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Jefferson Lab
Thomas Jefferson National Accelerator Facility

Operational Safety Procedure Review and Approval Form # 87369

(See ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure (OSP) and Temporary OSP Procedure for Instructions)

Type:	***OSP*** Click for OSP/TOSP Procedure Form Click for LOSP Procedure Form Click for LOTO-COMPLEX Information Click for LOTO-GROUP Information
Serial Number:	***SRF-19-87369-OSP***
Issue Date:	***6/26/2019***
Expiration Date:	***4/26/2022***
Title:	***Cryomodule Test Facility Operational Safety Procedure***
Location: (where work is being performed) Building Floor Plans	***58 - Test Lab - 1119*** — Location Detail: (specifics about where in the selected location(s) the work is being performed): ***CMTF Control Room and Cave. Mezzanine above the CMTF Cave***
Risk Classification: (See ES&H Manual Chapter 3210 Appendix T3 Risk Code Assignment)	Without mitigation measures (3 or 4): ***4*** With mitigation measures in place (N, 1, or 2): ***1***
Reason:	This document is written to mitigate hazard issues that are : ***Determined to have an unmitigated Risk code of 3 or 4***
Owning Organization:	***SRFOPS***
Document Owner(s):	***Drury, Michael (drury@jlab.org)*** Primary

Supplemental Technical Validations

Cryogenic Material - Gas or Liquid (Jonathan Creel, Kelly Dixon)
Mode 1: Class 1, 2, and 3 Electrical Equipment (Phillip Stanley, Tim Fitzgerald)
Lock, Tag, Try (Phillip Stanley, Tim Fitzgerald)
ODH 0 and 1 (Imani Burton, Jennifer Williams)
ODH 2 and Higher (Imani Burton, Jennifer Williams)
Controlled Area (Adam Hartberger, David Hamlette, Keith Welch)
Radiological Controlled Area (Adam Hartberger, David Hamlette, Keith Welch)
Radio Frequency (Imani Burton, Jennifer Williams)
Emergency Preparedness (Tina Johnson)
Personal Protective Equipment (Jennifer Williams)

Other Hazards:
High Power RF (Rick Nelson)

Personnel Safety Systems (Jerry Kowal)

Document History

Revision	Reason for revision or update	Serial number of superseded document
1	*OSP approaching expiration date*	*SRF-16-61553-OSP*

Lessons Learned	Lessons Learned relating to the hazard issues noted above have been reviewed.
Comments for reviewers/approvers:	***Updated references to current ODH Assessment. Attached most current ODH assessment. Updated language with respect to PSS certification intervals. Updated THA reference to ODH assessment***

Attachments

Procedure: ***CMTF-OSP 2015g.pdf***

THA: ***CMTF - THA 061119.pdf***

Additional Files: ***TestLab_CMTF-Final 20160128_addendum_3.pdf***
JLAB-TN-16-010.pdf
JLAB-TN-16-009.pdf
bolt pattern.pdf

Review Signatures

Additional Authorization : Personal Protective Equipment	**Signed** on 6/18/2019 11:48:41 AM by Jennifer Williams (jennifer@jlab.org)
Person : Bailey, Mary Jo (mbailey) **Reasoning:** Emergency Preparedness - Acting	**Signed** on 6/19/2019 7:37:52 AM by Mary Jo Bailey (mbailey@jlab.org)
Person : Subject Matter Expert : High Power RF	**Signed** on 6/18/2019 12:11:29 PM by Rick Nelson (nelson@jlab.org)
Person : Subject Matter Expert : Personnel Safety Systems	**Signed** on 6/18/2019 4:14:11 PM by Jerry Kowal (jkowal@jlab.org)
Subject Matter Expert : Cryogenic Material - Gas or Liquid	**Signed** on 6/18/2019 12:14:57 PM by Kelly Dixon (kdixon@jlab.org)
Subject Matter Expert : Electricity->Mode 1: Class 1-> 2-> and 3 Electrical Equipment	**Signed** on 6/18/2019 1:29:03 PM by Bill Rainey (wrainey@jlab.org)
Subject Matter Expert : Lock-> Tag-> Try	**Signed** on 6/18/2019 1:00:49 PM by Todd Kujawa (kujawa@jlab.org)
Subject Matter Expert : Oxygen Deficiency Hazards (ODH)->ODH 0 and 1	**Signed** on 6/18/2019 11:48:45 AM by Jennifer Williams (jennifer@jlab.org)
Subject Matter Expert : Oxygen Deficiency Hazards (ODH)->ODH 2 and Higher	**Signed** on 6/18/2019 11:48:49 AM by Jennifer Williams (jennifer@jlab.org)
Subject Matter Expert : Radiation - Ionizing->Controlled Area	**Signed** on 6/20/2019 11:33:53 AM by Keith Welch (welch@jlab.org)
Subject Matter Expert : Radiation - Ionizing->Radiological Controlled Area	**Signed** on 6/20/2019 11:34:11 AM by Keith Welch (welch@jlab.org)
Subject Matter Expert : Radio Frequency	**Signed** on 6/18/2019 11:48:53 AM by Jennifer Williams (jennifer@jlab.org)

Approval Signatures

Division Safety Officer : SRFOPS	**Signed** on 6/20/2019 11:52:21 AM by Harry Fanning (fanning@jlab.org)
Org Manager : SRFOPS	**Signed** on 6/26/2019 1:37:57 PM by Tony Reilly (areilly@jlab.org)
Safety Warden : Test Lab - 1119	**Signed** on 6/21/2019 8:17:15 AM by Stephen Dutton (dutton@jlab.org)

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Jefferson Lab
Thomas Jefferson National Accelerator Facility

Operational Safety Procedure Form

(See ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure (OSP) and Temporary OSP Procedure for instructions.)

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DEFINE THE SCOPE OF WORK

Title:	**Cryomodule Test Facility Operational Safety Procedure**		
Location:	Cryomodule Test Facility, Bldg. 58	**Type:**	[X] **OSP** [ ] **TOSP**
Risk Classification (per Task Hazard Analysis attached) (See *ESH&Q Manual Chapter 3210 Appendix T3 Risk Code Assignment*.)		**Highest Risk Code Before Mitigation (3 or 4):**	4
		Highest Risk Code after Mitigation (N, 1, or 2):	1
Owning Organization:	SRFOPS	**Date:**	
Document Owner(s):	Michael Drury		

Document History (Optional)

Revision:	**Reason for revision or update:**	**Serial number of superseded document**
	Document Expiration	SRF-15-47433-OSP

ANALYZE THE HAZARDS

1. Purpose of the Procedure – Describe in detail the reason for the procedure (what is being done and why).

The purpose of this procedure is to facilitate the safe operation of the Cryomodule Test Facility during operation and testing of RF structures and cryogenic devices.

2. Scope – include all operations, people, and/or areas that the procedure will affect.

This OSP addresses the activities associated with the Testing of RF structures and cryogenic devices in the Cryomodule Test Cave Facility with the dual output 1497 MHz 13 kW klystron system and with the eight individual 1.3 GHz solid state amplifiers (SSA's).
Individual tests of cryomodules or other equipment which require operating parameters outside the scope of this OSP and existing hazard analyses will be dealt with on an individual basis by separate TOSP's.

3. Description of the Facility – include floor plans and layout of a typical experiment or operation.

The Cryomodule Test Facility, Room 1119, is located in the center of the first floor against the east wall of the Test Lab, Bldg 58 (Figure 1). The facility includes the test area (the Cave), the production cryomodule control room along its north wall, 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 are located at various positions on this shield.

Access to the test area is through two doors, a concrete door that rises from and lowers through the floor at the west end, and a door and labyrinth at the northeast end. Both doors must be closed to begin preparation for testing. The labyrinth door at the northeast corner will be the primary access and egress used in preparing the test area for testing and must be closed and locked in order to set the interlock system. A ceiling vent exhausts gaseous cryogens in the event of a leak causing a potential oxygen deficiency condition. Above the roof, the sides of the vent are shielded by concrete, and, where appropriate, lead. This shield reduces the radiation exposure in this location to levels consistent with other locations on the roof. The area over the top of the vent is not shielded and may be a radiation area depending on operating conditions.

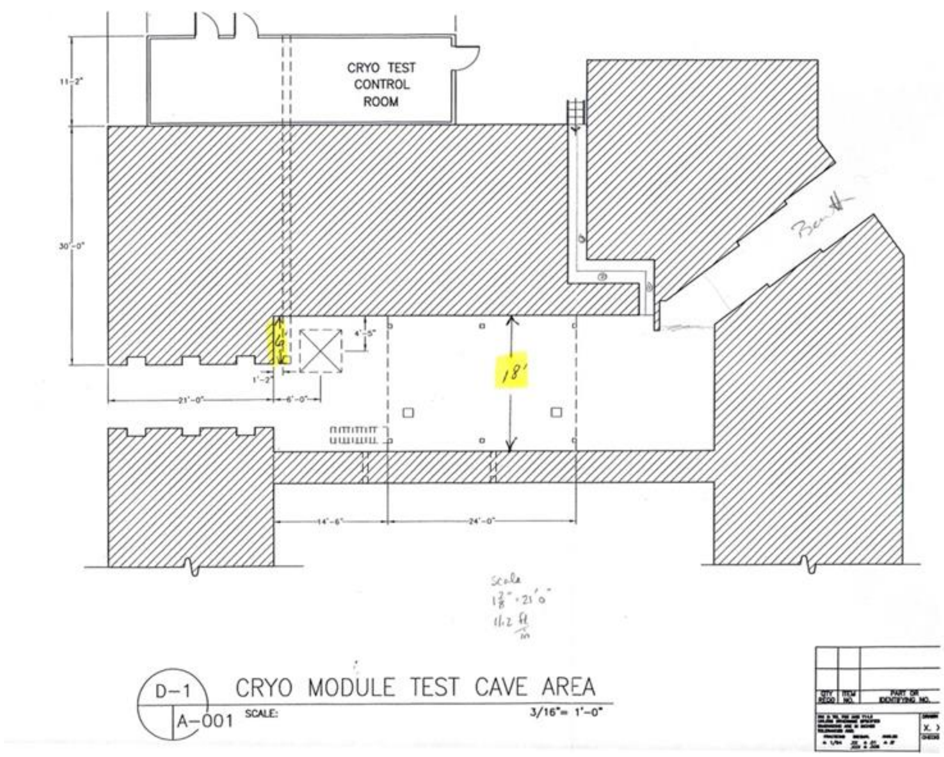

Figure 1

Utilities

- The Cryogenic Test Facility (CTF) supplies liquid and gaseous helium to cool the cryomodule helium vessel and shield. These cryogens will maintain the helium vessel at 2-4K and the shield at ~ 45K. The cryogenic equipment is located at the back of the cave, outside the magnetic shielding.
- High power RF will be coupled into the test cryomodule from the dual output 13 kW 1497 MHz RF-power system, on or all of the eight 1.3 GHz SSA's or from another RF amplifier that can be operated in accordance with the procedures for connecting alternative RF amplifiers on pages 15.
- Gaseous nitrogen feed is available at the front of the cave by the rollup door.

4. Authority and Responsibility:

4.1 Who has authority to implement/terminate

- **Facility Manager** – This responsibility is assigned by the Department head of the ISRFST department. This individual has ownership of the facility and has overall responsibility for safe configuration and operation of the facility.
- **Test Coordinator** – The test coordinator is assigned by either the Facility Manager or the Department head of the SRF Institute. The Test Coordinator has overall responsibility for a given test plan (such as a Cryomodule Acceptance Test). The Test Coordinator is responsible for planning and executing the test plan, ensuring that operations are carried out in a safe manner, directing the activities of system operators while they are on shift, and insuring that the facility is properly staffed. The Test Coordinator must be cognizant of the status of the facility and any device under test in the facility for the duration of the Test Plan. The TC must have a thorough understanding of the configuration and operation of the relevant systems required for the execution of the planned experiments. For most routine production testing, the Facility Manager may also serve as the Test Coordinator.

4.2 Who is responsible for key tasks

- **Principal Investigators** (PI's) have to demonstrate to the Test Coordinator that the test is appropriate. The PI must also ensure that the System Operator has the ability to perform the test. The PI or approved designee must be on call while the respective test is being performed.
- **RF System Operators:** They are to be authorized by the Facility Manager. They assist the Principal Investigators in the execution of tests and the changing of system configurations. They must have a thorough understanding of the configuration and operation of the PSS and MPS systems, as well as the configuration of the MPS and RF systems required for the execution of the planned experiments. They should also have a general understanding of the interactions of the cryogenic systems with the specific RF tests. They are responsible for safe operation of the facility and have the authority to stop any experiment if they feel that there is unnecessary potential to damage equipment or if there is an elevated level of risk of injury.
- **Cryogenic System Operators:** They are to be authorized by the Facility Manager. They assist the principal investigators in the execution of tests and the changing of system configurations. They must have a thorough understanding of the configuration and operation of the cryogenic systems required for the execution of the planned experiments. They should also have an understanding of the interactions of the specific RF tests with operations of the cryogenic systems. They are responsible for safe operation of the facility and have the authority to stop any experiment if they feel that there is unnecessary potential to damage equipment or if there is an elevated level of risk of injury.
- **Duty Operator:** The Duty Operator is the individual System Operator who has been assigned to be responsible for operations on a specific shift. The Test Coordinator assigns the Duty Operator. The Test Coordinator assumes this responsibility during unattended periods of operation such weekends or nights.
- **Visiting Operators** are approved by The Test Coordinator to assist PIs in the execution of tests and the changing of system configurations. When using high power RF systems, their activities are to be directed and closely monitored by the Duty Operator.

- **The Radiation Control Department** will provide radiation survey support as well as maintenance support of any radiation monitoring equipment that is associated with Personnel Safety.
- **Industrial Hygiene** shall provide RF survey assistance upon request.
- **The Group Leader of the Safety Systems Group** (SSG) or his designee is the owner of the Personnel Safety System (PSS).

