FESHM 5031.7: MEMBRANE CRYOSTATS

Revision History

Author	Description of Change	Revision Date
Michael Geynisman	• Modifications for the pressure test requirements to allow both, pneumatic and hydrostatic testing • Modifications per Lab-wide review comments, including: - Grammatical improvements - Addressing potential spill due to piping penetrations below the liquid level - Listing all loads to the support structure - Clarifying attachment of the top plate to structural support	November 2015
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1.0 INTRODUCTION

This chapter defines the policy for the design, construction, quality control, testing and operation of cryogenic metallic membrane cryostats. Membrane cryostats contain cryogens, in both gas and liquid state, and therefore possess the normal hazards associated with a cryogenic device including a potential pressure hazard. Membrane tank technology has been used in liquefied natural gas (LNG) stationary and transportation storage across the globe for the last half-century. It is now being used for neutrino physics using liquid argon (LAr) as the contained cryogenic fluid. It may also contain nitrogen for testing or storage purposes.

This chapter specifies the engineering policy that governs the design, construction, quality control, testing and operation of metallic membrane cryostats. The purpose is to minimize hazards, as well as to ensure consistent design review and approval. The intent of the policy is to assure a level of safety commensurate with ASME Boiler and Pressure Vessel Code, Section VIII as required by Code of Federal Regulations, 10 CFR 851 Worker Safety and Health Program.

2.0 SCOPE

The chapter applies to any metallic membrane cryostat containing gas or liquid argon or nitrogen as defined below, which is designed, installed or operated for Department of Energy by Fermilab, regardless of size, shape, site of installation, duration of use, origin of manufacture, operational location, or previous use at Fermilab or other facilities.

This chapter does not apply to cryostats or vessels, which use components of membrane tank technology without formation of a membrane cryostat in whole.

3.0 DEFINITIONS

Membrane: A metallic film, or metallic primary container, separating the insulation from the liquid or gas contained in the membrane tank.

Membrane cryostat: Integrated assembly, wherein a polyurethane foam-insulated metallic membrane formed of prefabricated panels containing the cryogen is integrated within a structural support with a top plate attached to the structural support and providing cryogenic feed-through and pipe penetrations. The metallic membrane only contains the liquid and gas and maintains the leak tightness. The load exerted by the liquid head and the gas pressure is transferred from the metallic membrane to the structural support through the rigid insulation. The metallic membrane cryostat constitutes a complete low pressure vessel, which provides for leak tightness and pressure containment.

Codes and Standards: Membrane cryostat technology utilizes containment at pressures below 15 psig and falls outside the scope of the ASME Boiler and Pressure Vessel Code, Section VIII. Furthermore, a number of United States (US) and international codes, standards and recommended practices apply to the design and construction of the membrane cryostats, or particular parts of them. A separate

document attached to this Fermilab Environment, Safety, and Health Manual (FESHM) chapter, "*Guidelines for the Design, Fabrication, Installation and Testing of Metallic Membrane Cryostats*", has been developed by the Fermilab Cryogenic Safety Subcommittee, and references the current understanding of best international practices in the design, fabrication, installation, examination, and testing of membrane cryostats. The "*Guidelines for the Design, Fabrication, Installation and Testing of Metallic Membrane Cryostats*" discusses the applicability and use of the specific codes, standards and recommended practices and recognizes that while the suppliers of the membrane cryostats are duly regulated by their respective international standards, Fermilab shall assure the level of safety commensurate with ASME Boiler and Pressure Vessel Code, Section VIII as required by Code of Federal Regulations, 10 CFR 851 Worker Safety and Health Program.

Engineering Note: A written analysis demonstrating that a given membrane cryostat 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.

Large Quantity Liquid Argon Panel: A panel specifically assigned to membrane cryostat note reviews to ensure uniformity in preparation and review.

