Person: Bueltmann, Stephen (bueltman@jlab.org)
Org: PHALLB

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Jefferson Lab
Thomas Jefferson National Accelerator Facility

Operational Safety Procedure Review and Approval Form # 97803
(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<br>Click for LOSP Procedure Form<br>Click for LTT-Individual Information<br>Click for LTT-Group Information |
| Serial Number: | ***ENP-20-97803-OSP*** | |
| Issue Date: | ***2/4/2020*** | |
| Expiration Date: | ***1/4/2021*** | |
| Title: | ***Bonus12 Gas Target System*** | |
| Location:<br>(where work is being performed)<br><br>Building Floor Plans | ***94 - Experimental Hall B***<br>***96B - Hall B Gas Shed*** | Location Detail:<br>(specifics about where in the selected location(s) the work is being performed) |

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

| | |
|---|---|
| Reason: | This document is written to mitigate hazard issues that are :<br>***Not Applicable*** |
| Owning Organization: | ***PHALLB*** |
| Document Owner(s): | ***Stepanyan, Stepan (stepanya@jlab.org)*** Primary<br>***Miller, Bob (rmiller@jlab.org)***<br>***Poudel, Jiwan (jpoudel@jlab.org)***<br>***Bueltmann, Stephen (bueltman@jlab.org)*** |

Supplemental Technical Validations

***Gas Cylinders (Robert Myles, Tim Minga)***
***ODH 0 and 1 (Imani Burton, Jennifer Williams)***
***Pressurized Vacuum Lines and Piping Systems (Dave Meekins, Kelly Dixon, Timothy Whitlatch, Will Oren)***
***Fire Protection (Tim Minga)***
***ESH&Q Liasion (Bert Manzlak)***

Document History

| Revision | Reason for revision or update | Serial number of superseded document |
|---|---|---|

| | |
|---|---|
| Lessons Learned | Lessons Learned relating to the hazard issues noted above have been reviewed. |
| Comments for reviewers/approvers: | ***Updated ODH comments in BonusGas Target.pdf*** |

**Attachments**

Procedure: ***3310T1Form.pdf***
THA: ***3210T1FormTarget.pdf***
Additional Files: ***BonusGasTarget.pdf***

**Review Signatures**

| | |
|---|---|
| Additional Authorization : Fire Protection - other than current engineered safeguards or fire watch | **Signed** on 2/4/2020 1:22:03 PM by Tim Minga (minga@jlab.org) |
| Subject Matter Expert : Gas Cylinders | **Signed** on 2/4/2020 1:22:03 PM by Tim Minga (minga@jlab.org) |
| Subject Matter Expert : Oxygen Deficiency Hazards (ODH)->ODH 0 and 1 | **Signed** on 2/3/2020 8:49:24 AM by Jennifer Williams (jennifer@jlab.org) |
| Subject Matter Expert : Pressure Systems->Pressurized Vacuum Lines and Piping Systems | **Signed** on 2/3/2020 4:46:40 PM by Will Oren (oren@jlab.org) |

**Approval Signatures**

| | |
|---|---|
| Division Safety Officer : PHALLB | **Signed** on 2/4/2020 3:24:03 PM by Ed Folts (folts@jlab.org) |
| ESH&Q Division Liasion : PHALLB | **Signed** on 2/4/2020 2:01:55 PM by Bert Manzlak (manzlak@jlab.org) |
| Org Manager : PHALLB | **Signed** on 2/4/2020 2:17:57 PM by Marco Battaglieri (battagli@jlab.org) |
| Safety Warden : Experimental Hall B | **Signed** on 2/4/2020 1:33:58 PM by Calvin Mealer (mealer@jlab.org) |
| Safety Warden : Hall B Gas Shed | **Signed** on 2/4/2020 3:03:28 PM by Todd Ewing (jtewing@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.)

Click For Word Doc

| | | | |
|---|---|---|---|
| **Title:** | BONuS12 Gas Target System | | |
| **Location:** | 94 - Hall B<br>94E – Hall B | **Type:** | ☒ OSP<br>☐ TOSP |
| **Risk Classification**<br>(per Task Hazard Analysis attached)<br>(See *ESH&Q Manual Chapter 3210 Appendix T3 Risk Code Assignment*.) | | **Highest Risk Code Before Mitigation** | 2 |
| | | **Highest Risk Code after Mitigation (N, 1, or 2):** | 2 |
| **Owning Organization:** | JLab – Hall B | **Date:** | 01/30/2020 |
| **Document Owner(s):** | S. Bueltmann, J. Poudel | | |

## DEFINE THE SCOPE OF WORK

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

The deuterium gas target to be installed inside the new Radial Time Projection Chamber (RTPC) is being commissioned for installation in CLAS12. Prior to usage, the deuterium gas target needs to be installed inside the centre bore of the RTPC. The functionality of the gas target and its monitoring systems need to be tested.

This document describes the procedures for operating the gas target. Operation of the gas target requires flammable gas up to 6 atm operating pressure.

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

The operation of the gas target includes: (details can be found at https://wiki.jlab.org/clas12-run/images/a/ac/BONuS_Target_Gas_System_Manual.pdf)

Operation of gas system.

The Bonus12 target gas system is continuously supplied through a flow restrictor to prevent excess flow in the case of a target gas cell rapture. The gas target is a 500 mm long thin-walled (50 μm wall thickness) aluminum-coated polyimide tube (straw) with an inner diameter of 6 mm. The target will be operated with either ultra-high purity deuterium or hydrogen at 6 atmospheres and at ambient temperature. These gases are flammable and care must be taken to mitigate the hazards involved with its use. After construction of the gas system a leak check using Snoop followed by a flammable gas leak detector will be performed. This operation is limited to trained RTPC maintenance personnel only, see list below. Safety procedures mentioned in the ESAD must be followed. The Hall B liaison is Stepan Stepanyan, the Hall B engineer is Robert Miller, and the design authority is Bob Crahen. The key workers are: Denny Insley, Bob Miller, Cyril Wiggins, Stephen Bueltmann, Eric Christy, Sebastian Kuhn, Stepan Stepanyan, Mohammad Hattawy, and Jiwan Poudel.

