FESHM 5033: VACUUM VESSEL SAFETY

Revision History

Author	Description of Change	Revision Date
Michael White Erik Voirin	• Added reference to FESHM 5031.5 to introduction section. Clarified that exceptional load cases do not need a separate low-pressure vessel engineering note • Added EN13445 as an alternative Code in Section 3.0. • Created new section on evaluating buckling using FEA and Div. 2 Part 5. Changed buckling safety factor requirement from 3.5 to 2.5 for linear elastic analysis type analysis when no plasticity present. Added requirements and flow chart instructions for performing a non-linear material and geometry analysis for any vessels with any plasticity occurring at design load. • Clarified guidance on weld joint efficiencies and weld inspection • Added references to API and EN standards covering pressure relief device sizing • Added instructions for uploading engineering notes to Teamcenter in Section 6.1	Nov 2019
Abhishek Deshpande	• Added information about testing and inspection of vacuum vessel relief devices. • Changed Department/Section Head/Center (D/S/C) to Department Head/Section Head/Project Manager (D/S/P).	July 25, 2017
Thomas Page	Added the new FESHM template.	March, 2013

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1.0 INTRODUCTION

Vacuum vessels, including evacuated chambers and insulating jackets on dewars, pose a potential hazard to equipment and personnel from collapse, rupture, or implosion. This chapter specifies the procedure to be followed in designing, fabricating, testing, and operating vacuum vessels in order to reduce hazards.

All vessels within the scope of this chapter shall have a written Engineering Note, as described in this chapter. Vessels operated with positive internal pressure under normal operating conditions will also require a FESHM 5031.5 low pressure vessel engineering note. Exceptional load cases of positive internal pressure may be covered within the vacuum vessel engineering note.

Guidelines to update this chapter are highlighted in the most recent version of ESH&Q Doc DB 3231.

2.0 SCOPE

This chapter applies to any vacuum vessel used at Fermilab or Fermilab-leased spaces except:

1. Any vacuum vessel whose inside diameter or cross section diagonal is under twelve inches with no limitation of length.
2. Any portions of beam pipes buried underground.
3. Any vessel with a volumetric capacity of less than 35 cubic feet.
4. Any vessel under external pressure whose product P x V is less than 515 (psi) (cu. ft.), where P is the external differential MAWP and V is the volumetric capacity.
5. Thin vacuum windows for beam lines are specifically excluded from this chapter, and are covered under FESHM Chapter 5033.1.

3.0 DEFINITIONS

The Code -ASME Boiler and Pressure Vessel Code, Section VIII, Divisions 1 and 2. The revision of the Code to be applied to a given vessel is the latest revision at the start of the vessel's design. EN 13445 *Unfired Pressure Vessels*, which has an approved FESHM 2110 equivalent safety performance white paper stored in ES&H DocDB #3303, may alternatively be applied as the Code.

Vacuum Vessel - any vessel having atmospheric pressure outside the vessel and a pressure less than atmospheric inside the vessel, or any vessel which is operated with a differential pressure greater on the outside than on the inside, except those operating under an external pressure greater than one atmosphere, which are covered under FESHM Chapter 5031.

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

Qualified Person – 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.

External Design Pressure - The external design pressure or maximum allowable external working pressure (MAWP) shall be greater than or equal to the maximum expected operating pressure differential. Reference ASME Code, Section VIII, Div. 1 Part UG-28(e)

Volumetric Capacity – the internal vacuum volume of the vessel. (Does not include volume occupied by pipes, valves, instruments, or other objects.)

Exceptional Load Case – cases corresponding to events of very low occurrence probability requiring the safe shutdown and inspection of the vessel. Examples are pressure loading of secondary containment due to failure of primary containment (e.g. leakage from an inner cryogenic vessel into a vacuum vessel used as an insulating vacuum jacket), seismic loading, shock-loading during transportation, or internal explosion

4.0 SPECIAL RESPONSIBILITIES

The Division Head/Section Head/Project Manager (D/S/P) that controls the area of operation of the vessel is responsible for carrying out the requirements of this chapter. The D/S/P, or designee, shall arrange for the review of required Engineering Notes by a qualified person and shall certify vessels comply with this chapter by signing the Engineering Notes. The D/S/P shall maintain an open, updated file on all vacuum vessels within the scope of this chapter located in their areas of operation. After certification, the Fermilab engineering standard conformance label shall be attached to the vessel.

