Theoretical External Collapse Pressure for Piping

(Method is not per ASME.)

The user is responsible for verifying that method and results are correct.

This method is not allowed for ASME vessels and pipes, except per ASME BPV Code, UG-28, F.

Method - 1  Theoretical External Pressure for Elastic Collapse:

"Elastic collapse occurs in the elastic region of the material's stress-strain curve. For thin-walled pipes, elastic collapse is the predominate mode of failure (i.e., those pipes with a $T / D$ of 0.10 or less). ..."


Elastic Collapse pressure given by von Mises' Equation:

$$P_e = \frac{1}{3} \left[ N^2 - 1 + \left( \frac{2N^2 - 1 - \mu}{(N^2 \left( 2L / \pi D \right)^2 - 1)} \right) \left( 2E \left( \frac{1 - \mu^2}{(N^2 \left( \frac{2L}{\pi D} \right)^2 + 1)} \right)^2 + \right) \right] \left( \frac{2E}{N^2 \left( 2L / \pi D \right)^2 + 1} \right)^2 \tag{1}$$

Number of lobes, $N$, created during elastic collapse. Since $N$ is a physical constant, it must be an integer.

Minimum $N = 2$ (Here, the pipe's cross-section would somewhat resemble a figure-8.).

$$N = \left[ \left( 1 - \mu^2 \right) / \left( 3 \left( T / D \right)^2 \right) \left( \frac{2 \pi D}{2L} \right)^3 \right] + 5 \left( \frac{\pi D}{2L} \right)^8 - 3 \left( 1 + \mu \right) \left( \frac{\pi D}{2L} \right)^{18} \tag{11}$$

This method has the following conditions:  
- $N \geq 2$  
- $L / D \leq 15$  
- $0.005 \leq T / D \leq 0.10$

Design Temperature: $\text{min. to} \ 100 \ \text{deg. F} = \text{min. to} \ 38 \ \text{deg. C}$

Material:  
- Material Data per ASME B31.3 -2010 Tables A-1 and A-1A  
- ASTM A312 TP304L SS Pipe S30403 EFW single butt 18Cr-8Ni  
- Electric fusion welded pipe, single butt seam  
- Min. yield stress, $S_y = 25.0 \ \text{ksi} = 172 \ \text{MPa}$  
- Min. metal temp. = $-425 \ \text{F} = -254 \ \text{C}$  
- Elastic modulus at design temp., $E = 28.3 \ \text{Msi} = 195122 \ \text{MPa}$  
- Poisson's ratio, $\mu = 0.305$

Outside diameter $D = 16.000 \ \text{in.} = 406.4 \ \text{mm}$  
Nominal thickness $T = 0.160 \ \text{in.} = 4.06 \ \text{mm}$

$T / D = 0.01$  
$L / D = 2.75$

Calculate $N$ per Eq. (11) above. Then, round $N$ up to the next integer. $N = 3$ = the number of lobes created at collapse.

Theoretical External Collapse Pressure per Eq. (1) above:

$$P_e = 266 \ \text{psi} = 1834 \ \text{kPa} = 18.71 \ \text{kg/sqcm} = 18.34 \ \text{bar}$$

OK. Your external design pressure is less than the theoretical collapse pressure.

Calculate stress in pipe at collapse, using a modified hoop stress formula,

$$S = \frac{P_e}{2 \left( T / D \right)}$$

Continue below only if your design requires stiffening ring/s.

Stiffening Ring

Pipe O.D.  
Stiffening Ring may be sized for the above $L / D$ since $P_d$ does not exceed $P_e$, and $L / D$ does not exceed 15:

Minimum required moment of inertia of stiffening ring, $I = 1/28 \ D^3 \ L \ P_d / E$

Material is like the pipe.  
Modulus of elasticity, $E = 28.3 \times 10^6 \ \text{psi}$  
Thickness, $t_r = 0.500 \ \text{in.} = 12.7 \ \text{mm}$  
Height, $h_r = 1.250 \ \text{in.} = 31.75 \ \text{mm}$

Available moment of inertia, $I_a = 1/12 \ t_r h_r^3$

$$I_a = 0.0814 \ \text{in}^4 = 33881 \ \text{mm}^4$$

Stiffening ring size is OK.