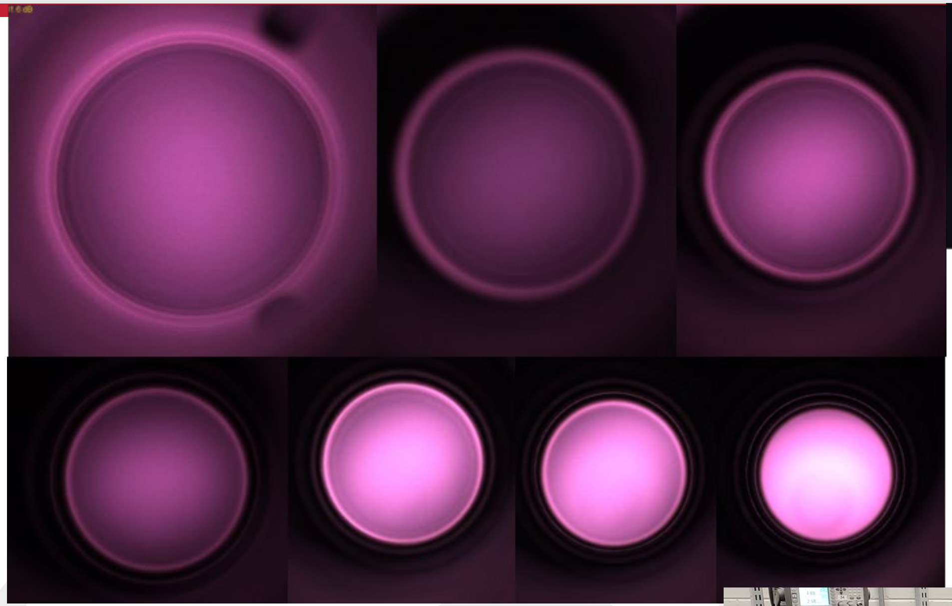
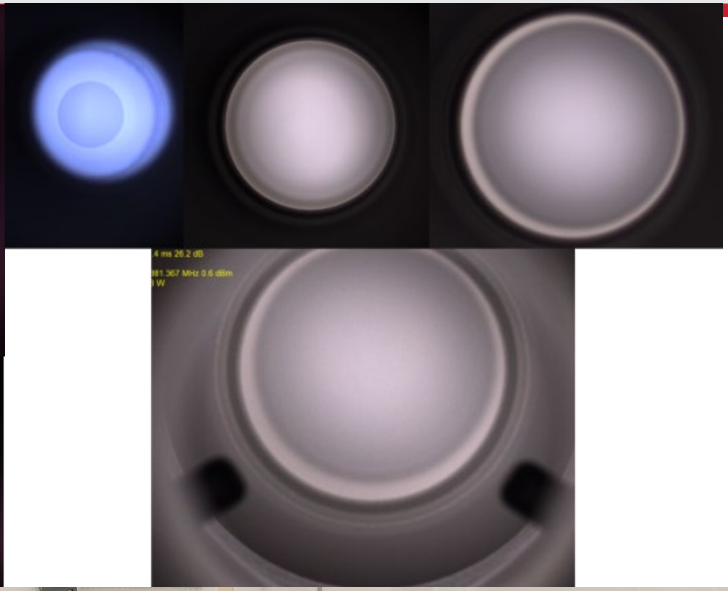
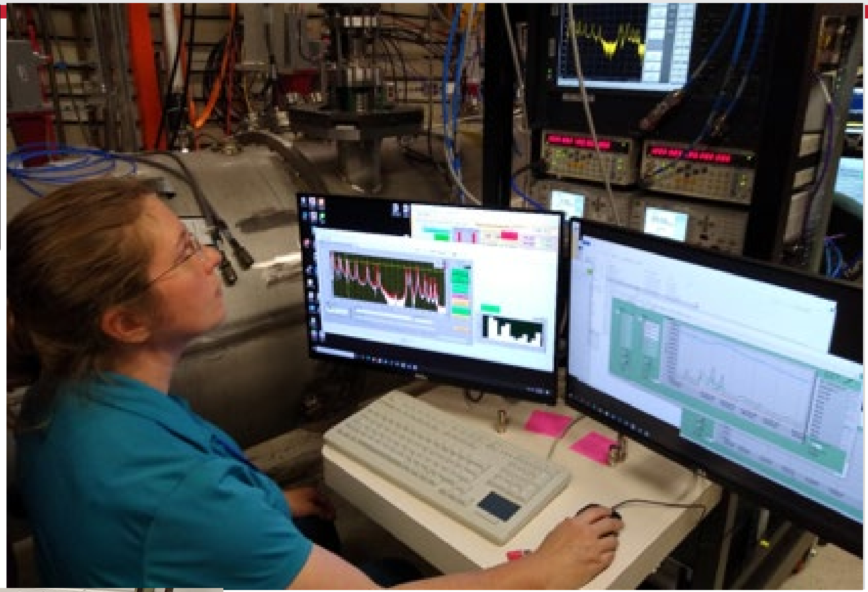
OSP and Task Hazard Analysis







