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Org: ACCCIS

Status: PROCESSED
Saved: 2/24/2017 11:24:02 AM
Submitted: 2/24/2017 11:24:02 AM

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Operational Safety Procedure Review and Approval Form # 65773
(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
Serial Number:	***ACC-17-65773-OSP***
Issue Date:	***3/10/2017***
Expiration Date:	***3/10/2020***
Title:	***keV beam line of the Upgraded Injector Test Facility (UITF)***
Location: (where work is being performed) Building Floor Plans	Location Detail: (specifics about where in the selected location(s) the work is being performed) — ***UITF***
Risk Classification: (See ES&H Manual Chapter 3210 Appendix T3 Risk Code Assignment)	Without mitigation measures (3 or 4): ***3*** 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:	***ACCCIS***
Document Owner(s):	***Poelker, Matthew (poelker@jlab.org)*** Primary

Supplemental Technical Validations

Lasers Class 3B or 4 (Ultraviolet, Infrared, and Visible Light)   (Bert Manzlak, Jennifer Williams)
Lock, Tag, Try   (Paul Powers, Todd Kujawa)
Radio Frequency   (Bob May, Jennifer Williams)

Other Hazards:
ionizing radiation   (Vashek Vylet)
SF6 toxicity   (Jennifer Williams)

Document History

Revision	Reason for revision or update	Serial number of superseded document

Comments for reviewers/approvers:	***Jennifer is writing an SF6 toxicity summary, but she provided information that is included inside the OSP***

Attachments

Procedure: ***UITF-OSP_keV region_2_24_2017_final submitted version.pdf***

THA: ***UITF THA-keV OSP 2_24_2017_final submitted version.pdf***

Additional Files: ***ODH_UITF - Final Preliminary.pdf***
UITF PSS Sweep Procedure2.pdf
LOSP_UITF_operational_safety_procedure_form_64784 (1).pdf

Convert to PDF

Review Signatures

Person : Subject Matter Expert : SF6 toxicity	**Signed** on 3/6/2017 1:08:54 PM by Jennifer Williams (jennifer@jlab.org)
Person : Subject Matter Expert : ionizing radiation	**Signed** on 2/24/2017 3:15:00 PM by Vashek Vylet (vylet@jlab.org)
Subject Matter Expert : Lasers Class 3B or 4 (Ultraviolet-> Infrared-> and Visible Light)	**Signed** on 2/28/2017 5:09:31 PM by Bert Manzlak (manzlak@jlab.org)
Subject Matter Expert : Lock-> Tag-> Try	**Signed** on 3/1/2017 1:22:02 PM by Todd Kujawa (kujawa@jlab.org)
Subject Matter Expert : Radio Frequency	**Signed** on 3/6/2017 1:08:58 PM by Jennifer Williams (jennifer@jlab.org)

Approval Signatures

Division Safety Officer : ACCCIS	**Signed** on 3/6/2017 1:23:30 PM by Harry Fanning (fanning@jlab.org)
Org Manager : ACCCIS	**Signed** on 3/9/2017 8:38:35 AM by Matthew Poelker (poelker@jlab.org)
Safety Warden : Test Lab - 1127	**Signed** on 3/10/2017 11:02:44 AM by John Hansknecht (hansknec@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.)**	**Click** For Word Doc

Title:	keV beam line of the Upgraded Injector Test Facility (UITF)			
Location:	Test Lab High Bay Area, room 1127-1129		**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
			Highest Risk Code after Mitigation (N, 1, or 2):	1
Owning Organization:	Center for Injectors and Sources, Accel. Div.	**Date:**	February 24, 2017	
Document Owner(s):	Matthew Poelker			

DEFINE THE SCOPE OF WORK

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

The purpose of this OSP is to describe in detail the procedures for safely operating the keV region of the UITF.

FSAD Rev. 7a considered the Injector Test Facility to be a Technical Area containing one or more accelerator components that did not constitute an accelerator and did not create hazards that presented an unacceptable risk (require the use of credited controls for hazard mitigation). FSAD Rev. 8, in DRAFT, considers the Upgraded Injector Test Facility (UITF) to be an accelerator, analyzes the hazards, and specifies the hazard mitigations. This OSP provides the basis for operating the keV region of the UITF and is consistent with the requirements in FSAD Rev. 8 DRAFT.

* Final Safety Assessment Document Rev 7a: https://jlabdoc.jlab.org/docushare/dsweb/View/Collection-4440

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

UITF operation with keV beam

There are two modes of operation:

1. Tune beam (pulsed) at voltage up to 450 kV (average current typically 100 nA)
2. CW beam administratively limited to 3 mA when using the 450kV power supply and 32 mA when using the 225kV supply.

The affected area is Cave 1 (See figure 1)

3. Description of the Facility – include building, floor plans and layout of the experiment or operation.

The location of UITF is the High Bay Area of the Test Lab. Figure 1 shows the UITF lay out and identifies Caves 1 & 2. This OSP covers keV beam operations which occur only in Cave 1. Figures 1 and 2 show the labyrinth, which is the main access to UITF. Figure 3 shows UITF with concrete shielding over the roof of Cave 1. Electronics racks are located above Cave1. In Figure 3, for illustration purposes only, the roof of Cave2 is shown removed.

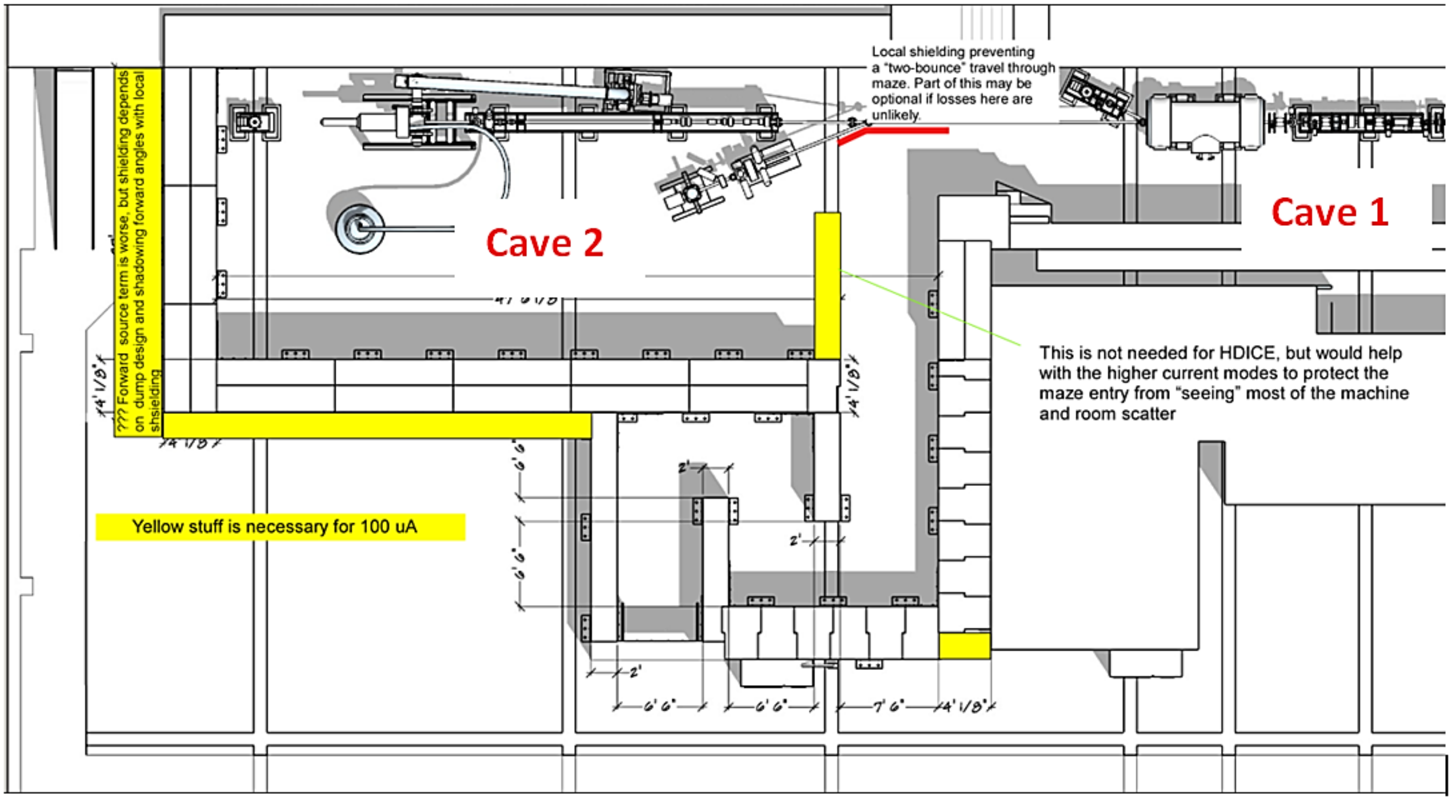

Figure 1 UITF beamline layout showing the two Caves. keV beam is confined to Cave 1

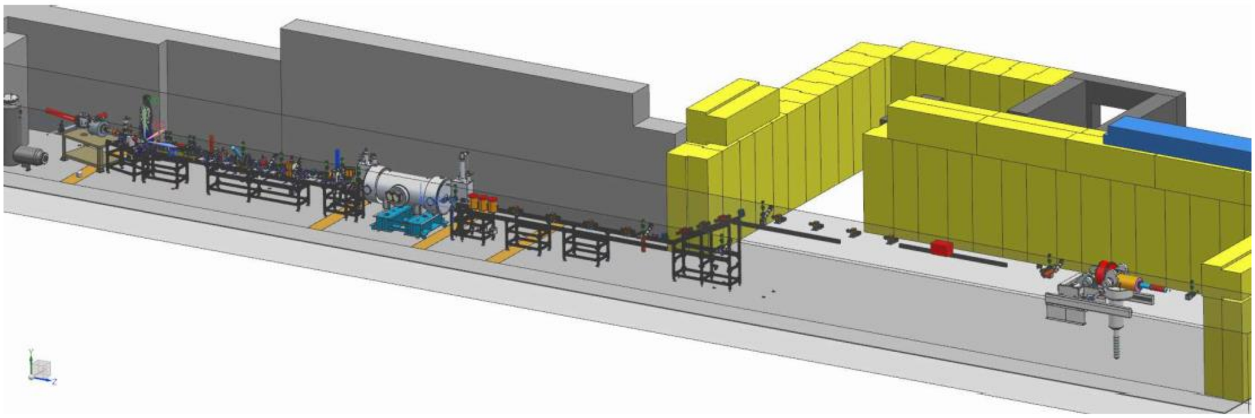

Figure 2 UITF layout showing the exit to main entrance through labyrinth towards the high bay area

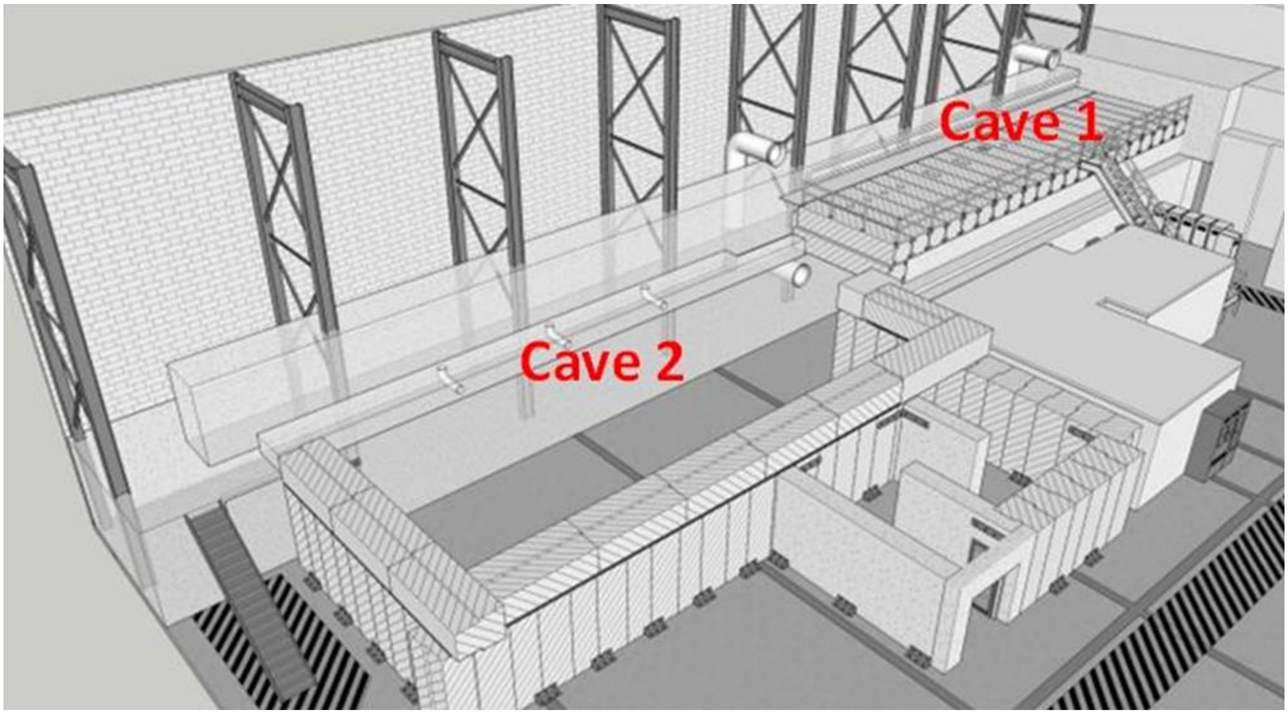

Figure 3 UITF layout showing the main entrance Labyrinth and shielded roof of Cave 1

ANALYZE THE HAZARDS and IMPLEMENT CONTROLS

4. Hazards identified on written Task Hazard Analysis

Refer to attached Task Hazard Analysis Work Sheet for details and mitigation. The following lists the hazards.

1. Ionizing Radiation
2. Laser non-ionizing Radiation
3. RF Non-ionizing Radiation
4. Magnetic Fields
5. Oxygen Deficiency
6. Electrical
7. Pressure / Vacuum
8. SF6 toxicity

5. Authority and Responsibility:

5.1 Who has authority to implement/terminate

Matthew Poelker

5.2 Who is responsible for key tasks

Matthew Poelker

5.3 Who analyzes the special or unusual hazards including elevated work, chemicals, gases, fire or sparks (See ES&H Manual Chapter 3210 Appendix T1 Work Planning, Control, and Authorization Procedure)

Ionizing Radiation – Vashek Vylet
Laser non-ionizing radiation – B. Manzlak, J. Williams

RF Non-ionizing radiation – J. Williams, M. Brown
Oxygen Deficiency – J. Williams
Electrical – T. Kujawa
Lead – M. Brown
SF6 toxicity – J. Williams
Fire – Ed Douberly
Safety Warden – J. Hansknecht
Pressure / Vacuum – W. Oren

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

UITF Operators must have the following Training

- SAF 100 – ES&H Orientation
- SAF 307 – Ladder Safety
- SAF 1140 – Laser Orientation
- SAF603A – Electrical Safety Awareness: Classes, Modes, etc.
- SAF 103 – Oxygen Deficiency Hazard
- SAF 104 – Lock, Tag and Try
- SAF 801– Rad worker
- SAF130AU – Pressure Systems Safety Awareness for Users
- SAF136 – Lead Worker Safety Awareness
- Read and sign this OSP

6. Personal and Environmental Hazard Controls Including:

6.1 Shielding

The keV beam line is operated in tune mode or CW mode. The tune mode beam is a pulsed beam at 60 Hz averaging 100 nA of beam current. In CW mode, the average beam current can be up to 3 milliamps when using the 450 kV power supply and 32 mA when using the 225 kV power supply.

