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Operational Safety Procedure Review and Approval Form # 74230
(See [ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure \(OSP\) and Temporary OSP Procedure](#) for Instructions)

Type:	<i>OSP</i> Click for OSP/TOSP Procedure Form Click for LOSP Procedure Form		
Serial Number:	<i>ACC-18-74230-OSP</i>		
Issue Date:	<i>6/6/2018</i>		
Expiration Date:	<i>4/6/2021</i>		
Title:	<i>QCM Operation at the Upgraded Injector Test Facility (UITF)</i>		
Location: (where work is being performed) Building Floor Plans	<i>58 - Test Lab - 1127</i> <table border="1"><tr><td>Location Detail: (specifics about where in the selected location(s) the work is being performed)</td><td><i>The UITF enclosure, the UITF control room, and the Cave1 rooftop and surrounding areas</i></td></tr></table>	Location Detail: (specifics about where in the selected location(s) the work is being performed)	<i>The UITF enclosure, the UITF control room, and the Cave1 rooftop and surrounding areas</i>
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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 : <i>Determined to have an unmitigated Risk code of 3 or 4</i>		
Owning Organization:	<i>ACCCIS</i>		
Document Owner(s):	<i>Poelker, Matthew (poelker@jlab.org) Primary</i>		

Supplemental Technical Validations

Cryogenic Material - Gas or Liquid (Jonathan Creel, Kelly Dixon)
Mode 1: Class 1, 2, and 3 Electrical Equipment (Paul Powers, Todd Kujawa)
ODH 0 and 1 (Imani Burton, Jennifer Williams)
ODH 2 and Higher (Imani Burton, Jennifer Williams)
Pressurized Tanks, Containers, and Vacuum Vessels (Dave Meekins, Kelly Dixon, Timothy Whitlatch, Will Oren)
Pressurized Vacuum Lines and Piping Systems (Dave Meekins, Kelly Dixon, Timothy Whitlatch, Will Oren)
Controlled Area (David Hamlette, Keith Welch)
Radiological Controlled Area (David Hamlette, Keith Welch)
Radio Frequency (Imani Burton, Jennifer Williams)

Other Hazards:
klystrons (Rick Nelson)

Document History

Revision <input type="checkbox"/>	Reason for revision or update <input type="checkbox"/>	Serial number of superseded document <input type="checkbox"/>
2	<i>This is my second official submission of this document using the OSP tool</i>	<u>previous submission was not assigned a serial number</u>
Comments for reviewers/approvers: <input type="checkbox"/>	<i>I want to apologize for how long this is taking, and the number of times I've put this document in your in-box. You have been extremely helpful and I hope all the relevant issues have now been addressed. In a separate email, I describe the changes I've made to this document, how I've addressed your comments. Thanks, Matt</i>	
Attachments <input type="checkbox"/>		
Procedure: <i>UITF-OSP_commissioning_QCM with RF_no beam_5_14_2018_per revision JW, KW, KD, VV, CP, MP, JK, RN, HF.pdf</i> THA: <i>UITF THA-QCM commissioning_5_16_2018_revision per JW, KD and RN.pdf</i> Additional <i>ODH_UITF - Final Approved.pdf</i> Files: <i>UITF PSS Sweep Procedure2-v3.pdf</i> <i>CP-C100-CMTF-CM-CAV-EMAX-V1.pdf</i>		
Review Signatures		
Person : Subject Matter Expert : klystrons	Signed on 5/24/2018 3:30:46 PM by Rick Nelson (nelson@jlab.org)	
Subject Matter Expert : Cryogenic Material - Gas or Liquid	Signed on 5/29/2018 11:51:49 AM by Kelly Dixon (kdixon@jlab.org)	
Subject Matter Expert : Electricity->Mode 1: Class 1-> 2-> and 3 Electrical Equipment	Signed on 5/17/2018 10:54:24 AM by Todd Kujawa (kujawa@jlab.org)	
Subject Matter Expert : Oxygen Deficiency Hazards (ODH)->ODH 0 and 1	Signed on 5/23/2018 10:00:29 AM by Jennifer Williams (jennifer@jlab.org)	
Subject Matter Expert : Oxygen Deficiency Hazards (ODH)->ODH 2 and Higher	Signed on 5/23/2018 10:00:33 AM by Jennifer Williams (jennifer@jlab.org)	
Subject Matter Expert : Pressure Systems->Pressurized Tanks-> Containers-> and Vacuum Vessels	Signed on 5/17/2018 10:34:57 AM by Will Oren (oren@jlab.org)	
Subject Matter Expert : Pressure Systems->Pressurized Vacuum Lines and Piping Systems	Signed on 5/17/2018 10:41:22 AM by Will Oren (oren@jlab.org)	
Subject Matter Expert : Radiation - Ionizing->Controlled Area	Signed on 5/29/2018 9:02:23 AM by Keith Welch (welch@jlab.org)	
Subject Matter Expert : Radiation - Ionizing->Radiological Controlled Area	Signed on 5/29/2018 9:02:28 AM by Keith Welch (welch@jlab.org)	
Subject Matter Expert : Radio Frequency	Signed on 5/23/2018 10:00:43 AM by Jennifer Williams (jennifer@jlab.org)	
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Operational Safety Procedure Form
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Title:	QCM Operation at the Upgraded Injector Test Facility (no beam acceleration)		
Location:	Upgraded Injector Test Facility (UITF) located in the Test Lab High Bay Area, rooms 1127-1129	Type:	<input checked="" type="checkbox"/> OSP <input type="checkbox"/> TOSP
Risk Classification (per Task Hazard Analysis attached) (See ESH&O 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:	May 16, 2018
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 applying high power RF to the cold Quarter Cryomodule (QCM) at the Upgraded Injector Test Facility (UITF), but not accelerating beam. There are two main concerns: prompt ionizing radiation as a result of field emission inside the QCM, and ODH conditions that result from cryogenic conditions required to operate the SRF accelerating cavities.

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 RF-commissioning of the QCM at 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.

High Power RF Commissioning of the QCM (no beam acceleration)

Apply high power RF energy to the cold QCM located inside the UITF enclosure using two klystrons. One klystron drives a unique 2-cell accelerating cavity described as an rf-capture section, and the other drives a 7-cell cavity similar to those used in C100 cryomodules at CEBAF. Compare RF performance at UITF to performance previously measured at Cryomodule Test Facility (CMTF). This is a necessary first step before using the QCM to accelerate an electron beam.

At UITF, liquid nitrogen at 80K will be used for the shield line, and not helium at 35K, which is the typical cryomodule configuration. This reduces the cryogenic burden on the Cryogenic Test Refrigerator (CTF) and we avoid repeated cooling and warm up cycles of the QCM. But depending on QCM performance, the shield line might also be operated with helium in the shield circuit.

Besides evaluating the performance of the QCM, we will be commissioning a brand new cryogenic system (the QCM connected to CTF with new controls and piping), and a new high power RF system (new high power amplifier and klystron racks). The klystrons used at UITF represent “CEBAF spares” and are expected to operate at 5 kW maximum power (typical CEBAF operating condition). Based on QCM performance observed at the CMTF, and based on the beam energy requirements of UITF (5 to 10 MeV), the QCM is not expected to operate in a field emission regime. The purpose of this OSP is to evaluate the onset of field emission now that the QCM is positioned inside the UITF enclosure.

The implementation of this OSP also represents the first tests of the cold and energized QCM interfaced to a new PSS system.

The affected area is the entire UITF enclosure composed of Cave 1 and Cave2, and the region above Cave1 where the electronics racks are located (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 QCM operation with RF (no beam acceleration) which occurs in Cave 1, but also affects Cave2 because Cave1 and Cave2 form a common space. The names “Cave1” and “Cave2” are convenient designations, referencing old and new test areas, respectively. 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.

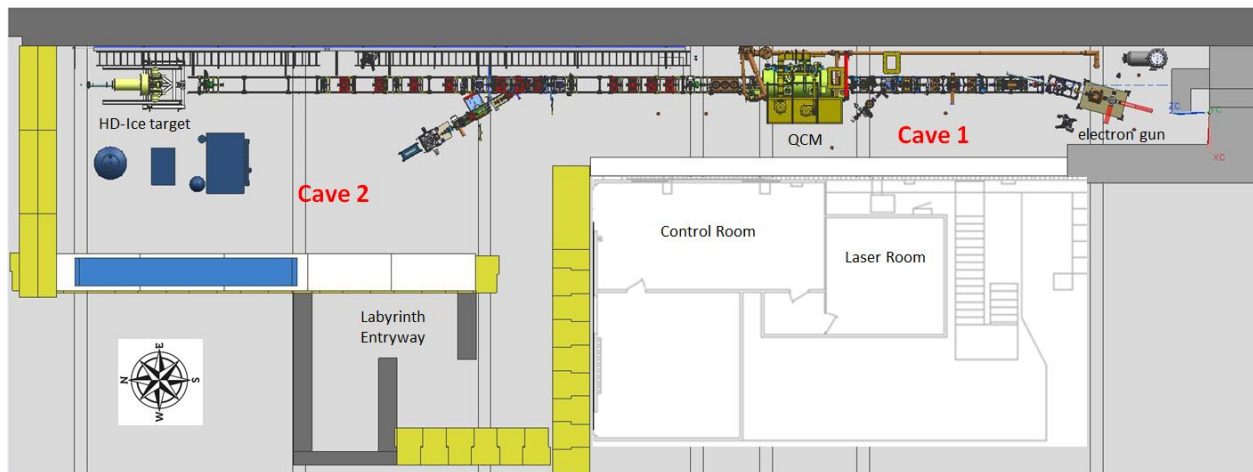


Figure 1: UITF beamline layout showing the two Caves. The QCM is inside Cave 1

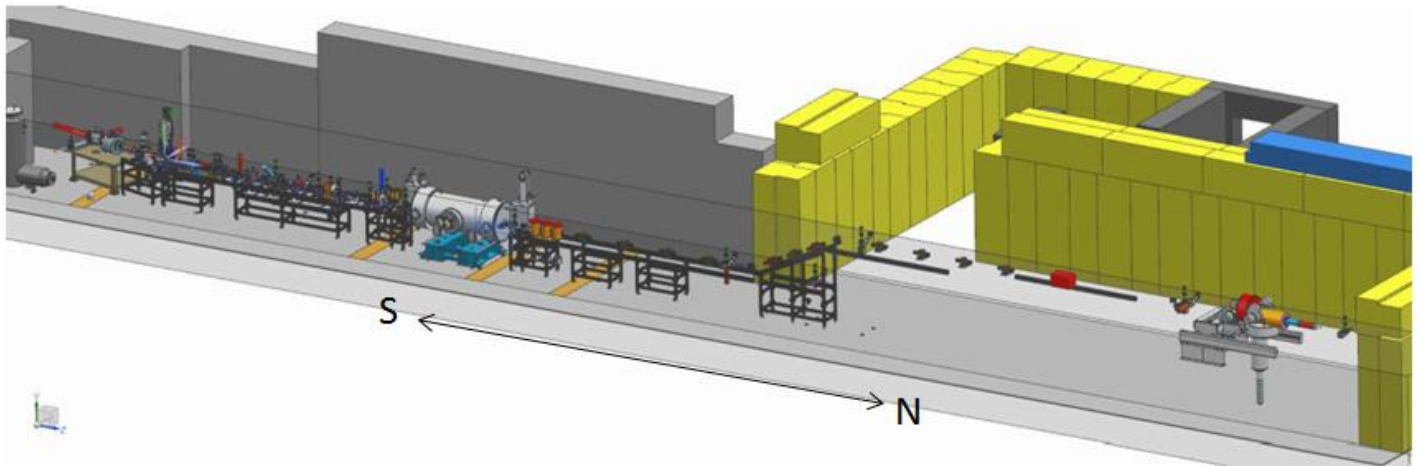


Figure 2: UITF layout showing the main exit towards the high bay area of the Test Lab and preliminary layout of the elevated beamline toward the HD-Ice target

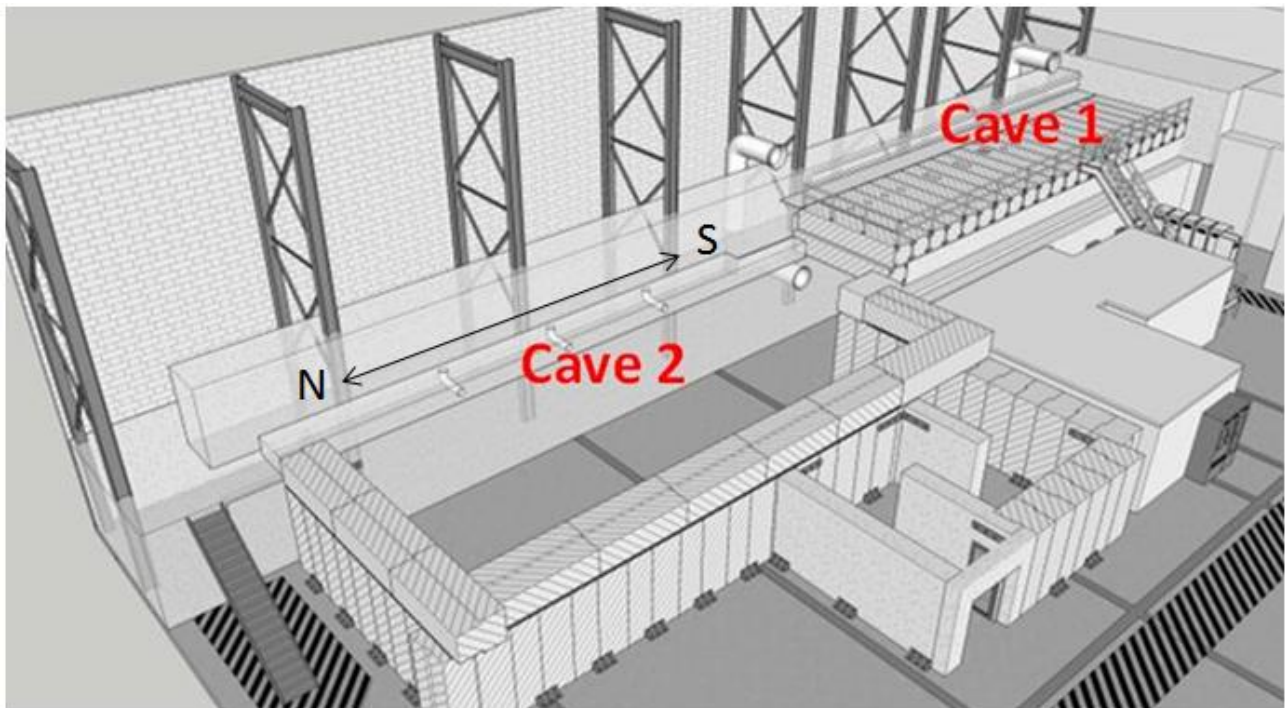


Figure 3: UITF layout showing the main entrance Labyrinth and shielded roof of Cave 1. The klystrons and RF controls are located above Cave1. Cryogenics are delivered to UITF from the CTF via piping that enters at the south end of Cave1.

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. RF Non-ionizing Radiation
3. Oxygen Deficiency
4. Electrical
5. Pressure / Vacuum

5. Authority and Responsibility:

5.1 Who has authority to implement/terminate

- **Facility Manager** – This responsibility is assigned by the Accelerator Division Associate Director. This individual has ownership of the facility and has overall responsibility for safe configuration and operation of the facility. Matt Poelker is the present UITF Facility Manager, but others in the Center for Injectors and Sources could be assigned this designation too.
- **Principal Investigator (PI)** – The PI is assigned by the Facility Manager. The PI has overall responsibility for a given test plan or experiment. The PI is responsible for planning and executing the test plan, ensuring that operations are carried out in a safe manner, directing the activities of system operators while they are on shift, and insuring that the facility is properly staffed. The PI must be cognizant of the status of the facility and any device under test in the facility for the duration of the test. The PI must have a thorough understanding of the configuration and operation of the relevant systems required for the execution of the planned experiments. For most routine operation, the Facility Manager may also serve as the PI. Presently, PIs are members of the Center for Injectors and Sources, the SRF Institute, and the Injector Group of the Operations Department.

5.2 Who is responsible for key tasks

- **Principal Investigators (PI's)** have to demonstrate to the Facility Manager that the test is appropriate. The PI must ensure that tests can be performed in a safe manner. The PI or approved designee must be on-call while the respective test is being performed. Members of the SRF Institute will be considered PIs during initial cooldowns and for RF commissioning.
- **RF System Operators:** They are members of the Engineering Division familiar with RF control systems and power amplifiers. They assist the Principal Investigators in the execution of tests and the changing of RF system configurations. They must have a thorough understanding of the configuration and operation of the PSS and MPS systems, as well as the configuration of the MPS and RF systems required for the execution of the planned experiments. They should also have a general understanding of the interactions of the cryogenic systems with the specific RF tests. They are responsible for safe operation of the facility and have the authority to stop any experiment if they feel that there is unnecessary potential to damage equipment or if there is an elevated level of risk of injury.
- **Cryogenic System Operators:** They are members of the Cryo Group, within the Engineering Division. They assist the principal investigators in the execution of tests and the changing of cryogenic system configurations. They must have a thorough understanding of the configuration and operation of the cryogenic systems required for the execution of the planned experiments. They should also have an understanding of the interactions of the specific RF tests with operations of the cryogenic systems. They are responsible for safe operation of the facility and have the authority to stop any experiment if they feel that there is unnecessary potential to damage equipment or if there is an elevated level of risk of injury.

- **UITF Operator:** UITF Operators are people familiar with electron beam generation, delivery and acceleration. Presently UITF Operators are members of the Center for Injectors and Sources, and the Operations Department.
- **The Radiation Control Department (RCD)** insures that all radiation safety requirements, e.g. shielding configuration and postings, are met for this specific running mode. RCD will provide radiation survey support as well as maintenance support of any radiation monitoring equipment that is associated with Personnel Safety.
- **Industrial Hygiene** shall provide RF survey assistance upon request.
- **The Group Leader of the Safety Systems Group (SSG)** or his designee is the owner of the Personnel Safety System (PSS).

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](#))

Task Hazard Analyses (THA's) for any Test Plans that require operation of the facility in a manner that is outside the scope of this OSP and existing THA's will be executed by the Facility Manager acting in concert with the relevant Subject Matter Experts (SME's):

SME's will include but are not limited to the following individuals or their designees:

- Chris Perry – Cryogenic Safety
- Jerry Kowal - Safety Systems Group Leader – PSS, MPS and ODH Monitoring
- Rick Nelson – RF Safety
- Keith Welch – Radiation Control Department
- Harry Fanning – Accelerator Division Safety Officer
- John Hansknecht – Safety Warden
- Jennifer Williams – Oxygen Deficiency
- John Fischer – SRF cool down procedure
- Mike Drury – SRF commissioning/operation of the QCM

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
- 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
- Read and sign this OSP

6. Personal and Environmental Hazard Controls Including:

6.1 Shielding

The accelerating cavities inside the QCM can be driven with sufficient RF power to initiate field emission, which will produce X-rays. And field emission accelerated to sufficiently high energy (>

8 MeV) can make some materials radioactive. The Radiation Control Department (RCD) has recommended and evaluated the shielding at UITF to mitigate radiation hazards.

Key Shielding Features:

The east wall of the UITF enclosure (see figure 1) is many meters thick and is an effective radiation barrier. The west wall of Cave1 is 55” thick to a height of approximately 7’. Above 7’, the wall thickness is approximately 27 to 28” thick. Cave 1 has 30” concrete shielding on the roof. There are nine penetrations in the Cave1 ceiling. Six circular penetrations (~ 10” diameter) provide a means to pass cables to connect beamline devices to the controls located in the electronics racks above. One rectangular penetration serves to pass RF waveguides from klystrons to the QCM. And two rectangular penetrations provide a means for helium gas to escape the UITF enclosure (see section 6.5 Ventilation). All of the penetrations, except the one used for RF waveguides, have 3.5” iron shielding directly beneath (Figure 4, below). The RF waveguide penetration is filled with sand (Figure 5).

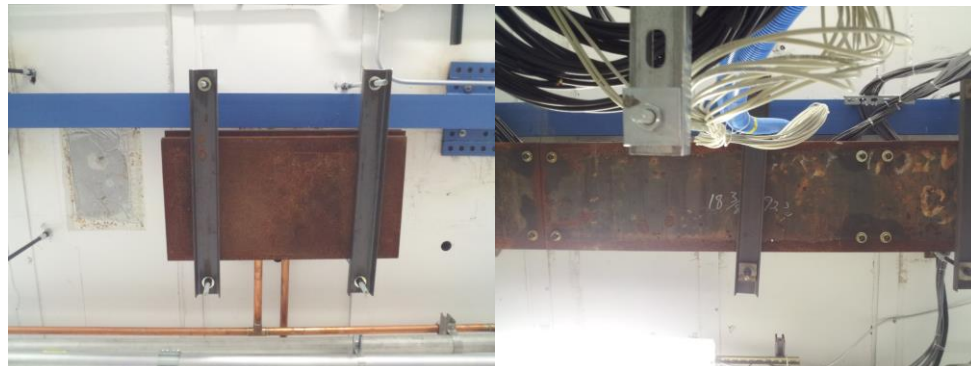


Figure 4: Steel plates covering penetrations in Cave1. Cables pass through the penetrations linking the electronics racks and beamline elements.

