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Status: WAPPR
Saved: 8/28/2015 3:52:02 PM
Submitted: 8/28/2015 3:52:02 PM

Jefferson Lab Thomas Jefferson National Accelerator Facility	Operational Safety Procedure Review and Approval Form # 52757 (See ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure (OSP) and Temporary OSP Procedure for Instructions)
Type:	***TOSP*** Click for OSP/TOSP Procedure Form Click for LOSP Procedure Form
Serial Number:	(Assigned after final approval)
Issue Date:	(Assigned after final approval)
Expiration Date:	***< Approximately 11/28/2015 >***
Title:	***Test of ANL Bubble Chamber Detector***
Location: (where work is being performed)	***Injector Service - IN01***
Location Detail: (specifics about where in the selected location(s) the work is being performed)	***Injector area 5D Beamline***
Risk Classification: (See ES&H Manual Chapter 3210 Appendix T3 Risk Code Assignment)	Without mitigation measures (3 or 4): ***4*** With mitigation measures in place (N, 1, or 2): ***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:	***ACCCIS***
Document Owner(s):	***Meekins, Dave (meekins@jlab.org)*** Primary ***Suleiman, Riad (suleiman@jlab.org)***

Supplemental Technical Validations

Air Contaminants - Hazardous (Dick Owen, Jennifer Williams)
Corrosives (Dick Owen, Jennifer Williams)
Flammables (Dick Owen, Jennifer Williams)
Oxidizers (Dick Owen, Jennifer Williams)
Toxic Agents (Dick Owen, Jennifer Williams)
50 V or Greater: Repair or Construction of Energized Components and Systems (Paul Powers, Todd Kujawa)
Gas Cylinders (Dave Kausch, Tim Minga)
Pressurized Tanks, Containers, and Vacuum Vessels (Dave Meekins, Kelly Dixon, Timothy Whitlatch, Will Oren)
Pressurized Vacuum Lines and Piping Systems (Dave Meekins, Kelly Dixon, Timothy Whitlatch, Will Oren)
Controlled Area (Keith Welch, Vashek Vylet)
Radiological Controlled Area (Keith Welch, Vashek Vylet)
Stored Energy: Mechanical, Hydraulic, Pneumatic (Bert Manzlak, Paul Collins)
Regulated Waste: Solid or Liquid (Jennifer Williams, Scott Conley)

Other Hazards:
Physics Div Sign (Patrizia Rossi)

Committee sign (Volker Burkert)

Document History

Revision	Reason for revision or update	Serial number of superceded document

Comments for reviewers/approvers:	***Please see pressure system folder PS-TGT-14-002 for more details. Please do not sign until formal review on 18 Aug is complete.***

Attachments

Procedure: ***TOSP-Aug.pdf***
THA: ***THA ANL bubble chamber.pdf***
Additional Files: ***TGT-PROC-15-001.pdf***
TGT-CALC-502-002.pdf
TGT502-1000-0000- PID.pdf
Rev-resp.pdf

Review Signatures

Person : Bailey, Mary Jo (mbailey) **Reasoning:** Subject Matter Expert : Committee sign per e-mail from Volker Burkert	**Signed** on 9/4/2015 1:11:45 PM by Mary Jo Bailey (mbailey@jlab.org)
Person : Bailey, Mary Jo (mbailey) **Reasoning:** Subject Matter Expert : Physics Div Sign per e-mail from Patrizia Rossi 09/04/15	**Signed** on 9/4/2015 11:26:02 AM by Mary Jo Bailey (mbailey@jlab.org)
Subject Matter Expert : Air Contaminants - Hazardous-> Nuisance	**Signed** on 8/31/2015 4:19:24 PM by Jennifer Williams (jennifer@jlab.org)
Subject Matter Expert : Chemicals->Corrosives	**Signed** on 8/31/2015 4:19:28 PM by Jennifer Williams (jennifer@jlab.org)
Subject Matter Expert : Chemicals->Flammables	**Signed** on 8/31/2015 4:19:31 PM by Jennifer Williams (jennifer@jlab.org)
Subject Matter Expert : Chemicals->Oxidizers	**Signed** on 8/31/2015 4:19:38 PM by Jennifer Williams (jennifer@jlab.org)
Subject Matter Expert : Chemicals->Toxic Agents	**Signed** on 8/31/2015 4:19:35 PM by Jennifer Williams (jennifer@jlab.org)
Subject Matter Expert : Electricity->50 V or Greater: Repair or Construction of Energized Components and Systems	**Signed** on 8/31/2015 8:42:25 AM by Todd Kujawa (kujawa@jlab.org)
Subject Matter Expert : Gas Cylinders	**Signed** on 9/3/2015 5:01:10 PM by Tim Minga (minga@jlab.org)
Subject Matter Expert : Pressure Systems->Pressurized Tanks-> Containers-> and Vacuum Vessels	**Signed** on 9/4/2015 9:56:57 AM by Kelly Dixon (kdixon@jlab.org)
Subject Matter Expert : Pressure Systems->Pressurized Vacuum Lines and Piping Systems	**Signed** on 9/4/2015 9:57:05 AM by Kelly Dixon (kdixon@jlab.org)
Subject Matter Expert : Radiation - Ionizing->Controlled Area	**Signed** on 9/4/2015 9:53:08 AM by Vashek Vylet (vylet@jlab.org)
Subject Matter Expert : Radiation - Ionizing->Radiological Controlled Area	**Signed** on 9/4/2015 9:53:26 AM by Vashek Vylet (vylet@jlab.org)
Subject Matter Expert : Stored Energy: Mechanical-> Hydraulic-> Pneumatic	**Signed** on 8/28/2015 3:57:30 PM by Bert Manzlak (manzlak@jlab.org)
Subject Matter Expert : Waste Generation->Regulated Waste: Solid or Liquid	**Signed** on 8/31/2015 4:19:43 PM by Jennifer Williams (jennifer@jlab.org)

Approval Signatures	
Division Safety Officer : ACCCIS	Authorized Signers • Harry Fanning (fanning@jlab.org) • Tim Michalski (michalsk@jlab.org) • Will Oren (oren@jlab.org)
Org Manager : ACCCIS	Authorized Signers • Andrew Hutton (andrew@jlab.org) • Bob McKeown (bmck@jlab.org) • Hugh Montgomery (mont@jlab.org) • Fulvia Pilat (pilat@jlab.org) • Matthew Poelker (poelker@jlab.org)
Safety Warden : Injector Service - IN01	Authorized Signers • Daniel Moser (moser@jlab.org)

Operational Safety Procedure Form

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

DEFINE THE SCOPE OF WORK

Title:	Test of ANL Bubble Chamber Detector		
Location:	CEBAF Injector 5D Beamline	**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):**	4
		Highest Risk Code after Mitigation (N, 1, or 2):	1
Owning Organization:	ACCCIS	**Date:**	8/4/15
Document Owner(s):	Riad Suleiman, Dave Meekins		

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).

The intent is to use the CEBAF Injector test area with a maximum beam energy of 9.5 MeV (kinetic) to test the operational characteristics of the Argonne Bubble Chamber. The electron beam will be fully stopped (with the exception of knock on electrons) by a water cooled copper dump/radiator. The chamber was tested at Duke where a high neutron background adversely affected the results (slight modifications have been made since this test). The detector is not capable of distinguishing events (bubbles) from photons and neutrons. The purpose of the test at JLAB is to determine the photon detection effectiveness in a low neutron background environment. Operating parameters (e.g. pressure, temperature, fluid, event rate, buffer fluid level) shall be adjusted within a safety envelope to improve photon detection and chamber recovery times. The active fluids for the test are N_2O and C_2F_6. Note that 150 ml of mercury is required as a buffer fluid in the detector. See the detailed procedure TGT-PROC-15-001 Argonne Bubble Chamber Test filed in the JLAB Document Repository and pressure system folder PS-TGT-14-002.

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

The test will take place in the CEBAF Injector area where the chamber is installed. The DAQ and remote controls system shall be placed in the Injector Service Building.

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

Test shall be performed in the CEBAF Injector area at the end of the 5D beamline. The formal songsheet for the beamline is given in ACC2008000-1100.

4. Authority and Responsibility:

4.1 Who has authority to implement/terminate

Riad Suleiman, Brad DiGiovine

4.2 Who is responsible for key tasks

1) Brad DiGiovine: Reassembly, installation, leak testing, alignment, filling, operation, disassembly, removal.
2) Riad Suleiman: Beam operation, beam current and energy changes.

Communication between Brad, Riad and MCC shall be accomplished verbally. Daily planning will be performed at the MCC 0800 meeting.

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

Todd Kujawa: Inspect electrical components as required by JLAB (ANL has also performed inspections)
Jennifer Williams: Analyze and inspect the HazMat systems (ANL has also performed inspections and monitored air quality while filling and other operations were performed)
Pressure systems DA is Dave Meekins. The reviewer for pressure systems is Ed Daly.

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

SAF 801 Rad worker I
SAF 103 ODH
SAF 130 Oil Spill Training (not required for all personnel)
SAF 132 Tunnel worker safety
SAF 801kd RWP for tunnel access
SAF 100 General safety

5. Personal and Environmental Hazard Controls Including:

5.1 Shielding

The copper beam dump, which has already been commissioned, shall require the shielding package 14-INJ-02. The photon dump shall require same shielding package.

5.2 Interlocks

The standard interlocks for the PSS system etc. shall be in place in the injector area.

5.3 Monitoring systems

Standard monitoring systems shall be in place in the injector area.

5.4 Ventilation

Standard ventilation of the injector area is required.

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

The system has been reviewed and inspected by Todd Kujawa.