Cave 1 has 30” concrete shielding on the roof. The penetrations have 3.5” iron shielding (figure 4 below)

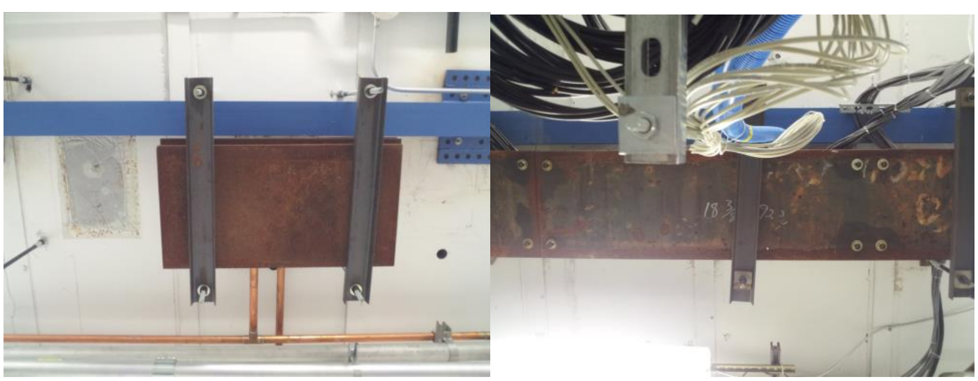

Figure 4 Steel plates covering penetrations in Cave 1. Cables pass through the penetrations linking the electronics racks and beamline elements.

The keV beam termination points are beam dumps and Faraday cups in Cave 1. Radiation Control Department (RCD) approved local shielding will mitigate radiation hazards. Of the two walls in Cave 1, the east wall (see figure 1) is many meters thick and is an effective radiation barrier. The west wall is 36" thick. The local shielding on the dumps will mitigat radiation hazard.

During beam operations, the entire roof area of Cave 1 will have signage and be roped off preventing access.

RCD will measure the radiation at the roof and the UITF walls in the high bay area at various beam currents to experimentally determine the current limits. Any additional shielding measures or reduction in measures will be described in an amendment to this OSP based on these radiological measurements.

The main entrance labyrinth and the south access labyrinth prevent line of sight exposure to x-ray radiation.

6.2 **Barriers** (magnetic, hearing, elevated or crane work, etc.)

1. Vacuum windows: The UITF beam line is under vacuum. If work involves thin windows (which is not anticipated), there will be signage warning personnel entering UITF that hearing protection is mandatory for entrance. Hearing protection will be available in well-marked containers.
2. Magnetic Fields: The magnets at UITF can be energized when the UITF is OPEN but these magnets have fields that off to less than 5 gauss within a few inches from the magnet. If there are cases where the field is > 5 gauss at a foot or more, there will be barriers to prevent personnel from exposure to the magnetic field.
3. The magnets have electrical terminals which are either insulated or have protective covers to prevent accidental contact.

6.3 **Interlocks**

The UITF's Personnel Safety System (PSS) protects personnel from being exposed to prompt radiation. Personnel exposure is prevented through both administrative (sweep procedures, postings) and engineered (concrete enclosures, gates, and interlocks) means. UITF (see Figure 5) is a completely enclosed area. No one is allowed inside the enclosure during beam operations, or gun high voltage conditioning, or when high power RF is applied to the buncher or the SRF quarter cryomodule.

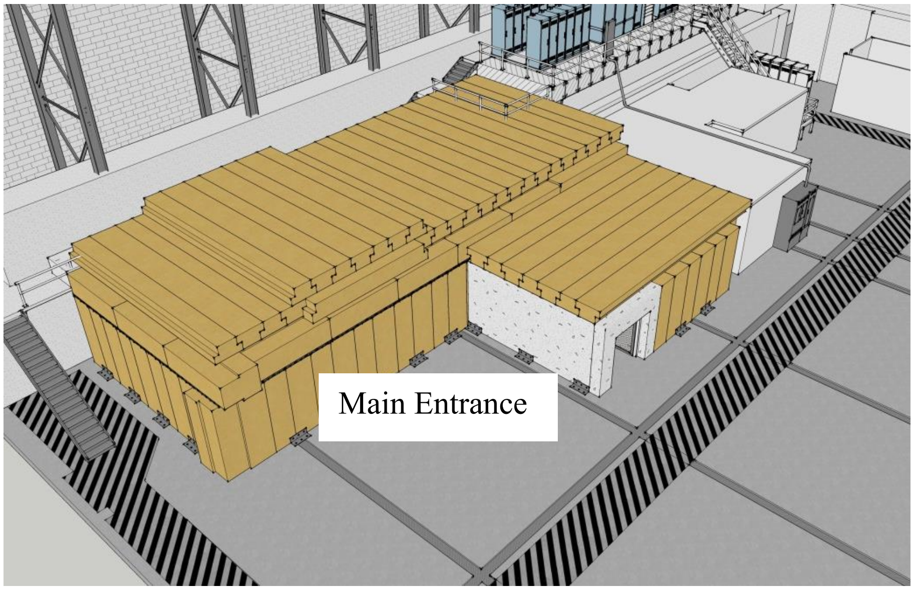

Figure 5 UITF With concrete shielding in place

Figures 6 and 7 show the two entry/exit ways to and from the UITF, the run safe box, signage along with the warning beacons.

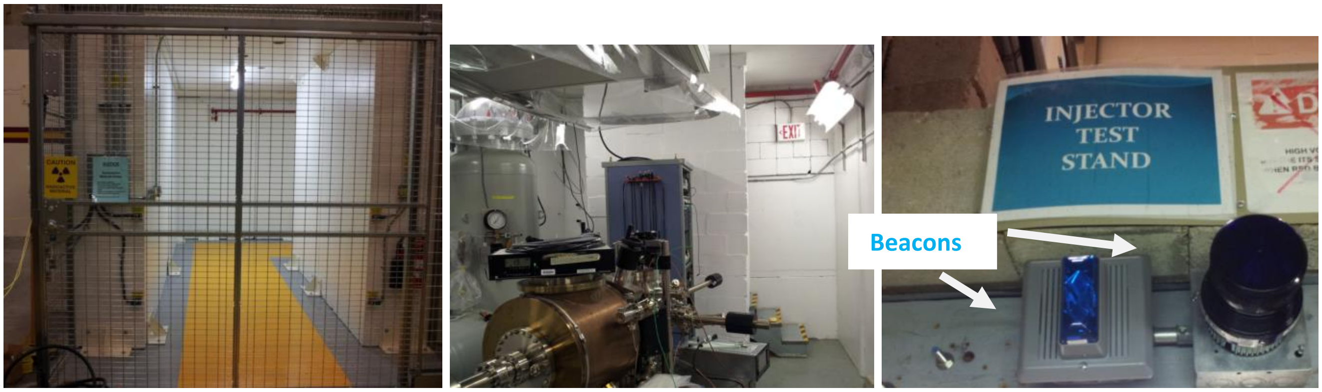

Figure 6 (Left) Main entrance/exit from high bay area through the labyrinth of UITF (Middle), Secondary exit into the high bay from the southern-most location of the keV section. Both doors have Personnel Safety System interlocks and emergency exit switches on the nearby walls (Right). Beacons exist at both entrance/exit ways

Figure 7 (Left) Exit into high bay from Cave 1 near the electron gun (Middle) Run/Safe Box (Right) Crash Switch for exit Run/Safe Boxes and Crash switches are at both the entrance/exit ways

During normal operations, the main entrance/exit will be in use. The secondary exit door can be used as needed, but is primarily considered an emergency exit.
The main and secondary entrance/exit doors are part of the PSS. The PSS interlocks are attached to the gun high voltage power supply, the drive laser shutter and the high power RF system. CARMs located outside the enclosure are interlocked to the PSS. The PSS will turn OFF beam when door interlocks are breached or when CARMs indicate excessive radiation measured outside the enclosure.

6.4 Monitoring systems

There are three monitoring systems. One is the PSS, explained above, which provides access control to the UITF and protects personnel from prompt ionizing radiation associated with UITF operation. The second is the ODH system, which alarms when the oxygen level in the UITF enclosure drops below 19.5%. The third monitoring system relates to the pressure within the SF6 tank that houses the Glassman gun high voltage power supply. There is a digital pressure gauge that monitors SF6 pressure, and can be configured to "alarm" when pressure falls below a User specified level. The alarm is a Yellow LED that illuminates at the SF6 tank. The alarm is also an EPICS signal. The alarm is triggered when pressure drops from 60 to 58 psi. Finally, there is an Ashcroft pressure switch that will shut off the Glassman HV power supply when SF6 pressure falls below 45psi.

6.5 Ventilation

There are two fans on the east wall of Cave 1 (Figure 8). In addition, there are three 0.15 m (6") diameter vent holes on the west wall near the ceiling and two 0.3m x 0.3m (12"x12") square vents. These square vent holes have chimneys attached to them on the ceiling. The height of the chimneys is about 7 ft. which will mitigate any hazard in the unusual event of cryogenic gas release in Cave 1. The existence of these fans is included for completeness of information, however the ODH assessment of UITF does not take credit for the existence of these fans. The ODH assessment (preliminary, see below) and the SF6 exposure assessment are attached to this OSP and can be found at:
https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-135009/UITF%20prelim_%20ODH%20assessment.pdf

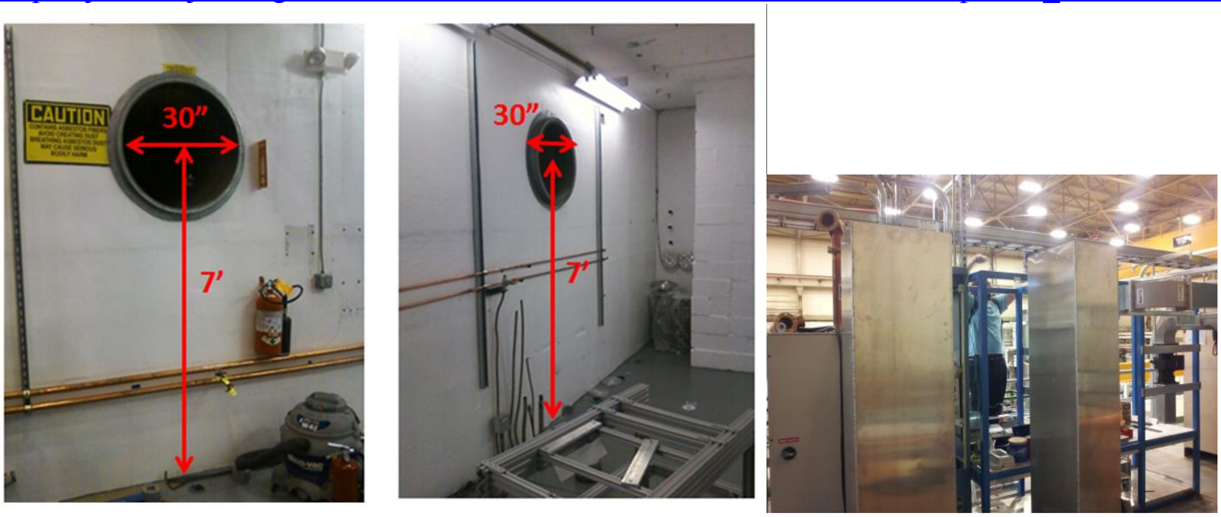

Figure 8 (Left) Fan with a capacity of 7400 CFM vents air into the high bay area, (middle) fan with a capacity of 4400 CFM vents air to outside the test lab, right two chimneys attached to the square vent holes in the ceiling of Cave 1

There is a passive 5.6 m^2 vent beneath the raised roof of Cave 2 (Figure 9) to vent lighter than air cryogens into the high bay area in the unlikely event of an equipment failure of experimental targets (e.g. HD-ICE). The existence of this vent area is not relevant to keV beam operations and is included for completeness of information.

Figure 9 (Left) Shielded elevated-roof section of Cave 2, which will be used for experimental targets, including cryogenic targets. (Right) 5.6 m^2 Vent area beneath the elevated roof section of Cave2, for lighter than air cryogenic gases to escape.

6.6 Pressure / Vacuum

The evacuated photogun and keV beamline is considered a Category 0 vacuum system, per Part 7 of the Pressure Safety Supplement. Specifically, the cross section of the vacuum system does not exceed 33 square inches, the relieving vacuum cannot exceed 15 psi, there are no cryogenic components, and there are no thin walled components that could rupture.

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

The manuals for photogun high voltage systems can be found at: https://wiki.jlab.org/ciswiki/index.php/ITF21 Manuals clearly state that the high voltage power supplies must be de-energized before work is performed, in accordance with JLab LTT policy.

The ODH assessment for the UITF is attached. It is deemed "preliminary" until the complete MeV beamline has been constructed and the ODH-related recommendations have been implemented and verified adequate. This assessment can be found at:
https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-135009/UITF%20prelim_%20ODH%20assessment.pdf

See Section 5.3 above for a complete list of hazards.

7. List of Safety Equipment:

7.1 List of Safety Equipment:

1. Safety glasses when performing mechanical work, as needed
2. Gloves depending on mechanical or shielding work
3. Hard hats and/or steel toed boots depending on materials handling needs

4. Laser safety goggles, as required by LOSP (ACC-17-64784-LOSP)

7.2 Special Tools:

n/a

8. Associated Administrative Controls

- Safety Systems Group staff is responsible for:
  - PSS administrative and engineered controls
  - Training on access controls and sweep procedures

- Radiation Control Department staff is responsible for:
  - Maintenance and calibration of fixed interlocked and hand held radiation monitors
  - Area and personnel dosimeters
  - Radiation surveys
  - Assigned Radiation Monitor Training (if needed)

- Center for Injectors and Sources (CIS) staff is responsible for:
  - LSS administrative controls
  - SF_6 Gas insulated HVPS administrative and engineered controls
  - Locking and Tagging the Faraday cup in front of the ¼ cryomodule for keV mode operation

The Faraday cup in front of the ¼ cryomodule is inserted and locked in place for all keV mode operations. The valve to the ¼ cryomodule is CLOSED and cannot be opened via EPICS (i.e., the compressed air line is NOT attached to the OPEN spigot of the valve mechanism)

*Administrative controls includes: Authority/responsibility, Procedures, Postings, and PPE

- CIS personnel are responsible for safe operation of the UITF. This includes limiting beam power to fall within the identified operations and safety parameters.
- UITF's PSS logic manages the two door switches and the Run/Safe Boxes to provide an "Area Secure" signal to the PSS logic
- The HVPS control unit is interlocked to the PSS, it cannot be energized unless the PSS is in "Run" mode, attained after the UITF enclosure has been swept.
- The laser shutter is interlocked to the PSS and LSS.
- The CARMs/radiation probes are interlocked to the PSS.
- High power RF (for buncher and ¼ cryomodule) is interlocked to the PSS

DEVELOP THE PROCEDURE

9. Operating Guidelines

The UITF's keV beam is operated under this Operational Safety Procedure, which addresses hazards associated with maintenance and operation and their mitigations through engineered and administrative controls. Fault conditions in the UITF can produce only local work area impacts.

Staffing

The UITF can be operated by a single trained and authorized user (typically the personnel conducting gun and/or beam studies). During keV beam operations, tests can happen in unattended mode, for example a long beam run to measure the photocathode charge lifetime.

UITF Operation

PSS state for the UITF is either: Open Mode (open access), Sweep Mode, Ready Mode and Run Mode. Ready Mode is an internal (logical) mode confirming that all interlocks are ready for transition to Run Mode.