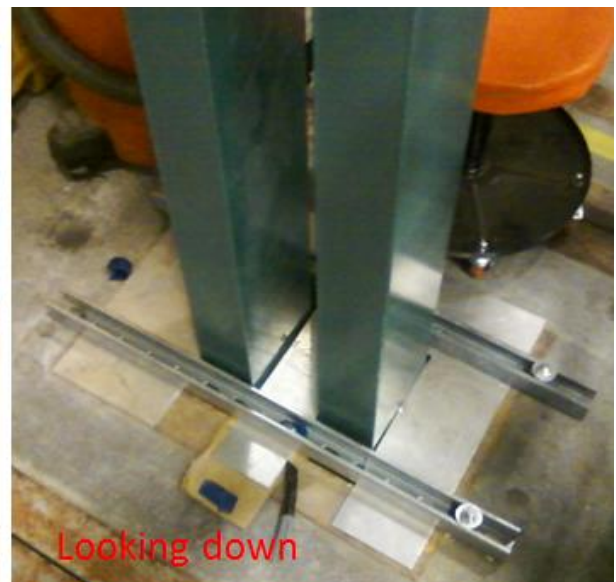


Figure 5: images of RF waveguides passing through a ceiling penetration in Cave1, connecting the QCM to klystrons. Left: view from inside the UITF enclosure looking up toward the ceiling, Right: view from cave rooftop, looking down, near the klystron racks.

Two penetrations serve as helium vent holes should the Cave1 enclosure fill with helium gas. Above the cave, these penetrations have “chimney stacks” attached (more in Section 6.5 Ventilation), to direct the light helium gas safely above the heads of occupants who might be working atop the Cave1 enclosure. Bags of gravel placed at the base of each chimney-vent stack provide additional shielding at these penetrations.

Although the QCM is located in Cave 1, the entire UITF enclosure (Cave 1 and 2) will be swept and made clear of personnel. The main entrance labyrinth and the south access labyrinth prevent line of sight exposure to x-ray radiation for people working in the main high bay area outside the UITF enclosure.

An assessment by the Radiation Control Department (RCD) indicates Cave1 is adequately configured with sufficient shielding to mitigate radiation hazards. The link to the shielding calculations can be found at: https://misportal.jlab.org/doc_validation/processes/13

The top of the UITF Cave1 roof is accessible during QCM operation but the area is considered a Radiologically Controlled Area (RCA) with signage provided by RCD indicating access restrictions and dosimeter requirements. Signage will be posted at the bottom of the stairs leading to the Cave1 roof (see Figure 6). RCD will monitor radiation levels and add, modify or remove postings as appropriate based on prevailing conditions. It is presently assumed that the minimum posting level of the Cave1 roof will remain RCA for the duration of QCM commissioning and subsequent commissioning of the accelerator.



Figure 6: During UITF operations, the top of UITF Cave1 roof is a Radiologically Controlled Area and dosimetry is required to access the roof.

During initial QCM commissioning, RCD will conduct radiation surveys of accessible areas outside the UITF enclosure to verify shielding effectiveness and establish final operational limits, alarm thresholds, and postings.

Activation

High-gradient accelerating cavities such as the 7-cell cavity used in the QCM have shown the potential to produce radioactivity when operated at high power. Under certain conditions, the energy of the photon field produced by field emitted electrons may exceed the threshold for giant resonance photo-nuclear interactions. These interactions result in the emission of neutrons and the production of residual radioactivity. This phenomenon is difficult to predict. However, the onset of the condition is easily detectable by means of neutron radiation monitoring in the vicinity of the cryomodule or direct survey after shutdown. See section 6.4 for specific procedures related to this.

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

The QCM is under vacuum, and for this test, the valves to the adjoining beamline are closed, with epics control of the valves disabled. Because the valves are closed, there is no possibility of injecting and accelerating an electron beam through the QCM.

The doors to UITF represent barriers, these are described below in Section 6.3 Interlocks

6.3 Interlocks

The UITF's Personnel Safety System (PSS) ensures that personnel cannot access the UITF enclosure when prompt radiation hazards are possible. And the PSS will turn OFF radiation sources when unacceptable radiation levels are detected by CARMS placed outside the enclosure at locations designated by RCD. Radiation exposure is prevented through both administrative (sweep procedures, locked gates, postings) and engineered means (shielding, interlocks, radiation monitoring, etc.). UITF (see Figure 7) 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 QCM.

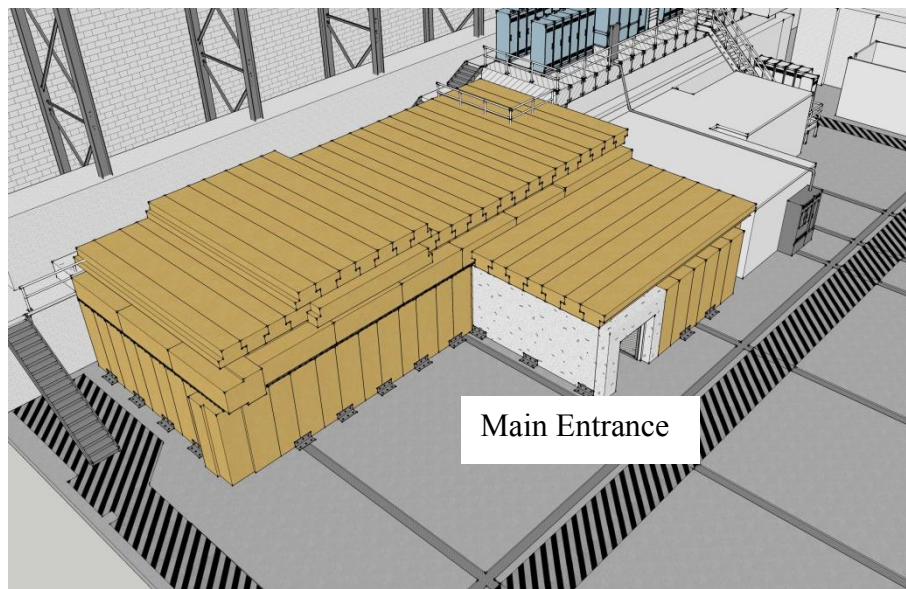


Figure 7 UITF With concrete shielding in place

As mentioned above, there are two entry/exit ways at the UITF. The main entrance/exit is from the high bay area through a labyrinth that leads to Cave 2. The secondary entrance/exit into the high bay is from the southern-most location of the keV section in Cave 1. Both doors have Personnel Safety System interlocks and emergency exit switches on the nearby walls (Right). Beacons exist at both entrance/exit ways. Photographs of the entry/exit ways are shown in Figures 8 and 9, along pictures of the run safe box, signage, and the warning beacons.

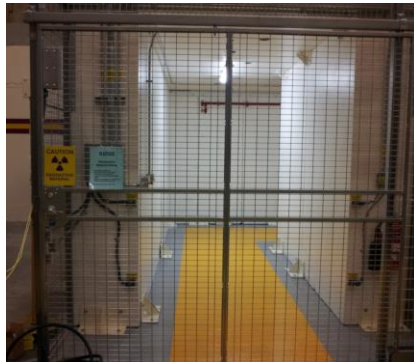


Figure 8 (Left) Main entrance/exit through the labyrinth of UITF, (Middle) Secondary entrance/exit from the southern-most location of the keV section in Cave 1. Both doors have Personnel Safety System interlocks and emergency exit switches on the nearby walls, (Right) Beacons exist at both entrance/exit ways



Figure 9 (Left) Exit door into high bay from Cave1 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

There are four PSS states: OPEN, SWEEP, READY and RUN. OPEN state is the safe state, when doors are open and the UITF enclosure can be occupied by personnel. The RUN state issues “permits” to RF sources, the Gun High Voltage power supply and PSS laser shutters. “Permits” allow these devices to be energized.

There are radiation monitors – referred to as CARMs – that are interlocked to the PSS system. CARMs are used to detect radiation outside the UITF enclosure. CARM placement is determined by the RCD, see Figure 10 for approximate CARM locations above Cave1. An additional interlocked probe is located in the Control Room. When CARMs detect unacceptable levels of radiation in Run state, the PSS will drop to READY state, removing all the permits.

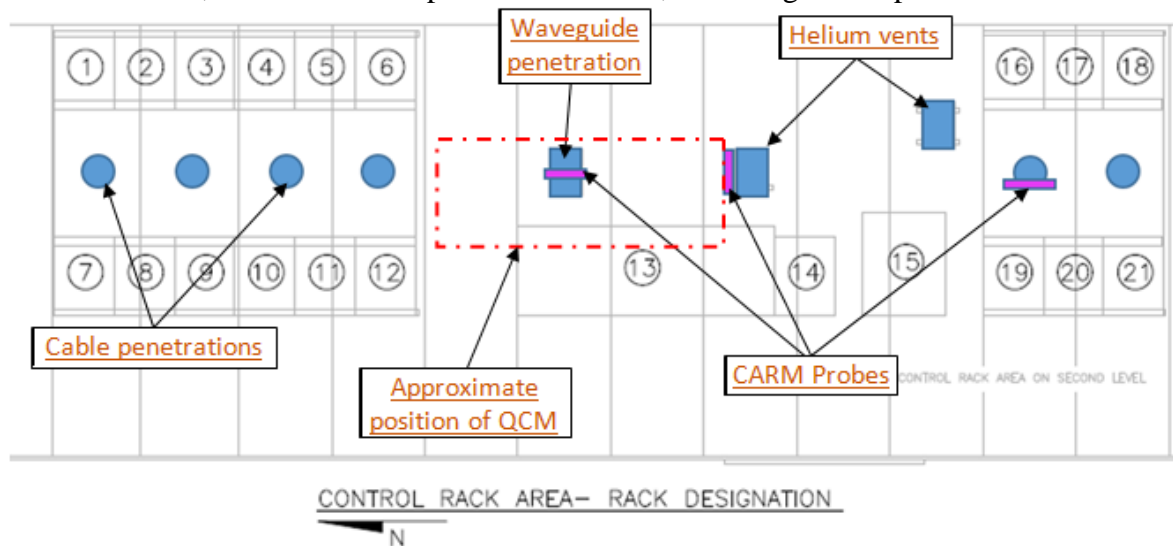


Figure 10, schematic layout of the electronics racks above Cave1 showing approximate location of CARM probes on the Cave1 rooftop. There is also a CARM in the Control Room.

In OPEN state, 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, with magnetic locks that engage and prevent entry when the UITF enclosure is swept and the PSS is set to the RUN state. When door interlocks are breached while the PSS is in the RUN state, it will drop to OPEN state and turn OFF all radiation sources.

Additional details related to the PSS interlocks:

There are signals warning about potential prompt radiation:

- Magenta Beacons are active as soon as UITF PSS Controller is switched to SWEEP State and these beacons stay ON for all higher States. Beacons are located at both doorways and above Cave1 near the electronics racks
- 30s siren is turned ON, when UITF is about to switch to RUN State. This means the RUN State is delayed by 30s while the warning siren sounds

In addition, when a CARM is tripped, it drops the UITF PSS Controller from RUN State to READY (safe) activating latched audible and visual alarm indicators in the UITF Control Room. The audible alarm can be silenced when RESET pushbutton is pressed once. If the cause of alarm is not present anymore, then the RESET pushbutton, when pressed 2nd time, will clear the visual alarm. It is not necessary to clear the latched alarms to return to RUN State as long as there is no active CARM trip. Trip of the CARMs will trigger radiation alarm (audible and visual) at the UITF Control Room independently of the PSS State.

Relevant to this OSP, the klystrons and high power amplifier (HPA) are interlocked to the PSS and can only be energized when the UITF enclosure is swept, cleared of personnel and taken to the RUN state. The PSS will turn OFF the applied RF to the QCM when UITF enclosure door interlocks are breached or when CARMs indicate excessive radiation measured outside the enclosure.

The klystrons and HPA are located within electronics racks positioned above Cave1, see Figure 11. Waveguides attached to the klystrons deliver RF energy to the QCM located below within the UITF enclosure, through a penetration in the roof top shielding that is filled with sand. Note, the photograph of the klystron rack will be updated once construction of the system is complete. There are interlocks associated with the high power RF klystrons (see Figure 12). These include electronics rack door/panel enclosure interlocks that prevent exposure to electrical hazards within the klystron racks and waveguide pressure interlocks that ensure RF energy does not leak from the waveguides. The waveguides are filled with air at 1.5 psi above ambient.



Figure 11, the UITF klystron racks under construction. Photo will be updated when construction is complete.

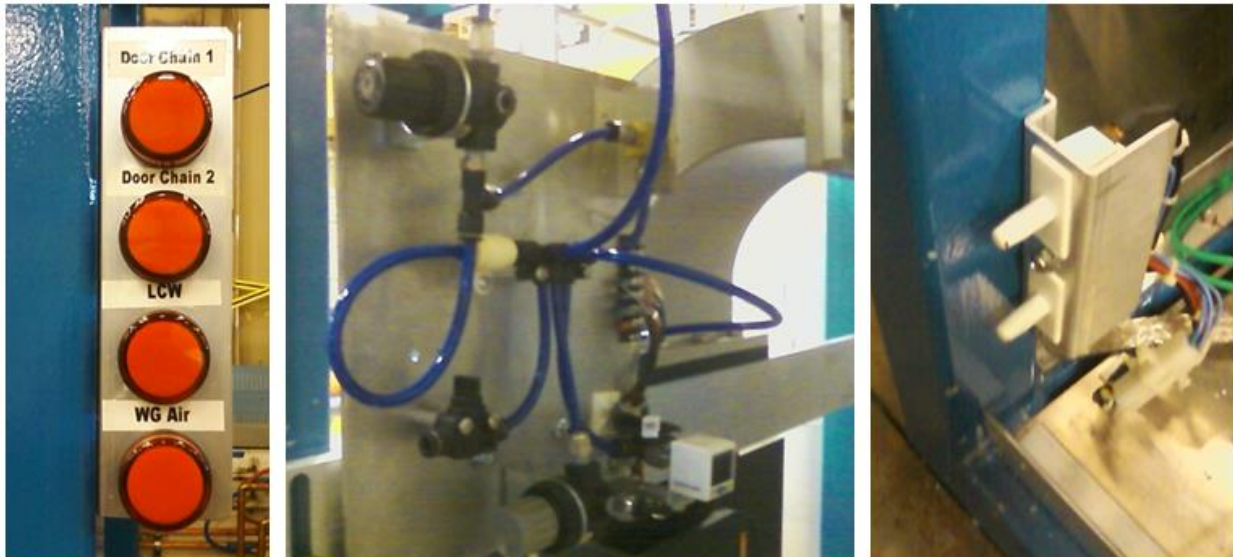


Figure 12: (left) Photograph of the indicator lights related to the electronics rack door/panel enclosure interlocks, low conductivity water flow, and waveguide air pressure, (middle) the waveguide air pressure manifold and interlock sensor, (right) one of the electronics racks door interlock sensors.

Configuration Control related to high power RF:

All PSS cable, conduit, and control devices are either labeled or placed in locked enclosures. Only Safety Systems Group personnel may access these devices.

Devices that are owned by the Safety Systems Group

- AC Contactors located in rack ITF14 near the klystron racks above Cave1

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

Devices not owned by the safety systems group but under PSS configuration control:

- 5kW / 1497 MHz klystron power supply PSS interlock chain
- Wave Guide pressure interlock

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

6.4 Monitoring systems

There are three monitoring systems related to safety at the UITF:

- 1) The PSS, explained above, provides access control to the UITF and protects personnel from prompt ionizing radiation associated with UITF operation. The PSS monitors the configuration of the doors, open or closed. CARMs are part of the PSS, used to detect radiation outside the UITF enclosure. When radiation levels exceed values specified by RCD, a laser shutter closes and terminates beam delivery. Similarly, CARMs will turn OFF high power RF when radiation levels exceed specified values, for example during QCM commissioning related to this OSP. CARM alarms are indicated inside the Control Room.
- 2) There is an ODH monitoring system, which alarms when the oxygen level in the UITF enclosure drops below 19.5%. There are three sensors for helium and one sensor for nitrogen. Helium sensors are located near the ceiling, and spaced roughly equidistant along the length of the enclosure: one helium sensor head near the expected location of the HDIce target, one near the QCM and the other near the keV beamline. The nitrogen sensor is located close to the floor, near the QCM. ODH alarms are located at each door and also in the Control Room.
- 3) 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. Note: the photogun high voltage power supply will NOT be energized during the implementation of this OSP and is only listed here from completeness sake.

Radiation Mitigation

Penetrations through the roof of Cave1 create potential for localized elevated radiation levels, even under normal operating conditions. All but one of these penetrations is equipped with shadow shielding to mitigate the condition, but these locations remain potential sources of exposure. As shown in Figure 10, interlocked CARM probes are placed adjacent to several penetrations and in the UITF Control Room. Administrative controls (e.g. posting as a Radiologically Controlled Area or Radiation Area) may be applied to limit access to portions of the roof until radiation monitoring proves that they are otherwise unnecessary. Additional shadow shielding will be used, if needed, to reduce the intensity of radiation oriented towards the labyrinth on the northeast end of the test area. An active area radiation monitoring system, surveys, and operations log reviews will be conducted to ensure that the doses to monitored and unmonitored personnel are less than the JLab design goals and ALARA. Passive integrating dosimeters at key locations will be used to provide additional verification that doses outside the shielded enclosure are kept ALARA. If exposure design goals appear to be in jeopardy of being exceeded, further controls will be established or documented justification to exceed them will be produced. The access points will be posted and controlled in accordance with the Jefferson Lab EH&S Manual and Radiation Control Manual.

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

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

For the QCM testing conducted under this OSP, four locations are monitored by interlocked CARM probes as described in Section 6.3. Trip of the CARMs will trigger radiation alarm (audible and visual) at the UITF Control Room independently of the PSS State. Resetting of alarms is described above. Response to CARM alarms is discussed below.

CARM Alarm Response

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

Neutron CARM Alert Response

One neutron radiation detector in the cave is configured to produce an “alert level” alarm in the control room. This alarm will occur if the neutron levels in the vicinity of the cryomodule exceed 0.5 mrem/hr. This alarm is not interlocked to the PSS and will NOT terminate the test. The operator may acknowledge the alarm to silence the audible annunciator. When this condition occurs, the operator shall place signage prominently at the PSS console stating “**Contact RadCon at 876-1743 Survey required**” and make an appropriate elog entry copied to hamlette@jlab.org and welch@jlab.org and to the Test Coordinator. Furthermore, the Operator will place identical signage on the QCM during the next available access.

6.5 Ventilation

Cryogenic fluids are delivered to the QCM from the CTF refrigerator, liquid helium (LHe) and liquid nitrogen (LN2). The ODH assessment is attached to this OSP and can be found at: https://misportal.jlab.org/railsForms/oxygen_deficiency_reviews/74180/edit

The QCM will be cooled to LHe temperature only periodically at UITF. Anticipated operation of the QCM will likely not exceed three periods of operation per year, with each period lasting approximately 1 week. During the majority of time, when the QCM is not being operated, only LN2 will be used to cool the QCM.

The QCM will be connected to the CTF refrigerator using two sets of u-tubes. One set of u-tubes is located at the CTF refrigerator, and the other set is located inside Cave1 of the UITF enclosure. As described by the ODH assessment, the UITF enclosure was assigned ODH0 status EXCEPT for elevations above 9’ (signs are posted), and when u-tubes are removed or stabbed. When u-tube operations occur, the Cryo group will perform these operations per "CRY-15-54131-OSP - Bayonet Installation and Removal". The Cryo Group and UITF Facility Manager will coordinate u-tube operations, and it is the responsibility of the Facility Manager to restrict access to the UITF enclosure to only authorized personnel (i.e., those with proper ODH training).

Vent piping (on the circle seal relief), a sheet metal deflector (on the parallel plate relief) and a 90 degree elbow (on the burst disc) serve to protect the relief ports from damage during u-tube operations.

There are two fans on the east wall of Cave 1 (Figure 13). 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.

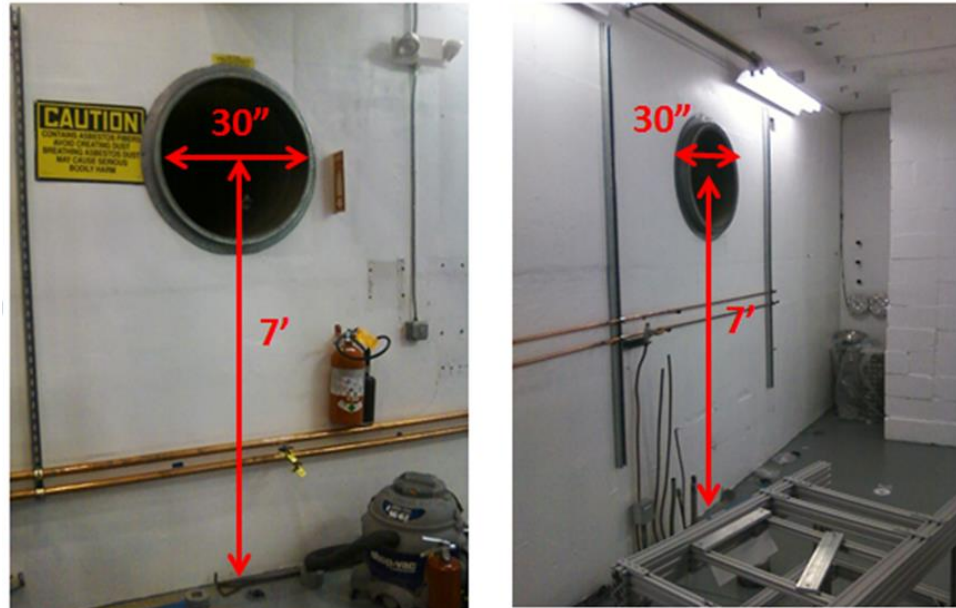


Figure 13: (Left) Fan with a capacity of 7400 CFM vents air into the high bay area, (Right) fan with a capacity of 4400 CFM vents air to outside the test lab

As mentioned above in the section related to Shielding, two penetrations serve as vent holes should the Cave1 enclosure fill with helium gas. Above the cave, these penetrations have “chimney stacks” attached, to direct the light helium gas safely above the heads of occupants who might be working atop the Cave1 enclosure (Figure 14). So called “memory foam” fills the remaining penetrations, to block the free flow of helium gas to the electronics racks located above, where personnel might be working. The foam can be removed from penetrations, for example to provide additional cabling to the UITF enclosure, but only after consulting with the Facility Manager to determine if foam removal creates an ODH hazard. If liquid helium is present within the QCM, the ODH level of the rooftop region becomes ODH1 when the foam is removed from penetrations, and the Safety Systems Group will be required to provide local oxygen monitoring throughout the duration of the work. If there is no liquid helium inside the QCM, the foam can be removed without taking extra ODH precautions. The Facility Manager will inform personnel as to the cryogenic state of the QCM. Signs placed near the penetrations on the Cave1 rooftop provide foam removal instructions.



