Revision 0

Jefferson Lab

THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY

CRYOMODULE TEST FACILITY

ACCELERATOR SAFETY ENVELOPE

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Approval Page
for the
Thomas Jefferson National Accelerator Facility
Cryomodule Test Facility (CMTF) Accelerator Safety Envelope
Revision 0

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Approvals

All revisions to this document require approval from the Thomas Jefferson Site Office (TJSO).

Major revisions require approval, on a new signature page. These include the Laboratory Director, the Associate Directors of Accelerator and Environment, Safety, and Health (ES&H), and the Department managers of SRF Operations, Engineering, and Facilities Management and Logistics (FM&L). Major revisions require a full number change incremented appropriately (i.e. Rev 2.1 becomes Rev 3; Rev 3 becomes Rev 4; etc.) and a notation within the Revision Summary.

Interim revisions incorporating minor changes such as clarifications, minor corrections that do not change the intent of the document, and typographical corrections require Jefferson Lab approval by the Associate Director(s) of the affected division(s) and Associate Director, ES&H Division. Minor revisions are denoted by a mantissa (fractional number) incremented as appropriate (i.e. Rev 0 becomes Rev 0.1; Rev 1.2 becomes Rev 1.3, etc.), and a notation is made within the Revision Summary.

Revision Summary

Rev.	Reason for Revision	Approval	Date
0	Initial issue.	See signature page	3/2025

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1.0 INTRODUCTION

The *Department of Energy (DOE) Order 420.2D Safety of Accelerators* establishes accelerator-specific safety requirements and approval authorities. The DOE O 420.2D requires Thomas Jefferson National Accelerator Facility (Jefferson Lab) to conduct a hazard analysis for accelerator-specific safety risks and identify the controls necessary to mitigate those risks. The accelerator-specific hazard analysis and necessary controls associated with operation of the Cryomodule Test Facility (CMTF) are provided in the *Jefferson Lab Safety Assessment Document* (SAD) Revision 9a. The set of accelerator-specific controls identified in the safety analysis that are essential for safe accelerator operations are referred to as Credited Controls. These Credited Controls collectively form the bounding conditions for the *Accelerator Safety Envelope* (ASE).

The ASE is approved by the Thomas Jefferson Site Office (TJSO) and is contractually binding for operation of the Jefferson Lab accelerators referenced herein.

2.0 FACILITY DESCRIPTION

The Cryomodule Test Facility (CMTF) located on the first floor Test Lab along the East wall of the High Bay Area (Building 58; Room 1119). The CMTF and Vertical Test Area are built on the repurposed site of the NASA Space Radiation Effects Laboratory 600 MeV Synchrocyclotron. The facility includes the testing area (the Cave; Room 1119), the production cryomodule control room along its north wall (Room 1121), and the labyrinth between the cave and the control room. The shielded area is 18 ft. wide by 20 ft. high by 56 ft. long. The wall shielding is concrete and at least 4.5 ft. thick on all sides, and 3 feet thick on the roof. A vent fan assembly and several small penetrations enter the facility at various positions and have been supplemented with additional shielding packages (when appropriate).

Access to the test area is through one of two doors, a retractable concrete door that rises and lowers to floor level in the west wall, or via a labyrinth with a personnel door at the northeast end of the cave. The labyrinth door at the northeast corner will be the primary access and egress used in preparing the enclosure for testing and both the personnel doors and the retractable concrete door must be closed and locked in order to satisfy the PSS interlock system. In the event of a leak resulting in potential oxygen deficiency conditions, a ceiling vent fixed with a fan will ventilate the enclosure into the high bay as a matter of defense in-depth. Above the roof, the vent is shielded by both movable lead and concrete shielding to reduce possible radiation exposure to levels consistent with other locations on the roof – which is posted as a Radiation Controlled Area (RCA).

The CMTF is primarily an acceptance testing facility for horizontally oriented SRF cavities packaged and assembled in cryostats which serve as beam accelerating devices at CEBAF and other accelerators and facilities throughout the world. Periodically the shielded and enclosed space may also be used for testing of other (S)RF devices, and technologies associated with them, as a conveniently located and available test bed.