Prior to beam operations, the laser bypass key must be returned to the PSS console in the Control Room in order to energize the gun high voltage power supply. In addition, the UITF must be placed in Open Mode using the Personnel Safety System (PSS) and the doors must be properly configured (i.e., closed). The sweep procedure is described in Section 11.

UITF Operator Requirements

In addition to the training listed in section 4.4, the UITF operator must:

1. Read and understand this OSP that includes PSS sweep procedures,
2. Receive the practical training on this OSP and on UITF operational procedures from system owner (Matthew Poelker or designee)
3. Perform walkthrough of the following areas: UITF control room and Cave 1 roof where the electronics racks are located.

10. Notification of Affected Personnel (who, how, and when include building manager, safety warden, and area coordinator)

Safety: UITF Safety Warden, John Hansknecht 269-7097
UITF system owner: Matthew Poelker, office 269-7357, cell. 757-897-9408

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

keV beamline

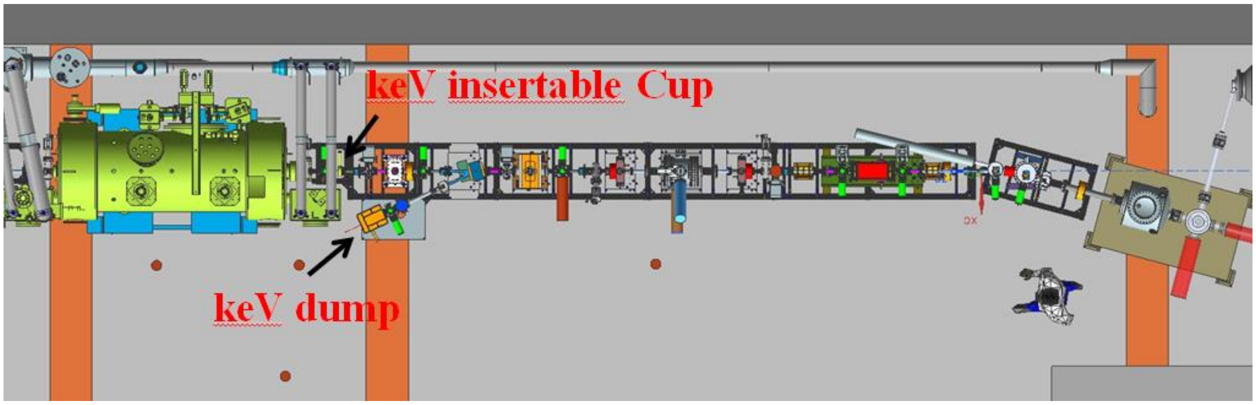

Figure 10 keV beam line top views. The figure shows the location of the 1/4 Cryomodule, the keV fixed dump, and the keV insertable Faraday Cup

The beam termination points such as the Faraday cup in front of the ¼ cryomodule, apertures and beam dump will have additional local shielding in compliance with Radiation Control Department's assessment.

During the transportation of the electron beam from the gun, whether in Tune mode or CW mode, there can be beam losses. This is especially true during commissioning with beam. The beam loss monitors (BLMs), will detect the beam losses and shutter the laser, terminating beam production. While this will protect the beam line from venting during CW operations, this can become a nuisance during beam tune up. The control system allows masking of the BLMs during Tune mode operations. Proper BLM response with a radioactive source is a requirement prior to their installation in the beam line.

The following describes the operating procedures for keV beam line.

Procedure:

In the UITF

1. Insert Faraday cup at the entrance of ¼ Cryomodule. Lock and Tag the cup. Verify that the valve in front of the ¼ cryomodule is CLOSED and cannot be opened via EPICS (i.e., the compressed air line is NOT attached to the OPEN spigot of the valve)
2. The following is an overview of the PSS sweep. Use the complete detailed sweep procedure and map attached to this OSP. A copy will also be maintained in the Control Room.
   i) Post the top (mezzanine) of Cave 1 as a restricted area
   ii) Inform all occupants to leave the UITF enclosure
   iii) Close both doors

iv) Go to control room and turn key to SWEEP

v) Enter the enclosure through the back door, close door behind you upon entry

vi) Arm RunSafe Box601 in the hallway

vii) Sweep the enclosure, walking all the way to the north wall of Cave2

viii) Verify the Faraday Cup is locked in place, and the valve to the ¼ cryomodule is locked CLOSED

ix) Arm RunSafe Box602 near labyrinth exit

x) Exit through the labyrinth closing screen gate door completely

xi) Return to control room, turn key to RUN to arm the Personnel Safety System

In the Control Room

1. Turn ON the gun high voltage
2. Set up Viewer Limited Mode.
3. Load the nominal optics file and look for beam on viewers (viewer limited mode, very low duty factor), working from the gun to the dump, using steering magnets as necessary. Adjust solenoid fields to obtain the desired beam size along the beamline.
4. Turn on the BLMs, take beam to Tune Mode, 8uA
5. Steer the beam to deliberately cause beam loss and ensure that the BLMs detect the beam loss and shut off the beam.
   a. If BLMs do not respond as expected, terminate beam operations and diagnose the BLMs with a radioactive source.
6. Once the BLMs are responding as expected, establish beam to the Faraday cup.
7. Verify that the Beam Position Monitors are reading back
8. Establish buncher and chopper settings using Harps and viewers, until the Tune beam looks ‘good’ in the spectrometer line
9. Set CW beam current to 100 nA and ensure that the beam transports cleanly to the Faraday cup.
10. Turn beam on in tune mode and ensure clean transportation to Faraday cup.
11. Go to 100 nA CW mode
12. Increase the current in steps to the desired permissible beam current
13. Save the keV beamline settings

Shielding Verification: *Contact the Radiation Control Group to verify shielding. This is done by delivering beam to the dump, and RadCon making radiation measurements inside and outside the cave enclosure. This must happen each time a new higher current is produced by the photogun.*

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

At any time during UITF operations, the PSS can be brought to OPEN Mode Access, in case there is a need for accessing the enclosure or to conclude high voltage operations.

Returning the PSS to OPEN Mode in normal operating conditions

- Turn off the gun HVPS from the EPICS control screen
- Turn OFF the buncher RF from EPICS control screens
- Switch the key to "OPEN" mode
- De-post restricted area on mezzanine

13. Special environmental control requirements:

13.1 List materials, chemicals, gasses that could impact the environment (ensure these are considered when choosing Subject Matter Experts) and explore EMP-04 Project/Activity/Experiment Environmental Review below

SF6 is used as an electrical insulating gas inside the pressurized (60 psi) high voltage power supply.

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

SF6 is a greenhouse gas that must be re-used to avoid releasing it into the atmosphere when there is a need to open the tanks, i.e. high voltage power supply maintenance. SF6 is a powerful greenhouse gas, 23,900 times worse than CO_2.

13.3 Abatement steps (secondary containment or special packaging requirements)

https://wiki.jlab.org/ciswiki/index.php/SF6_Inventory_and_Handling_Procedures

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

Returning the PSS to OPEN Mode in case of emergency or any other abnormal conditions

At any moment the PSS Safety Crash buttons can be depressed. This action will cut off the gun high voltage power supply, turn OFF high power RF, and will close the laser shutter if those systems are operational. It will also crash the sweep and will force unlock the doors.

Since ionizing radiation is present in the enclosure only when the gun is at high voltage, depressing any of the PSS RunSafe or Control Room crash buttons will restore the area to a safe level. NOTE: the emergency exit crash switch will only release the local door lock.

The following is a list of currently installed alarms:

1. ODH (blue strobe + buzzer)
2. Fire (white strobe + high pitch)
3. SF6 pressure sensor on Glassman high voltage power supply SF6 tank
4. Potential prompt radiation (magenta strobe beacon and 30 second siren)

The expected response to any of the alarms is to evacuate the UITF enclosure immediately and proceed to the high bay area of the Test Lab

Return to normal operations occurs when alarms are cleared by the following personnel:

1. ODH cleared by SSG or CIS Staff
2. Fire cleared by Facilities Management
3. SF6 CIS staff, SF6 custodian, UITF Safety Warden responsibility

Comments regarding SF6 hazards: The 45 lbs of SF6 that resides inside the high voltage power supply vessel would occupy 3.2 cubic meters if it were instantaneously released, compared to 207 cubic meter volume of Cave1. Since SF6 is about 5 times heavier than air, it will accumulate on the floor when released from the high voltage power supply vessel. It would reside within a layer less than 1" thick on the floor. However, if it fully mixed with air in Cave 1, the oxygen concentration would fall to ~ 20.5% which is not deemed hazardous (normal oxygen content of 21%). Accounting for the 4400 cfm exhaust fan, it will take ~ 45 minutes to remove all SF6 from the cave (assuming good mixing in the Cave). This time interval does not allow enough time for personnel to exceed the 8-hour exposure limit of 1000ppm. The estimated 8-hour average exposure concentration would be ~ 572ppm.

If the ventilation fan is not operating inside the UITF enclosure, the SF6 will remain along the floor. In this case, personnel are not allowed to work on the floor in case of known leaks.

Other emergency procedures not covered by alarms are:

a. Ventilation failure. Expected Response is to evacuate area immediately and convene at muster point.

b. Personnel inside UITF enclosure AND the doors are locked. **NOTE: This event should never occur if proper sweep procedures are followed.** Expected response is to proceed to the nearest Run/Safe Box and press the crash button. Each door has a local crash out button the will release its lock to allow exit. Opening the door will drop the PSS to OPEN mode.

c. Electrical Power failure and in case of personnel trapped inside UITF enclosure. **Personnel Entrapment should never occur if proper sweep procedures are followed.** PSS system will unlock the doors (Electrical power maintains the locks, loss of power unlocks – fail/safe mode)

Notifications:
UITF Safety Warden, John Hansknecht 269-7097
UITF system owner: Matthew Poelker, office 269-7357, cell. 757-897-9408
ODH, Fire: Guard gate 269-5822
Other Emergencies: Guard gate 269-5822

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

16. Inspection Schedules

PSS certification will happen twice per year, scheduled by SSG

17. References/Associated/Relevant Documentation

Task Hazard Analysis
LOSP (ACC-17-64784-LOSP)
UITF ODH assessment – preliminary
SF6 exposure assessment

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

Operations logbook (electronic)

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 1.4 – 06/20/16 – Repositioned "Scope of Work" to clarify processes
Qualifying Periodic Review – 02/19/14 – No substantive changes required
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 0.0 – 10/05/09 – Updated to reflect current laboratory operations

ISSUING AUTHORITY	FORM TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW DATE	REV.
ESH&Q Division	Harry Fanning	06/20/16	06/20/19	1.4

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Author:	M. Poelker	Date:	February 24, 2017	Task #: If applicable	

Complete all information. Use as many sheets as necessary

Task Title:	keV operations of the Upgraded Injector Test Facility (UITF)		Task Location:	UITF, High Bay Area of Test Lab
Division:	Accelerator	Department: Center for Injectors and Sources	Frequency of use:	
Lead Worker:	M. Poelker			

Mitigation already in place:
Standard Protecting Measures
Work Control Documents

Ionizing Radiation Engineered Controls

- Below 7' height inside Cave 1, the walls provide concrete shielding of at least 55". Above 7', the East wall thickness is 27"
- The ceiling in the keV section of UITF is made of concrete at least 30" thick. Iron plate 3" thick is placed below cable penetrations.
- The ceiling of MeV section of UITF is made of 22" concrete.
- The main entrance to UITF is a labyrinth with walls 36" concrete and ceiling 22" concrete.
- In the keV regions, the beam termination points (dumps and Faraday Cups) are shielded to handle up to 32 mA beam current.
- The gun HV Power Supply can only be turned ON when UITF is swept and armed with Personnel Safety System (all doors are locked)
- The RF system can only be turned ON when UITF is swept and armed with Personnel Safety System (all doors are locked)

Exposure to Laser non-ionizing Radiation

Drive Laser hazards are mitigated through use of Class 1 laser enclosures (hutch and laser beam line transport) and via redundant laser shutters interlocked to the Laser Personnel Safety System (LPSS). For laser alignment mode when a person needs to be in the enclosure with the laser turned ON, administrative procedures require use of laser goggles, training and closing of doors interlocked to the LPSS. Laser hazards and procedures are fully covered under a separate document ACC-17-64784-LOSP.

Oxygen Deficiency Hazard

A preliminary ODH assessment was performed that considers cryogenic nitrogen and helium, and gaseous nitrogen for the entire UITF enclosure and considering MeV beam production using the SRF ¼ cryomodule, and installation of the HDIce target. The assessment is deemed "preliminary" until all ODH-related precautions and requirements have been implemented and verified adequate. In this assessment, the UITF enclosure was assigned a rating of ODH0 for areas below 9'. Above 9' the enclosure is considered ODH1. Signage will clearly indicate these conditions. Fixed oxygen and nitrogen monitoring systems will be used to detect and alert for OHD conditions. Sensors are located in appropriate areas. The preliminary assessment can be found at:
https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-135009/UITF%20prelim_%20ODH%20assessment.pdf

In this THA, the focus is on keV beam operations, which does not require cryogenic nitrogen or helium. The analysis in this THA describes gaseous nitrogen used for venting the gun and beamline.

	The quantity of SF6 gas stored inside the gun high voltage power supply pressure vessel is relatively small and does not pose an ODH hazard. **SF6 Exposure** A complete release of the SF6 from the gun high voltage power supply pressure vessel would create a layer of SF6 gas less than 1" thick on the bottom of the Cave1 floor. However, if the gas were to mix with air in the Cave, it would take approximately 45 minutes to remove the SF6 from the UITF enclosure, when considering the 4400 cfm exhaust fan that vents to the outside of Building 58. This time interval does not allow enough time for personnel to exceed the 8-hour exposure limit of 1000ppm. The estimated 8-hour average exposure concentration would be ~ 572ppm.

