Experiment Safety Assessment Document (ESAD)
for
Experimental Hall C Base Equipment

May 17, 2022

Contents

Chapter 1

Introduction

The ESAD document describes identified hazards of an experiment and the measures taken to eliminate, control, or mitigate them. This document is part of the CEBAF experiment review process as defined in Chapter 3120 of the Jefferson Lab EHS manual, and will start by describing general types of hazards that might be present in any of the JLab experimental halls. This document then addresses the hazards associated with subsystems of the base equipment of the experimental hall and their mitigation. Responsible personnel for each item is also noted. In case of life threatening emergencies call 911 and then notify the guard house at 5822 so that the guards can help the responders. This document does not attempt to describe the function or operation of the various subsystems. Such information can be found in the experimental hall specific Operating Manuals.

Chapter 2

General Hazards

2.1 Radiation

CEBAF's high intensity and high energy electron beam is a potentially lethal direct radiation source. It can also create radioactive materials that are hazardous even after the beam has been turned off. There are many redundant measures aimed at preventing accidental exposure of personnel to the beam or exposure to beam-associated radiation sources that are in place at JLab. The training and mitigation procedures are handled through the JLab Radiation Control Department (RadCon). The radiation safety department at JLab can be contacted as follows: For routine support and surveys, or for emergencies after-hours, call the RadCon Cell phone at 757-876-1743. For escalation of effort, or for emergencies, the RadCon manager (Keith Welch) can be reached as follows: Office: 757-269-7212, Cell: 757-876-5342.

Radiation damage to materials and electronics is mainly determined by the neutron dose (photon dose typically causes parity errors and it is easier to shield against). Commercial-off-the-shelf (COTS) electronics is typically robust up to neutron doses of about $10^{13} n/\text{cm}^2$. If the experimental equipment dose as calculated in the RSAD is beyond this damage threshold, the experiment needs to add an appendix on "Evaluation of potential radiation damage" in the experiment specific ESAD. There, the radiation damage dose, potential impact to equipment located in areas above this damage threshold as well as mitigating measures taken should be described.

2.2 Fire

The experimental halls contain numerous combustible materials and flammable gases. In addition, they contain potential ignition sources, such as electrical wiring and equipment. General fire hazards and procedures for dealing with these are covered by JLab emergency management procedures. The JLab fire marshal (Tim Minga) can be contacted at 757-269-7310.

2.3 Electrical Systems

Hazards associated with electrical systems are the most common risk in the experimental halls. Almost every sub-system requires AC and/or DC power. Due to the high current and/or high voltage requirements of many of these sub-systems they and their power supplies are potentially lethal electrical sources. In the case of superconducting magnets the stored energy is so large that an uncontrolled electrical discharge can be lethal for a period of time even after the actual power source has been turned off. Anyone working on electrical power in the experimental Halls must comply with Chapter 6200 of the Jefferson Lab EHS manual and must obtain approval of one of the responsible personnel. The JLab electrical safety point-of-contact (Tim Fitzgerald) can be reached as follows: Office: 757-269-7052, Cell 619-392-9876 or tfitzger@jlab.org.

2.4 Mechanical Systems

There exist a variety of mechanical hazards in all experimental halls at JLab. Numerous electro-mechanical sub-systems are massive enough to produce potential fall and/or crush hazards. In addition, heavy objects are routinely moved around within the experimental halls during reconfigurations for specific experiments.

Use of ladders and scaffold must comply with Chapter 6132 of the Jefferson Lab EHS manual. Use of cranes, hoists, lifts, etc. must comply with Chapter 6141 of the Jefferson Lab EHS manual. Use of personal protective equipment to mitigate mechanical hazards, such as hard hats, safety harnesses, and safety shoes are mandatory when deemed necessary. The JLab technical point-of-contact (Suresh Chandra) can be contacted at 269-7248.

2.5 Strong Magnetic Fields

Powerful magnets exist in all JLab experimental halls. Metal objects being attracted by the magnet fringe field, and becoming airborne, possibly injuring body parts or striking fragile components resulting in a cascading hazard condition. Cardiac pacemakers or other electronic medical devices may no longer function properly in the presence of magnetic fields. Metallic medical implants (non-electronic) being adversely affected by magnetic fields. Lose of information from magnetic data storage driver such as tapes, disks, credit cards may also occur. In case of questions or concerns contact Jennifer Williams as follows: Office 757-269-7882, Cell 757-240-0031.

2.6 Cryogenic Fluids and Oxygen Deficiency Hazard

Cryogenic fluids and gasses are commonly used in the experimental halls at JLab. When released in an uncontrolled manner these can result in explosion, fire, cryogenic burns and the displacement of air resulting in an oxygen deficiency hazard, ODH, condition. The hazard level and associated mitigation are dependent on the sub-subsystem and cryogenic fluid. However, they are mostly associated with cryogenic superconducting magnets and cryogenic target systems. Flammable cryogenic gases used in the experimental halls include hydrogen and deuterium which are colorless, odorless gases and hence not easily detected by human senses. Hydrogen air mixtures are flammable over a large range of relative concentrations: from 4% to 75% H_2 by volume. Non-flammable cryogenic gasses typically used include helium and nitrogen. Contact Jennifer Williams at 757-269-7882 in case of questions or concerns.