The ESH&Q Section shall audit the Divisions, Sections and Projects on their compliance to this chapter.

The Mechanical Safety Subcommittee (MSS) and/or Cryogenic Safety Subcommittee (CSS) shall serve the D/S/P and ESH&Q Section in a consulting capacity on all vacuum vessel matters. These committees may propose appropriate modifications to this chapter as necessary. Changes in policy and responsibility shall be recommended by the Fermilab ES&H Committee (FESHCom) after consulting with the D/S/P. Changes in procedure shall be recommended by the Mechanical Safety Subcommittee and/or Cryogenic Safety Subcommittee.

The Laboratory Director is responsible for approving extended engineering notes for exceptional vacuum vessels.

5.0 PROCEDURES

Vacuum vessels shall be designed to ensure that allowable stresses are not exceeded and to ensure that the vessel is stable (resistant to buckling). This chapter requires adherence to the ASME Boiler and Pressure Vessel Code or alternatively EN13445. The ASME Code is not mandatory for vessels with an external pressure difference not exceeding 15 psid under Section VIII Paragraph U-1(c)(2)(h), but the design rules may be applied. Under Section VIII, Div. 1, Paragraph UG-28(f), such vessels may be code stamped. A similar provision allowing code-stamping on vacuum vessels is found in Div. 2 Paragraph 1.2.4.2(h). The engineering design and fabrication documentation for U-stamped vessels is recommended to be included in the engineering note, but is not required to be included or required to be reviewed.

As noted in EN13445-1 Part 1 the code may be used at low pressures including vacuum. Vacuum vessels with an internal design pressure less than 0.5 bar.g cannot be CE-marked per EN13445. EN13445 vessels without a CE-mark shall be protected from internal overpressure scenarios (exceptional load cases) that exceed 0.5 bar.g. If a CE-mark is desired to minimize engineering note documentation requirements, then an internal design pressure slightly greater than 0.5 bar.g (7.4 psi) will need to be specified to the vessel designer and manufacturer.

Materials

The Code allowable stresses shall be used. For materials not included in tables of Section II, allowable stresses shall be calculated as described in the ASME Code, Sec. II, Appendices. For materials not listed by EN13445, the allowable stresses shall be determined per EN13445-3 Paragraph 6 (steels) or EN13445-8 Paragraph 6.3 (aluminum) as applicable. Stresses and strains shall meet allowable stress and strain criteria described in the Code.

Design

Vacuum vessels covered by this chapter are not required to be U-stamped or CE-marked, but shall be designed according to the appropriate design rules in the Code revision current at the time of design, unless a determination has been made that another standard is more applicable. The D/S/P or designee shall make that determination in consultation with the MSS and CSS.

The engineering note preparer is responsible for comparing the Code design rules to their specific vacuum vessel design, then listing the relevant code sections applicable to the design within the engineering note. In the event of uncertainty whether a Code requirement should be applied to a vacuum vessel the Mechanical Safety Subcommittee shall be consulted.

Shapes not specifically covered by the Code shall be analyzed per the following requirements:

1) Stresses and vessel stability shall be calculated as described in the Code. Finite Element Analysis (FEA) may be used to refine stress calculations or model vessel geometries not described in the Code.