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

The gas target is mounted inside the RTPC detector, which is a part of the central detector on the Hall B Central Carriage.

## ANALYZE THE HAZARDS and IMPLEMENT CONTROLS

**4. Hazards identified on written Task Hazard Analysis**

Flammable gas mixture (hydrogen and deuterium) and pressurized system. THA attached.

**5. Authority and Responsibility:**

**5.1 Who has authority to implement/terminate**

Stephen Bueltmann, Sebastian Kuhn, Stepan Stepanyan

**5.2 Who is responsible for key tasks**

Stephen Bueltmann, Sebastian Kuhn and authorized experts

**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)

. Stephen Bueltmann, Bob Miller, Bob Crahen (design authority), Eric Christy, Sebastian Kuhn and JLab ESH&Q subject matter experts

**6. Personal and Environmental Hazard Controls Including:**

**6.1 Shielding**

N/A

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

N/A

**6.3 Interlocks**

Manual and software interlock for gas system

**6.4 Monitoring systems**

EPICS interface for monitoring gas from Counting House, and Labview from Gas Shed

**6.5 Ventilation**

Existing Hall B ventilations (gas hoses)

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

For servicing: fall protection training, ladder training, manlift training, harness training,

**7. List of Safety Equipment:**

**7.1 List of Safety Equipment:**

Extensive system interlocks, active flammable gas detectors, flow restrictors, flashback arrestors, and UPS system back up

**7.2 Special Tools:**

Non sparking tools are to be used when working with flammable gas cylinders. This work is limited to the Hall B flammable gas pad behind the counting house.

**8. Associated Administrative Controls**

Appropriate signalization for gas system.

Operations manuals, schematics and diagrams kept electronically and accompanied by hard copies in the counting house.

**9. Training**

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

SAF111
EH&S orientation
Pressure and Vacuum systems Hazard awareness
GERT & RadWorker-I

## DEVELOP THE PROCEDURE

**10. Operating Guidelines**

As directed in the 'Target Operations Manual' (see https://wiki.jlab.org/clas12-run/images/a/ac/BONuS_Target_Gas_System_Manual.pdf)

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

The Hall B Work Coordinator should be consulted before any target servicing work.

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

As described in the 'Target Operations Manual' (see https://wiki.jlab.org/clas12-run/images/a/ac/BONuS_Target_Gas_System_Manual.pdf)

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

1. End the run
2. Turn off Gas system
3. Check gas target status on control panels and online monitoring system

**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

Hydrogen, Helium and Deuterium are commonly used as target gases in very small amounts.

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

None

**14.3 Abatement steps** (secondary containment or special packaging requirements)

None

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

Contact
Bob Miller, phone: (757) 748-5048 (engineering on call)
Stephen Bueltmann, phone: 757-232-5368
Sebastian Kuhn, phone: 757-639-6640

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

None

**17. Inspection Schedules**

None

**18. References/Associated/Relevant Documentation**

Operation and Safety manual, ESAD, ODH, Target Operation Manual, ES&H manual

**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://mis.jlab.org/mis/apps/mis_forms/operational_safety_procedure_form.cfm
- 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 ESH&Q Document Control

**Form Revision Summary**

**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. |
|---|---|---|---|---|
| ESH&Q Division | Harry Fanning | 04/11/18 | 04/11/21 | 1.5 |

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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:** | S. Bueltmann, J. Poudel | **Date:** | 1/30/2020 | **Task #:** If applicable | |

**Complete all information. Use as many sheets as necessary**

| | | | | | |
|---|---|---|---|---|---|
| **Task Title:** | Operation of Bonus12 Gas Target | | | **Task Location:** | Hall B (Bldg. 94) |
| **Division:** | Physics | **Department:** | Hall B | **Frequency of use:** | Continuous |
| **Lead Worker:** | Cyril Wiggins, Bob Miller | | | | |
| **Mitigation already in place:** Standard Protecting Measures Work Control Documents | ES&H Manual (Pressure and Vacuum systems Hazard awareness), ODH training, GERT and RadWorker 1 training, Target Operations Manual, flammable gas detectors installed near target, software and hardware interlocks, flow restrictions, limited access | | | | |

| 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) |
|---|---|---|---|---|---|---|---|
| 1/5 | Start of operations- All procedures to run the target are performed on one of two industrial control system computers. One is located on the second level of the space frame in the Hall and the other is in the counting house. The solenoid magnetic field (5 T) may be on, access to the gas target is not possible because the gas target will be inserted into the solenoid. This first step is starting the software and preparing for operations, no significant hazard exists. | EL | EL | N | | Operational procedure manual | N |

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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) |
|---|---|---|---|---|---|---|---|
| 2/5 | Gas choice- The gas target system has four target gas choices H2, D2, He4 and N2. Flammable gases are supplied from the Hall B flammable gas pad behind the counting house. | M | L | 2 | Through interlocks of valve positions and signals supplied to the system by regulator identifiers, the target system intuitively knows what gas it is using. The gas pad is rated as class 1 pursuant to the ES&H manual supplement "Use of flammable gases in physics experiments." Current procedures for attaching flammable gases to the system require the operator to use a non-sparking wrench and set the regulator, equipped with a flow limiting orifice between it and the supply bottle, open. The system then pumps the lines out using an explosion resistant pump located on the flammable gas pad. A flashback arrestor is installed after the flammable gas regulator to prevent flames from reaching the flammable gas bottles during an unexpected event. | Expert operators manual, users manual, standard ES&H procedures, trained operators | 1 |