Tom Powers and Tiffany Ganey

Plasma Processing Readiness review
28 Feb. 2023

Other contributors:

JLAB:	ORNL
Natalie Brock	Marc Doleans
Christiana Wilson	Chris Mahan
Kurt Macha	

Vertical Tests:	Clean room staff VTA staff
Cryomodule Processing and testing:	Mike Drury Frank Humphry Larry King CM assembly team

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

Overview

- The existing OSP and task hazard analysis were written when we started the program and focused on working in the test lab. It was short on specific details regarding procedures, etc. as we were developing the protocols, etc.

- The revised OSP and THA addresses working in the test lab as well as in the tunnel. It has more details regarding the defined tasks of processing cavities in the VTA, CMTF and CEBAF tunnel.
- Testing in the off line area is still experimental. As such the procedures are a little more vague.
- The primary hazard concerns are.
  - Ionizing radiation both prompt and due to activated components.
  - ODH due to the use of inert gas and working in the tunnel.
  - RF hazards.
  - Potential for exposure to UV light.
  - Fall hazards while using ladders and platforms.

Jefferson Lab Thomas Jefferson National Accelerator Facility	**Operational Safety Procedure Form** **(See ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure (OSP) and Temporary OSP Procedure for instructions.)**

Title:	Plasma processing of SRF cavities process development and production processing		
Location:	Test Lab Vertical Staging Area (part of VTA) Test Lab Plasma Processing off line area (alcove off of high bay) Test Lab CMTF Test Lab High-bay CEBAF accelerator Tunnel LERF vault	**Type:**	☒ OSP ☐ TOSP
Risk Classification (per Task Hazard Analysis attached) (See *ES&H Manual Chapter 3210 Appendix T3 Risk Code Assignment*.)		**Highest Risk Code Before Mitigation**	
		Highest Risk Code after Mitigation (N, 1, or 2):	
Owning Organization:	SRF	**Date:**	27 Feb. 2023
Document Owner(s):	Tom Powers		

DEFINE THE SCOPE OF WORK

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

This Operational Safety Procedure lists the responsibilities, procedures, and hazard analysis for testing and developing the methods to ignite a plasma in a given RF cell using various gases or gas mixtures on a test bench and in the VSA. These tests will help to develop future procedures for plasma processing of cavity cells.

It also covers processing cryomodules in the CMTF, Test Lab High-bay and in the CEBAF and LERF accelerator enclosures.

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

1. On-going development task: Develop methods for processing cavities using plasmas of various gas non-poisonous gas mixtures. This will involve ignition studies, studies relating to moving plasmas from cell to

Jefferson Lab

Task Hazard Analysis

- The THA is essentially complete. It requires a few more relating to form rather than function.

- ODH hazard due to working in areas already covered by separate OSPs and THA for exampleVTA, CMTF, CEBAF tunnel.
- ODH hazard due to moving cylinders of inert gas from location to location.
  - Any time that we plan on working in a new area the existing ODH requirements will be reviewed and if necessary revised.
  - We used 80 cu.ft. cylinders for our gas carts in order to reduce the hazards when working in labs.