Figure 14. Two helium “chimney” stacks attached to rectangular penetrations in the ceiling of Cave 1. If helium gas is released inside the UITF enclosure, these chimneys will direct helium gas above the heads of staff members working near the electronics racks above Cave 1. Before energizing the QCM with high power RF energy, sandbags will be positioned at the base of each “chimney”.

There is a passive 5.6 m² vent beneath the raised roof of Cave 2 (Figure 15) to vent lighter than air cryogenics into the high bay area in the unlikely event of an equipment failure of experimental targets (e.g. HD-Ice).





Figure 15: (top) Shielded elevated-roof section of Cave 2, which will be used for experimental targets, including cryogenic targets. (bottom) 5.6 m² Vent area beneath the elevated roof section of Cave2, for lighter than air cryogenic gases to escape.

There are three main vent pathways by which helium gas can escape from the QCM, and each vent pathway is located on the QCM vent stack: a) circle seal relief which Opens at 17 psi, b) a parallel plate relief valve which Opens at 45 psig and c) a burst disk which Opens at 51 psig. See Figure 16, below. If a vent incident should occur, the circle seal relief would OPEN first. For this reason, the exhaust of the circle seal relief is piped outside of the UITF enclosure. Sheet metal wrapped around the parallel-plate relief serves to direct gaseous helium upward, and not toward personnel walking near the QCM.

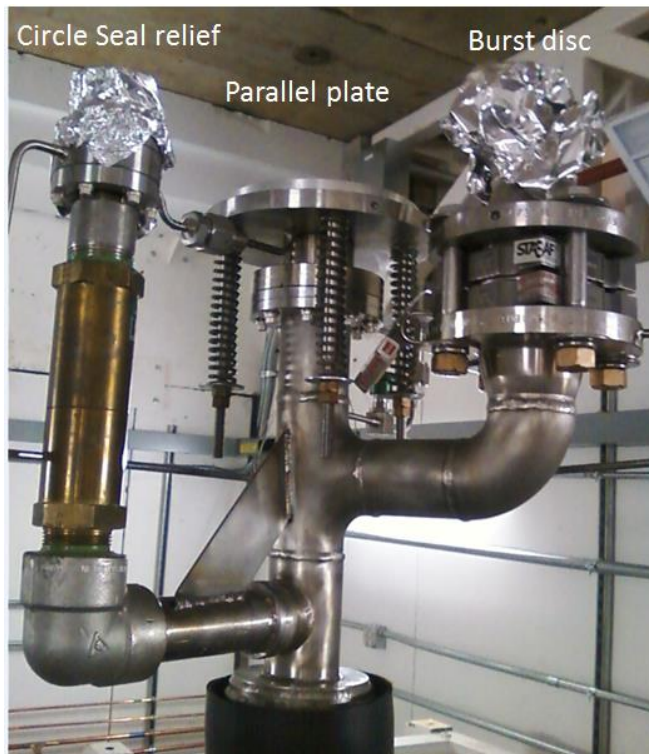




Figure 16: top left shows the three relief ports of the QCM vent stack. Top right shows the deflector sheet metal attached to the parallel-plate relief which would direct gaseous helium upward and not toward occupants inside the UITF enclosure. The bottom figure shows piping attached to the exhaust port of the circle seal relief which would direct vented gas out of the UITF enclosure.

6.6 Pressure / Vacuum

The QCM

The QCM pressure system documentation can be found in Docushare at:

<https://jlabdoc.jlab.org/docushare/dsweb/View/Collection-15912>

File folders and subfolders include: "Project Status and Information", "Engineering", "Manufacturing" and "Testing"

1. Under "Project Status and Information", there is a brief summary of the QCM status with an emphasis on pressure safety
2. The PS-1 form can be found under the Engineering root directory
3. Drawings can be found under Engineering>Drawings; Specifications can be found under Engineering>SOW
4. In-process weldmaps can be found under Manufacturing>Welding-brazing (for in-house fabrication)
5. PS-5 forms are combined into one file and stored under Manufacturing>Fabrication.
6. PS-7 form for QCM pressure test is stored under Manufacturing>Inspections-Examinations
7. Memos and Readme's are written to brief the status and whereabouts of some documentation
8. Vendor submitted documents are found in relevant subfolders under either Engineering or Manufacturing

Category 2 vacuum systems are described in the EH&S manual at the link below:
<https://www.jlab.org/ehs/ehsmanual/Pressure%20and%20Vacuum%20Systems%20Supplement/PSS%20Part%207%20Vacuum%20Systems.htm>

In section 7.2.3 of the EH&S manual, Category 2 vacuum systems are described as:

“Vacuum systems attached to or containing a credible pressure source that can exceed 15 psig and are protected from pressurization exceeding 15 psig through engineering controls (e.g. pressure relief devices). Insulating vacuums for cryogenic systems shall be considered Category 2 vacuum systems. Examples of Category 2 vacuum systems include cryostats, cryogenic transfer lines, cold boxes, and target scattering chambers.”

RF Waveguides

As mentioned above, the RF waveguides are pressurized with air at 1.5 psi above ambient base pressure, as part of the interlock system designed to ensure RF energy does not escape the waveguide. The air is delivered from a compressor that supplies much of the Test Lab with compressed air, also called “instrument air”. A dedicated regulator reduces instrument air pressure to 10 psi near the klystron rack. Beyond this regulator, additional regulators (see Figure 12) reduce the pressure to 1.5 psi delivered to the waveguides. Relief valves are used to ensure that pressure within the waveguides does not exceed levels that could damage the waveguides, and that pressure within the waveguides cannot exceed 15 psi. As such, the waveguides are not considered Pressure Vessels, and do not require ASME Pressure Vessel certification.

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

See above, Ventilation section. The ODH assessment for the UITF is attached. This assessment can be found at: https://misportal.jlab.org/railsForms/oxygen_deficiency_reviews/74180/edit

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

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
 - Configuration control of moveable shielding
 - Radiation surveys
 - Determining and posting the appropriate radiological control signage, boundaries and barricades
 - Assigned Radiation Monitor Training (if needed)
- Center for Injectors and Sources (CIS) staff is responsible for:
 - Ensuring that valves on either side of QCM are forced CLOSED, with controls disabled to prevent opening of valves

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

- CIS personnel are responsible for safe operation of the UITF.
- 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 CARMs/radiation probes are interlocked to the PSS.
- High power RF (for buncher and 1/4 cryomodule) is interlocked to the PSS

DEVELOP THE PROCEDURE

9. Operating Guidelines

The UITF's QCM commissioning procedure is described by 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 swept and operated by a single trained and authorized user (typically the personnel conducting gun and/or beam studies).

UITF Operation

PSS state for the UITF is either: OPEN (open access), SWEEP, READY or RUN State. READY State is an internal (logical) state confirming that all interlocks are ready for transition to RUN State.

Prior to QCM commissioning, 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 State 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.

OCM in position at Cave1





Figure 17, top and bottom: The QCM in position at Cave1 of the UITF, with u-tubes “stabbed” and waveguides connected.

General Operating Protocol

The following are general operating guidelines to be followed when using the test area for radiation producing experiments. Refer to the Conduct of Operations document for details.

One qualified System Operator, normally the Duty Operator, must be present in the facility during all high power RF operations. Their names are displayed on the control desk and entered in the UITF electronic logbook.

1. Only authorized personnel shall be permitted to enter the test area to make changes in the apparatus. Authorization must be obtained from the Duty Operator, Principal Investigator or Test Coordinator.
2. The Duty Operator is responsible for ensuring safe operation in accordance with the OSP during attended high power RF operations. All personnel entering any Radiologically Controlled Areas shall carry

Personal Dosimetry.

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

The following describes the **OCM Cool Down Procedure**, which can happen with the UITF enclosure OPEN, if RF commissioning is not performed, i.e., there is no radiation hazard. This procedure may be revised following the initial cool down, based on lessons-learned.

Cooldown of UITF cryomodule:

Preconditions:

- Cryomodule shield and primary U-Tubes are installed.
- Shield and primary circuits have been pumped and backfilled and have been left under positive pressure.
- All insulating vacuums have been pumped and are holding proper vacuum.
- Cryomodule temperature diodes are active and reading correctly.

LN2 Shield Cooldown

- Install the supply and return bayonets of the UITF Thermosiphon.
- Ensure EV27SH is locked fully open.
- Set the LN2 liquid level control to auto.
- Ensure positive pressure remains on the primary circuit during shield cooldown.
- Open EV249BY in UITF Transferline to keep PR2 under positive pressure.

Primary Cooldown

- Shut off Kinneys and repressurize Kinney suction
- Lower CPI2440 to 1.3 atm
- Close UITF EV27JT, EV27RT, and EV249BY
- Install PR then PS utubes
- Repressurize CPI2440 and turn Kinneys back on
- Open MV27BY on UITF HX can
- Set EV27RT to control CPI2732 at 1.05 atm, range=-10 to 100
- Set main compressor discharge pressure range from 12 to 15
- Ensure that CB3 injection valves are set to automatic and that CB4 HP supply MV2CB4 is open

- Give controls for CM JT to SRF during cooldown.
 - Recovery suction pressure CPI284 shall remain below 1.2 atm during cooldown
 - Kinney suction pressure CPI2091 shall remain below 0.05 atm during cooldown
- Once CM is cold, close MV27BY
- When CM is ready to pump down to 2K, slowly manually open EV27RT in ~0.3 increments
 - Keep Kinney suction CPI2091 below 0.09 during this time
 - Once CM pressure reaches ~0.04, put max and min of EV27RT to 100

Cryo Ops Contacts: Chris Perry, Sasa Radovic, Thilan Wijeratne, and/or Joe Wilson

The following describes **Commissioning the cold QCM with RF** procedure, which requires that the UITF enclosure be cleared of personnel:

Procedure:

Inside the UITF

1. Verify that valves on either side of the QCM are CLOSED and cannot be opened via EPICS (i.e., the compressed air line is NOT attached to the OPEN spigot of the valve). Figure 17 shows the QCM inside the UITF enclosure, with valves on both sides.
2. The following is an overview of the PSS sweep, which can be performed by a single individual. Use the complete detailed sweep procedure and map attached to this OSP. A copy will also be maintained in the Control Room.
 - i) Inform all occupants to leave the UITF enclosure
 - ii) Close both doors
 - iii) Go to control room and turn key to SWEEP
 - iv) Enter the enclosure through the back door, close door behind you upon entry
 - v) Arm RunSafe Box601 in the hallway
 - vi) Sweep the enclosure, walking all the way to the north wall of Cave2
 - vii) Verify the Faraday Cup is locked in place, and the valve to the ¼ cryomodule is locked CLOSED
 - viii) Arm RunSafe Box602 near labyrinth exit
 - ix) Exit through the labyrinth closing screen gate door completely
 - x) Return to control room, turn key to RUN to arm the Personnel Safety System

In the Control Room:

Following QCM cool down, RF can be applied to the QCM. **An appendix describes the RF commissioning procedure for C100 cryomodules.** Similar steps will be followed for the QCM, and performed by SRF Institute staff, with CIS staff observing. After the first few RF commissioning trials, a dedicated RF commissioning procedure will be written for the QCM and CIS staff will apply RF to the QCM in the future.

Shielding Verification: *In advance of QCM commissioning, Contact the Radiation Control Group to verify shielding.*

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 State, in case there is a need for accessing the enclosure or to conclude high voltage operations.

Returning the PSS to OPEN State in normal operating conditions:

- Turn off the QCM RF from EPICS control screens
- Switch the PSS State key to “OPEN”

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

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

13.3 Abatement steps (secondary containment or special packaging requirements)

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

Returning the PSS to OPEN State 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), located at each door and in the Control Room
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), located at each doorway and near the electronics racks on Cave1 rooftop.

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 20.8%). 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.

The pressure vessel assessment of the high voltage power supply SF6 tank can be found in DocuShare, Folder PS-ACC-17-001

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 State.
- 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

UITF ODH assessment found at:

https://misportal.jlab.org/railsForms/oxygen_deficiency_reviews/74180/edit

Shielding assessment and specifications from RCD at:

https://misportal.jlab.org/doc_validation/processes/13

QCM pressure vessel documentation and analysis:

<https://jlabdoc.jlab.org/docushare/dsweb/View/Collection-15912>

C100 RF commissioning procedure, as example of typical SRF commissioning procedure

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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Task Hazard Analysis (THA) Worksheet

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

Click
For Word

Author:	M. Poelker	Date:	May 16, 2018	Task #: If applicable	
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Complete all information. Use as many sheets as necessary

Task Title:	QCM Operation at 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:	Approximately three times per year		
Lead Worker:	M. Poelker		

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.
- During the QCM commissioning procedure, the valves on either side of the QCM will be closed, preventing field emitted electrons from leaving the QCM vacuum space
- The RF system can only be turned ON when UITF is swept and armed with Personnel Safety System (all doors are locked)

Mitigation already in place:
[Standard Protecting Measures](#)
[Work Control Documents](#)

Oxygen Deficiency Hazard

An 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. In this assessment, the UITF enclosure was assigned a rating of ODH0 for areas below 9'. Above 9' the enclosure is considered ODH1. During u-tube operations, the enclosure is considered ODH2. Signage clearly indicates these conditions. Fixed oxygen monitoring systems will be used to detect and alert for OHD conditions. Sensors are located in appropriate areas. The assessment can be found at: https://misportal.jlab.org/railsForms/oxygen_deficiency_reviews/74180/edit

Sequence of Task Steps	Task Steps/Potential Hazards	<u>Consequence Level</u>	<u>Probability Level</u>	<u>Risk Code</u> (before mitigation)	Proposed Mitigation (Required for <u>Risk Code</u> >2)	Safety Procedures/ Practices/Controls/Training	<u>Risk Code</u> (after mitigation)
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Task Hazard Analysis (THA) Worksheet

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

Sequence of Task Steps	Task Steps/Potential Hazards	<u>Consequence Level</u>	<u>Probability Level</u>	<u>Risk Code</u> (before mitigation)	Proposed Mitigation (Required for <u>Risk Code</u> >2)	Safety Procedures/ Practices/Controls/Training	<u>Risk Code</u> (after mitigation)
1	Exposure to Ionizing Radiation	M	M	3	See Mitigations already in place	<p>A Personnel Safety System (PSS) has been designed and implemented to protect individuals from ionizing radiation during QCM commissioning with high power RF.</p> <p>Radiation Control Department has approved the UITF shielding and installed CARM radiation monitors outside the enclosure, that trip OFF the RF power when radiation levels exceed specified amounts.</p> <p>A sweep will be done prior to closing the UITF entrance door using the procedure referenced in the UITF OSP.</p>	1
3	RF non-ionizing radiation	L	L	1	See Mitigations already in place	<p>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.</p> <p>A sweep will be done prior to closing the UITF entrance door using the procedure referenced in the UITF OSP.</p> <p>Waveguides filled with air at 1.5 psi above ambient, with pressure sensor interlock to ensure RF energy cannot leak from waveguide joints</p>	1

Task Hazard Analysis (THA) Worksheet

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

Sequence of Task Steps	Task Steps/Potential Hazards	<u>Consequence Level</u>	<u>Probability Level</u>	<u>Risk Code</u> (before mitigation)	Proposed Mitigation (Required for <u>Risk Code</u> >2)	Safety Procedures/ Practices/Controls/Training	<u>Risk Code</u> (after mitigation)
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	ODH (LHe and LN2)	M	M	3	UITF enclosure is designated as ODH 0 unless u-tubes are being removed or stabbed, and for people working on ladders at elevations > 9' (The OSP and THA will be revised when HDIce equipment is brought to the UITF enclosure)	The ¼ cryomodule has piping to vent gaseous helium through a hole in the wall to the high bay area, and a shroud to vent cryogenic gases upward and through penetrations in the Cave 1 roof, to the high bay area. On the roof of the cave there are 7' tall chimneys attached to two open penetrations that ensure that the released gases are well above the head level of any personnel working on the roof. The remaining penetrations used to pass cables are filled with foam to restrict the flow of gas to occupied areas. Cryo u-tube operations will be performed following the guidelines described in the OSP "CRY-15-54131-OSP Bayonet Installation and Removal"	1

Task Hazard Analysis (THA) Worksheet

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

Sequence of Task Steps	Task Steps/Potential Hazards	<u>Consequence Level</u>	<u>Probability Level</u>	<u>Risk Code</u> (before mitigation)	Proposed Mitigation (Required for <u>Risk Code</u> >2)	Safety Procedures/ Practices/Controls/Training	<u>Risk Code</u> (after mitigation)
6	Pressure / Vacuum	L	M	2	<p>Category 2 vacuum system, QCM designed with appropriate relief system, required when cryogenic fluids are used</p> <p>The RF waveguides are filled with air at 1.5 psi above ambient pressure.</p>	<p>Review by Design Authority</p> <p>Relief valves ensure air pressure within the waveguides cannot exceed 15 psi</p>	1
7	Material Handling as it relates to u-tube operation	L	M	2	A chain hoist attached to the Cave1 roof will be used to remove/stab the heavier return-side u-tubes	Review by Cryo Group	1
8	SF6	L	EL	1	<p>Contents of gun HV power supply SF6 tank does not constitute ODH hazard.</p> <p>Pressure gauge on SF6 tank provides visible alarm when pressure falls to specified level</p> <p>Commercial SF6 transfer/recovery system</p>	<p>Equipment specific training when transferring SF6 from the High Voltage tank to the Dilo recovery system</p> <p>Access to the floor is restricted when ventilation fan inoperative, or when there is a known leak on the SF6 tank</p>	1

Highest Risk Code before Mitigation:

3

Highest Risk Code after Mitigation:

1

Task Hazard Analysis (THA) Worksheet

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

When completed, if the analysis indicates that the [Risk Code](#) before mitigation for any steps is “medium” or higher ($RC \geq 3$), 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](#).)

For questions or comments regarding this form contact the Technical Point-of-Contact [Harry Fanning](#)

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Task Hazard Analysis (THA) Worksheet

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

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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ODH Assessment

DATE: 11/10/2016 (Revision 1, 2/13/18)

DIVISION: Accelerator & Engineering Divisions

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

ASSESSMENT AUTHOR: Hari Areti & Will Oren

APPROVAL: 
Chris Perry for the Engineering Division Head

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

Revision History:

2/13/18, W. Oren

- Eliminated "Preliminary" on assessment location
- Modified venting requirements for parallel plate and burst disk relief valves on the ¼ cryomodule.
- Changed ODH conditions for Mode 3 Operational Conditions

ODH Risk Assessment, UITF

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 cryogenics 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. A separate industrial hygiene assessment addresses 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 m³ and Cave 2 has a volume of 441 m³ for a grand total of 648 m³ 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.

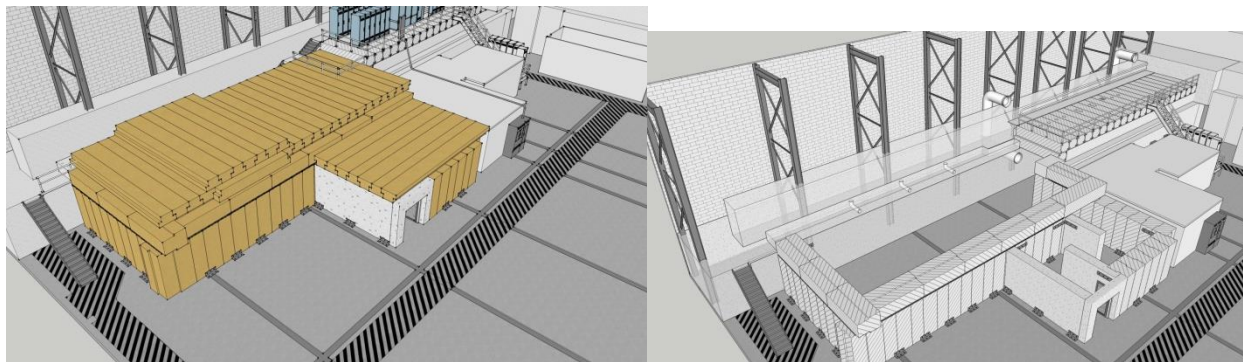
Cave 1 has six 0.25 (10") diameter ceiling penetrations, all of which can be used for cable routing. All six of these penetrations emerge under an expanded metal grating that spans the space between two sets of electronics racks on the top of the cave. None of these will be considered as possible vents 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 2.1m³/s – 4400CFM), and the other vents (capacity of 3.5m³/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.