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
1	Gun operation / Exposure to Ionizing Radiation	M	M	3	See Mitigations already in place	A Personnel Safety System (PSS) has been designed and implemented to protect individuals from ionizing radiation during high voltage and electron beam operations. In the keV region, Radcon approved shielding is in place at beam termination points. A sweep will be done prior to closing the UITF entrance door using the procedure referenced in the UITF OSP. Magenta beacons are activated prior to arming high voltage interlocks, indicating potential for ionizing radiation inside the UITF enclosure.	1
2	Laser operation / Exposure to non-ionizing laser radiation	M	L	2	See Mitigations already in place	Use of Class 1 laser enclosures (hutch) interlocked to the LPSS, use of laser goggles, training and LPSS laser shutters interlocked secured access during alignment	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
3	RF non-ionizing radiation	L	L	1	See Mitigations already in place	A Personnel Safety System (PSS) has been designed and implemented to protect individuals from non- ionizing radiation during operation of the buncher and the ¼ cryomodule. A sweep will be done prior to closing the UITF entrance door using the procedure referenced in the UITF OSP.	1
4	ODH (GN2)	M	L	3	Restricted flow orifices and automatic valve closure at power outage	Personnel will exit UITF when ODH alarms sound. All personnel entering the area must have ODH1 training and follow procedures based on EH&S signage.	1
5	Electrical and High Voltage	M	M	3	Terminals insulated or guarded to prevent inadvertent contact. Approved LTT procedure followed when attaching the electron gun to the HV power supply.	LTT training for and application by workers during maintenance PSS monitors power supply “off state” during access	1
6	Pressure / Vacuum	L	M	2	Category 0 vacuum system The SF6 tank was approved	Review by Design Authority	1
7	Magnetic Fields	L	L	1	Magnet fields fall to acceptable levels very near the magnet.	Signage posted as required on the basis of measurements by IH for energized magnets.	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
8	SF6	L	EL	1	Contents of gun HV power supply SF6 tank does not constitute ODH hazard. Pressure gauge on SF6 tank provides visible alarm when pressure falls to specified level Commercial SF6 transfer/recovery system	Equipment specific training when transferring SF6 from the High Voltage tank to the Dilo recovery system Access to the floor is restricted when ventilation fan inoperative, or when there is a known leak on the SF6 tank	1
9	Lead shielding	L	EL	1	Wear approved gloves when moving lead. Lead will be painted whenever possible.	Lead Worker training required SAF-136	1

Highest Risk Code before Mitigation:	3	**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

Periodic Review –

ISSUING AUTHORITY	TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW DATE	REV.
ESH&Q Division	Harry Fanning			

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Person: Hansknecht, John (hansknec@jlab.org)
Org: ACCCIS

Status: PROCESSED
Saved: 1/5/2017 3:11:14 PM
Submitted: 1/5/2017 3:11:14 PM

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Operational Safety Procedure Review and Approval Form # 64784
(See ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure (OSP) and Temporary OSP Procedure for Instructions)

Type:	***LOSP*** Click for OSP/TOSP Procedure Form Click for LOSP Procedure Form
Serial Number:	***ACC-17-64784-LOSP***
Issue Date:	***1/18/2017***
Expiration Date:	***1/18/2020***
Title:	***UITF Laser Systems***
Location: (where work is being performed) Building Floor Plans	***Test Lab - 1126B*** ***Test Lab - 1127*** Location Detail: (specifics about where in the selected location(s) the work is being performed) ***laser cleanroom and beam test cave***
Risk Classification: (See ES&H Manual Chapter 3210 Appendix T3 Risk Code Assignment)	Without mitigation measures (3 or 4): ***3*** 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:	***ACCCIS***
Document Owner(s):	***Hansknecht, John (hansknec@jlab.org)*** Primary

Supplemental Technical Validations

Lasers Class 3B or 4 (Ultraviolet, Infrared, and Visible Light) (Bert Manzlak, Jennifer Williams)
Lock, Tag, Try (Paul Powers, Todd Kujawa)

Document History

Revision	Reason for revision or update	Serial number of superseded document

Comments for reviewers/approvers: ***Lock and tag is an appendix at the end of the LOSP. There is presently no laser, so LTT is not required, but it will be implemented when a laser delivery method to the beamline is established.***

Attachments

Procedure: ***UITF Laser Systems LOSP.pdf***
THA: ***UITF Laser Systems THA.pdf***
Additional Files:

Convert to PDF

Review Signatures	
Subject Matter Expert : Lock-> Tag-> Try	**Signed** on 1/13/2017 2:01:11 PM by Todd Kujawa (kujawa@jlab.org)

Approval Signatures	
Division Safety Officer : ACCCIS	**Signed** on 1/18/2017 3:44:14 PM by Harry Fanning (fanning@jlab.org)
Org Manager : ACCCIS	**Signed** on 1/17/2017 2:19:48 PM by Matthew Poelker (poelker@jlab.org)
Safety Warden : Test Lab - 1126B	**Signed** on 1/13/2017 2:10:59 PM by John Hansknecht (hansknec@jlab.org)
Safety Warden : Test Lab - 1127	**Signed** on 1/13/2017 2:11:05 PM by John Hansknecht (hansknec@jlab.org)
Subject Matter Expert : Lasers Class 3B or 4 (Ultraviolet-> Infrared-> and Visible Light)	**Signed** on 1/13/2017 3:43:16 PM by Bert Manzlak (manzlak@jlab.org)

Laser Operational Safety Procedure (LOSP) Form

(See ES&H Manual Chapter 6410 Appendix T1 Laser Operational Safety Procedure)

Issue Date:			**Expiration Date:**	3 years from official issue date	
Title:	UITF Laser Systems				
Location:	Laser Cleanroom in bldg. 58 room 1126B and Test cave room 1127				
Description of Project	The project is a laser driven photo-electron gun for the UITF accelerator.				
Document Owner(s):	John Hansknecht			**Date:**	1/5/2017

Laser Inventory

Laser Serial # **	**Laser Class**	**Wavelength(s)**	**Maximum Power/Energy**
1. N/A Diode	3B and 4	405-455nm 630-680 760-860 1064 or 1560	1W 0.2W 0.2W 0.2W
2. PPLN SHG	4	780nm	3W
3. Nd:YVO4 & LBO SHG	4	532nm	11W
4. Near IR Fiber Laser	4	1064nm	5W
5. Mid IR Fiber Laser	4	1560nm	10W

** Actual serial numbers tracked in annual report to LSO.

Approval Signatures:	**Print**	**Signature**	**Date:**
Laser System Supervisor:	John Hansknecht		
Laser Safety Officer:	Bert Manzlak		
Division Safety Officer	Harry Fanning		
Department or Group Head:	Matt Poelker		
Other Approval(s):			

Document History:

Revision:	**Reason for revision or update:**	**Serial number of superseded document**

Distribution: ESH&Q Document Control (x7277, MS6B); affected area(s); Document Owner; Division Safety Officer

Introduction – In areas containing more than one laser, define operational sequence or parameters.

This document refers to laser class 1,3R,3B, and 4. These are hazard classes defined by ANSI Z136.1. The reader is expected to understand the meaning of these hazard classes.

This Laser Operational Safety Procedure (LOSP) addresses all aspects of safety and conduct specific to the operation and maintenance of the lasers used in the UITF Injector clean room and the UITF test cave. In the primary intended mode of operation, laser light is produced under a class 1 interlocked laser enclosure inside the clean room and then launched into a stainless steel armored fiber for delivery to a class 1 interlocked laser enclosure in the test cave, so there is no possibility of exposure to personnel.

During times where laser maintenance is necessary, the systems have engineered interlock controls that will allow either the test cave or the laser cleanroom act as a class 4 laser area. This will be described in detail under the "Laser Environment" and "Laser Interlocks" section below.

The primary light source for UITF operation is a 780nm laser delivered over fiber from a fiber laser amplifier. There may be a need to occasionally drive the electron gun with a different laser, which will also be connected to the engineered laser interlock system. This LOSP shall permit the temporary (less than 3 months) installation of any laser listed in the laser inventory if the need arises for a short term experiment. Such changes will be initiated with a TATL entry to provide notice and an opportunity for discussion with the LSO, affected laser workers, and Safety Systems Group (SSG) to ensure continuity of machine and personnel protection. Laser Experiments lasting longer than three months will require a revision or addendum added to this LOSP.

Personnel Only those authorized by the LSS are permitted to enter the location noted on the cover sheet of this document.	List: • Training and qualification requirements (including refresher training). • Medical requirements. • Spectator protection requirements.

A list of authorized laser personnel is maintained online within the Jlab Training Database for SAF161 training.

A Laser Worker must have completed SAF 161 "UITF Laser User Training". This means the Laser Worker has:

a) Been qualified by Jefferson Laboratory Occupational Health Physician (MED 02) as detailed in Section 6410 of the EH&S manual,
b) Taken a laser safety course (SAF 114O) administered by the laser safety officer
c) Read Section 6410 of the EH&S manual,
d) Read and understood this LOSP,
e) Received laser and laser room specific walkthrough training with the LSS and entered into the Jlab training database.

Accidental Eye Exposure: Accidental eye exposure to a laser beam requires ***immediate medical attention*** whether injury is apparent or not. If possible, the individual should remain and be transported in the upright position.

Spectator Protection Requirements: Injector Laser Workers may escort spectators in an interlocked laser area during alignment mode only after ensuring that the spectator is wearing appropriate safety eyewear and jewelry, watches removed. *Spectators must have received prior permission from the Laser System Supervisor before entering the interlocked laser area during alignment mode.*

Laser	Define: • Laser system specifications. • Define laser system components. • Copy of laser operating manuals or reference the location of the manual(s).

Lasers that can be installed and operated in the room are listed below:

Description: Diode lasers - Used as a direct optical source for an experiment on the laser table or used as to "seed" other lasers for wavelength or temporal control.

Type of Laser / Class	Semiconductor diode laser / Class 3A and 3B
Manufacturer	Ultimate manufacturers are unknown. Diodes are supplied by Thorlabs, Qphotonics, etc.
Model Numbers	Multiple model numbers. This information is not consequential for safety. All diodes are treated with equal concern based on power, wavelength, and beam shape.
Serial Numbers	Diode lasers are easily damaged and frequently replaced. Furthermore, vendors do not mark serial numbers on the diode housings because they are often too small. For this reason, serial numbers of seed lasers are not recorded in this LOSP.
Wavelength range	405nm, 445nm,630nm,700-900nm, 1064nm, 1560nm
Power Range	405nm to 0.5W, 445nm to 1W, all others up to 200mW.
Mode (i.e., time structure)	Worst case= pulsed at 250 MHz with 10ps Gaussian pulses. May also operate CW.
Beam Diameter (collimated, typical)	3mm
Divergence (uncollimated, typical)	0.35mrad +/- 10%

Description: Diode pumped 532nm laser

Type of Laser / Class	Frequency-doubled Nd:YVO4 / Class 4
Manufacturer	Jenoptik and Coherent
Model Numbers	Jenoptik (none) Coherent Verdi-V10
Serial Numbers	201,218,312, 248902, V10-A0436, V10-A0024
Wavelength range	532nm
Power Range	Up to 11 Watts
Mode (i.e., time structure)	CW
Beam Diameter (collimated, typical)	2.25mm
Divergence (uncollimated, typical)	0.35mrad +/- 10%

Description: Fiber Laser Amplifier at 1064nm

Type of Laser / Class	Fiber, single mode (class 4 at fiber output)
Manufacturer	IPG

Model Numbers	YAR-5K-1064-LP-SF
Serial Numbers	PA0605581
Wavelength range	1064nm
Power Range	Up to 5 Watts
Mode (i.e., time structure)	Worst case = 250MHz with 10ps Gaussian pulses
Beam Diameter (collimated, typical)	1.7mm
Divergence (uncollimated, typical)	0.35 mrad +/- 10%

Description: Fiber Laser Amplifier at 1560nm

Type of Laser / Class	Fiber, single mode (class 4 at fiber output)
Manufacturer	Keopsys & IPG
Model Numbers	Keopsys KPS-BT2-PEYFA-1560-PB-060-PM-FA. IPG EAR-5K-C-LP-SF. EAM-10K-C-LP
Serial Numbers	5090325, PA0605238, PA0605747, PA0706297, and future replacements
Wavelength range	1560nm
Power Range	Up to 10 Watts
Mode (i.e., time structure)	Worst case = 250MHz with 10ps Gaussian pulses
Beam Diameter (collimated, typical)	1.7mm
Divergence (uncollimated, typical)	0.35 mrad +/-10%

Description: Frequency doubling apparatus for creating 780nm from 1560nm *

Type of Laser / Class	Frequency doubling crystal. (Class 4)
Manufacturer	Jlab
Model Numbers	N/A
Serial Numbers	N/A
Wavelength range	1560nm input / 780nm output
Power Range	Up to 3 Watts delivered at 780nm
Mode (i.e., time structure)	Worst case = 250MHz with 10ps Gaussian pulses
Beam Diameter (collimated, typical)	2.5mm
Divergence (uncollimated, typical)	0.35 mrad +/- 10%

Description: Frequency doubling apparatus for creating 532nm from 1064nm *

Type of Laser / Class	Frequency doubling crystal. (Class 4)
Manufacturer	Jlab
Model Numbers	N/A
Serial Numbers	N/A
Wavelength range	1064nm input / 532nm output
Power Range	Up to 5 Watts delivered at 532nm
Mode (i.e., time structure)	Worst case = 250MHz with 10ps Gaussian pulses
Beam Diameter (collimated, typical)	1.5 mm

Divergence (uncollimated, typical)	0.35 mrad +/- 10%

* The frequency doubling apparatus is not a laser, but it modifies the wavelength delivered by the fiber lasers. This change in wavelength requires MPE calculations for eye and skin to cover both the fundamental and second harmonic wavelengths.

Hazards and Mitigation	Define: • Laser-specific hazards. • Occupational exposure hazards beyond laser light (e.g. fumes, noise, etc.). • Credible non-beam hazards (e.g. environmental hazards). • Describe all required personal protective equipment ES&H Manual Chapter 6410 Appendix T2 Laser Personal Protective Equipment (PPE) (include: clothing requirements (e.g.: no reflective jewelry, etc.).

Laser Specific Hazards

Hazard: The laser(s) described in this LOSP may produce optical energies that can cause temporary or permanent damage the eyes. The lasers may also produce a skin burn hazard.

Mitigation: This hazard is mitigated by training, professional conduct, optical beam-line layout, adherence to the *Use and Alignment procedures* listed in this document, and proper selection of laser protective eyewear by affected workers. The selection of laser protective eyewear is determined by the wavelength and power of the laser(s) in use as referenced in the *Required Calculations* section. Non-affected workers are protected by the system enclosure and room interlock system.

Hazard: Some of these lasers described in the LOSP are capable of producing laser generated air contaminants (LGAC).

Mitigation: We do not anticipate use of any materials within the beam enclosure that could produce these contaminants. If we find any LGAC production, laser operation will be shut down and the issue will be resolved by removing the offending material.

Non-Laser Hazards

Hazard: Historically we have listed high voltage as a hazard associated with lasers. Since the advent of solid state lasers, this is no longer an issue because they run at low voltage.

Mitigation: Any item requiring high voltage, (e.g. Pockels cells) will have electrically insulated connections making the high voltage inaccessible to the worker during operation.

Clothing Requirements: Laser workers and spectators must not wear jewelry or clothing that presents a specular reflection hazard.

Laser Environment System designs, including interlocks, require hazard evaluation review by SME.	Define: • Layout of the laser controlled area and/or table. (Show beam location in relation to user (waist height preferable).) • Interlock schematic (or similar) (including smoke detector interlocks). • Room lighting conditions during laser use and alignment procedure(s). • Targets. • Primary and all likely beam paths (open or enclosed).

The following paragraphs describe the normal production laser that will be found in the laser environment.

!!

VERY IMPORTANT CAUTIONARY NOTE: The lasers described within this LOSP are under remote EPICS computer control at all times unless specific steps are taken to gain manual control. Users should be

aware that any laser may start, stop, or change intensity without warning. These lasers are always treated as energized unless the system has been deenergized.
!!

Class 3a Fiber Coupled Diode Lasers:

(a typical fiber coupled laser diode)

Description: The laser is a standard "C" band communications laser diode that is fiber coupled. Although the laser is rated at 20mW, the gain-switching technique at Jefferson Lab reduces the average output power to a maximum of 2mW. This laser acts as the "Seed" source for the Fiber laser amplifier.

The 1560nm wavelength produced by these lasers can damage the lens of the eye and cause cataracts upon overexposure. Viewing of energized un-terminated fibers is prohibited.

In normal operation, the fiber laser seed resides in the 1126B laser cleanroom and is launched into the fiber laser amplifier without free space travel, thereby forming a Class 1 Laser system. The fibers will remain terminated and the terminations are contained beneath the interlocked chassis. The chassis is labeled as containing Class 3a and 3b lasers in accordance with the ANZI Z136.1 -2000 standard. The bare fibers will not be accessible at any location to untrained / unauthorized personnel. Due to system losses, small in-line fiber laser pre-amplifiers are used to boost the seed power to about 4mW.

Class 4 Fiber Laser Amplifiers


(a typical fiber laser amplifier)

Description: The Fiber laser amplifier is a high powered fiber Erbium-Ytterbium gain medium which amplifies the light introduced to the input of the amplifier from a Class 3a "seed" laser.

