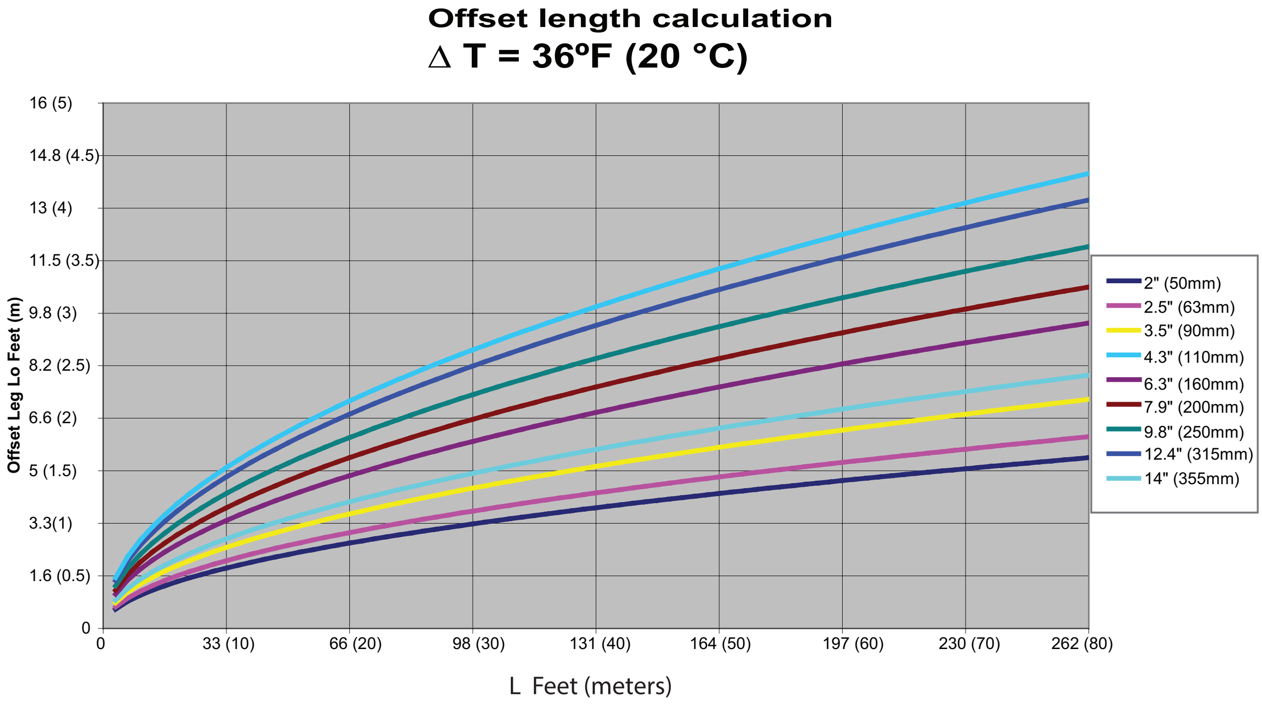
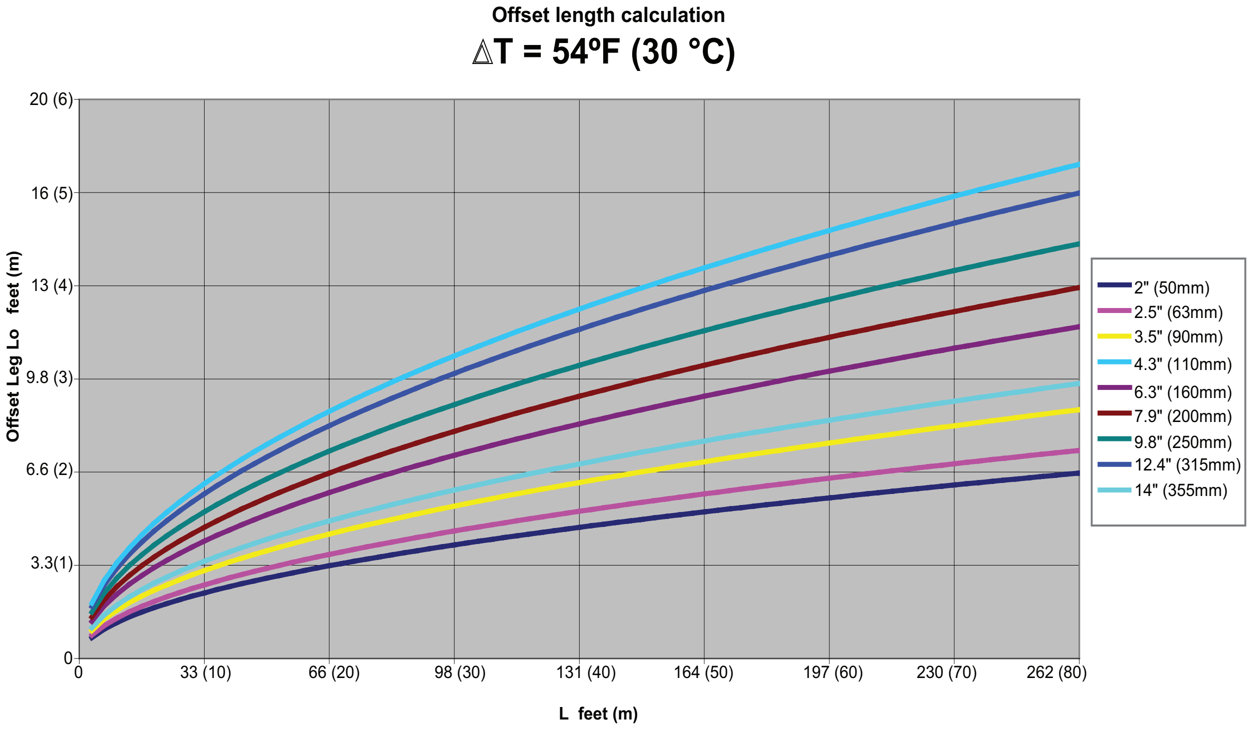