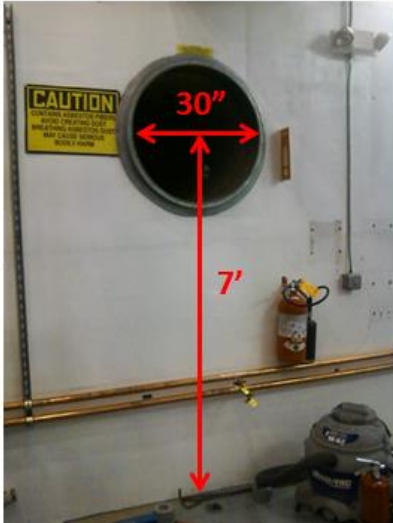
The total area in Cave1 available for venting helium, includes the two 0.30m X 0.46m penetrations and one of the 0.15m diameter vent holes on the west side, is 0.30m² (3.2ft²). The two remaining 0.15 diameter holes on the west side will be reserved for dedicated use to house a vent line coming from the ¼ cryomodule's primary Circle Seal relief. 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 m² (60ft²) 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 a 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.

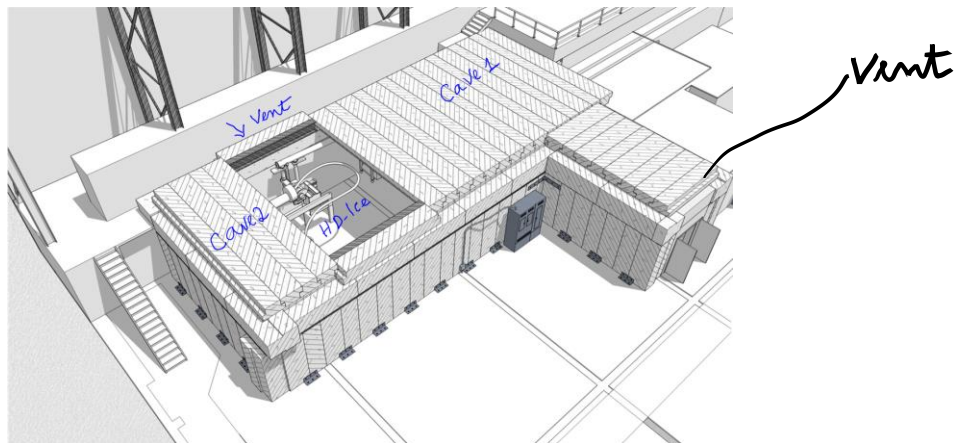


Figures 1 &2: UITF with Ceiling in place and without ceiling on Cave 2



6" Vents, West Wall

Figure 3: Vents in Cave1



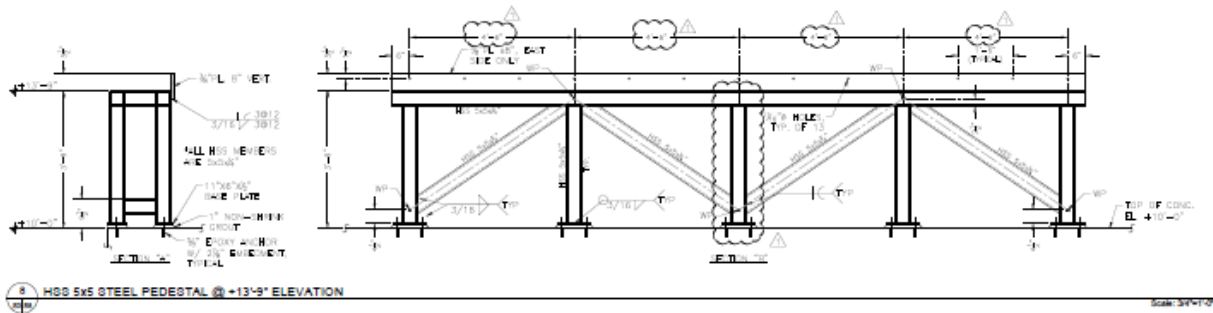


Figure 4. 5.6 m² vent area at the ceiling in Cave2

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)/m²/s. (Reference: Internal memo – “Helium Vent Investigation, July 9, 2001, Dana Arenius)

The possible sources of ODH producing gases or cryogenics 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 m³ (81.4m L x 40.5m W x 12.2m H - 1.4 million cubic feet, 267’ L x 133’ W x 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 1481m³ (52,315 ft³of 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 Supply	.015	1.50	0.010	Ok
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	<u>Issue</u>
Helium Dewar Relief – Spoiled Insulating Vacuum	0.23	1.50	0.153	Ok
Rupture 1000L Dewar	125kg ^{**}	1.50	NA	<u>Issue</u>
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 O₂ concentration of 18.7% resulting in a fatality factor of 0.

**** This is a release rate of $0.07\text{m}^3/\text{s}$. 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 $\frac{1}{4}$ 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 $\frac{1}{4}$ 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 on the new $\frac{1}{4}$ CM must be diverted to the outside of the cave. A penetration on the west wall of Cave 1 has been reserved for that function. The secondary parallel plate relief and the burst disk discharge directions must be directed away from the escape path past the $\frac{1}{4}$ CM if helium were to vent through either or both of these devices. 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 $1 \times 10^{-6}/\text{hr}$ but with a fatality factor of 1 in this case. This results in a $P_i F_i$ 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 relief of the $\frac{1}{4}$ 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 $0.30\text{m} \times 0.46\text{m}$ (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 entirety of Cave 2 is rated as **ODH 0** but from 9ft up to the ceiling in Cave 1 remains at an **ODH 1** rating with all gas and cryogen sources available and the ¼ cryomodule primary relief 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

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

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 $R = 0.0083 \text{ m}^3\text{-Kpa.mol}^{-1}\text{K}^{-1}$,

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

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

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

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

Dewar	$\sqrt{\frac{2\Delta P}{\rho}}$	$1.2 \cdot 10^{-4} (A_c/A_d)$
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/m²/s. (Ref. 1). The 5.6 m² ceiling vent of UITF can vent 1.4 kg/s. The 1.5m³/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 m³

Ceiling vent area = 5.6 m²

Pressure in liquid Helium dewars = 13.8KPa

Transfer pipe diameter of 1m³ dewar = 0.00635m

Transfer pipe diameter of 0.5m³ dewar = 0.003175m

Expansion factor for 4K He = 750

Expansion factor liquid N₂ = 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/m²

Volume of Helium venting through 1m² vent= 0.002 m³/s

Volume Helium venting capacity of 5.6 m² vent in Cave2 = 0.0112 m³/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 $M = V * \rho$

% 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.

$R = 0.0083 \text{m}^3 \cdot \text{Kpa} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$

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/ m³

Density of Helium at 300K = 0.165kg/ m³

Density of Liquid Nitrogen = 810kg/m³

Density of Nitrogen at 300 K = 1.165kg/m³

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 m³ of nitrogen in the cave's volume of 648 m³. The percentage of oxygen in the cave is

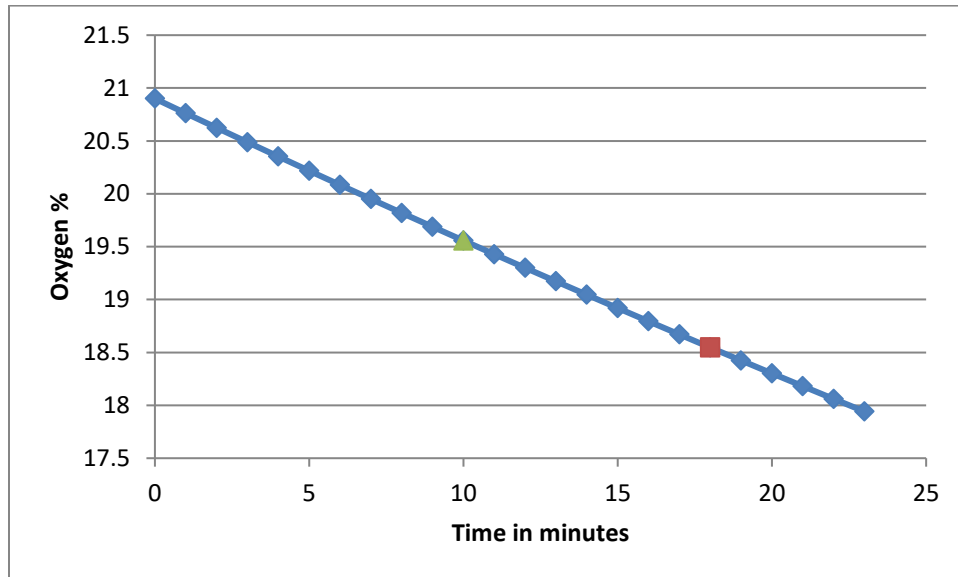
$21 * (1 - \text{nitrogen volume}/\text{cave volume})$, where 21 is the percentage of oxygen in air.

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 m³/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 O₂ is $X(\%)/648 \text{ m}^3$ (Vol. of UITF). The rate at which O₂ is leaving UITF (due to N₂) is 4.34 m³/min. giving the rate at which O₂ 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 valued 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 cryomodule, 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 later. *Do not stop the sweep to perform maintenance.*
 - b. 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.
 - c. Allow anyone found in the UITF enclosure 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. Inform occupants of the Cave 1 roof of impending keV beam operations, alert them to the personal dosimeter requirement. Verify RCD signage is properly posted.~~
- ~~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)

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NOTE: The total time allowed for the sweep is 5 minutes.

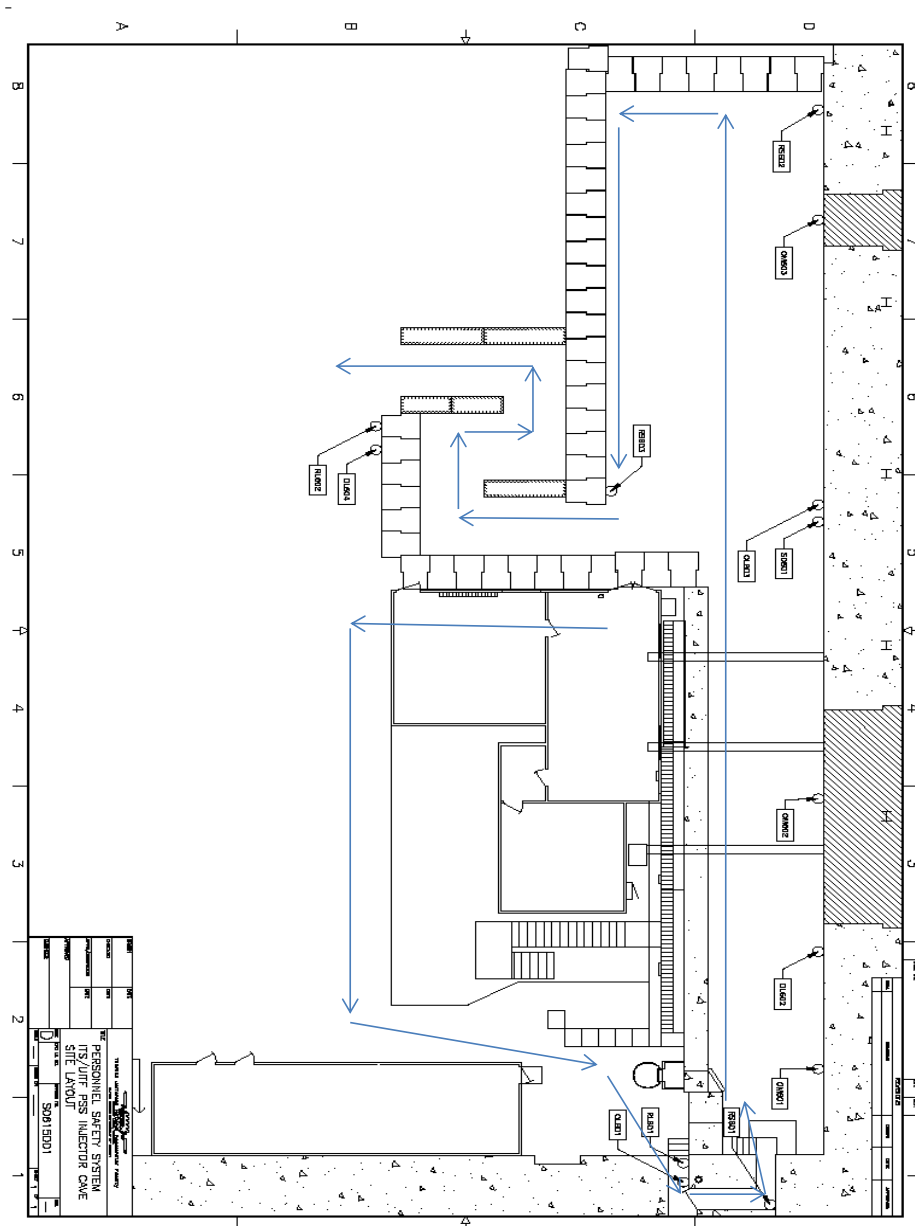
That's from initializing the sweep with the key to closing the last door.

Detailed Sweep Sequence

Step	Sweep Team
1	<p>Complete all pre-sweep steps.</p> <p>NOTE: A detailed sweep map for the UITF vault is <u>shown below and</u> available as a hard copy in the PSS binder or on-line at: https://jlabdoc.jlab.org/docushare/dsweb/View/Collection-27494/</p>
2	<p>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.</p> <p>b. Confirm that the magenta beacons are flashing (this assures that the system is ready for a sweep)</p> <p>c. The Lead Sweeper enters Cave 1 through the back door (D2).</p> <p>d. Arm RunSafe Box 601 in the hallway.</p> <p>e. Verify that the area behind the gun and the 1/4 cryomodule is unoccupied.</p> <p>f. Verify the Faraday Cup is locked in place and the valve to the ¼ cryomodule is locked CLOSED.</p> <p>g. Sweep the enclosure, walking all the way to the north wall of Cave 2.</p> <p>h. Look behind the beam line, cable tray, and any large obstacles.</p> <p>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.</p> <p>j. Exit Cave 2 through labyrinth and cage door (D1).</p> <p>k. Wait outside the cage door for up to 30 seconds and confirm that the door locks.</p> <p>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.</p>

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Sweep Map





Accelerator Division
 Institute for SRF Science & Technology
 Common Procedure

Procedure Title *C100 Maximum Gradient and Operating Gradient Determinations (CMTF)*

Procedure ID # *CP-C100-CMTF-CM-CAV-EMAX*

Procedure Description - The purpose of this procedure is to define the process steps required to determine C100 cryo-module Maximum Gradient and Operating Gradient in the tunnel.

Author	M. Stirbet	Date	Signature
	M. Drury	Date	Signature
Reviewers			
	Name: M. Stirbet	Date	Signature
	Name: J. Preble	Date	Signature
	Name:	Date	Signature
Version	1.0		
Approval Date			
Version Comments			
References	<u>List and Hyperlink</u> all documents related to this traveler.		
	ACC-10-037-OSP		

1. Required Signals

- 1.1. Forward Power
 - 1.2. Reflected Power
 - 1.3. Emitted Power
 - 1.4. Transmitted Power
 - 1.5. HOM A and HOM B Power
 - 1.6. He Pressure from 100 Torr pressure transducer
- ## **2. LHe Level Supply and Return**
- 2.1. Vacuum signals (Waveguide and Beam line)
 - 2.1.1. Cavity Vacuum
 - 2.1.2. Waveguide 1 – Waveguide 8 Vacuum
 - 2.1.3. Insulating Vacuum
 - 2.2. Radiation signals (from Decarad)
 - 2.2.1. CMTFDRAD01 - CMTFDRAD10

3. Other Requirements

- 3.1. This measurement requires one RF system operator and one cryogenics system operator (on-call).
- 3.2. Boonton Peak Power Sensors should be calibrated at the beginning of any shift in which high power operations will take place.
- 3.3. Cryomodule heaters must be turned off during Maximum Gradient determinations.
- 3.4. LHe Level must be higher than 83% before turning on RF
- 3.5. Helium Pressure must be no higher than 34 torr before turning on RF.
- 3.6.

4. Safety

- 4.1. **All operators involved in 12 GeV cryomodule Acceptance Tests should have the following trainings current:**
 - 4.1.1. MED13 – ODH-2 & Respirator medical certification
 - 4.1.2. SAF103 – Oxygen Deficiency hazards.
 - 4.1.3. SAF210 – 5-Minute Escape Pack use
 - 4.1.4. SAF603A – Electrical Safety Awareness
 - 4.1.5. SAF800 – General Employee Radiation Knowledge
 - 4.1.6. SAF801C – Radiation Worker I Knowledge Information
 - 4.1.7. SAF801P – Radiation Worker I Knowledge Implementation
 - 4.1.8. SAF801T – Radiation Worker I Knowledge Assessment
- 4.2. All operators must read and sign the following documents
 - 4.2.1. SRF-11-045-OSP CMTF-OSP
 - 4.2.2. CMTF Conduct of Operations

5. Hardware - Computers - see Figure 1.

- 5.1. SRFCMTF-RF – This computer runs Labview VI's intended to control the Voltage Controlled Oscillator (VCO), and to collect and log RF related data such as interlock states, RF power levels and field emission levels. Also gathers cryogenic data from the computer, CMTF-DAQ.
- 5.2. CMTF-DAQ – Collects data on the cryogenic state of the cryomodule under test. This includes temperature diode signals, LHe level probe signals, pressure transducer signals,

and vacuum ion pump signals. Also transmits some of these signals to Cryo Group epics database and allows for control of cryogenic heaters in the cryomodule.



Figure 1: CMTF Computers

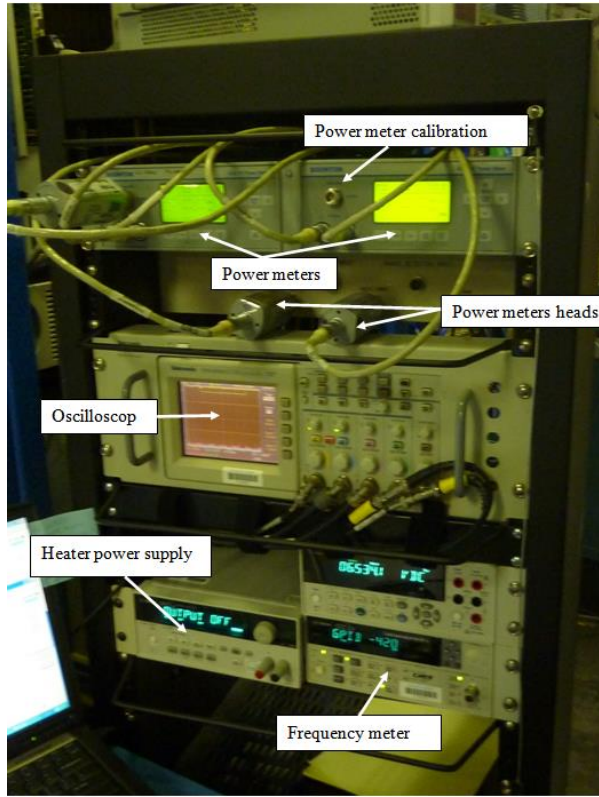


Figure 2: 12 GeV Commissioning Rack



Figure 3: 12 GeV Klystrons. One per Cavity



Figure 4: Location of HV Power Supply Knife Switch

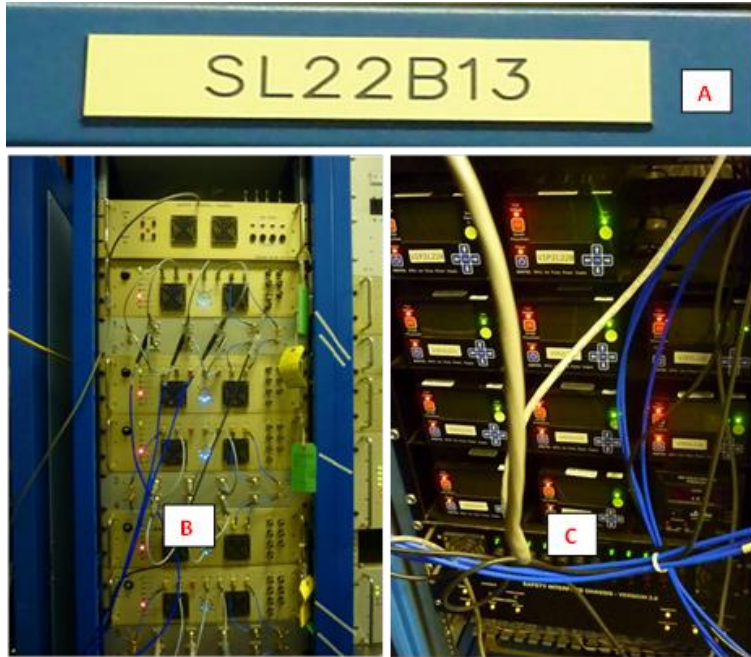


Figure 5: LLRF Rack (B) with Rack Location (A) and Vacuum Rack (C)



Figure 6: Klystron Power Supply with Knife Switch Highlighted

6. Computer Start up

6.1. SRFCMTF-RF:

- 6.1.1. Log on as **srs-ee**. The password may be obtained from Christiana Wilson, Mike Drury or Larry King.
- 6.1.2. If powering up the computer, first run the Measurement and Automation Explorer (MAX). Icon located on the desktop.
- 6.1.3. Under “My System>Devices and Interfaces>VXI System 0 (PCI-MXI-2)>Run VXI Resource Manager. (see Figure 7)

