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Jefferson Lab
Thomas Jefferson National Accelerator Facility

Operational Safety Procedure Review and Approval Form # 144152
(See ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure (OSP) and Temporary OSP Procedure for Instructions)

Type:	*LOTO-COMPLEX*	Click for OSP/TOSP Procedure Form Click for LOSP Procedure Form Click for LOTO-COMPLEX Information Click for LOTO-GROUP Information
Serial Number:	*ACC-22-144152-LTTI*	
Issue Date:	*11/4/2022*	
Expiration Date:	*11/4/2023*	
Title:	*GTS 500 kV Gas Insulated Power Supply resistor shorting/un-shorting and safety*	

Location: (where work is being performed) Building Floor Plans	*18 - Low Energy Recirculator Facility (LERF) - 109A*	Location Detail: (specifics about where in the selected location(s) the work is being performed)	*The Glassman HVPS is located in the GTS vault, room 109A LERF Building 18. The HVPS knife switch disconnect is located in the floor above the GTS vault in room 217*

Risk Classification: (See ES&H Manual Chapter 3210 Appendix T3 Risk Code Assignment)	Without mitigation measures (3 or 4):	*3*
	With mitigation measures in place (N, 1, or 2):	*1*

Reason:	This document is written to mitigate hazard issues that are : ***Determined to have an unmitigated Risk code of 3 or 4***
Owning Organization:	*ACCCIS*
Document Owner(s):	***Hernandez-Garcia, Carlos (chgarcia@jlab.org)*** Primary

Supplemental Technical Validations

50V or Greater: De-energized Work (Bonnie Rodriguez, Phillip Stanley)
Mode 1: Class 1, 2, and 3 Electrical Equipment (Bonnie Rodriguez, Phillip Stanley)
Lock, Tag, Try (Bonnie Rodriguez, Phillip Stanley)
Cranes & Hoists - Ordinary or Pre-Engineered (Bob Sperlazza, Mark Loewus)
ODH 0 and 1 (Dainnya Busbin, Imani Burton, Jennifer Williams)
Pressurized Tanks, Containers, and Vacuum Vessels (Dave Meekins, Nate Laverdure, Timothy Whitlatch, Will Oren)

Other Hazards:
Environmental (Scott Conley)

Document History

Revision	Reason for revision or update	Serial number of superseded document
1	***Expired OSP New procedure for transferring SF6 gas from HVPST tank to storage bag***	***ACC-16-63317-OSP***

Lessons Learned	Lessons Learned relating to the hazard issues noted above have been reviewed.
Comments for reviewers/approvers:	***The submitted OSP and THA incorporate comments by J. Williams, P. Stanely. and B. Rodriguez. P. Stanley performed a walkthrough of the GTS with document owner (C. Hernandez-Garcia) on 10/31/2022.***

Attachments

Procedure: ***GTS HVPS OSP 2022 Rev02.pdf***
THA: ***GTS HVPS THA 2022 Rev02.pdf***
Additional Files: ***TN-07-082_ODH_FEL_Gun Test Stand RevA_final.pdf***

Review Signatures	
Person : Subject Matter Expert : Environmental	**Signed** on 11/3/2022 2:24:42 PM by Scott Conley (econley@jlab.org)
Subject Matter Expert : Electricity->50V or Greater: De-energized Work	**Signed** on 11/2/2022 3:44:22 PM by Bonnie Rodriguez (bonnie@jlab.org)
Subject Matter Expert : Electricity->Mode 1: Class 1-> 2-> and 3 Electrical Equipment	**Signed** on 11/2/2022 3:44:26 PM by Bonnie Rodriguez (bonnie@jlab.org)
Subject Matter Expert : Lock-> Tag-> Try	**Signed** on 11/2/2022 3:44:38 PM by Bonnie Rodriguez (bonnie@jlab.org)
Subject Matter Expert : Material Handling Equipment->Cranes & Hoists - Ordinary or Pre-Engineered	**Signed** on 11/3/2022 10:10:19 AM by Mark Loewus (loewus@jlab.org)
Subject Matter Expert : Oxygen Deficiency Hazards (ODH)->ODH 0 and 1	**Signed** on 11/3/2022 10:28:21 AM by Jennifer Williams (jennifer@jlab.org)
Subject Matter Expert : Pressure Systems->Pressurized Tanks-> Containers-> and Vacuum Vessels	**Signed** on 11/3/2022 11:55:05 AM by Dave Meekins (meekins@jlab.org)

Approval Signatures	
Division Safety Officer : ACCCIS	**Signed** on 11/3/2022 2:32:47 PM by Harry Fanning (fanning@jlab.org)
Person : Lock, Tag, Try Coordinator	**Signed** on 11/3/2022 2:29:02 PM by Carlos Hernandez-Garcia (chgarcia@jlab.org)
Supervisor : Lock, Tag, Try Supervisor	**Signed** on 11/4/2022 12:41:52 PM by Joe Grames (grames@jlab.org)

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Operational Safety Procedure Form

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

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Title:	**GTS 500 kV Gas Insulated Power Supply resistor shorting/un-shorting and safety**		
Location:	LERF Building 18, Room 109A (AKA GTS vault)	**Type:**	**X 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**	3
		Highest Risk Code after Mitigation (N, 1, or 2):	1
Owning Organization:	Accelerator, Center for Injectors and Sources	**Date:**	October 25, 2022
Document Owner(s):	Carlos Hernandez-Garcia		

DEFINE THE SCOPE OF WORK

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

Provide safe working conditions for maintenance, repairs and troubleshooting of the Glassman 500 kV, gas-insulated High Voltage Power Supply (HVPS) located in the Gun Test Stand (GTS).

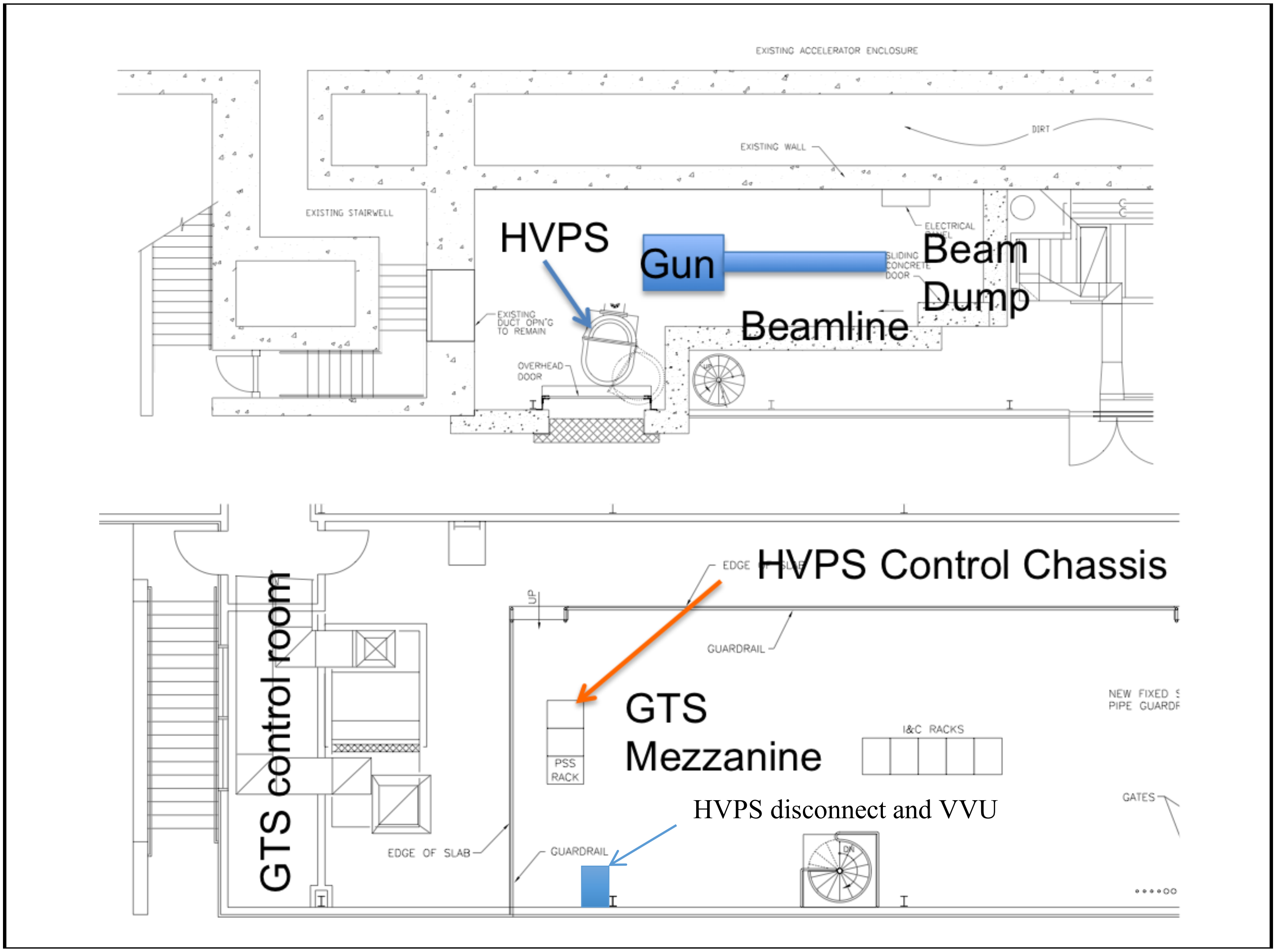
2. Scope – include all operations, people, and/or areas that the procedure will affect.

This document covers maintenance and safety procedures for the Glassman 500 kV gas insulated HVPS and/or for connecting it to the electron gun. When repairs/maintenance to the HVPS are needed, this document is to be used in conjunction with the manufacturer (Glassman) instruction manual.

Normal operations are performed via EPICS using a computer terminal in the GTS control room and are beyond the scope of this document.

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

The Glassman HVPS is located in the GTS vault, room 109A LERF Building 18. The Remote Control Unit is located in the floor above the GTS vault in room 217, rack GL01B02. A layout of both rooms is shown below.



ANALYZE THE HAZARDS and IMPLEMENT CONTROLS

4. Hazards identified on written Task Hazard Analysis

- Unlikely exposure to Arc flash from HVPS 208 VAC 3-phase feed knife switch disconnect
- Presence of pressurized vessels (potentially up to 15 PSIG)
- Handling of heavy objects (HVPS tank flanges)
- Unlikely exposure to high voltage (potentially up to 500 kV, 5 mA DC)
- Accidental release of SF6 causing potential ODH up to 5 inches from the floor

5. Authority and Responsibility:

5.1 Who has authority to implement/terminate

C. Hernandez-Garcia, and J. Grames.

5.2 Who is responsible for key tasks

C. Hernandez-Garcia, and M. A. Mamun

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)

High Voltages (AC & DC) - P. Stanley
Pressure Vessel – W. Oren
Oxygen Deficiency Hazards/Industrial Hygiene – J. Williams
Environmental - Scott Conley

6. Personal and Environmental Hazard Controls Including:

6.1 Shielding

There are no live exposed electrical components. The AC input drive has its own chassis connected to building ground and mounted on the top of the HVPS SF6 tank. The Cockcroft-Walton HV multiplying stack is inside the HVPS SF6 tank. The resistor and cable plug are inside an appendage of the HVPS SF6 tank. The opposite end of the high voltage cable connects to the gun insulator. The Remote Control Unit is located in a metal rack, which has no exposed wiring. A gas pressure-sensing interlock keeps the HVPS from turning ON if the tank is below 5 psi of instrument air or SF_6, therefore preventing ionizing radiation, which is only possible if voltage is present in vacuum conditions.