Figure 3

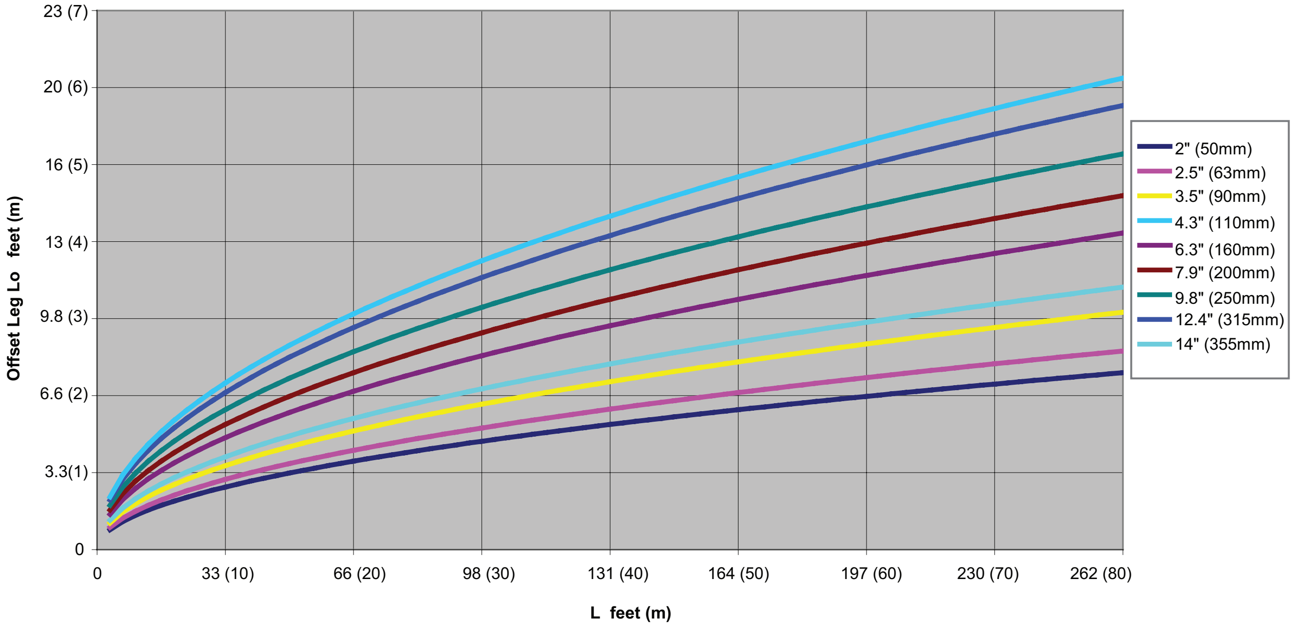
The following diagrams show the offset length calculation as a function of the anticipated temperature difference and pipe length to be compensated.





