SSC DETECTOR SOLENOID DESIGN NOTE # 30

TITLE: Shell Thicknesses per ASME Code for the "Excalibur" Geometry.

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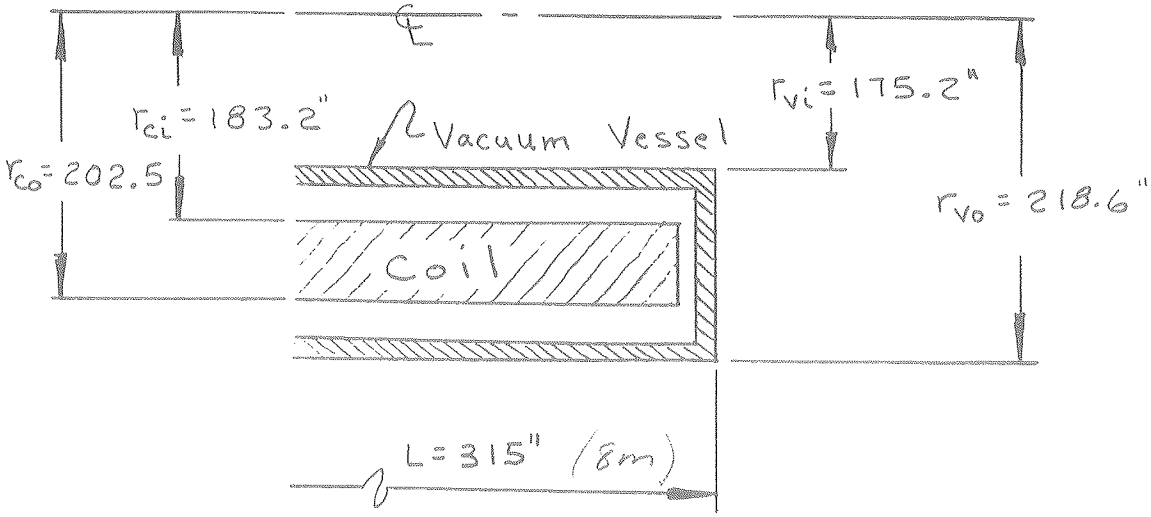
PROBLEM: To determine the minimum material thickness of the inner and outer cylindrical shells of the LHe Vessel and Vacuum Vessel.

ASSUMPTIONS: The shell material is 304 stainless steel. Longitudinal and circumferential joints are double-welded 75° V-grooves. No radiographic examination of the welds is assumed.



Coil Cross Section

SOLUTION: The shell thicknesses are approximated using the procedures outlined in Parts UG-27 and UG-28 (P.23-5) in Section VIII Division 1 of the ASME Boiler and Pressure Vessel Code. Therefore, minimum shell thicknesses due to internal pressure loading may be represented by:

$$t = \frac{PR}{SE-0.6P} \quad \text{and} \quad t = \frac{PR}{2SE-0.4P}$$

(Circum. Stress) (Long. Stress)

Where:

t = minimum required thickness (in)

P = design pressure (psi)

R = inside radius of shell (in)

S = maximum allowable stress (psi)

E = joint efficiency.

The maximum allowable external pressure for a given shell thickness is represented by:

$$P_a = \frac{4B}{3(D_0/t)}$$

where:

D_0 = outside diameter of shell (in)

t = given shell thickness (in)

The value of B is extracted from Fig. 5-UHA-28.1 (P.548) in Appendix 5 of the Pressure Vessel Code. The value of A in the same figure is determined by interpolating necessary values listed in Table 5-UG0-28.0 (P.553-4) of Appendix 5.