2) EN13445-3 has two Design-by-Analysis sections, which are Annex B and Annex C. Annex C.1 states that the annex does not contain rules for buckling instability and that the risk for buckling shall be assessed separately. Annex B.8.4 has two application rules regarding buckling instability:
   a) Application Rule 1 requires experimental tests of shape deviations to determine a reduction factor to apply to a theoretical model. Performing these tests is generally not practical.
   b) Application Rule 2 simply points back Clause 8, which is the Design-by-Rule section for buckling instability calculations. Clause 8 does not cover all geometries for vacuum vessels that have been used at Fermilab.
   c) Per Annex B.2.3, "Alternative design rules, different from the application rules given in this standard, may be used, provided that it is shown that the alternative rule accords with the relevant principles and is at least equivalent with regard to reliability, serviceability and durability".
      i) ASME BPVC VIII has been successfully used for designing vacuum vessels by Fermilab and other DOE laboratories for decades; therefore, guidance from ASME BPVC VIII will be used to create an Application Rule 3 specific to vacuum vessels used at Fermilab.
      ii) Also note that EN13445-3 8.4.4 requires a minimum safety factor of 1.5 for shells under external pressure when buckling stress is elastic, which is less than the 2.0 safety factor required by ASME BPVC VIII Div. 2 Part 4.4.2 when buckling stress is elastic. Therefore, applying ASME rules for elastic buckling is conservative.
   d) Application Rule 3: The capacity reduction factor to account for geometry imperfections shall be no greater than 0.8. The elastic buckling safety factor shall be 2.0. The overall required safety factor from buckling is then 2.5. No plastic deformation due to external pressure is permitted.
3) The external pressure for buckling failure predicted by Finite Element Analysis (FEA), used for shapes not specifically covered in the Code, shall not be less than 2.5 times the MAWP if there is no plasticity present at the design load
4) If plasticity occurs in any part of the geometry at the design load, and results of a linear elastic buckling analysis show a buckling factor of less than 6, the vessel could be subject to a combination plastic/buckling failure mode not found by the standard plastic and buckling analyses. Therefore, an additional analysis must be performed which considers both the effects of material plasticity as well as geometric non-linearities. Symmetry conditions shall not be used since it is possible that they exclude a critical buckling mode. See the technical memo "MSS Guidelines for Design of Vacuum Vessels using ASME Design by Analysis Methods" included with this chapter (see link below *Other Files* heading) for further background. See figure 1 for a flowchart on how to design vacuum vessels per ASME BPVC VIII Div. 2 Part 5 along with the supplemental guidance provided by this FEHSM chapter.

