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SAFETY CONSIDERATIONS FOR THE MUCOOL SYSTEM DESIGN

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1. Applicable Codes / Standards
2. Design and Safety Documentation Required
3. Safety Status
4. Conclusions

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APPLICABLE SAFETY CODES AND STANDARDS FOR MU-COOL HYDROGEN SYSTEM

FERMILAB STANDARDS (FESHM)

1. "Guidelines for the Design, Review and Approval of Liquid Cryogenic Targets"
2. "Liquid Hydrogen System Guidelines"
3. "Storage and Use of Flammable Gases"
4. "Cryogenic System Review"
5. "Oxygen Deficiency Hazards"
6. Other..... Pressure Vessels, Dewars, Electrical, etc.

NATIONAL CODES

1. ASME Code
2. National Electrical Code
3. National Fire Protection Association Code
4. Compressed Gas of America Standard
5. ISA Application of Safety Instrumented Systems

5032.2
Rev. 11/95

GUIDELINES FOR THE DESIGN, REVIEW AND APPROVAL

OF LIQUID CRYOGENIC TARGETS

INTRODUCTION

Liquid cryogenic targets are frequently used in fixed target experiments and beamlines. Typically these targets are filled with hydrogen or deuterium. The hazards posed by these targets include the normal cryogenic hazards, pressure safety considerations, as well as the hazards associated with flammable gases. Targets are generally fragile vessels installed in the midst of experiment apparatus. Frequently, the experiment requirements are at odds with normal engineering practices, e.g. standard pressure vessel safety factors vs. the need for vessel walls as thin as possible. Therefore, special precautions are necessary to ensure safe operation. These precautions take the form of specialized methods for design, fabrication, testing, secondary containment, personnel access, and stringent requirements on material specification and quality control. These techniques have been developed over many years within the Research Division Mechanical Support Department, and are continually refined. As a consequence, these techniques and technical requirements are specified in the Research Division Operating Manual chapter RD_ESH_010, which serves as a technical appendix to this chapter.

Procedures for controlling normal cryogenic hazards associated with cryogenic targets are given in Chapter 5032 of the Fermilab ES&H Manual. Chapter 5032, in concert with the this chapter, serve to define all requirements for design, review, approval and operation of liquid cryogenic targets.

DEFINITIONS

Cryogenic - at a temperature below -150^{o}C.

Cryogenic target - A vessel of any size holding a cryogenic liquid used in an experiment or beamline as a target.

Cryogenic personnel - Those engaged in or responsible for the production, use, transport or storage of cryogenic fluids and materials.

Safety Report - A written analysis demonstrating the target meets the requirements of Chapter 5032 and RD_ESH_010.

RESPONSIBILITIES

The division/section head responsible for the area of operation of the target is responsible for ensuring the requirements of this chapter are met. The head shall arrange for the review of the target by a Liquid Hydrogen Target Safety Review Panel (hereafter called the "Review Panel"). The head shall certify that the target complies with this chapter by a written memo authorizing the operation of the target. The head shall ensure that changes to RD_ESH_010 are appropriately reviewed by the Review Panel and/or the Cryogenic Safety Subcommittee.

The Review Panel is responsible for verifying that the target meets the engineering requirements specified in the Research Division Operating Manual Chapter RD_ESH_010.

The department head responsible for the design of the target shall ensure that the safety report is maintained and filed for future reference.

The ES&H Section shall audit divisions/sections on their compliance with this chapter.

The Cryogenic Safety Subcommittee and the Review Panel shall serve the division/section head and the ES&H Section in a consulting capacity in all matters related to cryogenic targets. These committees may recommend appropriate modifications to this chapter as necessary. Changes in this chapter shall be recommended by the Laboratory Safety Committee after consultation with affected division/section heads.

REQUIREMENTS

1. Design, Fabrication and Testing

a. The techniques and requirements of RD_ESH_010, sections II and III, shall be adhered to.

