External Pressure....

The critical (buckling) pressure is calculated as follows:

$$P_C = E.\, t_s^3 \;/\; 4\,(1 - \nu_{ha}.\nu_{ah})\, R_E^3$$

where
P_C = Critical buckling pressure, kN/m²
E = Hoop modulus in flexure, kN/m²
t_s = Structural wall thickness, mm
R_E = Effective radius, mm
ν_{ha} = Poisson's ratio, applied hoop stress
ν_{ah} = Poisson's ratio, applied axial stress

$P_{CA} = P_C$ / SF

where
P_{CA} = Allowable buckling pressure, kN/m²
SF = Factor of safety against buckling, 2.5

Thermal Expansion in un-restrained pipeline....

Fiberglass pipe may have a different expansion rate in hoop and axial directions. A filament wound pipe with a 55° winding angle has about the same thermal expansion as steel in the hoop direction and about twice the expansion as steel in the axial direction. The total expansion or contraction f or a pipe system is determined by the following equation,

$$\Delta L = 12.\alpha\ L.\ \Delta T$$

where
ΔL = Change in length, mm
α= Coefficient of Thermal expansion, mm/mm/ °C
L = Length of pipe between anchors, mm
ΔT = Change in temperature, °C

(ΔT – Maximum operating temperature minus installation temperature for expansion. Installation temperature minus minimum operation temperature for contraction)

Thermal End Loads in restrained pipeline....

The relatively low modulus of elasticity of the pipe is an advantage that becomes apparent during the design phase of a piping system. Since thermal end loads are smaller, restraining equipments like guides and anchors need not be as strong or heavy as for metallic pipe lines. The equation for calculating the thermal end load is,

$$F_T = \alpha . E_A . A . \Delta T$$

where
F_T = Thermal end load, N
A = Area of cross section, m^2
E_A = Axial modulus of elasticity, kN/m^2 (Compressive for expansion and tensile for contraction)

Thermal Expansion Design....

In the design of aboveground pipelines, the supports and guides for the pipe become important consideration because of thermal expansion. A number of methods accommodate the length changes associated with thermal expansion and contraction. The four most commonly used methods include:

- **Anchoring and guiding**
- **Direction changes**
- **Expansion loops**
- **Mechanical expansion joints**

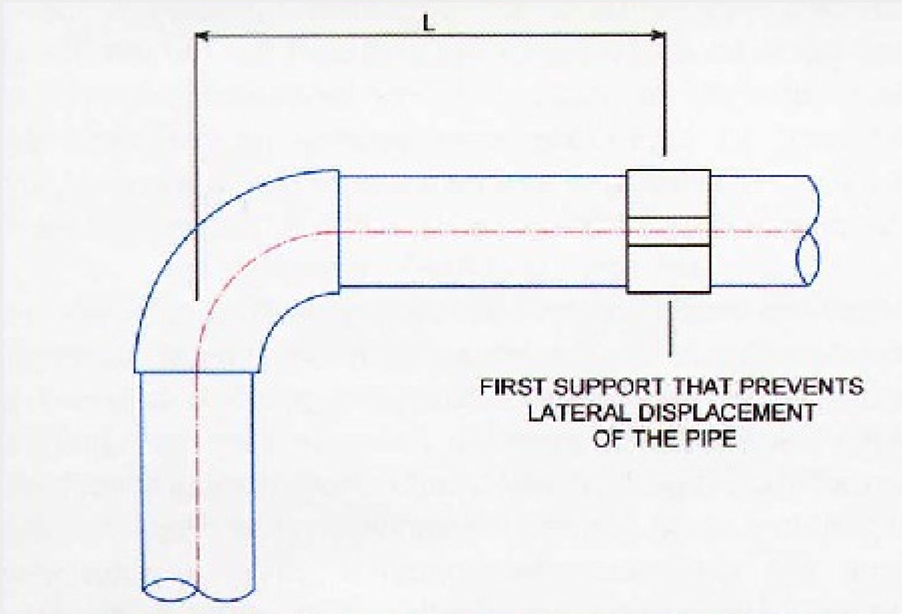
Guides, expansion loops and mechanical expansion joints are installed in straight lines that are anchored at each end. Direction changes are the least expensive method of accommodating thermal expansion. Guide spacing is the next most economical method, followed by mechanical expansion joints and expansion loops.

ANCHORING AND GUIDING

The guiding mechanism must be loose to allow free axial movement of the pipe. However, the guides must be attached rigidly to the supporting structure so that the pipe moves only in the axial direction. An anchor must restrain the movement of the pipe against all forces. Anchors divide a pipe system into sections. In some cases, pumps, t anks and other similar equipment function as anchors. However, most installations require additional anchor where pipe sizes change and fiberglass pipe joins another material or a product from another manufacturer. Additional anchor usually occur at valve locations, change in direction of piping runs, and at major branch connections.