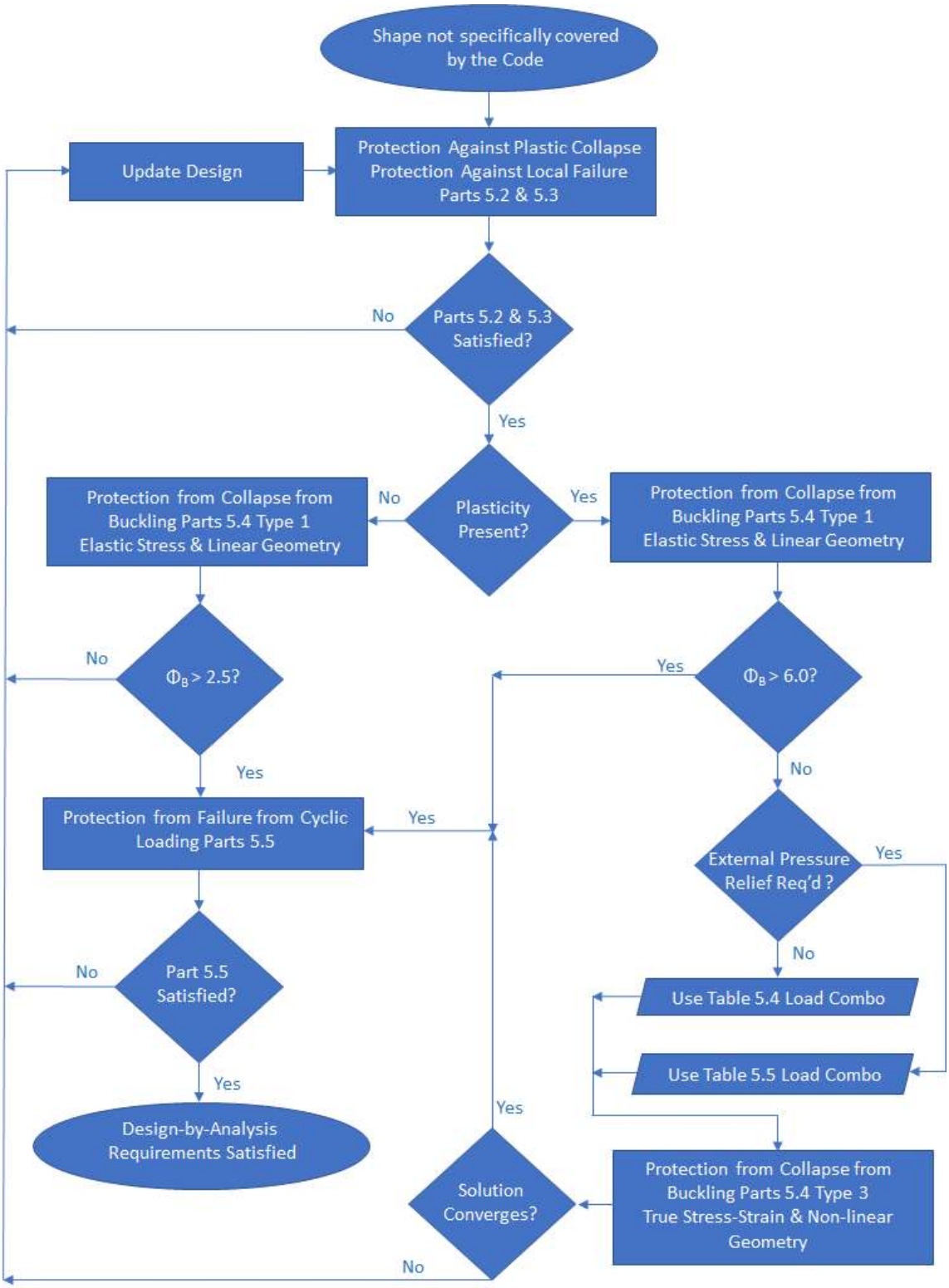

Figure 1: Flowchart describing the design-by-analysis process for shapes not specifically covered by ASME BVPC VIII

Welding

Weld configurations shall be designed per equations and rules found in the Code. Weld configurations not specifically approved or prohibited by the Code may be submitted with stress analysis calculations for approval by the Note reviewer.

Welders and weld procedures shall be qualified per the Code as described in paragraph 6 of this FESHM chapter. Code-stamped vessels do not require welding documentation.

However, strictly following the Code weld examination rules for vacuum vessels can lead to an unreasonable amount of weld examination that provides little or no safety value for weld joints that will be in compression when the vessel is under vacuum. For example, vessels designed-by-analysis per ASME BPVC VIII Div. 2 Part 5 or EN13445-3 Annexes B and C are automatically placed into examination group 1, which leads to the most extensive amount of weld examination. Therefore; an alternative set of weld joint efficiencies and weld examination requirements representing sound engineering practice has been developed for this chapter.

Option 1:

- The weld joint efficiencies and weld examination required in the chosen design Code may be applied to any vacuum vessel outside the scope of the Code.

Option 2:
As an alternative, vacuum vessels which satisfy the following criteria qualify for a simplified set of weld joint efficiencies and are exempt from further weld inspection requirements:

- External pressure is limited to atmospheric pressure.
- Internal pressure on the vacuum vessel is an exceptional load case or is not applicable.
- Vacuum vessel welds are subjected to 100% visual examination by a qualified person. This includes all internal weld surfaces wherever practical. Visual examination records and the qualifications of the weld inspector are included in the engineering note.
- The vacuum vessel materials satisfy the Code requirements for material elongation before rupture and fracture toughness across the range of normal operating and exceptional load case temperatures
- If the vacuum vessel contains internal piping or vessels:
    - Sensitive leak checking (e.g. helium mass spectrometer) is performed on the vacuum vessel while at full vacuum to demonstrate that sudden loss of vacuum is very low probability event. A record of the sensitive leak check is included the engineering note.
    - Sensitive leak checking (e.g. helium mass spectrometer) is performed on all internal vessels and piping to demonstrate that the internal pressure exceptional load case is very low probability event. A record of the sensitive leak check is included or referenced by the engineering note.
    - The vacuum vessel has a maximum relieving overpressure (set pressure plus accumulation) less than 7.5 psig (0.5 bar.g) and a relief device orifice flow area greater than 0.00024 in^2/lb (0.34 mm^2/l) of capacity by volume of the internal vessel and piping. The internal pressure relief device should be set at as low of a pressure as

practical to minimize tensile stress in the vacuum vessel during a relief event. See safety relief devices section below for additional requirements.

Based on code-referenced guidance, the simplified set of weld joint efficiencies to use in vacuum vessel design calculations is as follows:

- Butt welded joints in compression may use a weld joint efficiency of 1.0 (Reference ASME BVPC VIII Div. 1 Table UW-12)
- Butt welded joints in tension under normal operating conditions, which have complete penetration and full fusion, may use a weld joint efficiency of 0.7 (Reference ASME BPVC VIII Div.1 Table UW-12 and UW-35)
- Butt welded joints in tension under exceptional load cases may use a weld joint efficiency of 1.0. (Reference EN13445-3 5.3.2.2 and 5.6)
- Fillet welds shall have their allowable stress in tension de-rated by a factor of 0.49. The strength of fillet welds shall be based on the area subjected to shear (computed on the minimum leg dimension). The inside diameter of a fillet weld shall be used in figuring its length for nozzles. (Reference ASME BPVC VIII Div.1 UW-15)

Safety Relief Devices

If the vacuum vessel can be pressurized beyond its rating, either intentionally or inadvertently, relief devices shall be included in the design. Consideration shall be given for relief of over-pressure from all possible sources, including release of gases or fluids (by design or by accidental rupture of internal components), heat, fire, etc.

