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Jefferson Lab
Thomas Jefferson National Accelerator Facility

Operational Safety Procedure Review and Approval Form # 58956
(See ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure (OSP) and Temporary OSP Procedure for Instructions)

Type:	***OSP*** Click for OSP/TOSP Procedure Form Click for LOSP Procedure Form		
Serial Number:	***ENP-16-58956-OSP***		
Issue Date:	***4/12/2016***		
Expiration Date:	***3/12/2019***		
Title:	***Operation of PRAD Vacuum Chamber***		
Location: (where work is being performed)	***Experimental Hall B***	Location Detail: (specifics about where in the selected location(s) the work is being performed)	***Level 1 of the Hall B space frame***
Risk Classification: (See ES&H Manual Chapter 3210 Appendix T3 Risk Code Assignment)	Without mitigation measures (3 or 4): With mitigation measures in place (N, 1, or 2):		***3*** ***2***
Reason:	This document is written to mitigate hazard issues that are : ***Determined to have an unmitigated Risk code of 3 or 4***		
Owning Organization:	***PHALLB***		
Document Owner(s):	***Pasyuk, Eugene (pasyuk@jlab.org)*** Primary ***Miller, Bob (rmiller@jlab.org)***		

Supplemental Technical Validations

Pressurized Tanks, Containers, and Vacuum Vessels (Dave Meekins, Kelly Dixon, Timothy Whitlatch, Will Oren)
Stored Energy: Mechanical, Hydraulic, Pneumatic (Bert Manzlak, Paul Collins)

Document History

Revision	Reason for revision or update	Serial number of superseded document

Comments for reviewers/approvers:

Attachments

Procedure: ***PRAD_Vacuum_tank OSP V3-1.pdf***
THA: ***PRAD_Vacuim_tank_THA-1.pdf***
Additional Files: ***PRad Vacuum Tank Window Design.pdf***
Convert to PDF

Review Signatures	
Person : Physics ES&H Liaison	**Signed** on 4/8/2016 3:39:26 PM by Bert Manzlak (manzlak@jlab.org)
Subject Matter Expert : Pressure Systems->Pressurized Tanks-> Containers-> and Vacuum Vessels	**Signed** on 4/8/2016 3:38:59 PM by Will Oren (oren@jlab.org)
Subject Matter Expert : Stored Energy: Mechanical-> Hydraulic-> Pneumatic	**Signed** on 4/8/2016 3:39:22 PM by Bert Manzlak (manzlak@jlab.org)

Approval Signatures	
Division Safety Officer : PHALLB	**Signed** on 4/12/2016 7:12:28 AM by Ed Folts (folts@jlab.org)
Org Manager : PHALLB	**Signed** on 4/8/2016 3:54:00 PM by Volker Burkert (burkert@jlab.org)
Safety Warden : Experimental Hall B	**Signed** on 4/12/2016 6:04:24 AM by Doug Tilles (tilles@jlab.org)

xfa

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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.)

Click

DEFINE THE SCOPE OF WORK

Title:	Operation of PRAD Vacuum Chamber		
Location:	Experimental Hall B	**Type:**	☒ OSP ☐ TOSP
Risk Classification (per Task Hazard Analysis attached) (See *ESH&Q Manual Chapter 3210 Appendix T3 Risk Code Assignment*.)		**Highest Risk Code Before Mitigation (3 or 4):**	3
		Highest Risk Code after Mitigation (N, 1, or 2):	2
Owning Organization:	Hall B	**Date:**	03/24/2016
Document Owner(s):	Bob Miller, Eugene Pasyuk		

Document History (Optional)

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

ANALYZE THE HAZARDS

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

This document describes procedures for operating the PRAD Vacuum Chamber

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

The operations include but not limited to installation and removal of window cover, connection of the beam pipe to the window.
All operations near the window should be performed by authorized personnel only.

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

The PRad experiment is set up on level 1 of the Hall B Space Frame. PRad experiment a large ~5m long vacuum chamber extending from the target to the PRad detector system. There is a 1.7m diameter 63 mil Al. window at one end of the vacuum chamber, just before the PRad detectors. When this chamber is under vacuum it has very large stored energy. The accidental rupture of the window causes release of this stored energy. This presents a hazard to the personal and equipment.