Jefferson Lab Thomas Jefferson National Accelerator Facility	**Task Hazard Analysis (THA) Worksheet** (See ES&H Manual Chapter 3210 Appendix T1 Work Planning, Control, and Authorization Procedure)

Author:	Tom Powers	**Date:**	27 Feb. 2023	**Task #:** If applicable	
Complete all information. Use as many sheets as necessary					
Task Title:	Plasma processing of C100 Cavity			**Task Location:**	
Division:	Accelerator	**Department:**	SRF	**Frequency of use:**	Daily for VSA and off-line facility. Annually for a month or so for CEBAF/LERF/CMTF
Lead Worker:	Tom Powers				
Mitigation already in place: Standard Protecting Measures Work Control Documents	VSA/VTA RWP and OSP CMTF RWP and OSP CEBAF general access RWP ODH training and requirements. Tunnel radiation mitigations and full survey Tunnel and LERF ODH mitigations CMTF ODH mitigations				

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
1	ODH hazard due to compressed inert gas, argon or helium, or gas mixtures	H	L	3	High pressure compressed gas cylinders will not be used except in large rooms with sufficient volume such as the high bay or the RF structures lab which have already had an ODH assessment. Based on the assessment we will limit the amount of inert gas that we take into the room such that it can not create an ODH hazard,	Administrative controls. ODH analysis for work area. For awareness purposes it requires that the workers take SAF103 Oxygen Deficiency Hazard training.	N

Jefferson Lab

Task Hazard Analysis

- **Pressure system hazards.**
- **Gas supply and pumping systems were reviewed by Matt Marchlik.**
- **Modifications were made to the existing design to insure that the system remains “excepted”. This is useful in that the minor changes do not require detailed documentation and review.**
- **Regulators were chosen such that they had a reduced flow coefficient, Cv, of 0.05.**
- **A “matching” relief valve with a Cv of 0.35 which insures that it can handle the gas exiting the regulator.**
- **The critical volume of the system is 145 liters. The volume of a C100 cryomodule and associated piping was estimated to be 120 liters.**

SRF Cavity Plasma Processing
ES&H Manual Chapter 6151 Compliance Review

Matt Marchlik 9/24/2021

The cavity plasma processing system in SRF hae been operational for a couple of years. The system was never evaluated to show adherence to JLAB's ES&H manual Chapter 6151 - Pressure and Vacuum Systems Safety Program. The purpose of this analysis is to show that the system is safe to continue operation.

Stored Energy

Stored energy calculation (ES&H manual 6151, 6.1.4.1)

$P_{atm} := 14.7 \cdot \frac{lb}{in^2}$ — atm pressure

$P_2 := (15 + 14.7) \cdot \frac{lb}{in^2}$ — System design pressure, absolute

$V := 125 \cdot l = (7.628 \cdot 10^3)\ in^3$ — Total volume, includes C100 cryomodule.

$k := 1.40$ — N2 sepcific heat ratio.

** Argon is also used in the system, however the specific heat ratio of Ar is 1.66 which yields a lower stored energy than N2.*

$$E := \frac{(P_2 \cdot V)}{(k-1)} \cdot \left(1 - \left(\frac{P_{atm}}{P_2}\right)^{\left(\frac{(k-1)}{(k)}\right)}\right) = (8.592 \cdot 10^3)\ ft \cdot lb$$

Since the stored energy is less than 10,000 ft-lb and the system will not exceed 15 psig, this system is considered "excepted" per ES&H Manual chapter 6151.

The following calculations demonstrate that the system is protected from overpressurization above 15 psig through the use of 15 psig relief valves and adequately restrictive supply regulators.

Jefferson Lab

Explosive or flammable gases

Explosive or flammable gases

- **We work with oxygen and methane gas in these systems.**
- **In order to avoid explosion hazards or flammable gas issues we:**
  - **Order or oxygen premixed with 20% oxygen and 80% inert gas such as helium or argon.**
  - **Ordered methane premixed with 5% methane and 95% argon where a 10% mixture is considered to be non flammable.**

UV light and elevated work

Exposure to UV light

- **Low pressure gas discharges produce UV light.**
- **Unless we need to pass UV light we use borosilicate glass view ports which do not pass light below a wavelength of 400 nm.**
- **When we use a new gas mixture with quartz viewports we check the amount of UV light using a solar blind UV light power meter.**
- **When we use UV light sources their use will be covered by either a separate OSP or the existing OSP will be modified to accommodate them. The plan is to use an opaque interlocked enclosure.**

Working on ladders and elevated platforms.