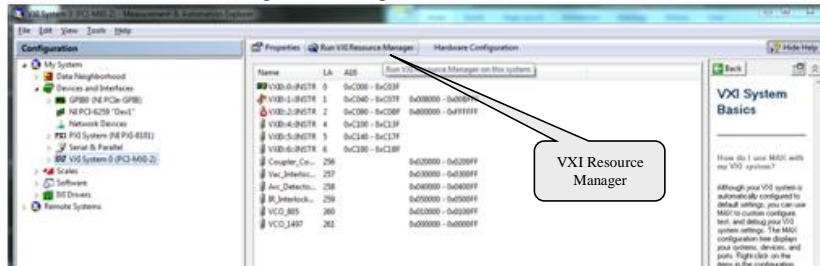


Figure 7: Measurement and Automation Explorer Window

- 6.1.4. You may then minimize the MAX window
- 6.1.5. Start the LabView program for RF testing by clicking on the icon “Click to run C100 RF test” placed on the desktop. If there are any issues, contact Mike Drury.
- 6.1.6. This will open the LLB Manager window.
- 6.1.7. Run the “**LOADER.vi**” from the “LLB Manager” window. See Figure 8

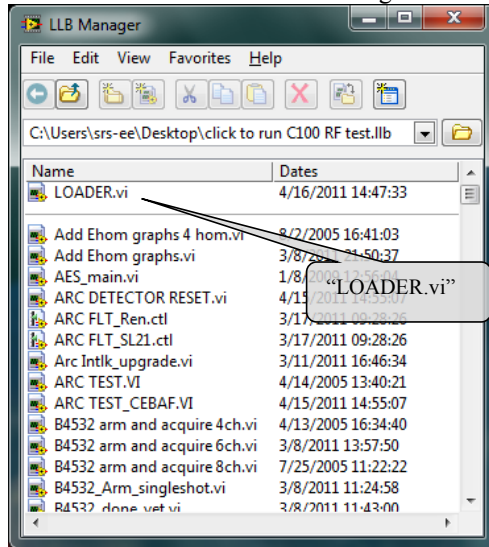


Figure 8: LLB Manager for C100 RF Test

6.1.8. This will bring up the pop up shown in Figure 9:

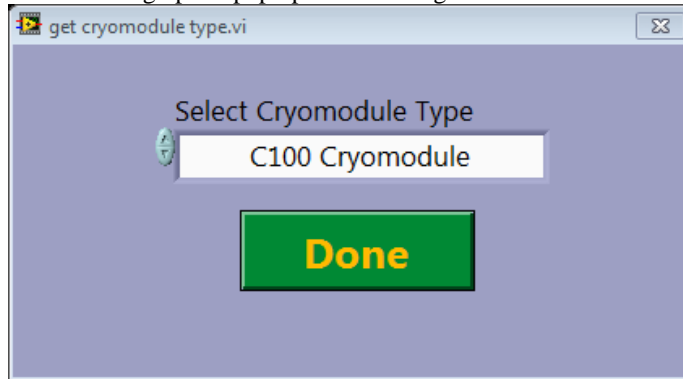


Figure 9: Selecting Cryomodule type

6.1.9. Select **C100 Cryomodule** as shown and click the “Done” button
6.1.10. This will open the VI Control VI

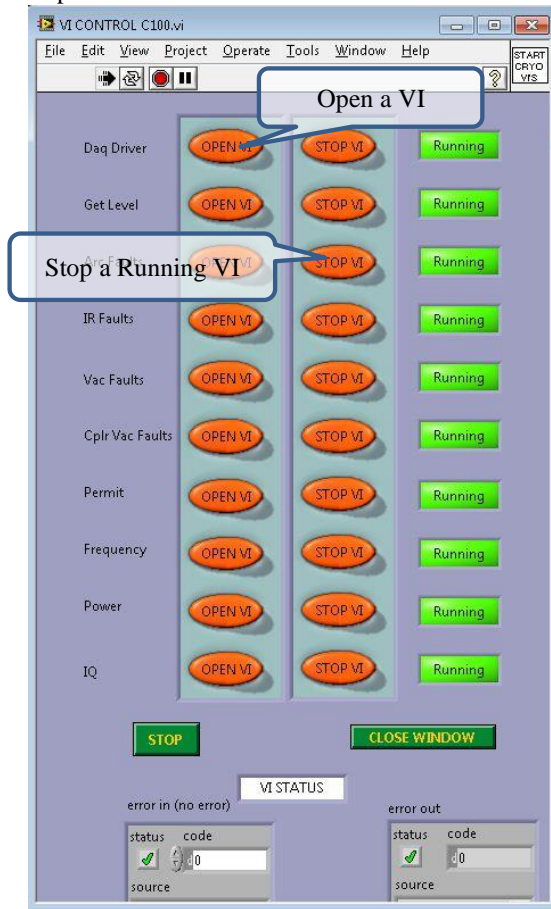
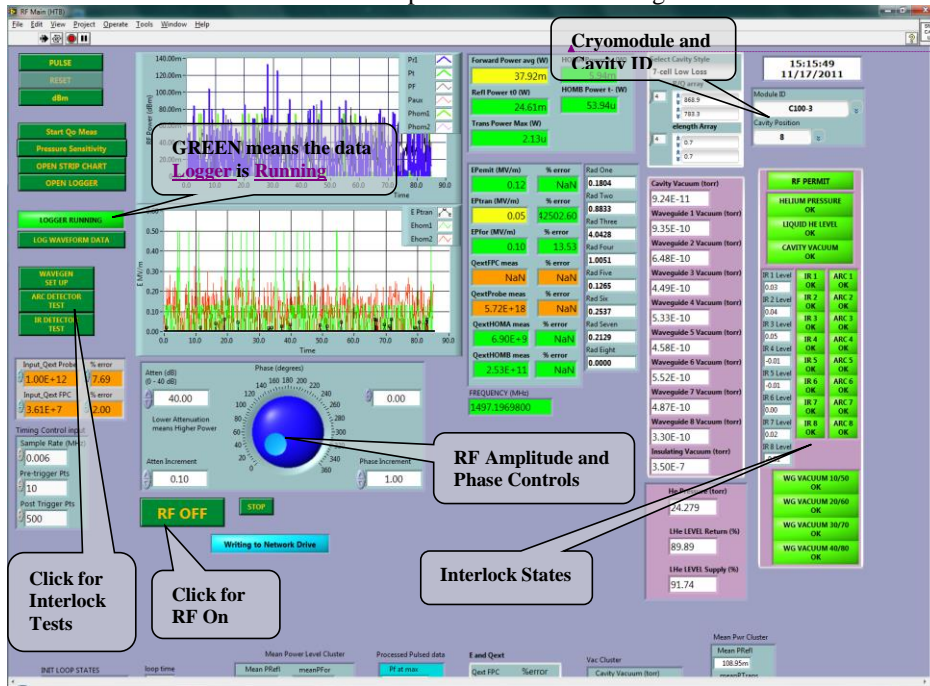


Figure 10: VI Control

6.1.11. The VI Control allows you to open and stop VI's that are running in the background.
 6.1.12. The RF main VI will also open at this time. See Figure 11.



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Figure 11: RF Main Window

6.2. CMTF-DAQ: In most cases, this computer will be up and running. If not, power up the machine and log in as srs-ee. The password may be obtained from Christiana Wilson, Mike Drury or Larry King.

6.2.1. On the desktop, find the icon labeled, “3_CMTF_C100_cryomodule_main.vi” and click. This will open the main CMTF-DAQ window.

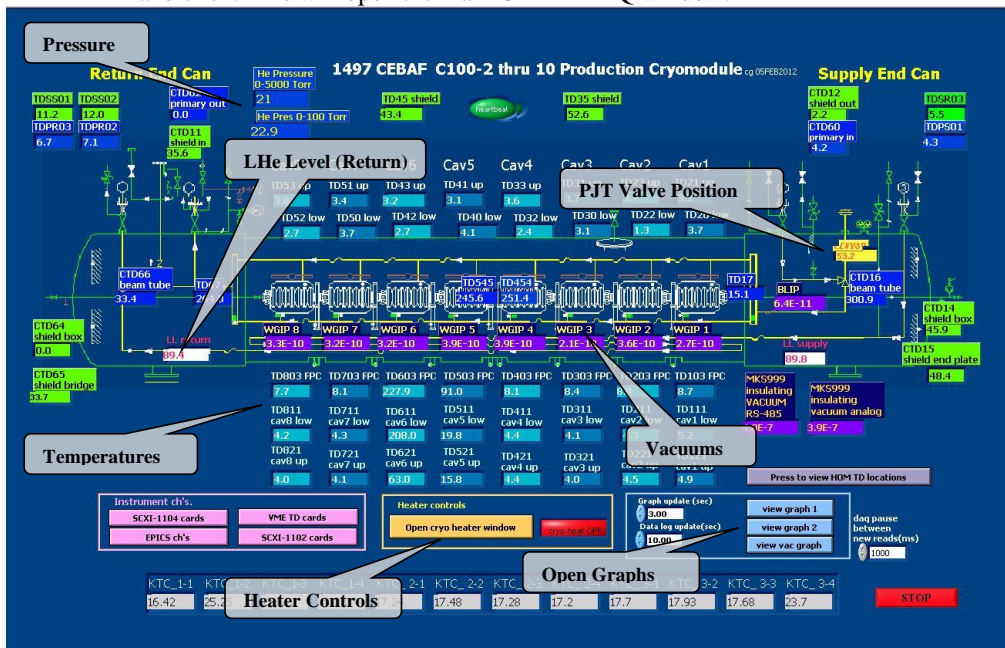


Figure 12: CMTF-DAQ Main

6.2.2. Start Exceed.

6.2.3. Start PuTTY

6.2.3.1. Figure 10 shows the PuTTY configuration window.

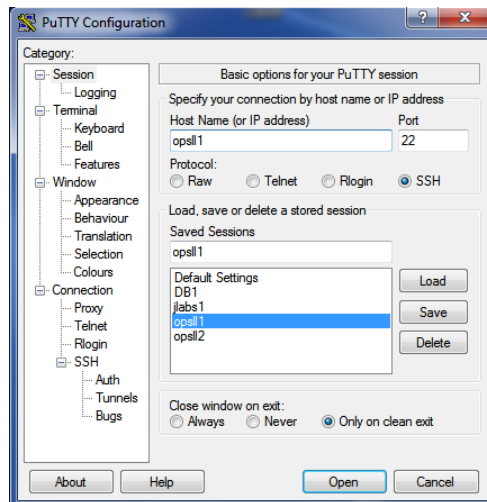


Figure 13: PuTTY Configuration

6.2.3.2.Type in opsl12 for hostname or select from saved sessions

6.2.3.3.Click Open button. This will open the PuTTY terminal window as shown in Figure 11.

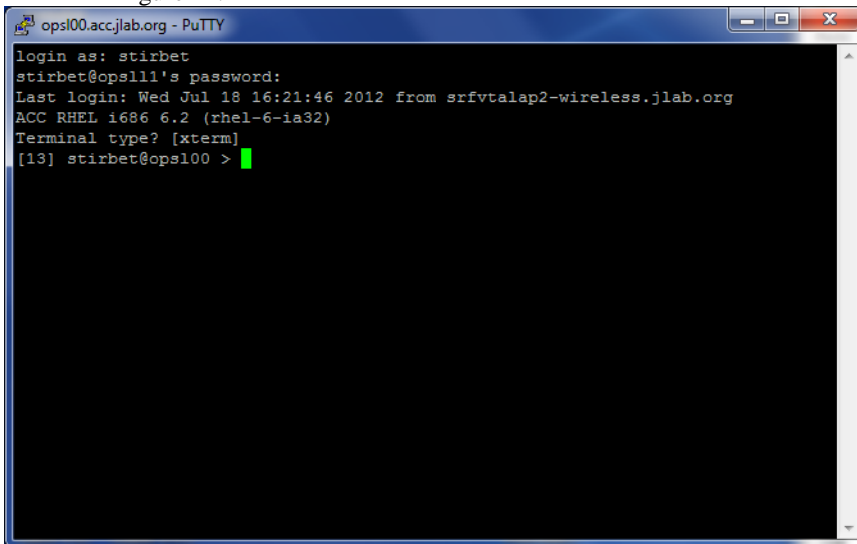


Figure 14: PuTTY Terminal Window

6.2.3.4.Login using your JLAB username and your Ops password (not your CUE password) as shown in Figure 12.

6.2.3.5.Use “xterm” as terminal type.

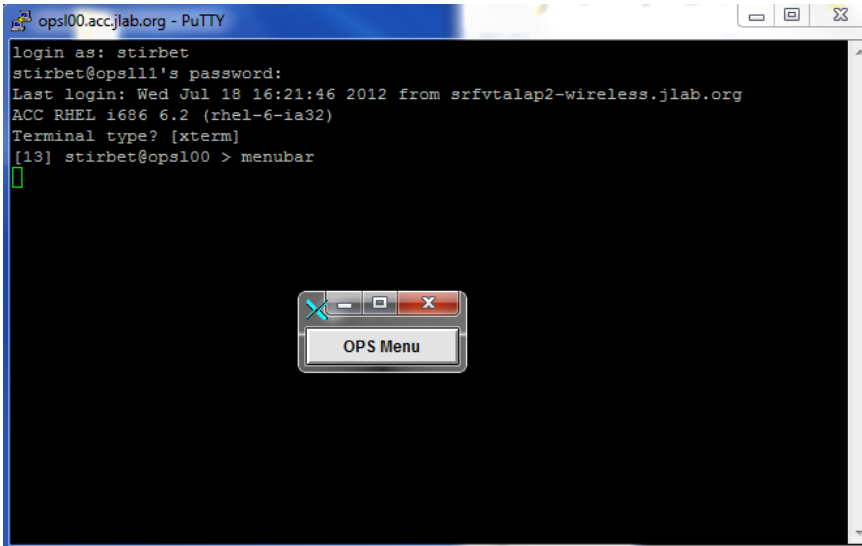


Figure 15: Opening the OPS Menu

6.2.3.6. Type in “menubar” to bring up the OPS Menu.

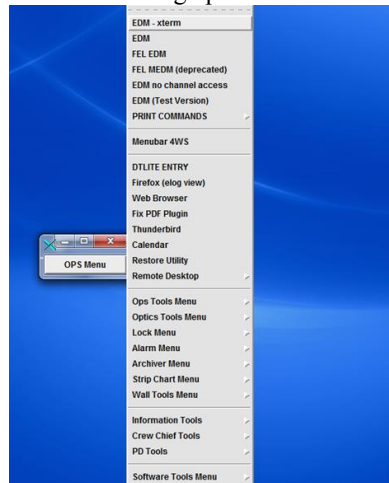


Figure 16: Selecting EDM from the OPS Menu

6.2.3.7. Click on the OPS Menubar and select “EDM” (See Figure 13). This will open the “Monticello” menu (See Figure 14).

6.2.3.8. Click on the small yellow button at the right of RF, to bring up RF Captain screen (see Figure 15):

6.2.3.9. Select the Zone where Commissioning will take place and click the corresponding blue button .

- 6.2.3.10. Select “SRF Commissioning Operator” from the menu. (Example shown in Figure 15 is for Zone 2L23).
- 6.2.3.11. This will open the Cavity menu as shown in Figure 16.

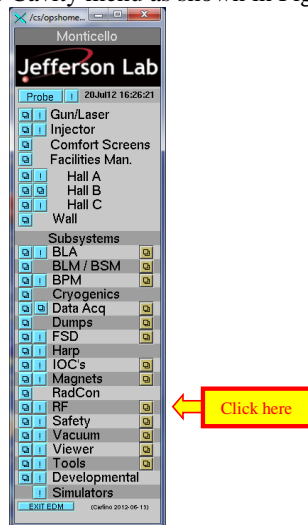


Figure 17: Monticello Menu

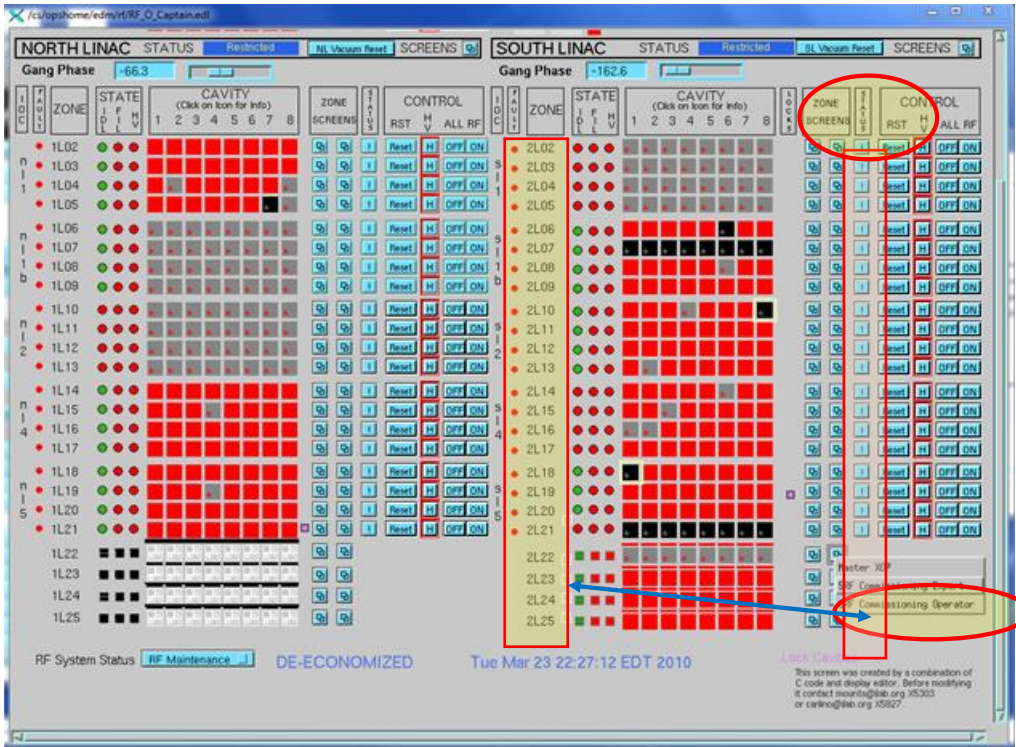


Figure 18: RF Captain



Figure 19: epics SRF Cavity Menu

7. Power Meter Calibration

- 7.1. Power Meter Calibration should be performed at the beginning of each shift prior to making any measurements.
- 7.2. Power Meters are located at the top of the rack shown in Figure 2.
- 7.3. Connect each power head to the calibration port on the appropriate power meter as shown in Figure 17.

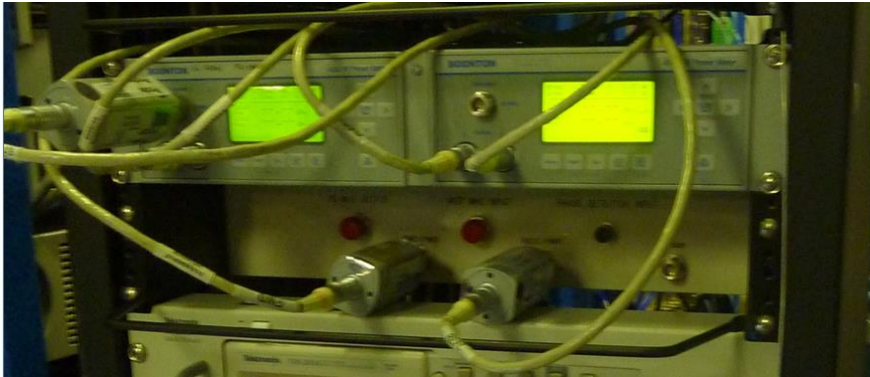


Figure 20: Power Meter Calibration

- 7.4. After the power head is connected, press the “ESC / STOP” button on the power meter front panel to take the instrument out of Remote mode.
- 7.5. Press the “Zero / Cal” button. Use the arrow keys to select the correct sensor.
- 7.6. Use the arrow keys to select “AutoCal”, then press the “Enter / Run” button.
- 7.7. After the calibration sequence is complete, repeat steps 6.3 – 6.6 for the next power head.

8. RF Cable connections- Commissioning Cart to Patch Panel:

- 8.1. Three RF cables for Probe, P_{Fwd} , P_{Ref} should be connected to the free ports of the RF couplers (the free port is nearest to the panel) on the **LLRF Patch Panel** (see Figures 18 and 19).
- 8.2. The BNC cable for the Pulse trigger should be connected to the TTL OUT 1 BNC port on the **Field Control Chassis** corresponding to the cavity to be tested.