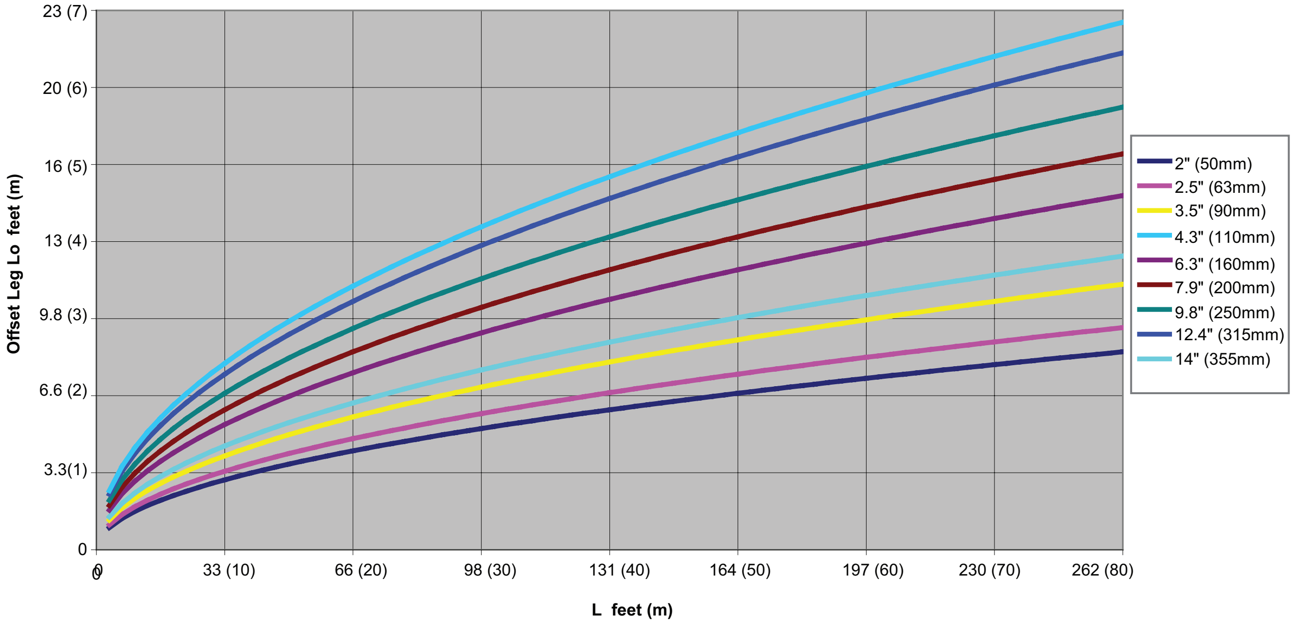
Offset length calculation

ΔT = 72ºF (40 °C)



Offset length calculation

ΔT = 90ºF (50 °C)



On-grade installations

Thermal expansion in long runs of piping that are supported continuously, either when placed on an above ground surface or in a pipe rack, can be absorbed by allowing the pipe to deflect laterally. In such cases there must be sufficient supporting room on either side of the pipe to accommodate the deflection. The pipe is confined in its right-of way by anchoring it periodically. In pipe racks, a centre anchor point may be used but this must be able to pivot with pipe deflection.