- **Working in the VTA, CMTF and in the tunnel will require that we use stepladders or platforms in order to access hardware that is between 5 and 10 feet off of the floor.**
- **Staff will be required to have appropriate ladder safety training.**
- **When working in the CEBAF tunnel such work requires a 2 person rule due to the ODH hazards.**

Radiation due to RF fields inside the cavity.

- **The structures that are being used are self shielded for radiation less than 10 keV.**
- **When operating the cavity with low pressure gas the mean free path is such that electrons can not be accelerated beyond a few hundred eV.**
  - **The mean free path for an electron in 1 Torr argon is 0.21 cm.**
  - **We operate our systems at pressures between 100 mTorr and 300 mTorr.**
- **The first experiments that were done in this program were done with a CARM local to the experiment.**
- **The electric field in a cavity is calculated using the following equation:**

$$E = \sqrt{\frac{4Q_0^2(r/Q)}{Q_1 L} P_{RF}}$$

- **For the pi modes and 500 W the maximum accelerating voltage can be produced by a 100, C75 and C50 cavity is 2.1 keV, 4.4 keV and 3.5 keV.**
- **When we process C100 cavities we use a 100 W amplifier and administratively limit (e.g. attenuators on the drive signal) the system to 50 W.**

Residual radiation

- **Cryomodules processed in the CMTF or test lab. In such cases we follow the guideline set up in the facility and the radiation control group for the specific cryomodule. To date they have not be activated to a point that required special handling other than that of Radioactive Materials Protocols.**
- **When we process cryomodules in the CEBAF tunnel**
  - **The end groups will be activated to a much higher level than that in the CMTF, with contact radiation levels on the order of 200 mRem/hr considered common for several weeks after beam delivery is stopped.**
  - **The tunnel in the C100 region is typically roped off as a radiation area where there is a potential for whole body exposure of 5 to 100 mRem/hr.**
- **All work preformed in the radiation areas will be reviewed by radiation control staff and there is a potential that we will be required to wear an SRPD and track our day to day exposure.**
- **We are going to set up computers in an area of the tunnel outside of the radiation area. We will use these computers to remotely access the plasma processing computers.**
- **Entry into the radiation area will be limited to only those times where it is necessary for completing hands-on tasks.**

Exposure to RF radiation

- **While plasma processing.**
- **Cryomodules and cavities are fundamentally a “sealed” metal device. The only port that has the potential for producing RF radiation is the waveguides. Those will have WR650 to type-N transitions firmly affixed to the waveguides when we are processing.**
- **For the off line system and the VTA systems we have view ports on the ends of the beam pipes. In order to mitigate exposure to RF radiation those devices have extension tubes with a diameter of 1.5” which act as cut off tubes and attenuate the RF energy by >50 dB.**
- **When changing the waveguide connections where the other end of the waveguide is attached to a high power (multi-kilowatt) source, LOTO will be applied to the source to insure that they can not be powered on until all open waveguides are sealed using a securely attached shorting plate or until they are attached to the cryomodule.**

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Operational Safety Procedure Form

Example of details in the OSP

Gas supply and vacuum system for cryomodule in the tunnel.

The “closed” beam line valves will be unplugged from the controls.

The “open” beam line valve will be controlled locally.

Appropriate log, and interlock bypass entries will be made.