2.7 Vacuum and Pressure Vessels

Vacuum and/or pressure vessels are commonly used in the experimental halls. Many of these have thin Aluminum or kevlar/mylar windows that are close to the entrance and/or exit of the vessels or beam pipes. These windows burst if punctured accidentally or can fail if significant over pressure were to exist. Injury is possible if a failure were to occur near an individual. All work on vacuum windows in the experimental halls must occur under the supervision of appropriately trained JLab personnel. Specifically, the scattering chamber and beam line exit windows must always be leak checked before service. Contact Will Oren 757-269-7344 (Cell 757-719-3123) for vacuum and pressure vessels issues.

2.8 Hazardous Materials

Hazardous materials in the form of solids, liquids, and gases that may harm people or property exist in the JLab experimental halls. The most common of these materials include lead, beryllium compounds, and various toxic and corrosive chemicals. Safety Data Sheets (SDS) for hazardous materials in use in the Hall is available from the Hall safety warden. Handling of these materials must follow the guidelines of the EH&S manual. Machining of lead or beryllia, that are highly toxic in powdered form, requires prior approval of the EH&S staff. Lead Worker training is required in order to handle lead in the Hall. In case of questions or concerns, the JLab hazardous materials specialist (Scott Conely) can be contacted as follows: Office: 757-269-7308, Cell: 757-814-6472.

2.9 Lasers

High power lasers are often used in the experimental areas for various purposes. Improperly used lasers are potentially dangerous. Exposure to laser beams at sufficient power levels may cause thermal and photochemical injury to the eye including retina burn and blindness. Skin exposure to laser beams may induce pigmentation, accelerated aging, or severe skin burn. Laser beams may also ignite combustible materials creating a fire hazard. At JLab, lasers with power higher than 5 mW (Class 3B) can only be operated in a controlled environment with proper eye protection and engineering controls designed and approved for the specific laser system. Each specific laser systems shall be operated under the supervision of a Laser System Supervisor (LSS) following the Laser Operating Safety Procedure (LOSP) for that system approved by the Laboratory Laser Safety Officer (LSO). The LSO (Jennifer Williams) can be reached as follows: Office 757-269-7882 or Email jennifer@jlab.org.

Chapter 3

Hall Specific Equipment

3.1 Overview

The following Hall C subsystems are considered part of the experimental endstation base equipment. Many of these subsystems impose similar hazards, such as those induced by magnets and magnet power supplies, high voltage systems and cryogenic systems. Note that a specific sub-system may have many different hazards associated with it. For each major system, the hazards, mitigations, and responsible personnel are noted.

The material in this chapter is a subset of the material in the full Hall C operations manual [1] and is only intended to familiarize people with the hazards and responsible personnel for these systems. It in no way should be taken as sufficient information to use or operate this equipment.

3.2 Checking Tie-in To Machine Fast Shutdown System

In order to make sure that hall equipment that should be tied into the machine fast shutdown (FSD) system has been properly checked, the hall work coordinator must be notified by e-mail prior to the end of each installation period by the system owner that the checks been performed in conjunction with accelerator (i.e. checking that equipment's signals will in fact cause an FSD). These notifications will be noted in the work coordinator's final check-list has having been done. System owners are responsible for notifying the work coordinator that their system has an FSD tie-in so it can be added to the check-list.

3.3 Beamline

The control and measurement equipment along the Hall C beamline consists of various elements necessary to transport beam with the required specifications onto the reaction target and the dump and to simultaneously measure the properties of the beam relevant to the successful implementation of the physics program in Hall C.

The beamline in the Hall provides the interface between the CEBAF accelerator and the experimental hall. All work on the beamline must be coordinated with both physics division and accelerator division; in order to ensure safe and reliable transport of the electron beam to the dump.

3.3.1 Hazards

Various hazards can be found along the beamline. These include radiation areas, vacuum windows, electrical hazards, magnetic fields and conventional hazards.

3.3.2 Mitigations

All magnets (dipoles, quadrupoles, sextupoles, beam correctors) and beam diagnostic devices (BPMs, scanners, Beam Loss Monitor, viewers) necessary for the transport of the beam are controlled by Machine Control Center (MCC) through EPICS [2], except for special elements which are addressed in the subsequent sections. The detailed safety operational procedures for the Hall C beamline should be essentially the same as the one for the CEBAF machine and beamline.

Personnel who need to work near or around the beamline should keep in mind the potential hazards:

- Radiation “Hot Spots” - marked by ARM or RadCon personnel,
- Vacuum in the beam line tubes and other vessels,
- Thin windowed vacuum enclosures (e.g. the scattering chamber),
- Electric power hazards in vicinity of the magnets,
- Magnetic field hazards in vicinity of the magnets, and
- Conventional hazards (fall hazard, crane hazard etc.).

These hazards are noted by signs and the most hazardous areas along the beamline are roped off to restrict access when operational. In particular, the scattering chamber, with it’s large volume and thin windows requires hearing protection once it has been evacuated. Signs are posted by RadCon for any hot spots along the beamline and RadCon must be notified before work is done in a posted area.

