Fermilab

Particle Physics Division
Mechanical Department Engineering Note

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Project Internal Reference:

Project: IRLabs CCD Testing Dewar

Title: IRLabs CCD Testing Dewar– Vacuum Window

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Key Words: Vacuum Window

Abstract Summary: The IRLabs CCD Testing Dewar is a vacuum vessel with a 100mm optical window. Optical vacuum windows do not apply to FESHM-**5033.1,** however the window 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 IRLabs CCD Testing Dewar is used to test one CCDs. A desired vacuum pressure of 10e-6 Torr is required in the vessel to prevent water vapor from condensing onto the CCD during operation. Optical tests are performed on the CCD through an optical window that is purchased from JML Optical Industries, Rochester, NY and is a 4mm thick by 100mm diameter sapphire window. The window is held in a cell that is described by drawing #9213.750-MD-466719. The vessel positive pressure relief that is supplied by the vendor IRLabs was rated for 38 psig, and is replaced with a 1/3 psig Nupro relief on the vessel's 3/8NPT port.

Optical windows do not apply to FESHM Chapter 5033 Vacuum Window Safety. 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 window is constructed of Sapphire with a manufacturing allowable tensile stress of 40,000 psi, a Young's modulus of 50e6 psi. Reducing the yield strength by a factor of 10 gives a maximum allowable stress of 4,000 psi.

*Ref. http://www.roditi.com/SingleCrystal/Sapphire/Properties.html

Calculating the Window Stress and Deflection:
The window deflection is much smaller than 0.50 times the window thickness so the window is considered to be simply supported and thick plate theory is used. The design of the window mount shall be such that the window is not significantly constrained against thermal motions or motions under loading. The diameter of the window is taken to be the O-Ring diameter.

Using Appendix A of the Brookhaven document:
Stress = K1* Pressure * (diameter /thickness)^2
K1 = 0.296
Stress = 0.296 * 14.7 psid * (3.94 inch / 0.157 inch)^2
Stress = 2,740 psi

2,740 psi is less than the maximum allowable design stress of 4,000 psi

Using Appendix A of the Brookhaven document:
Deflection at the center of the window
= K3 * Pressure * diameter^4 / (modulus * thickness^3)
K3 = 0.051
Deflection = 0.051 * 14.7 psi * 3.94^4 / (50e6 psi * 0.157 inch^3)
Deflection = 0.00094 inch = 0.03 microns

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

EXHIBIT A –Modified for Optical Window

Vacuum Window Engineering Note
(per Fermilab ES&H Manual Chapter 5033.1) –Modified for Optical Window

Vacuum Window Number: _____N/A_____

Purpose of vacuum vessel and vacuum window	IRLabs CCD Testing Dewar, Sapphire window	
Internal MAWP	14.7 PSI	
External MAWP	14.7 PSI	
Working Temperature Range	50 °F	100 °F

1. Design Verification: Provide design calculations in the Note Appendix.

2. Fabrication: Is this vacuum window fabricated in house? [ ] Yes [X] No
If "Yes", Attach the written fabrication procedure in the Note Appendix.

3. Inspection: Attach inspection reports and Travelers in the Note Appendix. Include date(s) of manufacture. Window will be inspected prior to use.

4. Testing: Attach failure and acceptance testing procedure and results in the Note Appendix. Include dates of testing

   Acceptance Testing performed using normal operational vacuum conditions. The Mechanical Engineer will be present during assembly and initial pump down of the vessel and window.

5. System Venting Verification:

   Is the relieving system of the vacuum vessel to which this vacuum window is attached sufficiently sized such that if the vessel is pressurized, the maximum differential pressure across the window cannot exceed the design differential pressure of the vacuum window?
   [X] Yes [ ] No

   1/3 psi NUPRO 3/8NPT relief.

6. Operating Procedure Section:

   Is an operating procedure necessary for the safe operation of this vessel? [ ] Yes [X] No

If "Yes", the operating procedure must be attached to the Note Appendix

7. Hazard Analysis: Is the safety factor on this vacuum window less than 2.0? [ ] Yes [X] No

If "Yes", a hazard analysis must be prepared and attached to the Note Appendix

8. Degradation from Exposure: Will the integrity of the window be compromised over time by exposure to radiation or cyclic stress? [ ] Yes [X] No
   If "Yes", include in the technical appendix any requirements for recording exposure, as well as a change-out schedule.