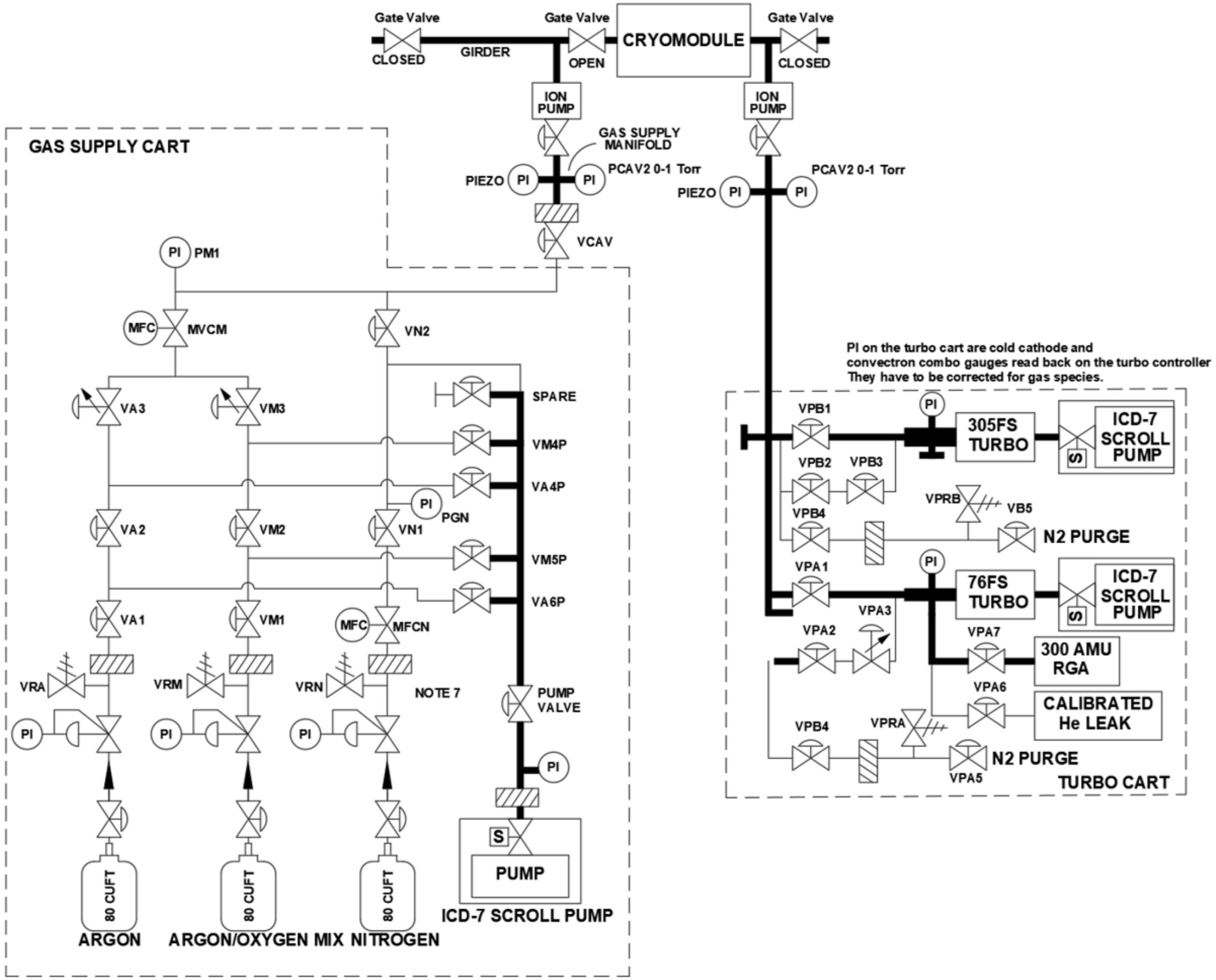


Figure 2. Plasma processing gas supply and turbo cart showing interface to a cryomodule in the CEBAF accelerator tunnel.

Example of details in the OSP

RF system and girder photo.

