PRESSURE VESSEL CALCULATIONS 4000m NiBrAl

PROJECT: I.S.M.S. Mass Spectrometer **DATE: Feb 06, 2007** **ANALYST: J.E.**

Revisions: (last rev date 8/4/99)

1)Added first ten buckling modes for determination of critical buckling pressure.
2) Corrected maximum bending stress equation for cap
3) Added von Mises calculation and corrected buckling calculation
4) Corrected von Mises equation
5) Added O-ring groove diameter for diametral clearance and tab bending calculations.
6) Corrected index problem with radial moment equations

The following calculations are for determining the margin of safety for a pressure vessel at a given depth. The equations are mostly from Roark's Formulas for Stress and Strain and are referenced when used. The user must input the dimensions, material properties, and design depth. A factor of safety will be included in the calculations to determine the minimum margin of safety. The minimum margin of safety must be greater than zero for the design to be suitable for the depth desired.

The format for this analysis package will be as follows:

A) Input of design parameters including dimensions, material properties, and design depth
B) Calculations for deformation and stresses in cylinders (check for thin wall or thick wall condition)
C) Buckling calculations for cylinders
D) Calculations for deformations and stresses in end plates,
E) Weight calculation
F) Summary of input and list of results including diametral gap, stresses, margins of safety and weight.

Note: The minimum margin of safety will be determined based upon the lowest margin calculated in the sections above. Thus, for a give pressure vessel, the maximum working pressure may be limited by the end plate thickness while for another it may be limited by the length of the cylindrical section. Therefor, if a desired allowable working depth is not reached, the limiting factor needs to be determined in order to effectively iterate the design to meet the requirements. Also, the diametral gap must be checked for the different pressures to assure that it falls within the maximum allowable from the o-ring vendor.

A) Design parameters:

(pp02)

1) Dimensional input:

Enter cylinder dimensions:

Inside Diameter : $ID_{cyl} \equiv 7.520 \cdot in$

Outside Diameter: $OD_{cyl} \equiv 8.800 \cdot in$

O-ring surface diameter: $ID_{cyl\_oring} \equiv 7.62500 \cdot in$

Case Length: $L_{cyl} \equiv 33.00 \cdot in$

Cylinder Base Thickness: $T_{cyl\_base} \equiv 1.600 \cdot in$

Wall thickness:

$$T_{cyl\_wall} \equiv \frac{OD_{cyl} - \left(ID_{cyl}\right)}{2}$$

$$T_{cyl\_wall} = 0.640\,in$$

Enter end cap and gland dimensions (O-Ring #2-366):

Plug Diameter: $OD_{plug} \equiv 7.622 \cdot in$

Groove Width: $W_{groove} \equiv .281 \cdot in$

Groove Diameter: $ID_{groove} \equiv 7.285 \cdot in$

Groove Base Thickness: $T_{oring\_tab} \equiv .219 \cdot in$

End Cap OD: $OD_{cap} \equiv 8.800 \cdot in$

End Cap Thickness: $T_{cap} \equiv 2.375 \cdot in$

Tab Thickness: $T_{endcap\_tab} \equiv 1.000 \cdot in$

Connector Diameter: $D_{conn} \equiv 1.530 \cdot in$

2) Material properties:

Enter material properties: Material: NiBrAl Alloy C95510 / AMS4880

Modulus of elasticity: $E \equiv 16.70 \cdot 10^3 \cdot ksi$

Material density: $\rho_m \equiv 0.272 \cdot \frac{lbf}{in^3}$

Poisson's ratio: $\nu \equiv 0.32$

Yield Stress: $S_y \equiv 62.5 \cdot ksi$

Shear stress: $S_s \equiv 37.5 \cdot ksi$

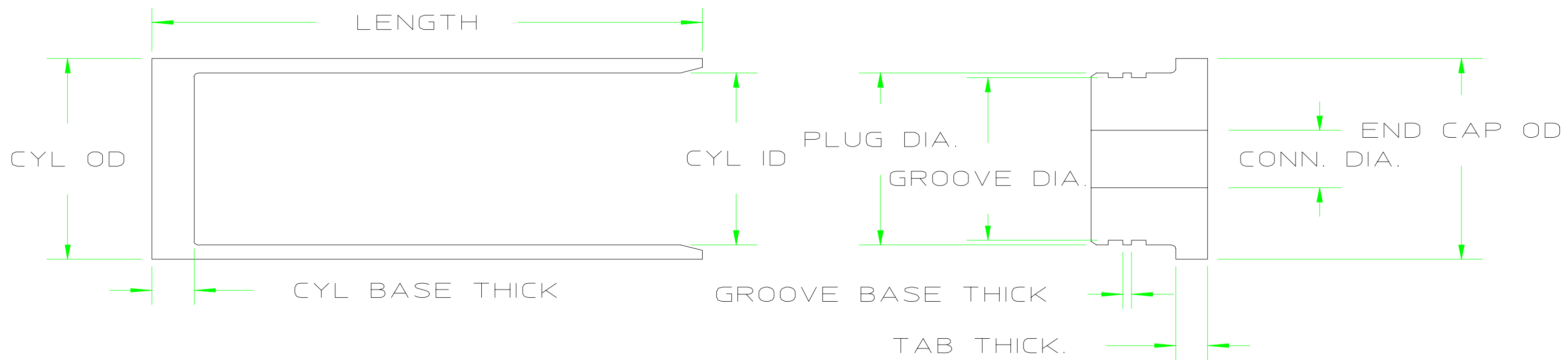
Water density: $\rho_{sw} \equiv 64.0974 \cdot \frac{lbf}{ft^3}$

3) Design depth and resulting pressure:

$depth \equiv 4000 \cdot m$ Number of pressure steps: $N_{pressure} \equiv 10$ Pressure: $q \equiv depth \cdot \rho_{sw}$ $q = 5.841 \times 10^3\,psi$

4) Factors of safety to be used:

for buckling: $FS_{buckling} \equiv 2$ for stress: $FS \equiv 1.25 \cdot 1.1$ $FS = 1.375$



$ksi \equiv 1000 \cdot psi$

SUMMARY

Thin Wall Calcs: Is it thin wall (1=yes)? $\text{thinWall} = 0$

Meridional (axial) stress: $\sigma_{1thin} = 18.62\,\text{ksi}$

Change in height: $\Delta y_{thin} = 0.013\,\text{in}$

Circumferential (hoop) stress: $\sigma_{2thin} = 37.239\,\text{ksi}$

Radial displacement of circumference: $\Delta R_{max} = 7.642 \times 10^{-3}\,\text{in}$

Margin of Safety: $MS_{cythin} = 0.409$

Thick Wall Calcs

Axial Stress: $\sigma_{1thick} = -2.165 \times 10^{4}\,\text{psi}$

Change in OD (radius): $\Delta a_{thick} = -7.554 \times 10^{-3}\,\text{in}$

Hoop Stress: $\sigma_{2thick}\left(b_{thick}\right) = -4.331 \times 10^{4}\,\text{psi}$

Change in ID (radius): $\Delta b_{thick} = -8.191 \times 10^{-3}\,\text{in}$

Radial Stress: $\sigma_{3thick}\left(b_{thick}\right) = 0\,\text{psi}$

Change in Length: $\Delta L = 0.0154\,\text{in}$

Shear Stress: $\tau_{thickb} = 2.165 \times 10^{4}\,\text{psi}$

Von Mises Stress: $\sigma_{vmthick} = 37.508\,\text{ksi}$

Margins of Safety: **for yield strength:** $MSyield_{cythick} = 0.212$ **for shear strength:** $MSshear_{cythick} = 0.05$

Closed End Cylinder Base Calcs:

$\sigma_{base} = 40.163\,\text{ksi}$ $\quad ycenter_{base} = -0.012\,\text{in}$ $\quad Q_{abase} = -1.098 \times 10^{4}\,\dfrac{\text{lbf}}{\text{in}}$ **Margin:** $MS_{base} = 0.132$

Buckling Calcs: For the expressions in the case to be valid, the following condition must be true (i.e., condition = 1):

$$\text{condition} := \frac{r_{buckling}}{T_{cyl\_wall}} > 10 \qquad \text{condition} = 0$$

$p_{critical} = 20.919\,\text{ksi}$ **Margin of safety on buckling:** $MS_{buckling} = 0.791$

END CAP Calcs

(pp19)

END CAP Circular Plate

$y_{endcapb} = -7.7 \times 10^{-3}\,in$ $\quad Q_a = -1.246 \times 10^{4}\,\frac{lbf}{in}$ $\quad \sigma_{endcap} = 4.528 \times 10^{4}\,psi$

MARGIN OF SAFETY: $MS_{endcap} = 3.761 \times 10^{-3}$

END CAP tabs:

$\sigma_{endcap\_tab} = -4.413 \times 10^{4}\,psi$ $\quad Q_{endcap\_tabb} = 1.286 \times 10^{4}\,\frac{lbf}{in}$

MARGIN OF SAFETY: $MS_{endcap\_tab} = 0.030$

O-RING tab:

$\sigma_{oring} = -2.204 \times 10^{4}\,ps$ $y_{oringmax} = -1.008 \times 10^{-4}\,in$ $\quad Q_{oringb} = 1.054 \times 10^{3}\,\frac{lbf}{in}$

MARGIN OF SAFETY: $MS_{oring} = 1.063$

WEIGHTS

$W_{cyl} = 166.595\,lbf$ $\quad W_{cap} = 33.608\,lbf$

$Wp_{dry} = 233.812\,lbf$ $Wp_{wet} = 157.105\,lbf$

CASE VOLUME CHANGE

$V_{ext} = 2.129 \times 10^{3}\,in^{3}$

$\Delta V_{case} = 8.171\,in^{3}$

$\Delta V_{CH2O} = 38.262\,in^{3}$

EndCap Flange/Case Bearing Stress

Bearing Area: $A_b := \frac{\pi}{4} \cdot \left(OD_{cap}{}^2 - ID_{cyl\_oring}{}^2\right)$ $A_b = 15.158\,in^2$

End Cap Force: $F_b := q \cdot \frac{\pi}{4} \cdot \left(OD_{cap}{}^2\right)$ $F_b = 3.553 \times 10^5\,lbf$

Bearing Stress: $\sigma_b := \frac{F_b}{A_b}$ $\sigma_b = 2.344 \times 10^4\,psi$

Margin of safey: $MS_{bearing} := \left(\frac{S_y}{\sigma_b \cdot FS} - 1\right)$ $MS_{bearing} = 0.94$

EndCap Flange Shear Thru Stress

Flange Shear Area: $A_s := \pi \cdot \left(ID_{cyl\_oring}\right) \cdot T_{endcap\_tab}$ $A_s = 23.955\,in^2$

End Cap Force: $F_s := q \cdot \frac{\pi}{4} \cdot \left(ID_{cyl\_oring}{}^2\right)$ $F_s = 2.667 \times 10^5\,lbf$

Shear Stress: $\sigma_s := \frac{F_s}{A_s}$ $\sigma_s = 1.114 \times 10^4\,psi$

Margin of Safety: $MS_{shear} := \left(\frac{S_s}{\sigma_s \cdot FS} - 1\right)$ $MS_{shear} = 1.449$