6. List of Safety Equipment:

6.1 List of Safety Equipment:

SKC Elemental Mercury Passive sampler
Assay Technology 575 Nitrous Oxide sampler

6.2 Special Tools:

There are no special tools required

DEVELOP THE PROCEDURE

1. Associated Administrative Controls

In August 2015, one of the rapid access probes in the Injector was relocated above the copper radiator/dump in the bubble chamber beamline. This ensures that rapid access will function as intended in this configuration and operation of the bubble chamber will not require RadCon surveys as the electron beam energy is gradually raised. If the radiator/dump gets activated, the probe will alarm at 1.4 mrem/h at 1 foot, i.e. a safety factor of ~3.5 below the radiation area limit. Therefore, as long as the Rapid Access beacon activates when the button is depressed, no survey is required for Controlled Accesses or prior to going to Restricted Access. See procedure TGT-PROC-15-001 for other administrative controls.
A walkthrough of the Injector and ISB, and short presentation on the bubble chamber will be led by Riad Suleiman on Sept 9, 2015.

2. Operating Guidelines

See procedure TGT-PROC-15-001 with detailed description.

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

1) Use of the ATLis work planning tool.
2) Briefings at the MCC 0800 meeting

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

1) Reassemble, install and align the bubble chamber
2) Leak test the bubble chamber and record results
3) Install operating cables and test
4) Inspect electrical systems (Todd Kujawa)
5) Fill detector and startup refrigeration
6) Place detector in standby mode
7) Take test DAQ measurements
8) Perform measurements with the beam on the 5D beam dump
9) Access as need to make adjustments to and to perform detector calibrations
10) Deenergize system
11) Remove detector from Injector area

Detailed procedures can be found in TGT-PROC-15-001 and in the pressure system folder PS-TGT-14-002.

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

The system may be deenergized by the system expert Brad DiGiovine if required. During emergencies, the system may be deenergized by following the Emergency Deenergizing Procedure. This second procedure is likely to break the inner glass vessel which will not result in hazard to personnel and will remove the stored energy from the system.

6. Special environmental control requirements:

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

Under normal operating conditions, release of < 20 STP liters N2O or C2F6. For complete cell failure, the air concentration is less than 25 ppm for N2O and 20 ppm for C2F6. See table below. Should leaks develop it is possible to release 150 ml of mercury. A secondary containment pan is installed under the chamber to contain the mercury.

GAS	Concentration after full vent	Exposure limit
N2O	25 ppm	50
C2F6	20 ppm	1000

6.2 Abatement steps (secondary containment or special packaging requirements)

The system has been designed and fabricated to National Consensus Codes and Argonne National Lab standards. This makes leaks due to mechanical failure extremely unlikely. There are operating procedures in place for operation of the detector and there is no intent to "handle" mercury at JLAB. The detector was preloaded with mercury in a clean room at ANL.

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

During a power loss the mechanical protection on the detector will prevent overpressure. See the procedure TGT-PROC-15-001. Detailed procedures can be found in the attached reference document and the pressure system folder PS-TGT-14-002.

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

There are no instrument calibrations required for this test.

9. Inspection Schedules

Because of the short duration of the test only initial inspections are required. Air monitoring shall be performed during the filling and venting/relief operations using the equipment listed in 6.1. The electrical components shall be inspected by Todd Kujawa.

10. References/Associated Documentation

1) Please reference PS folder PS-TGT-14-002
2) System P&ID TGT-502-1000-0000
3) Detailed procedures and description in TGT-PROC-15-001 and the pressure systems folder PS-TGT-14-002.

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

1) This procedure.
2) The THA associated with this procedure.
3) Procedure TGT-PROC-15-001 which includes a conduct of operations.
4) All pressure systems documentation is stored in the PS folder PS-TGT-14-002.
5) Attached reference document.

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 REQUIRED DATE	REV.
ESH&Q Division	Harry Fanning	02/19/14	02/19/17	1.3

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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

Author:	Dave Meekins	**Date:**	8/4/2015	**Task #:** If applicable	

Complete all information. Use as many sheets as necessary

Task Title:	Argonne Bubble Chamber Test	**Task Location:**	CEBAF Injector 5D beamline

Division:	Accelerator	**Department:**	Injector	**Frequency of use:**	1
Lead Worker:	Brad DiGiovne				

Mitigation already in place: **Standard Protecting Measures** **Work Control Documents**	Developed at ANL and used at Duke Tunnel Facility. System was fully reviewed by ANL and Duke and formally permitted to operate.

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	Filling/relieving of the bubble chamber detector: 1) Release of mercury 2) Release of N2O 3) Exposure of N2O to personnel 4) Overpressure of chamber and vessel 5) Damage to components 6) Flying debris	M	M	3	1) Overpressure protection by ASME relief device. Design and fabrication conforming to Code. 2) Developed procedures 3) Trained and experienced personnel only allowed to operate 4) Limited quantities of HazMat 5) Secondary containment.	See Procedure TGT-PROC-15-001	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	Operation of detector: Failure of vessel or pressure component. Flying debris, release of HazMat.	M	M	3	1) Low stored energy for the system when in operations mode. 2) Removal of gas bottles form system when in operation. 3) Developed procedures for operations with trained personnel allowed to operate system 4) Interlocks and normal relief valves to prevent overpressure. 5) Overpressure protection by ASME device. 6) Conservative design	See Procedure TGT-PROC-15-001	1
3	Removal of detector: 1) Dropped heavy load when handling. 2) Release of HazMat	H	M	4	1) Designed with integral lift points 2) Developed procedure for blowdown and recovery of fluids. 3) Filters on pumping system exhaust. 4) Trained personnel	Use of JLAB policies for lifting/material handling. Trained crane operators/riggers. See Procedure TGT-PROC-15-001.	1

Highest Risk Code before Mitigation:	4	**Highest Risk Code after Mitigation:**	1

Task Hazard Analysis (THA) Worksheet

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

When completed, if the analysis indicates that the Risk Code before mitigation for any steps is "medium" or higher (RC≥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 0.1 – 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 REQUIRED DATE	REV.
ESH&Q Division	Harry Fanning	06/19/12	06/19/15	0.1

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Review Response

This document is a response to the review of the Bubble Chamber performed on August 18, 2015 to evaluate the readiness of the bubble chamber test experiment in the CEBAF Injector. We wish to thank the committee members for taking the time to provide us with a very useful and detailed review. This document we will address the comments and recommendations of the committee and do so item by item.

1 Comments

In this section we respond to the comments made by the committee.

Comment 1: typo has been addressed.

Comment 2: A conduct of operations has been developed and is a section in the procedural document. Note that the procedural document is a number document in the Gillette document database (TGT-PROC-15-001).

2 Recommendations

2.1 Recommendation 1

A pretest verification checklist was added to the procedural document TGT-PROC-15-001.

2.2 Recommendation 2

The immediate area surrounding the bubble chamber shall be roped off cones and tape. Signage stating "TEST IN PROGRESS PLEASE DO NOT DISTURB" shall also be posted.

2.3 Recommendation 3

A call list has been added to the conduct of operations section of the procedural document TGT-PROC-15-001.

2.4 Recommendation 4

Riad Suleiman has prepared a short presentation for the office staff which shall be given on September 9, 2015. Following the presentation there will be a brief tour of the Injector and ISB.

2.5 Recommendation 5

A fan has been installed to promote mixing in the injector. Fan has a low-speed setting of 1300 cfm. The fan shall be used during all filling and venting operations.

2.6 Recommendation 6

Section 6.1 of the TOSP has been updated to show the expected concentration of N2O and C2F6 following a complete release of all fluid in the bubble chamber. The section now contains exposure limit information as well.

2.7 Recommendation 7

The TOSP form has been updated.

2.8 Recommendation 8

The TOSP and THA have been updated to reference the procedure TGT-PROC-15-001. This procedure has been filed in the JLAB document repository. Revision number of this document is “original”.

2.9 Recommendation 9

Unfortunately, at this time the only person qualified to perform the complicated tasks on the system is Brad DiGiovine.

2.10 Recommendation 10

A representative from the test collaboration shall be present at the 8 AM meeting in the MCC to discuss progress and future work plans.

2.11 Recommendation 11

An electronic logbook has been set up for the bubble chamber testing. An existing ATLis describing the work on the bubble chamber and updates to the workplan is also available.

2.12 Recommendation 12

A conduct of operations document is now part of the procedural document TGT-PROC-15-001. Note that this document includes contact information as well.

2.13 Recommendation 13

There is indeed no expectation of significant radiation that could cause activation of equipment or material during the test. A document including a statement by the RadCon group indicating this shall be posted in the test area.

JLAB Target Group Procedure

Procedure Number	TGT-PROC-15-001
Tittle	Argonne Bubble Chamber Test
Author	Dave Meekins
Rev	-
Active Date	9/1/2015
Expiration Date	9/1/2016
Description: Procedures for test of ANL bubble chamber. The chamber is described in detail in PS folder PS-TGT-14-002. This document includes FMEA and safety data. This document details the following procedures: • System prestart • Installation • Filling • Venting • Power loss • Fire • Basic user operation • Emergency Deenergizing	

1 Description of Test

The intent is to use the injector test area with a maximum total beam energy of 10 MeV (9.5 MeV kinetic) to test the operational characteristics of the Argonne Bubble Chamber. The electron beam will be fully stopped by a water cooled copper dump/radiator. The chamber was tested at Duke where a high energy bremsstrahlung background adversely affected the results. The purpose of the test at JLAB is to determine the photon detection effectiveness in a low neutron background environment. Operating parameters (e.g. pressure, temperature, fluid, event rate, buffer fluid level) shall be adjusted within a safety envelope to improve photon detection and chamber recovery times. The active fluids for the test are N_2O and C_2F_6.

1.1 Operational limits

Parameter	Limits
Bubble Chamber Pressure	0 to 1000 psig
Bubble Chamber Metal Temperature	-15 to 30 C
Total Beam Energy	4 to 10 MeV
Beam Current	0 to 10 µA
Detector Fluids	C2F6 and N2O
Active fluid temperature	-30 to 30 C
Bubble quenching pressure difference	500 psi max

1.2 Test Plan

The detector shall be tested within the limits listed above. For a detailed test plan see Section 11.4. Detailed procedures for operating the detector are given in Section 9.