Exceptional Vessel: A vessel within the scope of this chapter which does not fully meet the requirements of this chapter and the "*Guidelines for the Design, Fabrication, Installation and Testing of Metallic Membrane Cryostats*" referenced in the policy statement. The Engineering Note originator, in consultation with the Large Quantity Liquid Argon Panel, will make the determination whether the vessel needs to be considered exceptional. Engineering analysis and justification for all exceptions are required additions to the engineering note.

4.0 SPECIAL RESPONSIBILITES

The Division/Section Head or Project Manager (D/S/P) who controls the ownership of the metallic membrane cryostat is responsible for carrying out the requirements of this chapter. The D/S/P, or designee, shall certify compliance of the membrane cryostat with this chapter by signing the Engineering Note following review and approval by the Large Quantity Liquid Argon Panel. The original Engineering Note shall be placed into the laboratory engineering document management system.

The Cryogenic Safety Subcommittee may propose appropriate modifications to this chapter as necessary. Changes in policy shall be recommended by the Fermilab ES&H Committee after consulting with the D/S/P's.

The Large Quantity Liquid Argon Panel shall arrange for the review of required Engineering Notes by a qualified person and verify that the membrane cryostat meets the requirements specified in this

chapter, as well as any other FESHM chapter relevant to the design, installation and operation of the membrane cryostat.

5.0 POLICY AND REQUIREMENTS

The metallic membrane cryostat constitutes a complete low pressure vessel, which provides for leak tightness and pressure containment. All existing and new metallic membrane cryostats shall conform to the requirements of this FESHM chapter.

1. *Policy:* The design, construction, quality control, testing and operation for all metallic membrane cryostats shall be **in accordance with this chapter,** "*Guidelines for the Design, Fabrication, Installation and Testing of Metallic Membrane Cryostats*". Additionally, for the cryostats designed and provided by CERN for the LBNF/DUNE and SBN programs, the MOU between CERN and Fermilab "*Design, Fabrication, Installation and Testing of the LBNF/DUNE and SBND Membrane Cryostats*" **(**CERN EDMS 1554082 and Fermilab **SBN DocDB 651**) shall apply.

2. *Design:* The design pressures and temperatures of the vessel shall be established by accepted engineering practice. The maximum differences in internal and external pressures, both for pressure and vacuum scenarios, shall be included in the Engineering Note.

3. *Pressurization:* If the vessel can be pressurized beyond its design pressure, either intentionally or inadvertently, pressure 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, connected gas or liquid sources, etc. A relief device must be installed prior to commencing membrane cryostat in service and remain directly connected to the vessel while the vessel is in service. Unless excluded below, pressure relief devices shall comply with requirements of API 620 and API 2000.

   3.1 A relief device(s) shall be sized such that the vessel pressure does not exceed its design pressure and allowed accumulation and has a flow capacity in excess of the largest overpressure scenario. Allowed accumulation shall not be higher than allowed for ASME-coded vessels and must be documented (reference applicable code, vendor documents or calculations).

   3.2 Re-closing type relief valves with a relieving pressure under 15 psid are not required to be UV-stamped.

   3.3 All relief devices shall be certified by the manufacturer for relieving pressure. A test report and an analysis predicting the flow shall be included in the Engineering Note.

   3.4 Calculations of relief valve sizing shall be included in the Engineering Note. Calculations should follow appropriate US standards.

   3.5 A list of all potential means of pressurization shall be compiled.

3.6 Relief devices used on membrane cryostats shall be periodically inspected and tested as required by FESHM 5031.4, *Inspection and Testing of Relief System.*

3.7 Prior to putting the membrane cryostat in service, all relief devices shall be installed and the documentation requirements satisfied.

4. *Vacuum:* The metallic membrane cryostat shall be protected from every source of external pressurization. External pressurization scenarios shall be listed and discussed in the Engineering Note for the metallic membrane cryostat. When the cryostat can be evacuated or pressurized externally relative to atmosphere or secondary barrier beyond its design differential pressure, either intentionally or inadvertently, vacuum relief device(s) shall be included in the design for all external pressurization scenarios.