Where appropriate (such as for the Møller polarimeter magnets), magnet leads are covered with plastic guards for electrical safety.
Additional safety information is available in the following documents:

– EH&S Manual [3];
– Personnel Safety System procedures [4–6];
– Accelerator Operations Directive [7];

3.3.3 Responsible Personnel

Since the beamline requires both accelerator and physics personnel to maintain and operate and it is very important that both groups stay in contact that any work on the Hall C beamline is coordinated.

Name (first,last)	Dept.	Call [8]		e-mail	Comment
		Office	Cell		
Hall C Physicists					
Dave Gaskell	Hall-A/C	6092	757-719-5482	gaskelld@jlab.org	*1st Contact*
Mark Jones	Hall-A/C	7733		jones@jlab.org	*2nd Contact*
Liaisons from Accelerator Division					
Jay Benesch	Accel.	6505	757-289-3983	benesch@jlab.org	..to Hall-C
Bert Manzlak	ESH&Q	7556	757-897-2651	manzlak@jlab.org	..to Physics

Table 3.1: Beamline physics division and accelerator division points-of-contact.

3.4 Raster Systems

The Hall C beamline includes two raster systems permanently installed. These systems, the Møller Raster (MR) and the Fast Raster (FR), rapidly move the beam position on the Møller Polarimeter target and the Hall C target, respectively, in order to prevent possible damage to the target by overheating. A third raster system (the slow raster) can be installed for use with polarized targets and is not part of the "standard" beamline. The Møller raster is only used in special circumstances and operated under the auspices of a test plan or TOSP. The FR serves to reduce boiling and uncertainties in target thickness for cryogenic targets. The beam rastering is done with with vertical and horizontal air-core magnets that are driven by AC currents from a 250 W audio amplifier. The fast raster coils are shielded with a Plexiglas cage and a "Magnet On" sign indicates the presence of current in the raster coils. No DC fields exist when these magnets are operated and no remnant field remains when the current is switched off.

The Møller raster magnets are located on the accelerator side of the beamline shield wall (on the 3C07 girder) so are not normally accessible from Hall C.

The following conditions lead to a fast shutdown of the raster devices:

- Crate power failure
- Magnets power failure
- Overcurrent detection (short occurs inside the magnets)
- Over temperature
- Detection of missing cycles or improper frequency

- VME system reset
- Phase-lock network is broken

The FR power drivers have an automatic fault display and shutdown. The signals are also sent to FSD.

The following Reference Documents exist:

- Requirement for beam raster monitor for the beam dump and target, R. C. Cuevas, C. Yan, 12 July, 1995
- Technical requirement for Hall C beam dump raster, C. Yan, June 24, 1995, JLab-R-94-02
- Møller Raster Manual [9]

3.4.1 Hazards

The primary hazards associated with the updated fast raster system are electrical and are addressed in the accompanying OSP.

3.4.2 Mitigations

The electrical hazards are mitigated by enclosing the raster coils in Plexiglas covers while the raster power supplies are stored in a protective enclosure nearby. Only qualified personnel should access the power supplies or coils. The mitigations of this updated system are addressed in the accompanying OSP.

3.4.3 Responsible Personnel

Points of contact for the fast raster system are listed in the Tab. 3.2.

Name (first,last)	Dept.	Call [8]		e-mail	Comment
		Office	Cell		
Mark Jones	Hall-A/C	7733		jones@jlab.org	Primary Contact
William Gunning	Fast Electronics	5017		gunning@jlab.org	Secondary Contact

Table 3.2: Fast Raster responsible personnel

3.5 Møller Polarimeter

The Møller Polarimeter integrates beamline elements (magnets and vacuum systems) with particle detector systems. Typical hazards for both types of systems are present.

3.5.1 Hazards

There are several specific hazards (potentially beyond those found in the accelerator beamline) associated with the Møller Polarimeter. These include:

1. Radiation areas: These are potentially caused by use of the Møller using thick targets, at higher than normal currents, or at low energies.

2. Vacuum windows: There are thin vacuum windows at the ends of the Møller detector legs.

3. Electrical hazards: These exist in the vicinity of the magnet leads, as well as the detector high voltage.

4. Magnetic fields from the quadrupole and solenoid magnets.

5. Lead: The detectors are shielded using painted lead bricks.

3.5.2 Mitigations

The special hazards associated with the Hall C Møller are mitigated as described below.

1. Potential radiation areas are surveyed and posted before access to the hall is permitted after beam operations.

2. The thin vacuum windows at the end of the Møller legs are mitigated by shields that prevent inadvertent punctures of the window. If work near the exit windows (this includes the downstream half of the blue platform on which the Møller detectors sit) is required, hearing and eye protection is required.

3. Electrical hazards due to magnet leads are mitigated using Plexiglas shields where appropriate. The Møller detectors use standard SHV connectors.

4. Red blinking lights alert users to the presence of magnetic fields.

5. Before removing lead bricks to access detectors, contact the JLab Industrial Hygiene group to mitigate any possible lead exposure.

Additional safety information is available in the following documents:

- EH&S Manual [3];
- Accelerator Operations Directive [7];

3.5.3 Responsible Personnel

Points of contact for the Hall C Møller Polarimeter are listed in the Tab. 3.3.