2 Bubble Chamber Detector

2.1 General description

The Argonne Bubble Chamber was developed and tested at Argonne National Lab (ANL) by Brad DiGiovine et. al. The Chamber may be adapted for use with various super-heated target fluids. These fluids are contained in a glass vessel with a fluid volume of 40-60 ml depending on the fill configuration. There is an additional 150 ml of mercury (less than the 5 lbm Virginia state limit) that serves as a buffer fluid. The small bubble chamber vessel is contained in a larger (~7.5 liter) pressure vessel. The space between the two vessels is filled with a mineral oil based heat transfer liquid pressurized to a maximum of 1000 psi. The pressure in the glass vessel and the pressure vessel are commuted via a bellows assembly such that the differential pressure across the glass is very small. Should the inner vessel fail all fluids would be contained in the outer pressure vessel. See the figures below for more details. The system has two copper collimator/beam ports and two commercially supplied viewports. See Figure 1 below.

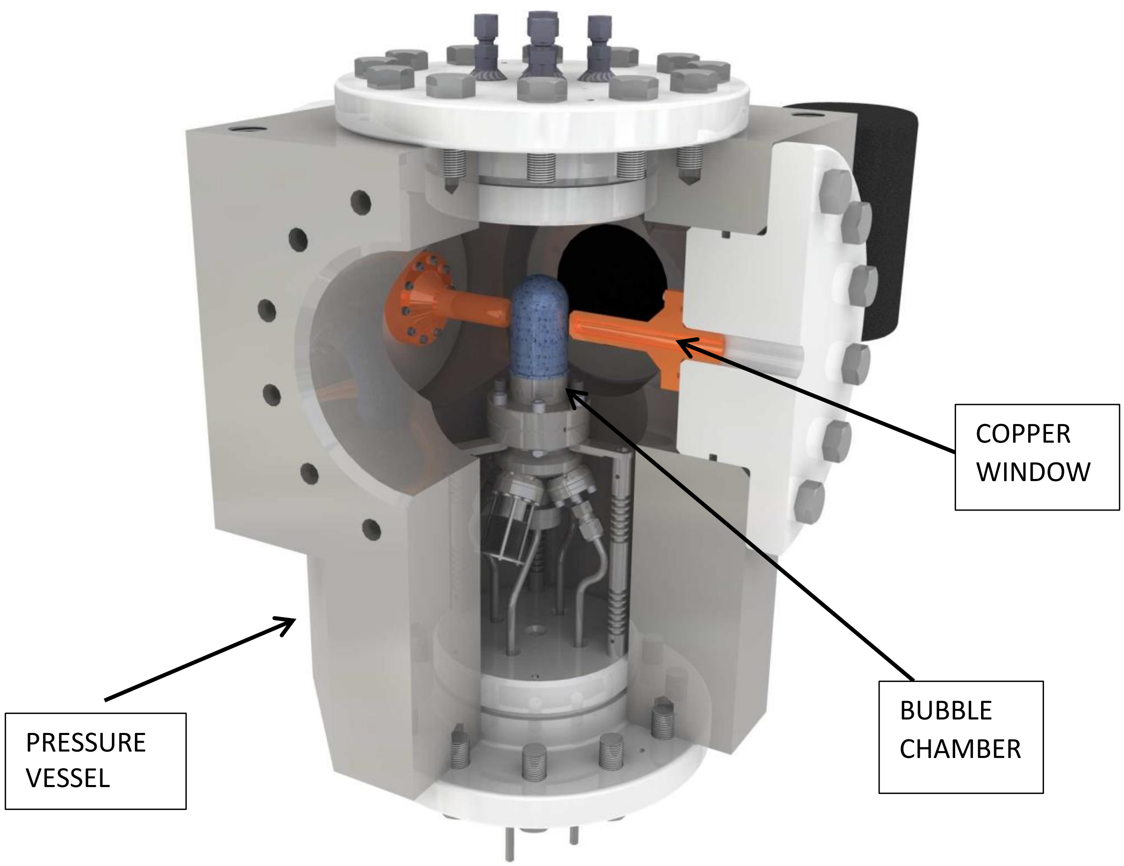


Figure 1: Bubble chamber and pressure vessel cut away view

2.2 Basic Theory of Operation

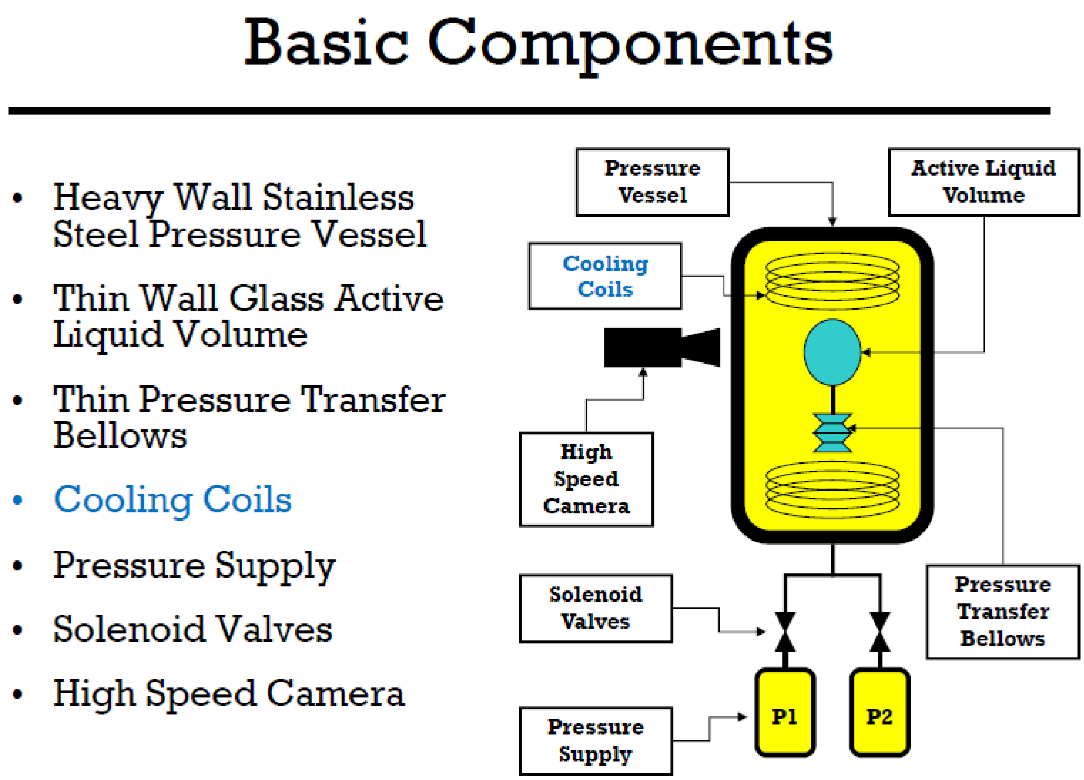


Figure 2: Basic Components

This system is designed to prepare the active fluid of choice into a metastable superheated state to act as an active target for low energy nuclear astrophysics research. There are two main volumes, the first is a small clean volume containing the active fluid and buffer fluid. This volume is built of stainless steel and glass and is contained within the heavy wall stainless steel pressure vessel. An edge welded bellows is incorporated into this clean volume to facilitate volumetric changes due to changes in operating temperature, as well as to equalize pressure between this clean volume and the outer hydraulic volume. Surrounding this clean volume within the heavy wall vessel is a hydraulic working fluid. This fluid provides for thermal stability of the active fluid, and is directly connected to the pressure supply system external to the vessel. The pressure supply system is a hydraulic system which controls the system pressure by the actuation of solenoid valves allowing the system to cycle between superheat pressure (low) and recovery (high) pressure (points 3 and 2 in the Figure 3). The active volume is backlit and observed by a fast machine vision camera operating at 100Hz. The data acquisition and control computer analyzes these images, determines if an event has occurred, stores the event, logs instrumentation data, and signals the system to pressurize to the default recovery state from the active superheated state. Once the system recovers, the computer signals to decompress to the superheated state and the system goes live again. Temperature control is accomplished via an external chiller and flow control system which is manually operated. This system feeds heat exchange coils within the hydraulic volume, this has replaced an existing heating system which is no longer present, but sometimes referenced in older documentation.

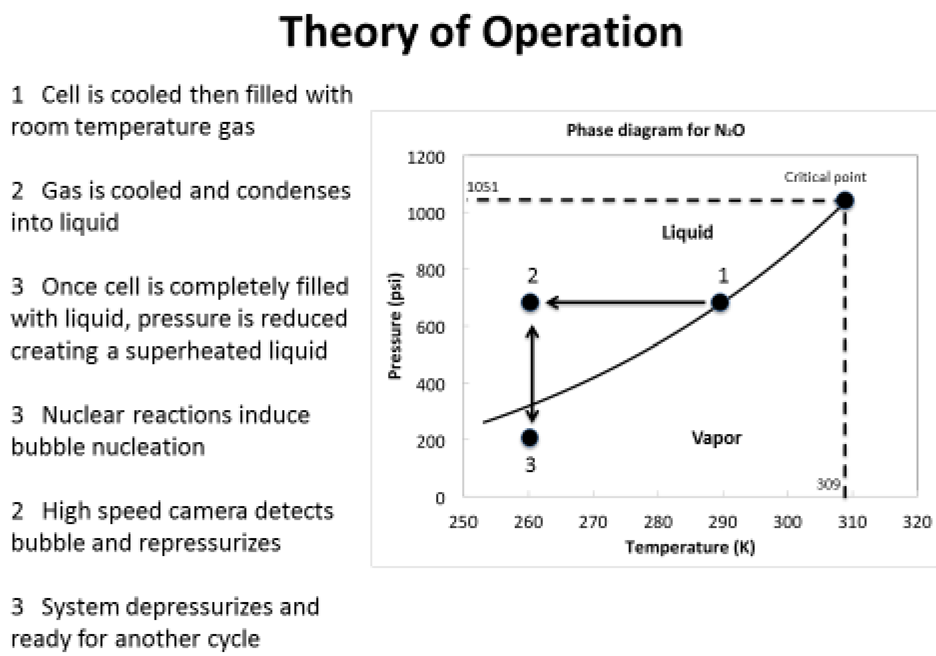


Figure 3: Phase Diagram and Theory of Operation

3 Hazardous Materials

3.1 Mercury

There is roughly 150 ml of mercury contained in the inner vessel. This fluid serves as a buffer fluid for the active target fluid. The mercury has been preloaded into the inner vessel at Argonne National Lab (ANL). Pump and purge cycles performed on this volume with small quantities of the target fluid are required to ensure a pure liquid sample. To prevent a mercury (droplets or vapor) release, two filters are installed (see P&ID). Filter F-001 is installed upstream of the vacuum pump and will prevent droplets from reaching the vacuum pump. Filter F-002 is installed on the outlet of the pump to prevent mercury vapor from escaping the system. While these safe guards are in place, mercury can still be released through human or mechanical failure. Mechanical failure is extremely unlikely given that the fluid systems have been designed and fabricated in excess of ASME Code requirements.