All relief devices with a relieving pressure of 15 psid or greater shall be UV-stamped for vacuum vessels designed per ASME BPVC VIII. Reclosing type relief valves with a relieving pressure under 15 psid are not required to be UV-stamped for vacuum vessels designed per ASME BPVC VIII CE-marked relief devices may be used in lieu of UV-stamped relief devices based on the approved FESHM 2110 equivalent safety performance white paper stored in ES&H DocDB #3303. Relief devices for vacuum vessels designed per EN13445 are required to be CE-marked when the internal relieving pressure is 0.5 bar.d (7.4 psid) or greater.

Non-reclosing and recloseable type relief devices such as rupture discs, flip-lids, and parallel relief plates with a relieving pressure under 15 psid are not required to be UV-stamped. All relief devices shall be certified by the manufacturer for relieving pressure and flow rate, or if designed by FNAL, shall be tested according to the Code part UG127 and a test report included in the Engineering Note. Calculations of relief valve sizing shall be included in the Engineering Note.

Additional standards are often referenced by the design codes. Code-referenced standards often have more detailed and/or specialized guidance on a specific topic. Engineering judgement is required in selecting the most appropriate Code-referenced standards given the range of operating conditions and credible failure scenarios for the vacuum vessel. The following Code-referenced standards are recommended for the sizing, selection, and installation of pressure relief systems.

ASME BPVC VIII Div. 1 Appendix M and ASME BPVC VIII Div. 2 Annex 9-A.9

Standard Organization	Standard Title
American Petroleum Institute (API)	Recommended Practice 520, Sizing, Selection, and Installation of Pressure-Relieving Systems, Part I Sizing and Selection
American Petroleum Institute (API)	Recommended Practice 520, Sizing, Selection, and Installation of Pressure-Relieving Systems, Part II Installation
American Petroleum Institute (API)	Recommended Practice 521, Guide for Pressure-Relieving and Depressuring Systems
American Petroleum Institute (API)	Standard 2000, Venting Atmospheric and Low-Pressure Storage Tanks (Nonrefrigerated and Refrigerated)
Compressed Gas Association (CGA)	S-1.1, Pressure Relief Device Standards Part 1 Cylinders for Compressed Gases
Compressed Gas Association (CGA)	S-1.2, Pressure Relief Device Standards Part 2 Cargo and Portable Tanks
Compressed Gas Association (CGA)	S-1.3, Pressure Relief Device Standards Part 3 Compressed Gas Storage Containers

EN13445-1 Clause 6.2.2

Standard Organization	Standard Title
EN	764-7 Pressure Equipment – Part 7: Safety systems for unfired pressure equipment
EN	13648-1 Cryogenic Vessels – Part 1: Safety valves for protection against excessive pressure
EN	13648-2 Cryogenic Vessels – Part 2: Bursting disc safety devices for cryogenic service
EN	13648-3 Cryogenic Vessels – Part 3: Determination of required discharge – Capacity and Sizing
EN ISO	4126 Safety devices for protection against excessive pressure Parts 1-7

Relief devices used on vacuum vessels are not required to be retested as required by FESHM 5031.4. However, the relief devices shall be visually inspected every three years and opened (if appropriate) every 5 years.

Implementation of Procedure

1. *Preparation of Engineering Note*: An Engineering Note shall be prepared by an engineer or designer for all existing or new operational vacuum vessels at Fermilab; whether purchased, in-house built, an experimenter's vessel, a used vessel, or located in an unmanned area. The format of the Engineering Note is shown in Exhibit A-1. Its purpose is to allow a reviewer to

check the design and installation and to inform a future user of the vessel parameters. The Engineering Note shall include design calculations for in-house built vessels and experimenter built vessels, and the manufacturer's data reports for purchased vessels if available. The Note shall also include precautions and operating procedures necessary for the safe use of the vessel.

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

3. *Amendment of Engineering Note*: Any subsequent changes in usage, operating temperature, valving, etc., which could affect the safety of the vessel, requires an amendment to the original Engineering Note. This amendment shall be reviewed in the same manner as the original Note.