To direct the pipe to only deflect to one side it can be laid with an initial deflection that undulates from one side to the other so that additional deflection will always continue in the same direction. An initial deflection should be provided so that when at its lowest anticipated temperature the pipe will not contract to a straight line and become subject to a high axial tensile thrust. To achieve the initial required lateral deflection at the time of installation, the anticipated change from installation temperature to minimum temperature should be determined. Using this value and the distance between lateral support points the pipe should be installed with this lateral deflection plus any added lateral deflection that may be specified by the designer.

The surface over which the pipe deflects should be free of large rocks, projecting stones, debris or other material that may damage the pipe and thereby compromise the pipe material's rated strain capacity.

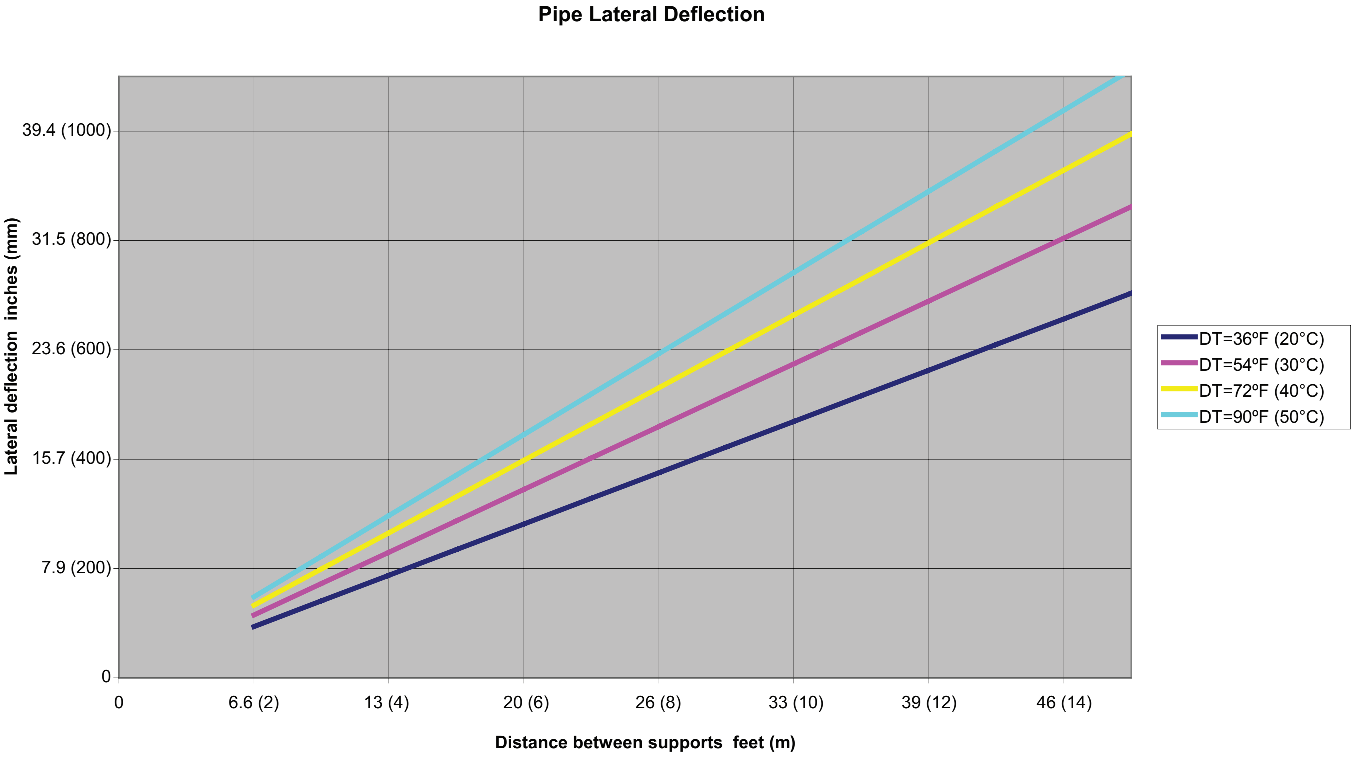
Lateral deflection of an end-constrained pipe may be determined from the following relationship

$$y = 1000 \cdot L\sqrt{\frac{1}{2} \cdot \alpha \cdot \Delta T}$$

Where: y = Lateral deflection (mm)
L = Distance between lateral supports (m)
α =Thermal linear expansion coefficient 1/°C
ΔT = Change in temperature (°C)

There needs to be sufficient free space on either side of the pipe to allow this deflection to freely take place.