4.3 Who analyzes the special or unusual hazards (See ES&H Manual Chapter 3210 Appendix T1 Work Planning, Control, and Authorization Procedure)

Task Hazard Analyses (THA's) for any Test Plans that require operation of the facility in a manner that is outside the scope of this OSP and existing THA's will be executed by the Facility Manager acting in concert with the relevant Subject Matter Experts (SME's):
SME's will include but are not limited to the following individuals or their designees:

- D. Arenius – Cryogenic Safety
- Safety Systems Group Leader – PSS and ODH Monitoring
- R. Nelson – RF Safety
- V. Vylet – RadCon
- T. Menefee – Emergency Manager
- S. Dutton – Safety Warden
- Any ESH&Q staff with relevant expertise

4.4 What are the Training Requirements (See http://www.jlab.org/div_dept/train/poc.pdf)

MED13 – ODH-2 & Respirator medical certification
SAF103 – Oxygen Deficiency hazards.
SAF104 – Lock, Tag, Try
SAF210 – 5-Minute Escape Pack use
SAF603A – Electrical Safety Awareness
SAF603S – Switching of Electrical Equipment
SAF800 – General Employee Radiation Knowledge
SAF801 – Radiation Worker I Training

5. Personal and Environmental Hazard Controls Including:

5.1 Shielding

Prompt Radiation Mitigation

The north wall and south wall are solid concrete, 20 feet thick and 4.5 feet thick, respectively. The west wall combines a solid concrete wall, 20 feet thick, and a concrete door 10 feet wide and 8 feet thick that rises from the floor in order to isolate the test area. This west door must be closed before the interlock system described in the next section can be set. The roof is concrete, 3 ft. thick. The east wall is a combination of the solid concrete test lab wall and a cinder block/lead brick barrier that surrounds the cryogenic piping from the Cryogenic Test Facility. The barrier is permanently secured to prevent entry to or from the CMTF area.

The two areas of concern for the shielding are the south wall and the roof. The cryostats will always be oriented such that the cavity axis is oriented parallel to the south wall. Therefore, the shielding required in the south wall is determined by the 90-degree radiation source. This has two effects: the source term is lower and the relative spectral hardness of the radiation source is reduced. The following table summarizes the *unshielded* dose rates: (Note that these calculations were for the CEBAF upgrade geometry, so are additionally conservative with respect to distances from hypothetical source to the vent fan and roll-up door)

Table 1

Sustained Dose Rate
Points of Interest (POI)

Number	1	2	3	4	5
Location	Vent Fan Assy	Roof	VTA Wall	Door/Labyrinth	Main Rollup Dr
Distance, cm	1024	664	434	343	1030
Source angle, deg.	40	90	90	40	0
Unshielded					
Photon, r/h	1.86E+01	1.41E+01	3.29E+01	3.82E+01	2.83E+02
Neutron rem/h	1.66E-04	3.95E-04	9.23E-04	1.48E-03	1.64E-04
Total	1.86E+01	1.41E+01	3.29E+01	3.83E+01	2.83E+02

The CMTF (south) wall consists of four and half feet of concrete. The CMTF roof consists of three feet of concrete. The shielding materials and shielded dose rates at the points of interest are presented in Table 2 and 3 below:

Table 2

Concrete Shielding	Thickness ft	**Steel Shielding**	Thickness ft	**Lead Shielding**	Thickness ft
Roof	3	Roof	0.0313	Roof	0
VTA Wall	4.5	VTA Wall	0.0313	VTA Wall	0
Vent Fan Assy	2	Vent Fan Assy	0.0313	Vent Fan Assy	0.33
Door Labyrinth	0	Door Labyrinth	0.0313	Door Labyrinth	0
Main Rollup Dr	7.5	Main Rollup Dr	0	Main Rollup Dr	0

Table 3

Shielded

Sustained Dose Rate
Points of Interest (POI)

Number	1	2	3	4	5
Location	Vent Fan Assy	Roof	VTA Wall	Door Labyrinth	Main Rollup Dr
Photon, r/h	5.67E-03	3.79E-02	5.14E-03	1.72E-04	3.45E-03
Neutron rem/h	1.23E-05	6.35E-06	1.01E-06	1.03E-04	2.22E-17
Total	5.68E-03	3.79E-02	5.14E-03	2.75E-04	3.45E-03

The steel shielding is associated with the steel cage around the inside of the CMTF. The concrete and lead shielding around the vent fan assembly was redesigned to minimize weight and provide shielding consistent with other locations outside the shielding.

Previous experience tells us that it is reasonable to invoke a duty factor (DF) for CMTF operations. The DF is a fraction based on the time that an activity actually occurs divided by the time that it can occur. The overall DF is the product of these fractions. For example, a cavity under testing does not continuously experience the full gradient assumed in the radiation source term calculation. The radiation source term is also intermittent. This will affect the instantaneous radiation levels over the nominal one-hour integration time used to decide whether administrative controls, such as postings and signs, are needed. In addition, the cavity testing does not occur continuously throughout the entire work year. There is a non-trivial cool-down time associated with each cryostat that is tested, and the bulk of testing time is not at high gradients. In addition, some fraction of high power operations are necessarily pulsed at varying duty factors. Relative to the conservative source term estimates, we estimate a duty factor of 0.01 during the period of testing this cryomodule.

The product of these duty factors should ensure that the integrated radiation doses outside the south wall and the roof are maintained less than 250 mrem yr^{-1}, the JLab shielding design goal. For example, 2000 hr y^{-1} x 5.68 mrem hr^{-1} x 0.01 DF = 114 mrem yr^{-1}. Note that this result is greater than the limit for unmonitored personnel, and that areas on the roof exceed 250 mrem yr-1, assuming dose rates calculated above are sustained continually during operations. This is a very conservative assumption and is addressed by both administrative postings and area monitoring (see Section 5.3 below).

New Mitigations for LCLS II Cryomodules

LCLS II cryomodule testing will include simultaneous operation of all eight cavities. This and experience with the C100 cryomodules has prompted a new RadCon assessment. This has led to new mitigations. New shielding has been added above the roll up doors as shown in Figure 2.

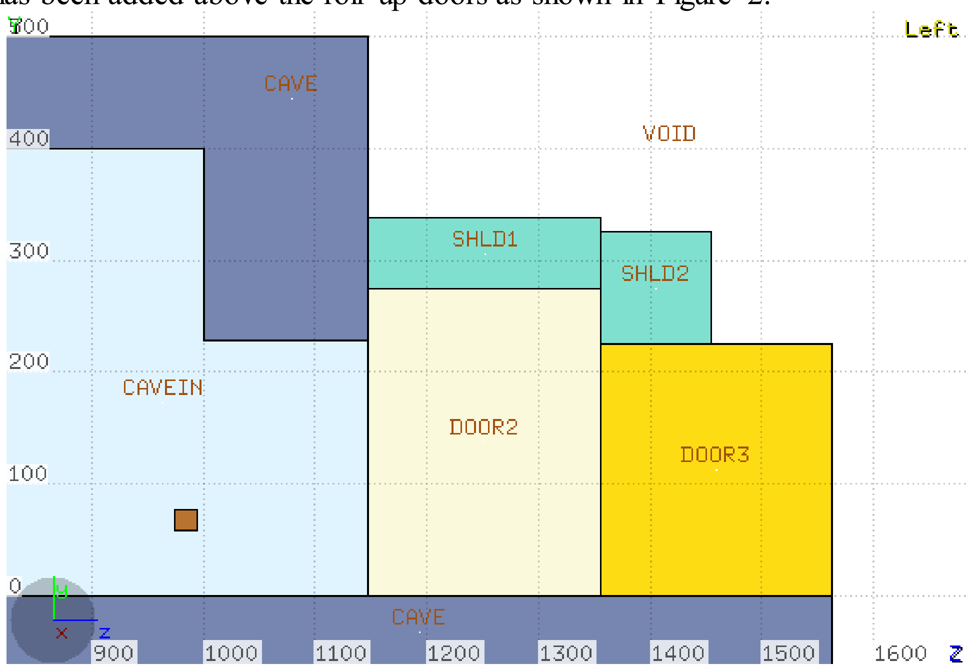

Figure 2: New Shielding Above Doors

Shield 1 above Door 2 is 208 cm x 64 cm thick and Shield 2 above Door 3 is 100 cm x 100 cm thick. Door 2 will continue to be the primary door. Door 3 is considered to be the backup.

Additional lead shielding will be added around the fan stack opening on the roof of the Cave. The new shielding configuration will consist of an inner layer of 2 in. of lead and an outer layer of 15 in. of concrete on all four sides of the fan stack opening. This added shielding is a requirement for testing of LCLS II cryomodules. The existing shielding configuration is sufficient for testing of any C20 or C50 style cryomodules.
Furthermore, the roof will be posted as a Radiologically Controlled Area (RCA) at the start of LCLS II cryomodule testing. This posting will remain in place for the duration of the LCLS II project.
The Vertical Test Area will be permanently posted as an RCA.

Local shielding may be used inside the Cave to restrict direct line of sight from the cryomodule to penetrations connecting the CMTF and VTA.

Activation
High-gradient cryomodules such as C-100 and similar designs contain cavities that have shown the potential to produce radio-activation when operated at high power. Under certain conditions, the energy of the photon field produced by field emitted electrons may exceed the threshold for giant resonance photo-nuclear interactions. These interactions result in the emission of neutrons and the production of residual radioactivity. This phenomenon is difficult to predict. However, the onset of the condition is easily detectable by means of neutron radiation monitoring in the vicinity of the cryomodule.

See section 5.3 for protocols to respond to this condition.

5.2 Interlocks

Personnel Safety System
The CMTF personnel safety system is composed of the following subsystems:

- Access Control System
- Safety Interlock System
- Oxygen Deficiency monitoring system

Operation of the PSS is divided into four modes:

- Open
- Sweep
- Ready/Sweep Complete
- RUN

RF power derived from the klystron source, SSA, or from other RF amplifier (see Procedure on Page 15) may only be supplied to the cryomodule in the CMTF when the test cave is in RUN mode.
In order to conduct CMTF operations, the PSS must have a current certification. Certifications are scheduled by the Safety Systems Group and must be performed at least twice in the calendar year. The interval between certifications must be at least 4 months but not more than 8 months. If the Principal Investigator is unsure of the certification status of the CMTF or associated RF systems, they may contact the Safety Systems Group Leader. Devices that are not certified shall be administratively locked and tagged by the Safety Systems Group.
Procedures for operation of the CMTF personnel safety system are given in the CMTF PSS Operator manual.

Configuration Control:
All PSS cable, conduit, and control devices are labeled. Only Safety Systems Group personnel may access these devices.
Devices that are owned by the Safety Systems Group

- AC Contactor in Control Room AC301
- AC Contactor in Test Cave AC302
- AC Contactor on Mezzanine above Test Cave AC303

Certain devices that are critical for safe CMTF operation, such as RF high power amplifier power supplies, are interfaced to the PSS but are not owned by the Safety Systems Group. The safety function of these devices still falls under PSS configuration control.
Devices not owned by the safety systems group but under PSS configuration control:

- Dual 13kW / 1497 MHz klystron power supply PSS interlock chain
- 1.3 GHz SSA's
- Waveguide Shutter WS01
- Waveguide Shutter WS02
- Waveguide section between the 1497 MHz klystron and the waveguide shutter switches.

The devices in the listed above shall have a PSS configuration control sticker. The sticker instructs anyone that may want to disconnect the device to first contact a member of the safety systems group.
As an alternative to the automated safety interlock system, the safety systems group may maintain configuration control through the use of administrative lock and tag and the PSS jumper request system. Administrative lock and tag may only be used to render a device Off/Safe. Administrative lock and tag and jumpers used for bypassing the normal PSS configuration of a device may only be applied by a member of the safety systems group.

5.3 Monitoring systems

Radiation Mitigation
Table 3 indicates values that result in administrative actions such as radiation area posting and access controls to minimize exposure. Location number 2 on the CMTF Roof approximately represents a maximum radiation dose rate for the roof. Administrative controls (e.g. posting as a Radiologically Controlled Area or Radiation Area) may be applied to limit access to portions of the roof until radiation monitoring proves that they are otherwise unnecessary. Additional shadow shielding will be used, if needed, to reduce the intensity of radiation oriented towards the labyrinth on the northeast end of the test area. An active area radiation monitoring system, frequent surveys, and operations log reviews will be conducted to ensure that the dose to monitored personnel is less than 250 mrem/yr and unmonitored personnel is below 10 mrem/yr. Passive integrating dosimeters at key locations will be used to provide a record of dose. If either of the administrative goals above appear to be in jeopardy of being exceeded, further controls will be established or documented justification to exceed them will be produced. The access points will be posted and controlled in accordance with the Jefferson Lab EH&S Manual and Radiation Control Manual.

Some scattered radiation (through cable trenches, penetrations, etc.) may be present outside even the thickest parts of the shielding. Consequently, the Radiation Control Department (RadCon) will evaluate the need for shielding and/or active radiation monitors outside the test area where there are trenches, joints or cracks between concrete walls, doors, etc. or other shielding discontinuities. Careful placement of shielding and/or interlocked radiation monitors will be used to prevent a "Radiation Area" condition from occurring outside the CMTF. Any removable shielding is inspected and posted as configuration controlled shielding. RadCon verifies the configuration of interlocked radiation monitors and shielding at least annually.

On-line interlocked radiation monitors (CARMs) and associated warning devices (magenta beacons) are installed at access points to the CMTF. On-line radiation monitoring is part of the operating procedures. If the radiation level outside the shielding should exceed administrative trip points, the radiation monitor will open the guard line that interrupts RF delivery to the CMTF. All radiation detectors associated with the on-line monitoring system shall be properly maintained, calibrated at least annually, and tested during each PSS certification. RadCon, in coordination with the Test Coordinator and Principal Investigator on duty, will perform these actions. Portable survey meters will be used to periodically survey areas outside of the test area. Routine and special surveys will be taken by RadCon staff or Assigned Radiation Monitors and will be coordinated with the operations staff to ensure that the surveys are appropriately coupled to operating conditions. Copies of these surveys will be made available to CMTF operations staff.

Low power operations in the cave are limited to 1 watt, in order to reduce the hazard of ionizing radiation.

CARM Alarm Response

CARM alarms will terminate radiation-producing activities in the CMTF. In the event of a CARM alarm, the Principal Investigator (PI) or Duty Operator shall notify (RadCon) through the duty phone 757-876-1743 and discuss the operational activities that preceded the alarm. The Test Coordinator should also be notified. RadCon staff may require a supplementary radiation survey as radiation producing activities recommence. An ARM, if available, may conduct the radiation survey and report the results to the Radiation Control Staff. RadCon staff will address the results of the radiation survey with the Test Coordinator, PI and/or Duty Operator and discuss the mitigating measures, if necessary, for continued operation. The Test Coordinator will then determine when operations may resume.