2. Safety Analysis and Review

a. A safety analysis and review in accordance with Chapter 5032 of the Fermilab ES&H Manual shall be performed on every cryogenic target system. Those responsible for the design, fabrication, testing, installation, and operation of the target system shall prepare the safety analysis in accordance with the technical appendix of Chapter 5032. The analysis shall be reviewed by the Review Panel, and conclusions reported to the appropriate division/section head.

b. The safety review of the cryogenic target shall be conducted using the procedure given in the technical appendix to Chapter 5032. The review will begin as early in the conceptual design stage as deemed appropriate by the designer of the target system and the Review Panel chair. The documentation specified in Chapter 5032TA, and detailed in Part 5 below, shall be provided to the Review Panel following a schedule which will permit a thoughtful and unhurried review. The target designers and the Review Panel should meet at a frequency which will facilitate the review process.

c. A Target Safety Review book shall be maintained for each target system. This book shall contain all required documents and any other documents considered appropriate by the Review Panel.

3. Authorizations and Permits

a. The safety review of the target system will result in several milestones at which the target designers will be given authorization to proceed. At least the following four milestones shall be present in the review process:

Milestone	Authorizing Person	Authorizing Vehicle
Accept Design	Review Panel Chair	Memo or signed assembly drawing
Testing with cryogens in test facility	Department Head	Memo
Installation	Department Head	Memo
Operation	Division Head	Memo

4. Operation

a. Operating procedures shall be documented in the Target Safety Review book. Operating procedures define all phases of cooldown, filling, warm-up and steady-state operations. Sub-atmospheric operation of a target must be specifically addressed in the procedures by a combination of administrative and engineered controls. All operating functions except transferring liquid from the target to the reservoir shall be done by qualified cryogenic personnel. The transfer of liquid to the target vessel or the reservoir may be performed by other suitably trained personnel (i.e. experimenters).

b. Emergency procedures for each target system will vary depending on the area in which the target is operated. Therefore, area specific procedures shall be written, reviewed and documented in the Target Safety Review book. Operators of the target shall be provided with a call-in list of qualified personnel who are available at all times.

5. Target Safety Review Book

a. The Target Safety Review book is the primary means of transmitting safety information about the target to the Review Panel. A book shall be provided to each member of the Review Panel. The target designer shall maintain a master book that contains i) all required documentation and ii) all correspondence to/from the Review Panel, and iii) notes from all meetings held.

b. The Target Safety Review book shall contain all of the required documents of Chapter 5032TA, including the following:

1. Structural calculations on all parts of the target

2. Venting calculations for the target

3. Venting calculations for the vacuum space

4. Venting calculations for the secondary containment

5. Complete drawings of the target, vacuum system and secondary containment

6. Instrument and valve summary

7. Interlock list

8. Operating procedures

9. Emergency procedures

10. Operational call-in list

11. Material certification data on parts

12. FMEA, what-if analysis

13. Flow diagram

14. Testing results

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SAFETY STATUS

1. Civil Construction
2. Absorber Windows
3. Vacuum Vessel (Absorber) Windows
4. Safety Controls System
5. Electrical Safety of Hydrogen Areas

MU COOL BUILDING SAFETY

D. Allspach, J. Priest
4-3-02, Rev. A

The following requirements are highlighted in response to the Gage-Babcock's Safety Report. The requirements below represent only a partial list of the required safety features of this test facility. Governing Fermilab standards include FESHM 6020.3, "Storage and Use of Flammable Gases" and the Liquid Hydrogen Guidelines referenced in FESHM 5032.2, "Guidelines for the Design, Review, and Approval of Liquid Cryogenic Targets".

Manifold Room Safety

1. Install one wall or area (1 sq.ft. per 50 cu.ft. of room volume) which is lightweight material designed for explosion venting.
2. Install a Flammable Gas Detector in the sump room. Sump room should maintain positive pressure. Use NEC Class 1 Division 2 Group B electrical equipment in the sump room. Sump pump will be submersed in water.
3. Sprinklers should not be installed in the manifold room per FESHM 6020.3 and CGA P-1 2000 paragraph 4.2.5.
4. Electrical equipment inside the Manifold Room shall meet NEC Class I Div. 2 Group B requirements.
5. Requirements of FESHM 6020.3 shall be met.
6. Heaters used in the Manifold room and the sump room shall meet the requirements of NEC Class 1, Division 2, Group B.
7. Flammable Gas and ODH Sensors shall be installed. In the case of an alarm, Safety Logic will cause the following actions:
   (a) notify FIRUS
   (b) automatically close supply valves
   (c) initiate emergency ventilation
   (d) show emergency status on Status Panel located on exterior of Manifold Room.
   (e) sound local audible alarm
   (f) notify remote control room
8. Crash buttons inside and outside of Manifold Room which when pressed cause the same actions as 7 above.
9. Exhaust / Venting points to be located outdoors. See Outdoor Venting Points.
10. Room to have normal ventilation per FESHM 6020.3.

