PIPE STRESS AND FLEXIBILITY ANALYSIS

AN OVERVIEW ON PIPE STRESS AND FLEXIBILTY ANALYSIS

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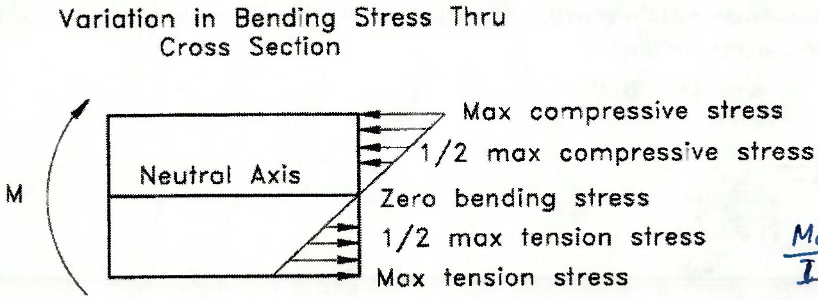
14.7 PSI = 1 atm = 101.325 kPa

3. Bending moment



$\frac{Mc}{I}$ c = dist center to outermost

I- moment of inertia

Figure 1-8

- Hoop stress : caused by internal pressure and acts in a direction parallel to the pipe circumference.

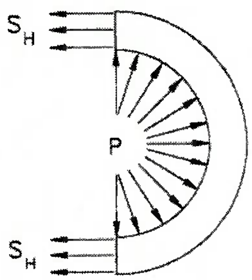


Figure 1 - 9

- Radial stress: caused by internal pressure and acts in the third orthogonal direction, parallel to the pipe radius.

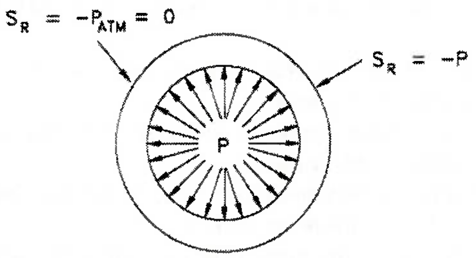


Figure 1-10

- Occasional loads - primary loads which occur less frequently throughout the operation : Earthquake

Secondary stresses. Secondary stresses are those developed by constraining the free displacement of piping subjected to thermal loads or imposed displacements from movements of anchor points etc.
Secondary load characteristics

1. Secondary loads are usually displacement driven (thermal expansion, imposed anchor displacements, settlement, vibration, etc.).
2. Secondary loads are almost self-limiting
3. secondary loads are typically cyclic in nature (except settlement)
4. Allowable limits for secondary stresses are based upon cyclic and fatigue failure modes, and therefore limited based upon requirements for elastic cycling after shakedown and the material fatigue curve.
5. A single application of the load never produces failure. Rather catastrophic failure can occur after some number of applications of the load. Therefore, even if a system has been running for many years, it is no evidence that the system has been properly designed for secondary loads.

❖ Calculation of Weight Stresses

Stresses due to weight loads acting on a supported pipe can be estimated through the use of beam theory. The simplest method of estimating pipe stresses due to weight is to first consider the pipe as being a continuous run, with supports located at constant intervals:

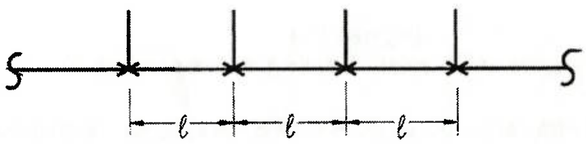


Figure 2-4

Elementary beam theory can be used to determine stresses in a member due to loading on that member.

- Beam theory states that if both support points are pinned (free to rotate):

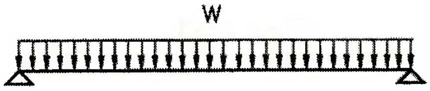


Figure 2-5

The maximum moment in the beam is in the center of the span, and has a value of:

sliding $M_{max} = Wl^2 / 8$

where:

M_{max} = maximum moment in the beam, in-lb
W = uniform weight of pipe, fluid, insulation, etc., lb/in
l = length of beam , in

- If both ends are fixed, or rigid (restrained against rotation):