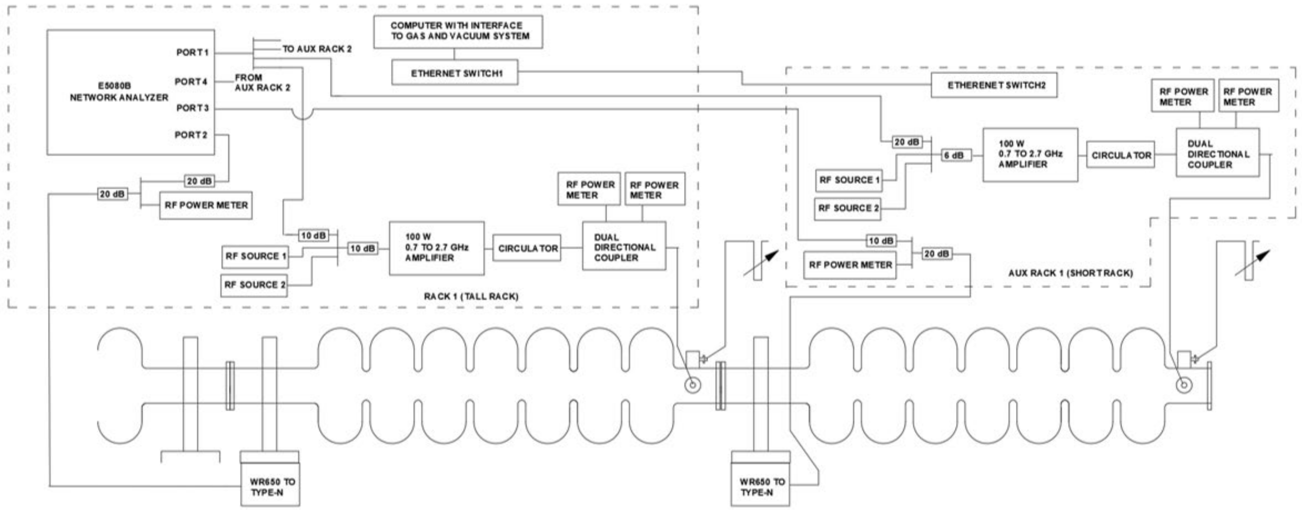


Figure 3. Typical two cavity setup for processing a cryomodule.

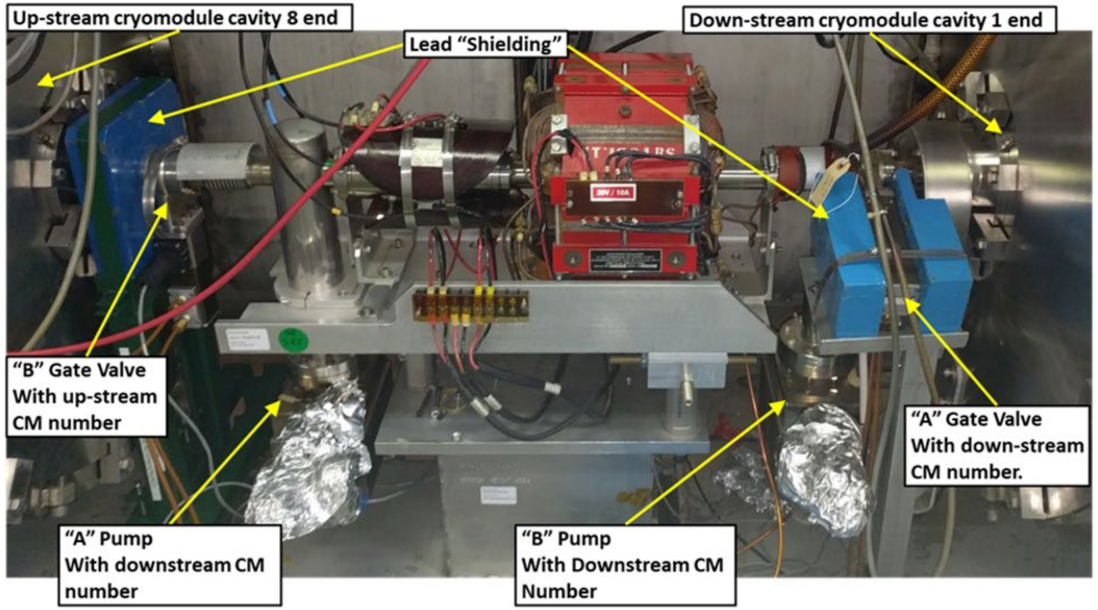


Figure 4, Photograph of a typical C100 girder showing vacuum valves and ion pumps.

Jefferson Lab

Example of details in the OSP

Level of detail for vacuum work.

Meta procedure for processing cavities in the Tunnel {CMTF}

Vacuum work.