Neutron CARM Alert Response

One neutron radiation detector in the cave is configured to produce an “alert level” alarm in the control room. This alarm will occur if the neutron levels in the vicinity of the cryomodule exceed 0.5 mrem/hr. This alarm will NOT terminate the test. The operator may acknowledge the alarm to silence the audible annunciator. When this condition occurs, the operator shall place signage prominently at the PSS console stating “**Contact RadCon at 876-1743 Survey required**” and make an appropriate elog entry copied to hamlette@jlab.org and welch@jlab.org and to the Test Coordinator. Furthermore, the Operator will place identical signage on the cryomodule during the next available access. The Test Coordinator must contact RadCon prior to removal of the cryomodule from the cave so that a survey for activation can be performed. The communications should be made far enough in advance to facilitate coordination of the survey.

Fixed Oxygen Deficiency Hazard (ODH) Monitoring and Alarm System

Oxygen monitors are located in the test cave at multiple levels to detect both helium and nitrogen gas leaks. Oxygen levels below 19.5% will trigger ODH alarms in the CMTF control room and the Test Cave. ODH alarms will also activate the Test Cave exhaust fan.

5.4 Ventilation

Exhaust Fan in the roof of the CMTF Test Cave is activated when an ODH alarm is triggered. This is designed to facilitate the venting of cryogenic gases.

5.5 Other (Electrical, ODH, Trip, Ladder) (Attach related Temporary Work Permits or Safety Reviews as appropriate.)

The potential hazards associated with the cave operations include electrical/electrocution, non-ionizing radiation (RF), ionizing radiation, vacuum, ODH, and material handling concerns. These hazards and their mitigation are covered in the attached Task Hazard Analysis.

Hazard Mitigation

Safe operation of the facility is accomplished through the use of a combination of engineering and administrative controls:

1. Radiation shielding and monitoring (covered in 5.1 and 5.3)
2. Personal Dosimetry monitoring for staff who must enter Radiologically Controlled Areas.
3. A Personnel Safety Interlock System (PSS). (covered in 5.2)
4. Provision of suitable hand held radiation monitors for periodic verification of shielding effectiveness.
5. Oxygen deficiency monitoring system.
6. Training for staff that must enter ODH areas.
7. Personal oxygen monitors and 5-minute escape packs for staff that must enter ODH 2 areas.
8. Detailed operational procedures under which all experiments are conducted by qualified staff scientists and engineers.
9. Several PSS emergency kill switches located in the test cave and in the control room. Activation of any of these kill switches releases the mag lock on the back door, opens the shield door and removes the permit from the high power RF sources' high voltage power supplies.
10. LOTO procedures for specific tasks.

Personnel training/qualification:

- ODH 2 medical required for accessing ODH 2 areas.
- ODH training required for accessing the test cave.
- Radiation Worker I required for accessing Radiologically Controlled Areas.
- PSS system training is required for System Operators, Principal Investigators and the Test Coordinator.
- General Employee Radiation Training is the minimum required for Visiting Operators.

ODH Rating for the Cave

Conditions	Rollup Door	First Floor	Mezzanine
No liquid in Cryomodule, No U Tube Stabbed	Open	ODH 0	ODH 2
No liquid in Cryomodule, No U Tube Stabbed	Closed	ODH 1	ODH 2
Cryomodule in Cave with liquid, U Tube Stabbed	Open	ODH 1	ODH 2
Cryomodule in Cave with liquid, U Tube Stabbed	Closed	ODH 2	ODH 2

Table 4

ODH assessment, **JLAB-TN-07-066** with addendum covering 01/09/2019 review, is attached.

6. List of Safety Equipment:

6.1 List of Safety Equipment:

A video camera is positioned with a monitor located at the back access door so that personnel can see the status of the cryomodules and therefore the ODH status before entering the cave.

The personal escape packs and oxygen monitors required for ODH 2 are located in the CMTF Control Room. They are maintained by the Safety Lab.

The Test Coordinator must verify that a clear pathway exists around the cryomodule prior to cool down and at the beginning of each day in which a cryomodule with u-tubes stabbed is in place in the Test Cave.

6.2 Special Tools:

N/A

DEVELOP THE PROCEDURE

1. Associated Administrative Controls

General

Operating Protocol

The following are general operating guidelines to be followed when using the test area for radiation producing experiments. Refer to the Conduct of Operations document for details.
One qualified System Operator, normally the Duty Operator, must be present in the facility during all high power RF operations. Their names are displayed on the control desk and entered in the CMTF electronic logbook.

1. Only authorized personnel shall be permitted to enter the test area to make changes in the apparatus. Authorization must be obtained from the Duty Operator, Principal Investigator or Test Coordinator.
2. The Duty Operator is responsible for ensuring safe operation in accordance with the OSP during attended high power RF operations. All personnel entering any Radiologically Controlled Areas shall carry Personal Dosimetry.
3. Any staff member has the responsibility to report to the Principal Investigator or the Duty Operator on issues of safety. If there is no Duty Operator assigned at the time of the event, the staff member shall contact the Test Coordinator, Facility Manager or their designee. An on-call list is posted in the control room to address off-hour conditions. If the issue cannot be resolved at this level, operation shall cease until such time as the issue is resolved.
4. Response to any emergency, accident condition, or injury shall be coordinated with the site security, phone extension 5822.
5. The control room must be attended when high power RF is on. High voltage operations may be left unattended for brief break periods. (See Table 5 for Staffing Requirements.)
6. One-person operation of the cryomodule test facility is permitted from the control room or in the cave when the cave ODH status is ODH 0.
7. The Test Coordinator or his designee must be on call for emergencies.

Cryomodule test cave waveguide shutter WR650 (1497 MHz) waveguide switch

1. The waveguide shutter switches located in the test cave provides a second level of assurance that high power RF is not routed to an open waveguide located beyond said shutter. The WR650 waveguide shutter switches are located in the second floor area of the cryomodule test cave. They are approximately 4 feet off of the floor adjacent to the south wall. One switch removes power from cavities 1, 3, 5 and 7. The second switch removes power from cavities 2, 4, 6, and 8. Cavity 1 is on the equipment door end (west) of the cryomodule test cave. These shutters are not currently used as LOTO points. When it is necessary to work on an open waveguide, LOTO must be applied directly to the circuit breakers controlling AC power to the high power amplifier in question.

Post High Power RF testing (Shutdown):

1. 1497 Klystrons
   a. First, change state of Klystron Power Supply to “RF Off”, then to “High Voltage Off”.
   b. Locate the AC circuit breaker panel behind the 1497 MHz racks and switch to the “Off” position and lock out with administrative lock. See Figure 3.
2. 1.3 GHz SSA’s
   a. First, change state of SSA to “RF Off”, then to “High Voltage Off”.
   b. Locate and open the 480 VAC breaker on the front of the SSA in use and open. See Figure 4
   c. Locate the AC circuit breaker panel behind the last pair of SSA’s and switch to the Off position.

Lock out with administrative lock. See Figure 5

Figure 3: 1497 HPA AC Circuit Breaker

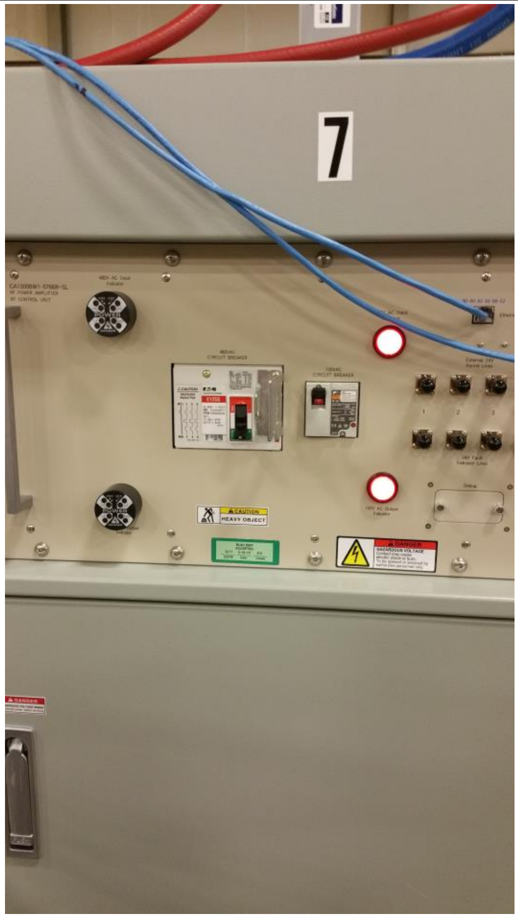

Figure 4: Front Panel 1.3 GHz SSA

Figure 5: Breaker Panel for SSA's

Procedure for connection and operation of TWT or other RF amplifier

Certain tests will require the use of an RF power source other than the 1497 MHz systems. These sources would include the TWT amplifiers that are able to operate at 2.8 – 3.2 GHz. These amplifiers are capable of exceeding the 1 Watt limit. There are three sets of AC outlets that are interlocked to the PSS. These interlocked AC contactors provide a way to interlock amplifiers that are external to the CMTF to the PSS. All of the interlocked contactors provide both 120VAC and 208 VAC power.

The three AC contactors are designated:

1. AC301: Located in the CMTF Control Room on the back wall between the two sets of equipment racks.
    a. The outlets are labeled SNSP1/14 (120VAC) and SNSP1/33 (208 VAC)
2. AC302: Located inside the Cave in the Southeast corner inside the shielding enclosure.
3. AC303: Located on the Mezzanine above the Test Cave near the 20 kW, 805 MHz klystron stand.

RF Amplifier connected to AC302 (Test Cave) or AC303 (Mezzanine)

1. Locate the RF Power source in proximity to the appropriate contactor.
2. While the CMTF Safety System is in the Open mode:
    a. Connect RF Amplifier output to Device Under Test through existing waveguide systems (Mezzanine), through RF cables to an input coupler (Test Cave) or through appropriate patch panel connector (Control Room).

   b. AC302 and AC 303 must be connected to an existing AC outlet through the attached power cables.
      i. AC302 must be connected to the outlets labeled L1400/31 for 120VAC and L1400/20 for 208VAC. These outlets are located on the wall directly below the AC302 enclosure. They are marked with yellow tape.
      ii. AC303 must currently be connected to AC power through the use of a portable transformer (Big Bertha).
   c. Connect the RF Amplifier's AC power cable to the appropriate outlet on one of the contactors.
3. Connect drive signal to RF Amplifier through RF crash switch in RF Interlock Switch Box in the Control Room.
4. The RF crash switch must be pushed in (for open circuit).
5. Make an entry in the electronic logbook (Pansophy) detailing actions taken.
6. Sweep the Test Cave and bring PSS to Run mode.

RF Amplifier connected to AC301 (CMTF Control Room)

1. While the CMTF Safety System is in the Open mode:
   a. Connect the Amplifier's power cable to either the 120 V or 208 V outlets. The outlets are located on the back wall of the control room between the two sets of equipment racks. They are labeled, SNSP4/33 and SNSP1/34
   b. Connect the amplifier's RF output to the appropriate patch panel connector.
   c. Connect the drive signal from a preamplifier or other device to the amplifier in the CMTF Control Room via the RF crash switch in the RF Interlock Switch Box.
   d. RF crash switch must be pushed in (circuit open).
2. Make an electronic logbook entry detailing the above actions.
3. Sweep the cave and bring the PSS into Run mode.
4. Turn on amplifier
5. Pull out RF crash button (closed circuit) when ready to drive amplifier.
6. Begin test
7. After completion of tests:
   a. Push in RF Crash button.
   b. Turn off amplifier
   c. Bring PSS into Open mode
   d. Disconnect RF drive and RF output cables from amplifier
   e. Disconnect power cable from AC contactor outlet.
8. Make another electronic logbook entry detailing action listed above.

Waveguide / Hardline Installation / Removal

1. Before working on open waveguide or hardline (connect / disconnect) AC Supply Power to either the 1497 MHz Klystron Power Supply or the 1300 MHz SSA's must be locked out:
   a. AC Breaker Panel for the 1497 MHz system is located behind the klystron racks (See Figure 3)
   b. AC Breaker Panel for the 1300 MHz system is located behind the last set of SSA's (See Figure 5)
2. When closing or opening a disconnect breaker and disconnecting the power plug, use proper PPE:
   1. **Use safety glasses,**
   2. **Heavy Duty Leather Gloves**
   3. **A Long Sleeve Shirt of a non-melting material or an untreated natural fiber**
   4. **Long Pants of a non-melting material or an untreated natural fiber.**

3. Open the breaker for the 1497 MHz system or for the specific 1300 MHz SSA.
4. Check the VVU associated with the breaker to insure that power is removed.
    a. VVU for the 1497 MHz system is located on the front of the klystron power supply rack
    b. VVU's for the 1300 MHz systems are located next to the SSA breaker panel (See Figure 6)
5. Each worker must apply a personal lock to a hasp o the breaker in question.