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

N/A

6.3 Interlocks

A position-sensing switch is installed on the HVPS tank entry door and a gas pressure-sensing switch is installed in the HVPS tank. These sensors are connected to redundant power supply interlock circuits. The first circuit is the normal power supply control circuitry external interlock connection. The second circuit is an independent AC contactor placed in the input 208 VAC power feeding the power supply. These interlocks are enunciated and latched by a fault-indicating panel in the control room.

The power supply interlock control chain is tied to the GTS Personal Safety System (PSS). This means, the energizing of the HVPS control unit is permitted only when the PSS interlocks are made up following sweeping GTS vault procedures.

6.4 Monitoring systems

A Voltage Verification Unit (VVU), mounted on the south wall of room 217 near the rack housing the Glassman HVPS Remote Control Unit, monitors the 208 VAC power coming into the HVPS. The VVU is wired just downstream of the power supply 208 VAC disconnect Switch. The VVU is used to verify that indeed the 208 VAC has been disconnected from the power supply.
A pressure sensor, located on the side of the HVPS tank, monitors the pressure of the SF_6 or instrument air in the tank. The output of the pressure sensor is also available in the gun HVPS EPICS control screen.
The GTS vault has an ODH sensor under the HVPSS tank and is part of the LERF PSS. This system is maintained by the SSG.

6.5 Ventilation

The GTS vault is the plenum for the air conditioning system of the LERF vault. When the air conditioning system is running, any SF_6 spill or leak would be quickly dispersed due to the high flow rate of the air conditioning system. When the air conditioning system is off, any SF_6 leak would drain out of the GTS vault through the air conditioning recovery port and into the rear stair well of the FEL vault and then into the LERF vault. ODH sensors are positioned in the GTS vault, in the rear stair well, and at collection points in the LERF vault. The Safety System Group (SSG) electronics continuously monitors the ODH sensors.

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

A HIGH VOLTAGE, DC:

Primary Hazard (A1) - Risk Code 3

Injury or death may result from interaction with high DC voltages.

The **500 kV** generated by the power supply system is a serious hazard, even with the power supply **maximum output current factory-limited to 5 mA**. *This is a Class 3, Mode 1 Hazard. It is considered Mode 1 because maintenance or repairs will be performed with the system de-energized and AC input knife switch locked out.*

The power supply generates a 12 kV square wave at a frequency of 26 k Hz. This is the input drive to a stack containing 48 stages of **voltage-multiplying capacitors.** The high voltage power supply stores about **264 Joules** of electrical energy when is operating at 500 kV.

4 kW Models, Open Stack

Positive Polarity	Negative Polarity	Reversible Polarity	Output Voltage	Output Current	Max Stored Energy (J)	High Freq. Ripple (P-P)	Line Freq. Ripple (P-P)
LH200P20	LH200N20	LH200R20	0-200 kV	0-20 mA	109	150	20
LH250P16	LH250N16	LH250R16	0-250 kV	0-16 mA	129	160	20
LH300P12.5	LH300N12.5	LH300R12.5	0-300 kV	0-12.5 mA	159	150	20
LH350P9	LH350N9	LH350R9	0-350 kV	0-9 mA	180	130	20
LH400P7	LH400N7	LH400R7	0-400 kV	0-7 mA	211	110	20
LH450P6	LH450N6	LH450R6	0-450 kV	0-6 mA	243	105	20
LH500P5	LH500N5	LH500R5	0-500 kV	0-5 mA	264	100	20

These capacitors, when charged can be a **significant hazard** and **require about 1 minute to discharge to a safe value** through the internal stack bleeder and metering resistors.

Glassman High Voltage Inc. Series PK

(3) HIGH VOLTAGE OUTPUT Connector (One per module for master/slave supplies)

Internal high voltage models:	JHV1
External high voltage models:	JHV3
Open stack models:	E2

WARNING!

DO NOT HANDLE EXPOSED HIGH VOLTAGE TERMINATIONS OR ATTEMPT TO MAKE OR REMOVE ANY CONNECTIONS TO THE SUPPLY UNTIL THE LOAD AND/OR SUPPLY HAS BEEN DISCHARGED (GROUNDED). AN UNLOADED SUPPLY MAY TAKE UP TO 60 SECONDS TO FULLY DISCHARGE.

Primary Hazard (A1) Mitigation - Risk Code 1

The 208 VAC, 3-phase knife switch powering the HVPS must be disengaged and its VVU used to verify voltage in each phase reads zero Volts.

According to the manufacturer (Glassman High Voltage, Inc) manual, it takes 1 minute for the store energy in the power supply to dissipate. See snapshot from the manual above. Thus, the HVPS and Gun tanks shall not be opened for at least 1 minute after the HVPS has been turned off. The time needed to open either of the HVPS or Gun tanks is about 2 hours. The power supply electrical components are inside the pressure tank and has many large bolts that must be removed to gain access to the electrical components inside. This engineering constraint of the system is adequate to ensure workers cannot come in contact with the stored electrical energy before it's had an opportunity to bleed off.

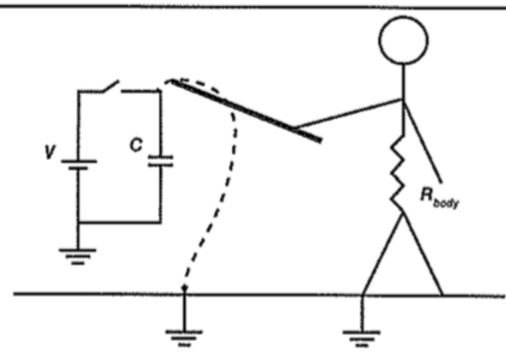
Interlocks are provided to ensure the pressure tank door is closed during normal operation of the power supply. A pressure-sensing switch is also installed to ensure the tank is pressurized before the high voltage is energized. These interlocks are independent from the PSS system and are tied directly to the HVPS interlock system.

Prior to performing work with any components inside the high voltage tank, high voltage cable connecting to the photocathode gun, workers wearing safety glasses shall any potentially remaining energy stored in the HVPS by using the grounding hook attached to the HVPS tank to touch the resistor inside the SF6 tank. Whenever practicable, the grounding hook or probe shall remain in place during Test and Maintenance mode to prevent accumulation of energy. The grounding hook has a long copper grounding wire attached to the HVPS tank and building ground. The copper wire has a clear plastic cladding.
According to Article 360 and annex r 2021 NFPA70E, the stored energy in the power supply (264 Joules) allows for hard grounding. See snapshots from the article below:

Table R.11.9 Capacitor Test and Grounding Matrix to Establish Safe Discharge

	Test Method				Grounding Method		
	0–100 volts	100–1 kV	>1 kV		0–100 volts	100–1 kV	>1 kV
< 0.25 joules	Not applicable	Not applicable	Not applicable	< 0.25 joules	Not applicable	Not applicable	Not applicable
0.25–100 joules	Not applicable	DVM	DVM with HV adapter	0.25–100 joules	Not applicable	Hard ground ok	Hard ground ok
100 joules–1 kJ	DVM	DVM	HV utility grade dc voltmeter	100 joules–1 kJ	Hard ground ok	Hard ground ok	Hard ground ok
1 kJ–100 kJ	DVM	DVM	HV utility grade dc voltmeter	1 kJ–100 kJ	Soft ground then hard ground	Soft ground then hard ground	Soft ground then hard ground
>100 kJ	Engineered method	Engineered method	Engineered method	>100 kJ	Remote grounding only	Remote grounding only	Remote grounding only

70E–102 Shaded text = Revisions. Δ = Text deletions and figure/table revisions. • = Section deletions. N = New material.



Hard grounding: An insulating stick with a grounding tip is used to discharge a capacitor between its two terminals and then to ground.

The 12 kV square-wave fed to the multipliers is enclosed in 40 kV insulated wires, with additional vinyl tubing over each of these wires. This connection is only a few feet long and has a protective barrier.

Secondary Hazard (A2) - Risk Code 3

Injury from involuntary reaction to electrical shock.

Secondary Hazard (A2) Mitigation - Risk Code 1

See Hazard Mitigation (A1).

B GAS PRESSURIZED TANK:

Primary Hazard (B1) - Risk Code 3

Injury may result from flying debris if the HVPS tank should experience a failure that leads to a rupture of one of the two polycarbonate viewports. Injury is also possible from the bolts securing the tank cover and flanges, if the bolts are improperly installed or some of the bolts are left out, causing the bolts to fracture.

Primary Hazard (B1) Mitigation - Risk Code 1

The HVPS tank is not considered to be a pressurized vessel per ASME Boiler & Pressure Vessel Code - Sec. VIII, since it cannot be pressurized over 15 psig. The HVPS tank and piping system includes a pressure relief valve to prevent system overpressure, two externally mounted pressure gauges, and system control valves. The relief valve was made and tested by an ASME qualified company to be fully open at 14 psig.

The HVPS tank was designed, built, tested, and stamped by the manufacturer as if it were going to be a pressure vessel. The tank and its components have been hydrostatically tested to 22 psig before installation in the GTS system. No alterations to the stamped vessel are allowed by JLab staff, it must be a code shop. Operators of pressure system devices should have SAF 130A training.

Primary Hazard (B2) - Risk Code 3

Damage or injury due to failure to install or remove the tank covers or flanges properly.

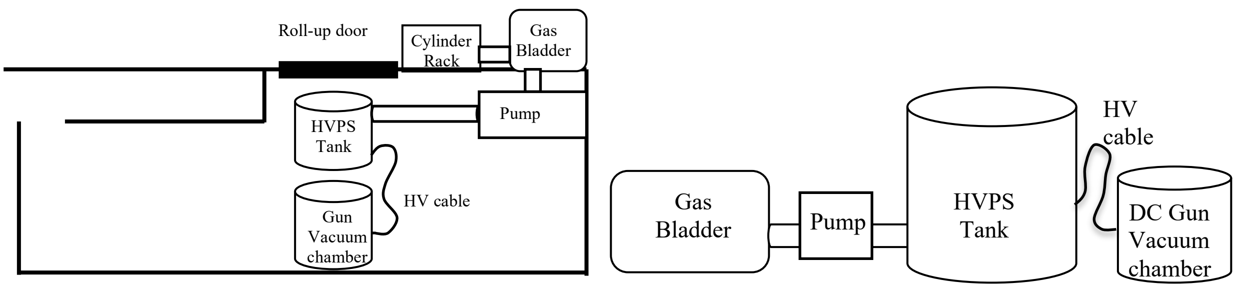
Primary Hazard (B2) Mitigation - Risk Code 1

Personnel performing maintenance tasks described in this document must carefully follow the administrative procedures for bolting, filling, pumping, purging, emptying, and unbolting the HVPS tank. Only in the Test & Maintenance mode, when the tank is not pressurized, will the flanges ever be closed with **less than** the full complement of bolts. When all bolts are fully engaged, the tank is designed to be capable of withstanding at least 73,964 lbs. of force at 22 psig.