4. Authority and Responsibility:

4.1 Who has authority to implement/terminate

Hall B engineer or designee

4.2 Who is responsible for key tasks

Hall B work coordinator or designee. Only the personnel authorized by the Hall Work Coordinator or designee can perform the work.

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

Hall B engineer

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

- Read the OSP
- EH&S orientation (SAF100)
- Hall B safety awareness training (SAF111)
- PRad ESAD

5. Personal and Environmental Hazard Controls Including:

5.1 Shielding

N/A

5.2 Interlocks

N/A

5.3 Monitoring systems

N/A

5.4 Ventilation

N/A

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

N/A

6. List of Safety Equipment:

6.1 List of Safety Equipment:

Hearing protection, safety glasses

6.2 Special Tools:

N/A

DEVELOP THE PROCEDURE

1. Associated Administrative Controls

- Appropriate training, as described in 4.4
- Written procedures in this document

2. Operating Guidelines

Hall work coordinator, in concert with the PRad Run Coordinator, shall determine the appropriate time for operations with Vacuum Chamber.

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

Hall work coordinator or designee shall notify PRad Run Coordinator before and after each operation with Vacuum chamber

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

1. Place barriers at all entries to level 1 spaceframe.
2. Place signs at all entries to level 1 that warn personnel of a thin window under vacuum.
3. Place signs at all entries to level 1 that state ear plugs and safety glasses must be worn to enter level 1.
4. Place ear plugs and safety glasses at the entries to level 1.
5. Personnel authorized by the Hall Work Coordinator will pump down the vacuum tank and check for leaks.
6. The signs and barriers will remain in place as long as the tank is under vacuum.

A window cover has been fabricated from 1/8" thick aluminum to protect the window from damage due to something falling into the window. This cover will be attached to the window at all times except when the experiment is running.

The protective window cover will be installed or removed only when there is no vacuum in the tank. This will remove the stored energy in the tank so people can work near the window.

Any operations in the vicinity of the window including maintenance and/or repair work on the PRAD detector must be done only when there is no vacuum in the tank and protective covers are in place.

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

In the event of a leak in the vacuum system, personnel authorized by the Hall Work Coordinator will bleed up the vacuum in the vacuum tank.

6. Special environmental control requirements:

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

N/A

6.2 Abatement steps (secondary containment or special packaging requirements)

N/A

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

If there is an emergency and personnel can enter the area, the vacuum tank can be bled up by personnel authorized by the Hall Work Coordinator. If personnel can not enter the area, the signs are in place to warn emergency responders of the thin window under vacuum.

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

N/A

9. Inspection Schedules

The Vacuum chamber and window shall be inspected prior to any operation.

10. References/Associated Documentation

Attachment A: PRad Vacuum chamber Task Hazard Analysis
Attachment B: PRad Vacuum window design

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

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

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 – 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	02/19/14	02/19/17	1.3

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Task Hazard Analysis (THA) Worksheet

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

Click For Word

Author:	Eugene Pasyuk	**Date:**	03/24/2016	**Task #:** If applicable	

Complete all information. Use as many sheets as necessary

Task Title:	Operation od PRAD Vacuum chamber			**Task Location:**	Hall B
Division:	Physics	**Department:**	Hall B	**Frequency of use:**	weekly
Lead Worker:	Doug Tilles				
Mitigation already in place: Standard Protecting Measures Work Control Documents	Standard Hall B protective measures and appropriate personnel training including but not limited to SAF111 PRad COO, PRad ESAD				

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
	PRad experiment a large ~5m long vacuum chamber extending from the target to the PRad detector system. There is a 1.7m diameter 63 mil Al. window at one end of the vacuum chamber, just before the PRad detectors. When this chamber is under vacuum it has very large stored energy. The accidental rupture of the window causes a release of large stored energy. This present hazard to the personal and equipment	H	L	3	A window cover has been fabricated from 1/8" thick aluminum to protect the window from damage due to something falling into the window. This cover will be attached to the window at all times except when the experiment is running. The protective window cover will be installed or removed only when there is no vacuum in the tank. This will remove the stored energy in the tank so people can work near the window.	The PRad experiment is set up on level 1 of the Hall B Space Frame. This area will be roped off whenever the tank is under vacuum and safety glasses and hearing protection will be required to enter level 1. All operations near the window should be performed by authorized personnel only. The operations include but not limited to installation and removal of widow cover, connection of the beam pipe to the window.	2

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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	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation

Highest Risk Code before Mitigation:	3	**Highest Risk Code after Mitigation:**	2

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

Form Revision Summary

Periodic Review – 08/13/15 – No changes per TPOC
Revision 0.1 – 06/19/12 - Triennial Review. Update to format.
Revision 0.0 – 10/05/09 – Written to document current laboratory operational procedure.