Figure 6: Breaker Panel for 1300 MHz SSA's

Waveguide Integrity

Before Power can be applied to either of the HP RF systems

1. Waveguide / hardline connected to the SSA or klystron output must be terminated by either:
    a. Shorting plate
    b. Load
    c. Reconnected to waveguide / hardline network
2. After completing work on waveguide or hardline, all waveguide / hardline joints that are upstream of the Cave penetrations must be surveyed for RF leakage.
    a. RF Survey of Waveguide
        i. Turn on the SSA Main Power
        ii. Close Front Panel Breakers
        iii. Adjust RF drive until the Forward Power is approximately 100 Watts (by power meter readout).
        iv. Using the calibrated RF survey meter provided by ESH&Q, survey all waveguide /hardline joints and ports between the SSA or klystron output and the termination for RF leakage. To do so, slowly move the probe along the flange joints at a distance of no more than one

inch from the surface. If leakage above 1 mW/cm2 is observed, turn off the RF and take remedial action. Successful completion of the RF survey shall be recorded in the CMTF elog. Entry shall include

1. The RF Forward Power reading in Watts
2. The maximum reading observed on the RF survey meter
3. The date and time
4. Name of the survey operator

v. Increase RF drive power slowly until Forward Power is 1 kW. Using the calibrated RF survey meter provided by ESH&Q, survey all waveguide / hardline joints and ports between the SSA Output and the termination for RF leakage. To do so, slowly move the probe along the flange joints or cutoff tubes at a distance no more than one inch from the surface. If leakage above 4 mW/cm2 is observed, turn off the RF and take remedial action. Successful completion of the RF survey shall be recorded in the CMTF elog. Said entry shall include

1. The RF Forward Power reading in Watts
2. The maximum reading observed on the RF survey meter
3. The date and time
4. Name of the survey operator

ODH Hazard Mitigation in CMTF Cave During Scheduled Electrical Outages:

The source of the ODH hazard in the cryomodule test cave is the CTF junction box located in the east end of the room and the helium supply end can located in the north-west corner of the magnetically shielded area. The junction box in the east end of the cave cannot be tagged out, because cryogens used in the vertical test area are routed through it. The end can in the north-west corner of the magnetically shielded area is an un-isolatable extension of the junction box. Thus the source of the ODH hazard cannot be eliminated during the time frame that the ODH system is not operational.

The cave shield door is an electrically controlled multi-ton concrete door. The primary power for this door is supplied by a single circuit breaker. This breaker is located in panel MCC-SU and is located on the west wall of the high bay.

Procedure 1:
The shield doors will be secured in the OPEN position for the duration of the scheduled outage by administratively locking and tagging out the circuit breakers labeled, "MCC-SU8-SHIELDG DOOR CC1"and MCC-SU9 SHIELD DOOR CC2, in the OFF position, RC=1. **The following procedure applies only to the first two cases in Table 4, "ODH Ratings for the Cave". There is either no cryomodule in the Cave or a cryomodule with no u-tubes installed.**

1. The SSG Group Leader or his designee shall first ensure the shield doors are in the OPEN position and then apply an administrative lock on the circuit breakers ""MCC-SU8-SHIELDG DOOR CC1"and "MCC-SU9 SHIELD DOOR CC2".
2. Once the lock is applied, the SSG staff shall ensure that the cave door has been disabled by trying to close it using the key.
3. The administrative lock shall not be removed until such time that the ODH system has been returned to service and tested.

4. The administrative lock and tag shall not be removed and the door re-energized until after the ODH system has been re-energized and certified.

ODH Hazard Mitigation in CMTF Cave During Scheduled Electrical Outages

Procedure 2
This procedure applies only to scheduled electrical outages during which the second two cases in Table 4 apply. This means a cryomodule is in place in the cave with u-tubes installed.

When a cryomodule is in the CMTF with U-tubes stabbed, there is no way to reduce the ODH classification to ODH 0. In this case, the ODH status of the facility will be administratively changed to ODH 2 and posted as such, both at the front door and at the rear access door. As a result, anyone who wishes to enter the area will need to be qualified for ODH2 operations and carry a personal oxygen monitor and escape pack (RC=1).

Emergency Procedures:

a. Oxygen Deficiency

1. In the event of an ODH alarm, all personnel in the test cave, and CMTF control room, shall leave those areas and assemble outside the CMTF control room. Leave the test area immediately by the nearest exit (away from the plume if possible).
2. While remaining outside of the test cave, a qualified System Operator, the Test Coordinator or the Facility Manager shall determine if there has been or is a significant release of cryogens.
3. If they determine that there has not a release of cryogen, the system operator, the Test Coordinator, or the Facility Manager shall summon the assistance the PSS staff member who is on call. The on call list is posted it the control room and in is available in the MCC x7045.
4. If there has been a significant release of cryogens or you are unable to determine that there has not been a release, the System Operator, the Test Coordinator, or the Facility Manager shall summon the assistance of the on-call cryogenic coordinator and the Industrial Hygiene Group.

Contact Information:

Industrial Hygiene Group	**240-0031 (EH&S Cell Phone)**
On-call Cryogenic Coordinator	**contact through Guard House ext 5822**
Contact the Guard House	**ext 5822 for off hours number**
ESH&Q Emergency Manager	**Tina Menefee –ext 5490**

The area should be posted as ODH 4. Only SCBA rescue qualified personnel from the Newport News Fire Dept. may enter an ODH 4 area.

1. If the alarm is found to be false, the System Operator, the Test Coordinator or the Facility Manager may bypass the offending ODH monitor using the procedure in the CMTF PSS Users Guide. Once clear of the area isolate supply of LHe or LN2 and other lines yourself or contacting the cryogenic coordinator.

b. Off Hours ODH Alarm:

The emergency contacts must respond to the ODH emergency following the same procedure used during normal operations.

c. Possible Excessive Radiation Exposure

1. Immediately call RadCon for assistance: 757 876-1743
2. Turn off the high power RF by crashing the PSS system.

d. RF Emergency

1. **Turn off the high power RF by crashing the PSS system.**
2. Page Rick Nelson at 757-584-7185 or Andrew Kimber 757-746-9312 for assistance.

e. Failure of Personnel Safety System

In the event the interlock system or radiation-monitoring system operate improperly or suffer a hardware failure, the Duty Operator will immediately:

1. Terminate RF operations
2. Notify PSS on call personnel, and Radiation Control Group on-call personnel.

f. Power Outage

1. Cryogenics: cryogenics coordinator will be automatically notified by the guard callback system in the event of power failure.
2. RF: no response required
3. Cryomodule: contact the cryomodule on call personnel.

e. Other Emergency Situations

For emergencies such as injury or fire, please refer to https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-24400/*.pdf (Jefferson Lab Emergency Response Procedures) or to the JLAB Emergency Action Card attached to all JLAB phones.

2. Operating Guidelines

Staffing

Open Mode

Open Mode requires no staffing of the CMTF. Additional restrictions based on ODH classification may be required. See section on ODH hazard classification.

Sweep Mode

Operation of the CMTF test cave PSS does not require a safety system operator (SSO).

During the sweep, the test cave is considered to be under ODH 2 conditions. As such, the sweep must be performed by two qualified personnel. Workers must have current training and carry an operational Personal Oxygen Monitor and carry a properly charged 5-minute escape pack when conducting the CMTF sweep. See section 4.4 for required training.

Personnel performing a sweep must have the following qualifications:

- ODH 2 medically qualified
- Trained in the use of the personal ODH monitors and 5-minute escape packs
- At least one member of the sweep team familiar with the sweep pattern
  A copy of the sweep pattern is shown in Figure 7. Instructions for the sweep procedure are given in the CMTF PSS Users Guide.

RUN Mode

When the PSS is in RUN mode and all high power RF sources are turned off along with any High Voltage supplies, a System Operator must be present in the Test Lab. This person shall check the status of the PSS and RF systems no less than once per hour.

When the PSS is in RUN mode and high power RF is ON, a System Operator must be present in the Control Room.

See Table 5 for detailed staffing requirements. Note: High Voltage refers to the 1497 MHz system. 480 V refers to the 1300 MHz systems

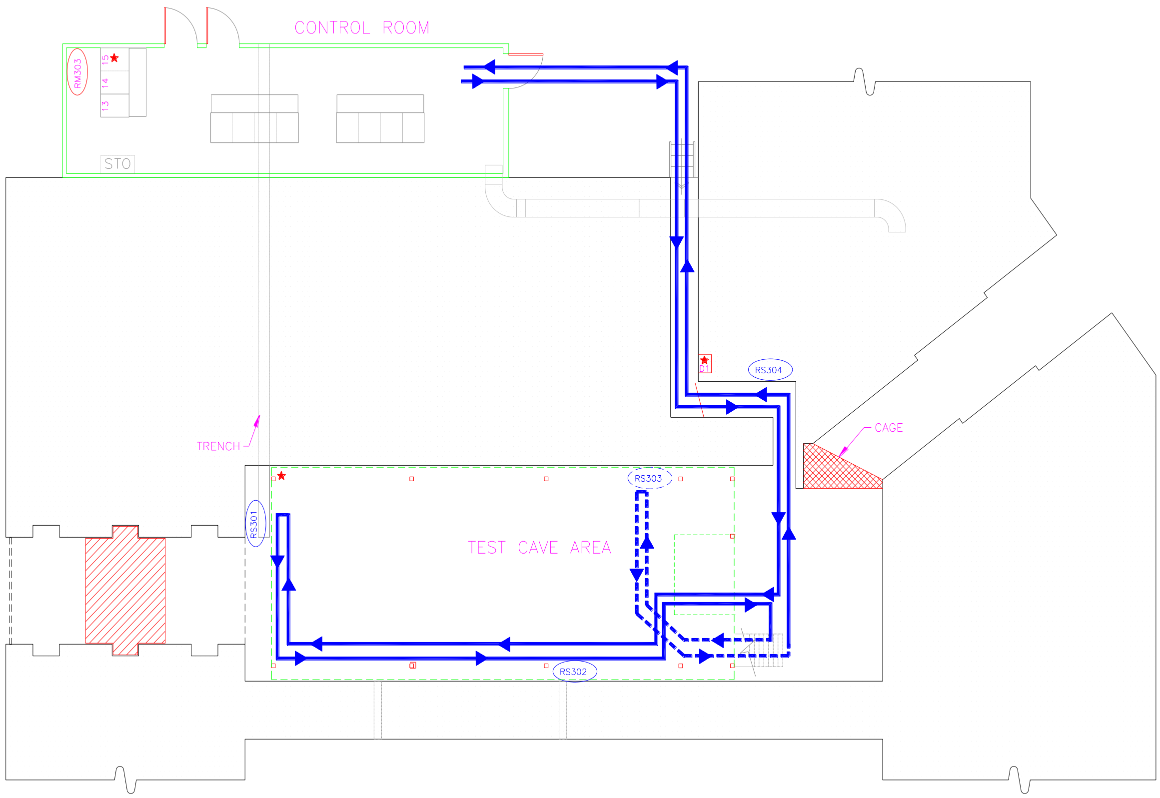

Figure 7 Sweep Pattern used for placing the PSS in RUN mode

Cave State	PSS	Staffing Requirements
Open Low Power RF Off	Open Access	Unattended Operations permitted 24 hour on call contact
High Voltage / 480V Off High Power RF Off	Run	One operator must check status in control room at least once per hour
High Voltage / 480V Off High Power RF Off	Sweep/Arm	Two operators required to complete sweep.
High Voltage / 480 V On High Power RF Off	Run	Operator may leave the control room for short breaks (up to 10 minutes)
High Voltage / 480 V On High Power RF on	Run	One operator must be present in control room.
High Voltage / 480 V Off Low Power RF on or off	Run	One operator must check status in control room at least once per hour
Low Power RF on	Open Access	Unattended Operations permitted 24 hour on call contact

Table 5 PSS / Cave States and Staffing Requirements

High Power RF Operation

The dual 13 kW / 1497 MHz sources as well as any other interlocked RF source may only be operated when the test cave is in RUN Mode.

Exceptions to this rule are allowed for the Warm Window Test Stand located in on the mezzanine. The Standard Operating Procedure for **CEBAF Replacement Warm Window RF Qualification Testing** describes the circumstances under which RF may be produced by the dual 13 kW / 1497 MHz without placing the Test Cave in the RUN mode. Configuration instructions are given in the CMTF PSS Users Guide.

The following are important notes about the interface between the CMTF PSS and high power amplifiers:

- Pushing any crash switch will shut off ALL RF systems.
- If any RF system indicates that it is ON/Unsafe before a sweep of the test cave is complete, the PSS will drop to OPEN mode.
- The test cave must be in RUN mode in order to operate any PSS interlocked, high power RF system configured to deliver RF to the Test Cave.
- An alarm from an ionizing radiation monitor (CARM) or non-ionizing radiation monitor (RF monitor) will trip off any PSS interlocked, high power RF system configured to deliver RF to the Test Cave. Before Operations can resume after a CARM or RF monitor alarm, the PSS must be reset by cycling the key to Ready then back to RUN.
- When the PSS is switched from Sweep to RUN mode, there is a 30 second delay before RF can be energized. This timer is to allow anyone caught in the test cave time to activate the nearest crash switch.

On Call Support

A member of the SSG group is on call at all times. An SSG on-call schedule shall be posted in the CMTF Control Room. On call support should only be initiated after the Principal Investigator or Duty Operator has attempted to solve the problem and failed. A short troubleshooting procedure is contained in the CMTF PSS Users Guide.

Log keeping

All PSS operations shall be logged by the Principal Investigator, or Duty Operator, in the CMTF PSS log book, located at the CMTF PSS console and in the CMTF electronic log (in Pansophy).

3. Notification of Affected Personnel (who, how, and when)

- The front entrance of the Test Cave is posted with signage that indicates the ODH state.
- Flashing magenta beacons at front and back of Cave indicate High Power RF and the potential for ionizing radiation.
- Blue flashing lights in case of ODH alarm
- Audible alarm sounds when Test Cave is placed in RUN Mode
- Video monitor at entrance to labyrinth at back of Cave indicates state of cryomodule (u-tube stabbed or not) and ODH state.

4. List the Steps Required to Execute the Procedure: from start to finish.

See Sections 1 and 2 above.

5. Back Out Procedure(s) i.e. steps necessary to restore the equipment/area to a safe level.

See Sections 1 and 2 above.

6. Special environmental control requirements:

6.1 Environmental impacts (See EMP-04 Project/Activity/Experiment Environmental Review)

N/A

6.2 Abatement steps (secondary containment or special packaging requirements)

N/A

7. Unusual/Emergency Procedures (e.g., loss of power, spills, fire, etc.)

Follow guidance in this OSP or in ES&H Manual as appropriate.

8. Instrument Calibration Requirements (e.g., safety system/device recertification, RF probe calibration)

PSS Certification is required at least twice a year with an interval between certifications of not less than 4 months and not more than 8 months and is carried out by the Safety Systems Group.
ODH monitoring sensors are maintained by Safety Systems Group.

9. Inspection Schedules

PSS Certification is required at least twice a year with an interval between certifications of not less than 4 months and not more than 8 months and is carried out by the Safety Systems Group.
Shielding and radiation monitoring configuration inspections are conducted every six months by RadCon.