The following diagram shows the lateral deflection for ΔT = 20, 30, 40 and 50°C



The closer the lateral supports are placed, the greater the pipe curvature will be as result of lateral bending. Spacing between lateral supports should not be so frequent as to result in excessive bending stresses in the pipe.

As a general rule, the frequency of lateral support is an economic decision. For example, if lateral deflection must be severely limited, the frequency of stabilization points increases significantly. On the other hand, if substantial lateral deflection is permissible, fewer anchor points will be required, and the associated costs are decreased.

The following table shows the recommended minimum distance between restraining points, for various pipe diameter as a function of the maximum anticipated temperature change (ΔT).

Recommended Minimum Spacing Between Restraining Points ft (m)				
Pipe Dia. Inch (mm)	ΔT=36ºF (20°C)	ΔT=54ºF (30°C)	ΔT=72ºF (40°C)	ΔT=90ºF (50°C)
1½ (50)	4.8 (1.470)	5.9 (1.800)	6.8 (2.079)	7.6 (2.324)
2 (63)	6.1 (1.852)	7.4 (2.268)	8.6 (2.619)	9.6 (2.929)
3 (90)	8.7 (2.646)	10.6 (3.241)	12.3 (3.742)	13.7 (4.184)
4 (110)	10.6 (3.234)	13.0 (3.961)	15.0 (4.574)	16.8 (5.113)
6 (160)	15.4 (4.704)	18.9 (5.761)	21.8 (6.652)	24.4 (7.438)
8 (200)	19.3 (5.880)	23.6 (7.201)	27.3 (8.316)	30.5 (9.297)
10 (250)	24.1 (7.350)	29.5 (9.002)	34.1 (10.394)	38.1 (11.621)
12 (315)	30.4 (9.261)	37.2 (11.342)	43.0 (13.097)	48.0 (14.643)
14 (355)	34.2 (10.437)	41.9 (12.783)	48.4 (4.760)	54.1 (16.502)

Table 2: Restraining Points Spacing

Suspended piping

Suspended piping is supported by means of two types of supports:

- **Continuous supports**: It supports the entire pipe length holding it in the bottom part over an arc of about 120°. The use of this type of supports does not induce any deflection on the piping.
- **Discontinuous supports**: Pipe is supported by means of discrete supports. Supports are generally made by steel rings, covered internally by soft material to avoid damaging the pipe surface. Support spacing for polyethylene pipe is determined much the same as for other types of suspended pipelines. The design methodology involves simple-beam or continuous-beam analysis of the proposed installation and is based on limiting bending stress.

The centre-to-centre span of supports can be calculated using the following equation:

$$x \leq 0.8 \cdot \sqrt[3]{\frac{(D^4 - d^4) \cdot E}{16 \cdot g \cdot [\, p_{PE}\, (D^2 - d^2) + p_f \cdot d^2]}},$$

Where:

x = centre to centre span

D = pipe OD (m)

d = pipe ID (m)

E = HDPE Long term Elasticity modulus

g = gravity constant (9.81 m/s^2)

ρ_{PE} = PE density (kg/m^3)

ρ_f = conveyed fluid density (kg/m^3)

Assuming that fluid density and PE density are the same (ρ) the equations simplify as follows:

$$x \leq 0.8 \cdot \sqrt[3]{\frac{(D^4 - d^4) \cdot E}{16 \cdot g \cdot p \cdot D^2}}$$

The following table gives the recommended maximum span length for suspended piping

Pipe Diameter inches (mm)	Span x ft (m)
1 (32)	2.0 (0.6)
1½ (50)	3.0 (0.9)
2 (63)	3.3 (1.0)
3 (90)	4.3 (1.3)
4 (110)	4.9 (1.5)
6 (160)	6.2 (1.9)
8 (200)	7.2 (2.2)
10 (250)	8.5 (2.6)
12 (315)	9.8 (3.0)
14 (355)	10.5 (3.2)

Table 3: Maximum Span

The supports should have adequate strength to restrain the pipe from lateral or longitudinal deflection, given the anticipated service conditions. If the design allows free movement during expansion, the sliding supports should provide a guide without restraint in the direction of movement. If on the other hand, the support is designed to grip the pipe firmly, the support must either be mounted flexibly or have adequate strength to withstand the anticipated stresses.