The CMTF Mezzanine also serves as the location of an RF Window test stand that is able to make use of the RF power from one pair of 8kW klystrons normally supplying the CMTF when not in use. Window test stand operation is not accelerator operation and is not governed by this ASE.

3.0 ACCELERATOR SAFETY ENVELOPE (ASE) VIOLATION

Operation of the CMTF without the specified credited controls in place and functional is a violation of the ASE. If a Credited Control is inoperable or ineffective, compensatory measures may be used. Acceptable compensatory measures are listed with each Credited Control. Other compensatory measures may be used if those measures are evaluated by the Safety Configuration Management Board (SCMB) and approved by the TJSO. When an ASE violation occurs, RF Operations in the CMTF shall cease and not resume until:

- The situation is investigated and documented in accordance with the Critical Event Response section of the *Testing Operations Directives (TOD) and ES&H Manual Chapter 5200*, the cause(s) identified, corrective actions or approved compensatory measures implemented, and,
- Formal notification is made to TJSO documenting the cause of the occurrence, requesting TJSO approval for corrective actions, and identifying requirements for the TJSO approval for restart of operations.

If an ASE Violation occurs or a Credited Control proves to be inoperative or ineffective, RF operations shall stop and the facility shall be placed in a safe and stable configuration until the actions specified above are taken.

A violation of the ASE is typically very clear. However, there may be minor failures of controls that are less obvious but still constitute a violation of the ASE. There may also be situations where a Credited Control is potentially ineffective, but the identified compensatory measures are in place. Determining whether a condition is a violation or a (less severe) safety concern can be subjective. The following examples of ASE violations are intended to serve as guidance to facilitate such determinations. Judgment may be necessary to evaluate specific situations, and the list below is not comprehensive:

- Surveillance of Credited Controls in an accelerator in operation is not conducted in the time frame specified in the ASE.
- Shielding identified as a Credited Control is not in place during the operation of the accelerator.
- Both independent Personnel Safety System (PSS) channels for the same Credited Control are inoperable during the operation of the accelerator.
- A locked access door or gate serving as a Credited Control remains unlocked during the operation of the accelerator.
- Accelerator operation without completing the required review process: a successful Accelerator Readiness Review with authorization to run granted by the TJNAF DOE Site Office, along with the Head of SRF Operations.
- Operation of the accelerator with less than the minimum specified qualified staff in the CMTF Control Room.

The SCMB is chartered by the Jefferson Lab Director to evaluate safety concerns and determine if they represent an *ASE violation and/or an Unreviewed Safety Issue (USI)*. A USI is a condition that may require an update to an existing hazards analysis in the SAD or may require the addition of a new SAD hazard along with new Credited Controls. The SCMB membership incorporates a TJSO Observer as an ex-officio member.

4.0 CREDITED CONTROLS

Credited Controls mitigate hazards that pose unacceptable risk and reduce that risk to acceptable levels. The Credited Controls, identified in the *Safety Assessment Document (SAD)*, are listed below. These Credited Controls must be in place and functional when required by the state of accelerator operations.

The ASE also specifies the management and surveillance practices that must be performed to assure the continued effectiveness of the Credited Controls. Management and surveillance practices are part of an approved configuration management process that helps ensure that the physical configuration and functionality of Credited Controls remain accurate and in accordance with the analysis and requirements in the SAD. The management and surveillance practices may have a specified frequency. Occasionally, it becomes apparent that a management and surveillance interval for a Credited Control may expire during a period when an accelerator is either scheduled for operation or is operational. Prior to the expiration of the management and surveillance interval, the interval may be extended based on the results of evaluation by the SCMB and approval by TJSO. A management and surveillance interval that expires during accelerator operation should be evaluated by the SCMB as a safety concern that represents a USI or a potential ASE violation. If a required management and surveillance interval exceeds one year the due date for the next required management and surveillance verification will be listed on the current operational authorization.