C HAZARDS ASSOCIATED WITH SULFUR HEXAFLUORIDE (SF_6) GAS:

Sulfur hexafluoride (SF_6) is used as the insulating gas for the GTS Gun HVPS. It is a heavier than air and can create a localized ODH area, especially in pits or enclosed rooms. SF6 also has toxic effect (fluorosis) on the body with repeated high exposures. The exposure limit for SF6 is 1000 ppm. Refer to the SDS for SF_6 for details.

In this analysis we followed standard practices for quantities of gas that are equal to or less than a K-size cylinder (2200 ft^3), a standard industrial size portable gas cylinder. Based on over 20 years of operating experience with a similar system, we assume there will be no arcs inside the SF_6 tank to cause decomposition of the gas.



GTS Vault

SF_6 System Configuration

The SF_6 is contained in the above configuration. The following is a detailed description of the arrangement for storing and utilizing the SF_6 including capacities. The system has an outside storage bladder that can hold up to 335 $ft^3$of SF_6. The SF_6 system volume in the HVPS tank is 154 ft^3, but the gas is pressurized up to a maximum of 13 psig (relief valve opens to return SF_6 back to storage bag). If the 154 ft^3, of SF_6 were released into the room, it would expand to 290 ft^3. Since all of the SF_6 must fit into the bladder when the tank is empty, the maximum volume of SF_6 at any time is therefore 335 ft^3. Once the SF_6 is in the storage bag, it can't flow back up into the vault due to its heavy density and being the lowest point.

The GTS vault, room 109A, has a floor area of 600 ft^2 with a 10-foot ceiling. At one end of the room is an intake duct to the air-handling unit that supplies heated or cooled air mixed with fresh air to the LERF accelerator vault. At the other end of the room is a large rectangular hole in the wall that is open to the back stairwell and hallway (Room 111) that leads to the main LERF accelerator vault, and is covered with steel screen. This hole extends down to within 5.5" of the floor of room 109A. Rooms 109A and 111 are considered air passageways. The air handling system circulates air through this system at 2000 ft^3/min.

There is one roll up door, normally closed, and a concrete door, normally open when personnel are working in room 109A. The concrete doorway has a metal panel that is normally closed to eliminate airflow, dust, and any possible laser light that might come through the doorway. The doorway opens to room 109B, with a similar area to 109A, namely 600 ft^2, but a higher ceiling.

Primary Hazard (C1) - Risk Code 1

Here we assume a release of SF_6 into room 109A with the air conditioning system off. With a room volume of 6000 ft^3, an SF_6 volume of 335 ft^3 with full dispersion and without air exchange, the dilution would be 1 part of SF_6 in 17 of air. This would not bring the oxygen levels in the room below 18%, ($0.944 \times 21 =$ 19.8%) but the level would exceed the Threshold Limited Value (TLV) for SF_6, which is 1 part of SF_6 in 1000 of air. However, because the SF_6 is considered to be a dense gas with a specific density of 5.1, it will concentrate on the floor of room 109A. The full discharge of SF_6 would cover the floor of room 109A to a depth of 6.7", but at a level 5.5" the gas would start flowing through the large air vent hole in the wall and out of the room.

Personal injury or death may happen from exposure to SF_6 caused by a sudden gas release inside the GTS vault for personnel with their faces 5.5" or closer to the floor with the air handling system off.

With the air handler on and the volume of SF_6 is dumped into the space, the resulting concentration of SF6 is 764 ppm. Reference Kevin Jordan's GTS SF6 gas transfer system description (on file with ESH/IH group).

Primary Hazard (C1) Mitigation - Risk Code 1

In the event of a release of SF_6 into the GTS vault, rooms 109A, 109B, and 111 must be evacuated and notify the Crew Chief and ESH&Q Reporting Officer. In the event the SF_6 disperses sufficiently to reduce the oxygen content at floor levels, an ODH head will alarm. An ODH is placed directly under the HVPS tank and about 3” above the floor. The Safety System Group electronics continuously monitor the ODH sensor.

To evaluate the ODH hazards we perform a risk assessment. It is assumed that workers will not have their face less than 6” off the floor in picking dropped parts. According to JLAB-TN-07-082, the failure rates of mechanical components that comprise this SF_6 system are 1.61 E-05 /hr. The Bureau of Labor Statistics says the probability rate of a professional worker falling and losing consciousness is 2.6 E-7/hr. The American Heart Association says the probability rate for a heart attack is 7.2 E-6/hr. The combined probability of either occurrence is 7.46 E-6/hr. The probability rate for both a mechanical failure and a worker falling to the floor unconscious with both events occurring simultaneously is 1.2 E-10/hr. Thus with a Fatality Factor of 1, the ODH Fatality rate is also 1.2 E-10/hr. Using the ESH manual 6500-T3 will give ODH class 0.

Secondary Hazard (C2) - Risk Code 3

Corona or arcing in the HVPS may cause toxic breakdown products to form. Electric arcs in SF_6 and oxygen can form toxic byproducts in gaseous or powder form. Examples are SO_2, HF, H_2S, SF4, S_2F_{10}, and others. These byproducts can be present as impurities in the virgin gas as well as in gas that has been subjected to corona or arcing.

Secondary Hazard (C2) Mitigation - Risk Code 0

In the event of corona or arcing in the HVPS, the Jefferson Lab Industrial Hygiene group must be notified. The arcing may cause decomposition by-products that are hazardous and should not be inhaled. The contaminated gas can be either processed through a cleaning machine or if needed vented to the atmosphere.

Secondary Hazard (C3) - Risk Code 3

Injury, death, or damage may happen due to mishandling of gas cylinders. Mechanical damage to a high-pressure gas cylinder may cause a "run-away cylinder" or a cylinder explosion due to excessive heat.

Frostbite to the eyes or exposed skin from venting high-pressure gas may occur due to an improper mechanical connection to a gas cylinder when placing it into service.

Secondary Hazard (C3) Mitigation - Risk Code 1

Safety glasses and leather gloves shall be used when connecting or disconnecting the SF_6 gas cylinders to the gas system. When opening on the valve, “crack” it open slowly to see and listen for gas escaping at a connection before fully opening the valve.

All high-pressurized gas cylinders shall be secured in a proper bottle storage rack and kept away from sources of heat.

D HAZARDOUS AC VOLTAGES:

Primary Hazard (D1) - Risk Code 3

Injury or death may result from component failure with the 208 VAC, 3ϕ knife switch that feeds the HVPS. This represents a Class 2, Mode 2 electrical hazard.

Primary Hazard (D1) Mitigation - Risk Code 1

Apply the engineering and administrative controls indicated in JLab EH&S Manual Chapter 6200, the electrical safety training listed in section 9 of this OSP and this OSP to safely disengage/engage the knife switch. Only personnel with ESC001-ESC008 training and Cat 2 PPE are authorized to disengage/engage this knife switch.

The input power to the HVPS driver is supplied through a lockable 208 VAC, 3ϕ disconnect knife switch, a voltage verification unit (VVU), and a 5-wire cable via conduit to the power supply. Barrier strips cover the power supply terminals. The VVU is connected to the load side of the disconnect switch to enable safe and quick verification of whether or not the 208 VAC power is going to the HVPS.

Primary Hazard (D2) - Risk Code 3

Physical injury may occur from involuntary reaction to arc flash.

E MATERIAL HANDLING:

Primary Hazard (E1) - Risk Code 2

Injury associated with moving heavy objects.

Primary Hazard (E1) Mitigation - Risk Code 1

While the HVPS pressure tank door is heavy, it rolls on a castor and is easily moved by one person. Care must be exercised to prevent smashed fingers when closing the door.

HVPS tank flanges are heavy ~ 50 lbs. a manual fork lift with lifting straps must be used to handle these flanges. Heavy material handling must be described in associated THA. Additionally, an ATLis must be submitted.

7. List of Safety Equipment:

7.1 List of Safety Equipment:

- Cat 2 arc flash PPE for engaging/disengaging the HVPS knife switch
- Safety shoes when removing HVPS 24” flange
- Safety glasses when using the ground hook to ensure the HVPS is discharged
- Hearing protection when using the ground hook to ensure the HVPS is discharged
- Leather gloves when handling bolts and heavy objects such a HVPS flanges
- Recommended working clothing: cotton pants and cotton long sleeve shirt

7.2 Special Tools:

- A grounding sticks is attached to the HVPS tank ground with a copper, plastic-cladded wire to be used for ensuring the internal capacitors have been discharged and that no high voltage is present in the HVPS.
- LOTO labels and a hasp to be used in the HVPS disconnect.
- Pipe stand and “Genie” 400 lbs. capacity manually operated forklift to handle HVPS flanges.

8. Associated Administrative Controls

Submit an ATLis and include request for assistance from installation group to remove/re-attach HVPS flange. Upon approval submit a GTSLOG with planned activities. Upon completions, submit GTSLOG with summary and outcome of work, and close the ATLis.

9. Training

9.1 What are the Training Requirements (See List of Training Skills)

- SAF100 ES&H Orientation
- SAF103 Oxygen deficiency hazard
- SAF130A Pressure systems awareness
- SAF143kd FEL Safety awareness
- ESC001 Basic Electrical Safety
- ESC002 Arc Flash and PPE
- ESC003 Electrical Work Site Safety
- ESC004 Work Planning and Documentation
- ESC005 Safe Switching of Electrical Equipment
- ESC006 Electrical Contact Release
- ESC007 Lockout/Tagout (LOTO)
- ESC008 Electrical Safety Practical Application
- SAF603B.KD Discharging, Storage and Disposal of Capacitors
- This document
- Training provided by this document owner (C. Hernandez-Garcia)

DEVELOP THE PROCEDURE

10. Operating Guidelines

Upon receiving ATLis approval, follow electrical safety training (section 9) to throw OFF the HVPS knife switch and apply LOTO. Every person that will be in contact with the HVPS resistor (powered off) needs to apply their lock and tag.
The HVPS disconnect is located on the south wall of the GTS mezzanine located in FEL building 18 Room 217. See section 3.

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

Carlos Hernandez-Garcia gives verbal notification to supervisor and CIS group leader J. Games, then submits ATLis, and upon approval, submits GTSLOG with planned activities.

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

Background:

A Voltage Verification Unit (VVU) is mounted on the south wall of room 217 near the rack housing the Glassman HVPS Remote Control Unit. The VVU is wired just downstream of the power supply 208 VAC disconnect Switch. The VVU is used to verify that indeed the 208 VAC has been disconnected from the power supply.

The 500 kV Power Supply is a JLab modified Glassman model PS/PK500N004YU2 consisting of a voltage multiplier stack, a monitor stack, and a power driver. The multiplier stack is a 48 stage full-wave Cockcroft-Walton (C-W) voltage multiplier, rated in air at 500 kV and 4 mA. The C-W stack was modified with smaller corona rings and installed in a pressure tank. When this tank is filled with sulfur hexafluoride (SF_6) gas above 5 psig, additional insulation and cooling is provided for operation up to 500 kV and 5 mA. The power driver electronics have also been modified to achieve this output.

