Fermilab
ES&H Section

July 13, 2004

TO: Jed Brown

FROM: Bill Griffing

SUBJECT: Revised FESHM Chapter 5033.1 – VACUUM WINDOW SAFETY

Enclosed you will find revised FESHM Chapter 5033.1 – Vacuum Window Safety. The chapter was revised to remove reference to TM-1380 (TM-1380 includes some mathematical errors) and to allow other forms of analysis to be used to justify the safety of vacuum windows.

After final approval, please return this approval page to Liz May at MS119 for posting on the web.

Encl.

Recommended for Approval:

Jed Brown — Date 7/19/2004

Approved:

Mike Witherell — Date 7/19/2004

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VACUUM WINDOW SAFETY

INTRODUCTION AND APPLICABILITY

Vacuum windows pose a potential hazard to equipment and personnel from rupture or implosion. This chapter specifies the procedure to be followed in designing, fabricating, testing, and using vacuum windows in order to reduce hazards. This chapter applies to any vacuum window used at Fermilab except:

1) Vacuum Windows inside of beam pipes where a failure of the window is fully contained within the volume of the beam pipe on either side of the window.

2) Portions of vacuum vessel through which beam may pass which are designed in accordance with the ASME Boiler and Pressure vessel code. Such 'windows' shall be documented in the engineering note prepared per FESHM 5033.

3) Optical windows

DEFINITIONS

Vacuum Window – Any relatively thin separation between a volume under vacuum and a volume at atmospheric pressure through which primary or secondary beam passes. ***This definition does not include optical windows.***

Engineering Note - A written analysis demonstrating that a given vacuum window satisfies the requirements of this chapter.

Qualified Person - A qualified person is "a person who, by possession of a recognized degree or certificate of professional standing, or who, by extensive knowledge, training and experience, has successfully demonstrated the ability to solve or resolve problems relating to the subject matter and work."

An Exceptional Vacuum Window - An exceptional vacuum window is defined as one which cannot meet the tenets of this chapter and therefore requires a Director's Exception.

Vacuum Window Failure – Failure of a vacuum window is defined as the onset of any condition which renders the window inadequate for its intended use. This includes not

only catastrophic burst, but any failure in the window or its mounting system that prevents sealing against vacuum.

Similar Windows – Windows are deemed similar if they share one or more of several characteristics with a window for which an Engineering Note has been approved. These characteristics include, but are not limited to: material, thickness, differential pressure, fabrication techniques, mounting system, beam exposure, and hazard analysis.

Identical Windows – Windows are deemed identical if they differ in no way from a representative window for which an Engineering Note has been approved.

RESPONSIBILITIES

The division/section head who controls the area of operation of the vacuum vessel system with a vacuum window is responsible for carrying out the requirements of this chapter. He shall:

1) Arrange for the review of the Engineering Note by a qualified person.
2) Certify vacuum vessel window compliance with this chapter by signing the Engineering Note
3) Maintain an open, updated file on all vacuum windows located in his areas of operation.
4) After completion of the Review of the Engineering Note, place the Engineering Note for the Vacuum Window into the Laboratory Vacuum Vessel Window master file maintained by the ES&H Section. Where possible, the note shall be filed with the Engineering Note for the Vacuum Vessel to which the Vacuum Window is mounted.
5) Assign a number to each vacuum window, and assure that this number is applied by some legible and durable means to the window or its mounting hardware (permanent marker, scribed on flange, adhesive sticker, etc). If the window is one-of-a-kind, the assigned number must be unique. If the window is one of a group of identical windows for which a single Engineering Note has been approved, the assigned number need not be unique, but may be the same for all windows in the group.

The ES&H Section shall audit the divisions and sections on their compliance to this chapter.

The Mechanical Safety Subcommittee shall serve the division/section heads and ES&H Section in a consulting capacity on all vacuum window matters. This committee may propose appropriate modifications to this chapter as necessary. Changes in policy and responsibility shall be recommended by the Laboratory Safety Committee after

consulting with the division/section heads. Changes in procedure shall be recommended by the Mechanical Safety Subcommittee.

DESIGN CRITERIA

Thin vacuum windows shall be designed according to the requirements of 5033.1TA, "Technical Appendix to Vacuum Window Safety: Requirements for Vacuum Window Design, Fabrication, Inspection, Testing, and Documentation."