DIRECTION CHANGES

Axial stress at given direction change depends on the operating pressure, the total change in length and the distance to the first secure pipe support past the direction change. Support must prevent lateral movement or pipe bucking. To ensure that the flexible leg length is sufficient to accommodate the total change in length anticipated, it is necessary to compute the combined axial stress and compare with the allowable stress. The leg length is calculated from the equation,
The flexible leg length (the distance to the first restraining support from the direction change) is calculated from the equation,



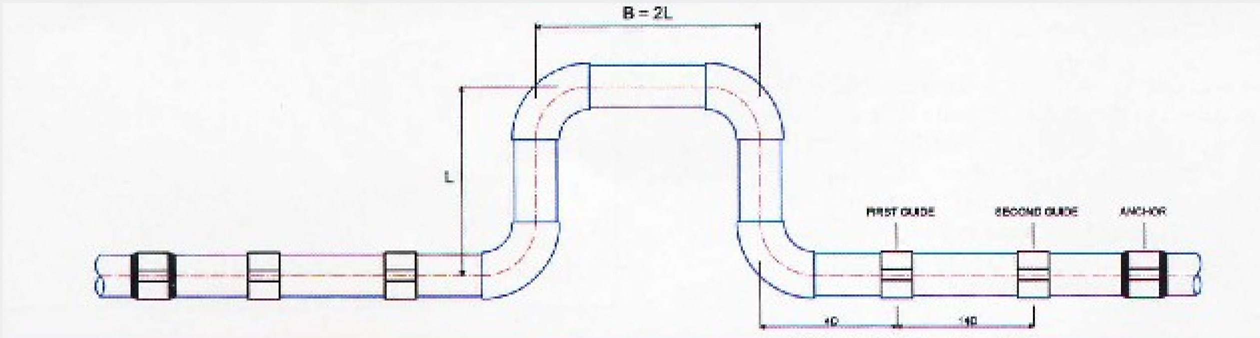
DIRECTION CHANGE TO ABSORB EXPANSION

$$L = [(1.5\ \Delta l.\ E_{AF}.\ D_o) / \sigma_i]^{1/2}$$

where
L= Flexible leg length, mm
Δl = Change in length, mm
E_{AF} = Axial modulus in flexure, kN/m^2
D_o = External diameter of pipe, mm
σ_i = Remaining axial stress, kN/m^2
  = $\sigma_a - \sigma_p$
σ_a = Allowable axial stress, kN/m^2
σ_p = Axial stress due to pressure, kN/m^2

EXPANSION LOOPS

Expansion loops are used where simple direction changes cannot accommodate changes in length of a pipe run. Normally, expansion loops are used in very long pipelines with relatively few changes in direction. The design method assumes a cantilevered beam with a concentrated load at the free end to calculate axial stress. The recommended guide spacing on the main pipeline is shown in the following figure. First guide is placed at a distance of 4 times the diameter and second guide at a distance of 14 times the diameter from the expansion loop. Additional guides and supports should be added to support the expansion loop as required.



EXPANSION LOOP

$$L = [\ (k.\ \Delta l.\ E_{AF}.\ D_o)\ /\ \sigma_i\ ]^{1/2}$$

where
L = Flexible leg length, mm
k = 0.75 (for non-guided cantilever)
= 3.00 (for guided cantilever)

MECHANICAL EXPANSION JOINTS

Expansion joints may be used to absorb thermal expansion in long, straight pipe runs. Various types of expansion joints are available and suitable for use with fiberglass piping systems. Since the fiberglass pipe will expand more than most metallic system, the required movement per expansion joint and the number of expansion joints may be greater for fiberglass systems.
The allowable activation force for expansion joints depends on both the thermal forces developed in the pipe and the support or guide spacing. Guide spacing at the entry of an expansion joint is typically 4 pipe diameters (first guide) and 14 pipe diameters (second guide) from the inlet of the expansion joint. The spacing of remaining supports should remain within the maximum calculated interval.

Support Spacing....

To prevent excessive pipe deflection due to the weight of pipe and fluid, support the horizontal pipe at intervals determined by the following method based on allowable deflection. The deflection of a particular pipe between supports will depend on the length of the pipe run and number of supports used within this length.

$$L_S = [(384\ E_{AF}.\ I.\ d_m)\ /\ (5\ W)\ ]^{1/4}$$

where
L_S = Unsupported span length, m
E_{AF} = Axial modulus in flexure, kN/m²
I = Moment of Inertia, m^4
$= \pi / 64\ (D_o^4 - D_i^4)$
D_o = Outer diameter, m
D_i = Inner diameter, m
d_m = Allowable midpoint deflection, m
$W = W_P + W_F$
W_P = Pipe weight, kN/m
W_F = Fluid weight, kN/m
The mid-span deflection, d_m is 12 mm for fiberglass pipe. When it is limited to 12 mm, the bending stress on the pipeline is typically below the allowable bending stress for the pipe.