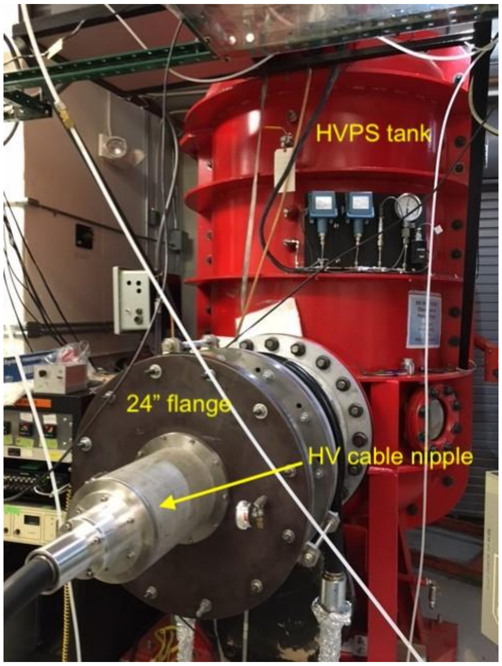
The monitor stack acts as the voltage feedback divider for the power driver circuitry, provides a divider probe for both the AC and DC components of the output voltage, and acts as bleeder resistors for the capacitors of the multiplier stack. The AC and DC outputs can be viewed on an oscilloscope to verify proper operation.

The solid-state pulse width modulated (PWM) power drive unit provides up to 12 kV of drive voltage for the C-W multiplier stack. The power input to the driver is 208 VAC 3-phase, which is directly rectified and filtered for use in the PWM chopper.

Refer to the Glassman service manual for a more complete description of this unit.

The insulating Gas Handling system consists of mechanical pumps and various solenoid control valves used to fill the HVPS tanks with SF_6. Instrument air or nitrogen is used to purge and backfill prior to opening the tank. The mechanical pumps with switching valves are used to evacuate the SF_6 from the tank to the gas storage bag and to evacuate the air or nitrogen prior to backfilling with SF_6. If the pressure in the tank is above 15 psi, a relief valve opens and the SF_6 flows back into the recovery gas bladder. The system is designed to be pressurized up to 10 psig and is equipped with the normal complement of control valves and pressure gauges. Refer to JLab drawing 05001-E-0001, FEL GTS Inst. Air, N2, and SF_6 Flow Schematic FEL Building for the details of the GTS Gas Handling system.

The connection between the HVPS and the electron gun is a gas insulated 18 inch OD tube (referred to as nipple from now on) bolted to the bottom of the HVPS SF_6 tank, and oriented 90 degrees with respect to the axis of the tank. The transmission line consists of a 320 Mega-Ohm resistor between the high voltage end of the HVPS and an epoxy socket that seals the SF_6 environment from atmospheric air. The resistor is coaxial to the nipple and can be connected to the electron gun with an industry standard, R30 high voltage cable. The epoxy socket is a “350kV wideband” from Essex X-Ray & Medical Equipment LTD that has been proven to withstand over 500kV in this configuration. It is bolted to a 20 inch OD blank flange, which in turn is bolted down to the nipple providing electrical connection between the resistor and a cable as well as mechanical support to the resistor. The other end of the cable is connected to the CEBAF-style electron gun that an R30 insulator holding the electrode inside the vacuum chamber.

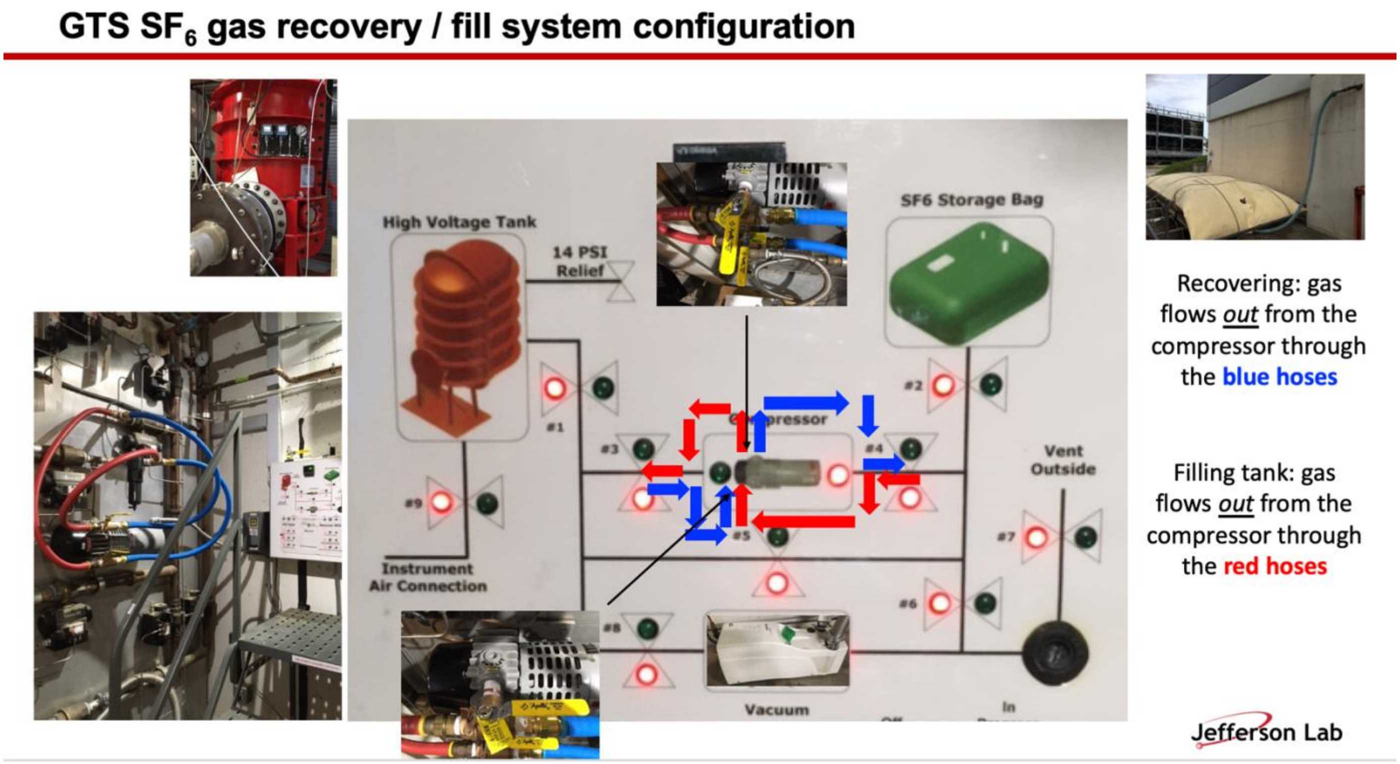


Picture of the gas insulated Glassman HVPS tank (red) connected to the DC electron gun via high voltage cable.

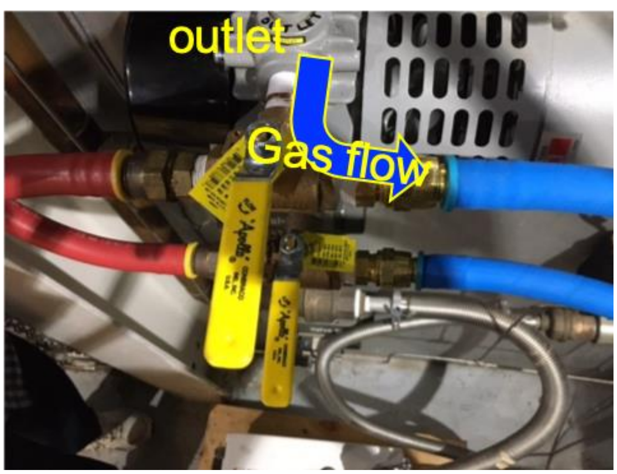
Step 1/5: Throw OFF and LOTO HVPS knife switch.

1. Check the HVPS Voltage Verification Unit (VVU) for proper operation. The green LED's are ON, and the line-to-line readings are 208 VAC, and the Line to Neutral readings are 120 VAC.
2. Don Cat 2 arc flash PPE
3. Throw knife switch OFF per ESCC005 Safe switching of Electrical Equipment training
4. Check the VVU again. The green LED's must be Off, the Line-to-Line readings must be 0 VAC, and the Line to Neutral readings are also 0 VAC. If this is not correct, stop and contact the system owner (Carlos Hernandez-Garcia). Do not proceed until these conditions are established.
5. Apply hasp and personal lock following LOTO per ESC007 training.
6. Doff PPE
7. Any other person working on this OSP that will be in contact with any internal HVPS component (i.e. resistor) and or high voltage cable connector between the gun and the HVPS MUST be a witness of the knife switch being thrown off and VVU verified to be de-energized, and apply their personal lock to the hasp following LOTO per ESC007 training.

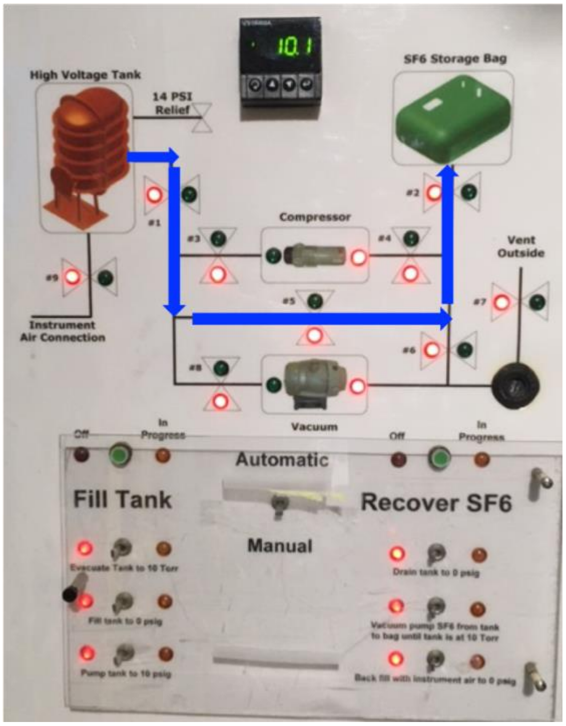
Step 2/5: Evacuate the HVPS tank of SF_6 insulating gas and backfill to atmosphere with instrument air.
Initial condition: HVPS tank filled to 10 PSIG with SF6. Storage bag empty.