10. References/Associated Documentation

References:

ES&H Manual Sections:

- 6140 Cranes and Hoists
- 6200 General Electrical Safety
- 6310 Ionizing Radiation Protection
- 6315, Environmental Monitoring of Ionizing Radiation
- 6420 Radio Frequency and Microwave Radiation
- 6540 Oxygen Deficiency Hazard

Attachments:

- SOP A-06-003-SOP **CEBAF Replacement Warm Window RF Qualification Testing**
- **Conduct of Operations for the Cryomodule Test Facility**
- JLAB-TN-07-066 **ODH Risk Assessment, CMTF, Jan 12, 2016 with addendum covering review on Jan 9, 2019**
- JLAB-TN-16-010 **Calculation of CMTF Roof Shielding and Radiation Skyshine**
- JLAB-TN-16-009 **Shielding Basis of the Cryomodule Test Facility Upgrade**
- Bolt Pattern for Waveguide Flanges
-

11. List of Records Generated (Include Location / Review and Approved procedure)

All data acquired during CMTF operations are stored in Pansophy traveler system and /or Docushare along with folders on the M drive.

Click
To Submit OSP
for Electronic Signatures

Distribution: Copies to: affected area, authors, Division Safety Officer
Expiration: Forward to ESH&Q Document Control

Form Revision Summary

Revision 1.3 – 11/27/13 – Added "Owning Organization" to more accurately reflect laboratory operations.
Revision 1.2 – 09/15/12 – Update form to conform to electronic review.
Revision 1.1 – 04/03/12 – Risk Code 0 switched to N to be consistent with 3210 T3 Risk Code Assignment.
Revision 1.0 – 12/01/11 – Added reasoning for OSP to aid in appropriate review determination.
Revision 0 – 10/05/09 – Updated to reflect current laboratory operations

ISSUING AUTHORITY	FORM TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW REQUIRED DATE	REV.
ESH&Q Division	Harry Fanning	12/01/11	12/01/14	1.3

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Task Hazard Analysis (THA) Worksheet

(See ES&H Manual Chapter 3210 Appendix T1 Work Planning, Control, and Authorization Procedure)

Click

Author:	Michael Drury	**Date:**	2/5/2015	**Task #:** If applicable	

Complete all information. Use as many sheets as necessary

Task Title:	Cryomodule Test Facility Operation Hazards			**Task Location:**	Cryomodule Test Facility
Division:	Accelerator	**Department:**	SRFOPS	**Frequency of use:**	Variable
Lead Worker:	Michael Drury				
Mitigation already in place: Standard Protecting Measures Work Control Documents	Personnel Safety System				

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
	Cryomodule Installation and Preparation for Testing: Electric Shock Ion pump power supply Cold cathode gauge high voltage +/- 3kV at 5 mA	H	M	4	Only SHV connectors are used. This type of connector makes the ground connection first when plugging in and breaks it last when unplugging the connector	All voltage sources are "plug in ". Must unplug before servicing. Power-down procedures are in place.	1

Task Hazard Analysis (THA) Worksheet

(See ES&H Manual Chapter 3210 Appendix T1
Work Planning, Control, and Authorization Procedure)

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
	Cryomodule Installation and Preparation for Testing: Electric Shock Piezo element Power supply Up to 1 kV at 2 A.	H	M	4	Admin Lockout on power supply	• SAF603A Electrical Safety Awareness • SAF104 Lock, Tag and Try	N
	Cryomodule Installation and Preparation for Testing: Hoist Failure while lifting the return U-tube into place	M	L	2	The hoist is rated for 5x the load. Hoist is load tested on an annual basis	• SAF403 Overhead Crane Operator Qualification • MED01 Medical Monitoring for Hazardous Work	1
	Cold cryomodule ODH hazard Blocked egress due to equipment around cryomodule impedes evacuation during an ODH event	H	L	3	Staff advised via this OSP to maintain egress path around the cryomodule.		1

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
	Cold cryomodule ODH hazard Pressure relief due to cryogenic failure	H	L	3	• ODH Monitoring system turns on Static Vent Exhaust Fan. • Non – vent penetrations sealed.	• ODH assessment and rating of cave. • ODH2 training required for all CMTF personnel. • Personal escape packs and oxygen monitors required for ODH2	1
	ODH Hazard in Control Room due to cryogenic failure in the Cave while using liquid Nitrogen	M	L	2	Trenches that connect the control room and the cave are sealed.	• JLAB-TN-07-066, Rev 1 ODH Risk Assessment, CMTF, Jan 2016, Reviewed in Jan 2019 (addendum 3) • ODH training Required for CMTF Personnel	N
	Cryomodule vacuum failure: • Implosion: puncture ear drum • Vacuum failure when cryomodule is full of cryogen will lead to cryogen release (refer to mitigation for oxygen deficiency)	H	L	3	• All vacuum windows are covered or contained in waveguide during normal operations. • All reliefs are located away from face level.		1

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
	Egress from the 2nd floor during power failure	M	M	3	Additional emergency lighting. Railings installed to prevent fall hazard		1
	Energizing 1500 MHz HPA 480 V Hazards Arc Flash from Disconnect	H	M	4	• Safety glasses • Hearing protection • Heavy duty leather glove • Long sleeve shirt and long pants both of a non-melting material or untreated natural fiber	General Electrical Training • SAF603S Switching of Electrical Equipment	1

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
	Non- Ionizing Radiation due to RF leakage from waveguide: RF burns, eye damage, tissue heating due to improperly assembled waveguide joints or component failure	M	M	3	• Bolt torque pattern (attached) to be followed for all waveguide connections upstream of the LOTO shutter located within the cave. • RF survey after assembly of joints upstream of the LOTO shutter located within the cave. • No personnel in cave during high power RF operations through the use of Personnel Safety Interlocks.		1

Task Hazard Analysis (THA) Worksheet

(See ES&H Manual Chapter 3210 Appendix T1 Work Planning, Control, and Authorization Procedure)

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
	Ionizing Radiation Inherent hazard from operating high gradient cavities in vacuum.	H	H	4	• Shielding in place (including the roll up equipment doors). • Personnel Safety System ensures that high voltage is not permitted on the high power RF sources when the switching network permits the RF to enter the cave and the cave can be occupied. • Radiation surveys by trained staff or fixed monitoring equipment at turn on and at regular power increase intervals. Area radiation monitors are interlocked to RF power.	Personnel excluded from the cave during high power ops (anything above 1W RF power delivered to input coupler of device under test). SAF800 GERT SAF801 Rad Worker I	1

Highest Risk Code before Mitigation:	4	**Highest Risk Code after Mitigation:**	1

When completed, if the analysis indicates that the Risk Code before mitigation for any steps is "medium" or higher (RC≥3), then a formal Work Control Document (WCD) is developed for the task. Attach this completed Task Hazard Analysis Worksheet. Have the package reviewed and approved prior to beginning work. (See ES&H Manual Chapter 3310 Operational Safety Procedure Program.)

Form Revision Summary

Revision 0.1 – 06/19/12 - Triennial Review. Update to format.

Revision 0.0 – 10/05/09 – Written to document current laboratory operational procedure.

ISSUING AUTHORITY	TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW REQUIRED DATE	REV.
ESH&Q Division	Harry Fanning	06/19/12	06/19/15	0.1

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Shielding Basis of the Cryomodule Test Facility Upgrade

George Kharashvili, Jefferson Lab Radiation Control

Introduction

The cryomodule test facility (CMTF) in the Test Lab (Bldg. 58) is being upgraded to allow testing of fully assembled LCLS II type cryomodules capable to accelerate electrons to energies up to 120 MeV by design. The total duration of tests at the full accelerating gradient will not exceed 200 hours per year.

Electron field emission is the major source of ionizing radiation in a superconducting cryomodule test facility. Field emitted electrons may accelerate up to the full accelerating energy of the cryomodule. The radiation source term related to the electron field emission depends on the accelerating gradient, and the nature and the distribution of surface imperfections in accelerating cavities. It is challenging to predict as it typically greatly varies from cavity to cavity and may also change in time for a given cavity. Therefore the available empirical data, Monte-Carlo calculations, and series of conservative assumptions are used to determine the radiological control requirements of CMTF.

Calculation of Sourceterm and Shielding Parameterization

In the absence of any experimental measurements of the radiation sourceterms caused by field emission at the LCLS II type cryomodules, projections were made based on the radiation measurements conducted during C100 cryomodule tests at Jefferson Lab. As reported in JLAB-TN-13-023, neutron equivalent dose rates of up to 20 mSv/h (2 rem/h) were measured at a distance of 1 m from the return end of a C100 cryomodule. The measurements were taken during a C100 test at the full accelerating energy of 100 to 105 MeV. It is assumed that the field emissions at the LCLS II type cryomodules will produce a sourceterm 10 times greater that C100, which is 200 mSv/h (20 rem/h) at 1 m from either end of a cryomodule.

FLUKA Monte-Carlo code was used to calculate the shielding requirements of the upgraded CMTF. 120 MeV electron beam was incident on a thick (30cm-long, 2cm-radius) copper target inside of a cylindrical shield made of the ordinary concrete. Dose rates outside of the shielding in forward and sideways directions were calculated for shielding thicknesses from 50 cm to 300 cm. Results were normalized to 127 nA beam current, which corresponds to the neutron dose rate of 200 mSv/h at 1m distance, discussed in the previous paragraph. Results are presented in Figure 1.

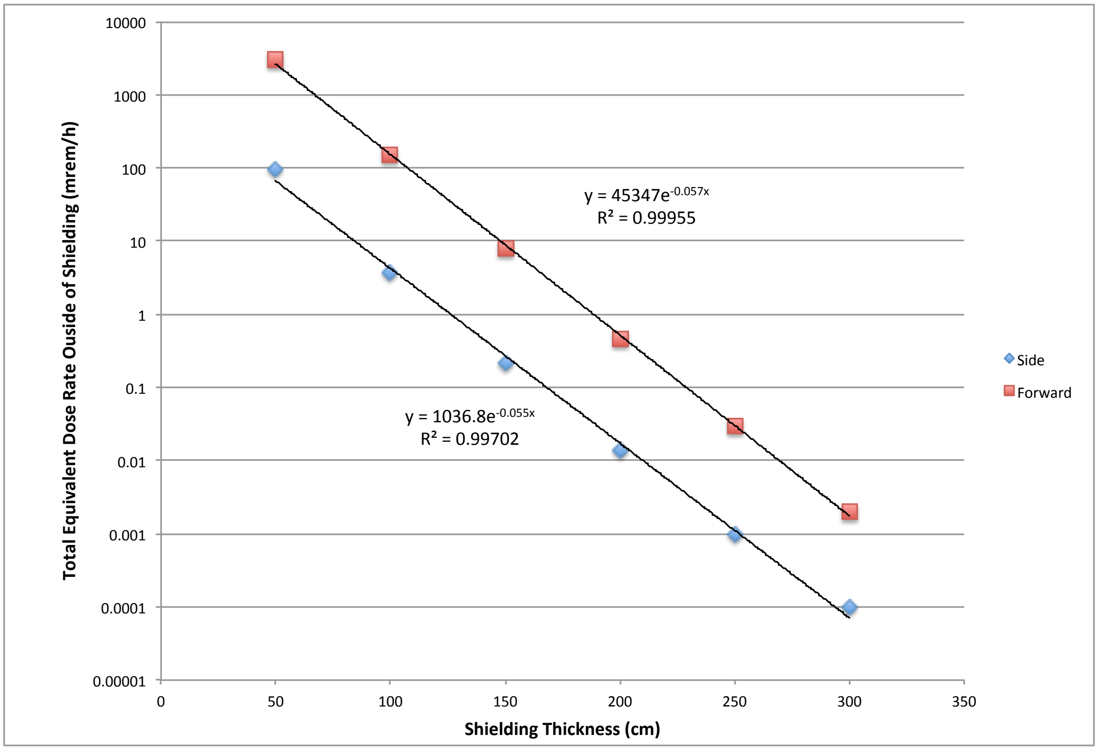


Figure 1. Concrete shielding parameterization – 120 MeV, 127 nA electron beam on a 30 cm long, 2.5 cm radius copper target.

CMTF Shielding Requirements and Radiological Controls

JLAB Shielding Policy for Ionizing Radiation defines the following Shielding Design Criteria for normal facility operations:

a) Integrated equivalent dose in occupied Radiologically Controlled Areas (RCA) will not exceed 2.5 mSv (250 mrem) per year.

b) Integrated equivalent dose in occupied areas other than RCAs will not exceed 1.0 mSv (100 mrem) per year.

Each of the doors 2 and 3 is over 200 cm thick. Assuming the sourceterms described in the previous section (200 mSv/h of neutron dose at 1m) 200 hours of full energy cryomodule tests per year will result in 0.92 mSv (92 mrem). In all other directions at least 140 cm shielding is required to keep the annual dose below the RCA limit. In the direction above the movable doors this can be achieved by adding concrete shielding blocks over the movable doors according to the drawings presented in Figure 2 and Figure 3.

There is a 137 cm thick concrete wall separating CMTF from the vertical testing area (VTA). This thickness is not sufficient to meet the 1 mSv (100 mrem) per year limit as it could result in 1.25 mSv (125 mrem) in a year. In addition, the wall has several penetrations that may result in even higher radiation levels. As a solution, VTA will be permanently posted as RCA (currently it is only posted during VTA tests).

Other requirements to control radiological conditions in the areas surrounding CMTF are:

- Introduce local shielding inside CMTF to restrict direct line of sight from the cryomodule ends to the penetrations connecting CMTF and VTA.
- Install interlocked CARMs to prevent dose rates exceeding the levels assumed in this document.