Hazards associated with long term or acute mercury exposure are:

- Neurological symptoms:
  - Headache, short term memory loss, incoordination, weakness, tremors, etc.
- Kidneys may also be affected
- Intense exposure to vapors can lead to severe respiratory damage.

The following mitigating steps shall be employed to limit exposure or loss of mercury:

- Only the system expert, Brad DiGiovine, shall be allowed to perform the filling and venting operations using the procedures given in Section 9.
- Fluid systems that are designed and fabricated in excess of ASME Code requirements.
- Documented TOSP including specific procedures for bubble chamber fluid handling operations.
- Perform leak tests of the system prior to introducing active fluid into the system piping.
- Monitor personnel/room air for mercury; SKC Elemental Mercury Passive Sampler
- Secondary spill containment under the bubble chamber.
- Limited amount of mercury 150 ml.
- Spill kit placed in injector

The MSDS or MDS for Mercury is filed in the pressure system folder PS-TGT-14-002.

3.2 N2O

Nitrous Oxide (N2O) may be used as an active fluid in the bubble chamber. If selected as the active fluid, the chamber shall contain 40 to 60 ml of liquid N2O. Note that the N2O is a liquid at the high operating pressure even at room temperature. At STP this quantity of N2O expands to roughly 17 liters. The occupational limit for N2O exposure (based on 2000 hour/year exposure) is 50 ppm. Should all of this gas escape the system, the concentration in the injector area would be 25 ppm which is below the limit (see TGT-CALC-502-002). This limit could be exceeded if the contents of the supply bottle is released. This bottle shall be valved closed at all times other than when the filling procedure is being performed. While N2O is not flammable it does rapidly decompose to release oxygen which can accelerate or reignite fires.

This material presents the following hazards from an acute overexposure:

- Dizziness
- Drowsiness
- Poor coordination
- Oxidizer can accelerate or reignite fire.

The following mitigating steps shall be employed:

- Limited quantities do not present ODH/asphyxiant hazard.
- Only the system expert, Brad DiGiovine, shall be allowed to perform the filling and venting operations using the procedures given in Section 9.
- Fluid systems that are designed and fabricated in excess of ASME Code requirements.
- Documented TOSP including specific procedures for bubble chamber fluid handling operations.
- Perform leak tests of the system prior to introducing N2O into the system piping.
- Monitor personnel/room air for N2O exposure using Assay Technology 575 N2O sampler
- N2O is an oxidizer; therefore all flammable gases in the CEBAF Injector shall be stored at least 20 ft from the N2O bottle. This is typically not an issue in the Injector.
- Removal of N2O bottle when not in use. Store bottle in locked storage area.

The MSDS or SDS for N2O is filed in the pressure system folder PS-TGT-14-002.

3.3 C2F6

Hexaflouroethane (C2F6) may be used as an active fluid in the bubble chamber. If selected as the active fluid, the chamber shall contain 40 to 60 ml of liquid C2F6. Note that the C2F6 is a liquid at the high operating pressure even at room temperature (see Section 5). At STP this quantity of C2F6 expands to roughly 1 liter. The occupational limit for C2F6 exposure (based on 2000 hour/year exposure) is 1000 ppm. Should all of this gas escape the system, the concentration in the injector area would be much less than the limit (14 liters at STP or 20 ppm) (see TGT-CALC-502-002). This limit could be exceeded if the contents of the supply bottle are released. This bottle shall be valved closed at all times other than when the filling procedure is being performed.

The hazards associated with C2F6 over exposure:

- Difficulty breathing
- Does not pose ODH risk with the limited quantities needed for the bubble chamber.

The following mitigating steps shall be employed:

- Only the system expert, Brad DiGiovine, shall be allowed to perform the filling and venting operations using the procedures given in Section 9.
- Fluid systems that are designed and fabricated in excess of ASME Code requirements.
- Documented TOSP including specific procedures for bubble chamber fluid handling operations.
- Perform leak tests of the system prior to introducing C2F6 into the system piping.

Removal of C2F6 bottle when not in use.

The MSDS or SDS for C2F6 is filed in the pressure system folder PS-TGT-14-002.

3.4 Duratherm 450

The hydraulic fluid in the space between the inner and outer vessels is a mineral oil based heat transfer fluid. This fluid is not considered hazardous material. An MSDS/SDS is filed in the pressure system folder. The fluid is considered non-toxic and environmentally friendly. It poses no ill effects to worker safety. Duratherm 450 is flammable with a flash point slightly above 290 F.

The MSDS or SDS for Duratherm 450 is filed in the pressure system folder PS-TGT-14-002.

4 Required Training

The following training is required for operation of the detector and for installation and removal activities. Filling and relief procedures shall only be performed by the system expert Brad DiGiovine who is considered fully trained. All users, prior to operating the DAQ system require a short briefing, given by B. DiGiovine. The following is a list of additional general training required for users:

- SAF 801 Rad worker I
- SAF 103 ODH
- SAF 130 Oil Spill Training (not required for all personnel and only if needed)
- SAF 132 Tunnel worker safety
- SAF 801kd RWP for tunnel access
- SAF 100 General safety

5 Electrical Safety

The detector and all ancillary equipment was developed and assembled at Argonne National Lab. Detailed schematics can be found in the pressure systems folder (PS-TGT-14-002). The system was inspected by both Argonne and JLAB SMEs and found to be sound.

5.1 Maintenance Procedures

Maintenance shall only be performed by Brad DiGiovine (ANL) after disconnecting the power source (at the plug) obviating lock tag and try procedures. Work shall not be performed on exposed equipment when energized.

6 Radiation Safety

The electron beam has a maximum total energy of 10 MeV for the test. No radiation hazards are expected when the beam is off. In August 2015, one of the rapid access probes in the Injector was relocated above the copper radiator/dump in the bubble chamber beamline. This ensures that rapid access will function as intended in this configuration and operation of the bubble chamber will not require RadCon surveys as the electron beam energy is gradually raised. If the radiator/dump gets activated, the probe will alarm at 1.4 mrem/h at 1 foot, i.e. a safety factor of ~3.5 below the radiation area limit. Therefore, as long as the Rapid Access beacon activates when the button is depressed, no survey is required for Controlled Accesses or prior to going to Restricted Access. See procedure TGT-PROC-15-001 for other administrative controls.

7 Material Handling

The chamber has engineered lift points that are centered over the center of gravity. The weight of the chamber is less than 500 lbm and shall be lifted by trained (crane and rigging) JLAB staff under the direct supervision of Brad DiGiovine (ANL). There is no lift procedure required for these operations. The chamber must be lifted about 3 ft. off the floor to be installed onto and removed from the cart. Note that the flanges are heavy and caution must be taken when removing and installing them.

8 Pressure Safety

The pressure systems documentation is filed in the pressure system folder PS-TGT-14-002 on DocuShare. There is extensive documentation for the original ANL system including reviews performed at ANL. This includes the review alteration of the system to operate with N2O and C2F6 with mercury as a buffer fluid. ANL documentation requirements for low stored energy systems is not as extensive as JLAB requirements. The total stored energy of the system is less than 1000 ft-lbf (1300 J) and is therefore considered low risk. Additional calculations confirming the design of the system have been performed by the JLAB DA for the system (Dave Meekins). These calculations indicate the system is safe to operate within the following parameters.

Parameter	Limits
Operating pressure	1000 psi
Operating Temperature	-30C to 30C
Cycle depth for quench	500 psi max
Hydraulic pump	1 GPM
Design Pressure	1100 psi
Applicable Code	ASME B31.3 2010

Note that care must be taken when filling and relieving to prevent damage to the glass bubble chamber. Should the chamber rupture, the glass would be contained in the outer vessel but the detector assembly would need to be returned to ANL for repair. For this reason, only the system expert Brad DiGiovine may perform the fill or relief procedures. See Section 9 for details.

8.1 Major Subsystems

The system consists of the following subsystems

- Hydraulic fluid system
  - Outer vessel and beam ports
  - Hydac hydraulic pump
  - Gas and hydraulic fluid handling control panel.
  - Ancillary piping for hydraulic and nitrogen gas fluids (nitrogen is used to charge the accumulators)
  - Camera with Canty glass windows.
- Target fluid system
  - Inner vessel (actual bubble chamber)
  - Ancillary piping for gas handling
- Refrigerator system
  - Commercially supplied refrigerator and insulated flex lines
- DAQ and control system

8.2 Component list

The following is a general list of components for the entire system. These components are rated by the manufacturer to have working pressure limits in excess of the operating pressures for the system.