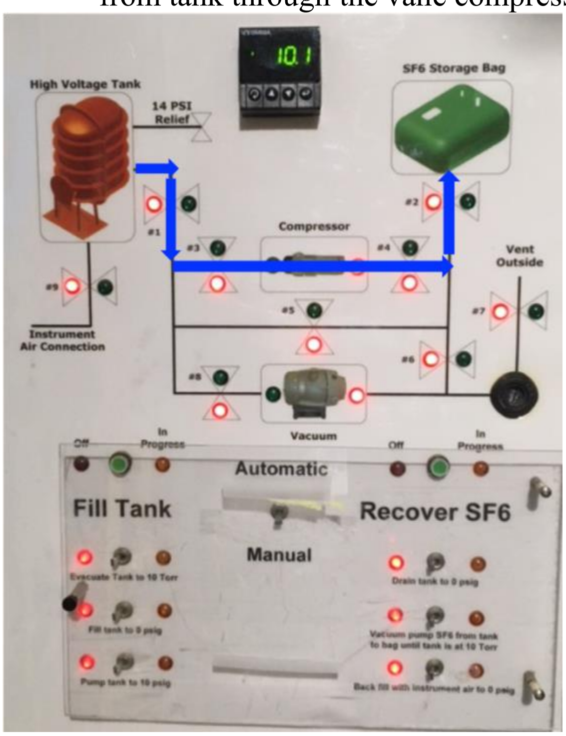
1. Ensure manual valves on the compressor are set in the “Recover gas” configuration (both valve handles pointing towards the compressor) as shown below



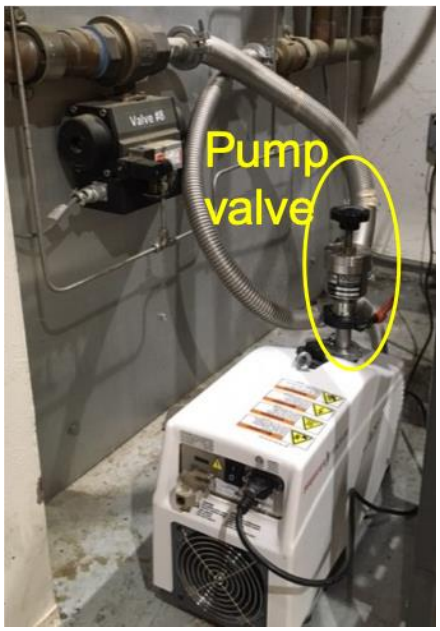
2. In the SF6 gas transfer control panel, under Recover SF6 (right column) flip to the right the switch labeled: “Drain tank to 0 PSIG”. The SF6 in the HVPS tank at 10 PSIG will move to the bag by differential pressure until the pressure in the bag and the tank are both 0 PSIG. This switch opens valves 1, 2 and 5 and the gas follows the path shown below:

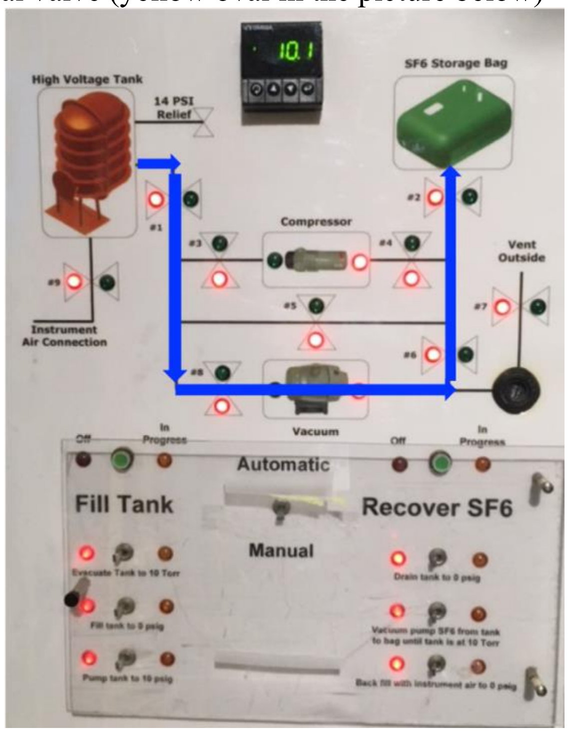


3. When the pressure reads 0 PSIG in the control panel LED display, flip back to the left the switch “Drain tank to 0 PSIG”. This closes valves 1, 2 and 5 and stops the flow of gas.
4. Now on the left column of the control panel, flip to the right the “Pump tank to 10 psig” switch. This will open valves 2, 4, 3 and 1 and will automatically start the vane compressor pushing the SF6 from the tank to the bag. Because the manual flow diverter valves are in the “recover gas” configuration, gas will flow from tank through the vane compressor and into the bag as shown below:



5. When the pressure in the digital display reads -13 (PSIG), flip the "Pump tank to 10 psig" switch to the left. This will turn the vane compressor off and will close valves 2, 4, 3, and 1. The HVPS tank analog gauge should read about 26 in-Hg. There is still remnant SF6 in the tank, but the vane compressor is not sufficient to continue moving gas to the bag. This is done with a Pfeiffer scroll pump in the following steps, but this pump cannot handle SF6 at higher pressures than ~20 in-Hg.
6. On the right column of the control panel, flip to the right the switch "Vacuum pump SF6 from tank to bag". This will open valves 1, 8, 6 and 2.
7. Manually turn Pfeiffer vacuum pump ON using its power switch located in the back.
8. Open the pump's MDC manual valve (yellow oval in the picture below)





9. When the digital pressure display reads -14 equivalent to 28 inHg in the HVPS tank gauge, flip back to the left the "Vacuum pump SF6 from tank to bag". This will close valves 1, 8, 6 and 2.
10. Close Pfeiffer pump valve and turn the pump OFF. The HVPS tank is now under vacuum and the SF6 is in the storage bag.
11. Flip the "Back fill with instrument air to 0 psig" to the right. This will open valve 9 to fill the tank with instrument air.
12. When pressure reads 0 psig, flip the "Back fill with instrument air to 0 psig" switch back to the left. The tank may be opened now.

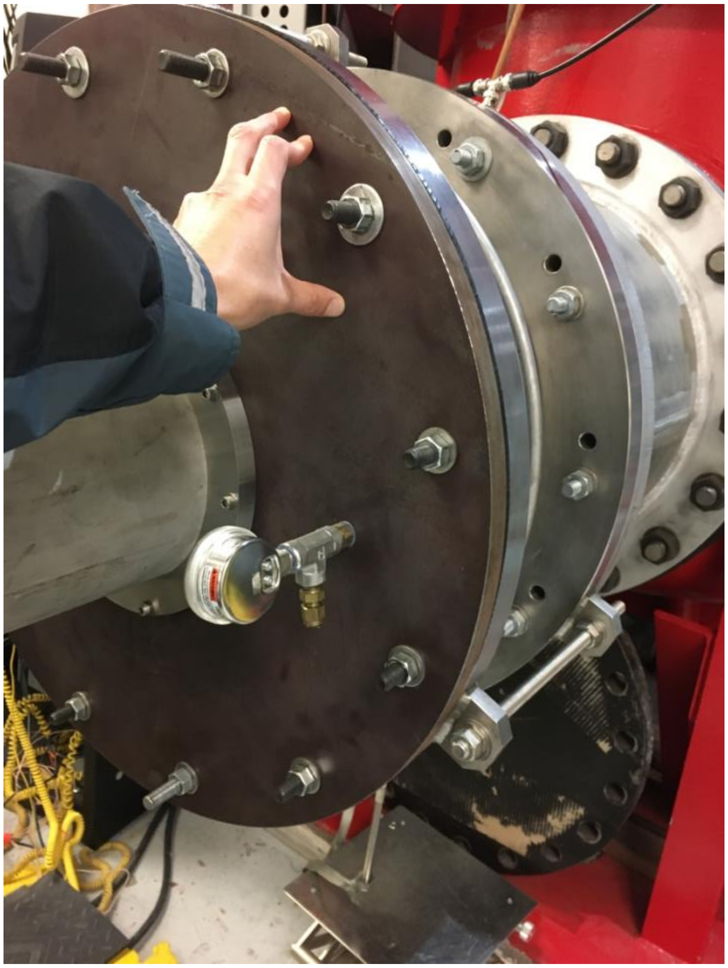
Step 3/5: Remove tank 24" flange where the HV connects to the HV cable nipple to have access to the resistor for shorting it out or for unshortening it.

1. Remove the Allen metric screws that secure the HV cable to the receptacle. The receptacle is bolted down to the HV cable nipple. Once the screws have been removed, pull the cable out of the receptacle. Be mindful of the silicone grease the cable plug has. Bag the cable plug to protect the rubber from dirt, and set aside.
2. Insert resistor holder rod located under the SF6 tank appendage that houses the resistor. The rod has a Swagelok fitting for tight sealing. It also has a plastic cradle to prevent direct electrical contact with the resistor. Tighten the Swagelok to ensure the rod will not move with the weight of the resistor.

3. Use pipe stand under the HV cable nipple as shown below to support its weight.

4. Don safety shoes.
5. Unbolt the HV cable nipple, and carefully pull away. Then pick it up by hand when the receptacle is all the way out. Use a bag to protect the receptacle and set aside as shown below.

6. Replace two of the 24 inch flange bolts with lifting eyes.
7. Attach lifting straps to “Genie” 400 lbs. capacity manually operated lift.
8. Secure the lifting straps to the lifting eyes already installed to the flange.
9. Ready the “Genie” lift to hold the flange.
10. Remove the rest of the flange bolts. The flange should now be being held by the manual lift.
11. Maneuver the lift to move the flange out of the way and lower the flange to rest on the floor.
12. Safety shoes may be doff now.



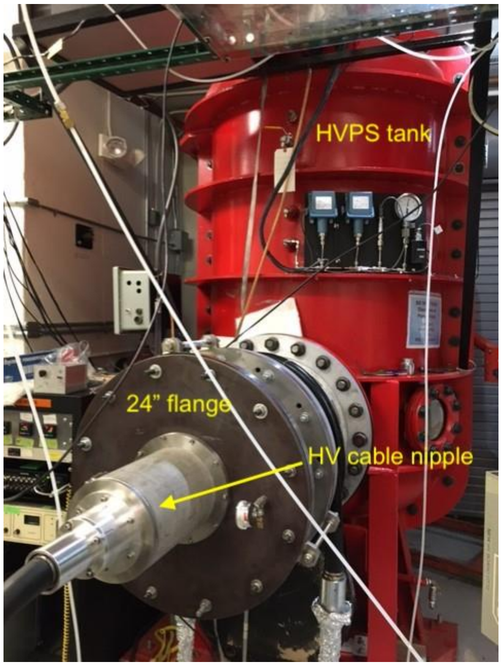
13. Once the flange is removed: ***CAUTION stored energy potentially present***. Be aware that the resistor will be clearly visible inside the HVPS appendage, and thus within hand reach. This is an exposed conductor which, although is supposed to be uncharged, it must be assumed charged up. Follow the instructions below to complete the complex LOTO for putting the system in a safe configuration.
    a. Perform visual inspection of grounding hook. The copper wire must be affixed firmly to the copper hook and plexiglass rod.
    b. Check that the grounding hook copper wire opposite end is connected to the HVPS tank ground.
    c. Don safety glasses
    d. Don hearing protection
    e. The HV cable nipple removed in step 4 has a receptacle with a pin at the end of it. This pin inserts into the hole of the resistor front cover shown in the picture below. Use the grounding hook to touch the resistor. The resistor should not have any charge, but this is a cautionary step. The grounding hook may be put away from the resistor now. Unfortunately there is no place to leave the hook attached to the resistor.
    f. Safety glasses and hearing protection may be doff now.

14. Remove the resistor cover by rotating it counterclockwise. The cover is affixed by means of a threaded rod. Along with the cover, a 3 inch long spool piece / spacer will come off, exposing 3 Allen screws
15. Remove the 3 Allen screws, this will allow for taking the cover off exposing the interior of the hollow resistor where the grounding wire is housed.

16. To UNSHORT the resistor, remove the wire from the threaded rod, and then coiled it up and push it as far back as possible. The resistor acts as a Faraday cage, thus the wire will be at the same potential as the resistor when the HVPS is powered on. To SHORT OUT the resistor, pull the wire from inside the resistor and connect to the threaded rod, securing it using the nut on the threaded rod.
17. When finishing either UNSHORTING or SHORTING out the resistor, replace the resistor cover and secure it with the 3 Allen screws.
18. Reattach the resistor spool piece along with the resistor front cover, align it so that the threaded rod can be screwed into the front cover. The resistor should look like the figure in step 6 above when done.
19. Don safety shoes
20. Use the "Genie" 400 lbs. capacity manually operated lift to reposition the 24 inch flange for re-installation.
21. Secure with all bolts in the 24 inch flange.
22. Replace the two lifting eyes with bolts.
23. Move "Genie" manually operated lift out of the way.
24. Tighten all bolts.
25. Use the pipe stand to hold the HV cable nipple in preparation for reattaching it to the 24 inch flange. Make sure to remove the protective bag, and wipe off the receptacle with iso-propanol.
26. Carefully guide the HV nipple into the hole of the 24 inch flange, until the pin of the receptacle inserts into the hole of the resistor front cover. This will be obvious because the HV cable nipple will then be flushed with the 24 inch flange.