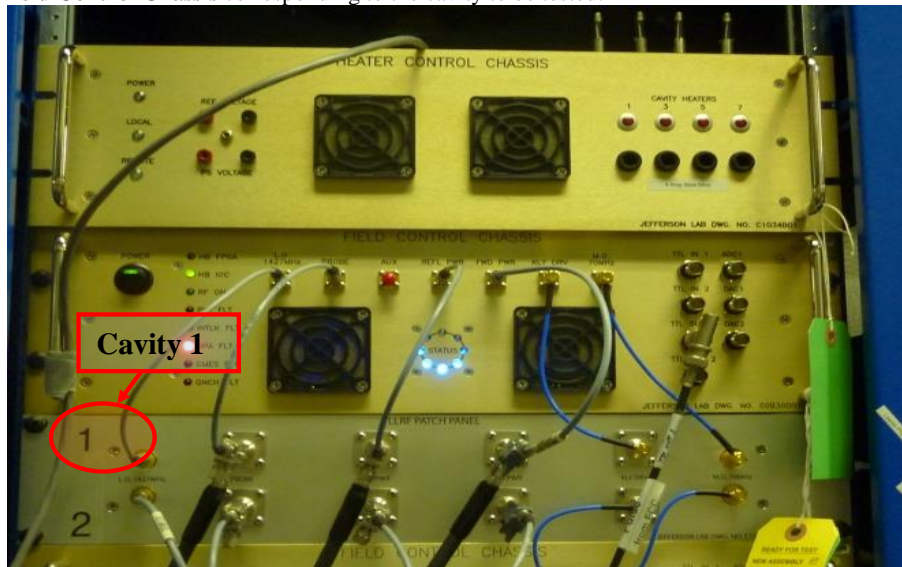


Figure 21: Patch Panel Connections and Field Control Chassis

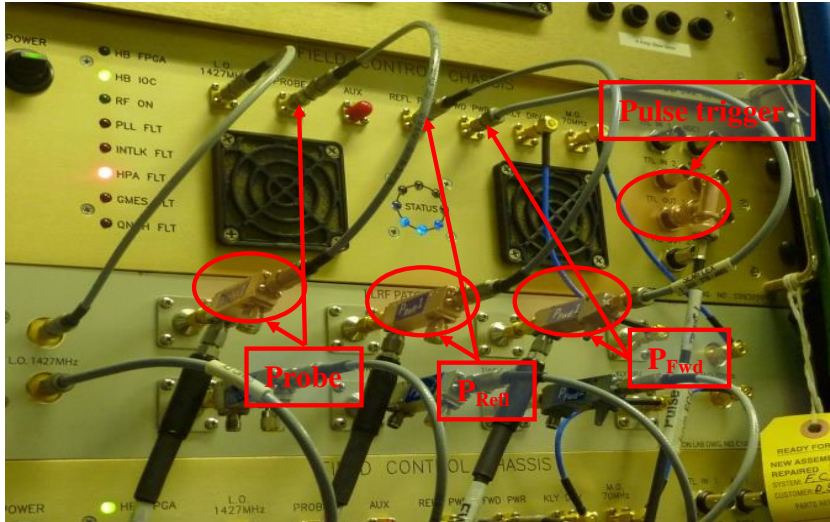


Figure 22: Patch Panel Connection Details

9. Labview Set up Steps:

- 9.1. Input the module ID for the cryomodule which is to be commissioned in the input field labeled ZONE at the bottom of the screen (Ex. 2L22_com). See Figure 20.

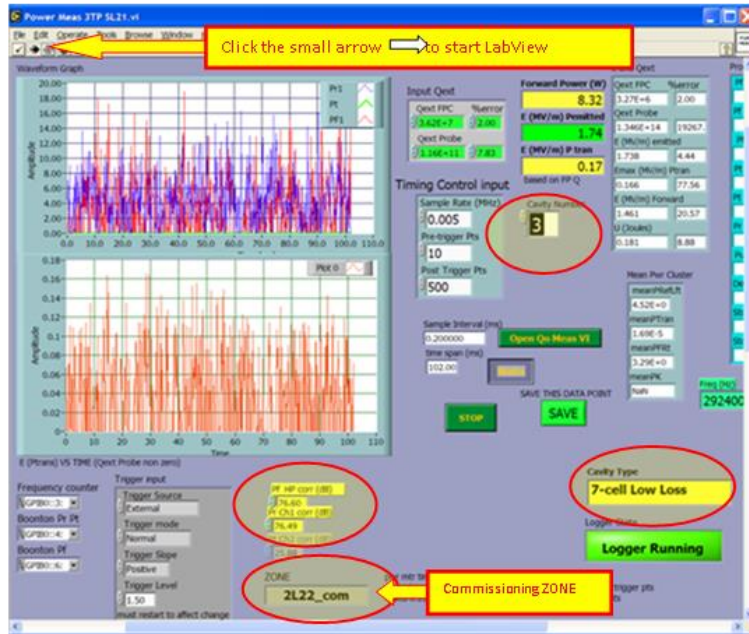


Figure 23: Labview Window Set Up

- 9.2. Enter the Cavity type (C100 cavities are 7-cell Low Loss).
- 9.3. Select the cavity number to be tested, central right side of the screen (Ex. Cavity Number 3).
- 9.4. Input the Cable Corrections in the two corresponding input fields at the bottom of this screen (Ex. Pf HP corr (dB) 76.60 and Pr Ch1 corr (dB) 76.49). Values for input cable correction are found in white binder located on the commissioning cart (see Figure 21). If there are any questions or issues, contact Mike Drury (757 748 6982) or Larry King.

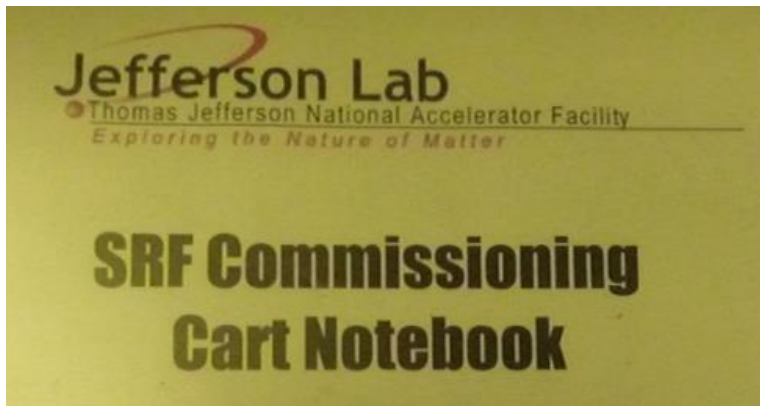


Figure 24: White Binder Cover

- 9.5. To save input data:
 - 9.5.1. Right click on each input field
 - 9.5.2. Select “Data Operations”
 - 9.5.3. Then Select “Make Current Values Default”
 - 9.5.4. After performing this operation on each of the updated input fields, perform a Save (CNTRL – S or select “Save” from the File menu).
 - 9.6. Start Labview main routine by clicking on the black arrow at top left (see Figure 19).
 - 9.7. Start the logfile writing routine (see Figure 9) in the same manner.
 - 9.8. The Main RF measurement window contains an indicator which shows whether the logfile writer is running. (See Figure 20, lower right corner).
- 10. RF Startup Steps**
- 10.1. From the SRF Cavity Menu (shown in Figure 16), select the Cavity to be tested. This will open up the window shown in Figure 22:

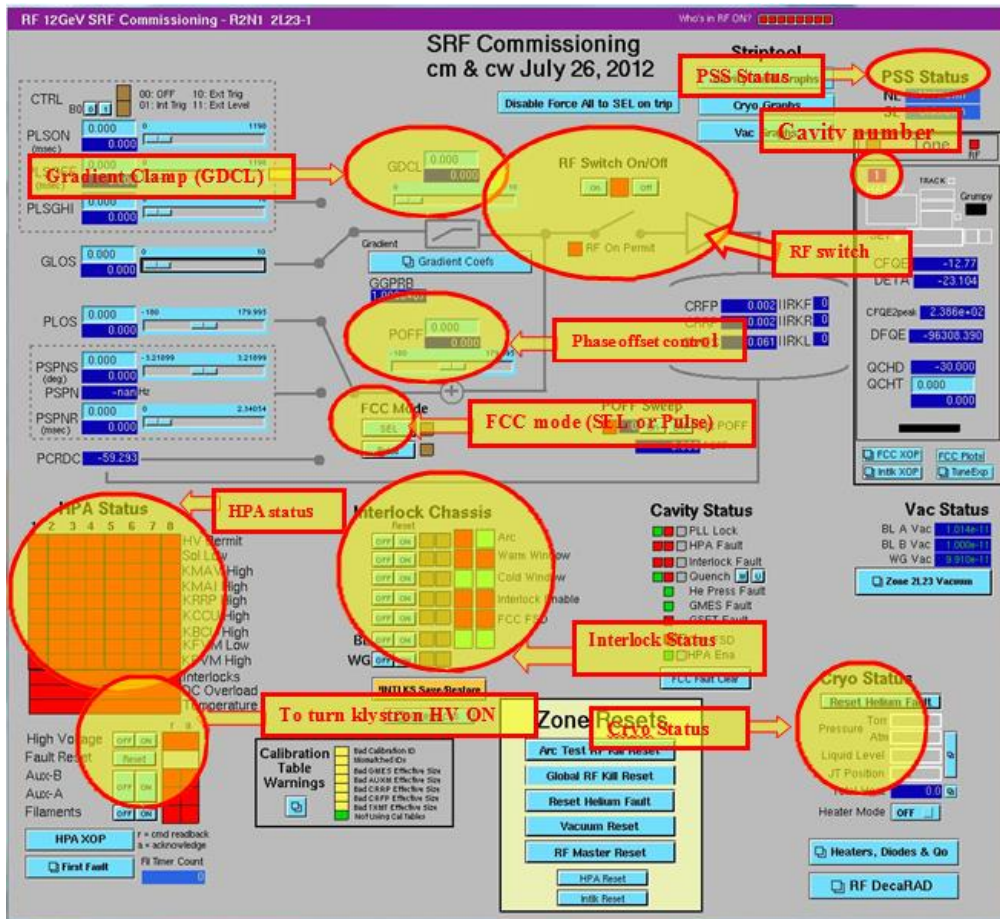


Figure 25: SRF Commissioning Operator Screen

- 10.2. The screen shown in Figure 22 has the following controls and indicators:
- 10.2.1. PSS Status – on the right top of the screen (Status must read Beam Permit or Power Permit before RF can be turned on).
 - 10.2.2. Cavity number can be identified on the right side of the screen.
 - 10.2.3. Select tuner operation mode – Manual or Auto. For SRF Commissioning, the tuner must be in Manual mode.
 - 10.2.4. RF switch On/Off at the top middle right on the screen. When RF is ON the knife switch is closed (RF Permit indicator must be green).
 - 10.2.5. Gradient Clamp (GDCL) slider(used as gradient control during SRF Commissioning) and Phase Offset slider (POFF).

- 10.2.6. Pulsed / Self Excited Loop (SEL) Field Control Chassis (FCC) Mode controls. SEL mode similar to CW VCO control as used in CMTF.
- 10.2.7. RF Forward Power (CRFP), RF Reflected Power (CRRP) and Measured Gradient (GMES) indicators. Center right of screen
- 10.2.8. HPA controls and status (bottom left side of screen).
- 10.2.9. Interlock status – bottom middle right – Interlock Chassis
- 10.2.10. Cryogenic Status (He Pressure, He Level, JT Position, Heater Status (bottom right).
- 10.3. **Turn On Klystron High Voltage (HV):**
 - 10.3.1. To turn on klystron HV, filament voltage must be turned on (there is a 600 s delay after filament turn on before HV will be enabled. Click the blue Filaments “ON” button to turn on filament voltage.
 - 10.3.2. The Klystron Cathode power supply switch handle must be in the down position (see Figure 6).
 - 10.3.3. PSS status must be **Power Permit** or **Beam Permit** mode to enable HV. PSS status is indicated on the screen shown in Figure 22. Contact Crew Chief at 7045 if there are any questions about the PSS status.
 - 10.3.4. **Aux A** and **Aux B** must also be turned on. Click the appropriate blue “ON” buttons.
 - 10.3.5. Reset any Power Supply Faults by clicking the blue “**FAULT RESET**” button.
 - 10.3.6. When all of the HV Power Supply Status indicators are Green, click the blue HV “ON” button to enable HV.
- 10.4. **Epics Striptool Setup**
 - 10.4.1. From OPS Menu select Strip Chart Menu and then MyaViewer – Strip Chart – See Figure 23.

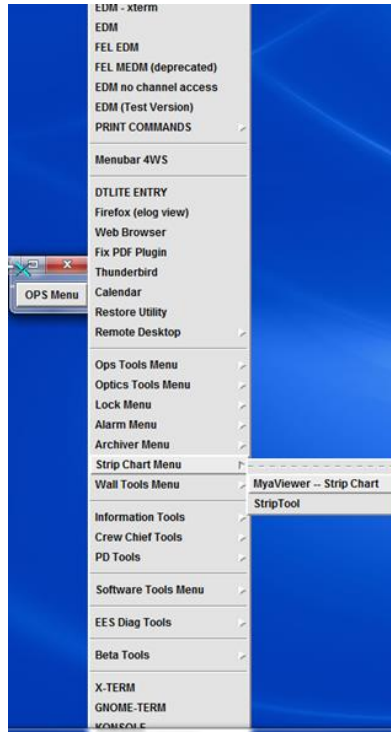


Figure 26: Opening MyaViewer

10.4.2. From OPS Menu select Strip Chart menu, then MyaViewer → Strip Chart.

10.4.3. This will open a blank Strip Chart as shown in Figure 24.

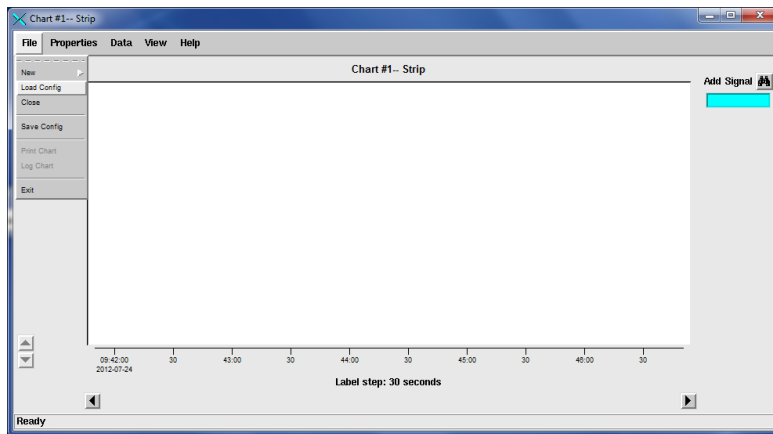


Figure 27: Load Strip Chart Configuration

10.4.4. Select Load Config from the File menu

10.4.4.1. Scroll down in the Load configuration menu (choose directory: /cs/certified/config/MyaViewer/*.xml).

10.4.4.2. Scroll left side window down to SRF_xLxx_DRADS.xml. Select Load, then Close buttons. This will load the ten DecaRad radiation monitoring channels.

10.4.5. Load the configuration file for the main commissioning strip chart (SRF_xLxx_com.xml). Select Load, then Close buttons. See Figure 25.

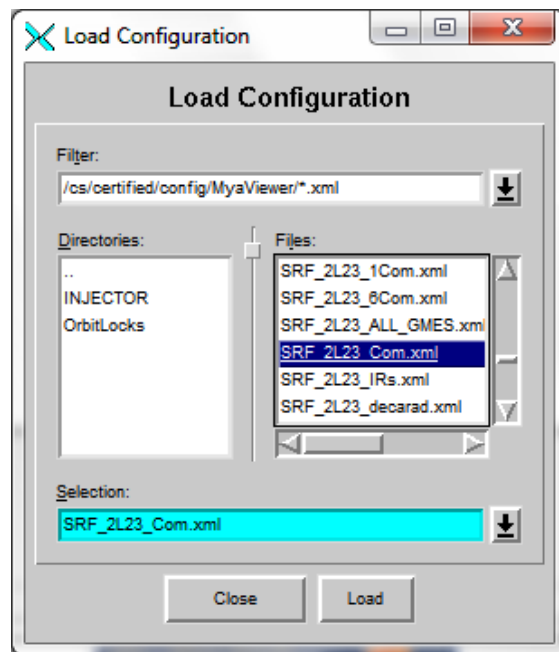


Figure 28: Load Configuration Example (for 2L23)

10.4.5.1. The following set of signals will be loaded into the Strip Chart:

10.4.5.1.1. Cryogenic Signals:

10.4.5.1.1.1. JT valve: CEVxLxxJT.ORBV (ex. for cryomodule 2L23-CEV2L23JT.ORBV),

10.4.5.1.1.2. Liquid Helium level: CLLxLxx50 (ex. for cryomodule 2L23-CLL2L2350).

10.4.5.1.1.3. Helium pressure: CPIxLxx60 (ex. for module 2L23-CPI2L2360)

10.4.5.1.1.4. 2K Primary input temperature :CTDxLxx10 (ex. for cryomodule 2L23-CTD2L2310).

10.4.5.1.2. RF signals:

- 10.4.5.1.2.1. RF Forward Power: RxxxCRFP (for 2L23-1 - R2N1CRFP)
- 10.4.5.1.2.2. RF Reflected Power: RxxxCRRP (for 2L23-1 - R2N1CRRP).
- 10.4.5.1.2.3. IR-Vacuum side sensor: RxxxCWWT (for 2L23-1 - R2N1CWWT).
- 10.4.5.1.2.4. IR-Air side sensor: RxxxCWWTW (for 2L23-1 - R2N1CWWTW).
- 10.4.5.1.2.5. Gradient: RxxxGMES (for 2L23-1 - R2N1GMES)

10.4.6. Figure 26 shows an example Strip Chart:

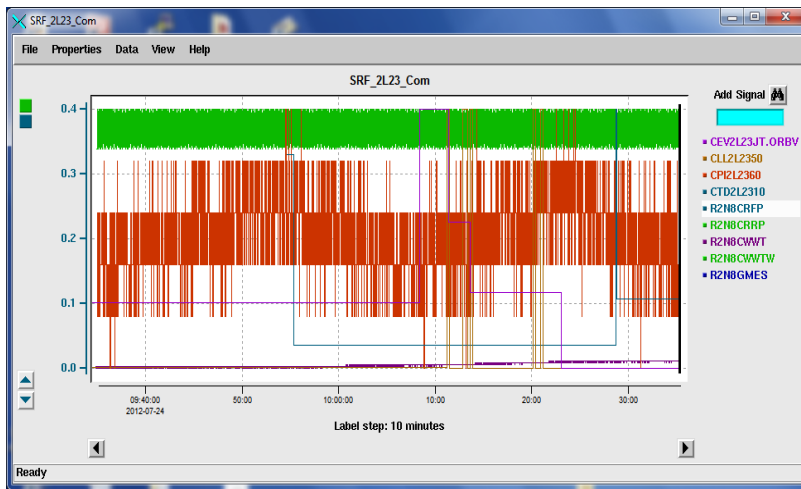


Figure 29: Example SRF_xLxx_Com Chart

10.4.7. By right clicking on an individual signal, you may hide or Show any of the signal traces in the Strip Chart. See Figure 27.