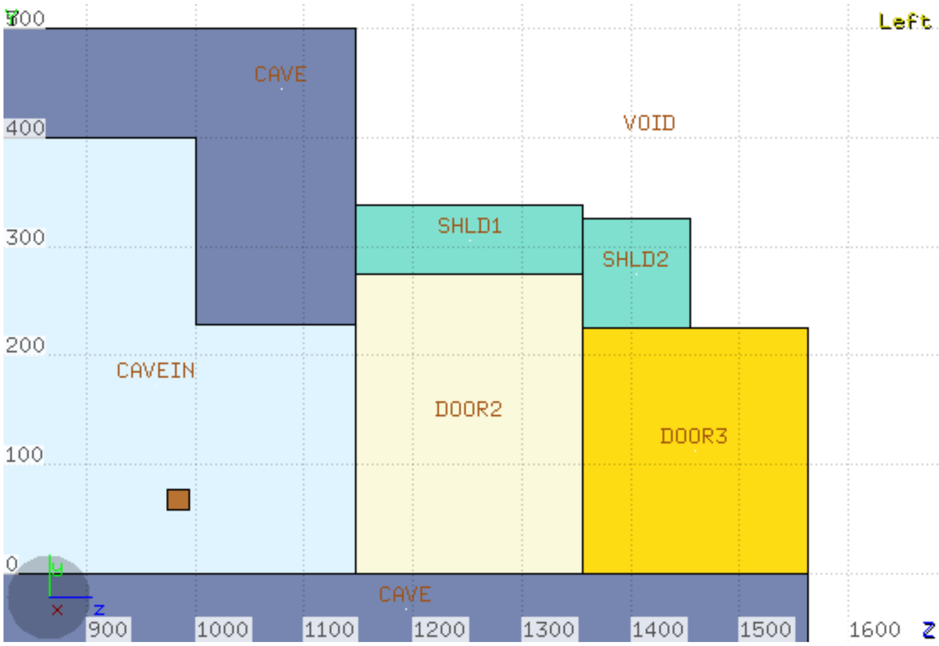


Figure 2: Schematic representation of CMTF movable doors and the overhead shielding.

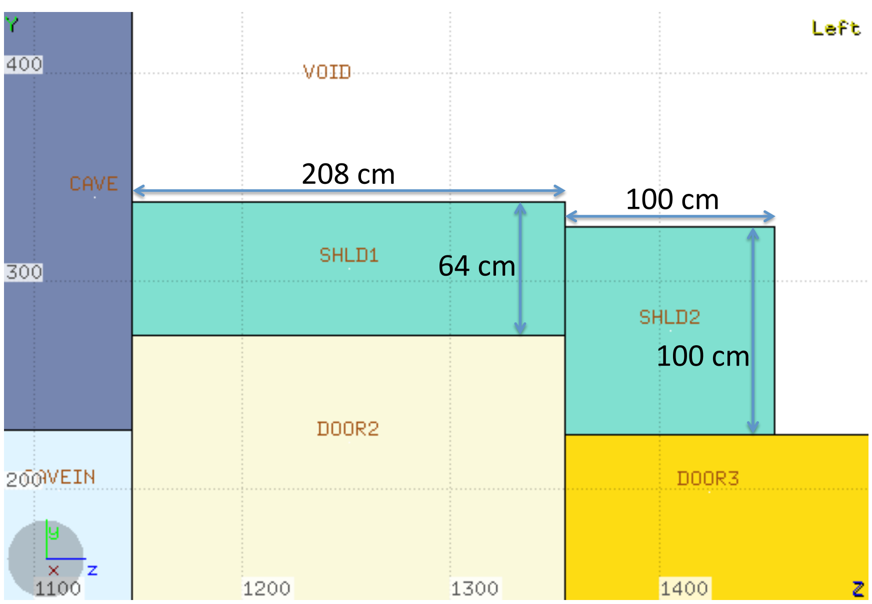
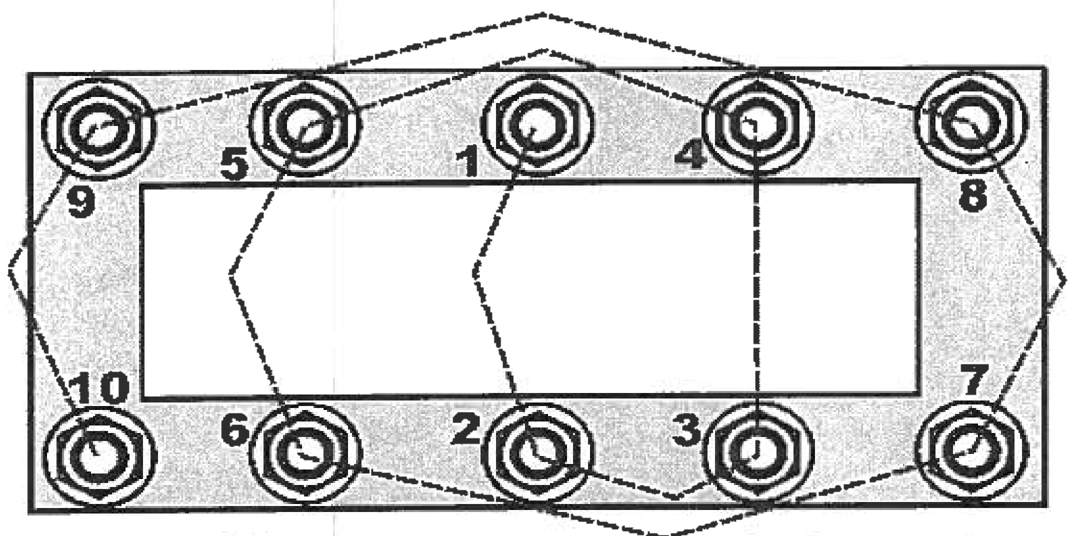


Figure 3: Schematic representation of CMTF movable doors and the overhead shielding.



Spiral Tightening Sequence Starting in the Middle for Non-Circular Bolt Patterns.

Tests have shown that the elastic interaction between bolts in a joint can have a significant effect on the preload (a reduction of 35%). If a gasket is present between the joint surfaces the effect can be even more pronounced.

ODH Assessment

Date: **12 January 2016**

Division: **Cryogenic Systems**

Location: **Test Lab**
Cryomodule Test Facility

Assessment Author: **Dana Arenius**

Harry Fanning (Jan 2016)

Approval

Engineering Division Manager: **Will Oren** W. Oren 1/28/16

Reviewed 01/09/2019, see addendum 3 (attached)

Final ODH Risk Assessment, CMTF
June 8, 2002

Introduction

This assessment addresses the risk of oxygen deficiency hazard for the Cryomodule Test Facility (Cryomodule Test Cave) within Building 58. The assessment is conducted according to the requirements of Appendix 6500-T3, "ODH Risk Assessment". Two general categories of ODH hazards are identified in the facility. These are sources of nitrogen and helium gas which can dilute the normal oxygen content with health effects as outlined in Appendix 6500-T3.

The following sections covers the modeling scope and methodology for the cryogen dispersion release, a description of the work space, operational modes which affect the risk factors, the risk assess assessment, failure rates of the components, the resultant Area Classification, and self-rescue-atmosphere respirators.

Model for Cryogen Dispersion Release

The Model for Cryogen Dispersion Release is based on a fully operational cryogenic distribution junction box, supply can, and a system connected full size (1600L capacity) cryomodule at 2K under test. An occasional 500L nitrogen dewar is to be rolled in for vacuum break purposes. A ½ inch GN2 supply line with 80 PISG supply pressure with no flow restriction other than line pressure drop is also located in the room along with a warm gaseous helium supply header. Primary/secondary vessel vacuum relief valves and primary/secondary cryomodule process relief valves are vented into the CMTF room for the model. Unlike the JLAB accelerator tunnel, there is no guard vacuum piping system which extends outside of the CMTF for cryomodule primary relief nor is there sufficient 2K return line volume which tends to absorb a possible cryomodule liquid vaporization inventory. Two occupied floor levels are used in the model. The upper floor level has a steep stair for egress. Also, egress from the lower first floor room with the main lift door closed would have to come in close proximity to a cryomodule end can relief which is the major helium inventory venting point.

Recent helium spill tests within the JLAB accelerator tunnel has shown that rising helium gas interacts with the surrounding air, mixing with it as it rises. Once combined with air, the helium does not readily separate out of the air/helium mixture thus is not reversible. It will retain the same helium to air percentages as long as it does not further interact with additional sources of air (dilution) or higher concentrations of helium (enrichment, which is unlikely). Since the helium/air gas "mixture is lighter than air, the mixture rises. If natural convection ventilation is provided, both oxygen and helium are purged from the contained area and the helium will displace more of the confined space in a vertical downward direction.

The model for a helium release rate is based on the worst release cases listed under the Operational Modes below. Failure rate estimates (P_i) are based on previous JLAB cryomodule probability and JLAB listed equipment rates under EH+S Section 6500. Fatality Factors (F_i) are derived from Figure 3, of the EH+S Appendix 6500-T3. The sum of the failure product of the F_i and P_i for each of the operational modes determined the area classification in accordance with table 6 of Section 6500 of the EH+S manual. The classification was adjusted if the normal calculation placed the event in the upper range of the classification and factors, such as ease of escape, were apparent.

Description of Work Space: (see figure 1)

The enclosed space measures 18' wide, 57 feet long and 19 feet in height for a total of 19,500 ft^3. The space is divided into two floors at elevations at grade and 10'. The upper level is comprised of a solid platform (18'W x 41.5' L) with opening to the first floor of 18' W x 2.5' L on the west end and 18' X 13' on the east end. The upper platform forms a complete seal between the first and second floor levels along the room north and south floor edges.

A single steep stair connects the first and second floor at the south east corner of the platform for egress from the second floor. A 16 Ft^2 cross area (4'x4') exhaust fan opening is located in the northwest corner of the ceiling. The opening is fitted with a 42" diameter, 5 hp, approx. 10K cfm electric exhaust fan. The fan shutters are gravity close and normally only open when the fan is in operation. A cover plate with side openings between the ceiling opening and fan inlet allows for the same cross section area as the ceiling opening. (~16.8 ft^2).

Three 10" diameter wall vent tubes are located 15" down from top of ceiling along the south upper platform wall. The vent tubes exit at floor level for wave guides into the upper instrumentation rack and vacuum pair pump work area on top of the CMTF room. Unless sealed these could create ODH hazard for upper CMTF roof area for cryomodule fault. Five 12" diameter wall vent tubes are located along the north side upper platform wall at an elevation of 18" above the platform floor level. Three of these tubes directly communicate with an upper instrumentation rack room located along the upper north wall of the CMTF work space. The other two are HVAC duct work supplies which are routed through the same instrumentation rack room and also communicate with an office space on the top of the CMTF roof. If left unsealed, these can present the same ODH hazard as the CMTF in the event of a cryomodule fault. At the first floor northwest corner of the room, an approximate 12"x 12" unsealed trench is currently being used to bring control cabling and conduits in from the control room. The trench appears to travel under the floor of the control room. The trench has been used to bring in a 80 PSIG, ½ inch, gaseous source of nitrogen into the room. The trench has a fill percentage of approximately 40%. An unsealed block wall (visible openings in a cable tray and cryogenic transfer line) is located at the first floor northeast corner of the room. The other side of the block wall is a non-ODH protected utility room. Multiple 3"- 4" wall conduits along the east end of the north wall communicate outside the room with two feet of the rear emergency roof exit stair mid platform.

There are two entrances to the area. A standard door entrance at the east end of the north wall and an 8.5 foot wide main lift door at the west end. During RF Power operations both doors are closed. One or both doors may be open at other times. Because a test