27. Bolt down the HV cable nipple ensuring all bolts are tighten.
28. The resistor is now again supported by the HVPS stack inside the tank and by the HV cable nipple receptacle. Retract the resistor holding rod all the way down and ensure to tighten by hand its Swagelock nut.
29. Safety shoes may be doff now.
30. Reinsert the HV cable ensuring the silicone grease is well distributed on the surface of the rubber cable plug and that all bolts are tighten after insertion.

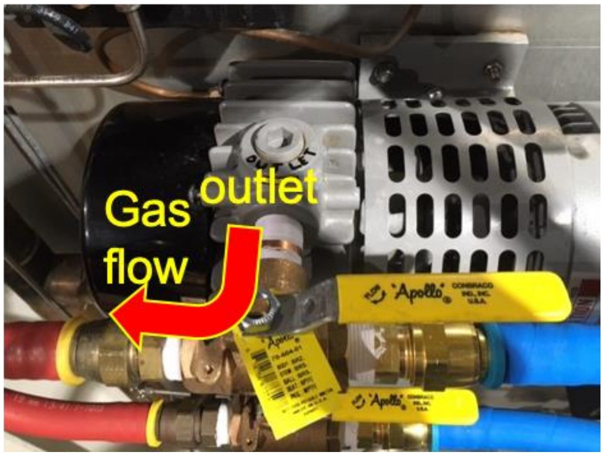
This is how the HVPS tank should look like when this step in the procedure is complete:



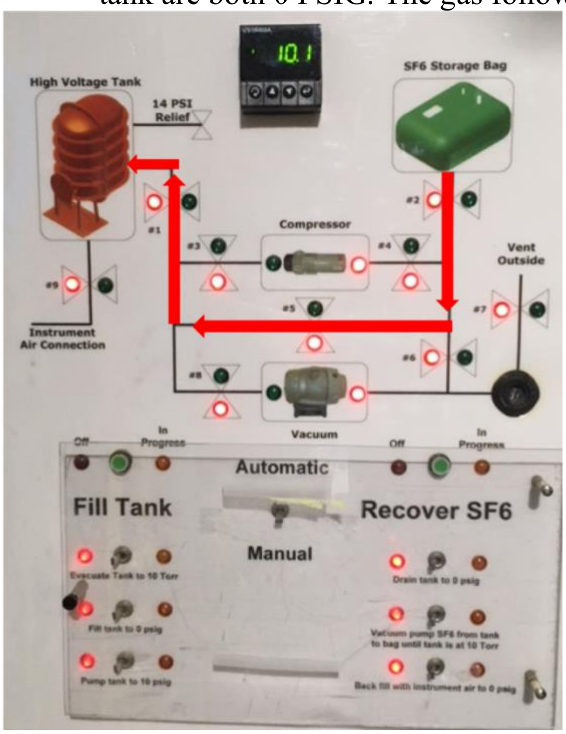
Step 4/5: Backfill the HVPS tank with SF_6 insulating gas to 10 PSIG

Initial condition: HVPS tank at atmospheric pressure with ambient air. All flanges and doors bolted down. Storage bag holding the amount of SF6 gas originally in the HVPS tank.

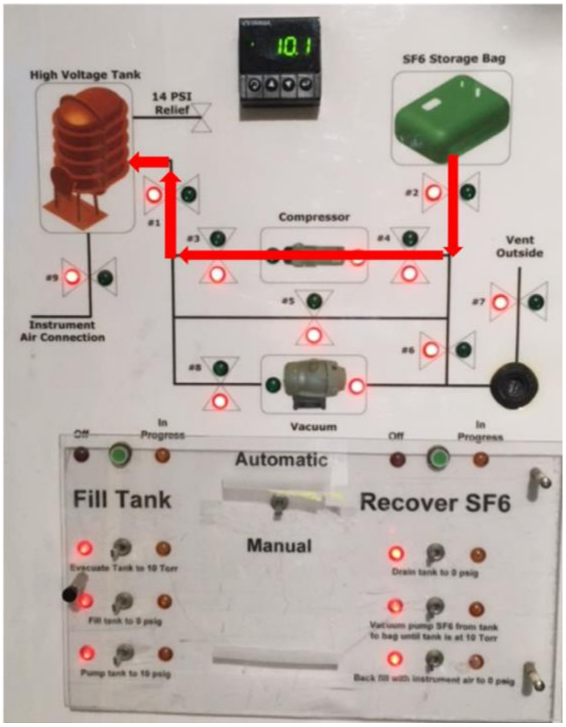
1. Flip the switch "Evacuate tank" to the right. This will open valves 1, 8 and 7 (vent to outside as shown in the SF6 gas transfer control panel)
2. Manually turn Pfeiffer vacuum pump ON and slowly open its MDC manual valve. This will start pumping down the air in the tank. The pump vents the ambient air to outside of the GTS.
3. When the digital pressure displays reads -14.0 equivalent to 28 inHg in the HVPS tank gauge, flip the "Evacuate tank" switch back to the left. This will close valves 1, 8, and 7. The HVPS analog gauge should read 28 in-Hg vacuum.
4. Close Pfeiffer pump valve and turn the pump OFF. HVPS tank is now under vacuum.
5. Ensure manual valves in the vane compressor are set in the "Fill tank" configuration (both valve handles parallel to the blue hoses) as shown in the figure below.



6. Flip the “Fill tank to 0 PSIG” switch to the right. This will open valves 1, 5 and 2. The SF6 in the bag will be sucked in by the vacuum in the HVPS tank by differential pressure until the pressure in the bag and the tank are both 0 PSIG. The gas follows the path shown below:



7. When the pressure reads 0 PSIG in the control panel LED display, flip back to the left the switch “Fill tank to 0 PSIG”. This closes valves 1, 2 and 5 and stops the flow of gas.
8. Flip the “pump tank to 10 psig” switch to the right. This will open valves 2, 4, 3 and 1 and will automatically start the vane compressor. Because the flow diverter manual valves are in the “fill tank” configuration, gas will flow from the bag through the vane compressor into the tank. The figure below shows the gas flow.



9. When the pressure in the digital display reads 10 psig, flip the "pump tank to 10 psig" switch to the left. This will turn the vane compressor off and will close valves 2, 4, 3, and 1. The analog gauge in the HVPS tank should also read 10 PSIG. Do not pressure tank higher than 10 PSIG, otherwise the relief valve will open.

Process to backfill the tank with SF6 to 10 PSIG complete.

Step 5/5: Throw ON and LOTO HVPS knife switch.

1. Check the HVPS Voltage Verification Unit (VVU). The green LEDs must be Off, the Line-to-Line readings must be 0 VAC, and the Line to Neutral readings are also 0 VAC
2. Every person must remove their personal lock from the hasp.
3. Before removing the hasp, don Cat 2 arc flash PPE
4. Throw knife switch ON per ESCC005 Safe switching of Electrical Equipment training training
5. The green VVU's LEDs should be ON, and the Line to Line readings are 208 VAC, and the Line to Neutral readings are 120 VAC. Check this for all three phases.
6. Doff PPE

Procedure complete.

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

The HVPS tank must never be left open to air when there is no trained personnel in the GTS enclosure.

14. Special environmental control requirements:

14.1	**List materials, chemicals, gasses that could impact the environment** (ensure these are considered when choosing Subject Mater Experts) and explore EMP-04 Project/Activity/Experiment Environmental Review below
	SF6
14.2	**Environmental impacts** (See EMP-04 Project/Activity/Experiment Environmental Review)

SF6 is a powerful greenhouse gas. The GTS HVPS has an in-house gas recovery system that allows gas transfer between the HVPS tank and a storage bladder located outside the GTS. In the event of over-pressurization > 15 PSIG, the system has a relief valve that would vent SF6 into the GTS enclosure.

14.3 Abatement steps (secondary containment or special packaging requirements)

N/A

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

In the event of injury, or an immediate emergency exists, call **911** and also notify:

- Guards (**x5822**)
- Occupational Medicine (**x7539**)
- Crew Chief (**x7045**) (if inside the fence)

In case of an injury follow standard JLAB procedures. Initial response cards are located with each phone for appropriate emergency phone numbers. Additional information can be found at https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-24400/*.pdf.

1. **Exposure to Liquid or Cold Sulfur Hexafluoride**

Eye: Flush eyes with plenty of lukewarm water for several minutes.
Call the Crew Chief at 7050 for help.
See Emergency/Medical Services.

Inhale: Immediately leave room and seek fresh air.
Call Crew Chief at 7050 for help.
If person is not breathing, call 911 and administer artificial respiration.
If breathing is difficult, seek Emergency/Medical Services.

Skin: Remove contaminated clothing and flush with lukewarm water for several minutes.
Call Crew chief at 7050 for help.
Seek Emergency/Medical Services for frostbite.

2. **ODH Alarm in GTS Vault**

Leave the building and call the Crew Chief at 7050 to investigate the problem.
After permission is given to re-enter the building, ensure the building air handling system is functioning to dissipate any residual gas.

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

1. The Pressure Relief valve is tested by backfilling the HVPS with instrument air and verifying the Relief valve opens at about 12.5 psi. Verify the Pressure Relief valve is closed above 10 psi by monitoring the tank pressure gauge for 10 minutes.

2. The tank Door Closed switch is tested by removing the switch's cover/striker plate and verifying the interlock permission is lost on the EPICS GTS Glassman Power Supply screen. Re-install the cover/striker plate after the test.

3. The tank Pressure Switch is tested by lowering the SF_6 pressure in the HVPS tank until the interlock permission is lost. This must happen at 5 psi or slightly higher.

4. Make a GTSLOG entry stating the HVPS interlocks were successfully tested and verified.

17. Inspection Schedules

Once a year in October C. Hernandez-Garcia performs SF6 inventories of all SF6 systems and reports to Aubrey Davie and David Fazenbaker.