The same configuration management process is applied to temporary changes during maintenance to ensure the integrity and performance of Credited Controls are restored before accelerator operation. Configuration control is accomplished through Safety Systems Group Procedures, Radiation Control Department (RCD) Procedures, the SCMB, and in accordance with the relevant Quality Assurance Program Procedures/Processes. For example, Accelerator Safety is assessed as part of a five-year assessment cycle. This cycle is incorporated into the Annual Assessment Schedule.

Certain management and surveillance records, such as verification of the functionality of a Credited Control before accelerator operations, may rely on electronic records and logs. Software that supports electronic records and logs is developed and maintained in accordance with the *Site-Wide Cyber Security Program* and controlled in accordance with the *Accelerator Division Controls Software Group User Account/Usage Policy*.

Sections 4.1 – 4.3 below list the Credited Controls which are applied to the Cryomodule Test Facility. These sections follow the “hierarchy-of-controls” principles – the controls which are most effective and least prone to failure are applied first. These are typically passive engineered controls - physical safety features that are built into the accelerator design. Certain Credited Passive Engineered Controls are listed in the SAD as initial assumptions, that is, they are assumed to be in-place and functional prior to the start of accelerator operations - the concrete accelerator enclosure, for example. Active engineered controls are used next when the control requirements are more complex, interactive, or interdependent. Finally, Administrative controls, which are typically programmatic in nature or are embodied in specific processes and procedures, are used last and often in conjunction with engineered controls.

4.1. Credited Passive Engineered Controls

Credited Passive Engineered Controls such as physical design features which include shielding, flow limiting devices, and vents.

4.1.1. Permanent Shielding

Applicability:

Whenever the supply of high voltage to an RF source supplying a cavity in the accelerator enclosure is possible.

Controls:

- Structural shielding, reinforced concrete that defines the accelerator enclosure,
- Design feature: access labyrinth and penetration routing to prevent line-of-sight to beamline.

Management and Surveillance:

- Permanent shielding shall be subject to the *Jefferson Lab Shielding Policy for Ionizing Radiation*.
- Shielding design and changes shall be reviewed in accordance with the *ASE Violation/USI Review Process* and approved by the Radiation Control Manager (RCM) or their designee.
- Structural shielding shall be inspected as specified by FM&L at least every five years. The inspection results shall be communicated to the RCM or designee, who shall evaluate the results against applicable design specifications and SAD requirements, and its general condition with respect to shielding effectiveness. The final evaluated status of the shielding packages shall be recorded in the CMTF portion of the J*efferson Lab Authorization Manager (JAM)*.
- The Dig/Blind Penetration Permit specified in *ES&H Manual Chapter 3320 Temporary Work Permits* shall be used to manage penetrating or otherwise disturbing the structure in a way that can impact shielding effectiveness.

Acceptable Compensatory Measures:

If RCM evaluation determines the condition of permanent shielding associated with an accelerator enclosure does not meet the requirements specified in the SAD or is otherwise unacceptable, the RCM or desingee will recommend compensatory measures (such as additional access control, installation of temporary shielding, etc.), if necessary, to maintain the performance specified in the *Jefferson Lab Shielding Policy for Ionizing Radiation* until the shielding is restored to the values specified in the SAD or the SAD is amended. The SCMB shall review and evaluate RCM recommendations using the *ASE Violation/USI Review Process*. The design, approval, and use of compensatory measures for permanent shielding shall be subject to the *Jefferson Lab Shielding Policy for Ionizing Radiation*.

4.1.2. Movable Shielding

Applicability:

Whenever the supply of high voltage to an RF source supplying a cavity in the accelerator enclosure is possible.

Controls:

Movable Shielding[1].

Management and Surveillance:

- Movable shielding shall be subject to the *Jefferson Lab Shielding Policy for Ionizing Radiation*.
- Movable shielding design and changes shall be reviewed in accordance with the *ASE Violation/USI Review Process* and approved by the RCM or designee.
- Movable shielding shall be visibly labeled or tagged consistent with *ENG-AD-01-001 Conduct of Engineering Manual Section 5.2.6.1 Implementing Item Identification.*
- Correct placement of movable shielding shall be verified in accordance with the *Jefferson Lab Radiation Control Department Procedures* specified in *HPP-OPS-002, Performance of Periodic Routines* and *HPP-OPS-015, Shielding Package Determination and Tracking.*
- The RCM or designee shall record the movable shielding status, along with the expiration date for the status determination, in the JAM before facility operation.