1. Assemble a portable clean hood covering the area around the upstream and down-stream girders {or end cans}.
2. Using appropriate clean hood and clean assembly techniques connect the pumping cart to the valve located on the ion pump just upstream of the cryomodule.
3. Pump out the line to UHV and open the valve between the pump cart and the ion pump.
4. Insure that the "B" beam line valve just upstream of the cryomodule is closed and unplugged* from the control system. *Unplugging it makes it such that no one from operations can open the valve while we have the cryomodule beam line up to 0.3 Torr.
5. Using appropriate clean hood and clean assembly techniques, connect the supply line manifold to the closed valve located on the downstream ion pump {downstream beam line valve}.
6. Pump out the supply manifold {for CMTF do this with the right-angle valve attached to the beam line open}.
7. Using a local* valve control box, open the valve connected to the downstream ion pump {for the CMTF open the downstream beam line valve. *Using a local box insures that no one from ops can close the valve when we are flowing gas through the cryomodule.
8. Turn off the two ion pumps that one just upstream of the cryomodule and one just down stream of the cryomodule and unplug them from their respective power supplies.
9. Using established procedures establish gas flow to the cavity and process the cavity and adjust the oxygen percentage.
10. After processing stop the flow of gas to the cavity using the MFC.
11. Close the valve between the gas supply cart and the gas supply manifold.
12. When the gas supply and pump out manifolds are below 10 mTorr, open the main valve to turbo pump B.

Example of details in the OSP

Level of detail for RF work for actual processing.

RF work for plasma processing a cryomodule accelerator tunnel {and CMTF}

1. Using appropriate LOTO procedures remove a section of waveguide upstream of the one-half to full-height waveguide transition. Place a metal blank on the upstream waveguide and a waveguide to type-N transition on the downstream waveguide. (EES-RF {SRF cryomodule assembly} group task)
2. Using established procedures calibrate the RF cables.
3. Using a calibrated network analyzer S1 port connected to the HOM coupler being used to drive the cavity and connect the motorized phase shifter to the second HOM port use the established procedure to measure S11 and S21 as a function of phase shifter position for all 8 cavities. The phase shifter position shall be varied between 0 and 360 degrees of two-way phase shift in 5 degree increments.
4. Using established procedures determine the optimal phase shift position for processing each cavity.
5. Connect the output of the RF system to the selected HOM and the input to the RF system to the waveguide top-hat.
6. Using established procedures, process each cell or combination of two cells for one hour. Up to four cavities can be processed at the simultaneously. One may not process adjacent cavities simultaneously.
7. The RF controls must be attended at all times when the coupler interlock is not engaged.
8. Process all of the cavities twice with at least a 24-hour break between processing cycles on individual cavities.

Characterizing field emission radiation onset before and after plasma processing.

This work can be done from the control room the service building or, with crew chief approval from an office.

1. During an appropriate maintenance day install decaRad system(s) on appropriate zones.
2. With the tunnel in power or beam permit (beam will not be possible in the zone under test) and adjacent cryomodules turned off.

Example of details in the OSP

Level of detail for backout procedures.

13. **Back Out Procedure(s)** i.e. steps necessary to restore the equipment/area to a safe level.
For processing in the VSA Turn off the 100 W RF amplifier Disconnect the RF cables and reconnect the cables used for vertical testing. Disconnect the vacuum and gas supply hardware as described above. Turn on the test stand turbo pump. **For cryomodule processing.** Turn off the 100 W amplifier. Disconnect the vacuum and gas supply hardware as described above. Configure the waveguide to its original configuration. Disconnect all RF cables and reconnect the cables and terminations to the cryomodule Turn off the high voltage on the DecaRad system. **For the off line facility.** Turn off the 100 W RF amplifier Close the pump out valves between the cavity and the turbo cart and between the cavity and the scroll pump. Backfill the cavity with inert gas to a few PSIG Turn off the scroll pump on the gas supply cart. Turn off the turbo pumps and let them spin down for 20 minutes. Turn off the scroll pumps after the turbo pumps have spun down.

Summary

- **The OSP is ready for final review and sign off.**
- **The THA is in the final editing stage.**

Questions?

Jefferson Lab