18. References/Associated/Relevant Documentation

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

Submit Procedure for Review and Approval (See ES&H Manual Chapter 3310 Appendix T1 OSP & TOSP Instructions – Section 4.2 Submit Draft Procedure for Initial Review):

- Convert this document to .pdf
- Open electronic cover sheet: https://jlabdoc.jlab.org/docushare/dsweb/Get/Document-24048/3310T1Form.doc
- Complete the form
- Upload the pdf document and associated Task Hazard Analysis (also in .pdf format)

Distribution: Copies to Affected Area, Authors, Division Safety Officer
Expiration: Forward to ES&H Document Control

Form Revision Summary

Revision 1.7 – 02/25/2021 – Corrected link to Word doc; updated 'ESH&Q' to "ES&H'; other minor edits. No approval required.
Revision 1.6 – 06/23/2020 – Update section 15 to reflect guard number, what to do in an emergency, crew chief numbers, etc. approved by H. Fanning
Revision 1.5 – 04/11/18 – Training section moved from section 5 Authority and Responsibility to section 9 Training
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.
ES&H Division	Harry Fanning	04/11/18	02/25/24	1.6

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

Author:	Carlos Hernandez-Garcia	**Date:**	October 25, 2022	**Task #:** If applicable	

Complete all information. Use as many sheets as necessary

Task Title:	**GTS 500 kV gas insulated power supply resistor shorting/un-shorting and safety**	**Task Location:**	FEL Building 18, Room 109A (AKA GTS vault)

Division:	Accelerator	**Department:**	Center for Injectors and Sources	**Frequency of use:**	As needed, about once per year
Lead Worker:	Carlos Hernandez-Garcia				

Mitigation already in place: **Standard Protecting Measures** **Work Control Documents**	• The high voltage power supply is installed inside the GTS enclosure. There are no exposed electrical components. The AC input drive has its own chassis connected to building ground and mounted on the top of the HVPS SF6 tank. The Cockcroft-Walton HV multiplying stack is inside the HVPS SF6 tank. The resistor and cable plug are inside an appendage of the HVPS SF6 tank (nipple). The opposite end of the high voltage cable connects to the gun insulator. The Remote Control Unit is attached to the equipment rack in the GTS mezzanine. • A Voltage Verification Unit (VVU), mounted on the south wall of room 217 near the rack housing the Glassman HVPS Remote Control Unit, monitors the 208 VAC power feeding the HVPS. The VVU is wired just downstream of the power supply 208 VAC disconnect Switch. The VVU is used to verify that the power supply has been de-energized. • A pressure sensor, located on the side of the HVPS tank, monitors the pressure of the SF_6 or instrument air in the tank. The output of the pressure sensor is also available in the gun HVPS EPICS control screen and in the SF6 transfer system control panel. • The GTS vault is the plenum for the air conditioning system of the LERF vault. When the air conditioning system is running, any SF_6 spill or leak would be quickly dispersed due to the high flow rate of the air conditioning system. When the air conditioning system is off, any SF_6 leak would drain out of the GTS vault through the air conditioning recovery port and into the rear stair well of the LERF vault and then into the LERF vault. ODH sensors are positioned in the GTS vault, in the rear stair well, and at collection points in the LERF vault. The Safety System Group (SSG) electronics continuously monitors the ODH sensors

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	Throw OFF the HVPS knife switch and follow LOTO procedures / Arc flash Cat 2 from 208 VAC 3-phase feed	M	L	2	Only trained personnel in JLab QEW are authorized to perform this step. An ATLis must be submitted and approved before executing this THA.	• ESC001 Basic Electrical Safety • ESC002 Arc Flash and PPE • ESC003 Electrical Work Site Safety • ESC004 Work Planning and Documentation • ESC005 Safe Switching of Electrical Equipment • ESC006 Electrical Contact Release • ESC007 Lockout/Tagout (LOTO) • ESC008 Electrical Safety Practical Application • VVU used to verify voltage in each phase reads zero Volts. ESC001-008 = JLab QEW (Qualified Electrical Worker)	1

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
2	Transfer SF6 gas from HVPS tank to storage bag and backfill with instrument air to atmospheric pressure (0 PSIG) / SF6 leaks into the GTS enclosure	M	L	2	Only trained personnel in the GTS SF6 gas transfer procedure are authorized to perform this step	The HVPS tank drains into a bladder located outside the GTS. The transfer system is self-contained. A 15 PSIG relief valve vents SF6 into the GTS enclosure preventing over-pressurization. In the event of a release of SF_6 into the GTS vault, rooms 109A, 109B, and 111 must be evacuated and notify the Crew Chief and ESH Reporting Officer. In the event the SF_6 disperses sufficiently to reduce the oxygen content at floor levels, an ODH head will alarm. An ODH is located directly under the HVPS tank and about 3" above the floor. The Safety System Group electronics continuously monitor the ODH sensor	1
3	Insert resistor holder rod / awkward positioning	L	L	1	The rod has a Swagelok fitting for tight sealing. It also has a plastic cradle to prevent direct electrical contact with the resistor		1
4	Open HVPS tank / handling of heavy objects	L	M	2	Task must be included in ATLis	• Wear safety shoes. • It is recommended to use protective leather gloves. Use pipe-stand to support nipple bolted to the HVPS 24 inch flange while being pulled out of the way. Use "Genie" 400-lbs capacity manually operated lift with lifting straps to secure and remove the 24 " flange.	1

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
5	Ground HVPS resistor / sudden move reaction to loud noise from electrical discharge if the HVPS has not been allowed to discharge	M	M	3	The HVPS and Gun tanks shall not be opened for at least 1 minute after the HVPS has been turned off. It takes about 2 hours to transfer SF6 from the tank to the storage back and backfill with instrument air before any of the bolts can be removed.	1. Perform visual inspection of grounding hook. The copper wire must be affixed firmly to the copper hook and plexiglass rod. 2. Check that the grounding hook copper wire opposite end is connected to the HVPS tank ground. 3. Don safety glasses and hearing protection 4. Use the grounding hook to touch the resistor. The resistor should not have any charge, but this is a cautionary step. The grounding hook may be put away from the resistor now. Unfortunately there is no place to leave the hook attached to the resistor 5. Safety glasses and hearing protection may be doff now JLab QEW training	1

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
6	Remove the resistor front cover. A green wire is connected to the back of the resistor. The resistor is a hollow tube 4 inches diameter. Disconnect the green wire from the front resistor cover to un-short the resistor, or attach the green wire to the front cover to short the resistor. Reattach resistor front cover.	L	L	1	See step 5 above. This discharges any potential remaining electrical charge in the HVPS	Recommend using protective hand gloves.	1
7	Re-install 24” flange and nipple to close the HVPS tank / handling of heavy objects	L	M	2	Task must be included in ATLis	• Wear safety shoes. • It is recommended to use protective leather gloves. Use “Genie” 400-lbs capacity manually operated lift with lifting straps to secure and reattach the 24 “ flange. Use pipe-stand to support nipple and bolted it to the HVPS 24 inch flange.	1
8	Retract resistor holder rod / awkward positioning	L	L	1	The rod has a Swagelok fitting for tight sealing. It also has a plastic cradle to prevent direct electrical contact with the resistor		1

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation
9	Evacuate HVPS tank and back fill to 10 PSIG of SF6 from the storage bag/ SF6 leaks into the GTS enclosure	M	L	2	Only trained personnel in the GTS SF6 gas transfer procedure are authorized to perform this step	The HVPS tank drains into a bladder located outside the GTS. The transfer system is self-contained. A 14 PSIG relief valve vents SF6 into the GTS enclosure preventing over-pressurization. In the event of a release of SF_6 into the GTS vault, rooms 109A, 109B, and 111 must be evacuated and notify the Crew Chief and ESH&Q Reporting Officer. In the event the SF_6 disperses sufficiently to reduce the oxygen content at floor levels, an ODH head will alarm. An ODH sensor is located directly under the HVPS tank and about 3" above the floor. The Safety System Group electronics continuously monitor the ODH sensor	1
10	Throw ON the HVPS knife switch / Arc flash Cat 2 from 208 VAC 3-phase feed	M	L	2	Only trained personnel in JLab QEW are authorized to perform this step.	JLab QEW training	1

Highest Risk Code before Mitigation:	3	**Highest Risk Code after Mitigation:**	1

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

Form Revision Summary

Revision 0.2 – 07/26/21 – Periodic Review; updated header and footer
Periodic Review – 08/29/18 – No changes per TPOC
Periodic Review – 08/13/15 – No changes per TPOC
Revision 0.1 – 06/19/12 - Triennial Review. Update to format.
Revision 0.0 – 10/05/09 – Written to document current laboratory operational procedure.

ISSUING AUTHORITY	TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW DATE	REV.
ES&H Division	Harry Fanning	08/29/18	07/26/24	0.2

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ODH Assessment

Date: **7 November 2007 Revised 24 June 2008**

Division: FEL

Location: **FEL Gun Test Stand (Rooms 109A, 109B, & 111)**

Assessment Author: **Mathew Wright & Dana Arenius**

Approval

Engineering Division Department Head: **Will Oren 12/14/07**

EHS&Q: ________________________________

Facility Manager: _________________________

ODH Risk Assessment, FEL Room 109
March 20, 2007

Introduction

The following assessment addresses the risk of oxygen deficiency hazard (ODH) for the FEL (bldg. 18) room 109A. Because rooms 109B and 111 have openings to room 109A, they are also assessed by this document. The assessment is conducted according to the requirements of Appendix 6500-T3, "ODH Risk Assessment". Two general categories of ODH hazards are identified in the facility. These include sources of nitrogen and sulfur hexafluoride gas which can dilute the normal oxygen content with health effects as outlined in Appendix 6500-T3. It is recommended that a separate evaluation address sulfur hexafluoride as a toxic hazard in addition to what is covered here as an ODH hazard.

The following sections cover the modeling scope and methodology for cryogen and sulfur hexafluoride dispersion release, a description of the work space, risk assessment, failure rates of components, and requirements. The process work procedures presented in the May 1 2007 "GTS SF6 Gas Transfer System" review were considered in this assessment.

Model for Cryogen Dispersion Release (Ref Diagram Page 7 of 7)

The model for cryogen dispersion release of nitrogen is based on a ½ inch supply line at 80 PISG supply pressure with a ¼ inch solenoid valve. Because of the large capacity of the nitrogen dewar, the nitrogen source will be treated as an infinite supply source.

Because the nitrogen is considered to be an infinite source, the rooms have been modeled to limit the nitrogen flow and never let the oxygen levels go below the 18% by use of engineering controls. This means that there must be a limiting device in the nitrogen supply line located outside the room 109A. An interlock outside the room that will shut off the nitrogen source if fresh air supply is not on must also be provided.

The model for dispersion release of sulfur hexafluoride is based on a total source volume of 490 scf. One source of volume is a gas storage bag that is approximately 2500 gallons (335 scf) located outside. The other source of volume is the gun test stand vessel (HV tank) that is approximately 150 scf in room 109A. The HV vessel is pressurized to approximately 15 psig with the sulfur hexafluoride and therefore represents ~300 scf of gas. Because the sulfur hexafluoride is considered to be a dense gas with a specific density of 5, it is considered to be concentrated at the room floor level at ODH concentrations that yields a fatality factor of one (Fi). Room air is drawn from the FEL accelerator room through a stairway (room 111) via two wall air duct openings. The air duct opening into room 109A is six inches off the floor of room 109A. Therefore the oxygen level would be below 8.8% in room 109A and 109B less than or equal to this 6 inch height.

Six inches off the floor for rooms 109A and 109B would represent 573 cubic feet. If all the sulfur hexafluoride was to be released onto the floor, no sulfur hexafluoride would pour through the air duct. Sulfur hexafluoride gas flow would not be in the opposite direction of the air flow from room 111 into 109A.

One model for an oxygen deficiency hazard is based on the largest quantity of gaseous nitrogen available for use. A separate model is based on the total amount of sulfur hexafluoride that is possible. Failure rate estimates (P_i) are based on JLAB listed equipment rates under EH&S Section 6500. Fatality Factors (F_i) are derived from Figure 3, from EH&S Appendix 6500-T3. The sum of the failure product of the F_i and P_i determined the area classification in accordance with table 6 of Section 6500 of the EH&S manual.