Heavy fittings or flanges should be fully supported and restrained for a distance of one full pipe diameter, minimum, on both sides. This supported fitting represents a rigid structure within the flexible pipe system and should be fully isolated from bending stresses associated with beam sag or thermal deflection

Thermally induced loads when pipe is fully constrained

In case of a pipe length which is restrained against lengthening or shortening, a change in pipe temperature results in the development of axial compressive or tensile stress. This stress is resisted by a compressive or tensile force that acts on the pipe ends or at any point in the pipe at which it may be anchored.

A primary concern in above ground installations is the possibility that an excessively large thrust may be transmitted to a piping component or to the supporting structure. However, the thermal reaction thrust with HDPE piping is generally of much lower magnitude than that which is generated in a metal or FRP piping for the same temperature change. This fact is due the high elasticity of HDPE material (low modulus). Also, due to the significantly low elastic modulus of plastic materials when placed in compression they can more easily deform laterally and when allowed to do so are somewhat less likely to fully transmit compressive loads onto external restraints than other rigid types of pipe would.

Piping Material	Elasticity Modulus (MPa)
HDPE PE100 (short term)	1000
HDPE PE100 (long term)	160
HDPE PE80 (short term)	900
HDPE PE80 (long term	150
Steel	210,000
FRP	10,000-20,000
Copper	120,000

Table 4: Elasticity Modulus

The magnitude of the tensile or compressive axial stress that can be generated in a pipe that is constrained both against axial and lateral deformation may be calculated using the following equation:

Equation (2) $\sigma = E \cdot \alpha \cdot \Delta T$

Where:

σ = axial direction stress (compressive or tensile in MPa)

E = Elasticity Modulus (MPa)

α = Thermal expansion coefficient (m/m °C)

ΔT = Temperature Change

The thermal thrust in a pipe that is constrained against axial movement may be calculated from the axial stress by using the following equation:

Equation (3) $F = A \cdot \sigma$

Where:

F = Axial thrust force, compressive or tensile (Newton)

A = pipe cross section (mm^2)

σ = tensile or compressive stress as defined in eq. (2) (MPa)

Example:
The thrust force of a 160 mm pipe SDR13.6 made from PE100 is subject to a temperature change of 20 °C, assuming the pipe is constrained to prevent axial and lateral movement calculate the thrust force at supports:

The short term axial stress in the pipe will be from equation (2):

E =900 (MPa)

$\alpha = 220 \cdot 10^{-6}$ (°C^{-1})

$\Delta T = 20$ (°C)

$\sigma = 900 \cdot 220 \cdot 10^{-6} \cdot 20 = 3.96$ MPa

The pipe cross section is

A = 5479 mm^2

From equation (3):

$F = 3.96 \cdot 5479 = 21697$ (N)

The stress relaxation of HDPE will reduce gradually from this value, this taken into account using the long term elasticity modulus:

E = 160 MPa

In this case we obtain from equations (2) and (3)

σ =0.704 (MPa)

F= 3857 N

Chemical exposure

Unlike many piping materials, HDPE pipe will not rust, rot, pit, or corrode as a result of chemical, electrolytic, or galvanic action. The primary chemical environments that pose potentially problems for polyethylene pipe are strong oxidizing agents. Common oxidizing agents are: Hypochlorite and compounds such as bleach, peroxide compounds, ozone, nitric acid, iodine and other halogens.

Environments that contain these harsh chemicals may affect the performance characteristics of an above-ground system made from polyethylene pipe. The continued exposure of polyethylene to strong oxidizing agents may lead to crack formation or crazing of the pipe surface. Occasional exposure to these agents will not, however, significantly affect the long-term performance of UPP pipe.