Outdoor Venting Points

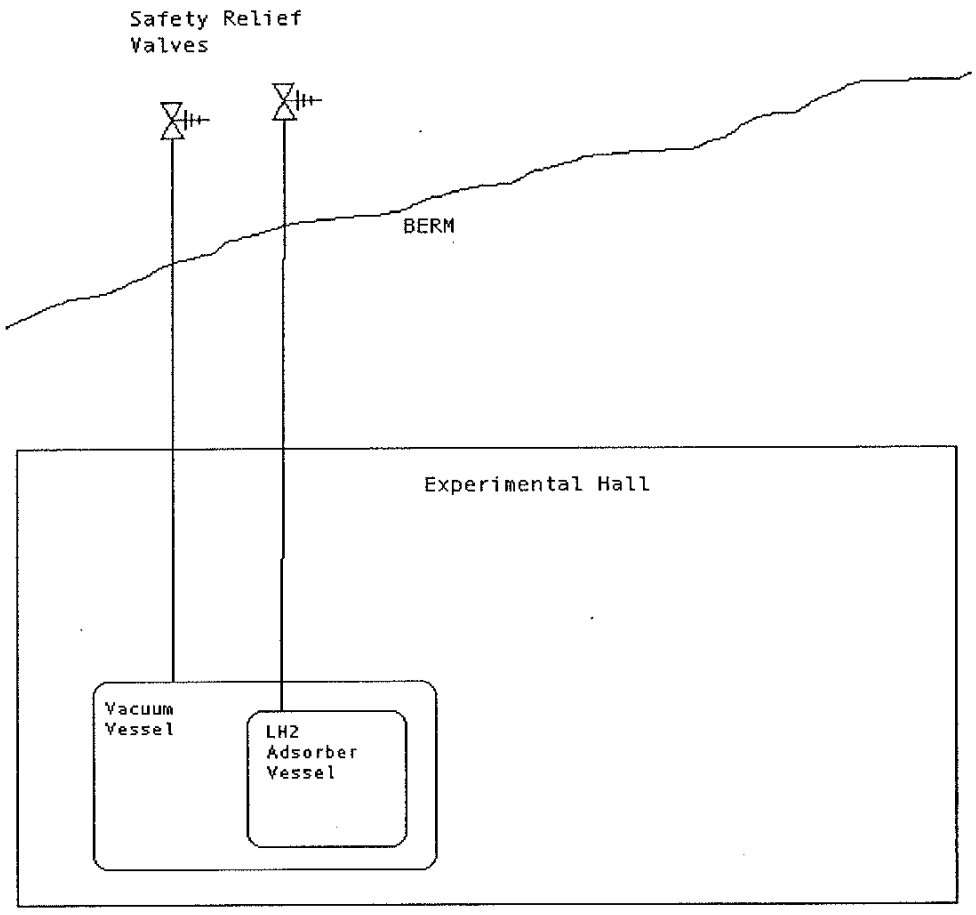
1. Exhaust from Pressure/Safety Relief Valves shall vent outdoors.
2. A sphere with a radius of 15 feet is NEC Class 1 Group B. No electrical equipment in this area.
3. No welding, burning, brazing, or grinding within 10 meters.

Outdoor Gas Cylinder Storage

1. Equipment Elevator location is OK but administrative control may be imposed on its use.
2. Recommendation to include a canopy to protect the cylinder storage area from weather.