Acceptable Compensatory Measures:

Fences or barriers with informational signs or postings consistent with the hazard present that prevent inadvertent access to the affected area, and which mitigate the radiation hazard consistent with the requirements of the *Jefferson Lab Shielding Policy for Ionizing Radiation*.

4.1.3. ODH Vents and Facility Configuration

Applicability:

When cryogens are supplied to the CMTF enclosure.

Controls:

CMTF passive ceiling vent.

Management and Surveillance:

FM&L shall record the status of passive vents incorporated into movable shielding and identified as Credited Controls, along with the expiration date for the status determination, in the JAM before facility operation.

[1] Discrete shielding materials or an assembly of material that can be moved and/or disassembled and is determined to be a Credited Control in the SAD hazard analysis. This discrete shielding includes but may not be limited to the CMTF East Wall and Ceiling penetrations.

Acceptable Compensatory Measures:

Work control procedures for work in affected area shall specify ODH mitigation as required by the *ES&H Manual Chapter 6540 Oxygen Deficiency Hazard (ODH) Control Program*.

4.2. Credited Active Engineered Controls

Active Engineered Controls include the PSS and the ODH Monitoring systems. The PSS provides monitoring of the perimeter and access points of the accelerator enclosure in order to keep people from RF and field emission-based radiation hazards. In combination with Passive Engineered Controls such as shielding and Administrative Controls such as doors, gates, fences, etc. the PSS serves to keep people away from radiation hazards. The ODH System provides monitoring of oxygen levels in the accelerator in order to protect people from possible hazards resulting from the release of oxygen-displacing gases.

4.2.1. PSS Access Controls

Applicability:

Whenever the supply of high voltage to an RF source supplying a cavity in the accelerator enclosure is possible.

Controls:

The CMTF PSS shall have no loss of safety function during accelerator operation[2].

Management and Surveillance:

- CMTF PSS components shall be visibly labeled or tagged consistent with *ENG-AD-01-001 Conduct of Engineering Manual Section 5.2.6.1 Implementing Item Identification.*
- Interim changes to the PSS are reviewed and approved in accordance with the *PSS Configuration Management Procedure* and the *ASE Violation/USI Review Process*. PSS functional requirements are established in the *Beam Containment and Access Control Policy*.
- The CMTF PSS shall be certified annually.
- The Safety Systems Group shall verify the status of the CMTF PSS, along with the expiration date for the status determination, in the JAM before facility operation.

Acceptable Compensatory Measures:

Use of locked doors, gates, or fences consistent with 4.3.1 Doors, Gates, Fences, and other Barriers, below.

4.2.2. ODH System Controls

Applicability:

When required by the *ES&H Manual Chapter 6540 Oxygen Deficiency Hazard (ODH) Control Program* and an ODH analysis document, a fixed ODH monitoring system shall be installed and maintained functional in CMTF areas.

[2] Loss of safety function is considered to be failure of both independent interlock chains.

Controls:

An ODH system shall provide adequate monitoring coverage of the affected areas.

Management and Surveillance:

- CMTF ODH system components shall be visibly labeled or tagged consistent with *Labeling Procedure for PSS and ODH Equipment*.
- The system shall be maintained such that it is operational when required by the ODH assessment for the location.
- Maintenance shall be performed in accordance with *Labeling Procedure for PSS and ODH Equipment*.
- ODH sensing devices shall be tested no less than every two years.
- The Safety System Group shall verify the status of ODH System Controls, along with the expiration date for the status determination, in the JAM before facility operation.

Acceptable Compensatory Measures:

- Entry only by authorized personnel in accordance with *ES&H Manual Chapter 6540 Oxygen Deficiency Hazard (ODH) Control Program* requirements for entry into a reduced oxygen atmosphere.
- Exclusion of personnel from the areas in which the ODH system performance is inadequate.