Name (first,last)	Dept.	Call [8]		e-mail	Comment
		Office	Cell		
Hall C Physicists					
Dave Gaskell	Hall-A/C	6092	757-719-5482	gaskelld@jlab.org	*1st Contact*
William Henry	Hall-C	6989		wmhenry@jlab.org	*2nd Contact*

Table 3.3: Møller Polarimeter points of contact.

3.6 Cryogenic Target System

The Hall C cryotarget system allows for multiple configurations depending on the requirements of the experiment(s). In the standard configuration, the system has three separate target loops. One of these loops is used as a spare, and contains ^{4}He gas usually pressurized up to ∼30 psia. The other two loops are usually used for liquid hydrogen and deuterium targets. Each loop can have one or two target cells, which is again dependent on experiment requirements. Below the loops, solid targets such as carbon foils can be added.

A wealth of information about the Hall C cryotarget system is available at https://userweb.jlab.org/~smithg/target/Qweak/. At that location links to the target training talk can be found, as well as contact numbers for the target experts, a guide to the control system (GUIs), a FAQ, descriptions of the essential responsibilities and how-tos for the target, the operational restrictions (current and raster limits) for each target, the slow controls archiver, and much more.

It is *mandatory* to have an audible alarm handler, ALH, running at all times when the target gas has been condensed. Further, it is *mandatory* that the alarm handler be visible in all work spaces on the target control computer and "on top" of other GUIs. It is further mandatory that all alarms be "serviced" in the sense that each alarm must be investigated. No alarm may ever be ignored. While engineered controls ensure personnel and equipment safety, the alarm handler can save the experimenter lots of time, grief and potentially prevent problems with data. The ALH will alarm if any of its parameters go out of normal range. Servicing the alarm is the responsibility of the target operator. At high beam currents, the ALH may alarm when the beam goes from on to off or from off to on, if the high power heater does not respond quickly enough to the change in the beam heat load, or if there is insufficient reserve heater power available. The ALH can also repeatedly alarm if there are noisy analog channels. If the AH alarms repeatedly or the cause of the alarm is not clear, the target operator should contact the on-call target expert.

3.6.1 Hazards

The cryogenic hydrogen and deuterium targets present a number of potential hazards, such as fire/explosion hazard of the flammable gas as well as the hazards connected with the vacuum vessel and cryogenic liquids (ODH and high pressure). The target system benefits from many years of experience using it at Jefferson Lab. Hazards, mitigation measures, and causes and corrective measures associated with past failures are described in the "Hydrogen Target Safety Assessment Document" at https://polweb.jlab.org/hallc/Cryotarget/Target%20Safety%20Assessment%20Document1.5.doc.

3.6.2 Mitigations

Flammable Gas The basic idea behind safe handling of any flammable or explosive gas is to eliminate oxygen (required for burning) and to prevent exposure to any energy source that could cause ignition. In the Hall C environment, the most likely source of oxygen is of course the atmosphere and the most likely ignition sources are from electrical equipment. Oxygen is removed from the internal volumes of the system by pumping and purging the system. Extensive procedures reviewed by an independent expert are used to perform this task. This task shall only be performed by system experts.

Gas Handling System The most important aspect of hydrogen safety is to minimize the possibility of explosive mixtures of hydrogen and oxygen occurring. Therefore the gas handling system has been made of stainless steel components (wherever possible) and as many junctions as possible have been welded. Flanged connections are made with metal seals where possible. Reasonable measures have been implemented to ensure that the system pressure does not fall near or below atmospheric pressure.

The pressure in the gas handling system is monitored in numerous places. Most importantly, the absolute pressure of the target is viewed by two pressure transducers, one on the fill line, PT127 for H_2 and PT136 for D_2, and one on the return line, PT131 for H_2 and PT140 for D_2. These pressures are also measured by manual gauges. The fill line gauges are PI126 for H_2 and PI135 for D_2. The return line gauges are designated PI130, H_2 and PI139, D_2. The gas tanks are viewed with both pressure transducers (PT133 for hydrogen and PT142 for deuterium) and pressure gauges (PI123 for hydrogen and PI112 for deuterium).

If the pressures significantly deviate either from one another or from the normal operating pressure, the target operator shall call the target-expert-on-call. When they differ from one another, it often is due to a failure of one (or more) of the pressure transducers. If more than one deviates significantly from the normal operating pressure, it could be due to temperature change or could be a more serious situation (i.e. a leak in the system).

The target system is considered by JLab to be a pressure system which must be in compliance with the requirements of ESH&Q Manual Chapter 6151. This is a legacy system where the original design and construction was not in full compliance with the applicable ASME pressure Codes. A JLab Design Authority shall be responsible for all alterations and repairs to this system which shall meet the requirements given in Chapter 6151. All currently used cells and cell blocks also meet the requirements of ASME B31.3. Overpressure protection of all piping components is also in full compliance with ASME B31.3 The large volume storage tanks located outside the Hall also meet the requirements of the ASME Boiler and Pressure Code Section VIII Division 1 and bear a valid ASME nameplate. These tanks are inspected on a regular basis and currently meet the National Board NB-23 Code requirements. Overpressure protection of these vessels is in full compliance with the appropriate division and edition of the ASME BPVC VIII.

