Fermilab

Particle Physics Division
Mechanical Department Engineering Note

Number: MD-ENG-273 Date: 9/10/10

Project Internal Reference:

Project: Solid Xenon

Title: Solid Xenon inner glass chamber engineering note

Author(s): Herman Cease

Reviewer(s):

Key Words: Solid Xenon, glass

Abstract Summary: The solid Xenon Vessel is a vacuum vessel that is mostly glass. The vessel diameter is less than 6 inches and is a small volume so formal ASME analysis is not required, however an analysis is still provided using the Brookhaven ES&H manual (Standards-Based Management System) engineering guidelines.

Applicable Codes:
Brookhaven: GUIDE FOR GLASS AND PLASTIC WINDOW DESIGN FOR PRESSURE VESSELS

Introduction

The Solid Xenon inner chamber holds the Xenon gas, condenses the gas into a liquid, then a solid. The glass chamber is 100 mm outer diameter, with a 5 mm side walls, and a 10mm thick flat bottom. During the process the chamber will be under full vacuum to a maximum pressure of 17 psig. The stress in the glass is calculated over the maximum differential pressure range which is 17 psid. Drawing 9214.00-MD-486085 shown in Figure 1 describes the chamber geometry.

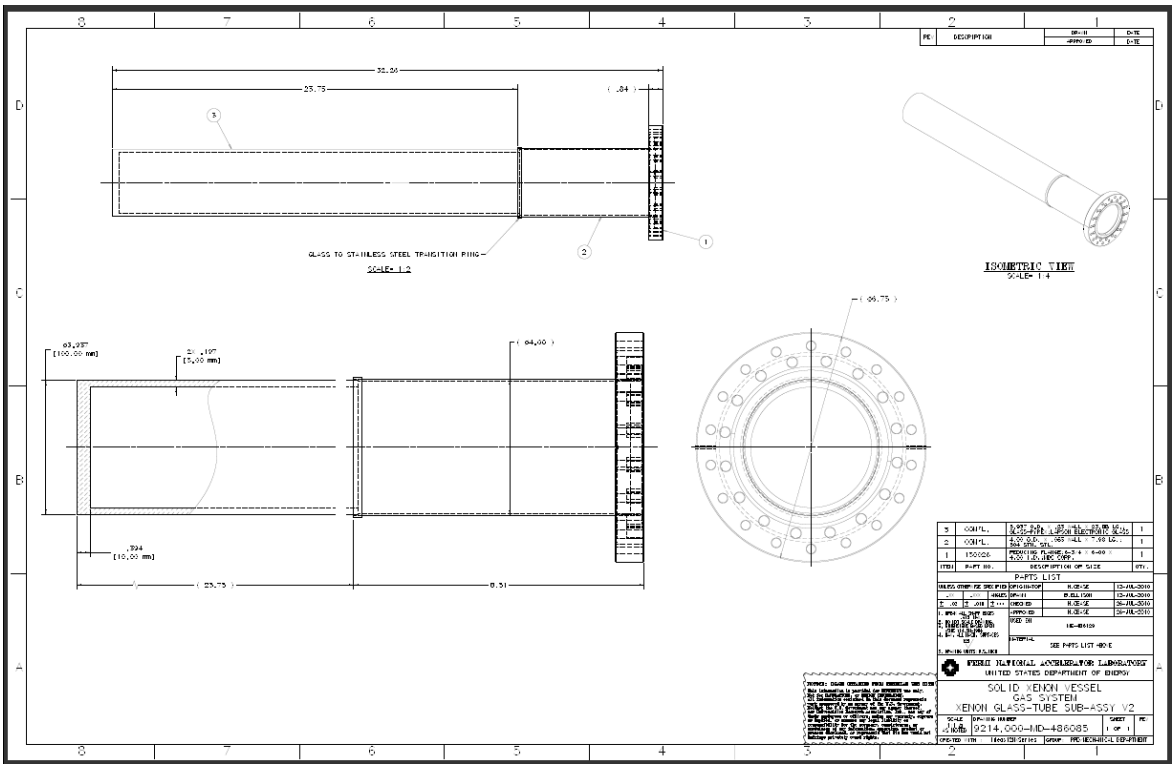

Figure 1. Drawing 486085, Solid Xenon Inner Chamber.

The glass chamber does not apply to FESHM Chapter 5033 Vacuum Window Safety, or 5031 for pressure vessels. However, Brookhaven's Standards-Based Management System provides engineering guideline titled: GUIDE FOR GLASS AND PLASTIC WINDOW DESIGN FOR PRESSURE VESSELS.

Design:

Allowable Material Stress:
Due to possible stress concentrations and the brittleness of the material, the maximum allowable stress is a factor of 10 times less than the yield strength of the material. The chamber is constructed of Fused Silica with a manufacturing allowable tensile stress of 7250 psi, a Young's modulus of 10.5e6 psi, and a Poisson's ratio of 0.16. Reducing the yield strength by a factor of 10 gives a maximum allowable stress of 725 psi. For long term applications, the Brookhaven document further reduces the allowable stress to 680 psi.

*Ref. H0607_Fused_Silica_Industrial_Grade_ProductSheet.pdf

Calculating the Stress and Deflection at the flat bottom of the chamber:
The chamber flat bottom deflection is much smaller than 0.50 times the flat thickness so the window is considered to be simply supported and thick plate theory is used. The diameter of the window is taken to be the outer diameter of the chamber.

Using Appendix A of the Brookhaven document:
Stress = K1* Pressure * (diameter /thickness)^2
K1 = 0.296
Stress = 0.296 * 17 psid * (3.437 inch / 0.393 inch)^2
Stress = 384 psi

384 psi is less than the maximum allowable design stress of 680 psi

Using Appendix A of the Brookhaven document:
Deflection at the center of the bottom flat
= K3 * Pressure * diameter^4 / (modulus * thickness^3)
K3 = 0.051
Deflection = 0.051 * 17 psi * 3.437^4 / (10.5e6 psi * (0.393 inch)^3)
Deflection = 0.00002 inch = 5 microns

Deflection is less than 0.5 times the window thickness so thick plate theory is satisfied.

Calculating the Stress in the chamber wall:

The chamber is considered a thin wall vessel since the radius of the chamber is greater than 5 times the wall thickness.

The hoop stress due to internal pressure in the chamber walls is given by:
Stress = Pressure*radius/thickness
Stress = 17 psid * 1.96 inches / 0.196 inches
Stress = 170 psi

The longitudinal stress due to internal pressure in the chamber wall is given by:
Stress = Pressure*radius/(2*thickness)
Stress = 17 psid * 1.96 inches / (2*0.196 inches)
Stress = 85 psi

Summary:
The stresses in the Solid Xenon Inner Xenon vessel are suitably low. Both the hoop stress and the longitudinal stress due to a differential pressure of 17 psid is much lower than the allowable design stress of 680 psi.