IMPLEMENTATION

1. Preparation of Engineering Note: An Engineering Note shall be prepared by a qualified person for all vacuum windows at Fermilab. The format of the Engineering Note is shown in Exhibit A. The Engineering Note allows a reviewer to check the design and installation and to inform future users of the window parameters. The Engineering Note shall include design calculations for the vacuum window and shall also include precautions and operating procedures necessary for the safe use of the vacuum window. See Appendix 5033.1TA for additional information.

2. Review of Engineering Note: All vacuum window Engineering Notes shall be reviewed by an independent, qualified reviewer, other than the preparer, for compliance with this chapter. The reviewer shall be from a group not reporting to the preparer or his supervisor.

3. Amendment of Engineering Note: Any subsequent changes in the fabrication, assembly or operation of the vacuum window which could affect the performance of the window require an amendment to the original Engineering Note. This amendment shall be reviewed in the same manner as the original Engineering Note.

4. Similar Windows: Similar windows need not have the full Engineering Note repeated. Adequate documentation can be provided by referencing an approved Engineering Note and noting differences.

5. Identical Windows: Identical windows do not require any documentation beyond the approved Engineering Note representative of the design.

6. Director's Exception: Exceptions to the provisions of this chapter shall be allowed only with the signature of the Laboratory Director or his designee, documented in the Engineering Note. The need for such exceptions is to be minimized by adhering to the provisions of this chapter. Exceptions shall be identified and submitted to the Director for review in a timely manner, and shall only be allowed after the Director is assured that sound engineering

practice will be followed during design, fabrication and testing of the vacuum window. The ES&H Section shall maintain copies of exceptions for the Director. If the Engineering Note cannot be approved, operation shall not be permitted until modifications are made which result in the Engineering Note being approved, or until a Director's Exception is granted. Should a Director's Exception be sought, the division/section head shall provide a brief statement justifying the application for a Director's Exception.

TECHNICAL APPENDIX TO 5033.1 VACUUM WINDOW SAFETY

REQUIREMENTS FOR VACUUM WINDOW DESIGN, FABRICATION, INSPECTION, TESTING, AND DOCUMENTATION

1. Design:

   a) Loads

      1. In addition to vacuum loading, window design shall take into account any other load which may affect window function. These loads include, but are not limited to, those resulting from variation of pressure on the window (due to normal operation, or possible faulty procedure), as well as all relevant effects of beam deposition such as thermal loading, cyclic mechanical shock due to very brief, high intensity beam pulsing, and materials degradation from long-term beam exposure. Considering these effects may lead to additional analyses or tests related to creep or fatigue failure of the window.

      2. Vacuum windows constructed of materials subject to creep rupture such as Kevlar, shall have a calculation of the stress in the window and an evaluation of the expected lifetime before a creep rupture failure can be expected at that stress. Calculate and document that the maximum design lifetime permissible to ensure to a 95% confidence level that the vacuum window will not fail.

   b) Safety Factor – Manned Areas

      Vacuum windows used in manned areas shall be designed with a minimum safety factor of 2.0 on failure.

   c) Safety Factor – Unmanned Areas

      Vacuum windows used in unmanned areas shall be allowed to have minimum failure pressures approach the external differential pressure as long as the following additional criteria are met:

      1. Sufficient means and methods shall be developed to either relieve the differential pressure or protect the area from the effects of a vacuum window failure when people enter the area. A hazard analysis shall be performed and attached to the engineering note to show the means and methods implemented to remove the hazard during personnel access.

2. Property losses resulting from the effects of a vacuum window failure shall be determined, documented, and acknowledged by the appropriate Division Head and Experiment Spokesperson (if applicable).

d) Failure Testing

1. Vacuum window safety factors shall be verified by testing a window or windows. Deflections and pressure shall be measured during the test.

2. For manned areas, it is not necessary to burst the window if stable deflections at a pressure differential corresponding to an SF ≥ 2 is demonstrated.

3. For unmanned areas, where SF < 2, the window(s) must be burst to verify the safety factor.

4. For the tested windows, all details of fabrication and assembly such as flanges, bolts, welds, etc, shall be identical to those of the window intended for service.

5. Whether multiple failure tests are necessary is determined by a qualified person based on the repeatability of fabrication, integrity of materials, and experience with similar window designs.

6. A hazard analysis shall be written for the failure tests, describing hazards to personnel and equipment associated with the test, and documenting the safeguards provided.

e) Compliance with Additional Design Load Requirements

1. Failure testing as required by this Appendix cannot demonstrate safe window operation under any loading but static vacuum. The designer shall demonstrate compliance with the additional loads of (1)(a) of this Appendix through analysis, or testing, or both.