ISSUING AUTHORITY	TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW DATE	REV.
ESH&Q Division	Harry Fanning	08/13/15	08/13/18	0.1

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PRad Vacuum Tank Window Design

Bob Miller

Hall B Physics

February 13, 2016

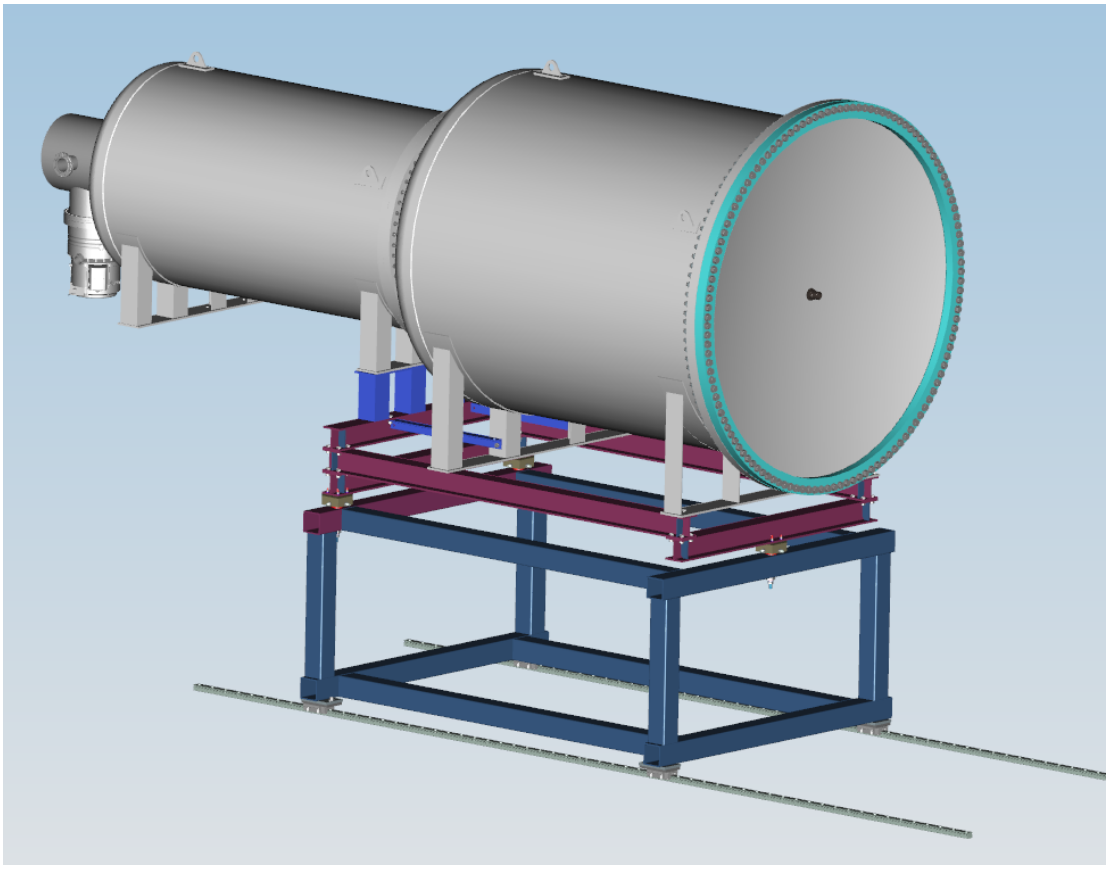

Figure 1: PRad Vacuum Tank and Window on Stand

Description

The PRad experiment requires a vacuum tank from the target to the detectors. At the end of the vacuum tank, a thin window is installed to maintain the vacuum and allow the particles to pass through to the detectors. The experiment requires that a beam pipe is attached to the center of the window which goes all the way to the beam dump.