Description of Work Space (Ref Diagram Page 7 of 7)

Room 109A has a floor area of 606.5 square feet with a 10 foot ceiling. At one end of the room is an intake duct to the air handling unit that supplies heated or cooled air mixed with fresh air to the FEL accelerator room. At the other end of the room is a hole in the wall that is open to the accelerator room and is covered with steel screen. Between the accelerator room and room 109A is a hallway (Room 111). Therefore, rooms 109A and 111 are considered air passage ways. There is one roll up door, normally closed, and a concrete door, normally open. The concrete doorway has a metal panel to eliminate air flow and any possible laser light that might come through the doorway. The doorway opens to room 109B.

<u>Gaseous Nitrogen Sources</u>

The gaseous nitrogen ODH source is a 20,000 gallon dewar. Liquid nitrogen is piped from the dewar to an ambient vaporizer. The gas that leaves the vaporizer is then piped to a header. The FEL has a connection to that header that supplies different locations at the FEL, including room 109A. This dewar represents approximately 1,900,000 standard cubic feet (SCF) of nitrogen gas at 300 Kelvin. If the nitrogen was accidentally released into an unventilated room, the oxygen level could become dangerously low if engineering controls were not in place.

<u>Sulfur Hexafluoride Sources</u>

The sulfur hexafluoride ODH source is from bottles kept outside. Those bottles are then vented into a large bag that is also outside. The sulfur hexafluoride is then drawn inside the room through piping and a pump to the gun test stand vessel. There are seven valves and approximately 20 elbows and fittings. The plumbing is mostly copper tubing with brazed joints. There are some flexible hoses.

Type of Ventilation

In accordance with Appendix 6500-T3, reliable ventilation may be considered a relevant factor for this ODH assessment on the nitrogen source only if the volume of air in the room is replaced with fresh air at a minimum of once an hour. There is no data at this time to support that the sulfur hexafluoride would be evenly mixed in the airspace if the ventilation is on.

ODH Risk Assessment

The following are a set of events for the nitrogen system associating the probability and fatality factors that are true only after the engineering ventilation control interlocks have been implemented in room 109A.

Event	**Spill Rate** SCFH	**Spill** scf	**%O2**	**Pi**	**Fi**
Fittings	310	1,900,000	>18	See note	0
Power Outage	0	0	21	See note	0
Operator Error	310	1,900,000	>18	See note	0
Valves	310	1,900,000	>18	See note	0
Hose	310	1,900,000	>18	See note	0

Pi Note: The probability factor Pi is assumed to be $0 \leq Pi \leq 1$ for this part of the ODH analysis. It does not depend on the value of Pi. For all values of probability, engineering ventilation interlock controls will maintain O2 levels >18% where the fatality factor Fi will always be equal to zero. **Therefore** $\phi = \sum P_i F_i = 0$ **for all values of Pi.**

The following are a set of events for the sulfur hexafluoride system associating the probability and fatality for rooms 109A & 109B.

Event	**Spill Rate** SCFH	**Spill** scf	**%O2**	**Pi**	**Fi**
Flanges, Closures, Elbows	See Note	300	<8.8	3.00E-07	1.20E-05
Pipes < 3", high quality	See Note	300	<8.8	1.00E-10	4.00E-09
Valves: orifices, flow, meters, (test)	See Note	300	<8.8	1.00E-08	7.00E-08
Welds	See Note	300	<8.8	3.00E-09	2.40E-07
FEL SF6 Vessel	See Note	300	<8.8	3.80E-06	3.80E-06
				S	1.61E-05

Spill Rate Note: This assessment does not account for the rate at which the sulfur hexafluoride would be released into the room. Instead, the total amount of sulfur hexafluoride was used.

The following are a set of events for the sulfur hexafluoride system associating the probability and fatality for room 111.

Event	**Spill Rate** SCFH	**Spill** scf	**%O2**	**Pi**	**Fi**
Flanges, Closures, Elbows	See Note	300	<8.8	See note	0
Pipes < 3", high quality	See Note	300	<8.8	See note	0
Valves: orifices, flow, meters, (test)	See Note	300	<8.8	See note	0
Welds	See Note	300	<8.8	See note	0
FEL SF6 Vessel	See Note	300	<8.8	See note	0

Pi Note: The probability factor Pi is assumed to be $0 \le Pi \le 1$ for this part of the ODH analysis. It does not depend on the value of Pi. For all values of probability, the O2 levels will remain >18% where the fatality factor Fi will always be equal to zero. **Therefore** $\phi = \sum P_i F_i = 0$ **for all values of Pi for room 111.**

Resultant Classifications

ODH Classification

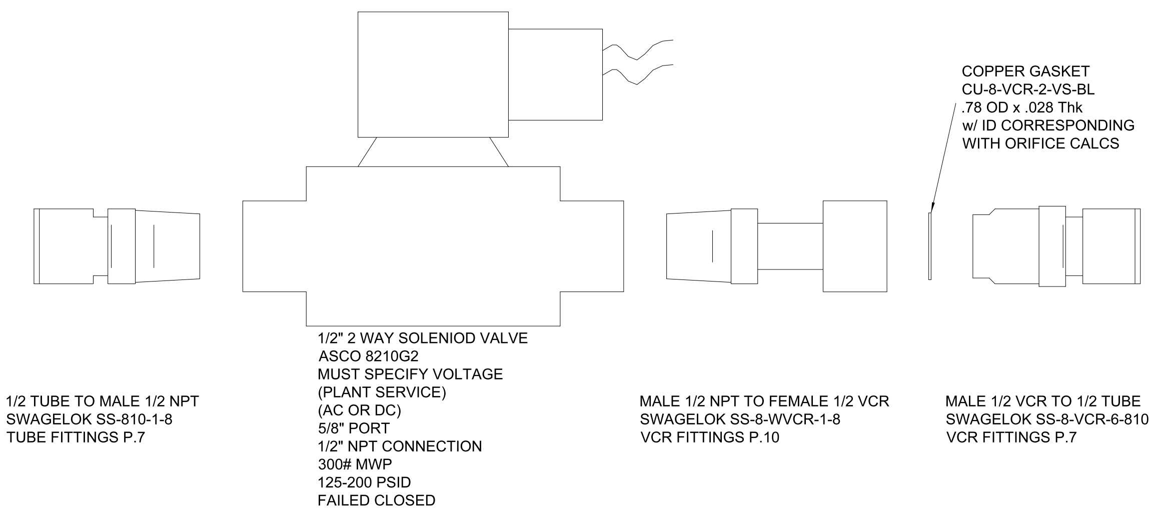
Because Φ is > 10^{-5} but < 10^{-3}, the **ODH classification is 2** for rooms 109A and B.

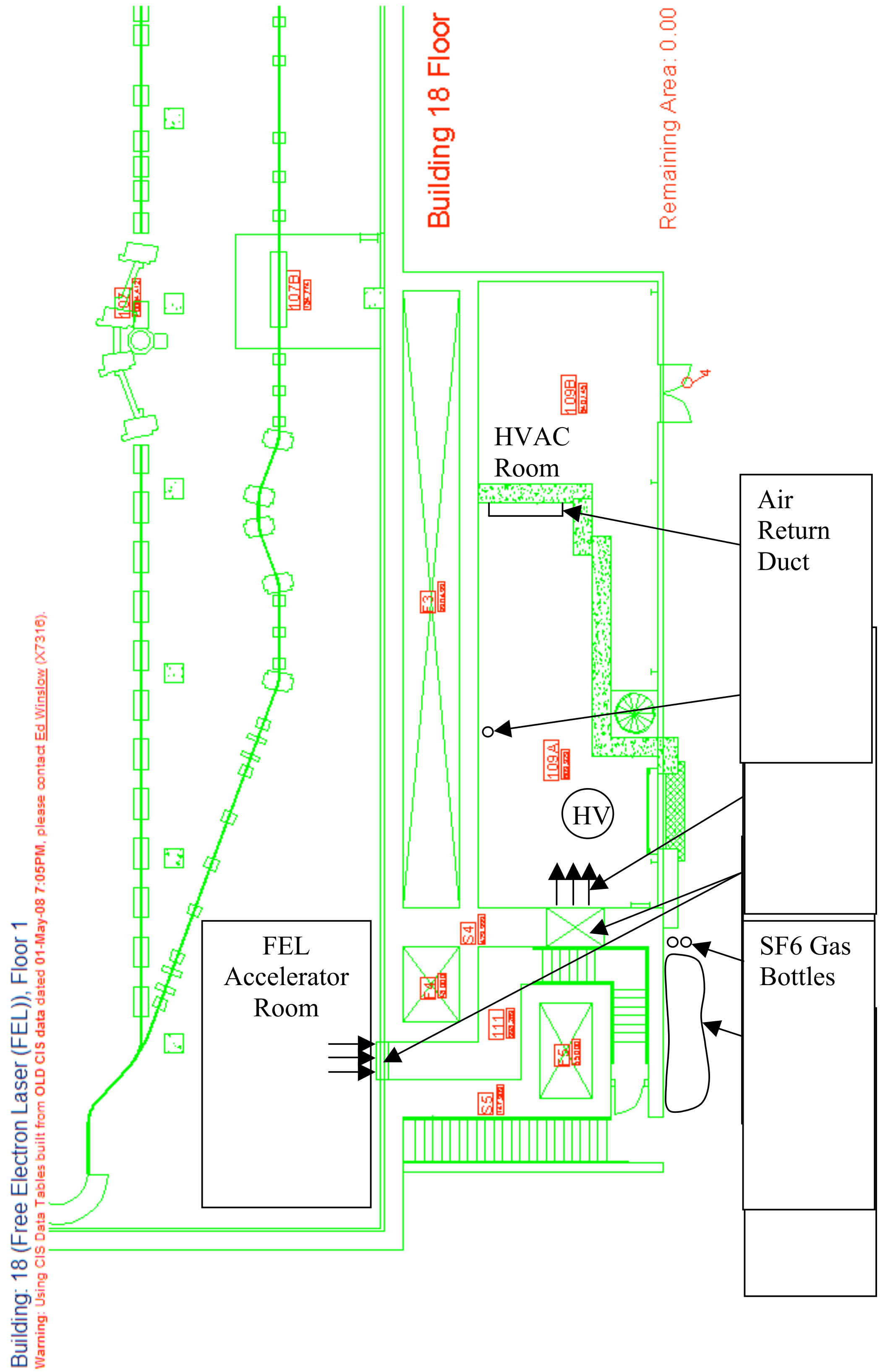
Because $\Phi < 10^{-7}$, the **ODH classification is 0** for room 111.

Engineering Controls

The following engineering controls are necessary to provide a safe working environment while retaining an ODH 0 posting for the nitrogen source.

This analysis requires an interlock between the nitrogen source and the air handling unit. The interlock is to be a fail-closed solenoid valve up-stream and outside of the room that closes when the air handing unit is not working. Normally an orifice plate is installed, as shown in the diagram, but is not required for this analysis because there is already an orifice of 1/8 inch at the gas nitrogen header behind CHL. This will limit the N2 flow rates which allow the ventilation air to maintain O2 levels > 18%.




Building: 18 (Free Electron Laser (FEL)), Floor 1
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107B
109B
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F3
F4
F5
S4
S5
HVAC Room
Air Return Duct
HV
FEL Accelerator Room
SF6 Gas Bottles

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Serial Number: ACC-22-144152-LTTI

Title: GTS 500 kV Gas Insulated Power Supply resistor shorting/un-shorting and safety

Name	Signature	Date