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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) |
|---|---|---|---|---|---|---|---|
| 3/5 | Conditioning of the target circuit- The target system in the hall is located on the beam line with the target cell in the center of the CLAS12 solenoid. During the conditioning process the system is flushed with N2 gas two times, see gas system manual. | M | L | 2 | There are two flammable detectors located near the target that will shut the system down to a safe state if they detect any flammable gas. If the target were to fail at any point the increased flow rate would be detected and interlocks would shut down the supply. | operational procedures manual, trained operators | 1 |
| 4/5 | Filling of the target circuit- The target is filled with either flammable gas (H2 or D2) or He4. | M | L | 2 | If the target were to fail at any point the increased flow rate would be detected and interlocks would shut down the supply. | operational procedures manual, trained operators | 1 |
| 5/5 | Purging of the target circuit- The target is repeatedly (three times) depressurized (to 0 psig) and then refilled with either flammable gas (H2 or D2) or He4. | M | L | 2 | If the target were to fail at any point the increased flow rate would be detected and interlocks would shut down the supply. | operational procedures manual, trained operators | 1 |

| | | | |
|---|---|---|---|
| **Highest Risk Code before Mitigation:** | 2 | **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.)

# Task Hazard Analysis (THA) Worksheet

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

**Form Revision Summary**

**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. |
|---|---|---|---|---|
| ESH&Q Division | Harry Fanning | 08/29/18 | 08/29/21 | 0.1 |

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# OSP for Hall B Bonus12 Target

January 31, 2020 Rev 1.2 Stephen Bueltmann

# 1 Introduction

The purpose of this OSP is to provide a written procedure for installing, commissioning and initial operation of the Hall B Bonus12 target and gas system. It outlines the procedures necessary to operate it.

# 2 Description of the Target

"Bonus12" is the acronym for the Barely Offshell Nucleon Structure experiment at 12 GeV. The main purpose of the group is to study the neutron structure by scattering electrons from a moderate-pressure deuterium gas target and detecting a slow-moving recoil "spectator" proton in coincidence. This experiment will use a Radial Time Projection Chamber (RTPC) with gas electron multiplier (GEM) amplification as the proton recoil detector together with the CLAS12 detector.

The Bonus12 target consists of a spiral-wound polyimide (Kapton) tube with 6 mm inner diameter, 55 μm thick walls, and 500 mm length. The upstream end of the tube is fixed to an aluminum cylinder that provides for gas plumbing. Aluminum windows (15 μm thick) cap the upstream and downstream ends of the target. This target will be fixed to the central axis of the Bonus12 RTPC, see Fig. 1, and the assembly will be placed within the field of the central detector solenoid magnet, on axis with the beam in Hall B.

# 3 Target Gas System

The Bonus12 target gas system is continuous flow through the target.

The target will be operated with either ultra-high purity deuterium or hydrogen (and helium) at 6 atmospheres and at ambient temperature. These gases are flammable and care must be taken to mitigate the hazards involved with its use. Before flowing any of these gases, an inert gas (nitrogen) will be used to displace the air in the system. Nitrogen will also be used to purge the target gas system once the test or experiment is finished. After construction of the gas system a leak check using Snoop followed by a flammable gas leak detector will be performed.

The basic schematic of the target gas system is shown in Figs. 2 and 3. In addition to the outlined piping, equivalent measures will be taken in the region close to the target straw to ensure safe operation in the form of a flashback arrestor between the isolation valve and cell to prevent flame entry into the gas system and an excess flow valve between the isolation valve and cell to stop the flow of the target gas if there is a sudden loss of pressure in the cell due to bursting.

Flow of all gases is also restricted by an orifice. Stainless steel tubing is used throughout the whole gas system. Remote control of the valves is incorporated. A flammable gas detector is installed in the vicinity of the target. Sensing of flammable gas will result in closing of all solenoid valves in the system.

# 4 Hazards

## 4.1 Flammable Gas

(Ref. JLAB EH&S Manual, Ch. 6152 and Appendices 6152-T1, 6152-T4, 6152-R1 and 6152-R2 and the SDSs for each gas).

The gases which will be used for the Bonus12 target are hydrogen and deuterium which are both flammable. The flammable limits in air of hydrogen are between 4.0% and 75% by volume. It has low ignition energy and can be ignited by a spark or flame or may ignite

spontaneously from a sudden release of gas. Deuterium is a stable isotope of hydrogen. The flammable limits in air are between 4.9% and 75% by volume and has similar ignition characteristics to hydrogen. Exposure to air could occur from improperly connecting the high-pressure gas bottle to the target gas system, by leaking or broken process piping or by rupturing of the target cell.

### 4.1.1 Target Gas Pad

One bottle each of hydrogen, deuterium and nitrogen will be piped into the BoNuS target gas system. In order to minimize the gas inventory in the hall, these bottles will be located outdoors on the Hall B target gas pad which sits behind the Counting House. All three gas lines will be equipped with flow limiting valves before the lines enter the Hall. These valves will be set to provide no more than 4 slpm at 10 atm to the target.

As hydrogen and deuterium are flammable there can be no smoking, open flames or any operation nearby which generates sparks or flames. There are already signs in place to warn of the potential dangers. Each bottle of hydrogen contains 300 scf. The Q value is:

$Q_{\text{hydrogen, 1cyl}} = 300 \text{ scf} * 0.028 \text{ m}^3/\text{ft}^3 * 0.0899 \text{ kg/m}^3 = 0.76 \text{ kg}$ Each bottle of deuterium contains 300 scf and therefore the Q value is:

$Q_{\text{deuterium, 1cyl}} = 300 \text{ scf} * 0.028 \text{ m}^3/\text{ft}^3 * 0.180 \text{ kg/m}^3 * 0.5 = 0.76 \text{ kg}$

There will also be one bottle each of hydrogen and deuterium on the gas pad for the cryotarget gas system bringing the total Q value of all flammable gases on the pad to 3.04 kg hydrogen equivalent. All of the cylinders will be connected to their respective gas systems. There will be no storage of gas on the pad. Using the flow chart for determining risk classification we see that the Hall B gas pad will remain at Risk Class I.