The Fiber Laser amplifier is a commercial 19" rack mounted device which amplify incoming fiber sources. It is mounted below the Class 1 laser enclosure inside 1126B laser cleanroom. Both the incoming and exiting fibers fully contain the laser light and thereby form a Class 1 laser system. The amplifier face plate conforms to the CDRH requirements for emission warnings, keyed operation, anti-restart, etc. There are no user serviceable parts within the amplifier chassis. The output fiber from the chassis is permanently attached to the chassis, thus preventing the possibility of exposing personnel to the amplified light. The output fiber is taken into the interlocked class 1 enclosure on the laser table where it is terminated with a collimating optic. The light exiting this collimating optic is completely invisible and powerful enough to burn skin and eyes through direct illumination or specular reflection. It is immediately launched into the PPLN second harmonic crystal described below. The methods used to mitigate exposure to this light are described in detail with the Frequency Conversion Apparatus description.

Class 4 Frequency Conversion Apparatus

Description: A periodically polled Lithium Niobate (PPLN) crystal is used to frequency double the 1560nm output light from the fiber amplifier. This conversion of wavelength from 1560nm down to 780nm significantly impacts safety and eyewear requirements, so it is listed here as a laser source.

(A typical frequency conversion apparatus)

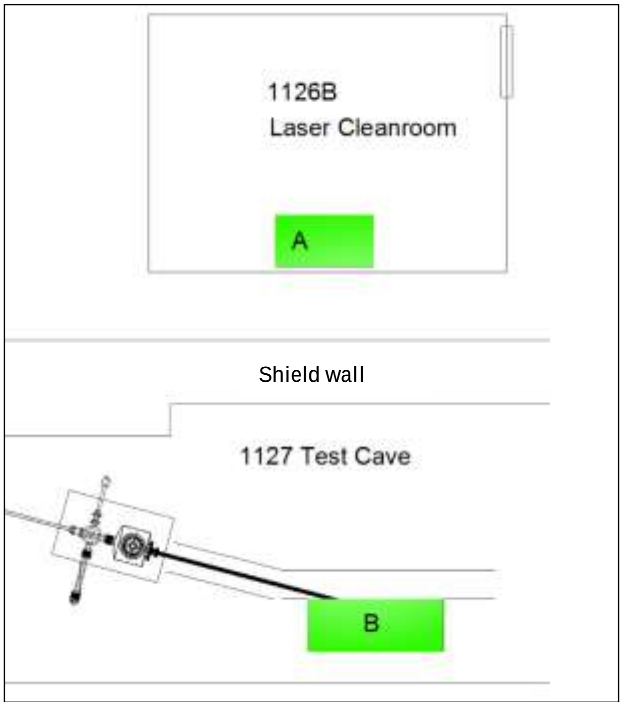
The photo above gives a clear overview of the apparatus. This apparatus is located inside the 1126B laser cleanroom class 1 interlocked laser enclosure. This apparatus is where the hazardous laser conditions are first encountered in the system. Until reaching this point, the high power light has been safely contained in an optical fiber, and is now launched into the periodically polled lithium niobate (PPLN) crystal which subsequently converts about ½ the incoming light from 1560nm down to 780nm. The residual 1560nm light is safely dumped. The useful 780nm light is reflected by a pair of mirrors out onto the main laser table. These mirrors are dichroic and serve to reflect only the 780nm light while allowing the 1560nm light to dump into a beam dump. The 780nm exiting light is both a skin hazard and an eye hazard affecting the cornea of the eye. It is worthwhile to note that there is also a very small (<2mW) amount of harmonic light produced at a wavelength near 530nm. This green light is produced by the PPLN crystal and is non-hazardous.
The entire apparatus is designed with close tolerances between the primary optics. This minimizes the possibility of inadvertently coming in physical contact with the 1560nm beam. This is important because of the highly invisible nature and high power of the 1560nm light.

****** Keep in mind that the high power 1560nm beam is not visible with the Find-IR-Scope that we are accustomed to use. The beam is only visible using a 1560nm rated IR viewer card. The fluorescent image produced on this card will be visible through the required protective eyewear *******

Laser eyewear for this apparatus must protect against exposure to the 1560nm and 780nm light. When performing active alignment of the PPLN crystal, it is appropriate to run the fiber amplifier at the lowest possible setting while still achieving second harmonic power. This further serves to reduce the chance of exposure to specular reflections from the 1560nm source.

Area Schematic:

Schematic 1 shown below is a pictorial representation of the laser areas. There is a class 1 interlocked laser enclosure (A) within room 1126B and a class 1 interlocked laser enclosure (B) in the 1127 test cave. A stainless steel armored optical fiber delivers light from point A to B.



Schematic 1; Plan view of laser cleanroom and test cave electron gun region.

Description of operation:
Case 1 Normal: Lids are in place on laser enclosures A & B. System is Class 1 laser safe.

Fault condition 1: If the lid is lifted on laser enclosure A, the laser trips off on interlock fault.
Fault condition 2: If the lid is lifted on laser enclosure B, a shutter on laser enclosure A closes to stop laser delivery into the optical fiber so there is no light that can reach enclosure B. There is a small control panel that shows the status of the interlock and shutter position at enclosure B so a worker can be confident in the operational status of the interlock.
Fault condition 3: If smoke is detected above enclosure A or B, the laser interlock trips the laser off.

Case 2 Laser work in 1126B: If laser work (alignment, etc) is occurring in room 1126B, the "room" interlock system for room 1126B is armed. Once armed, there are illuminated warnings outside the room and the door is controlled with a defeatable access control system. The door is magnetically locked and only authorized laser works are afforded access. Once the room interlock is armed, the lid of laser enclosure A can be lifted without tripping the laser. Note: Since 1126B is a class 4 laser area, there may be short term experiments on the other tables within this room that involve the lasers listed in inventory. In all cases, notification of wavelength and power and appropriate laser protective eyewear will be available in the gowning area of this cleanroom.

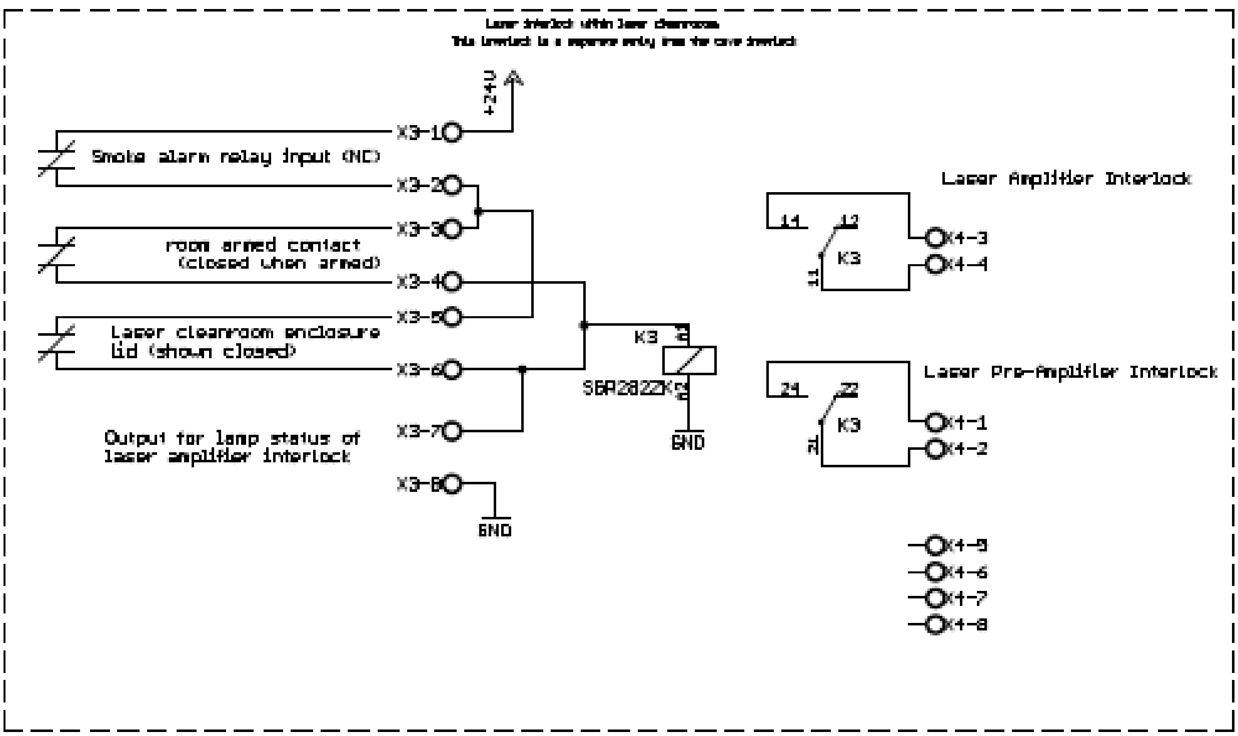
Case 3 Laser work in 1127 Test Cave: If work is required in laser enclosure B, there are two ways of performing the work described below:

Case 3A: We have the option of aligning the laser by connecting a class 3R laser to the fiber launch. The 3R laser is a 635nm laser less than 5mW in power and does not require laser protective eyewear. It would also allow other workers to be in the test cave area while the laser alignment is in progress.

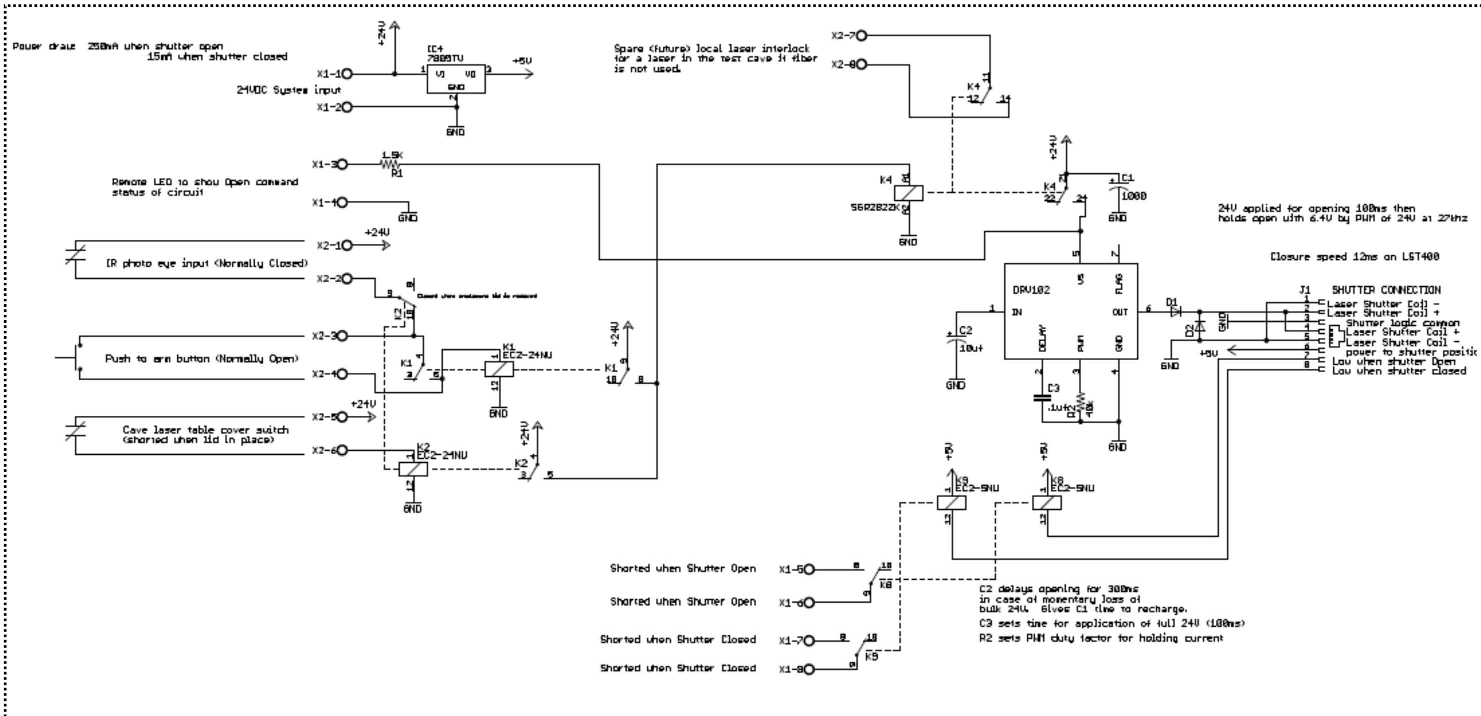
Case 3B: When the high power 780nm light requires alignment, the laser worker shall clear out all personnel from the test cave complex. A "Laser Alignment in progress" sign on a cone will be placed at both entry doors to the test cave complex. The worker can then return to the laser table and remove the lid on laser enclosure B. This will immediately trip the shutter in laser enclosure A. The worker can then wear the appropriate laser safety eyewear and push an "override" button inside enclosure B. This will cause the shutter to open and 780nm light will be delivered to the enclosure. During work, if a worker enters the cave in violation of the posted sign, the light curtains at the cave entryways will trip the shutter closed. Work can proceed only if the worker is escorted back out of the cave complex and the "override" button is pressed again. Upon completion of work, the lid is placed on enclosure B. The lid contacts automatically reset the circuit so it is in the normal condition and no longer in an override condition.

Case 3C: If a different laser from the inventory list were to be installed locally at laser enclosure B, the interlock system provides contacts to interlock this laser and perform the same safety function as described in case 3B above. At no time will we allow a condition where enclosure B is not a class 1 interlocked device.

Interlock system schematics:



Schematic 2: Enclosure A interlock.



Schematic 3: Enclosure B interlock

The schematics in this document are only intended to show the existence of the official design. Actual detailed schematics are located in the following directory: M:\inj_group\Official Electronic Design Packages\UITF laser interlock circuit.

Written Procedure for Use and Alignment	Provide: • All process steps – including unattended operation controls. • All process steps for detailed alignment – Include manufacturer's protocols for alignment. • Maintenance and service. • Off-normal and emergency procedures (e.g. beam loss, fire).

Procedural Considerations

1. Watches, rings, dangling badges, necklaces, reflective jewelry are taken off before any alignment activities begin. Non-reflective tools are used when beam is present.
2. Access to the room/area is limited to authorized personnel only.
3. Consider having someone present to help with the alignment.
4. All equipment and materials needed are present prior to beginning the alignment
5. All unnecessary equipment, tools, combustible material (if fire is a possibility) is removed to minimize the possibility of stray reflections and non-beam accidents.
6. Persons conducting the alignment have been authorized by the LSS

Alignment Methods to be used for this laser system:

1. Laser Protective Eyewear shall be worn at all times during alignment with laser rated > class 3R.
2. There shall be no intrabeam viewing with the eye.

3. Co-axial low power lasers should be used when practical for alignment of the primary beam.
4. Reduce the beam power through the use of ND filters, beam splitters and dumps, or reducing power at the power supply. Avoid the use of high-power during alignment.
5. Beam Control- the beam is enclosed as much as practical, the shutter is closed as much as practical during course adjustments, optics/optics mounts are secured to the table as much as practical, beam stops are secured to the table or optics mounts.
6. Areas where the beam leaves the horizontal plane shall be labeled.
7. Any stray or unused beams are terminated.
8. Invisible beams are viewed with IR/UV cards, business cards or card stock, craft paper, viewers, 3x5 cards, thermal fax paper, Polaroid film or similar technique. NOTE: The Find-R-Scope Infrared viewer is not sensitive to the 1560nm beam. Operators are aware that specular reflections off some of these devices are possible, and that they may smoke or burn.
9. Intrabeam viewing is to be avoided by using cameras or fluorescent devices.
10. Normal laser hazard controls shall be restored when the alignment is completed. This includes enclosures, covers, beam blocks/barriers have been replaced, and affected interlocks checked for proper operation.