5. *Piping penetrations below the liquid level*: The design of the metallic membrane cryostat shall address potential for uncontrolled spills of liquid argon into enclosure. Specifically, any side or bottom penetrations shall be reviewed in early design stages for justification and by the Large Quantity Argon Cryogenic Panel for requirements for spill prevention and mitigation.

6. *Inspection*: Membrane shall be leak checked with ammonia gas per British Standard BS EN 14620-2 "*Design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0°C and -165°C*", French Standard NF A09-106 "*Testing for leak tightness by means of ammonia*", or Japanese Standard JIS Z2333 "*Test method for leaks using ammonia gas*".

7. *Test*: The membrane cryostats shall be pressure tested. The pressure test shall be per rules of either API 620, Annex Q or ASME BPVC Section VIII, Div.1. Both, hydrostatic and pneumatic pressure test options are allowed. The decision for choice of the pressure test option shall be made in the design stage to ensure adequacy of design and necessary mitigation measures. If the pneumatic test option per ASME BPVC Section VIII, Div.1, UG-100 is selected, then the hazards of such pneumatic test shall be determined and an appropriate risk-based hazard level is assigned per "Pressure Systems Stored-Energy Threshold Risk Analysis, PNNL-18696, 2009". The results of this analysis and mitigation measures should consider the environment of the test location and adjacent structures. The testing procedures shall be reviewed and approved by the Large Quantity Liquid Argon Cryogenic Panel.

8. *Documentation*:

8.1 An Engineering Note for the metallic membrane cryostat low pressure vessel shall be prepared by a qualified person for each membrane cryostat. Its purpose is to allow a reviewer to document the completion of the requirements of this chapter and "*Guidelines for the Design, Fabrication, Installation and Testing of Metallic Membrane Cryostats*".

8.2 A set of documentation shall be prepared per FESHM 5032, *Cryogenic System Review* to demonstrate to the review panel that aspects of the system which could present a hazard to equipment or personnel have been examined.

9. *Reviews*:
   10.1 All required Engineering Notes shall be reviewed by the Large Quantity Liquid Argon Panel.

   10.2 The associated cryogenic system shall be reviewed by the Large Quantity Liquid Argon Panel per FESHM 5032, including solutions for preventing and mitigating spills of argon into enclosures.

10. *Modifications to a compliant system*: Any subsequent changes in usage or operation of a membrane cryostat (already in compliance with this chapter) shall meet the requirements of this chapter. Significant modifications impacting system safety shall be documented in a reviewed Amendment to the original Engineering Note.

11. *Director's Exception*: Exception to the provisions of this chapter shall be allowed only with the signature of the Laboratory Director or designee and 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 is assured that sound engineering practice will be followed during design, fabrication, testing, and operation of the cavity. The Environment, Safety, Health and Quality Section shall maintain copies of exceptions for the Director.

6.0 ENGINEERING NOTE

An Engineering Note shall follow format of the FESHM 5031.7TA "*Metallic Membrane Cryostat Low Pressure Vessel Engineering Note Form"*. Its purpose is to allow a reviewer to check the design and to inform a future user of the appropriate vessel parameters. At a minimum the following should be included and attached to the Engineering Note:

1. Membrane cryostat description
2. Design codes and evaluation criteria
3. Calculations for:
   a. Load-bearing structural support, including the loads from the experimental equipment inside the cryostat or mounted on the top plate
   b. Passive insulation
   c. Stainless membrane vessel
   d. Top plate(s)
4. Material data
   a. Materials and properties used in construction
   b. Material certifications

5. Fabrication information
    a. Assembly procedures for stainless membrane vessel
    b. Assembly procedures for the passive insulation
    c. Assembly procedures for the structural support
    d. Assembly procedures for the top plate
    e. Welding / brazing details and specifications
    f. Welder's qualification
    g. Ammonia leak check inspector's qualification
6. Design drawings
7. Examination reports
    a. Inspections
    b. Welds leak check
8. Pressure relief system design calculations and selection of reliefs
9. Vacuum protection system design calculations and selection of reliefs
10. Design and safety considerations for piping penetrations into the liquid volume
11. Pressure test reports
12. Operating procedures