All the requirements for Risk Class 0 and 1 installations must be read and understood by all operators of the Bonus12 target gas system (see Appendix I).

### 4.1.2 In Hall B

The target is on the Hall B beamline, installed inside the Bonus12 RTPC and is surrounded by helium gas. This target is used in place of the Hall B cryo-target that operates with the same gases. When Bonus12 is installed the entire cryo-target gas inventory is removed from the hall.

Once the gas lines enter the hall, the volume including the target amounts to approximately 0.7 $ft^3$. At 10 atmospheres the equivalent volume of gas will be 7 $ft^3$, therefore,

$Q_{hydrogen,\ hall} = 7\ scf * 0.028\ m^3/ft^3 * 0.0899\ kg/m^3 = 0.02\ kg$ and

$Q_{deuterium,\ hall} = 7\ scf * 0.028\ m^3/ft^3 * 0.180\ kg/m^3 * 0.5 = 0.02\ kg$

Since there will be only one gas at a time used in the target, the Q value in the hall for the Bonus12 target is 0.02 kg hydrogen equivalent. The amount of flammable gas in the Bonus12 target is certainly no greater than the amount used in the cryo-target. This fact along with the measures that are already in place to reduce the fire hazards keep the risk classification in the hall at 0.

All the requirements for Risk Class 0 installations must be read and understood by all operators of the Bonus12 target gas system (see Appendix I).

## 4.2 High Pressure Gas Bottles

(Ref. JLAB EH&S Manual, Ch.6150 and the SDSs for each gas.)

The gases used for the Bonus12 target are in high-pressure (2000 psi) gas bottles. This confined high-pressure gas represents a tremendous amount of stored energy. Use appropriate label to identify each gas cylinder, vessel and piping with its contents. Tear off tags are available to identify bottles that are full, in-use and empty. Because the target gas bottles are located on the existing gas pad, no special storage requirements are necessary but make sure that the bottles are secured in

an upright position by an approved stand.

Care must be exercised in transporting the bottles from the storage racks near the Hall B gas shed to the target gas pad (approx. 30 yds.). Use a gas cylinder hand truck with securing strap. Roll the cart slowly and try to avoid hitting the large gravel lying in top of the asphalt as it may cause the cart to tip. There is thick bed of gravel about 2 ft. wide between the end of the asphalt and the start of the raised gas pad. Do not try to roll the cart over this gravel. Use a ramp.

### 4.3 Magnetic Fields

The strong magnetic field of the solenoid (5 T) represents a hazard for all equipment installed inside the solenoid, including the gas target.

Mitigation: The gas target is not accessible during regular CLAS12 operation; accessing the detector area implies the displacement of the moving cart that requires the solenoid magnet to be turned off. Energized magnets are noted by red flashing beacons. After any sort of maintenance work is done on the gas target, the area must be inspected and all ferromagnetic tools, equipment and loose parts must be removed before the field is ramped up again.

# 5 Procedures

There are some automatic, firmware driven, safety features in place that will over-ride any manual operations that could cause damage to the target, cross contamination of the target gases or release of flammable target gas into the hall. Details will be described once the final schematic is drawn.

The following preventive measured will be implemented

- Valve closures to prevent the target from collapsing due to sub-atmospheric pressure.

- Valve closures to prevent cross contamination of gas bottles.

- If the flammable gas leak detector signals the presence of hydrogen or deuterium then all solenoid valves (SVs) will be closed.

## 5.1 Flushing the Air or Target Gas Out of the System

This procedure is used when there is air in the system upon initialization or for removing flammable target gas from the system. No other procedure should be run until air has been replaced with N2 in the system.

## 5.2 Filling the System with Target Gas, Recharging the Target Gas or Changing the Target Gas

After air has been purged from the system, a procedure to fill the target with the working gas will be developed.

## 5.3 Exchange of Gas Bottles

When connecting or disconnecting a bottle of hydrogen or deuterium you must use the bronze explosion proof wrench located near the gas bottles on the gas pad.

# 6 List of Authorized Personnel

When the BoNuS Target is used during the test phase or the production phase of the experiment, one of the authorized personnel shall be on-call, and his/her contact information posted in the counting house. Furthermore at least one shift worker shall be trained to perform the tasks described in Section 5. This training shall include a familiarization with this OSP and with the hazards involved in the operation of the

The Bonus12 Target contact person shall keep a list of the trained Bonus12 Target operators, together with their signatures.