Inner Vacuum Shell

Internal loading 15 psi – normal operating pressure (vacuum)

$$t_{CIR} = \frac{PR}{SE-0.6P}$$

$$= \frac{(15)(175.2)}{(18.8\times10^3)(.7)-0.6(15)}$$

$$\boxed{=.200\text{in}}$$

$$t_{long} = \frac{PR}{2SE-0.4P}$$

$$= \frac{(15)(175.2)}{2(18.8\times10^3)(.7)-0.4(15)}$$

$$\boxed{=.100\text{ in}}$$

External loading 15 psi

$\boxed{t = 1.125\text{in}} \rightarrow 29\text{ mm}$

$$L/D_0 = \frac{315}{353}$$

$$= .893$$

$$D_0/t_{1.125} = 314$$

$$A = .276\times10^{-3}$$

$$B = 4000$$

$$P_a = \frac{4B}{3(D_0/t)}$$

$$= \frac{4(4000)}{3(314)}$$

$$\boxed{= 17.0\text{ psi}}$$

Inner LHe Vessel Shell

Internal Loading 15 psi

$$t_{CIR} = \frac{PR}{SE\text{-}0.6P}$$

$$= \frac{(15)(183.2)}{(18.8\times10^3)(.7)\text{-}0.6(15)}$$

$$\boxed{= .209\text{ in}}$$

$$t_{long} = \frac{PR}{25E\text{-}0.4P}$$

$$= \frac{(15)(183.2)}{2(18.8\times10^3)(.7)\text{-}0.4(15)}$$

$$\boxed{= .104\text{ in}}.$$

External loading 100 psi

$$\boxed{t = 2.25 \text{ in}} \rightarrow 58 \text{ mm}$$

$$L/D_0 = 78.74/370.9$$

$$= .212$$

$$D_0/t = 165$$

$$A = .370\times10^{-2}$$

$$B = 12{,}800$$

$$P_a = \frac{4B}{3(D_0/t)}$$

$$= \frac{4(12{,}800)}{3(165)}$$

$$\boxed{= 103 \text{ psi}}.$$

Outer LHe Vessel Shell

Internal loading 175 psi*

$$t_{CIR} = \frac{PR}{SE-0.6P}$$

$$= \frac{(175)(199.8)}{(18.8\times10^3)(.7)-0.6(175)}$$

$$\boxed{= 2.68 \text{ in}} \rightarrow 70 \text{ mm}$$

$$t_{long} = \frac{PR}{2SE-0.4P}$$

$$= \frac{(190)(201.7)}{2(18.8\times10^3)(.7)-0.4(190)}$$

$$\boxed{= 1.46 \text{ in}}.$$

* For radially outward magnetic loading.

External loading 15 psi

$$\boxed{t = .75 \text{ in}}$$

$$L/D_0 = 78.74/405$$

$$= .194$$

$$D_0/t = 540$$

$$A = .670\times10^{-3}$$

$$B = 7{,}200$$

$$P_a = \frac{4B}{3(D_0/t)}$$

$$= \frac{4(7200)}{3(540)}$$

$$\boxed{= 17.8 \text{ psi}}.$$

Outer Vacuum vessel Shell

Internal Loading 15 psi

$$t_{cir.} = \frac{PR}{SE-0.6P}$$

$$= \frac{(15)(217.3)}{(18.8\times10^3)(.7)-0.6(15)}$$

$$\boxed{= .248 \text{ in}}$$

$$t_{long.} = \frac{PR}{2SE-0.4P}$$

$$= \frac{(15)(217.3)}{2(18.8\times10^3)(.7)-0.4(15)}$$

$$\boxed{= .124 \text{ in}}.$$

External loading 15 psi

$$\boxed{t = 1.25 \text{ in}} \rightarrow 32 \text{ mm}$$

$$L/D_0 = 315/437.1$$
$$= .721$$
$$D_0/t = 350$$
$$A = .301\times10^{-3}$$
$$B = 4200$$

$$P_a = \frac{4B}{3(D_0/t)}$$

$$= \frac{4(4200)}{3(350)}$$

$$\boxed{= 16 \text{ psi}}.$$

SUMMARY: The minimum shell thicknesses are:

Inner Vacuum	1.125 in	or	29 mm	
Inner LHe	2.250 in	or	58 mm	
Outer LHe	2.750 in	or	70 mm	
Outer Vacuum	1.250 in	or	32 mm	+

+ CGA-341 and Formtek 32-41 requires a [illegible] MAWP of 15 psi for a vacuum vessel.