1. Commercially supplied
    a. Hydraulic pump 1 gpm
    b. Low, high and supply accumulators Hydac SB 200 and SB 210 series.
    c. Hand and solenoid actuated valves
    d. Relief valves.
    e. 0.25” and 0.375” nominal tubing; SST 0.035” wall.
    f. Pressure regulators
    g. Various relief valves (hydraulic and pneumatic)
    h. Phase separator
    i. Pressure gauges and transducers
    j. Flow controller/valves
    k. Filter, strainer, and check valves
    l. Camera and high pressure window
2. The following components are custom
    a. Beam ports (copper subject to compression loading).
    b. Bubble chamber (glass vessel fully contained in the larger pressure vessel).
    c. Pressure vessel (because of limited size <6 inch bore this component is not required to meet the ASME BPVC). The most applicable ASME Pressure Code is ASME B31.3 2012.

The commercially supplied components have maximum working pressure ratings of 1500 psi or higher. Fittings are Swagelok with non-welded connections (i.e. there are no welded joints outside of the commercial components boundaries). Commercially supplied components are accepted without further calculations. The fully assembled (without camera) system is shown in Figure 4.

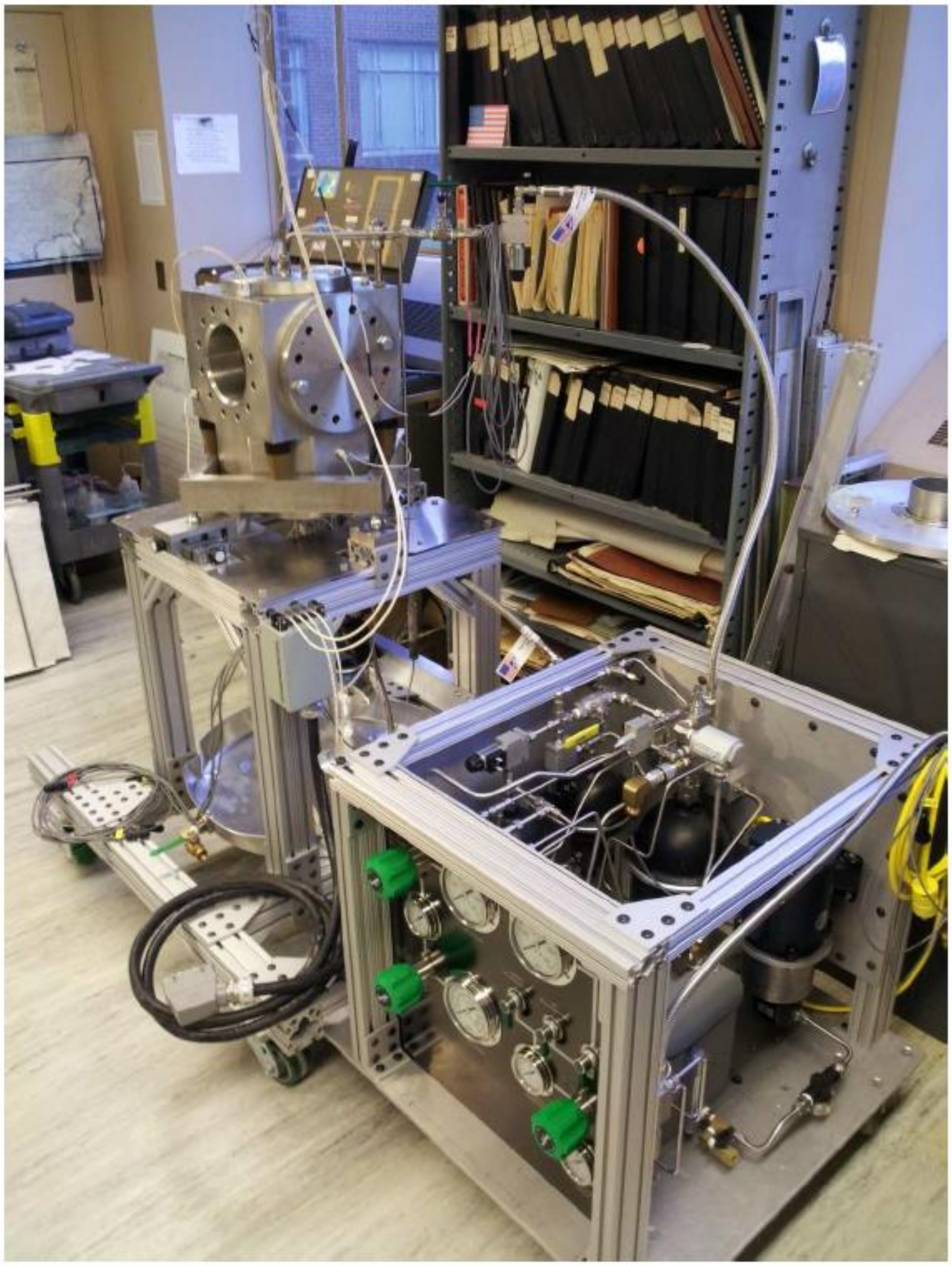


Figure 4: Fully assembled system

8.3 Canty Camera and Glass Windows

The camera and window are commercially supplied and have operating pressure ratings of 1300 psi as indicated in the drawing below (see Figure 5). These components have technology considered proprietary by the manufacturer and do not have additional documentation beyond this certification. This drawing can be found in the pressure system folder. These components are accepted without further analysis. See Figure 5.

8.4 Vessel and chamber

The vessel is machined from a single forged block of SST 304. The design pressure is 1700 psi (1100 psi for beam ports). The maximum operating pressure is 1000 psi. This is determined by the relief valve PSV-4. This valve is not an ASME valve but does have a capacity higher than the pump can deliver. The vessel is protected by a Flow Safe ASME liquid relief set at 1100 psi with a capacity far greater than the pump can supply. It is JLAB policy that piping less than 6 inch in diameter need not be protected from fire. The relief device is a Flow Safe S8L2P-05FN-05FN-SS-SS-KVN.

8.5 Piping

All piping components are commercially available from the following suppliers.

- Swagelok: Fittings, valves, flex lines, and tubing
- Parker: small hand valves
- Hydac: hydraulic pump, fittings, relief/check valves, and accumulators
- Kunkle relief valves
- Wika pressure gauges

All components have a working pressure rating (with the exception of the lower range pressure gauges) in excess of the relief device set points. The N2 piping is protected by an AMSE relief valve: Kunkle 1000 psi 207 SCFM.

8.6 Vacuum System

The vacuum system is temporarily connected when filling and venting (relieving) the system. There is a vacuum pop-off installed on the vacuum line that will prevent an accidental overpressure of the vacuum system due to operator error. Note that only the system expert is allowed to perform procedures requiring the vacuum subsystem.

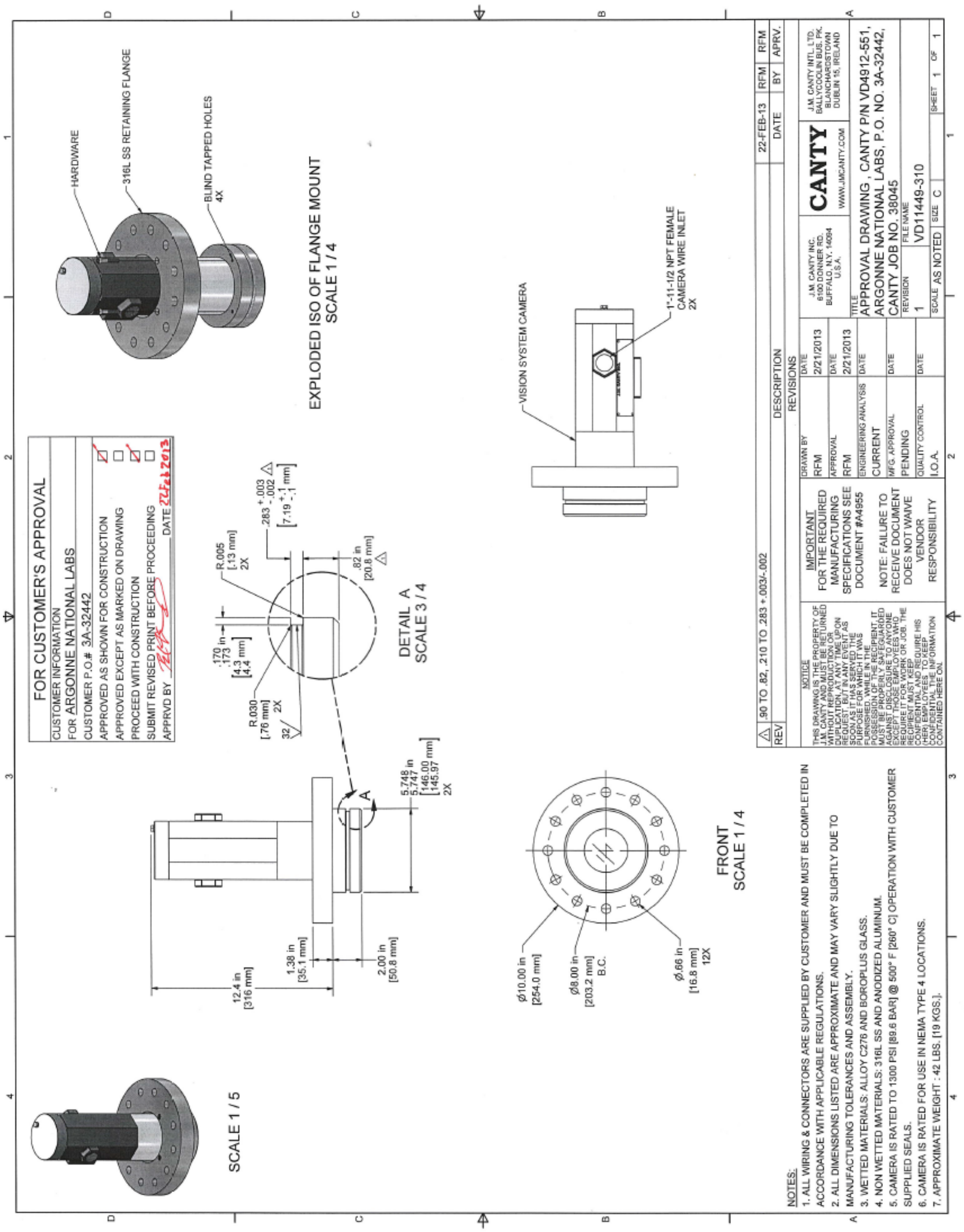


Figure 5: Canty camera and window assembly.