4. *Similar Vessels*: Vacuum vessels that are similar to previously constructed and approved vessels need not have the full engineering analysis repeated. Adequate documentation can be provided by referencing the approved engineering analysis and noting any differences. Acceptance testing is still required. For the purposes of this paragraph, similar vessels mean that the same kinds of materials and construction techniques are used and similar operating parameters will be used. The geometry must be similar, however, this paragraph may be applied if geometry differences do not affect the engineering analysis or safety.

5. *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 adherence to the provisions of this chapter. Exceptions are to be identified and submitted to the Director for review as early in the design process as possible. These exceptions shall only be allowed after the Director has assured himself that sound engineering practice will be followed during design, fabrication and test of the vessel. The ESH&Q Section shall maintain copies of exceptions for the Director. An exceptional vessel is hereby defined as one which cannot meet the tenets of this chapter and therefore requires a Director's Exception.

6. A technical appendix describing procedures for an Engineering Note analysis is included.

6.0 TECHNICAL APPENDIX TO VACUUM VESSEL SAFETY

6.1 PROCEDURES AND REQUIREMENTS FOR DESIGN, FABRICATION, INSPECTION AND TEST

1. Purchased Vessels: All vacuum vessels purchased by Fermilab or its experimenters shall be made (designed and fabricated) in accordance with the "Procedure" section of Chapter 5033.

2. In-House Built Vessels: All vacuum vessels built at Fermilab or experimenter's shops shall be made (designed and fabricated) in accordance with the "Procedure" section of Chapter 5033.

3. Vessels with Thin Windows: If the thin windows can be detached from the vessel, the vessel falls within the scope of this chapter and shall be made (designed and fabricated) in accordance with the "Procedure" section of Chapter 5033. For testing, a cover plate shall be substituted for each thin window.

   A vacuum vessel with a thin window that cannot be detached is covered by this chapter, but only the vessel itself, not the thin window. The thin window is covered under Chapter 5033.1 for thin windows. For testing of such a vessel, the maximum allowable differential pressure of the thin window shall not be exceeded, and the vessel shall be rated at that pressure.

4. Welding Information:
   Welding shall be done using qualified weld procedures and welders under the rules of the ASME Boiler and Pressure Code, Section IX or EN13445-4 Clause 7. The Weld Procedure Specification (WPS), Procedure Qualification Record (PQR), and Welder Performance Qualification (WPQ) shall be attached to the Engineering Note.

   Code-stamped vessels do not require welding documentation.

5. Existing Vessels In Service: All such vessels in service need an Engineering Note.

6. Used Vessels: Used Vessels shall be classified as an existing vessel and will have their previous service taken into account during the review process. Questionable vessels or those with unknown histories shall be re-tested per the "Inspection and Testing" section of this chapter.

7. Non-manned Area Vessels: If a vacuum vessel cannot be made in accordance with the preceding requirements, it may be installed in a non-manned area with suitable administrative and physical controls to restrict access when operating the vessel and restraints to minimize damage in case of failure. The vessel must be clearly and indelibly identified for use in non-manned areas only and be sufficiently secured to prevent its removal from the non-manned area. An Engineering Note shall be completed for all such vessels.

8. Inspection and Testing: The vessel shall be inspected during fabrication by the designer/engineer for compliance to the standard. All vacuum vessels shall be acceptance tested by pumping out the vacuum volume. Before this test is performed, the Engineering Note shall be reviewed by the assigned reviewer.

   For ordinary vacuum vessels the test pressure shall be full atmospheric pressure differential of 15 psid.

   For vacuum vessels not intended to be pumped out to the full atmospheric pressure differential of 15 psid, the test pressure shall be 125% of the maximum allowable external differential pressure, but not more than full atmospheric pressure (15 psid).

   For a vacuum vessel within a pressure vessel, the test differential pressure shall be 125% of the maximum allowed working pressure differential.

   Thin windows and other delicate equipment may be removed for the test of the vacuum vessel. The test shall be documented with a brief description and the signatures of two witnesses.