Target Cells The target cells themselves represent the most likely failure point in the hydrogen system. The outer wall is made of 0.006 *in* thick aluminum. The entrance and exit windows are thinner, but no less than 0.004 *in*. There is typically one 15 *cm* long cell bolted on to each cell block. The cell has an outer diameter of (typically) 3 inches. The upstream windows are connected to 0.8 *in* diameter tubes with flanges which are also bolted on to the cell block. A vertical flow diverter plays a role to make the coolant flow in the vertical direction to help remove the beam heating more effectively. The cell and cell block are piping components and have been designed, fabricated, examined, and tested in compliance with ASME B31.3 (2014) The design pressure of the current cell is 100 psi. Overpressure protection is in compliance with ASME B31.3 322.6.3 which allows for an accumulated overpressure of 120% of the design pressure.

Pressure Relief The gas handling and control systems have been designed to prevent excessive pressure build up in the system in order to protect the target cells from overpressure and rupture. It has been determined that the worst case pressure load will arise from an insulating vacuum loss. The calculation of this load was reviewed by a JLab Design Authority not associated with the target group. Under normal conditions, i.e. vacuum loss with unobstructed return path to storage vessel, the target safely relieves to the storage vessel. Overpressure protection, in the form of a reclosing ASME relief valve, for the target loops (including cells) in compliance with ASME B31.3 322.6.3 is provided on both the supply and return of each loop. These reliefs exhaust to a dedicated hydrogen exhaust system. The estimated relief load is 350 scfm of hydrogen The capacity of each relief is 1100 scfm for hydrogen. The hydrogen exhaust line is 2 inch Sch 10s IPS stainless steel pipe by an end of line vent. This line is maintained at a positive pressure of 1.5 psig using the 4 atm He system. The scattering chamber and pump/purge vacuum pumps are also exhausted to this line. Thus any vented target gas is placed in an inert environment until it is released outside of Hall C.

Scattering Chamber Vacuum The scattering chamber will be leak checked before service, but the possibility of vacuum loss cannot be eliminated. A conservative calculation estimating the relief load on the relief system of each loop has been performed. This calculation was performed as part of Code and JLab policy requirements and was reviewed by an independent JLab Design Authority. This calculation (TGT-CALC-301-010) has been filed in the Hall C Cryotarget pressure system directory PS-TGT-XX-026. In summary, this calculation conservatively indicates that the relief path and safety devices limit the maximum developed pressure in the cell to less than the 120 psi for all credible overpressure conditions as required by ASME B31.3 322.6.3.

Target Freezing Solid hydrogen is more dense than the liquid phase, so freezing does not endanger the mechanical integrity of a closed system. The chief hazard is that relief routes out of the system will become clogged with hydrogen ice, making the behavior of the system during a warm-up unpredictable. For this reason, the relief route bypasses the heat exchanger and should not freeze during any credible scenario.

In the unlikely event that the target temperature drops too low, an alarm will sound and the target operator shall turn down the corresponding J-T valve(s) or apply auxiliary heater power. Target temperature can fall after target IOC reboot. After the reboot the high power heater will be reset to zero before going back to PID control. Although the time the high power heater is zero is short (for about 1 minute), the temperature will drop. To prevent this from happening, an auxiliary heater is used in parallel to the regular heater. During an IOC reboot, the auxiliary heater supply will replace the main supply to keep the temperature from dropping unacceptably. Since 2008, the IOC has been relocated to the entry labyrinth where the radiation exposure has been minimized. As a result the frequency of IOC reboots has dramatically decreased.

ODH The total volume of the targets is relatively small, with the entire scattering chamber containing only 12000 STP l of target gas when all three targets are full. As the scattering chamber is located in the middle of Hall C (i.e. not in a confined area) and the total Hall C volume is 26,000 m^3 (40,000 m^3 for Hall A), the ODH hazard is minimal. In the event that all the H2 was released into the hall, the oxygen content would drop from 21.0% to 20.99%.

Further Reading More detailed information about the mitigations discussed above can can be found in the full Hall C operations manual [1].

3.6.3 Responsible Personnel

The principle contacts for the cryogenic targets were listed in table 3.4. Every shift must have a trained target operator whenever the cryogenic targets contain liquid. These operators are trained by one of the "experts" listed in the table and certified by J.P. Chen, Silviu Covrig, or Greg Smith. If the target operator suspects issues with the ESR are impacting the target, the target expert on call should be called first. The target expert may then recommend that the cryo expert on call be contacted through the MCC.