9 Procedures for bubble chamber operations

9.1.1 Installation

Mercury (Hg) was preloaded into the bubble chamber space at ANL in a clean room environment. There shall be no handling of Hg at JLAB outside of extreme emergency situations. If necessary, the chamber shall be shipped back to ANL for any and all Hg handling. Installation shall proceed under the direct supervision of B. DiGiovine and D. Meekins. An electrical inspection shall be performed by Todd Kujawa.

9.1.2 Prestart Checklist

Perform the following prestart checklist prior to filling and operating the detector for the first time or after down period exceeding 1 month:

1. Post area as "Test in Progress: Keep Out"
2. Visually inspect all mechanical supports and ensure that the position of the chamber is acceptable.
3. Ensure that shielding is in place for beam dump
4. Ensure that electrical inspection has been performed
5. Visually inspect all mechanical connections on flex lines and tubing
6. Ensure that the fill level of the hydraulic reservoir is acceptable
7. Ensure that power is supplied to equipment rack
8. Visually inspect insulation

9.1.3 Filling Procedure

The following procedure shall be used for all filling operations. Only Brad DiGiovine from ANL shall perform this procedure.

1. Notify Industrial Hygiene prior to proceeding. Operate a 1000 cfm fan to recirculate air in the injector and provide mixing.
2. Ensure that the correct personnel monitoring equipment for exposure to the target fluid (Assay Technology 575 N2O sampler) and mercury (SKC Elemental Mercury Passive Sampler) is in place.
3. Make sure LabVIEW is online and temperature/pressure data is available and accurate
4. Connect filling manifold to detector fill port with new VCR gasket, connect dry pump, connect gas supply bottle.
5. Perform a leak down vacuum test of filling manifold
6. Open the bottle supply valve and bleed a small amount of gas from supply into filling manifold and pump out, several times to purge system.
7. Pump out filling manifold and open valve to detector phase separator to pump.
8. Open valve to detector upper fill line to pump active volume of detector.
9. Connect hydraulic fluid reservoir to fill port on the heavy wall vessel, connect vacuum pump to pump port on top of vessel.
10. Pump and fill hydraulic volume of vessel
11. Turn on chiller system, adjust temperature and flow control valves to appropriate values based on active fluid and threshold calculations.
12. Once fluid temperature has reached operating conditions filling can begin

13. Close detector upper fill valve and use regulator on filling manifold to set fill pressure to 3 atm
14. Open valve to detector lower fill and fill upper volume with appropriate amount of mercury
15. Close valve to lower detector fill and open valve to upper detector fill to begin letting gas into inner volume, constantly check the pressure differential across glass.
16. Once the pressure differential is close to 1atm, begin to increase hydraulic pressure to equalize the pressure differential.
17. Repeat 13 and 14, increasing gas and hydraulic pressure until vapor pressure is reached at temperature, gas will begin to liquefy. Continue to fill with liquid active fluid until there is no remaining gas volume and the mercury meniscus has been displaced down several millimeters.
18. Close valve to upper detector fill, close valve to detector phase separator, close valve to gas bottle
19. Let system sit and settle for some time to allow thermal equilibrium to be reached.
20. **Ensure that the bottle valve is fully closed**. Disconnect from system.
21. Verify proper setup and operation of LabVIEW system, verify proper operating pressures and temperatures.
22. Set system into standby for users to take over operation.

9.1.4 Venting

The following procedure shall be used for venting. Only Brad DiGiovine shall perform this procedure.

1. Notify Industrial Hygiene prior to proceeding. Operate a 1000 cfm fan to recirculate air in the injector and provide mixing.
2. Ensure that the correct personnel monitoring equipment for exposure to the target fluid (Assay Technology 575 N2O sampler) and mercury (SKC Elemental Mercury Passive Sampler) is in place.
3. Verify filling manifold is still properly setup, if not, install manifold and pump.
4. Turn on pump, pump out manifold
5. Open valve to detector phase separator and pump
6. Begin lowering hydraulic pressure slowly to vapor pressure at temperature
7. Wait for gas bubble to form in active volume, leave pressure so little change in gas bubble volume occurs
8. Slowly open detector upper fill valve and begin bleeding liquid into phase separator
9. Once all liquid is gone continue bleeding until differential pressure across glass is close to 1atm, close detector upper fill valve
10. Lower pressure in hydraulic system to equalize differential pressure
11. Open detector upper fill valve and repeat 7&8 until system is completely vented and pumped, hydraulic system pressure should be 1atm, inner volume FV.
12. Close detector upper fill valve, close detector phase separator valve; turn off pump.
13. Power down chiller, and shut down hydraulic system, electronics and DAQ can now be powered down if necessary.

9.1.5 Power loss

In the event of a power loss, place the remote override box into its default position as described in the general user section. The system automatically switches to recovery (high) pressure to prevent any active fluid boiling. The chiller system will of course fail due to loss of power so the system will begin warming up. The bellows in the active volume will provide the necessary expansion volume for the possible excursion to room temperature, and the hydraulic system relieving regulators (and backup relief valve) will provide the necessary relief for the inevitable expansion of the hydraulic fluid. The hydraulic supply system also has a large supply accumulator which will provide the necessary hydraulic supply pressure for weeks in system standby. A system expert must inspect and determine the proper course of action once power is available again, ideally the system will be able to be cooled back down to operating temperature and returned to service with minimal disruption.

9.1.6 Fire

In the case of a fire, place the remote override box into its default position as described in the general user section. Do not approach the system, it is designed to relieve excess pressure in events like this, but due to the chemical hazards present from operating fluids, and possible thermal decomposition, the composition of the venting material will likely be hazardous. Stay away.

9.1.7 Basic User Operation

Any user not considered an expert is limited to the start/stop of runs, and the placement of the system into and out of standby. The main interface of the system for standard user is a LabVIEW interface and control panel. This panel allows for the naming of runs, specifying data storage locations, and the start/stop function.

The system will be available for users once it is prepared and placed into standby by an expert. This means that the system will be at operating temperature and pressurized to its recovery (high) pressure. The LabVIEW system will be online but not running.

9.1.7.1 Start Run

Step 1. Enter (or verify) the storage location of data files in the “path” textbox

Step 2. Enter run number in the appropriate textbox

Step 3. Click the run (arrow) button

The system will decompress to the active pressure and become live, the acquisition and control system will automatically recognize events, log data, pressurize the system to recover, and decompress to the active pressure to go live again.

9.1.7.2 End Run

To end a run and place the system in standby

Step 1. Click the red “STOP” button on the LabVIEW interface

Step 2. Verify system pressure has increased to recovery (high) as indicated by LabVIEW

9.1.7.3 DAQ Failure

A remote override box is available to users, this is only necessary in the event of acquisition failure, emergency, or as a redundant backup for standby mode. A user must verify proper position of override switches before enabling the box with the toggle switch in the upper left corner. The switches should be left in this orientation to facilitate a fast enabling of override.

The default standby positions are:

- Heater Power: Disabled
- Hydraulic Supply Pump: Enabled
- Valve High: Open (Green)
- Valve Low: Closed (Green)
- Valve Bleed: Closed (Green)
- Valve Inner: Closed (Green)

These switches are found on the System Override Box shown in Figure 6.

Figure 6: System Override Box

9.1.7.4 Control System Alarms

The user interface is simple to use as there are few functions for the interface to perform. The following is a list of the control functions:

- There is an alarm on the temperature which indicates possible failure of the refrigerator. This will stop the DAQ Run and return the system to the high pressure (stable) condition.
- Backlight failure alarm. The alarm and interlock Stops the DAQ Run and returns the system to the high pressure condition.
- Differential pressure alarm: this alarm indicates that the DP limit between the inner and outer vessel has been exceeded. The interlock with stop the DAQ Run and return the system to the high pressure condition. This limit is adjustable however B. DiGiovine is the only authorized person for setting this limit.

9.1.8 Emergency Deenergizing

This procedure shall only be performed in cases of emergency. Performing this procedure will likely cause damage to the bubble chamber glass vessel. Damage to this vessel does not pose a personnel risk but, will require that the chamber is shipped back to Argonne National Lab for repair.

1. Turn off hydraulic pump.
2. Turn off refrigerator.

3. Open HA-18 bypass valve.
4. Close PRV/RV 1 This is a pressure relieving regulator that will relieve pressure as the setpoint is lowered.
5. Close PRV/RV 2 This is a pressure relieving regulator that will relieve pressure as the setpoint is lowered.
6. Close PRV/RV 3 This is a pressure relieving regulator that will relieve pressure as the setpoint is lowered.
7. After pressure is relieved (verify on gauges PI
8. Power down chiller, and shut down hydraulic system, electronics and DAQ can now be powered down if necessary.
9. Do not attempt to open vessel or valves or disconnect lines on the system. The system expert shall disassemble the system for shipment to ANL for repair and inspection.

10 Failure Modes and Effects

This section details the possible credible failure modes and their effects as well as mitigations to reduce risk to personnel and equipment.

10.1 Failure of glass bubble chamber

Failure of the glass vessel will be detected with the camera during operations mode. At all other times manual observation is required to detect the failure. This failure mode released N_2O/C_2F_6 and mercury into the hydraulic fluid. The integrity of the system is still maintained and is safe as long as the system is not disassembled. The system must be shipped back to ANL for repair. Industrial Hygiene shall be required to cover the disassembly of system for shipment back to ANL. Procedures to perform the disassembly shall be agreed upon by IH and the system expert.

10.2 Failure of pump cut off switch

The pump is controlled by the pressure switch PS-1. Should this switch fail the pump would run continuously and supply a steady flow of 1 gpm. Multiple Hydac relief devices and control regulators should ensure that the pressure in the vessel and piping do not exceed the design pressures. However these devices are not ASME. Should these all fail, relief valve PSV-8 with a set pressure of 1100 psi ensures that the pressure in the vessel does not exceed the design pressures beyond Code limits.