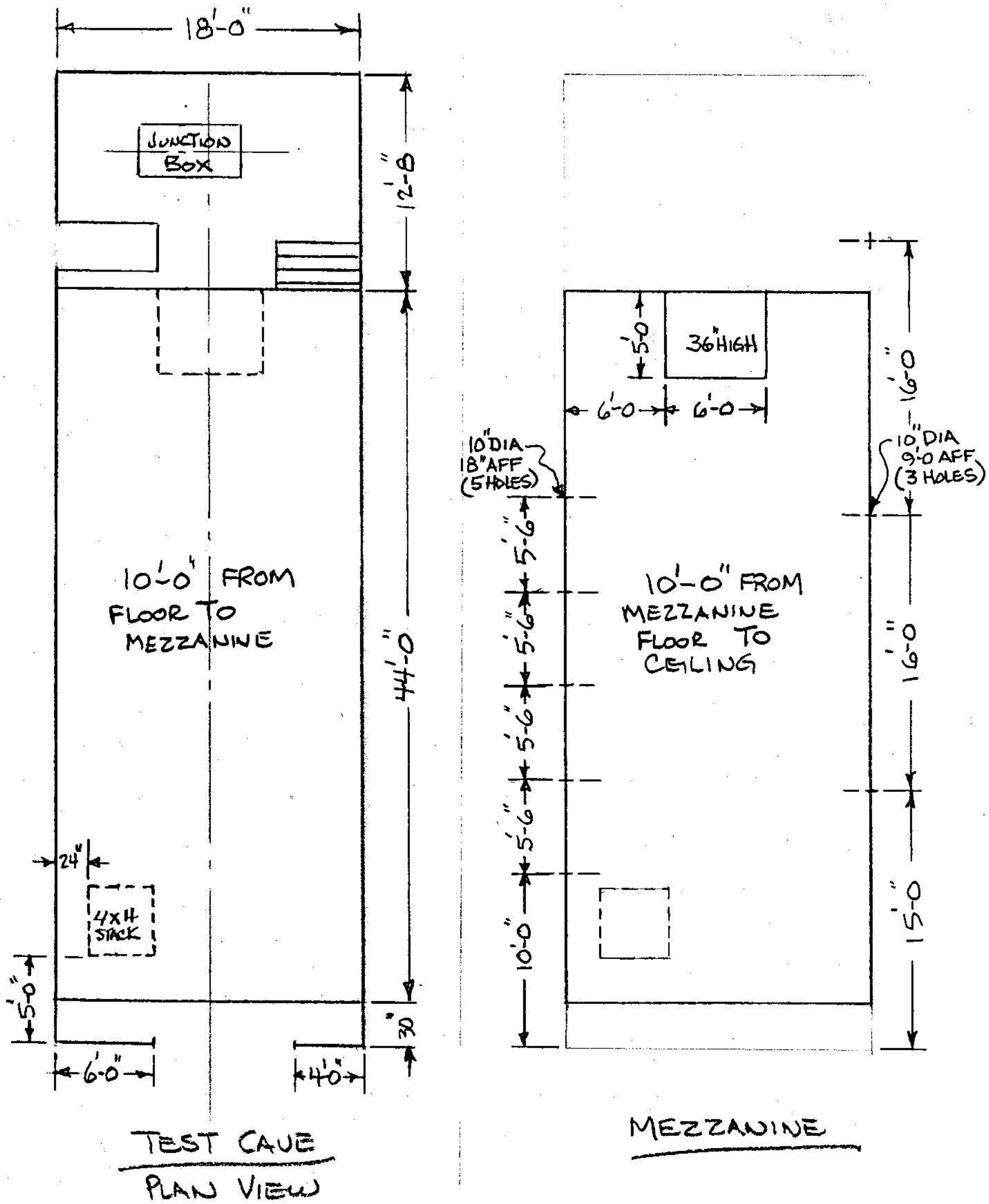


FIGURE 1

1st Floor Main Lift Door/Floor Trench

1st Floor CTA Supply Can

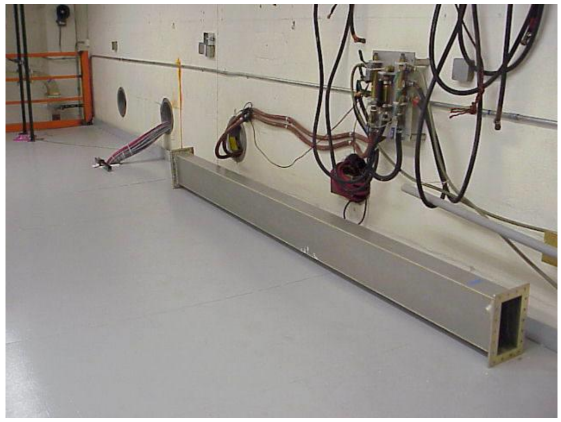
1st Floor, East End Passage Way

1st Floor Junction Box

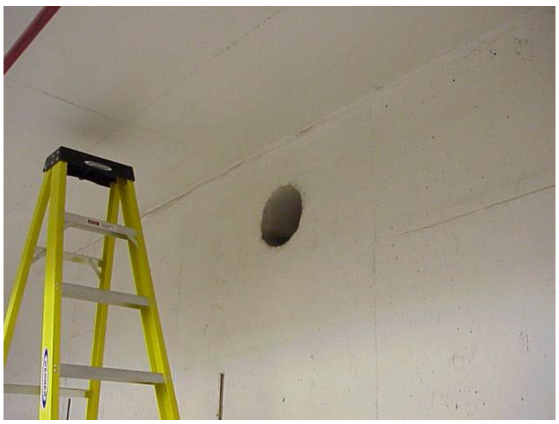
2nd Floor Stairway

2nd Floor Facing West, can not see ODH light

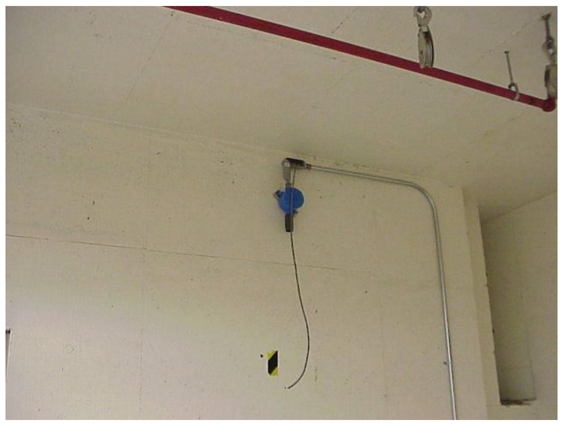
2nd Floor 4x4 Ceiling Vent, West End



2nd Floor Open Wall Vents to Instr Room



2nd Floor Open Waveguide Vent



2nd Floor ODH Head on Ceiling

Cryomodule is positioned in the lower platform area with its major relief valves in close proximity to the 5’8” wide east opening, there may be difficulty in exiting the lower platform area and exiting via the northwest door in an ODH emergency if the lift door is closed and the source of the ODH is a cryomodule relief valve. This may be less than a 3 foot passageway pass a major spill vent of the cryomodule.

A cryogenic distribution junction box is located on the first floor at the east end of the room. The junction box has internal cryogenic supply and return process lines, bayonets, and control valves of 3 atm shield flow and 2K flow. A transfer line interconnects the junction box to the CTF and VTA areas. An additional cryogenic “CTA” supply/return can is located at the first floor level along the north wall. A transfer line connects this can to the distribution junction box.

Two ODH heads are located at two opposite ceiling corners of the 2nd floor. Two low ODH heads are located at the other two room corners at the floor level. It is planned that the ODH heads will be tied to the 10K cfm ceiling fan. Two ODH horns are located at opposite corners on the second floor.

***Sources of ODH are gaseous and liquid nitrogen and helium*. *The fatality factors are driven by the helium inventory of the cryomodule in the event of beam line vacuum, insulating vacuum, or waveguide vacuum failure. Unlike the JLAB tunnel design, the vaporized helium liquid is not adsorbed by a large 2K vapor return header. Instead, under the current CMTF design, it is vented directly into the room*.**

Vaporized Liquid Nitrogen Sources
Liquid nitrogen ODH is a result of utilization of an occasional 500 liter roll in dewar to break cryomodule vacuums. The vaporized liquid nitrogen represents approximately 12,600 CF of gas or 65% of the room volume.

Gaseous Nitrogen Sources
The gaseous nitrogen ODH source is an 80 PSIG , ½ inch Swagelok tubing source which comes into the room via a first floor trench at the northwest room corner. The 80 PSIG source is currently unregulated and limited only by the line size and the quantity of liquid nitrogen in the outdoor SRF LN2 dewar. The choked flow rate through the ½ inch supply tube with 300 feet of tube is approximately 25 CFM due to line breakage.

Vaporized Liquid Helium Sources
The source for vaporized helium liquid ODH is the cryomodule beam line or insulating vacuum loss. The 1600 liters of liquid at 2K represents 50K cubic feet of vaporized helium gas (250% of the room volume) or if the liquid is at 4K it represents 43K cubic feet of vaporized gas (220% of the room volume). Complete release durations for the vaporized liquid into the room varies from 1-1 ½ minutes for a beam line vacuum loss and 4-5 minutes for an insulating vacuum loss. The release location is the cryomodule return end can primary and secondary relief location at the lower platform 5' 8" walkway opening.

Gaseous Helium Vent Sources
There are three sources of gaseous helium ODH.
One gaseous helium ODH sources is associated with a rupture or break in the warm 3 atm gaseous helium supply line into the room or a cryogenic line break in the transfer line, junction box, or supply can. The 3 atm warm gas source is a ½ inch tube supply of approximately 150 feet with a maximum source supply of 2.8 g/s or 74 CFM. The second gaseous helium ODH source is the 4K, 3 atm helium supply, which has a maximum supply rate of 20 g/s (an equivalent of 250 CFM for approximately 1-1/2 hours or 22,500 CF total release) from ether the ESR/CTF transfer line or CTF refrigerators. The third source is a 3atm shield line rupture or break at a flow rate of 15 g/s (188 CFM) for a total release of 22,500 CF.

ODH RISK ASSESSMENT

The following are the set of events and the associated probability and fatality factors.

JUNCTION BOX (normal ops, natural 4x4 roof vent opening)

EVENT	SPILL RATE, cfm	SPILL, cf	%O2	P_i	Fi
Valve Leak	12.5	22500	19.5(1)	5.2×10^{-6}	0
4K Line Rupture	250	22500	17(2)	3×10^{-6}	5.9×10^{-6}
Shield Line Rupture	188	22500	17(2)	3×10^{-6}	5.9×10^{-6}
Power Outage	0	0	21	1×10^{-4}	0
Relief Close Failure	12.5	22500	19.5(1)	1×10^{-4}	0
Blocked Shield Rtn	188	3760	17(2)	1×10^{-7}	5.9×10^{-6}

Super Scrip Notes:
Note 1: Not detected by upper ceiling ODH sensors
Note 2: Detected by upper ceiling ODH sensors, affected area 4 feet down

CTA Supply Can (normal ops, natural 4x4 roof vent opening)

EVENT	SPILL RATE, cfm	SPILL, cf	%O2	P_i	Fi
Valve Leak	12.5	22500	19.5(1)	1.3×10^{-6}	0
4K Line Rupture	250	22500	17(2)	3×10^{-6}	5.9×10^{-6}
Shield Line Rupture	188	22500	17(2)	3×10^{-6}	5.9×10^{-6}
Power Outage	0	0	21	1×10^{-4}	0
Relief Close Failure	12.5	22500	19.5(1)	1×10^{-4}	0
Blocked Shield Rtn	188	3760	17(2)	1×10^{-7}	5.9×10^{-6}

Super Scrip Notes:
Note 1: Not detected by upper ceiling or under platform ODH sensors
Note 2: Detected by upper ceiling ODH sensors, affected area 4 feet down

Cryomodule (normal ops, natural 4x4 roof vent opening)

EVENT	SPILL RATE, cfm	SPILL, cf	%O2	P_i	Fi
Valve Leak	12.5	22500	19.5(1)	2.6×10^{-6}	0
4K Line Rupture	250	22500	17(2)	3×10^{-6}	5.9×10^{-6}
Shield Line Rupture	188	22500	17(2)	3×10^{-6}	5.9×10^{-6}
Power Outage	0	0	21	1×10^{-4}	0
Relief Close Failure	12.5	22500	19.5(1)		0
Blocked Shield Rtn	188	3760	17(2)	1×10^{-7}	5.9×10^{-6}
Blocked 2K return	188	22500	17(2)	1×10^{-6}	5.9×10^{-6}
Insul Vac Loss	12500	50000	<9(3)	1×10^{-6}	1
Beam Line Vac Loss	49000	50000	<9(3)	1×10^{-6}	1
Waveguide Vac Fail	12500	25000	<9(3)	1×10^{-6}	1

Super Scrip Notes:

Note 1: Not detectable by upper ceiling or under platform ODH sensors
Note 2: Detectable by upper ceiling ODH sensors, affected area 4 feet down
Note 3: Major Helium Release with or without natural/powered existing ventilation. Room is pressurized by release rapid expansion out open doors, vents, etc. would take a number of minutes for natural ventilation or fans to clear ODH. Oxygen level will be very low but only has to meet <9% for F_i factor.

Helium and Nitrogen Gas Supplies (normal ops, natural 4x4 roof vent opening)

EVENT	SPILL RATE, cfm	SPILL, cf	%O2	P_i	Fi
3 atm Helium	74	22500	18(1)	1.3×10^{-6}	0
80 psi Nitrogen	25	280,000	<9%(2)	3×10^{-6}	1

Super Scrip Notes:

Note 1: Not detected by upper ceiling or under platform ODH sensors
Note 2: Detected by lower ODH sensors, possible hazard spread to other areas via unsealed northwest floor trench and unsealed passages in northeast transfer line tunnel to CTF utility room on first floor.

ODH Operational Mode Recommendations

Mode 1: CTF is operational (junction box, CTA can, TL to VTA), Gaseous He and N2 are available for use, No RF Power, No installed Cryomodule, Ceiling Vent Locked Open, Lift door and rear access door locked open, LN dewar may be used, rear door and lift door posted ODH 0, Stairway to upper platform unlabeled or posted ODH 0, ODH alarm system fully operational

- Area is classified ODH 0, sum/product of all $P_i \times F_i < 10^{-7}$

Mode 2: CTF is operational (junction box, CTA can, TL to VTA, Gaseous He and N2 are available for use, No RF Power, **cryomodule in place…can be warm or cold but with no liquid inventory**, Ceiling Vent Locked Open, Lift door and rear access door locked open, LN2 dewar may be used, rear door and lift door entrances posted ODH 0, Stairway to upper platform unlabeled or posted ODH 0, ODH alarm system tied to exhaust fan fully functional.

- Area is classified ODH 0, sum/product of all $P_i \times F_i < 10^{-7}$

Mode 3: CTF is operational (junction box, CTA can, TL to VTA, Gaseous He and N2 are available for use, No RF Power, cryomodule in place…**cryomodule has liquid inventory**, Ceiling Vent Locked Open, Lift door and rear access door locked open, LN2 dewar may be used, rear door and lift door entrances posted ODH 1, Stairway to upper platform posted ODH 2 (egress difficulty), ODH alarm system tied to exhaust fan fully functional.

- First Floor Area is classified ODH 1, sum/product of all P_i x F_i < 10^{-5}, >10^{-7} for CMTF first floor.
- Second Floor Area is classified ODH 2, sum/product of all P_i x F_i < 10^{-5}, >10^{-7} is same as first floor but egress problem with upper range ODH1 classification range.

Mode 4: CTF is operational (junction box, CTA can, TL to VTA, Gaseous He and N2 are available for use, No RF Power, **Cryomodule is in place with liquid, Lift door is closed, rear door is open for limited access,** Ceiling Vent Locked Open, LN2 dewar may be used, rear door and lift door entrances posted ODH 2, Stairway to upper platform posted ODH 2 (egress difficulty), ODH alarm system tied to exhaust fan fully functional**.**

- First and Second Floor classified ODH2, egress problems around cryomodule return end can and second floor stairway. Fan has reduced effect on clearing area of ODH hazard in a cryomodule event.

Mode 5: Emergency Repairs…..JT valve, relief valve, etc., CTF is operational, No RF Power,
cryomodule in place, Ceiling Vent Locked Open, Lift door and rear access door locked open, LN2 dewar may be used, rear door and lift door entrances posted ODH 1, Stairway to upper platform posted ODH 2 (with liquid in module) or ODH1 (without liquid in the cryomodule), ODH alarm system tied to exhaust fan fully functional. No standard cryo repairs (JT valve, Relief Valve, etc on cryomodule which has liquid inventory.

- First Floor Classified ODH1
- Second Floor classified ODH1 with no Cryomodule liquid, ODH 2 with cryomodule liquid.

Mode 6: U-Tube Operations…..same conditions as Mode 5 but no liquid allowed to be present in the cryomodule.

Mode 7: RF Power Operations…..Access not allowed, assumed cryomodule is full and CTF is running. Ceiling vent open or closed.

- ODH 2 classification for first and second floor…same as limited access classification.

OTHER RECOMMENDATIONS:

- Install 3 ODH warning lights inside the CMTF. One centrally located on first floor under the platform, second one centrally located on 2nd floor, third one in junction box area. Current ones can not be seen readily…
- Seal waveguide tubes and vent tubes to instrument rack room

- Seal 1st floor wiring trough….question of LN2 line under the control room
- Seal penetrations to CTF utility room or provide alarm.
- Marked shutoff valves for GN2 should be outside of enclosure
- Camera views of cryomodule end can, junction box and CTA Can/Cryomodule supply end can be valuable in determining ODH hazard source without entering.