Ultraviolet exposure

When polyethylene pipe is used outdoors in above-ground applications, it will be subjected to extended periods of direct sunlight. The ultraviolet component in sunlight can produce a harmful effect on polymers that are not sufficiently protected.

UPP pipe is protected from the harmful effects of UV radiation for indefinite periods of time due to its content of finely divided and evenly dispersed carbon black.

Mechanical or Impact Loading

Any piping material that is installed in an exposed location is subject to the rigors of the surrounding environment. It can be damaged by the movement of vehicles or other equipment, and such damage generally results in gouging, deflecting or flattening of the pipe surfaces. If an above-ground installation must be located in a region of excessive mechanical abuse (along a roadway, etc.), the pipe requires extra protection. It may be protected by building a berm or by encasing the pipe where damage is most likely. Other devices may be used, as appropriate to the situation.

In general, in an installation in which any section of polyethylene pipe has been gouged in excess of 10% of the minimum wall thickness, the gouged portion should be removed and replaced.

UPP Transition Fittings for Marine Applications

Polyethylene Stub Flanges

Product Code	Description	Materials
05-032-A 06-032-A	32mm (1") Stud 32mm (1") Flange, DN25, ANSI	**Stub Flange** - Polyethylene - PE100 **Flange** – Polypropylene 30% Glass reinforced
05-050-A 06-050-A	50mm (1, 1/2") Stud 50mm (1, 1/2") Flange, DN40, ANSI	
05-063-L 06-063-A	63mm (2") Stud 63mm (2") Flange, DN50, ANSI	
05-090-A 06-090-A	90mm (3") Stud 90mm (3") Flange, DN80, ANSI	
05-110-L 06-110-A	110mm (4") Stud 110mm (4") Flange, DN100, ANSI	

Polyethylene Flange Transitions

Product Code	Description	
90-050F	50mm (1, ½") Flanged Transition	**Threaded Insert** - Steel 43A - Zinc Passivate **Over-moulding** - Polyethylene - PE100
90-063F	63mm (2") Flanged Transition	
90-090F	90mm (3") Flanged Transition	
90-110F	110mm (4") Flanged Transition	

Nickle Plated Brass Transitions

Product Code	Description	Materials
91-050 NPT	50mm x 1, ½”NPT Male Transition	**Threaded Insert** - Nickel Plated Brass - CW612N Dezincification Resistant Brass - Nickel Plating detail:- Measuring of Ni settled by means of **Fischerscope xray xdl-b”** average settle: 4-7 µm (micron) **Over-moulding** - Polyethylene - PE100
91-050 BSPT	50mm x 1, ½”BSPT Male Transition	
91-063 NPT	63mm x 2”NPT Male Transition	
91-063 BSPT	63mm x 2”BSPT Male Transition	
91-063-1 NPT	63mm x 1, ½”NPT Male Transition	
91-063-1 BSPT	63mm x 1, ½”BSPT Male Transition	
91-090 NPT	90mm x 3”NPT Male Transition	
91-090 BSPT	90mm x 3”NPT Male Transition	
91-110 NPT	110mm x 4”NPT Male Transition	
91-110 BSPT	110mm x 4”NPT Male Transition	
92-050 NPT	50mm x 1, ½”NPT Female Transition	
92-050 BSPT	50mm x 1, ½”BSPT Female Transition	
92-063 NPT	63mm x 2”NPT Female Transition	
92-063 BSPT	63mm x 2”BSPT Female Transition	
92-063-1 NPT	63mm x 1, ½”NPT Female Transition	
92-063-1 BSPT	63mm x 1, ½”BSPT Female Transition	
92-090 NPT	90mm x 3”NPT Female Transition	
92-090 BSPT	90mm x 3”NPT Female Transition	
92-110 NPT	110mm x 4”NPT Female Transition	
92-110 BSPT	110mm x 4”NPT Female Transition	
92-050 UF NPT	50mm x 1, ½”NPT Union Transition	
92-050 UF BSPT	50mm x 1, ½”BSPT Union Transition	
92-063 UF NPT	63mm x 2”NPT Union Transition	
92-063 UF BSPT	63mm x 2”BSPT Union Transition	

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