10.3 Accumulator failure

Should the accumulator fail and allow N_2 into the hydraulic system, there will be no effect aside from the system DAQ and control issues. The amount of N_2 stored in the accumulators is negligible. The N_2 bottle is disconnected after the charging procedure is complete. This event is considered extremely unlikely as these devices have a working pressure rating of 3000 psi.

10.4 Regulator failure

Should the N_2 regulator fail on the accumulator charging line, an ASME relief valve will protect the system from overpressure. The orifice at the bottle connection ensures that the Cv is known and that the valve has adequate capacity. See TGT-CALC-502-003 for more details.

10.5 Refrigerator failure

Should the refrigerator fail without a full power failure while in operation or standby mode, the DAQ system will alarm and interlocks will open CV-1 and close CV-4. This returns the chamber and vessel to the stable condition. The active fluid will stay in the liquid state at room temperature and no damage to the bubble chamber will occur. The system may then be manually relieved in a safe and controlled manner with no damage to the bubble chamber and no additional risk to personnel. The consequences of this failure mode are minimal.

10.6 Power failure

Should a power failure occur while the detector is in operation or standby mode, the solenoid valves will go to the normal state with control valve CV-1 open and CV-4 closed. The bubble chamber and outer vessel are then set to the high pressure which is the stable condition for the fluid. This will prevent boiling of the fluid even with a full warm up to room temperature. The refrigerator will also fail during a full power failure. The system may then be manually relieved in a safe and controlled manner with no damage to the bubble chamber and no additional risk to personnel. The consequences of this failure mode are minimal.

11Beam Operations

11.1 General

The chamber will be operated remotely from the MCC control room. The control shall be separate from the beam control. Beam operations shall be limited to the following:

- Beam current shall be varied up to 10 μA
- The total beam energy shall be varied up to 10 MeV
- Vary bubble chamber operating parameters as required inside limit envelop given in Section 1.1.

Note that the beamline with the dump was commissioned in 2014. It is approved for a total beam energy of 10 MeV and 10 μA.

11.2 5D Beamline

The 5D beamline is in the injector region and was used for the PePpo experiment. The line was modified in 2014 to accommodate the future experiment E12-13-005 $^{16}O(\gamma,\alpha)^{12}C$. The beamline is formally described in the Song Sheet ACC2008000-1100. The line currently has an operational limit of 10 μA and 10 MeV total energy (9.5 MeV kinetic). The dump on this line shall also serve as a radiator to produce photons for the test of the bubble chamber detector. A Schematic of the beamline is shown in the figure below.

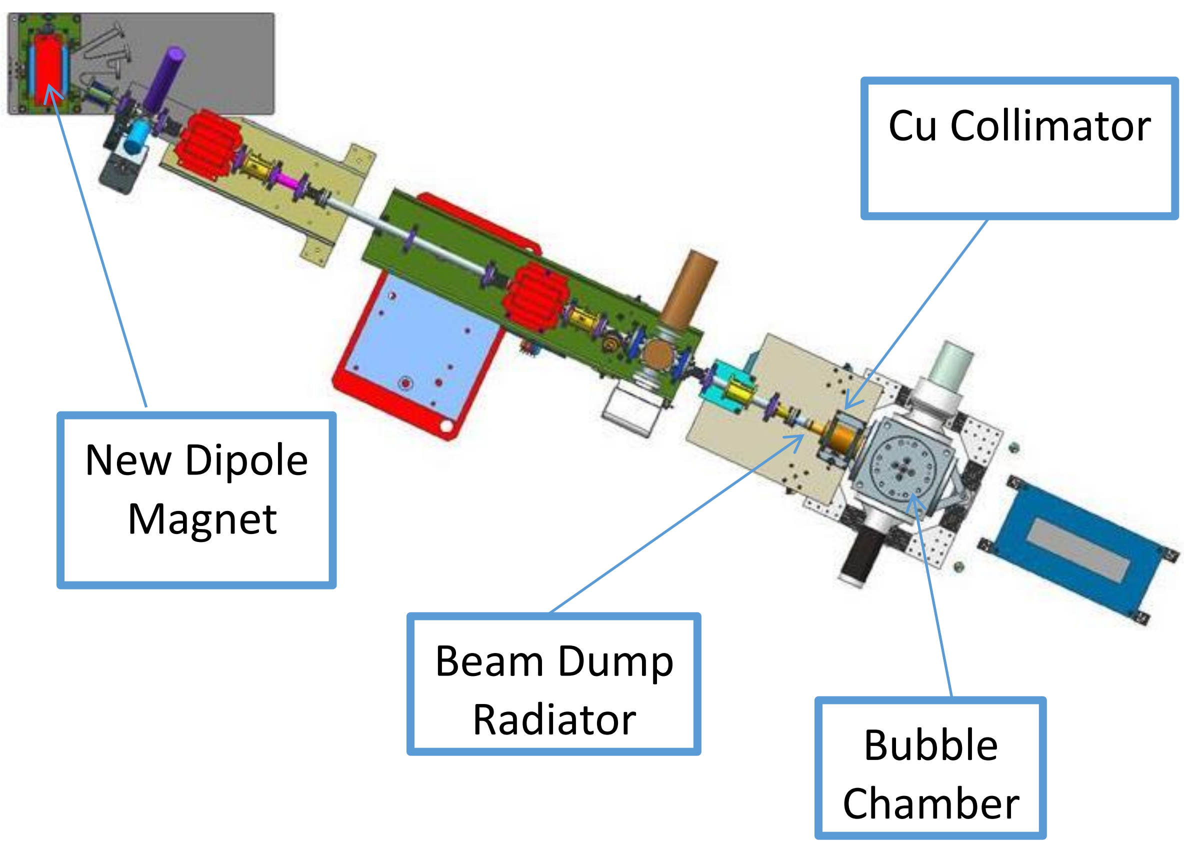


Figure 7: 5D Beamline Schematic

A new fast acting gate valve has been added to the beamline upstream of the 5D line. This valve closes when pressure is high in the downstream line thus protecting the ¼ cryomodule in the injector. This provides a layer of protection in the unlikely event that the copper dump fails.

11.3 Beam Dump/Radiator

The beam dump for the 5D line shall also serve as the radiator (source of photons) for the test. A thermal analysis using conservative assumptions was performed by J. Matalevich. This analysis can be found in the pressure system folder PS-ACC-14-003. A summary of the analysis is given in Figure 8. For the input power of 100 W the temperature rise on the beam dump is acceptable, about 100 C. This dump was commissioned in 2014. A GEANT4 simulation indicates that electrons from the beam will not penetrate the radiator/dump but knock on electrons produced by the incident photon shower will escape at much lower energies. These electrons are not expected to have any measurable effect on the detector.

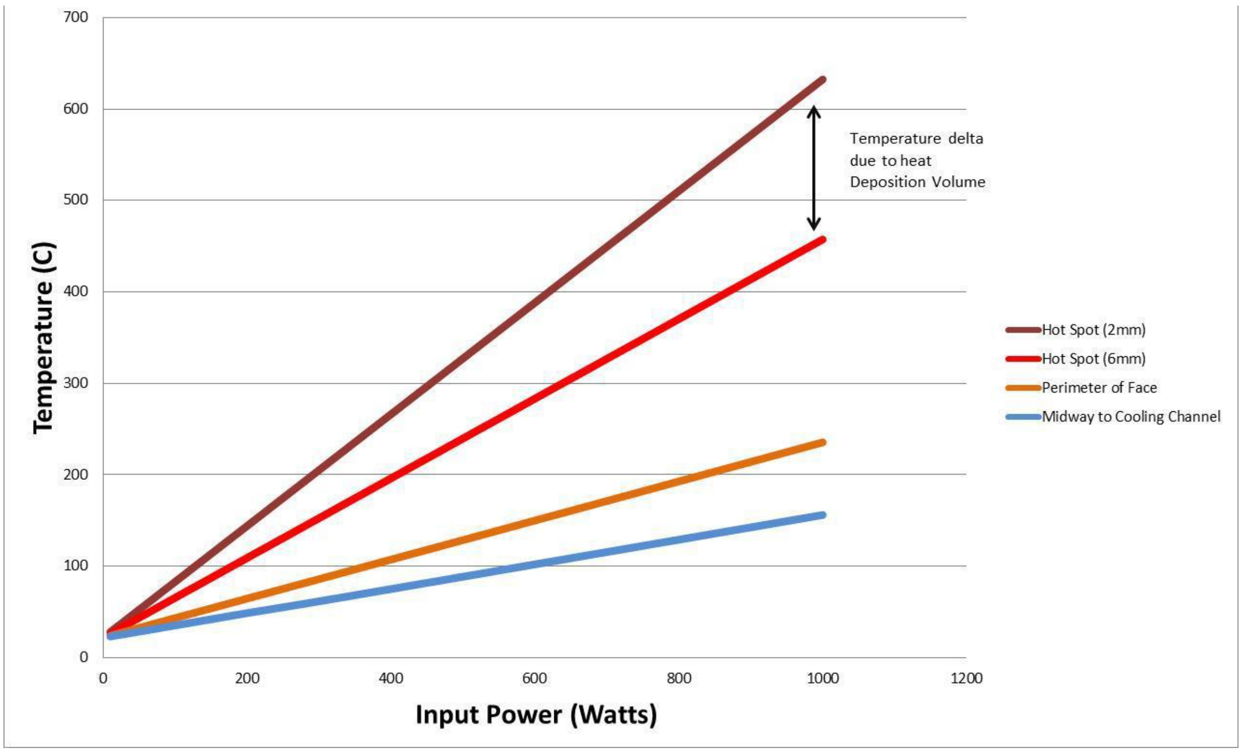


Figure 8: Beam dump/radiator temperature rise

11.4 General Test Plan

The test plan shall consist of two phases. The first where the chamber is filled with N_2O as the active fluid and the second where this fluid is C_2F_6. The following is an outline plan for the test:

- Phase 1:
  - Ensure that the DAQ and hydraulic systems are functioning properly.
  - With beam on the dump operate the detector.
    - Check counting rates especially multiple bubble production
  - Measure bubble distribution in the chamber.