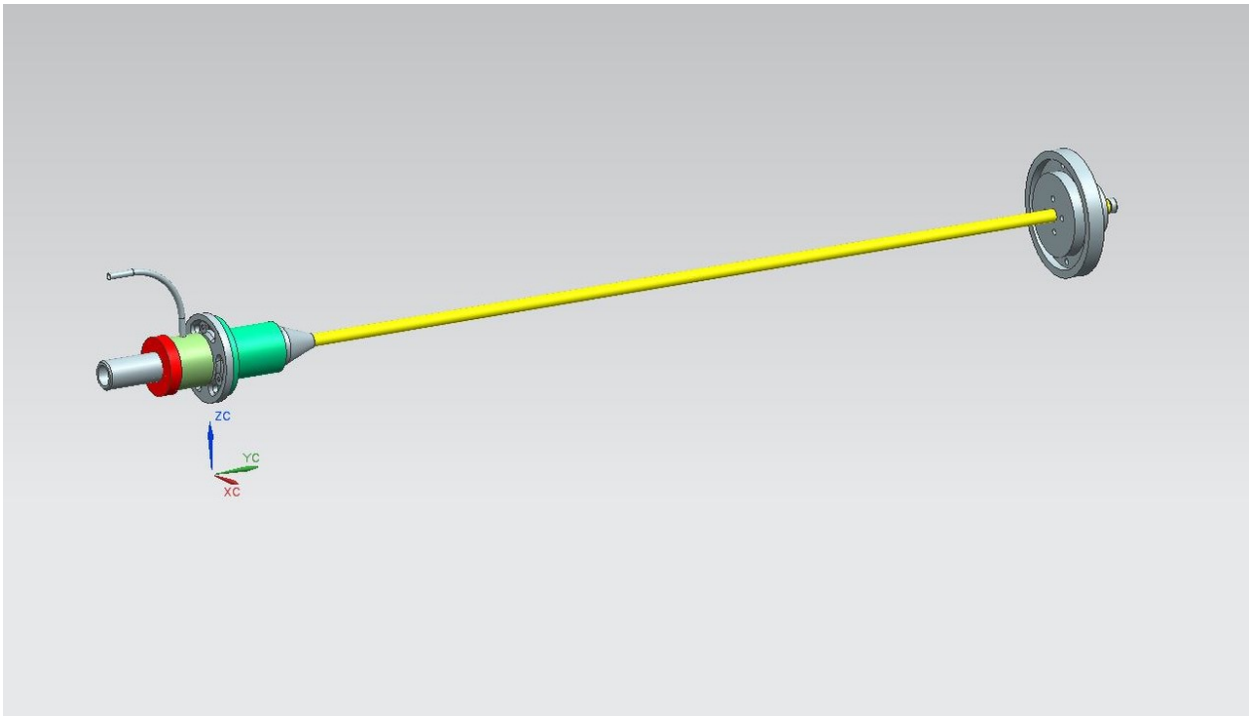


**Figure 1 Bonus12 Target**

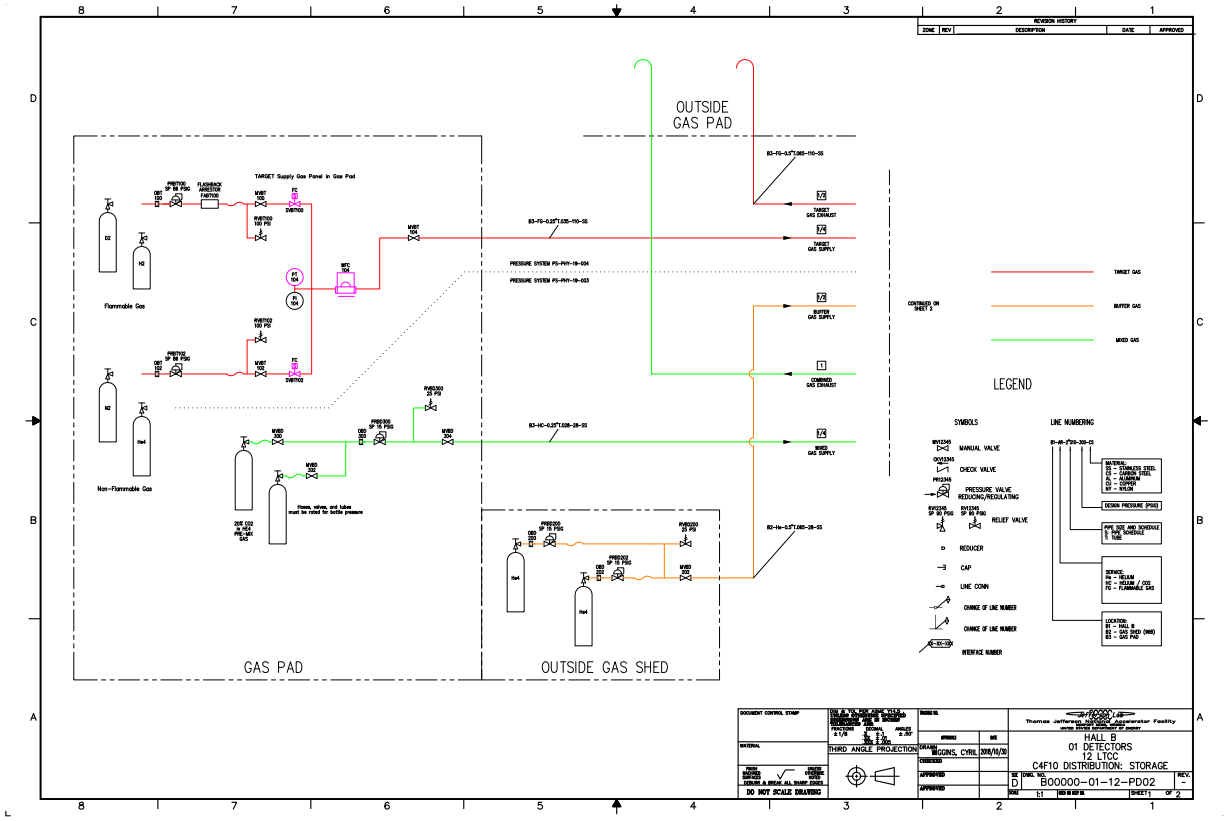


**Figure 2 Target Gas System (Outside)**

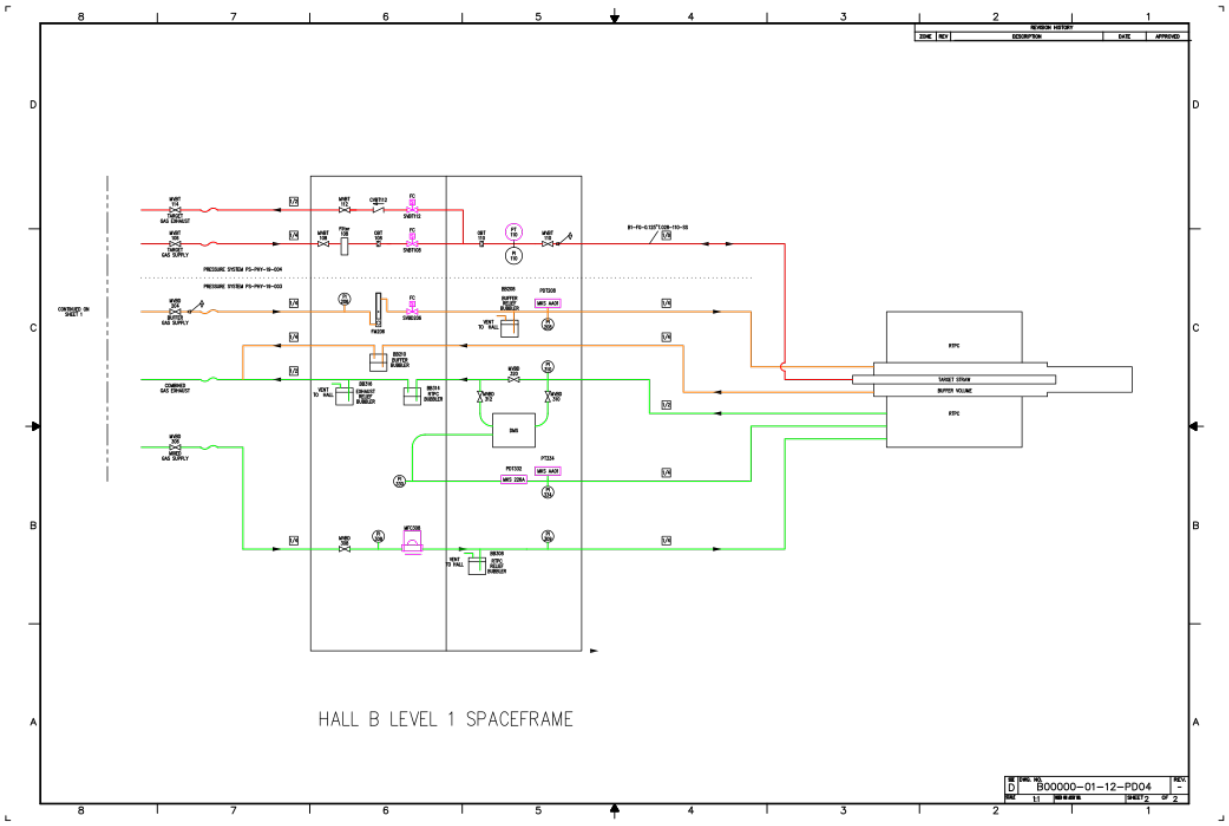


**Figure 3 Target Gas System (Space Frame)**

# Appendix I

## Requirements for Flammable Gas Installations

### A. Class 0 Installations:

1.The area shall be posted "Danger-Flammable Gases, No Ignition Sources" using standard signs available from the Jefferson Lab ESH. A list of responsible persons with their phone numbers shall also be posted.

2.Combustibles and ignition sources shall be minimized within 10 feet or three meters of gas handling equipment, piping or apparatus. 3.A pressure regulator appropriate for the gas and its environment shall be used. 4.An orifice, excess flow valve or other fixed means of limiting the flow to no higher than ten times the maximum operational flow rate shall be installed.

5.All gas cylinders shall be secured. Cylinders not in use shall be capped. Empty cylinders shall be removed at the earliest convenient date or on a predetermined, regular schedule coordinated with vendor delivery of new cylinders. See also Chapter **6150** *Compressed Gases*. 6.Enclosed volumes containing piping or equipment shall be incapable of becoming pressurized. For example, chest freezers shall not have latching doors. Electrical devices enclosing or enclosed within these volumes shall be listed for use in Class 1, Division 2 locations per NEC Article 500 or otherwise be documented and approved as non-sparking devices. 7.Leaks from experimental devices such as drift chambers shall be measured and documented prior to initial operation (with nonflammable gas, if possible). Leakage above seven liters/hour from any one chamber shall be mitigated. Recheck for leaks after major repairs or modifications, and at least every twelve months. Leakage exceeding 20% of the lower explosive limit at a distance over five