Experimental Hall

1. The Experimental Hall is technically only subject to the Liquid Hydrogen Guidelines per the FESHM. The Adsorber container and its vacuum containment shall meet this guideline. These containers include safety relief devices which vent safely to the outdoors. See sketch on page 3.
2. Wall/Ceiling relief panels are not required.
3. Sprinkler system should be installed.
4. Ceiling Lights and other standard electrical equipment (outlets, light switches, etc.) in the entire test facility and any other area within 15 feet of any component containing hydrogen shall be rated for NEC Class 1 Div 2 Group B.
5. Experimental Equipment within 15 feet of the hydrogen adsorber system shall be on shunt trip.
6. Exhaust / Venting points to be located outdoors. See Outdoor Venting Points.
7. No welding, burning, brazing, or grinding within 10 meters.
8. Hall to have normal ventilation per FESHM 6020.3.
9. Ventilation to include a blower pulling air/gas from ceiling and exhaust outdoors while another blower provides fresh air at opposite end of hall. These emergency blowers shall be controlled via the hydrogen safety system. Manual controls outside of the test facility shall be provided as well.
10. Flammable Gas and ODH Sensors shall be installed. In the case of an alarm, Safety Logic will cause the following actions:
    (a) notify FIRUS
    (b) automatically close supply valve
    (c) initiate emergency ventilation
    (d) shunt trip within 15 feet those devices not meeting NEC Class 1 Group B requirements.
    (e) show emergency status on Status Panel located at the Experimental Hall Entry.
    (f) sound local audible alarm
    (g) notify remote control room
11. Crash buttons inside and at entry to perform actions as in 10 above.


Safety Relief
Valves
BERM
Experimental Hall
Vacuum
Vessel
LH2
Adsorber
Vessel

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REQUIREMENTS FOR WINDOWS

Absorber Windows (metal - Aluminum alloy)

Design:
a. Internal MAWP = 25 psid
b. FEA showing maximum allowable stress ≤ 0.25 UTS
c. Material Certification
d. Window drawing
e. other

Tests:
a. Room Temperature testing per UG-100 of the ASME Code + room temperature burst test
b. Liquid Nitrogen test - burst test per UG-101 of the ASME Code

Note: The liquid hydrogen circuit safety relief system includes two valves with a 10 psig set point. In addition, a PLC controlled Vent Valve will be installed.

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REQUIREMENTS FOR WINDOWS

Vacuum Windows (metal - Aluminum alloy)

Assumption: Design assumes that the beampipe attaches to absorber vacuum windows, thus vacuum exists on both sides of the windows.

Design:
a. Internal MAWP = 30 psid
b. External MAWP = 15 psid
b. FEA showing maximum allowable stress is smaller of 2/3 S_y or 0.4 S_u
c. Material Certification
d. Window drawing
e. other

Tests:
a. The first test is destructive. Burst test five vacuum windows at room temperature to demonstrate a burst pressure of at least 75 psid for all samples. This test is for the condition in which pressure is exerted on the interior side of the window relative to the absorber vacuum.

b. Subsequent tests are nondestructive and are meant to certify the windows and vacuum chamber which houses the absorber for actual use in the experimental hall. All tests are at room temperature.

(i) Perform an external pressure test on each vacuum window to 25 psid to demonstrate no failures will result; i.e. no creeping, no yielding, no elastic collapse/buckling, no rupture.

(ii) Other absorber vacuum jacket testing to ensure its integrity.

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Safety Interlocks (Quadlog PLC) and Controls (Apacs)

Functions include:

1. Control Operations of the Hydrogen System.
2. Provide Safety Interlocks for the Hydrogen System.
3. Carry out Safety Actions in the case where Flammable Gas or ODH conditions are detected.

System design:

1. Design requires knowledge of the Equipment $$$ Value in the Experimental Hall.
2. An estimate of Failure Severity and Frequency will be made as well as the Consequences to Personnel and Equipment.
3. These overall risk will be evaluated to detemine a Safety Integrity Level (SIL).
4. The SIL will determine the Safety Controls architecture (level of redundancy required) per the ANSI/ISA-84.01, "Application of Safety Instrumented Systems for the Process Industries".

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Electrical Safety of Hydrogen Areas

1. Civil Construction
2. Safety of Absorber Instrumentation
3. NEC Class I Division 2 of Electrical Equipment in the Experimental Hall

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CONCLUSIONS

1. Design decisions are being made based on the applicable codes and standards.

2. Need to provide safety documentation to the Safety Panel and begin meeting with them regularly throughout the design/planning process.