- Background measurements:
  - Measure beam off background
  - Measure beam on background by examining outside the fiducial volume
  - Measure background with beam on Faraday Cup.
  - Measure neutron events in chamber when beam energy is above kinetic 8.5 MeV. Use neutron detectors in Injector area to measure neutron production rate.

- Phase 2:
  - Ensure that the DAQ and hydraulic systems are functioning properly.
  - Measure rate to calibrate detector using Penfold-Leiss unfolding analysis. This can be compared to the neutron rich data from Duke.

12 Conduct of Operations for Test

12.1 Organization and Administration:

Accelerator Program Deputy: Steve Cooper (cell: (757) 876-7997)

Accelerator Physics Experiment Liaison: Daniel Moser (phone: 5089)

Accelerator Work Coordinator: Steve Suhring (phone: 7670)

Bubble Chamber Shift Crew:
a. Riad Suleiman (cell: (757) 254-7895)
b. David Meekins (cell: (757)-968-9076)
c. Roy Holt
d. Brad DiGiovine (cell: (815) 780-7777)
e. Claudio Ugalde
f. Ernst Rehm

The Bubble chamber will be operated from the Injector Service Building. The phone number to reach the bubble chamber shift crew is 5248.

We will us a computer electronic logbook, which serves as the record of the experiment. All relevant activities are to be recorded, including all changes of experiment conditions and equipment failures. The log book assigned to this experiment is: https://logbooks/book/bubblelog

The bubble chamber proposal, detailed test plan, and all other documents and references are available online at:https://wiki.jlab.org/ciswiki/index.php/Bubble_Chamber

12.2 Beam Operations

All beam operations will be conducted from the MCC. To contact the Crew Chief please dial 7045. The phone number to reach the MCC Operator is 7048.

There will be one long shift: 9:00 am to 10:00 pm. The MCC will sweep the injector from 8:00 - 9:00 am. The Injector will be in Beam Permit and ready to deliver beam to the bubble chamber in the 5D line at 9:00 am. The beam operations will stop at 10:00 pm.

For any issue related to the bubble chamber, please contact Riad Suleiman (cell: (757) 254-7895) or Brad DiGiovine (cell: (815) 780-7777).

To limit access to the bubble chamber when Injector in Restricted Access, an exclusion zone will be marked with a ribbon and cones. The area shall be posted “TEST IN PROGRESS PLEASE DO NOT DISTURB”.

Riad Suleiman will represent the collaboration at the 8:00 am meetings in the MCC during the work week. Daily work planning will occur at this time.

12.3 Injector Segment Access:

Access to the injector segment will be governed by the JLab beam containment policy, and work in designated radiation areas will be carried out in accordance with the JLab RadCon Manual. The injector segment is not a posted Radioactive Materials Area.

During bubble chamber test, the injector segment will normally be in Beam Permit. When temporary access to the area is needed the shift crew can ask the MCC to bring the injector segment to Controlled Access. If long term access to the injector segment is required, the shift crew may request the injector segment be brought to Restricted Access.

Restricted Access is a state where delivery of beam and/or accelerating RF power is not permitted, and entry to and exit from the injector segment is not controlled by the Personnel Safety System (phone 7050). This is the normal state of the area when the accelerator is off and no experiments are running. Access is “restricted” only in the sense that the injector segment is not open to the general public. Well-defined check-list procedures are to be followed whenever the injector segment is brought to and from Restricted Access.

Project: PS-TGT-14-002 Bubble Chamber

Tittle: General calculations for occupational exposure

Document Number: TGT-CALC-502-002

Revision: Original

Author: Dave Meekins

Date: 7/13/2015

Description:
General calculations for occupational exposure

Reference Drawing(s):

Units specific to this calculation

$$ppm := \frac{1}{10^6}$$

Dimensions of Injector Area

$L_{inj} := 100 \cdot ft$ length of injector tunnel stopping at fence

$W_{inj} := 21. \cdot ft$ width of injector tunnel

$H_{inj} := 11.25 \cdot ft$ height of inector tunnel

$V_{inj} := L_{inj} \cdot W_{inj} \cdot H_{inj} = \left(6.69 \cdot 10^{5}\right) L$

The occupational exposure limits for both fluids are

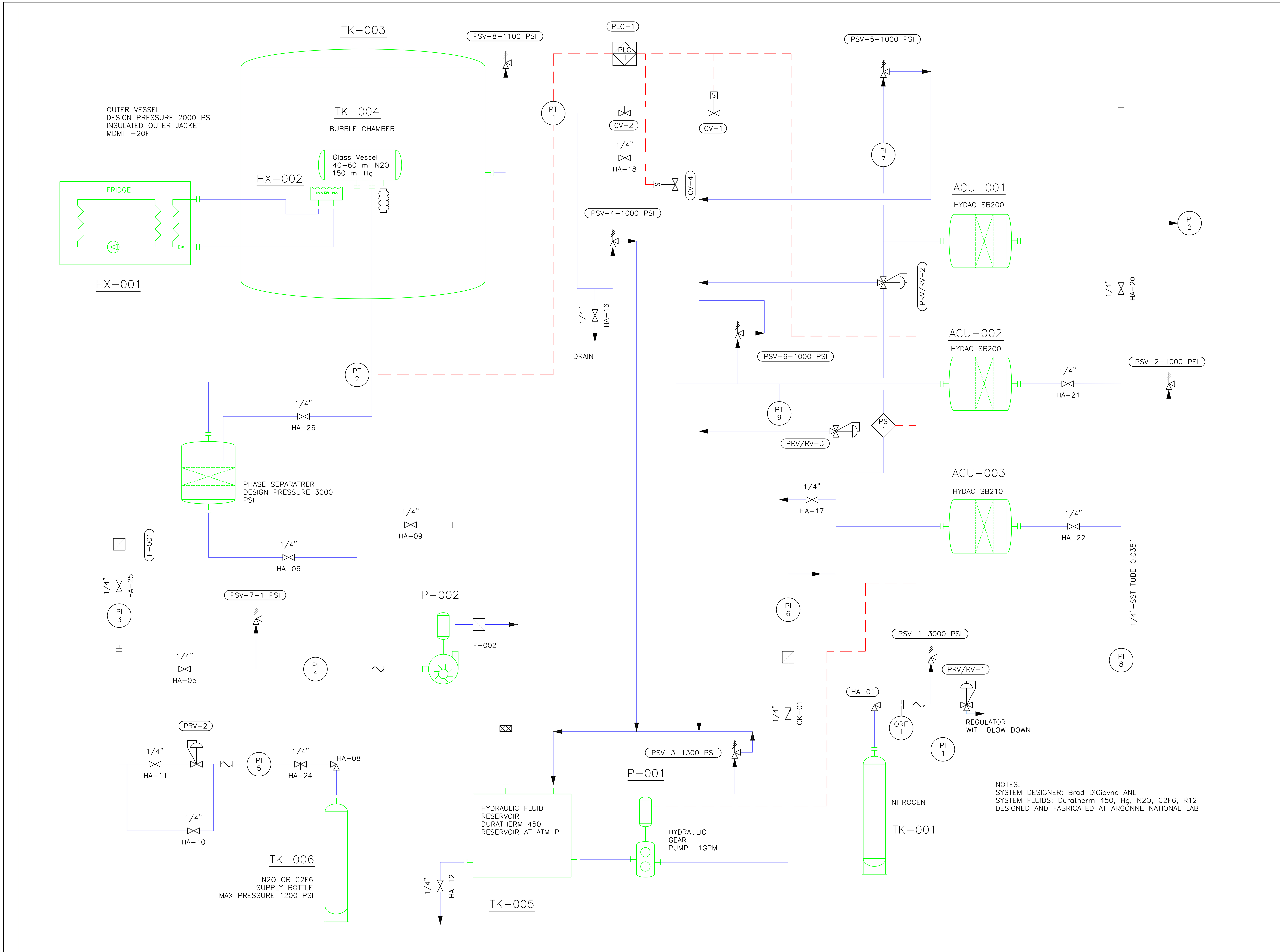
$lim_{N2O} := 50 \cdot ppm$ listed occ exposure limit for N2O

$lim_{C2F6} := 1000 \cdot ppm$ listed occ exposure limit for C2F6

$Va_{N2O} := lim_{N2O} \cdot V_{inj} = 33.449\ L$ max quant limit for N2O at STP

$Va_{C2F6} := lim_{C2F6} \cdot V_{inj} = 668.986\ L$ max quant limit for C2F6 at STP

The N2O stored in the small glass vessel would occupy 17 liters at STP. This is about 1/2 of the estimated allowable for the injector area. This is conservative in that the area is considered to stop at the fence to the linac. The C2F6 estimate is much more conservative. Upon completion of the chamber fill cycle the the supply bottle shall be valved off.



NOTES:
SYSTEM DESIGNER: Brad DiGiovne ANL
SYSTEM FLUIDS: Duratherm 450, Hg, N2O, C2F6, R12
DESIGNED AND FABRICATED AT ARGONNE NATIONAL LAB

General Notes

ANL BUBBLE CHAMBER DETECTOR

MOST APPLICABLE ASME CODE: ASME B31.3 2010.

SYSTEM WAS DESIGN AND FABRICATED BY ANL FOLLOWING ANL PRESSURE SAFETY REQUIREMENTS

SYTEM FLUIDS:

ACTIVE FLUID: N2O OR C2F6
BUFFER FLUID: Hg
HYDRAULIC FLUID: DURATHERM 450

No.	Revision/Issue	Date

Drawing Name
PS-TGT-14-002
ANL BUBBLE CHAMBER

Project Name and Address

Area | Stamp

Drawing Number
TGT502-1000-0000

Author
D. Meekins

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