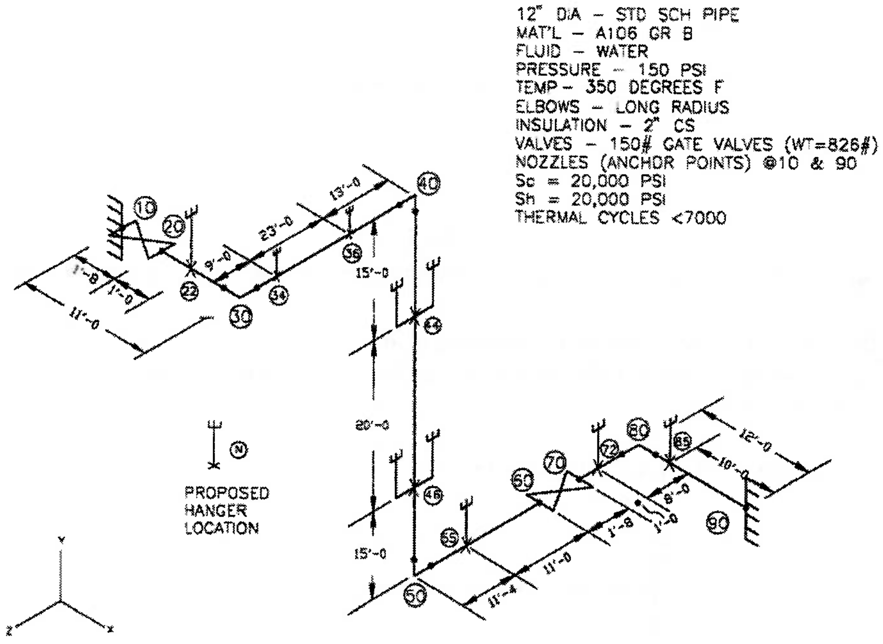


Figure 2-12

Note:Density of steel = 490 lb/ft³

By using the standard span criteria, the engineer can assume that the maximum stress in the piping system due to weight loading does not exceed 1500 psi. Therefore, substituting this value for the weight component of the stress equation:

$S_L = PA_i / A_m + S$
$= [150(3.1416*12^2/4) / [3.1416*(12.75^2-12^2)/4] + 1500$
$= 2664$ psi

- Therefore, the system meets the sustained criteria ≤ 20000 psi = S_h/S_c.

❖ **Designing for expansion loads**

- Magnitude of thermal load

  A piping system, when heating up, normally tries to expand against its restraints, resulting in internal forces, moments and stresses:

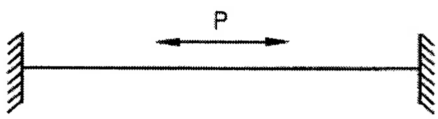


Figure 2-17

If one end is freed and allowed to grow,

- Guided cantilever method

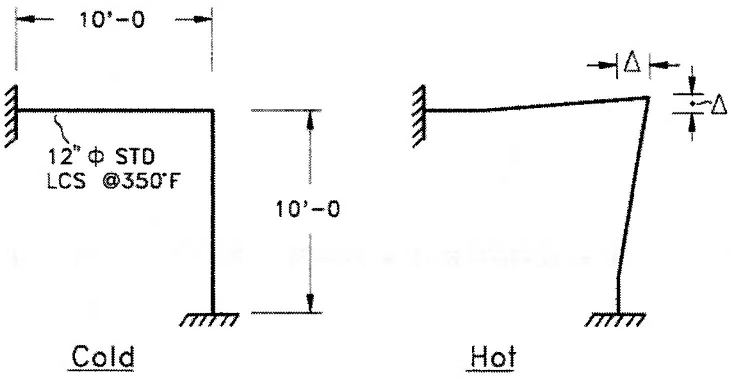


Figure 2-20

Each leg can be modeled as a guided cantilever. According to beam theory:

$\Delta = Pl^3 / 12EI = \alpha l$

$M = Pl / 2$

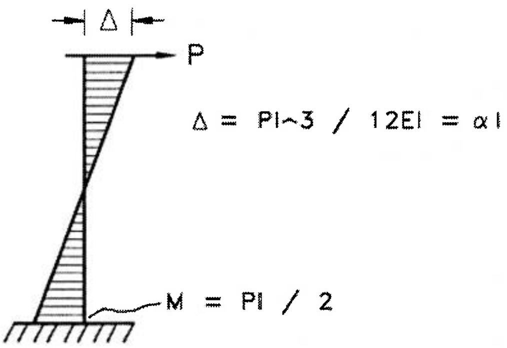


Figure 2-21

Solving for $P = 12EI\ \Delta/l^3$

$M = 6EI\ \Delta/l^2$

$S_E = M/Z = 6EI\ \Delta/l^2Z = 6ER\ \Delta/l^2$

where:

I = moment of inertia of pipe cross-section, $\pi \frac{[D^4 - d^4]}{64}$, in^4

l = length of leg absorbing thermal growth, in

Z = section modulus of pipe cross-section ,in^3

R = outer radius of pipe, in

For the configuration shown in figure 2-20,

$\Delta = 1.88E\text{-}3 \times (10 \times 12) = 0.23"$

$S_E = 6 \times 29E6 \times 6.375 \times .23 / (10 \times 12)^2$

= **17,700 psi**

- From ASME B31.3 para. 302.3.5d, the computed displacement stress range, S_E, in a piping system shall not exceed the allowable displacement stress range, S_A, which is:

  $S_A = f\ [1.25\ (S_c + S_h) - S_L]$, or , conservatively,

  $S_A = f\ [1.25S_c + 0.25S_h]$

$y_y = [50 \times 12 \times 1.88E\text{-}3]^2$
$y_z = [(45 + 33) \times 12 \times 1.88E\text{-}3]^2$
$y = [\, y_x + y_y + y_z \,]^{1/2}$
$= 2.154$ in

L = 11 + 45 + 50 + 33 + 12
= 151 ft

- $\frac{Dy}{(L-U)^2} = \frac{12.75*2.154}{(151-95.46)^2} = 0.0089 < 0.03$

This would imply that the maximum expansion stress in the system is somewhere in the range of:
0.0089 / 0.03 = 0.2968
$S_{Emax} = f\,[1.25S_c + 0.25S_h\,]$
= 1.0 [(1.25*2000) + (0.25*2000)] *0.2968
= **8904 psi**