Off-normal and Emergency Procedures

In Case of Fire, leave the area immediately and pull the nearest fire alarm. The fire alarm system will disable the laser power supplies.

Maintenance & Service

Routine maintenance of the laser systems consists of realignment and cleaning. These procedures are described in the vendor manuals and are typically considered "general knowledge" to laser workers trained on a specific system.

Vendor Service:
Alignment or replacement of parts by an outside vendor representative will require a JLAB escort qualified on this LOSP.

Maintenance requiring Lock-Tag-& Try:
The Electron beamline forms part of the Class 1 enclosure. If vacuum maintenance is being performed that will violate this enclosure, either the gun valve or the laser must be locked out using the Lock/Tag/Try procedure located in appendix A.

Laser Controls	• Describe all controls (administrative and engineering). (If a different control is recommended the rationale for not using a typical/recommended control.)

The engineered controls are essentially those schematic 1,2,3 and operationally described earlier.

The administrative controls are the contents of this LOSP, the labels affixed to the laser enclosure, and the signage posted on the entryways. These controls supplement the PPE requirements and engineered controls.

Required Calculations	• Maximum permissible exposure. • Optical density. • Nominal hazard zone.

The MPE, NOHD, and OD requirement for the eyewear are calculated using software package Easy Haz Industrial LSO (V2.12) by Laser Professionals Inc.

Laser parameters needed to calculate these values:

Assumptions:

- Beams always collimated.
- Beams are circular.
- CW beams: exposure 10 seconds for IR lasers, 0.25 seconds for visible lasers
- 7mm pupil diameter limiting aperture
- Collimated beam diameter is a "worst case" 1.5mm and lowest possible divergence of 0.2mrad.

Results are shown in the table below:

Laser Wavelength	Worst case pulsed conditions	Max average power at stated pulse conditions	Worst case Collimated Beam Diameter (mm)	MPE Ocular (W/cm^2)	MPE Skin (W/cm^2) CW	NOHD (meters)	Required OD (eyewear)
Laser diode 405-445 nm	250 MHz with 10ps Gaussian pulses	1W	1.5	2.55E-3	3.34	646	3.00
Any laser type @630-680 nm	250 MHz with 10ps Gaussian pulses	200mW	1.5	2.55E-3	3.11	707	2.31
Any laser type @700-900 nm	31 MHz with 10ps Gaussian pulses	5 Watt	1.5	2.55E-3	3.11	3530	3.71
Any laser type @532nm	250 MHz with 10ps Gaussian pulses	11 Watt	1.5	2.55E-3	3.11	5240	4.05
Any laser type @1064nm	250 MHz with 10ps Gaussian pulses	5 Watt	1.5	5.00E-3	1.00	2520	3.41
Any laser type @1560nm	250 MHz with 10ps Gaussian pulses	10Watt	1.5	1.00E-1	1.00E-1	798	3.02

Remarks:

1. OD rating printed on eyewear must exceed the calculated value of required OD.

2. Multiple wavelengths may be present in a given experiment. Eyewear must be selected that provides the proper OD for all wavelengths present.

Example: Our normal fiber laser system has 1560nm and 780nm beams present, thus eyewear selected must cover both wavelength bands with an OD meeting or exceeding the value determined in the chart above.

3. The specific laser from the laser inventory is not consequential for this table. The reasoning for this statement is:

a. All lasers in our inventory are run with collimated beams smaller than the 7mm pupil diameter.

b. One could argue that we are not going to get an accurate Nominal Hazard Distance (NOHD) result when we categorize all of our lasers to have a 1.5mm collimated beam diameter and 0.2mrad divergence. After all, our lasers each have a slightly different spatial profile. The typical NOHD for our lasers will range from 200 meters to several thousand meters. Since all lasers are run within a Class 4 laser room, the NOHD is known to be confined to the limits of the room. Any calculation error resulting from a slight variation of beam spatial profile is not consequential to our application.

c. All lasers run in Continuous Wave or at a high megahertz repetition rate that is "effectively" CW based on the calculations. The OD and MPE calculation results are thus driven by wavelength and average power alone. Skin MPE is undefined for our pulse structure, so CW is used to calculate.

4. For a given wavelength band, the lower wavelength of the band is the most restrictive. This value is used for the calculations to provide the greatest safety factor.

Labeling/Posting (See ES&H Manual Chapter 6410 Appendix T5 Laser Labeling/Posting Requirements	• Equipment/area labeling/posting requirements. • Area signs.

Non- interlocked tooled housings: must have indication on label that housing is not interlocked
All beam pipes containing a laser beam must be labeled: non-interlocked beam pipes must have indication on label that beam pipe is not interlocked
Entrance to room must have ANSI laser sign that includes entire class 3b and 4 laser inventory and indication of the nature of laser beams must be noted: invisible and visible
Entrance to room must have a separate sign if class 3a lasers are in use in the room
LSO will provide assistance for label and signage

Authorized/Trained Individuals	
Print Name/Signature	**Date**
Electronically listed in SAF161 List not maintained locally with this document.	

Appendix A – Lock, Tag & Try

Lockout/Tagout procedure for securing the UITF laser system for beamline vacuum work upstream of the laser entrance window.
Procedure produced in accordance with section EHS&Q manual section 6110 appendix T1

Scope of work: When a non-laser trained worker needs access to the beamline electronics inside the outrigger table or if disassembly of the vacuum system upstream of the laser table is planned, the laser system must be locked and tagged with an approved lockout device to prevent accidental exposure to the laser light to eyes or skin.

Step 1: Determine need for a written work control document.

Each tagger shall use this procedure when locking and tagging out the laser path for maintenance and repair. Each tagger must be either:
1. Laser safety trained and qualified on the UITF system or
2. Accompanied by a qualified laser system operator during the process.

Step 2: Determine hazards
The hazard is a class 4 laser beam capable of blinding or burning an individual who comes in direct contact with the beam. The hazard is completely mitigated by utilizing an engineered shutter mechanism to completely block the laser path.

Step 3: Notify others
Notify all affected employees. Tell them that you will be placing the equipment out of service until repairs or adjustments are completed. When two or more groups have separate or overlapping responsibilities for the equipment, the group requesting the work is responsible for notifying the other group or groups that the equipment will be placed out of service.

Step 4: Isolate energy sources
There are several places where an opaque clamshell device can be used to stop the transmission of light. These include:

a. Covering over the laser window
b. Disconnecting and covering the launch fiber that takes light from enclosure A to enclosure B.

If these are not suitable to the situation, the laser system supervisor will be able to point out the amplifier power source to be tagged. The amplifier has a removable power cord, so the cord receptacle safety lockout devices (stock # 6100-41050) must be utilized. Locks must be affixed so as to hold the devices in the safe (usually "off") position. Fill out tags completely and place them in such a way as to be immediately apparent to anyone who might attempt to operate the device. Tags must be attached by a durable means capable of withstanding a 50-pound pull, at least equivalent to a nylon cable tie. String and tape are prohibited.

Step 5: Remove potential energy
The lasers used in the injector have no stored or potential energy.

Step 6: Verify lockout
The tagger shall ensure that the LO/TO is effective.

Step 7: Perform the needed work. Check the integrity of the lock & tag when work lasts more than one shift.

Step 8: Prepare for re-energizing
When work is complete on the equipment or system, notify all affected people that the work is complete and ready for testing. Inspect to ensure equipment has been properly reassembled.

Step 9: Remove locks and tags
When all affected people are ready, each tagger removes their own locks and tags.

Step 10: Energize

1.0 Revision Summary

Periodic Review – 12/22/15 – No changes per TPOC
Revision 1.1 – 07/01/14 – TechPOC changed from D. Owen to B. Manzlak.
Revision 1.0 – 12/05/10 – Updated to reflect current laboratory operations.

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Task Hazard Analysis (THA) Worksheet

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

Click For Word

Author:	John Hansknect	**Date:**	12/14/2016	**Task #:** If applicable	

Complete all information. Use as many sheets as necessary

Task Title:	Routine laser maintenance, installation, and operation			**Task Location:**	Bldg 58 room 1126B and UITF cave room 1127
Division:	Accelerator	**Department:**	Center for Injectors and Sources	**Frequency of use:**	Indeterminate
Lead Worker:	John Hansknect				
Mitigation already in place: Standard Protecting Measures Work Control Documents	None. This is the preamble to a new LOSP				

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
	Laser exposure above MPE to eyes or skin	M	L	3	Follow processes outlined in the new LOSP	LOSP training and Job training	1
	Laser induced fire	M	L	3	Eliminate flammables from laser enclosure. Smoke alarm in 1126B or fire system in 1127 test cave shuts off laser.	The structure is engineered to prevent laser exposure to any flammable material.	1

Highest Risk Code before Mitigation:	3	**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

Periodic Review – 08/13/15 – No changes per TPOC
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 DATE	REV.
ESH&Q Division	Harry Fanning	08/13/15	08/13/18	0.1

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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: ACC-17-64784-LOSP

Title: UITF Laser Systems

Name	**Signature**	**Date**

ODH Assessment

DATE: 11/10/2016

DIVISION: Accelerator & Engineering Divisions

LOCATION: Upgrade Injector Test Facility (UITF) at Building 58 **(Preliminary)**

ASSESSMENT AUTHOR: Hari Areti & Will Oren

APPROVAL: ____
Mat Wright for the Engineering Division Head

cc:
Building Manager
EHS IH Group, MS 35
EHS Documentation, MS 35

ODH Risk Assessment, UITF
2016

Introduction

This assessment addresses the risk of oxygen deficiency hazard for the Upgrade Injector Test Facility (UITF). The assessment is conducted according to Jefferson Lab's ODH Risk Assessment Process (ODHRAP). This assessment addresses the cryogens and gas (Helium, Nitrogen and Sulfur Hexafluoride-SF6) ODH hazards associated with the facility. These gases and cryogenic fluids are sources of gases which can dilute the normal oxygen content with health effects as outlined in the Lab's ODH Risk Assessment Process. However, according to the Safety Data Sheet (SDS), the maximum exposure of SF6 is 1000ppm. Therefore, SF6 should not be considered as an asphyxiant. It is recommended that a separate industrial hygiene assessment address SF6 as a toxic hazard other than what is covered here as an ODH hazard.

The following sections cover the modeling scope and methodology for a cryogen or gas dispersion release, a description of the work space, operational modes which affect the risk factors, failure rates of the components, and the resultant area classification.

UITF Configuration

The facility description is depicted in Figures 1 - 4, shown below where the entire complex is within the Test Lab, Bldg 58. The work areas covered in this analysis include the UITF enclosure which is composed of Cave 1 and Cave 2, the adjacent Test Lab high bay area and the tops of Caves 1 and 2

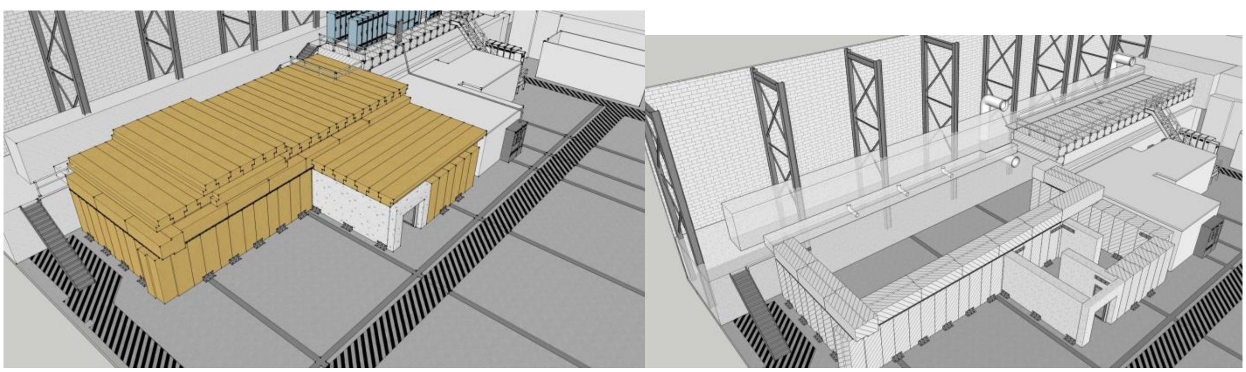
Cave 1 has a volume of 207 m^3 and Cave 2 has a volume of 441 m^3 for a grand total of 648 m^3 for the combined space. These areas, while they have differing ceiling heights with a 1 m divider between them, will be treated as a combined space. The bottom of this divider is 3m (10') from the floor.

Cave 1 has six 0.25 (10") diameter ceiling penetrations, all of which can be used for cable routing. All six of these penetrations emerge under an expanded metal grating that spans the space between two sets of electronics racks on the top of the cave. None of these will be considered as possible vents for helium in this analysis. To prevent helium from venting through these penetrations and exposing workers in the racks to a possibly oxygen deficient environment these penetrations must be blocked so that helium cannot escape from the cave. Additionally, in Cave 1 there are two 0.76m (30") diameter ventilation tubes, with active fans, on the east wall approximately 2.1m (7') above the floor: one tube vents to the exterior of the building (capacity of 2.1m^3/s – 4400CFM), and the other vents (capacity of 3.5m^3/s – 7400CFM) to the high bay region. Because of the need to power the fans, these vents will not be used in this analysis which assumes that powered active controls may fail. However, since the discharge of the northern most fan is towards the electrical support racks on the top of the cave, this exhaust will need to be directed either up or to a level higher than the racks to avoid helium/nitrogen exposure during a spill event. In addition, there are three 0.15m (6") diameter vent holes on the west wall near the ceiling which go to the High Bay area. Finally there are three 0.30m x 0.46m (12"x18") penetrations that go through the ceiling terminating outside the access area to the electronics racks. It is assumed that one of these will be filled with waveguide but the other two can be used as vents.

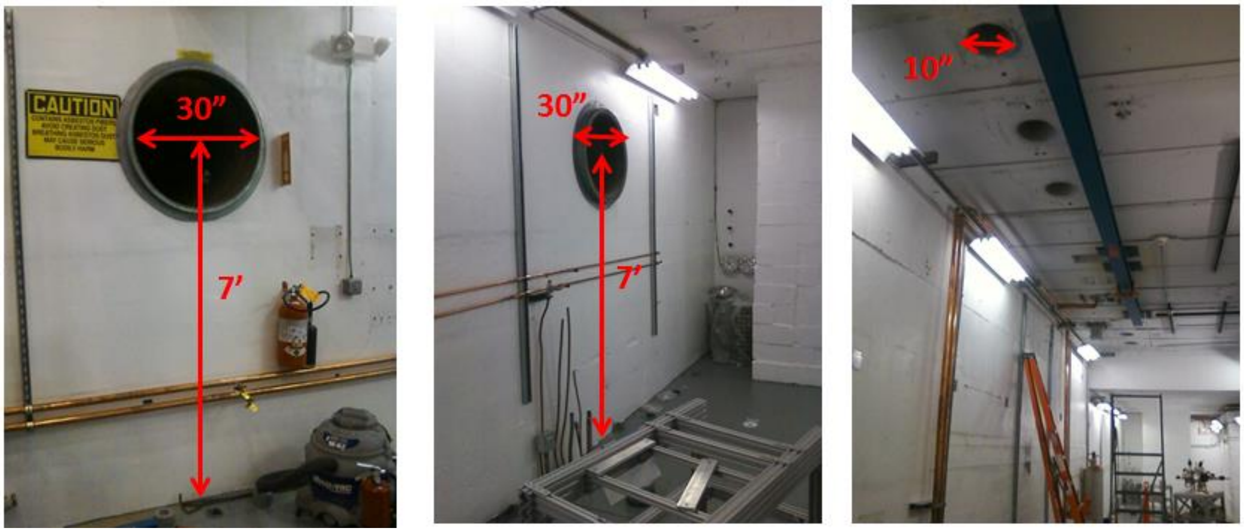
The total area in Cave1 available for venting helium, includes the two 0.30m X 0.46m penetrations and one of the 0.15m diameter vent holes on the west side, is 0.30m^2 (3.2ft^2). The two remaining 0.15 diameter holes on the west side will be reserved for dedicated use to house vent lines coming from the ¼ cryomodule's primary Circle Seal relief, the parallel plate relief and the burst disc. Since the two 0.30m X 0.46m penetrations will be used as vents, some kind of chimney ~8ft tall must be installed on the cave roof over each penetration to direct any vented helium above the heads of anyone in the area.