centimeters from an identified “point” leak shall be repaired. 8.Ventilation above one air change per hour shall be maintained in areas using or storing flammable gas if normal operational flow rates are less than 5 Standard Cubic Liters Per Minute (SCLM). This ventilation may be accomplished by mechanical or natural ventilation. For natural ventilation a room vent with a minimum of 1⁄2 square foot of free area shall be provided per 1000 cubic feet of room volume. If normal operational flow rates are greater than or equal to 5 SCLM, supervised mechanical ventilation in accordance with Section 7-2.2.1(a) of NFPA 58 Liquefied Petroleum Gas Code, 2004 edition shall be provided (not applicable to outdoor Jefferson Lab storage). 9.Welding permits (Fire Hazard Work Permit) Reference *Appendix 6122-T1 Use of Fire Hazard Work Permits* shall not be issued for areas within 35 feet or ten meters of the equipment containing flammable gas unless approved in advance by the responsible Division/Section head or designee.

## Class I Installations are subject to the following additional requirements:

10.The system, including vessels, chambers, supply and vent piping, and exhaust points shall be labeled “flammable gas.” 11.Piping requirements: Exceptions to this paragraph are permitted adjacent to experimental apparatus where needed for flexibility, electrical isolation, repairs or because of congestion. This exception is limited to within five meters of the normal operating position.

a. Piping and fittings shall be protected from mechanical damage. b. Piping shall be rated for the expected temperature and pressure. c. Supply piping shall be metallic. d. Piping shall be supported in a substantial and workmanlike manner. e. Piping shall not be installed inside cable trays with electrical conductors.