9. Records: Approved engineering notes shall be filed in Teamcenter.
   a. A New Item shall be created in Teamcenter with the type chosen as Engineering Note
      i. The New Item Name shall use the Vacuum Vessel prefix followed by a meaningful Name which briefly describes the contents of the note
      ii. A full Description shall be entered for the New Item
   b. If applicable the Division Legacy Number shall be entered
   c. The appropriate Engineering Note category of Vacuum Vessel shall be chosen
   d. The Revision Author, Revision Comments, Lab Location Code, Exceptional Status, and Division\Section\Center shall be entered
   e. The Engineering Note and supporting files shall be added as Data Sets. All documentation required for independent review of the Engineering Note must be included.
   f. Approval
      i. The Teamcenter Workflow may be used to electronically obtain the required approvals and release the Engineering Note.
      ii. Approvals may also be obtained by physical signature, scanned, and included with the Engineering Note. A Teamcenter Workflow must still be completed so that the Engineering Note is released. This workflow need not involve the required approvers in the case of physical signature.
   g. Amendments to existing Engineering Notes shall be entered as a Revision to the original Item in Teamcenter.

6.2 ENGINEERING NOTE

An Engineering Note (see technical appendix for note format) shall be prepared by the designer addressing the topics below for the vessel, series of vessels, or vessel system, as appropriate. Its purpose is to allow a reviewer to check the design and installation and to inform a future user/re-tester

of the appropriate vessel parameters. The note shall be signed and filed as noted in Chapter 5033 under "Special Responsibilities."

1. Description and Identification

   Obtain a vessel identification number from the Division or Section safety officer. Describe the vessel, its purpose, site location, and how the maximum allowable working pressure (MAWP), internal or external, was established.

   All drawings deemed pertinent to the safety review shall be listed and included. Include in the note a copy of the information on the engineering standard conformance label.

2. Design Verification

   Provide the design calculations. For externally manufactured vessels, a copy of their design calculations is acceptable.

3. System Relief Verification

   When relief devices are included in the design, provide a schematic of the vacuum vessel relief system and appropriate calculations or test results to prove that the vacuum vessel will not be subject to pressures over its calculated MAWP or under its maximum external differential pressure. (Note: If the MAWP is greater than 15 psi, a FESHM Chapter 5031 Engineering Note is required.) Prove that the relief valve(s) cannot be isolated from the vacuum vessel except as allowed by ASME Code (Reference Sec. VIII Div. 1 Appendix M and Div. 2 Appendix A). The relief calculation shall take in account a failure of any piping or vessel inside the vacuum vessel, and shall be sized according to the maximum system flow rate of that piping, and/or a reasonably expected leak rate from the inner vessel.

4. Operating Procedures

   Provide cautions and operating procedures for the vessel if required for safe operation.

5. Welding Information

   Attach the required welding records. Code-stamped vessels do not require welding records.

6. Extended Engineering Note for Exceptional Vessels:

   The Note shall be prepared using the same or similar format as noted on Exhibit A-1, but in addition shall include the following information.

   a. *Reason for Exception*: D/S/P or designee shall provide a statement showing the necessity of a Director's Exception.

b. *Analysis/Collapse Test*: The system designer shall provide a stress/collapse analysis of all exceptional parts of the vessel. Include data, formula or test results that demonstrate the anticipated safety factor. Source of information shall be referenced.

c. *Fabrication*: The system designer shall provide a fabrication procedure, a list of planned and completed inspections and any other quality control procedures taken.

d. *Hazard Analysis*: The system designer shall provide a description of personnel hazards associated with vessel operation and the methods used for protection. The hazard analysis shall address vessel application, operating limits and controls, possible effects in the event of vessel failure and inherent safeguards provided.

e. *Acceptance Test*: An acceptance test shall be performed per this chapter.

Engineering Note for Existing Vessels, Used Vessels and Non-manned Area Vessels

The D/S/P or his designee shall provide a written record of the decisions, judgments, tests, administrative controls and hazard analysis that were necessary to approve these types of vessels under this chapter.

In the event that the Engineering Note cannot be approved, operation shall be discontinued until appropriate modifications or administrative safeguards are instituted, or Director's Exception is granted.

6.3 DESIGN REFERENCE DATA BY TM NUMBER AND SUBCATEGORY

A Design Chart for Long Vacuum Pipes and Shells TM-1378 (SCN 0121.585).
Design Charts for Spacing of Vacuum Line Supports TM-1377 (SCN 0121.585).
Design Charts for Vacuum Plates TM-1052 Rev A. (SCN 5540.100).

7.0 FORMS

There is an Engineering Note Cover Page form to be included in the Vacuum Vessel Engineering Note.

- Vacuum Vessel Engineering Note

This form can be found on the ES&H website or the ES&H document management database under FESHM Chapter 5033.