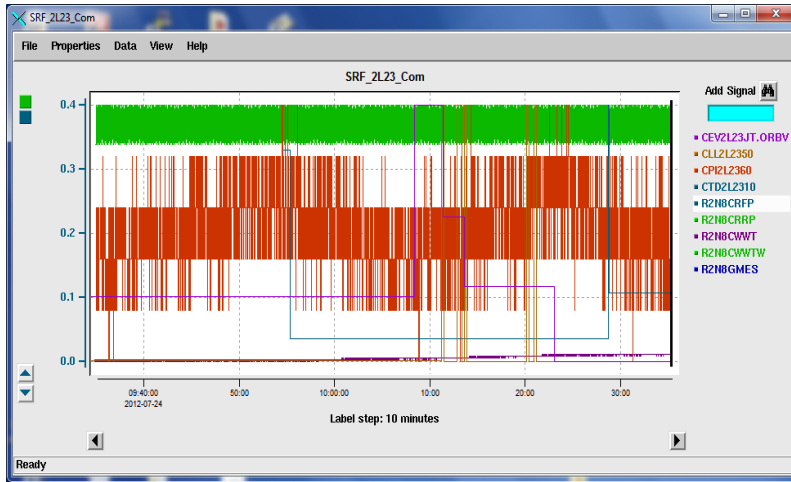


Figure 30: Hiding signals in Strip Chart

10.4.8. For cryomodule Vacuum signals, load the configuration Vac_xLxx.

10.4.8.1. Figure 28 has examples of Decarad and Vacuum Strip Charts:

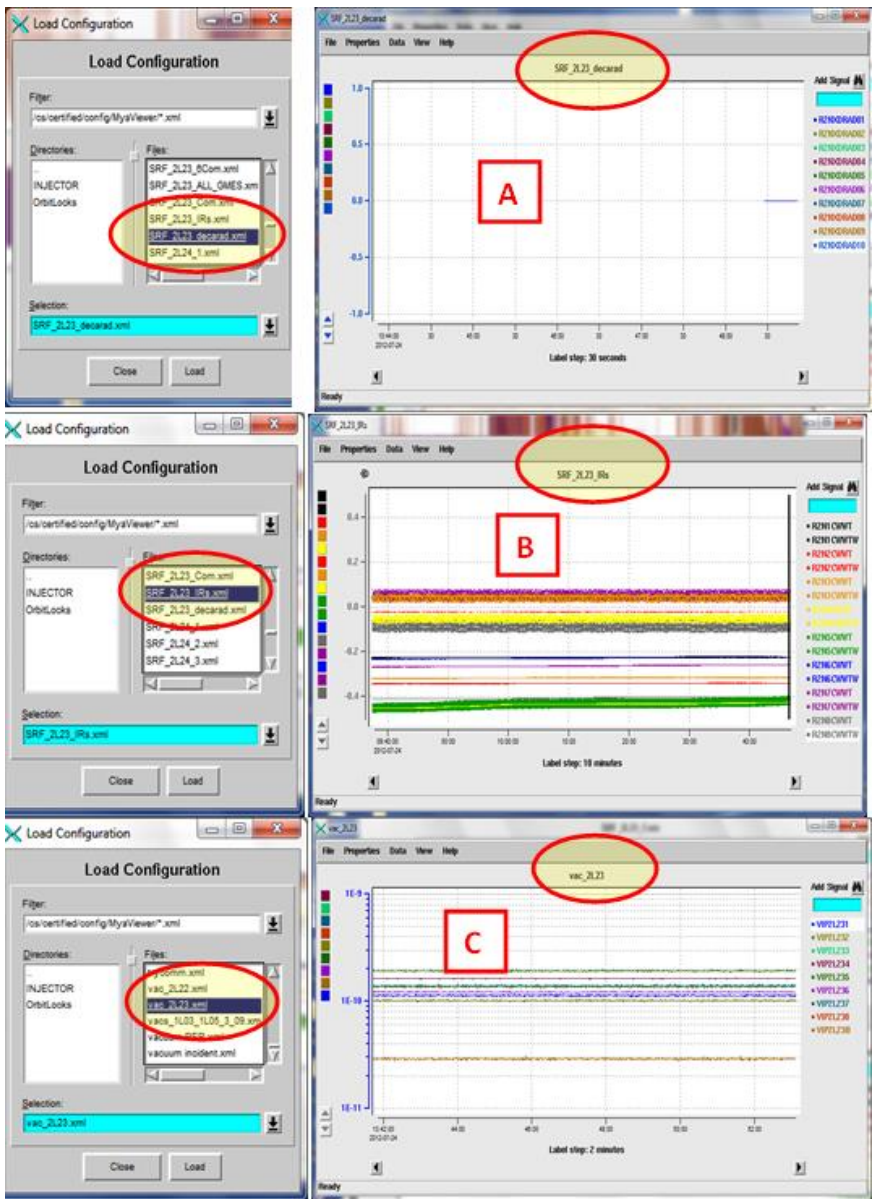


Figure 31: Strip Chart examples

10.4.9. The timescale of any Chart may be modified by clicking on the arrow buttons below the graph.

10.4.10. After the Strip Charts are set up, it is time to turn on RF.

10.5. RF Turn On

10.5.1. Use Figure 29 as a reference for the following steps:

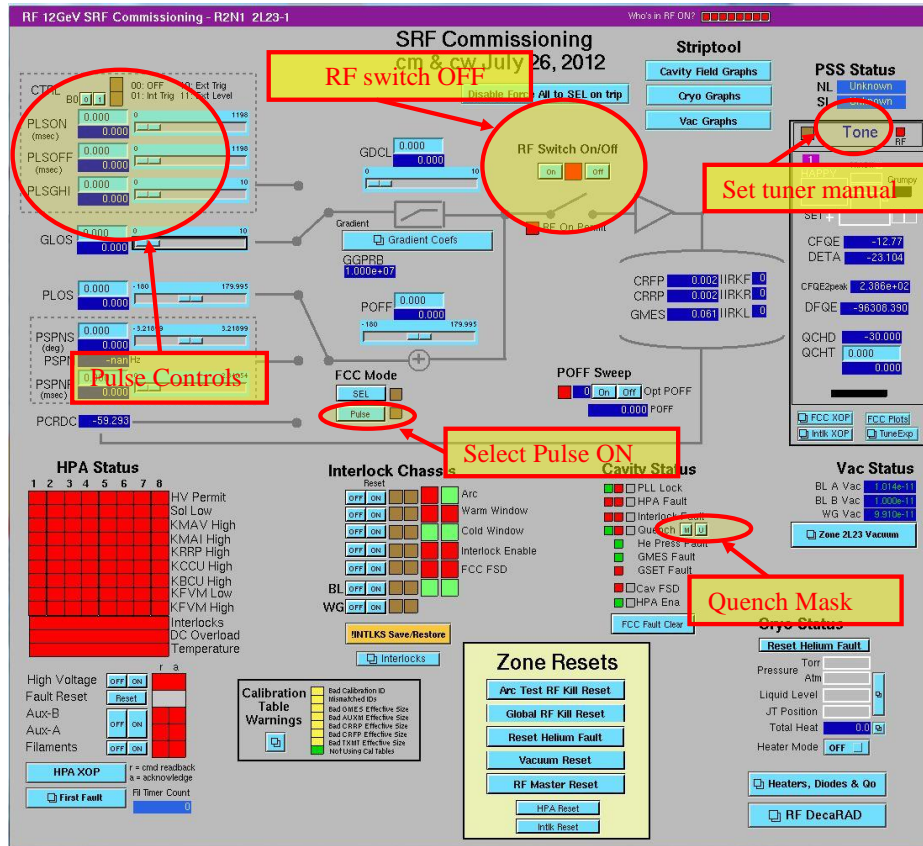


Figure 32: Preparation for Turning RF On

- 10.5.1.1. On the RF 12 GeV SRF Commissioning screen, check that the knife switch is in the up (or Off) position.
- 10.5.1.2. Check that the tuner is in Manual Mode (on the top right of the screen).
- 10.5.1.3. Check the following settings:
 - 10.5.1.3.1. Set RF mode to Pulse (center of screen).
 - 10.5.1.3.2. Find pulse control settings: B0 bit should be turned on by clicking on small blue button labeled "1" (upper left screen).
 - 10.5.1.3.3. PLSON should be set to 60 ms.
 - 10.5.1.3.4. PLSOFF should be set to 120 ms.
 - 10.5.1.3.5. PLSGHI should be set to 1.500.
 - 10.5.1.3.6. PLSGLO should be set to 0.0 (Default).

- 10.5.1.3.7. GLOS should be set to 1.500 (just below Pulse controls).
- 10.5.1.3.8. GDCL (Gradient Clamp) should be set to 0.000 (Left of RF Switch).
- 10.5.1.3.9. GDCL starting increment set to 0.03-0.04 by left clicking on the slider.
- 10.5.1.3.10. POFF increment set to 1 by left clicking on the slider (center screen).
- 10.5.1.3.11. Quench must be masked by clicking on small blue button labeled “M”. Yellow indicator means mask is enabled.

10.5.2. The operator may now to turn RF ON and perform the probe calibrations.

11. Probe Calibration:

- 11.1.1. Insure the High voltage is On (see Step 9.2).
- 11.1.2. Turn RF ON in **PULSE** mode.
- 11.1.3. Increase GDCL until you have 200-300 W of Forward Pwr (as shown on the Labview screen. See Figure 30)

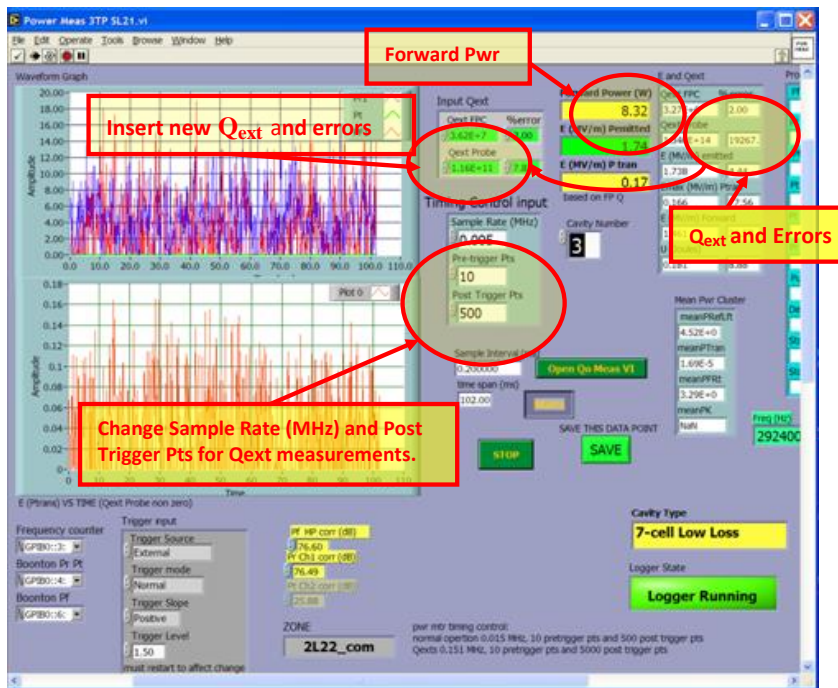


Figure 33: Qext Measurement - Labview screen

- 11.1.4. Tune the RF using the POFF slider center of screen see Figures 22 or 29.
- 11.1.5. On the LabView_Laptop, set the power meter Sample Rate and Post Trigger Points for the high resolution mode (Sample rate = 0.050 and Post Trigger Pts =

5000 in the Timing Control Input cluster in the center of the LabView screen (see Figure No. 34) then measure and log Qext's and errors (Q_{extFPC} and Q_{extFP}).

11.1.6. After the Waveform Graph has updated to new settings, measure and log Qext's and errors (Q_{extFPC} and Q_{extFP}).

11.1.7. It may be necessary to adjust the Sample Rate so that one complete Pulse waveform is displayed in the Waveform Graph window.

11.1.8. Enter Qext's and errors into the green input fields. See Figure 30.

11.1.9. Record the Qext values, the value for E (MV/m) PTran and the time in the paper logbook.

11.1.10. Click the green button labeled "Save This Data Point" located on lower right side of the screen. This will save the waveform data to a file.

11.2. Gradient Calibration

11.2.1. On the epics screen shown in Figure 29, switch to SEL mode.

11.2.2. After both epics and Labview screens have updated, check for good agreement between E (MV/m) PTran (Labview) and GMES (epics).

11.2.3. After 15 – 30 seconds, when readings are stable, record time, EPtrans and GMES in the logbook.

11.2.4. If there is not good agreement (discrepancy greater than 2%):

11.2.4.1. Click on the blue Gradient Coefficients button located in the middle upper part of the SRF Commissioning screen (see Figure 31).

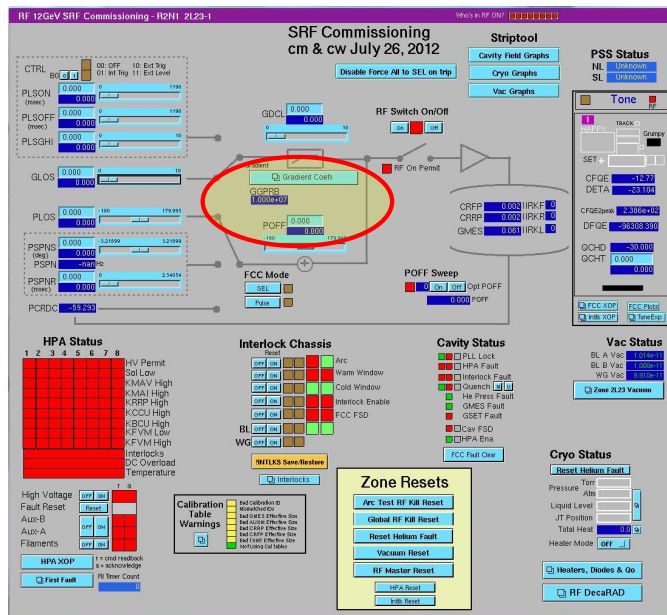


Figure 34: Location of Gradient Coefficients Button

11.2.4.2. This will open the “Gradient Setpoint” screen (see Figure 32).

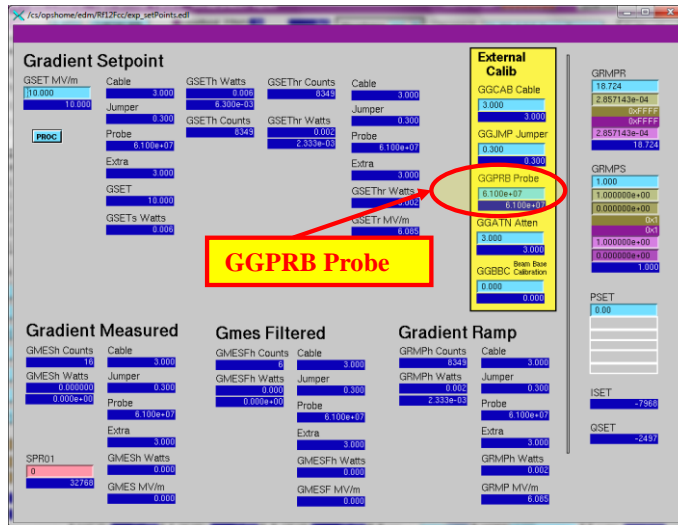


Figure 35: Gradient Setpoint screen

- 11.2.4.3. Record in the logbook the old GGPRB value.
- 11.2.4.4. Calculate the correct probe calibration (New GGPRB = old GGPRB * EPtrans / GMES).
- 11.2.4.5. Enter the new probe calibration in the GGPRB Probe field (see Figure 32).
- 11.2.4.6. Again check for agreement between EPtrans and GMES. If the discrepancy is still too large, repeat steps 9.5.13.1 – 9.5.13.6.
- 11.2.5. Save the new settings as follows:
 - 11.2.5.1. On Monticello screen click on the blue button to the left of the IOC's entry (see Figure 33).

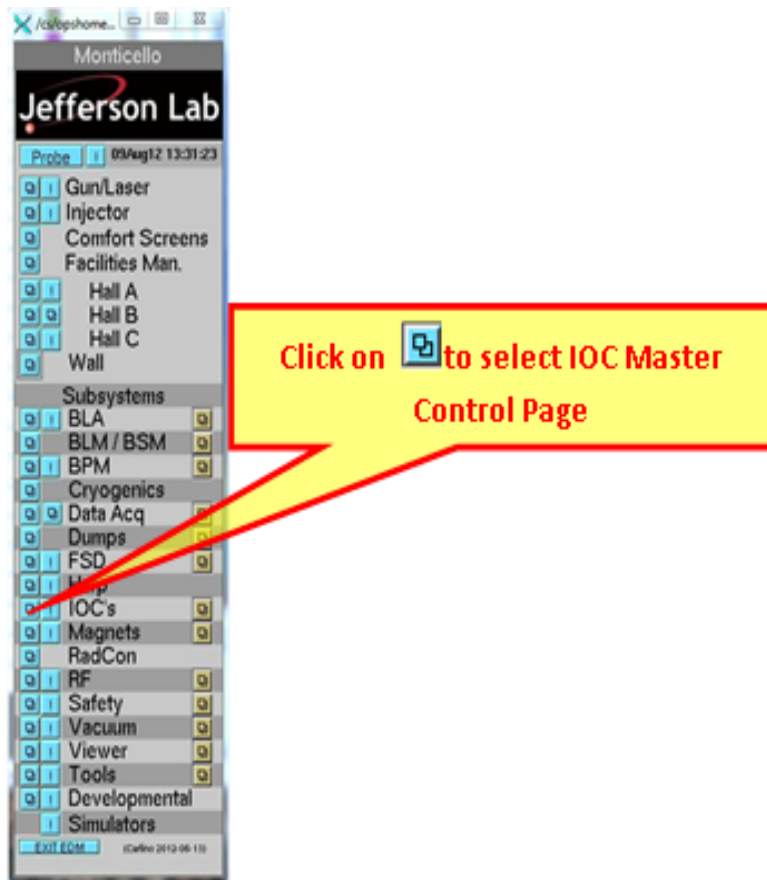


Figure 36: Selecting IOC Master Control Page

11.2.5.2. This will open the IOC Master Control Page (see Figure 34).

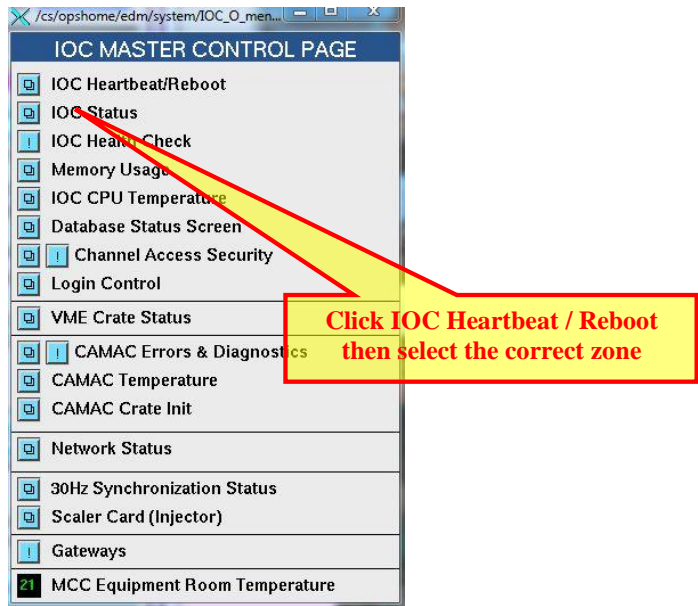


Figure 37: IOC Master Control Page

11.2.5.3. Click IOC Heartbeat/Reboot and select the correct zone. See Figure 35.

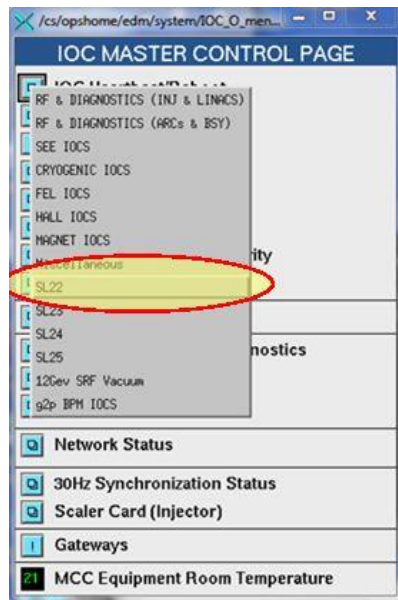


Figure 38: Selecting Correct Zone

11.2.5.4. This will open the screen shown in figure 36.

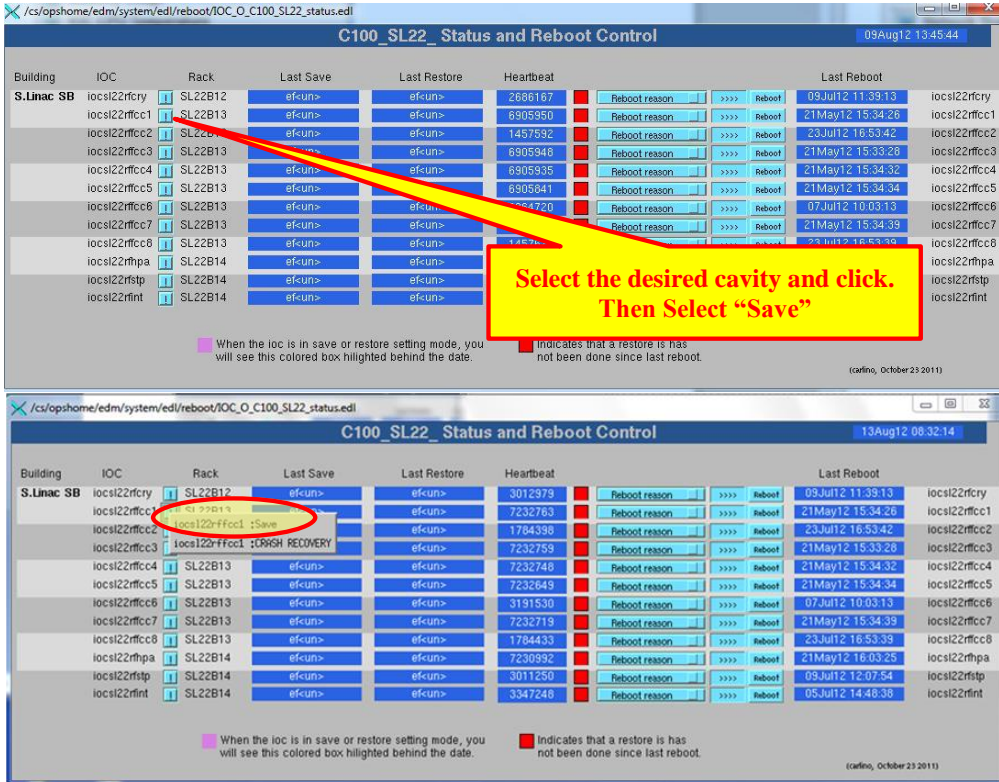


Figure 39: Status and Reboot Control Screen

11.2.5.5. On the C100_SL22_Status and Reboot Control for selected zone click on the small blue button at the left of iocsl22rffcX (in Figure 36, Cavity 1 in Zone SL22 is selected).

11.2.5.6. From the pull-down menu select Save.

11.2.6. Return to Pulse mode.

11.2.7. On the Labview screen, return the power meter settings to the normal resolution mode (0.005 MHz sample rate and 500 post trigger points).

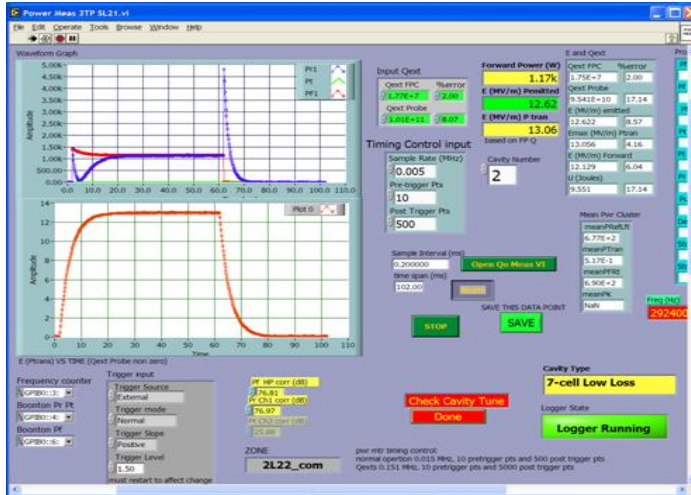


Figure 40: Labview screen showing Pulsed Waveforms

12. Emax Determination (Pulsed Mode)

- 12.1. For the C100 cryomodules, Emax measurements should start at approximately 7 MV/m.
- 12.2. Set the GDCL slider to a 0.03 increments. See Figures 29 or 31.
- 12.3. Check the white binder to see the value for Emax that has been established in previous RF power tests made in the VTA or CMTF. The Summary sheet will contain the information for the cavity you wish to test. These earlier measurements should be used to guide the operator. (if there are any questions contact Mike Drury).
- 12.4. In the logbook, prepare a table with the following headings:
 - 12.4.1. Time, GDCL (no units), $E_{P_{trans}}$ (MV/m), P_{Fwd} (kW).
- 12.5. Starting at approximately 7 MV/m and in Pulse mode, increase the gradient by GDCL increment (0.03). See Figure 37 for Labview screen with RF in Pulse mode.
- 12.6. Wait for no less than two minutes between each increase to allow time for the cavity to either stabilize or for the RF to fault.
- 12.7. While waiting:
 - 12.7.1. Make an entry in the logbook table.
 - 12.7.2. Watch the cryogenics signals for signs of instability.
- 12.8. Continue to increase the gradient in this mode until you reach ~18.0 MV/m.
- 12.9. When you reach ~18 MV/m and assuming no faults have yet occurred, decrease the GDCL increment to 0.01.
- 12.10. Once the gradient has been increased above 18.0 MV/m, the likelihood of encountering fault conditions will increase greatly.
- 12.11. See Sections 13 and 14 for information on RF fault conditions and how to handle them.