The PRad window is made of 2024-T3 aluminum with a thickness of 0.063 inches. The window is 66 inches in diameter and has a 1.75 inch hole in the center for an adapter to the beam pipe.

Background

During the design phase of this project, the rough size of the window needed was 72” in diameter. It turns out the Hall C already had a vessel with a 66” aluminum window that had already been formed, tested, and installed on a chamber for their Heavy Gas Cerenkov (HGC) detector. Therefore, the PRad window was made the same size, with the same bolt pattern so the Hall C tooling and forming experience could be used. The differences between the HGC and the PRad windows are: the HGC window is 0.040” thick, where the PRad is 0.063” thick, and the PRad window has a center hole for the beam pipe. The material thickness of the PRad window was increased because the 0.040” thickness material was no longer available in this size.

HGC Window Forming

The HGC window was formed at 45 psi and a second window was tested to 60 psi without failure.

Window Forming Requirements

The ES&H manual, chapter 6151, part 7 gives direction on designing formed vacuum windows. The PRad window is a Category 1 window, the volume of the tank is larger than 35 ft^3 and the tank is not attached to a credible pressure source that can exceed 15 psig and is protected from pressurization exceeding 15 psig through engineering controls.

The only credible pressure source connected to the vacuum tanks is a temporary source of nitrogen used to backfill the tank. The nitrogen source is limited to 1 psi by a relief valve.

7.2 Design Requirements for Category 1, or 2 Vacuum Windows

7.2.1 General

The design of any thin vacuum window shall consider the following:

- Material compatibility
- Life cycle and fatigue
- Effects from radiation or corrosion
- Possible accidental damage from puncture etc
- Magnitude of deformation
- Crack and tear propagation

Design calculations (see 7.2.2) or proof test (see 7.2.3) shall be performed to ensure that the stresses in the thin window are acceptable

7.2.2 Stress and Deformation Calculations

The stress in the window shall be determined after all fabrication steps have been completed (i.e. hydro-forming). The calculated stress in the window shall be less than the allowable stress. The allowable stress in tension for any thin vacuum window shall be the lesser of
Sa = 0.5 Sut (allowable stress is ½ ultimate tensile)
Sa = 0.9 Sy (allowable stress is 9/10 yield)

7.3 Documentation
Documentation for thin windows (design calculations, material certifications, test data, etc.) shall be maintained by the Responsible Vacuum Engineer. A Vacuum System folder within the Pressure Systems webpage is available for documentation storage.

7.4 Formed Windows

Windows that are shaped by hydro-forming or some other process can often be safely made from much thinner material than a corresponding flat window of the same diameter. Typically, a thin flat disc of Aluminum is hydro-formed into a predetermined spherical shape. A typical hydroforming pressure is two to three times the usual operating pressure (14.7 psi). This pressure is necessary to yield the material into the desired shape and has the benefit of an inherent overpressure test. Many hydro-formed windows exist at Jefferson Lab - typically made from Al 2024 Alclad which is available in a half soft state and has a large elongation and a moderately high yield and ultimate strength. It is recommended that only 30% of the available elongation be used so that adequate reserve remains in the window to provide safety against foreign object penetration. The thin window stock or precut blanks shall be carefully inspected prior to use to ensure that there are no defects, deep scratches or wrinkles that could easily compromise the strength of these thin materials.

Window Material and Properties

Material	2024-T3 Aluminum
Yield Stress (psi)	39200
Tensile Stress (psi)	58700
Elongation at Break (%)	12

Allowable Stress

Sa = 0.5 Sut (allowable stress is ½ ultimate tensile) = 0.5 * 58700 = 29350 psi
Sa = 0.9 Sy (allowable stress is 9/10 yield) = 0.9 * 39200 = 35280 psi

The allowable stress is the lower of the two, which is 29350 psi.

Recommended Maximum Elongation

The recommended maximum elongation is 30% of elongation at break. 30 % of 12 % elongation is 4 %.

Therefore, the maximum recommended elongation of the window is 4%.

Design Calculations for PRad Window

The design calculations are included in the attached spreadsheet and are summarized in the following table.

Forming pressure (psi)	35
Window bow at operation pressure (in)	2.7
Stress at operation pressure (psi)	24650
Elongation at operating pressure (%)	0.7

Therefore, the window meets the stress and elongation requirements of Chapter 6151, Part 7.2 of the ES&H manual for Category 1 windows.