4.3. Credited Administrative Controls

Credited Administrative controls include processes, limits, and conditions necessary for safe accelerator operation as described.

4.3.1. Doors, Gates, Fences, and other Barriers

Applicability:

Whenever the supply of high voltage to an RF source supplying a cavity in the accelerator enclosure is possible.

Controls:

Entrances to accelerator enclosures shall be interlocked via the PSS Interlocks or shall be locked in accordance with *ES&H Manual Chapter 6111, Administrative Control Using Locks and Tags*, barred, or bolted into place to prevent unauthorized access.

Management and Surveillance:

- Doors, gates, fences, and other barriers serving as Credited Controls shall be clearly identified by visible labels or tags consistent with their function.
- Access shall only be permitted in accordance with approved procedures.
- The RCM or designee shall verify the locked, barred, or bolted entrances in accordance with the *Radiation Protection Department Procedures* specified in *HPP-OPS-002, Performance of Periodic Routines* and *HPP-OPS-015,*

Shielding Package Determination. The status, along with the expiration date for the status determination, shall be recorded in the JAM for the CMTF.

4.3.2. Staffing – Sweep

Applicability:

When CMTF is being made ready for a PSS state above Open Access.

Controls:

Trained Sweeper and Guard per the CMTF PSS Sweep Procedure (Note: Control Room can be unstaffed during Sweep).

Management and Surveillance:

Trained CMTF staff carry out the CMTF Sweeps and follow the steps defined in the specific sweep procedure maintained by the Safety System Group.

4.3.3. Staffing – Operations

Applicability:

When CMTF PSS is being made ready for RF Operations and PSS State is set to RUN.

Controls:

Authorized RF Operator in Control Room.

Management and Surveillance:

One trained RF operator – approved by the Cryomodule Test Facility Manager – must be on-site and in the control room with the CMTF PSS state in RUN mode.

DOCUMENT LIST (Alphabetical Order)

Accelerator Division Controls Software Group User Account/Usage Policy
Accelerator Safety Envelope (ASE)
Accelerator Safety Envelope Violation/Unreviewed Safety Issue Review Process
Beam Containment and Access Control Policy
CMTF PSS Sweep Procedure
CMTF Testing Operations Directives (TOD)
Conduct of Engineering Manual ENG-AD-01-001 Section 5.2.6.1 Implementing Item Identification
Department of Energy (DOE) Order 420.2D Safety of Accelerators
ES&H Manual Chapter 3320, Temporary Work Permits
ES&H Manual Chapter 5200, Unplanned Incidents
ES&H Manual Chapter 6111, Administrative Control Using Locks and Tags
ES&H Manual Chapter 6540, Oxygen Deficiency Hazard (ODH) Control Program
Jefferson Lab Safety Assessment Document
Jefferson Lab Shielding Policy for Ionizing Radiation
Labeling Procedure for PSS and ODH Equipment
PSS Configuration Management Procedure
Radiation Control Department Procedures - HPP-OPS-002, Performance of Periodic Routines
Radiation Control Department Procedures - HPP-OPS-015, Shielding Package Determination and Tracking
Site-Wide Cyber Security Program

ACRONYMS

Acronym	Definition	Page
FM&L	Facilities Management and Logistics	II
ASE	Accelerator Safety Envelope	1
CMTF	Cryomodule Test Facility	1
DOE	Department of Energy	1
Jefferson Lab	Thomas Jefferson National Accelerator Facility	1
RCA	Radiation Control Area	1
SAD	Safety Assessment Document	1
TJSO	Thomas Jefferson Site Office	1
PSS	Personnel Safety System	2
SCMB	Safety Configuration Management Board	2
TOD	Testing Operations Directives	2
USI	Unreviewed Safety Issue	2
RCD	Radiation Control Department	3
ES&H	Environment, Safety, and Health	4
RCM	Radiation Control Manager	4
JAM	Jefferson Lab Authorization Manager	4
ODH	Oxygen Deficiency Hazard	6