- 12.12. Continue raising the gradient in this manner until:
 - 12.12.1. You reach a gradient that you are unable to exceed due to faults.
 - 12.12.2. The Administrative Limit of 25 MV/m is reached.

13. Emax Determination (SEL mode)

- 13.1. Once the maximum gradient has been reached in pulsed mode:
- 13.2. Prepare a new table in the logbook with the following headings:
 - 13.2.1. Time, GDCL (no units), GMES, EP_{trans} (MV/m), CRFP(kW), P_{Fwd} (kW).
- 13.3. Reduce the gradient by ~2 MV/m.
- 13.4. Switch FCC mode to SEL.
- 13.5. At this time recheck the gradient calibration by repeating steps 10.2.2 – 10.2.5.6.
- 13.6. Before increasing the gradient, insure that cryogenics (esp. Liquid Level) are stable.
- 13.7. If so, begin raising the gradient as defined in Step 14.1.6 below.
- 13.8. In addition to the faults described in Section 12.9 below, you must now watch for signs of boiling in the liquid Helium bath. When this occurs, the RF Heat Load has increased to a level that can no longer be handled by the cryomodule design.
 - 13.8.1. The signature of boiling is an unstable Liquid Level signal. The Liquid Level will change rapidly by as much as 10% or more in either direction in a matter of seconds.
 - 13.8.2. The Helium Pressure will also begin to rise.
 - 13.8.3. Note: Expect a delay of at least one minute between the time you increase the gradient until boiling actually starts.
 - 13.8.4. If boiling occurs, you must decrease the gradient.
 - 13.8.5. Decrease the GDCL value by 0.01.
 - 13.8.6. Wait at least one minute to see if the Liquid level begins to stabilize.
 - 13.8.7. If stabilization does not occur, repeat steps 12.9.1 and 12.9.2.
 - 13.8.8. The gradient at which boiling does not occur will be considered as Emax.
- 13.9. If no boiling occurs:
 - 13.9.1. Continue raising the gradient in this manner until:
 - 13.9.1.1. You reach a gradient that you are unable to exceed due to faults.
 - 13.9.1.2. The Administrative Limit of 25 MV/m is reached.
- 13.10. This gradient is Emax.
- 13.11. Once Emax has been determined, proceed to the One Hour Run Section below.

14. Possible causes of RF faults are:

- 14.1. Cavity quench
 - 14.1.1. Note: Since the quench detector is masked, a quench will not cause RF to trip. The operator is responsible for clicking the RF switch off if a quench occurs.
 - 14.1.2. Signs of a quench include:
 - 14.1.2.1. Sudden large drop in gradient (GMES and EP_{Trans}) without a concurrent drop in Forward Power.
 - 14.1.2.2. Drop in gradient is accompanied by instability in the Liquid Level read back.
 - 14.1.2.3. Helium Pressure will begin to rise rapidly until RF is turned off.
 - 14.1.2.4. It is therefore important to pay attention to the cryogenic signals.
- 14.2. Waveguide Vacuum events

- 14.3. Arcing
- 14.4. Window Temp (Warm or Cold).
- 14.5. Beamline Vacuum events.
- 14.6. For the C100 cryomodules, the most likely fault will be a quench or in some cases, waveguide vacuum events.
- 14.7. In general, you will not see faults until the gradient has reached above 18 MV/m.

15. Dealing with Fault Conditions

- 15.1. If the cavity quenches:
 - 15.1.1. **TURN RF OFF IMMEDIATELY!**
 - 15.1.2. Wait for cryogenic conditions to stabilize (specifically Liquid Level) prior to turning the RF back on. This may take several minutes.
 - 15.1.3. Lower the gradient by several GDCL increments.
 - 15.1.4. Lower the GDCL increment to 0.001.
 - 15.1.5. Note: when you turn the RF OFF or the cavity faults, the RF mode will automatically switch to SEL mode. Make sure you are in Pulse mode before turning RF ON.
 - 15.1.6. From this point on, raise the gradient by incrementing GDCL **slowly** in 5 steps of 0.001 each adding up to an increment of 0.005. Example: 5 clicks to get from GDCL=0.800 to GDCL=0.805.
 - 15.1.7. At least three attempts must be made to challenge the quench gradient. In many cases, you will be able to surpass the previous quench gradient. This is where knowledge of previous Emax determinations as contained in the summary sheet will be useful.
- 15.2. If a vacuum event (Beamline or Waveguide) causes an RF fault:
 - 15.2.1. Wait for the vacuum in question to recover.
 - 15.2.2. Reset vacuum interlocks. (See Appendix II)
 - 15.2.3. Follow steps 14.1.3 - 14.1.6.
- 15.3. Window temperature Faults
 - 15.3.1. If a window temperature related RF fault occurs do not attempt to further increase the gradient.
 - 15.3.2. Reset the fault and proceed to the section on One Hour Runs.
 - 15.3.3. Contact Mike Drury
- 15.4. If an arcing event causes an RF fault:
 - 15.4.1. Reset vacuum interlocks.
 - 15.4.2. Follow steps 14.1.3 - 14.1.6.
 - 15.4.3. Try to exceed the original arcing gradient.
 - 15.4.4. All fault events must be recorded in the logbook with the time and gradient at which they occurred.

16. One Hour Run

- 16.1. If the cavity reached the Administrative Limit try to complete the Run at that gradient.
- 16.2. If the cavity is limited by quench or other fault, decrease the gradient by 0.8 MV/m and try to complete the Run there.
- 16.3. The GDCL increment must be set to 0.001.
- 16.4. If the gradient droops or begins to drift upwards, use GDCL to correct the gradient level.
- 16.5. Watch for boiling.
- 16.6. If the Run is interrupted by an RF fault such as a quench or if boiling occurs:
 - 16.6.1. Decrease the gradient by 0.2 MV/m and try again.
- 16.7. Record start and end times along with the gradient for each attempt in the logbook and any faults that interrupt an attempted run.
- 16.8. The gradient at which a successful One Hour Run is completed is designated as Emaxop.
- 16.9. Once Emaxop has been determined, proceed to the Field Emission section below.

17. Field Emission Survey (FE vs. Eacc)

- 17.1. On the SRF commissioning screen (bottom right) click RF DecaRAD button (see Figure 38)

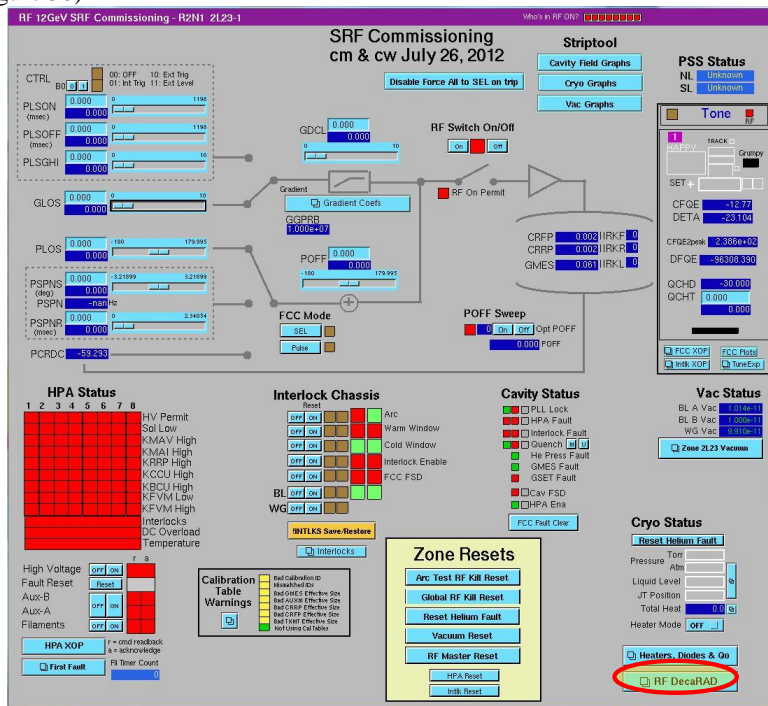


Figure 41: Opening the DecaRad Screen

- 17.2. That will bring up the DecaRAD screen with information for location and the readings for each radiation monitor installed on the cryomodule under test (see Figure 39)

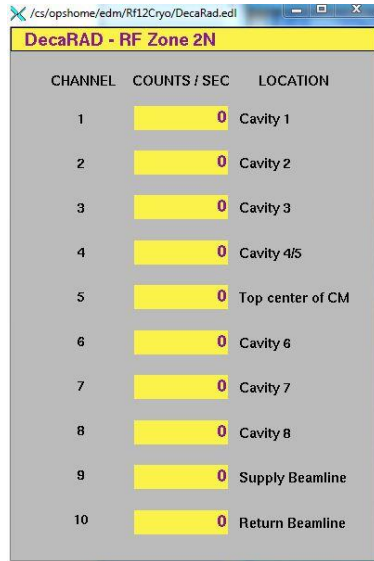


Figure 42: DecaRad screen

- 17.3. Bring the Stripchart graph for DecaRAD signals to the front (see Figure 40).

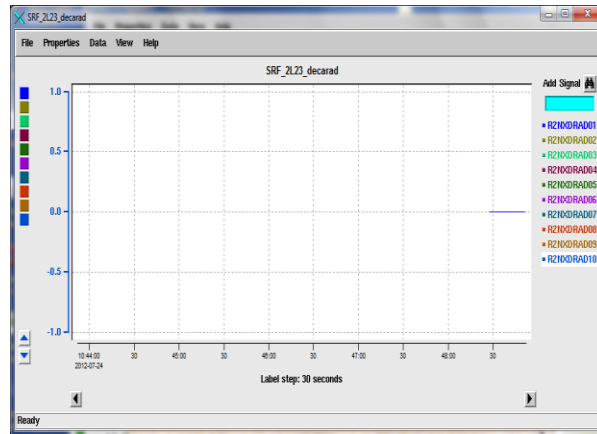


Figure 43: DecaRad StripChart

- 17.4. Set the GDCL increment to a value of 0.02
 17.5. Starting at Emaxop, begin decreasing the gradient in one increment steps.

- 17.6. Wait at least 30 seconds between each step to insure a stable read back.
- 17.7. Continue lowering the gradient until all monitoring channels have reached zero counts / second. This gradient is the Field Emission Onset gradient.
- 17.8. Record this gradient in the logbook.

18. End of Shift Activities

- 18.1. Turn HV OFF on the SRF Commissioning screen.
- 18.2. Turn Klystron HV power supply OFF by moving the green knife switch DOWN (See Figure 6).
- 18.3. Inform the Crew Chief at 7045 that SRF activities have ended.
- 18.4. Go to the ELOG webpage:
http://opweb/CSUEApps/elog/elog.php?default_settings=true
- 18.5. Use your CUE login
 - 18.5.1. Complete an elog entry that includes the following information:
 - 18.5.1.1. Zone and cavities under test
 - 18.5.1.2. Tests performed
 - 18.5.1.3. Preliminary results, if any
 - 18.5.2. Select the following logbooks:
 - 18.5.2.1. ELOG
 - 18.5.2.2. SADLOG
 - 18.5.2.3. LLRFLOG
 - 18.5.3. In the Notify field, enter the following names:
 - 18.5.3.1. Drury
 - 18.5.3.2. Hogan
 - 18.5.3.3. Harwood
 - 18.5.3.4. Preble

Appendix I: Signal Nomenclature

1. Zone Location Code: xLxx
 - 1.1. 1st Digit:
 - 1.1.1. 0 = Injector
 - 1.1.2. 1 = N. Linac
 - 1.1.3. 2 = S. Linac
 - 1.1.4. 4 = FEL
 - 1.2. 3rd and 4th digits: Zone number
 - 1.3. Examples:
 - 1.3.1. 1L02 = 2nd zone in the N. Linac
 - 1.3.2. 2L24 = 24th zone in the S. Linac
 - 1.4. Currently, all C100 cryomodules are to be installed in zones 22 -26 in the N. Linac and S. Linac
2. RF signal nomenclature: RxxxXXXXXX
 - 2.1. First three digits after the R indicate the linac, zone and cavity.
 - 2.2. 1st Digit:
 - 2.2.1. 0 = Injector
 - 2.2.2. 1 = N. Linac
 - 2.2.3. 2 = S. Linac
 - 2.2.4. 4 = FEL
 - 2.3. 2nd digit:
 - 2.3.1. 2 – 9 for zones 2 - 9
 - 2.3.2. A- Q for zones 10 -26
 - 2.4. 3rd digit: 1 – 8 for the cavity number
 - 2.5. Last four -six digits for signal type
 - 2.5.1. CRFP – Forward Pwr
 - 2.5.2. CRRP – Reflected Pwr
 - 2.5.3. CWWT – Warm Window Temp (Vacuum side).
 - 2.5.4. CWWTW Warm Window Temp (Air side).
 - 2.5.5. GMES –Measured Gradient
 - 2.5.6. GSET – Gradient Set
 - 2.5.7. DRAD01 – DRAD10 – GM tube channels (See the binder for tube locations)
 - 2.6. Examples:
 - 2.6.1. R131GMES – Measured Gradient for Cavity 1 in zone 3, N. Linac
 - 2.6.2. R2PCRFP – Forward Pwr for Cavity 2 in zone 25, S. Linac
3. Vacuum signals:
4. Ion Pumps (Waveguide or Beamline)
 - 4.1. VIPxLxxB B pump on the cryomodule beamline vacuum.
 - 4.2. VIPxLxx1 – VIPxLxx8 – Waveguide vacuum pump. (one for each cavity)

4.3. See Section 1 above for Zone Codes.

4.4. Cold Cathodes on the Insulating Vacuum:

4.4.1. VCGxLxx10

5. Cryogenic Signals

5.1. CEVxLxxJT.ORBV – JT valve position

5.2. CEVxLxxRT.ORBV – RT valve position

5.3. CLLxLxx50 – Liquid Helium Level (%)

5.4. CPIxLxx60 – Liquid Helium Pressure (atm)

5.5. CTDxLxx10 – Primary Inlet Temperature (K)

5.6. CTDxLxx60 – Primary Outlet Temperature (K)

Appendix II Interlocks

1. Interlock Trip Levels

1.1. Beamline vacuum interlocks :

1.1.1. Fast vacuum trip: pressure $\geq 1 \times 10^{-7}$ torr will turn RF OFF

1.1.2. Slow vacuum trip: $\geq 3 \times 10^{-9}$ torr for longer than 60 minutes will turn RF OFF

1.2. Waveguide vacuum $\geq 1 \times 10^{-7}$ torr will turn RF OFF

- 1.3. Helium Liquid Level : $\leq 83\%$
- 1.4. Window Temperature Trip: ≥ 4.0 V
- 2. Resetting Interlocks After RF trip
 - 2.1. Vacuum trips

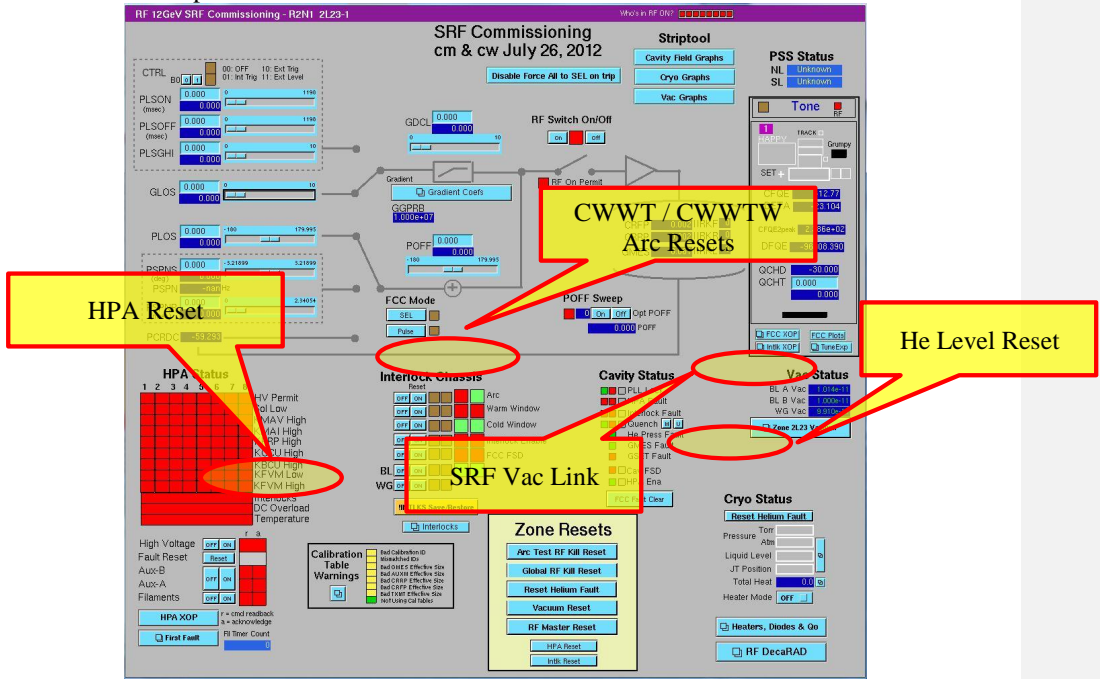


Figure 44: Interlock Resets

2.1.1. Click the blue “Zone Vacuum” button as shown in Figure 41 and select “SRF Vac Operational”. This will open the window shown in Figure 42:

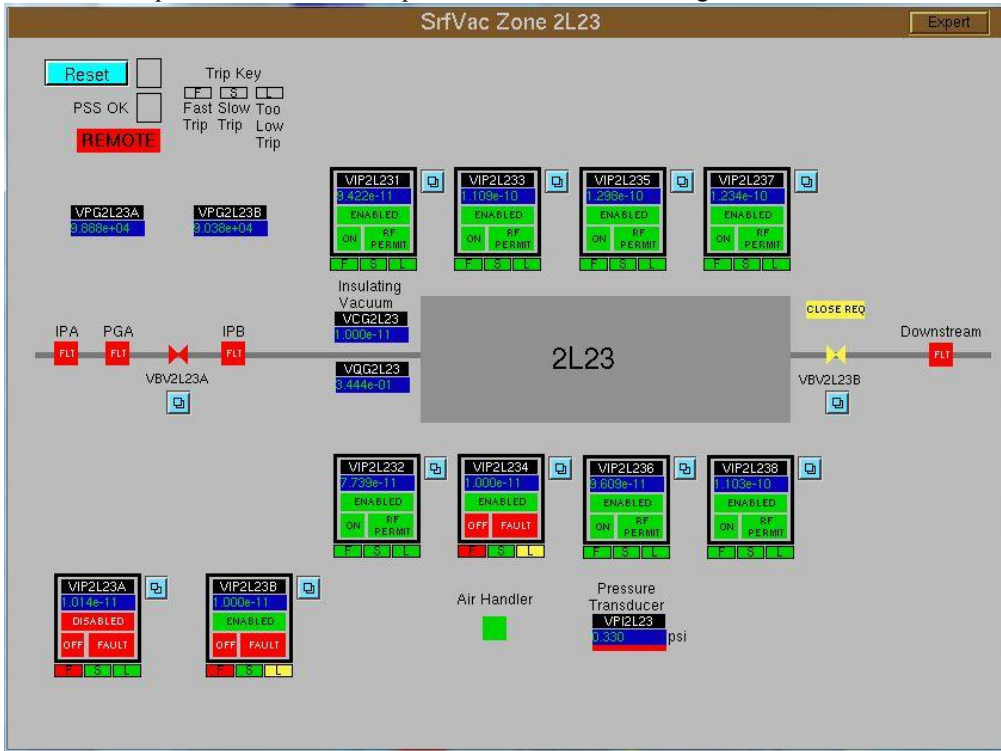


Figure 45: SRF Vac Operational Screen:

- 2.1.2. Click the blue Reset button located in upper left hand corner. This should reset any vacuum faults as long as the vacuum in question is given time to recover (drop below trip level).
- 2.2. Window Temp and Arc Faults: Locate the group of buttons in the center of the screen as shown in Figure 41. Click the “ON” button for the type of fault. This should clear the fault in question. Be sure to click the “OFF” button after clearing the fault.
- 2.3. Liquid Level Faults; Click the blue “Reset Helium Fault” button in the lower right hand corner of the screen as shown in Figure 41. Be sure that the Liquid Level has had time to recover.
- 2.4. HPA / klystron Faults: Locate the blue “Reset” button below the HPA Status block in the lower left hand portion of the screen. This should clear any faults.
- 2.5. If you are unable to clear RF faults as described, contact M. Drury.