2. Fabrication:

a) The qualified person shall provide a written fabrication and assembly procedure, a list of planned and completed inspections, and any other quality control procedures taken for vacuum windows built in house. Use of a 'Traveler' to document the fabrication and assembly is recommended, but not mandatory.

b) Windows purchased from a manufacturer do not require a fabrication procedure to be included in the engineering note.

3. Inspection:

   a) The vacuum window shall be inspected during fabrication by the qualified person for compliance to this chapter, conformance to the design calculations, conformance to the design drawings, and conformance to the assembly procedure for windows built in house.

   b) Windows purchased from a manufacture can be inspected after delivery.

4. Acceptance Testing:

   a) Acceptance testing is required, and shall occur after the Engineering Note has been prepared and approved.

   b) The acceptance test shall consist of successfully achieving the full differential pressure across the vacuum window and demonstrating that the deflections are stable, i.e., that the window does not creep.

   c) For manned areas, the initial operation of the system may be considered to fulfill the acceptance test requirement. For unmanned areas where SF < 2 and the resulting risk to system components higher, a separate test is required.

   d) A hazard analysis shall be written for the acceptance test, describing hazards to personnel and equipment associated with the test, and documenting the safeguards provided.

5. Venting of Positive System Pressure:

   a) If a vacuum system may experience an excursion to positive pressure under any circumstance, a calculation shall be provided to show that venting is sufficient to keep the maximum pressure at or below one fourth of the pressure which would cause failure of the thin vacuum window.

6. Operating Procedures:

   a) Provide cautions and operating procedures necessary for the safe use of the vacuum window.

7. Hazard Analysis:

a) A hazard analysis shall be written for operation, describing hazards to personnel and equipment associated with vacuum window operation, and documenting the safeguards provided.

8. Documentation:

a) All documents generated in compliance with paragraphs 1-7 of this Appendix shall be assembled into a technical appendix to the Engineering Note to document the design, fabrication, inspection, testing, assembly, operating procedures, and hazard analysis for the vacuum window.

The design and testing requirements for vacuum windows are summarized in Table TA-1 below.

Table TA-1. Summary of Design and Testing Requirements for Vacuum Windows

		Manned Areas	Unmanned Areas
Safety Factor		≥ 2.0	> 1.0
Failure Testing			
	Measured quantities?	Pressure and Deflection	Pressure and Deflection
	Is burst necessary?	No, if stable deflection at SF ≥ 2 is demonstrated	Yes, if SF < 2
	How many windows are tested?	Discretion of Qualified Person	Discretion of Qualified Person
	HA required for failuretest?	Yes	Yes
Acceptance Test			
	Test Pressure	Operating differential	Operating differential
	Test same as operation?	Optional	Separate test required if SF < 2
	HA required for acceptance test?	Yes	Yes
Operation			
	HA required?	Yes	Yes

EXHIBIT A

Vacuum Window Engineering Note
(per Fermilab ES&H Manual Chapter 5033.1)

Vacuum Window Number: _____

Identification and Verification of Compliance:

Prepared by	_____	Date	_____	Div/Sec	_____
Reviewed by	_____	Date	_____	Div/Sec	_____
Div/Sec Head	_____	Date	_____	Div/Sec	_____

Director's signature (or designee) if vacuum window requires an exception to the provisions of this chapter.

_____

Amendment No.	Reviewed by	Date

Vacuum Vessel Title for the vacuum vessel to which the Vacuum Window is attached.

_____

Vacuum Vessel Number for the vacuum vessel to which the Vacuum Window is attached.

_____

Vacuum Window Drawing Number (List all pertinent drawings):

Drawing No.	Location of Originals

Laboratory location code	_____
Purpose of vacuum vessel and vacuum window	_____
Internal MAWP	_____
External MAWP	_____
Working Temperature Range	_____ °F _____ °F

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

2. Fabrication: Is this vacuum window fabricated in house? [ ] Yes [ ] 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.

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

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?
[ ] Yes [ ] No

Attach Calculations in the Note Appendix

6. Operating Procedure Section:

Is an operating procedure necessary for the safe operation of this vessel? [ ] Yes [ ] 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 [ ] 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 [ ] No
If "Yes", include in the technical appendix any requirements for recording exposure, as well as a change-out schedule.