12.Joints shall be made by welding, brazing, pipe thread, or commercial fittings appropriately installed. Custom-made fittings required by

detector design shall provide secure connections. 13.The entire piping system shall be pneumatically tested for leaks at approximately 0.9 times the relief pressure before operating the system. Any piping with relief valve settings above 150 PSIG shall be tested at 1.25 times the relief pressure. 14.Bubblers, flow meters, and other instruments shall be securely mounted and protected from possible breakage. 15.Provisions shall be made to purge the entire system with an inert gas. If vacuum pumps are used for this, they shall be listed for flammable gas service. 16.Pressure relief devices shall be provided to limit the pressure to the maximum working pressure in various parts of the system. In the case of low pressure equipment, dedicated bubblers may be used as relief devices. Common exhaust piping (where the flammable gas vent is shared with exhaust vents for other systems) shall not be used if equipment overpressure from any combination of devices sharing the exhaust could result due to built up back pressure. 17.Relief devices in flammable gas service with a capacity over two standard liters per minute shall be vented outdoors. The exhaust locations shall be chosen to minimize fire hazards and shall not be within 10 feet or three meters of an air intake. Vents shall be protected from clogging by debris, snow, or ice. 18.Flammable gas detectors shall be installed near equipment installations, mixing stations, and in storage sheds (the measures in this requirement are not necessary for outdoor storage applications):

a. A low level alarm no higher than 10% of the lower explosive limit (LEL) shall sound a local alarm and be used to initiate corrective action according to a plan included in the documentation of system operating procedures. b. A high level alarm no higher than 25% of the lower explosive limit (LEL) shall summon the Newport News Fire Department through the Jefferson Lab fire alarm network. This high level alarm shall also automatically shut off the supply of flammable gas and turn off power to potential ignition sources within 10 feet or three meters of operative gas usage apparatus.

c. “Crash buttons” shall be provided to accomplish the shutdowns described above. These devices shall be conveniently located, and one

shall be adjacent to the fire alarm panel, if present. Crash buttons should shut off all flammable gas

sources which could conceivably be confused by unfamiliar person in a state of panic. Crash buttons shall be labeled “Gas System and Experiment Power Shutdown.” They shall be located on the Building Evacuation Plan Maps. d. Automatic restart of flammable gas systems and power sources shall not be allowed after a high level alarm. This restriction is intended to require a safety assessment of the situation. In case of an alarm follow the local emergency plan.

19.Visual indication of the actual use of flammable gas shall be provided at both the storage location and at the experimental apparatus. Such lights shall be controlled automatically and shall indicate actual “gas on” and “gas off” status in real time. Flammable gas alarm status shall be also be displayed at the locations of these warning lights.

20.Possible Oxygen Deficiency Hazards shall be addressed according to Chapter **6500** *Cryogenic and ODH Safety*. The hazard shall be considered for each building or room using or storing flammable or inert gas.

21.The following documentation shall be provided to the Experimental Equipment Review Committee (E2RC) and a copy kept at the system site.

a. A general description including the types of gases to be used. b. An accurate piping and instrument diagram with symbols per ISA S5.1 (Instrument Society of America), including the normal set point of regulators. c. An instrument and valve summary. d. A plan view of the installation including the locations of flammable gas detector heads with their elevations marked. e. Procedures for normal and abnormal operations including purging, start-up, gas bottle changes, mixing, leak detection, tests, alarms, shutdown, emergency situations, and ventilation. f. Documentation and/or test results demonstrating the adequacy of the pressure- relief system. g. A call list, including home

telephone numbers and available pagers, of personnel familiar with the operation of the system.  h. A summary of leak-test measurements.

22.The Physics Division EH&S group shall be notified of actual gas start-up and system shutdown.

23.The Physics Division EH&S group shall be notified before using any types of gas not found in the stockroom, and a copy of the SDS for the new gas shall be provided to both the Physics Division EH&S group and to the Jefferson Lab SDS Coordinator. Reference Chapter **6610** *Chemical Hygiene* and *Appendix 6610-T1 Safety Data Sheets*.

# BONuS Target Gas System Manual

Bob Miller

Dec 2019

**Introduction**

The Bonus target consists of a Kapton straw filled with pressurized gas.

The target parameters are:

| | |
|---|---|
| Straw Length | 50 cm |
| Straw diameter | 6 mm |
| Straw wall thickness | 55 microns |
| Target pressure | 86 psig |
| Beam energy | 11 GeV |
| Beam current | 200 nA |
| Target gas | D2, H2, He4 |
| Target flush gas | N2 |

The target straw is connected to the target gas panel on the SVT cart; a transfer line connects the target gas panel to the supply gas panel in the gas pad. Four gas bottles will be stored in the gas pad that can be connected to the gas panel; H2, D2, N2, and He4.

The target straw can only be connected to the gas system at one end; therefore, the gas cannot be changed by flowing gas through the straw. Therefore, the gas will be changed by emptying and refilling the straw. When a different type of gas is used, the target will be filled and emptied 3 times to remove the first gas and replace it with the second gas.

**Installation**

The flammable gas regulator is installed on the D2 or H2 bottle, and a hose is connected to the supply gas panel.

The non-flammable gas regulator is installed on the N2 or He4 bottle, and a hose is connected to the supply gas panel.

Both regulators are set at 86 psig. A 0.050 inch orifice is installed upstream of the regulators to limit gas flow during a regulator failure. 100 psig relief valves are installed on the gas panel, before the solenoid valves. A flashback arrestor is installed after the flammable gas regulator to prevent flames from reaching the flammable gas bottles during an unexpected event.

A pressure transducer is also installed on the supply gas panel, as well as a mass flow meter.

The transfer line is a ¼" SST line that goes from the gas pad to the level 1 space frame, beam left, near the target. A ¼" SST hose will connect the gas line to the target gas panel mounted on the SVT cart. A 1/8" SST hose will connect the target gas panel to the target straw.

A 0.010 inch orifice is installed at the entrance of the target gas panel to reduce the flow during system flushing. A 0.001 inch orifice is installed before the straw to reduce the flow into and out of the straw to reduce stress on the straw and windows.

The vent line from the target gas panel will discharge outside of the Hall near the gas pad.

**Controls**

The control system will control 4 solenoid valves

- SVBT100, flammable gas supply
- SVBT102, non-flammable gas supply
- SVBT108, straw supply
- SVTB112, exhaust

The control system will read out 2 pressure transducers and 1 mass flow meter

- PT104, gas supply pressure
- PT110, straw pressure
- MFC104, gas supply flow

The control system will operate solenoid valves based on user commands and interlocks, and a purge command.