3.7 Hall C Spectrometers

3.7.1 Hazards

The spectrometers have associated vacuum, electrical, cryogenic and magnet systems all of which can be extremely dangerous due to the size and stored energy in the systems. Parts of the spectrometers are at elevated levels which would present fall hazards if the installed safety equipment were not present. Hazards of rotating the spectrometers as

Name (first,last)	Dept.	Call [8]		e-mail	Comment
		Office	Cell		
Hall C Technicians					
Tech-on-Call	Hall-C	W.B.			Vacuum
Hall A/C Physicists					
Cryotarg-on-Call	Hall-C	W.B.			Cryotarget
Greg Smith	Hall-A/C	5405		smithg@jlab.org	Cryotarget
Silviu Covrig	Hall-A/C	6410		covrig@jlab.org	Cryotarget
Jian-Ping Chen	Hall-A/C	7413		jpchen@jlab.org	Cryotarget
JLab Cryo-Target Group					
Dave Meekins	Physics	5434		meekins@jlab.org	
Christopher Keith	Physics	5878		ckeith@jlab.org	
Central Helium Liquefier (CHL) Experts					
Cryo-on-Call		5822			via Guard Shack
CHL-group	Cryo	7405			ESR

Table 3.4: Cryo target: authorized personnel and contacts. "W.B." stands for the white board in Counting House.

well as the particle detectors that get placed inside the detector hut of the spectrometer are covered in detail in following sections.

Signage and alerts are placed to remind workers of some of the potential hazards in Hall C, but each individual is ultimately responsible for his or her own safety. Always read and respect warning signs, and never attempt to circumvent barriers or other equipment that has been installed for your protection. If you discover what appears to be a new or unidentified hazard, protect your coworkers by warning them and alert the Hall-C management and Safety Warden.

3.7.2 Mitigations

Both of the spectrometers have elevated work platforms that are secured by gates and handrails. Never attempt to bypass these protections. During experiment running periods, in order to allow spectrometer rotation, it may be necessary to remove the handrails around the target platform. In this condition access to the target platform is restricted to trained individuals who have been specifically authorized to work near there. Fall-protection equipment is required.

The vacuum systems associated with the spectrometers are essentially pressure vessels and care should be exercised so as not to damage or puncture the vacuum windows. The large vacuum windows inside the two shield houses are protected by shutters which must be lowered into place before the access door to the detector rooms will open. (When the Noble-Gas Cherenkov (NGC) is installed in the SHMS, the NGC itself protects the vacuum window and the shutter is not present.) During hall maintenance, covers are placed over the spectrometer vacuum windows near the pivot to help prevent anything from accidentally hitting a window. Hearing protection may be required when you work near a vulnerable vacuum window. As conditions may change, please take note of currently posted warning signs and instructions.

The magnets themselves are installed inside cryostats. These vessels are exposed to high pressures and are therefore equipped with safety relief valves and burst discs.

The cryogenic system operates at an elevated pressure and at temperatures about 4 Kelvin (helium system) and about 90 Kelvin (nitrogen system). One must guard against cold burns and take the normal precautions with pressure vessels when operating or working near this system. Manipulation of any cryogenic system component such as a U-Tube or manual valve may only be performed by a trained cryogenic-system expert.

When they are powered, the magnets have a great deal of stored energy as they are large inductors. Always make sure people are clear of the magnets and their dump resistors.

3.7.3 Responsible Personnel

In the event that problems arise during operation of the spectrometers, qualified personnel should be notified (see Table 3.5). This includes any prolonged or serious problem with the source of magnet cryogens (the ESR). On weekends and after hours there will be a designated individual on call for magnet services. Any member of the Hall C technical staff is qualified to deal with unusual magnet situations but in the event of serious problems the person on call should be contacted.

Name (first,last)	Dept.	Call [8]		e-mail	Comment
		Office	Cell		
Tech-on-Call	Hall-C	W.B.			*Contact*
Steve Lassiter	Hall-C	7129	252-340-1845	lassiter@jlab.org	
Joe Beaufait	Hall-A/C	7131	757-256-2776	beaufait@jlab.org	
Jack Segal	Hall-A/C	7242	Web [10]	segal@jlab.org	
Heidi Fansler	Hall-A	6915	Web [10]	fansler@jlab.org	

Table 3.5: List of spectrometer responsible personnel where "W.B." stands for the white board in the counting house.

3.8 SHMS Fringe Fields and Small Spectrometer Angles

The horizontal bender (HB) and second quadrupole (Q2) of the SHMS have significant fringe fields. At small scattering angles and sufficiently high fields, these fringe fields may deflect the electron beam beyond acceptable limits at the dump and/or trip dump ion chambers. To minimize beam deflection and beam interruptions, magnetic shielding will be installed to minimize the deflection of the beam and an accelerator test plan will be executed at the start of the run to determine any restrictions on SHMS angles and fields.

Under certain combinations of angles and magnet settings, determined from this test plan, the shift crew will be required to notify MCC before making changes to the spectrometer angle or magnet fields and follow a prescribed procedure. This procedure may include requesting tune (pulsed) beam and masking the dump ion chambers FSD while new SHMS spectrometer settings are established.

Independent of fringe field considerations, when the HMS and SHMS angles are below certain limits, or the sum of the HMS and SHMS angles is below a certain limit, angle changes will require spotters in the Hall to watch for spectrometer/beamline and spectrometer/spectrometer interferences.

3.9 Spectrometer Carriage and Rotation Systems

The Carriage is the support structure of the spectrometer.

Each entire spectrometer can be rotated. Rotation is driven by motors mounted near one of the sets of wheels. These motors are controlled by synchronous pulse width modulated drives which are mounted near the bottom of the shield house steps on the HMS, and under the rear of the SHMS structure.