Clamping Load of Window Flange

The clamping load required to hold the window was determined by calculating the linear load along the edge of the window and bolt preload required with the friction between the aluminum window and steel flanges. The factor of safety against the window sliding at the clamping surfaces was calculated for similar windows, which were found to be in the range of 4.5-6.2. The window flange bolt torque is set at 210 ft-lbs for the ¾-10 grade 5 bolts, resulting in a factor of safety of 4.2. These calculations are based on the linear load during window forming; therefore, the factor of safety is higher under the operating vacuum.

Beam Line Adapter

The experiment requires that a beam tube is attached to the window. Windows with holes are not specifically addressed in the ES&H manual, but have been successfully used at JLab. Hall B has used a beam tube adapter for a Polarized Target experiment (dwg 66850-C-02743), and Hall C has a beam tube adapter for a Target Chamber Window (dwg 67153-56029).

The PRad window uses the Polarized Target design to attach the beam tube to the window. To ensure that the beam tube adapter was safe to use on the vacuum tank, a hydrostatic test was completed.

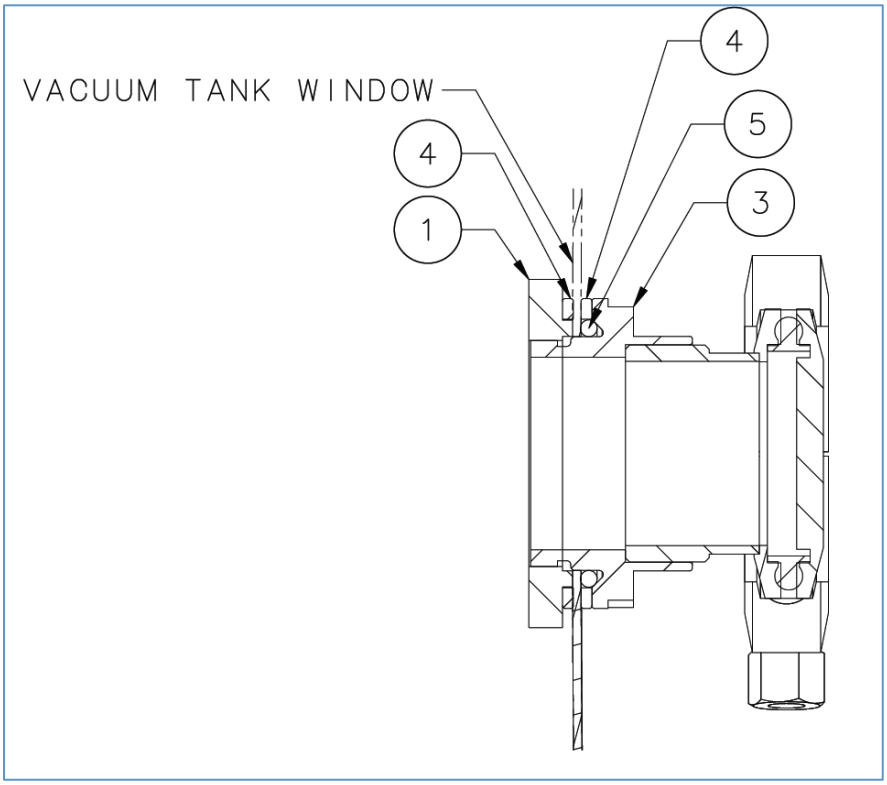

Figure 2: PRad Beam Tube Adapter

To complete the hydrostatic test, the beam tube adapter was attached to the window and a blank was installed in place of the beam tube. The window was attached to the forming fixture and hydrostatic ally tested to 30 psi with no leaks present.

Window Protection

A window cover has been fabricated from 1/8” thick aluminum to protect the window from damage due to something falling into the window. This cover will be attached to the window at all times except when the experiment is running.

The window will be installed or removed only when there is no vacuum in the tank. This will remove the stored energy in the tank so people can work near the window.

Personnel Protection

The PRad experiment is set up on level 1 of the Hall B spaceframe. This area will be roped off whenever the tank is under vacuum and safety glasses and hearing protection will be required to enter level 1.

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

Serial Number: ENP-16-58956-OSP

Title: Operation of PRAD Vacuum Chamber

Name	Signature	Date