Within Cave2, there is a 5.6 m^2 (60ft^2) area at approximately 3.7 m (12') under the raised part of ceiling available for venting into the high bay volume. This raised portion can be seen in Fig 4 below and corresponds to the planned longitudinal location of the HDice target.

The main entry/exit to UITF is through a labyrinth with chain-link fence gate, approximately 1.8m (6') wide and 2.4m (8') tall, which also provides an escape path for helium gas and/or a path for makeup air. The vent tubes, penetrations and chain-link fence gate allow lighter than air mixtures of ODH gases to leave the enclosure to the high bay.

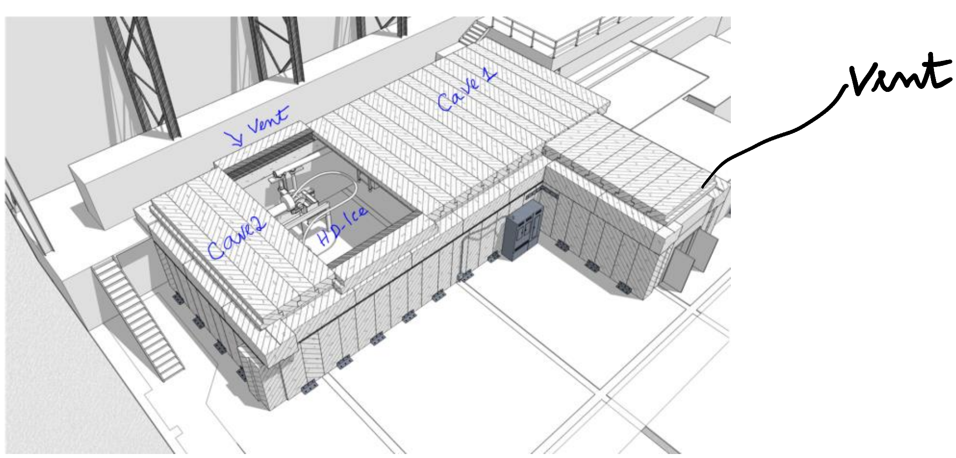


Figures 1 &2: UITF with Ceiling in place and without ceiling on Cave 2



6” Vents, West Wall

Figure 3: Vents in Cave1



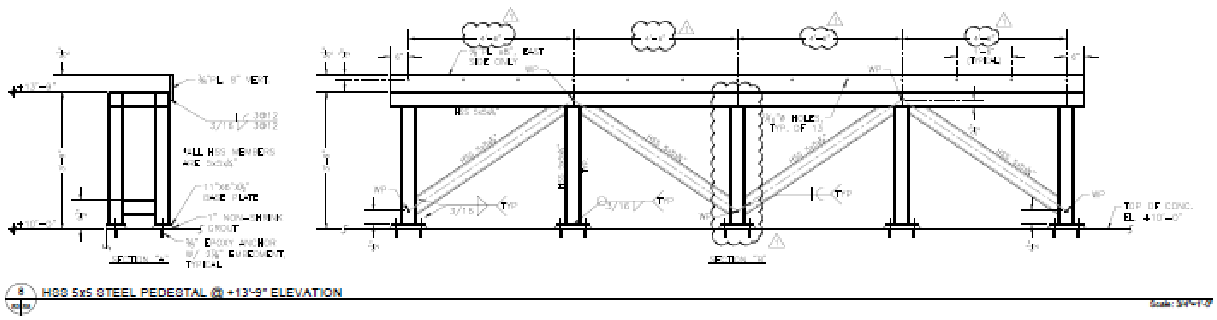


Figure 4. 5.6 m^2 vent area at the ceiling in Cave2

Model and Sources for Cryogen and Gas Dispersion Release

Helium spill tests within the JLab accelerator tunnel and the CHL vent stack test apparatus have shown that rising helium gas interacts with the surrounding air, mixing with it as it rises to predominately produce a mixture with 16.5-17% oxygen. Once combined with air, the helium does not readily separate out of the air/helium mixtures 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 high concentrations of helium (enrichment). Since the helium/air gas mixture is "lighter than air", the mixture rises but at a substantially slower rate than pure helium gas since the mixture is heavier. When natural convection ventilation (in the form of vertical vent tubes) is provided, both oxygen and helium are purged from the enclosure area. The helium/air mixture will displace more of the enclosed space in a vertical downward direction from the ceiling if no additional sources of air are provided to replace the escaping helium/air mixture. Calculations indicate for ideal conditions, where the vented mixture is replaced by air, that we can expect a passive vent capacity of 0.26kg(He)/m^2/s. (Reference: Internal memo – "Helium Vent Investigation, July 9, 2001, Dana Arenius)

The possible sources of ODH producing gases or cryogens in Cave 1 are based on a fully operational quarter-cryomodule with 400L of 2K liquid helium and the associated cryogenic distribution system at 4K located within the UITF accelerator enclosure. Liquid helium is supplied to the quarter-cryomodule from the Cryomodule Test Facility (CTF) refrigerator located adjacent to building 58. The UITF ODH sources of pressurized helium gas are a cryogen distribution 3 atm 4k supply line, a 4K .034/1 atm return line, a warm (300K) 3 atmosphere helium supply line and the component failures associated with the quarter-cryomodule. The cryogen transfer line relief valves are located outside the UITF enclosure either outdoors (supply and shield return lines), in the CTF (primary supply line) or inside the Testlab (shield supply) and do not contribute as a source for ODH for the UITF accelerator enclosure. The quarter-cryomodule has a cryogenic shield circuit with liquid nitrogen supplied from outside the UITF enclosure at a rate of 6.2 liquid liters/minute.

In addition to the quarter-cryomodule, this ODH assessment considers: a fully functional HDIce target attached to an In-Beam-Cryostat of 50L LHe, a 500L LHe buffer dewar, a 500L or 1000L LHe supply dewar and a 100L LN2 service dewar. The helium gas boil off from the HDIce target is captured and returned to the CTF refrigerator, using a return line at 1.08 atm attached to the exhaust port of vacuum pumps used to cool the helium within the HDIce target.

Additionally, gaseous nitrogen is available from a supply line originating at the LN2 dewar that services the Testlab. An ODH analysis, using a smaller cave volume, is documented in JLab Technote "JLAB-TN-07-075" for Room 127 (old cave room number) and requires an orifice bore of 0.114in and an interlock from active fans to a solenoid cut off valve on the N2 supply line that limits the area to an ODH 0 state. These features have been installed in the N2 supply line system.

ODH Analysis

The Test Lab high bay volume is large, roughly 40220 m^3 (81.4m L x 40.5m W x 12.2m H - 1.4 million cubic feet, 267' L × 133' W × 40' H), the high bay is considered to be equivalent to the outdoors. To justify the assumption that the high bay volume is large enough to be considered equivalent to the outdoors, consider 1,900 L of LHe released simultaneously from the quarter cryomodule (400L) and from the HDIce target (500L buffer dewar and a 1000L fill dewar). This amount of LHe would expand to 1481m^3 (52,315 $ft^3$of gas) with a resulting O2 concentration of 20.2% in the Test Lab high bay.

This ODH analysis is based on the premise that the passive venting capacity built into the UITF cave is large enough that ODH gases from failure of any component in the supply circuits will never accumulate to the level where the O2 content will go below 18.5% outside the spill plume. If the O2 content never goes below 18.5% then the fatality factor will be 0 for all failure cases where the passive vent rate is greater than the failure flow rate. Of course O2 levels will be less than 18.5% in the vent plume but the layout of the equipment in the cave does not restrict access to the point where those qualified for ODH work cannot move away to a point where there is no ODH danger. The tables below quantify the flow rates upon failure of any of the circuits associated with the UITF cave with the HDice target and the ¼ cryomodule fully functional. (Note: an alternative analysis methodology is present by Hari Areti in Appendix A which confirms the conclusions from the table below)

Equipment failure and passive vent rates

Item and Event	Spill Rate kg/sec	Passive Vent Rate kg/sec based on 5.9m^2 vent area	Ratio (Spill Rate)/(Vent Rate)	If <1 "Ok", If >/=1 "Issue"
Rupture 4K Supply	0.02	1.50	0.013	Ok
Blocked 4K Return	0.02	1.50	0.013	Ok
Rupture Shield	.015	1.50	0.010	Ok

Supply				
Blocked Shield Return	.015	1.50	0.010	Ok
¼ CM Insul Vac Loss	0.22	1.50	0.147	Concern[+]
¼ CM Beam Line Vac Loss	0.89	1.50	0.593	Concern[+]
Rupture 300K Helium Supply	0.01	1.50	0.007	Ok
Rupture HDice 50L IBC	NA[*]	1.50	NA	Ok
Rupture transfer line 500L Buffer Dewar	0.06	1.50	0.040	Ok
Rupture transfer line Supply Dewar	0.25	1.50	0.167	Ok
Rupture 500L Dewar	63kg[**]	1.50	NA	Issue
Helium Dewar Relief – Spoiled Insulating Vacuum	0.23	1.50	0.153	Ok
Rupture 1000L Dewar	125kg[**]	1.50	NA	Issue
Rupture HDice boil off return line	0.0003	1.50	<<1	Ok
Rupture 100L LN2 Dewar	81kg[***]	NA	NA	Ok
LN2 shield line rupture	0.084****	NA	NA	Ok

Notes:

+ Because of the direction of discharge and distance to substantial passive venting these events remain a concern

*Instantaneous failure of 50L IBC results in a 19.9% O2 concentration in the cave with a fatality factor of 0.

** Instantaneous failure of dewar dumping entire contents results in O2 concentration for 500L of 8.8%, 1000L inerts the cave – Initial operations will be with a 500L supply dewar.

*** Instantaneous failure of dewar dumping entire contents results in O_2 concentration of 18.7% resulting in a fatality factor of 0.

**** This is a release rate of $0.07m^3/s$. It will take 10 mins before the oxygen content in the cave goes down to 19.5%. See the figure and discussion in Appendix B.

Referring to the table above one sees that two concerns and two issues need to be addressed. While the passive venting is able to accommodate a full venting of the ¼ cryomodule, the direction of flow from the reliefs (close to head height) and the long distance to the majority of available venting in Cave 2 is a concern if an actual event were to occur. The venting of the entire helium inventory upon the loss of beam line vacuum in the ¼ cryomodule will take place in approximately 70secs with a large discharge plume. To ensure clear egress and clear flow of the spill out of the cave, the primary relief, the secondary parallel plate relief and the burst disk on the new ¼ CM must be diverted to the outside of the cave. Two of the penetrations on the west wall of Cave 1 have been reserved for that function. The two issues involving dewar failures must be dealt with in a traditional ODH risk analysis taking into account fatality factors and failure rates.

The median failure rate for a dewar from the old EH&S manual chapter 6500-T3 indicates 1×10^{-6}/hr but with a fatality factor of 1 in this case. This results in a P_iF_i product of 10^{-6} and an ODH 1 rating from the presence of a 500L helium dewar or larger. The failure of insulating vacuum on a 500L dewar would trigger the release of gas through the relief valve at a rate which is less than a rupture in the transfer line to the target as quantified in the above table. For this analysis, it is recognized that the most probable failure that would result in an instantaneous dumping of the entire dewar contents would involve the movement of such a dewar. This is taken into account in the analysis of ODH states for the configurations enumerated below.

ODH Ratings and Operational Configuration

Mode 1: The ODH rating of the UITF cave is **ODH 1** when a 500L helium dewar or larger is being moved into/out of the cave or the supply transfer line is being installed into the supply dewar with the roof fully installed.

Mode 2: The ODH rating of the UITF cave is **ODH 0** from the floor to an elevation of 9ft (The height of the bottom of the lintel separating Cave 1 from Cave 2) with the roof fully installed, the primary reliefs of the ¼ Cryomodule diverted outside the cave and the passive vent areas outlined above free and clear for the passage of helium gas. From 9ft up to the ceiling the ODH rating is **ODH 1**. Additionally, the access labyrinth must have a chain-link fence gate allowing free passage of air.

Also, the two 0.30m x 0.46m (12"x18") penetrations on the roof of Cave 1 must have chimneys installed to divert any vented helium above the heads of anyone working in the vicinity of the electronics racks. The six 0.25 (10") diameter ceiling penetrations in Cave 1 must be sealed to prevent the passage of helium.

Mode 3: When the Cave 2 roof is partially removed for work on the HDice target the entire cave is rated as **ODH 0** with all gas and cryogen sources available and the ¼ cryomodule reliefs diverted outside the cave.

Mode 4: When the cave roof is fully installed, during u-tube operations to connect or disconnect the ¼ Cryomodule the entire cave will be rated **ODH 2.** The ODH 2 rating reflects the poor egress conditions from the ¼ Cryomodule during u-tube operations.

Appendix A

Assessment: Cave2 – HDIce Area – Using ceiling vent and chain link entrance gate

Helium:

Helium released in the cave tends to rise towards the ceiling. The ceiling vent is located close to the cryogenic dewars facilitating the venting of cryogenic gases into the high bay. The pressure increase in an enclosure due to release of cryogenic gas is given by $\Delta P = n\,RT/V_c$, where n is moles of the released gas, R is the gas constant, T is gas temperature in K and V_c is the volume into which the gas is released. N = m/M, where m is the mass of the released gas and M is its molecular weight. This equation could be rewritten as $\Delta P = mRT/MV_c$. Since m/V_c is the density of gas, rearranging the equation gives, $\rho = M\,\Delta P/RT$ or, $\Delta P/\rho = RT/M$. Recognizing that $\Delta P/\rho$ is related to the volume flow, we find that volume flow of gas is given by

$$V = A\,C\sqrt{\frac{2\Delta P}{\rho}}.\ \text{Or, } V = A\,C\sqrt{\frac{RT}{M}}.$$

There will be no ODH hazard in cave2 if the volume of the released gas is replaced by the air entering the cave from the openings. No ODH condition then is,

$$A_d\,C_d\sqrt{\frac{2\Delta P}{\rho}} < A_c\,C_c\sqrt{\frac{RT}{M}},\ \text{where}$$

A_d is the area of the dewar's transfer tube, ΔP is the pressure in the dewar and ρ is the density of liquid in the dewar, A_c is the area of the ceiling vent and C_d and C_c are discharge coefficients. Using the values for expansion factor of Helium (750) and the gas constant R = 0.0083 $m^3\cdot Kpa.mol^{-1}K^{-1}$,

$$\sqrt{\frac{2\Delta P}{\rho}} < B\sqrt{\frac{T}{M}},\ \text{where}$$

$B = (1/750)(A_c/A_d)(C_c/C_d)\sqrt{R}$. Substituting values for gas constant R, $B = 1.2\ 10^{-4}(A_c/A_d)(C_c/C_d)$.