Since the Hall C spectrometers each weigh hundreds of tons, it is very important that all safety precautions are carefully adhered to. During operations, the spectrometers are certified to allow remote rotation by shift crews within prescribed limits. In the absence of this certification, the spectrometers may only be rotated by trained technical staff.

3.9.1 Hazards

Hazards include:

- Knocking items over during spectrometer movement.
- The wheels crushing things (including fingers and toes) on the floor in the path of the spectrometer
- Damaging the beamline or other equipment on the floor if one goes to too small or too large an angle. There is only a small gap between the rear of the SHMS shield house and the shielding wall behind it.
- Tearing out of cables etc. physically attached to the superstructure
- Elevated platforms on the spectrometer carriages.
- Magnetic fields. Spectrometer magenets may be energized under either local or remote control.

3.9.2 Mitigations

Hazard mitigations:

- Stop-blocks attached to the rails to prevent spectrometer rotation beyond the needed angular range for each experiment.
- During experiments, the spectrometers are certified for rotation by shift crews within specied angle ranges. Spectrometer movement at other times may only be performed by authorized personnel.
- Hand rails are installed to prevent falls. Access is only allowed to areas on the carriage protected by hand rails.
- Hard hats may be required under certain conditions when working on or near the spectrometer carriages.
- Magnetic fields hazards are indicated by either red flashing lights and/or illuminated **Magnet on** signs.

3.9.3 Responsible Personnel

Following the experimental run plan, as posted in the counting house by the run coordinator, shift workers are allowed to rotate the Hall C Spectrometers following guidelines of the standard equipment manual. In the event of a problem getting the spectrometers to rotate the run coordinator should notified. If the run coordinator is unable to solve the problem, and with the run coordinators concurrence, qualified personnel should be notified to repair the problem (see Table 3.6).

Name (first,last)	Dept.	Call [8]		e-mail	Comment
		Office	Cell		
Tech-on-Call	Hall-C	W.B.			*Contact*
Steve Lassiter	Hall-C	7129	252-340-1845	lassiter@jlab.org	
Amy Comer	Hall-C	6064		acomer@jlab.org	
Walter Kellner	Hall-C	5512	757-592-1527	kellner@jlab.org	
Joe Beaufait	Hall-A/C	7131	757-256-2776	beaufait@jlab.org	

Table 3.6: List of Spectrometer Rotation responsible personnel where "W.B." stands for the white board in the counting house.

3.10 Detector High Voltage

All of the detector systems in Hall C use high voltages, from hundreds to several thousand volts, to either power photomultiplier tubes or maintain electric fields around sense wires in drift chambers. These include scintillators, drift chambers, scintillators, shower detectors, and aerogel Cherenkovs.

3.10.1 Hazards

The personnel hazard with these devices is the high voltage. This qualifies as a Class I electrical hazard due to the supplies providing voltage >50 VDC with current limited to $\leq 5\,\text{mA}$.[1] This same hazard can damage phototubes if voltage is left on when tubes are exposed to room lighting.

3.10.2 Mitigations

- All user configurable high voltage cabling/patching is made with coaxial cables rated for high voltage with SHV connectors.
- High voltage shall be turned off before disconnecting (or connecting) high voltage cables from (or to) phototubes, power supplies or patch panels.
- High voltage shall be turned off and high voltage cables shall be removed from phototubes before handling phototubes or the detector elements they are used with.
- Current limits are set on power supplys to trip high voltage in case of shorts or shocks.
- External metal parts of detectors such as mu-metal shields are wrapped with electrical tape. Exposed metal parts are grounded through both the HV cable and signal cable grounds.

3.10.3 Responsible Personnel

The individuals responsible for the operation of the high voltage system are shown in Table 3.7.

Name (first,last)	Dept.	Call [8]		e-mail	Comment
		Office	Cell		
Brad Sawatzky	Hall-A/C	5947	757-344-2494	brads@jlab.org	
Joe Beaufait	Hall-A/C	7131	757-256-2776	beaufait@jlab.org	
Jack Segal	Hall-A/C	7242	Web [10]	segal@jlab.org	

Table 3.7: Detector high voltage responsible personnel.

[1] JLab ES&H Manual, Chapter 6230 - Appendix T1 - “Determining Equipment Class and Work Modes”

3.10.3.1 High Voltage System Checkout

Before starting an experiment, or before using the high voltage system to test detectors, proper functioning of the HV supplies and EPICS controls should be verified with this checklist.

- Check EPICS: Using the EPICS Control system as described in the CAEN HV Operation Howto [11], verify that voltage set points and current/voltage limits are read by the control system.
- Verify Operation: For the detector(s) of interest, individually turn on each channel. Verify that the channel reaches the desired set voltage. If the readback voltage exceeds the set voltage by more than a few volts (Overvoltage), or fails to reach full voltage (Undervoltage), immediately turn off the channel, report the observation in the logbook and consult an expert.
- Verify Limits: Make a backup of HV settings. For each channel in the detector, set a current limit below the current being drawn by the detector channel. Verify that each channel trips. Similarly, set a maximum voltage for each channel below the set point and verify that the voltage limit is enforced. (This may change voltage set points, so they may need to be restored from backup.) Consult an expert if any channels fail to trip on overcurrent or if maximum voltage is not enfored.
- Interlocks: If any high voltage systems are interlocked with other systems, verify that assertion of the interlock signal turns off high voltage.