Control System Modes of Operation

1. Manual
    a. All solenoid valves can be opened or closed by the operator
    b. Used to clean and flush the system

2. Auto Flammable
    a. Solenoid valves are open from the flammable gas bottle to the target straw

3. Auto Non-Flammable
    a. Solenoid valves are open from the non-flammable gas bottle to the target straw

4. Empty Target
    a. Close SVBT100
    b. Close SVBT102
    c. Close SVBT108
    d. Open SVBT112

5. Purge
    a. Control system operates SVBT108 and SVBT112 and monitors PT110 to empty and fill the target straw
        i. Initial condition is PT110 at full pressure
        ii. Close SVBT108 to stop the supply of gas to the target straw
        iii. Open SVBT112 to exhaust gas from target straw
        iv. PT110 down to 5 psi
        v. Close SVBT112
        vi. Open SVBT108 to charge target straw

**Interlocks**

System in manual, auto, or purge mode

- Flammable gas detector senses flammable gas:
  - Close SVBT100
  - Close SVBT102
  - Close SVBT108
  - Open SVBT112
  - Secure HV
  - These actions stop the supply of gas and open the exhaust to reduce the gas pressure

- PT104 or PT110 read greater than 95 psi
  - Pressure regulator failure indicated
  - Close SVBT100
  - Close SVBT102
  - Close SVBT108
  - Open SVBT112
  - Secure HV
  - These actions stop the supply of gas and open the exhaust to reduce the gas pressure

- System may be left in manual mode and left unattended with bottles open and supplying pressure to the system
  - Flammable gas detector senses flammable gas, system must close the valves to stop the flow of flammable gas.

System in manual mode:

- No additional interlocks

System in auto mode:

- PT104 or PT110 fall below 75 psig, or MFC reads higher than 100 ccm
  - Leak indicated
  - Close SVBT100
  - Close SVBT102
  - Close SVBT108
  - Open SVBT112
  - Secure HV
  - These actions stop the supply of gas and open the exhaust to reduce the gas pressure

System in purge mode:

- If PT104 or PT110 do not reach 80 psi after 30 seconds when filling, leak or open exhaust solenoid valve indicated
    - Close SVBT100
    - Close SVBT102
    - Close SVBT108
    - Open SVBT112
    - Secure HV
    - These actions stop the supply of gas and open the exhaust to reduce the gas pressure

**Failure Mode Analysis**

| **Failure** | **Action** |
|---|---|
| Pressure regulator fails open | Pressure increases to 100 psi and relief valve opens<br>PT104 and or PT110 read higher than 95 psi, Solenoid valves are operated to stop supply flow and reduce pressure |
| PT104 fails | If out of range, solenoid valves are operated to stop supply flow and reduce pressure<br>Check PI104 to compare |
| PT110 fails | If out of range, solenoid valves are operated to stop supply flow and reduce pressure<br>Check PI110 to compare |
| SVBT100 or SVBT102 fail open | SVBT108 will control the flow |
| SVBT108 fails open | SVBT100 or SVBT102 will control the flow |
| SVBT112 fails open | Exhaust will be open all the time, PT110 will indicate low pressure and solenoid valves are operated to stop supply flow and reduce pressure |
| SVBT100, 102, or 108 solenoid valve fails closed<br>Supply manual valves closed | System will not build pressure, operator to correct issue |
| SVBT112 exhaust solenoid fails closed<br>Exhaust manual valves closed | System will not reduce pressure, operator to correct issue |

**Procedures**

Flushing the Target with N2

1. Connect the non-flammable regulator to the N2 bottle
2. Open:
    a. N2 bottle valve
    b. MVBT102
    c. SVBT102
    d. MVBT104
    e. MVBT106
    f. MVBT108
    g. SVBT108
    h. MVBT110
    i. SVBT112
    j. MVBT112
    k. MVBT114
3. Flush the system with N2 for 10 minutes
4. Close exhaust solenoid valve SVBT112 to pressurize the target with N2
5. When straw pressure reaches 80 psig, close supply solenoid valve SVBT108 and open exhaust solenoid valve SVBT112 to reduce pressure
6. When straw pressure reaches 0 psig, close exhaust solenoid valve SVBT112 and open supply solenoid valve SVBT108 to increase pressure
7. Repeat steps 5 and 6 two times
8. Close non-flammable solenoid valve SVBT102
9. Open exhaust solenoid valve SVBT112 to reduce pressure
10. Close:
    a. N2 bottle valve
    b. MVBT102

Filling the Target

1. Connect the flammable gas regulator to the H2 or D2 bottle
2. Open:
    a. H2 or D2 bottle valve
    b. MVBT100
    c. SVBT100
3. Flush the system with the target gas for 3 minutes
4. Close exhaust solenoid valve SVBT112 to pressurize the target with H2 or D2
5. When straw pressure reaches 80 psig, PURGE the Target 3 times
6. Now the target is clean and pressurized with the target gas

Purging the Target

This is required to remove helium from the target straw on a regular basis

1. Click on the PURGE button on the Bonus target gas screen
2. The controls will:
    a. Close the supply solenoid valve SVBT108
    b. Open the exhaust solenoid valve SVBT112
    c. When the straw pressure reaches 5 psi, the exhaust solenoid valve SVBT112 is closed, and the supply solenoid valve SVBT108 is opened
    d. The straw pressure will increase back to 86 psig
3. This process is done 3 number of times when the PURGE button is pressed to remove the helium from the target straw.

Questions

1. PT406 – what alarm or interlock
    a. EPICs alarm to engineering on-call
2. How to secure high voltage due to gas system failure
    a. Email to Sebastian Nov 15
3. Test entire system in the Hall? January 2-4
    a. Email to Sebastian Nov 15

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-20-97803-OSP

Title: Bonus12 Gas Target System

| Name | Signature | Date |
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