Note that for any gas mixture in this document $\sqrt{\frac{T}{M}}$ is never less than 1 - even when T is 5K, for Helium its value is 35 and, for air its value is 13.

If we make a reasonable assumption that C_c/C_d is 1, the condition for no ODH reduces to

$$\sqrt{\frac{2\Delta P}{\rho}} < 1.2\ 10^{-4}(A_c/A_d)\sqrt{\frac{T}{M}}$$

Dewar	$\sqrt{\frac{2\Delta P}{\rho}}$	$1.2\ 10^{-4}(A_c/A_d)$
1000L LHe	0.22	2.7
500L LHe	0.22	10.6

The above table shows that the openings in UITF exclude ODH conditions in Cave2 due to transfer pipe ruptures of the Helium dewars, even without the $\sqrt{\frac{T}{M}}$ factor. Note that this analysis is valid even when the two caves are considered together. In the coupled cave case, T will be larger than if only Cave2 is considered because the gas released has to warm up a larger volume.

Rupture of the In-Beam-Cryostat will increase the pressure in the cave and move the gas towards the ceiling vent. This requires a different calculation, based on the gas law, and calculating the pressure increase in the cave. One can use this pressure increase in the formula for volume flow to find the flow rate of Helium through the ceiling vent. However, in this document we will not take credit for venting of this small amount of Helium. At 19.3% oxygen content due to In-Beam-Cryostat rupture, (if only Cave2 is considered), the fatality factor for this incidence is zero. If the entire UITF volume is used, the oxygen content is higher (19.9%) and again there is no ODH.

An earlier leak test has established a volume vent rate for Helium as $0.26kg/m^2/s$. (Ref. 1). The 5.6 m^2 ceiling vent of UITF can vent 1.4 kg/s. The $1.5m^3/s$ of Helium spill from 1000L dewar is equivalent to 0.25kg/s of spill. Thus, both the calculations shown in this document and the data from spill test show no ODH due to Helium spill from dewars in Cave2. (The conditions for the test are different from those in UITF. There was a 10.7m chimney but the enclosure did not have a chain link fence type opening that UITF. Not having such an opening limits the flow of gas mixture through the chimney).

Relevant Data:
Percentage of Oxygen in ambient air = 21%
Oxygen level below which ODH exists = 19.5%
Cave2 ambient temperature = 300K
Cave2 Volume = 441 m^3
Ceiling vent area = 5.6 m^2

Pressure in liquid Helium dewars = 13.8KPa
Transfer pipe diameter of $1m^3$ dewar = 0.00635m
Transfer pipe diameter of $0.5m^3$ dear = 0.003175m
Expansion factor for 4K He = 750
Expansion factor liquid N_2 = 700
Pressure in liquid Nitrogen dewar = 139KPa
Transfer Pipe diameter of Nitrogen dewar = 0.003175m

From Reference 1:
Rate of escape of Helium = $250g/s/m^2$
Volume of Helium venting through $1m^2$ vent= 0.002 m^3/s
Volume Helium venting capacity of 5.6 m^2 vent in Cave2 = 0.0112 m^3/s

Formulas and constants Used:

Volume flow of fluid V= A C $\sqrt{\frac{2\Delta P}{\rho}}$, where A is the area of the opening, C is the discharge coefficient, ΔP is the pressure differential and ρ is the density of the fluid.

The value of C will be less than 1 due to friction. In this document, we assume C to be 1 for liquid Helium and liquid Nitrogen venting from the dewars which dilutes the oxygen content of ambient air more quickly.

Mass flow M = V* ρ
% Oxygen Content in a volume = $(V - V_r)/V$, where V is the volume of the cave and V_r is the volume of the released gas.

R = $0.0083 m^3 \cdot Kpa.mol^{-1}K^{-1}$
Molecular Weight of Helium = 0.004kg/mol
Molecular Weight of Nitrogen = 0.028kg/mol
Molecular Weight of air = 0.029kg/mol
Density of Liquid Helium = 125kg/ m^3
Density of Helium at 300K = 0.165kg/ m^3
Density of Liquid Nitrogen = 810kg/m^3
Density of Nitrogen at 300 K = 1.165kg/m^3

Appendix B

Nitrogen:

There are two sources of nitrogen. One is the 100 L Nitrogen dewar and the other is the liquid nitrogen shield supply to the quarter-cryomodule.

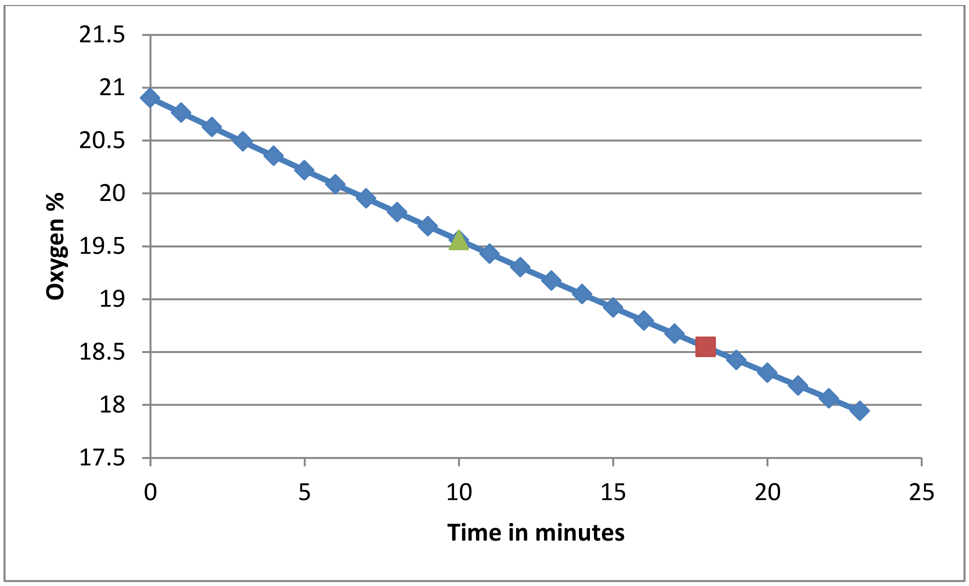
Instantaneous rupture of the 100L dewar dumps all of nitrogen into the cave which amounts to 70 m^3 of nitrogen in the cave's volume of 648 m^3. The percentage of oxygen in the cave is

21 * (1- nitrogen volume/cave volume), where 21 is the percentage of oxygen in air.

In the case of shield supply transfer line failure, the amount of nitrogen that will enter the cave is 6.2 L/min, which is equal to 4.34 m^3/min of gas. Since the UITF has a large vent and an open entrance (chain link gate), we assume that the volume of gas in UITF stays the same though the oxygen content is going down. The rate of loss of oxygen in air is calculated as follows:
The original, (at time =0 mins) percentage of O_2 is X(%)/648 m^3 (Vol. of UITF). The rate at which O_2 is leaving UITF (due to N_2) is 4.34 m^3/min. giving the rate at which O_2 is depleted from UITF

as 4.34/648 per minute. Therefore, the rate of change in O_2 concentration in the cave with time is $dX/dt = -X * 4.34/648$. Thus, the percentage of O_2 in UITF after time t minutes is $X = C * \exp(-4.34t/648)$, where C is the constant of integration which can be valuated as 21 at time t= 0.

The graph below shows the concentration of Oxygen with time in case of a rupture. ODH alarms are set to alert occupants when the oxygen level reaches 19.5%. The occupants have 17 mins to exit UITF before the oxygen level falls to 18.5%.



UITF PSS Sweep Procedure

Document Number: SSG-PR-17-001

Revision Number: Rev. 1; February 13, 2017

Technical Custodian: Henry Robertson

Estimated Time to Perform: ~10 minutes

Procedure Overview

This procedure documents the protocol for performing sweeps of the Upgrade Injector Test Facility (UITF). A sweep, which verifies that all personnel have exited the area, must be carried out before changing the Personnel Safety System (PSS) state from OPEN to RUN mode.

Prerequisites

The sweep requires only one person, but he/she must be certified by the Safety System Group as a qualified sweeper for the area to be swept.

Sweep Team Responsibilities

1. Lead Sweeper – Qualification requires that the Lead Sweeper be familiar with the sweep procedure and have participated in a sweep of the area at least once.

2. The sweep team shall do the following:
   a. Check in all confined areas, such as behind cryomodules, cable trays, storage bins, etc.
   b. Arm all Run/Safe boxes in the proper order without deviation.
   c. Perform the sweep in a timely manner.
   d. Ensure that all exit doors are pulled tight and locked.
   e. Ensure that all crash switches are not activated
   f. Have anyone found in the sweep area during a sweep *accompany the sweep team for the remainder of the sweep.*

3. The sweep team *shall NOT* do the following:

   a. Perform any function other than those listed in Step 2, above. Mixing responsibilities can lead to distractions and the possibility of missing personnel in the sweep area. If a problem is found that needs attention or repair, fix it after the sweep has been completed and the area is in Controlled Access. *Do not stop the sweep to perform maintenance.*

   b. Leave any area unguarded. This might lead to someone deliberately or accidentally getting behind the sweep team when they are not looking.

   c. Have more than two people sweeping an area at any one time. An exception to this rule is that up to five personnel can participate in a sweep for training purposes.

   d. Allow anyone found in the tunnel during a sweep to remain behind while the sweep team finishes the sweep. This means that the sweep team *shall not* allow anyone found in the enclosure to continue their work and "get them on the way back." Anyone found in the sweep area during a sweep *MUST* accompany the sweep team for the remainder of the sweep.

4. The sweep team must be alert for any unusual conditions in the sweep areas, such as tools, wiring, or shielding out of place, and notify responsible personnel before securing the area.

Pre-Sweep Steps

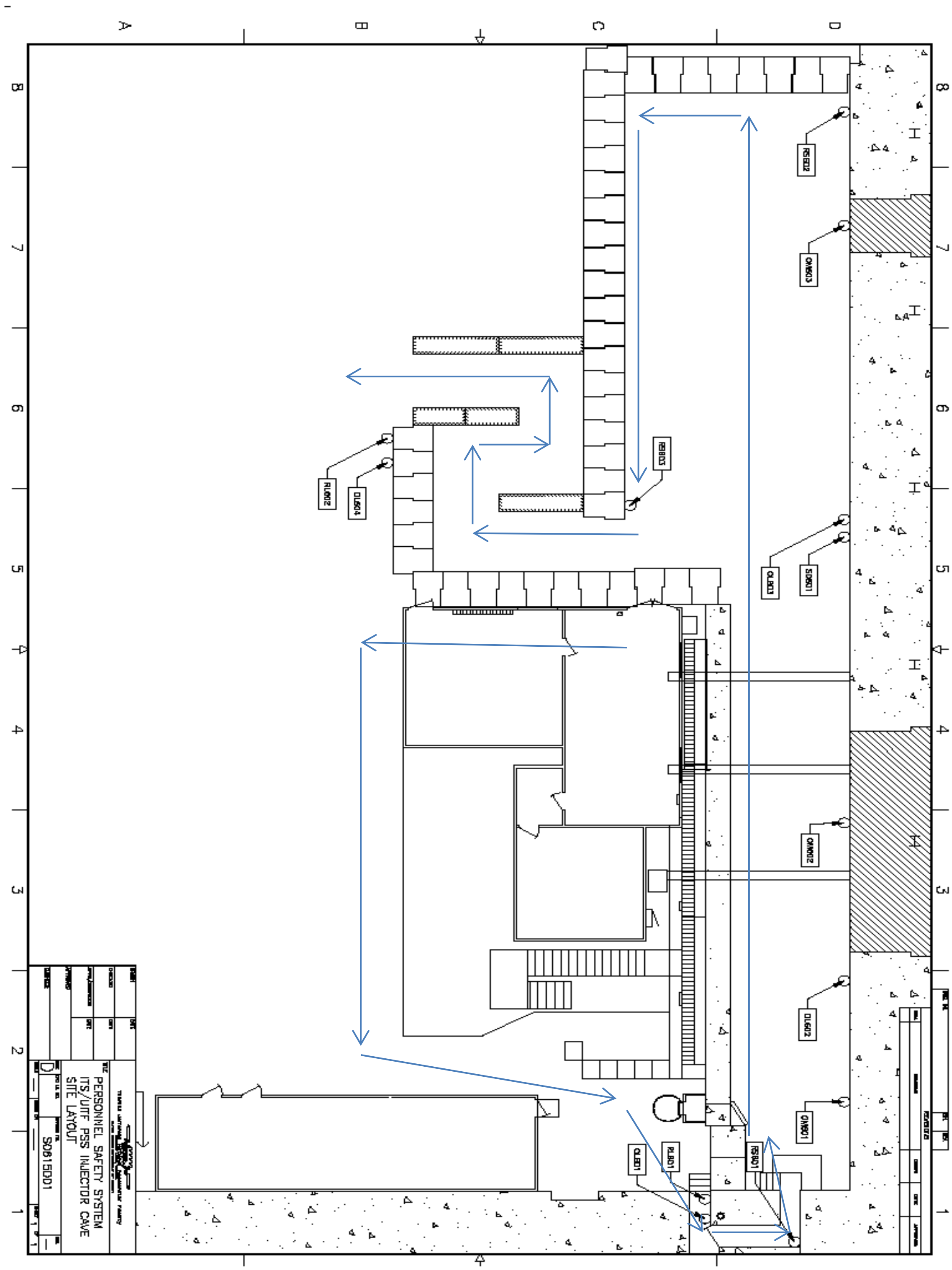
1. Post the top (mezzanine) of Cave 1 as a restricted area
2. Inform all occupants to leave the UITF enclosure
3. Verify that all access room crash switches are not activated (i.e. the switch is not pushed in)
4. Close both doors completely
5. Confirm that the magenta beacons are flashing (this assures that the system is ready for a sweep)

NOTE: The total time allowed for the sweep is 5 minutes.
That's from initializing the sweep with the key to closing the last door.

Detailed Sweep Sequence

Step	Sweep Team	
1	Complete all pre-sweep steps. **NOTE:** A detailed sweep map for the FEL vault is available as a hard copy in the PSS binder or on-line at: https://jlabdoc.jlab.org/docushare/dsweb/View/Collection-27494/	
2		a. Go to control room and turn the key in the left hand lock from OPEN to SWEEP and remove it. NOTE: Once you turn the key to SWEEP you have 60 seconds to enter the cave through Door 2 before the Sweep drops. b. Confirm that the magenta beacons are flashing (this assures that the system is ready for a sweep) c. The Lead Sweeper enters Cave 1 through the back door (D2). d. Arm RunSafe Box 601 in the hallway. e. Verify that the area behind the gun and the 1/4 cryomodule is unoccupied. f. Verify the Faraday Cup is locked in place and the valve to the ¼ cryomodule is locked CLOSED. g. Sweep the enclosure, walking all the way to the north wall of Cave 2. h. Look behind the beam line, cable tray, and any large obstacles. i. Arm RunSafe Box 602 near labyrinth exit. NOTE: Once the box is armed you have 30 seconds to exit the cave and close the door. j. Exit Cave 2 through labyrinth and cage door (D1). k. Wait outside the cage door for up to 30 seconds and confirm that the door locks. l. Return to the control room and replace the key into the right hand lock. Turn the key from SWEEP to RUN to arm the Personnel Safety System when ready.

Sweep Map


PERSONNEL SAFETY SYSTEM
ITS/UITF PSS INJECTOR CAVE
SITE LAYOUT
S0615D01

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: ACC-17-65773-OSP

Title: keV beam line of the Upgraded Injector Test Facility (UITF)

Name	Signature	Date