RESULTS OF RECOMMENDATIONS (FINAL Report):

- OSP # A-01-001-OSP, "ODH Hazard Mitigation" in CMTF Cave, March 14, 2002 was developed which impose higher (more strict) ODH classifications that recommended in order to reduce the number of operating modes as outlined in "Recommended ODH Operational Mode Recommendations" listed above. The higher ODH classifications are outlined below in the Addendum 1.
- Action Items were conducted under Addendum 1 below to address the "Other Recommendations" listed above from the Preliminary ODH Risk Assessment.

Addendum 1 to the ODH Assessment:

Cryomodule Test Facility (CMTF)
April 2002

Issue	**Resolution**	**Signoff/ Date**
Louvres for the exhaust fan have to be locked open when cave is occupied under certain ODH modes.	Louvres for the exhaust fan located in the ceiling were removed. The fan is exposed, but a guard is not necessary because the fan is out of reach for all normal work in or around that fan outlet and only operates in the event of a helium release.	(Mutton)
Primary relief on return can vents at face level.	The direction of the primary relief on the return can has been rotated 90 degrees to face the ceiling	(Preble)
Control room is not isolated from the cave.	The trench leading to the CMTF control room is sealed to prevent nitrogen gas from entering the control room	(Preble)
There are three wall vents along the south side. The wall vent tubes currently vent to two work areas outside the cave: an instrumentation rack and the vacuum pair pump area. The ductwork has to be extended at that area to a minimum of 7 feet from the ground in those areas, so that a helium accident would not affect personnel outside the cave, or the vents should be sealed.	Attach a listing of the vents and their status.	(Mutton/ Merz)
The "Barn" area, located above the CMTF, has openings to the CMTF. This area needs to be isolated or also addressed as an ODH area	The Barn is an ODH 0 area. It is equipped with an ODH alarm system tied into one of the cave monitors.	(Mahoney)
Two air supply duct openings are approx 18" above the CMTF second floor. There is an office area which shares this common air duct supply which connects the barn, upper office, and CMTF at the CTMF upper level. During	Damper installed: in event of power failure, will close and remove ODH threat to the adjacent areas.	(Mutton)

Issue	**Resolution**	**Signoff/ Date**
power outage circulator fan failure these areas may be subject to ODH should a spill event occur.		
A CTF utility room backs up to the CMTF. This room is not isolated. This area must be reviewed for ODH from the CMTF and the CTF.	The area has been posted ODH 2. Plans are in place to remove the makeshift wall and door that form the utility room.	(Arenius)
ODH beacons are not visible from all parts of the cave.	The ODH system has been installed and is visible from all locations in the cave.	(Mahoney)
There are 7 ODH modes for the cave. The scheme is too complicated for staff.	• The ODH modes for the cave have been simplified • A video camera will be positioned with screen located at the back access door so that personnel can see the status of the cryomodules, and therefore the ODH status, before entering.	(Preble)

Addendum 2 to the ODH Assessment:

Cryomodule Test Facility (CMTF)
January 2016

Issue	**Resolution**	**Signoff/ Date**
Formatting and typographic errors in ODH Risk Assessment.	• Corrected formatting and typographic errors.	(Fanning/ Oren)
"Beam" references within the assessment are incorrect as there are no beam related operations possible within the Test Cave.	• Replaced all references to "Beam Operations" with "RF Power Operations."	(Fanning/ Oren)
ODH rating in table "ODH Rating for the Cave" for first floor contains an error when the shield door is closed with no liquid in cryomodule based on active GN2 line.	• Updated ODH mode table when the shield doors = Closed, and the cryomodule is empty to ODH = 1 • More consistent with 7 operational mode ODH assessment.	(Fanning/ Oren)

<u>ODH Rating for the Cave</u>*

Conditions	**Shield Door**	**First Floor**	**Mezzanine**
No liquid in Cryomodule, No U Tube Stabbed	Open	ODH 0	ODH 2
No liquid in Cryomodule, No U Tube Stabbed	Closed	ODH 1	ODH 2
Cryomodule in Cave with liquid, U Tube Stabbed	Open	ODH 1	ODH 2
Cryomodule in Cave with liquid, U Tube Stabbed	Closed	ODH 2	ODH 2

* Assumes active gaseous nitrogen supply in the CMTF cave

Addendum 3 to the CMTF ODH Assessment

To: Cryomodule Test Facility (CMTF) ODH assessment file

From: Jennifer Williams & Will Oren

Date: 01/09/2019

Source inventory, analysis assumptions, and controls were reviewed and the area inspected to determine the applicability of the ODH assessment for continued installation and testing of CEBAF and LCLS-II cryomodules.

Summary of issues reviewed:

Issue/Assessment Assumption	Current status
Gas/Cryogenic sources: fully operational cryogenic distribution junction box, supply can, and 1600 L capacity cryomodule at 2K under test, and a ½ inch gaseous nitrogen supply line.	No change in sources.
Penetrations: Five 12" diameter wall vent tubes located along the north wall of the mezzanine are sealed.	3 of the 5 vent tubes remain sealed; the other 2 have been re-purposed. One tube containing cables is not sealed; the other houses a HVAC supply air duct. The 5 vent tubes vent directly to the Test Lab High Bay since the "barn" utility room was removed during the 2012 Test Lab renovation. All vent tubes therefore would release helium gas to the Test Lab High Bay. Sealing these penetrations is no longer a required ODH control.
Penetrations: Trench connecting the CMTF to the control room is sealed.	Verified; foam brick seals the trench in the CMTF to prevent nitrogen gas entering the control room.
Penetrations: CTF utility room attaches to the CMTF. Concrete block wall in place to separate the room from the CMTF. Utility room posted ODH2 and "plans in place to remove makeshift wall and door that form the utility room."	Wall and door are still in place. An ODH1 sign replaces the ODH2 post on the utility room door. Penetrations through the concrete block wall will be sealed with foam (Facilities work order # 69187) to further inhibit gas flowing into the utility room.. ODH analysis of the utility room for the helium supply and return lines present in the space is required. The CMTF side of the room (space behind fence at the east side of the cave) is a permit required confined space.
Venting: Exhaust fan louvers are removed.	Verified that the louvers are removed.
Venting: Three 10" diameter wall vent tubes available along the south wall of the mezzanine	Confirmed three 10" vent tubes are available and not restricted.
Safety system: Functional area oxygen monitoring and alarm system maintained by Safety Systems Group.	Verified locations of oxygen sensor heads and alarm lights/horns.

Based on review of existing controls and validation of assumptions used in the existing assessment, operation of the CMTF should proceed.

Calculation of CMTF Roof Shielding and Radiation Skyshine

George Kharashvili, Jefferson Lab Radiation Control

Expected radiological conditions above the cryomodule test facility (CMTF) and around the Test Lab (Bldg. 58) related to the LCLS II type cryomodule testing were calculated using the FLUKA code [1]. The sourceterm assumptions described in JLAB-TN-16-009 [2] were applied with the exception of the maximum value of the total accelerating gradient, which was set to 130 MeV [3]. It is worth noting that this change does not automatically undermine the results of [2]. The validity of the assumptions will be tested during the facility commissioning.

The shielding parameterization approach outlined in [2] is not applicable for calculating the roof shielding and radiation skyshine due to the presence of a 16 ft^2 penetration in the CMTF ceiling. Instead, a realistic CMTF model was created with a 130 MeV, 127 nA electron beam incident on a thick copper target. A 180 cm tall shielding wall was placed around the ceiling penetration. Two shielding configurations were examined. In the first case the shielding wall consisted of 2 inches of lead and 15 inches of ordinary concrete (similar to the existing shielding in place), in the second case – 3 inches of iron and 15 inches of concrete. A 5 cm thick iron slab represented the Test Lab roof.

The calculated equivalent dose rates 30 cm above the CMTF roof are presented in figure 1 (2" lead) and figure 2 (3" iron). The highest levels of 12 μSv/h (1.2 mrem/h) are expected next to the shielding. The projected 200 hours per year duty cycle would then result in 2.4 μSv (240 mrem) per year level, which is below the 2.5 μSv (250 mrem) upper limit of a Radiologically Controlled Area (RCA).

The radiation skyshine, which mostly consists of the neutrons scattered of the Test Lab roof were calculated at 1 m above the Test Lab floor. Up to 1.3 μSv/h (0.13 mrem/h), 0.26 mSv/year (26 mrem/year) levels are expected, which is below the 1 mSv (100 mrem) annual limit for non-RCA areas.

As a result, a shielding wall made of a 2-inch lead or 3-inch iron inner layer and 15-inch outer concrete layer is required around the roof penetration. The roof will then be posted as an RCA and appropriate controls will be implemented.

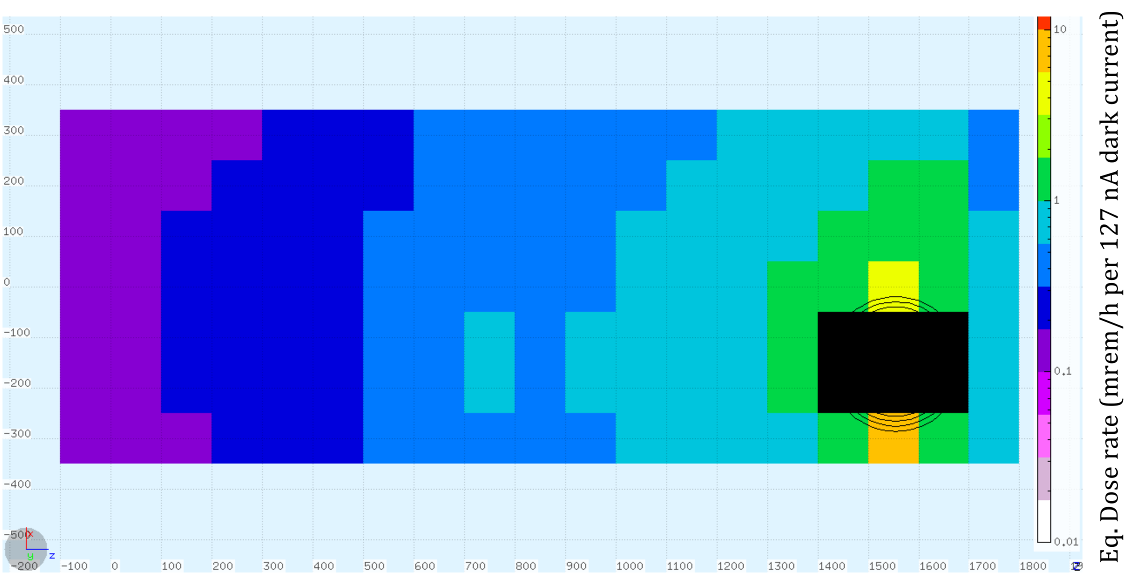


Figure 1: Calculated equivalent dose rates 30 cm above the CMTF roof – shielding around the penetration is made of 2 inches of lead and 15 inches of concrete.

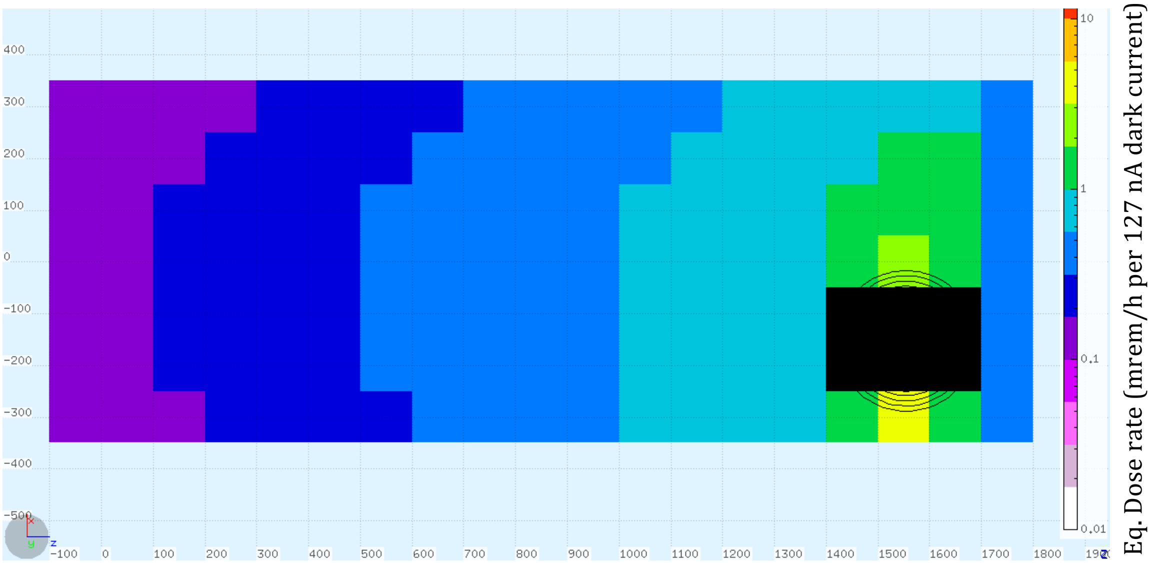


Figure 2: Calculated equivalent dose rates 30 cm above the CMTF roof – shielding around the penetration is made of 3 inches of iron and 15 inches of concrete.

References:

[1] A. Ferrari, P.R. Sala, A. Fassò, and J. Ranft, "FLUKA: a multi-particle transport code", CERN 2005-10 (2005), INFN/TC_05/11, SLAC-R-773
T.T. Böhlen, F. Cerutti, M.P.W. Chin, A. Fassò, A. Ferrari, P.G. Ortega, A. Mairani, P.R. Sala, G. Smirnov and V. Vlachoudis,"The FLUKA Code: Developments and Challenges for High Energy and Medical Applications", Nuclear Data Sheets 120, 211-214 (2014)

[2] George Kharashvili, "Shielding Basis of the Cryomodule Test Facility Upgrade", JLAB-TN-16-009

[3] Michael Drury – private communication.

By signing this page, you testify that you have read, understand, and agree to abide by the procedure specified in the above referenced work control document:

Serial Number: SRF-19-87369-OSP

Title: Cryomodule Test Facility Operational Safety Procedure

Name	Signature	Date