3.11 Detector Gas Supply System

The Hall C wire chamber gas mixing system is located in the gas shed located to the left of the counting house (when facing the counting house) in the parking lot between the counting house and the accelerator service building (building 96C). The SHMS gas sysystem for the SHMS Noble Gas Cherenkov is also located in this shed. The gas cylinders in use are along the outside of the Gas Shed in a fenced area. There are racks next to the Gas Shed for storage of full gas cylinders. Hall C currently uses ethane, argon, ethanol, carbon dioxide, nitrogen and neon.

3.11.1 Hazards

Some of the gases that are used are flammable. Also, the gas bottles are under high pressure and can become missiles.

3.11.2 Mitigations

The bottles are located in a fenced area next to the gas shed with the bottles secured so that they can not fall.

In the Hall C counting house, alarms for the gas system are integrated into the VESDA system located on the left side of the control console. The VESDA system will go into alarm if elevated levels of flammable gas are present in either of the two spectrometer detector huts or the gas shed. Response to an alarm should be to contact the personnel listed below.

3.11.3 Responsible Personnel

Maintenance of the gas systems is routinely performed by the Hall c technical staff. Shift personnel are not expected to be responsible for maintaining the detector gas systems (see Table 3.8 for the names of persons to be contacted in case of problems).

Name (first,last)	Dept.	Call [8]		e-mail	Comment
		Office	Cell		
Tech-on-Call	Hall-C	W.B.			*Contact*
Larry Carraway	Hall-C	7342	Web [10]	larryc@jlab.org	
Jerry Nines	Hall-C			jnines@jlab.org	
Joe Beaufait	Hall-A/C	7131	757-256-2776	beaufait@jlab.org	
Jack Segal	Hall-A/C	7242	Web [10]	segal@jlab.org	

Table 3.8: Responsible personnel for detector gas system.

3.12 Drift Chambers

The Drift Chambers in the HMS and SHMS spectrometers provide a precise ($\pm 125\ \mu$m) measurement of the position and angle of incidence of particles at the respective spectrometer focal planes. This information may be combined with the knowledge of the spectrometer optics to determine the position and angle of the particles in the target.

Operation of the Hall C drift chambers requires the application of both High Voltage (HV) across the chambers themselves and Low Voltage (LV) across the preamplifier/discriminator cards, which are mounted on the sides of the drift chabmers. The chamber gas is a combination of argon (Ar) and flammable ethane (C_2H_6) which is bubbled through alcohol. Gas is routed from bottles located next to the Hall C gas shed, through the gas mixing system in the gas shed, to the chambers in the spectrometer detector huts.

3.12.1 Hazards

The following hazards are associated with the chambers:

The High Voltage System CAEN SY403 high voltage/low current power supplies provide high voltages to the chambers in the range of -1.5 kV to -2.5 kV.

Explosive Gas The Ar C_2H_6 chamber gas is explosive and must be handled accordingly. Further, gas flow should be maintained for at least 24 hours prior to the enabling of HV.

High Pressure Gas Bottles The gas used in the chambers is supplied in high pressure ($\geq$ 2000 psi) gas bottles. This confined high pressure gas represents a tremendous (potentially lethal) amount of stored energy.

3.12.2 Mitigations

For the HV, red HV RG-59/U cables good to 5 kV with standard SHV connectors are used to connect the power supply to the chamber high voltage distribution splitters on each chamber. A given chamber draws a current from 50–100 nA. When servicing the chambers, the HV for that element must be turned off and disconnected.

The high pressure gas bottles are stored far from the equipment in a controlled area as discussed in the Hall C gas handling section of the operations manual.

3.12.3 Responsible Personnel

The individuals responsible for the operation of the drift chambers are shown in Table 3.9.

Name (first,last)	Dept.	Call [8]		e-mail	Comment
		Office	Cell		
Liguang Tang	JLab/Hampton U			tangl@jlab.org	
Joe Beaufait	Hall-A/C	7131	757-256-2776	beaufait@jlab.org	
Jack Segal	Hall-A/C	7242	Web [10]	segal@jlab.org	

Table 3.9: DC responsible personnel.

3.13 Gas Cherenkov Detectors

The Hall C spectrometer include 3 gas Cherenkov detectors, the HMS Cherenkov (CER), the SHMS Noble gas Cherenkov (NGC) and the SHMS Heavy Gas Cherenkov (HGC). These detectors each contain several cubic meters of inert gas (CER: 2.7 m^3, HGC: 3.4 m^3, NGC: 3.0 m^3). The Noble gas detector operates at 1 atm with a low continuous gas flow for the Hall C gas system. The HGC and CER operate at sub-atmospheric pressure. After filling, the detectors and their gas supplies are valved off and no gas flows through the detectors.

3.13.1 Hazards

The detectors have phototubes that operate at high voltage with the HGC operating with negative HV and the CER and NGC with positive high voltage. The detectors contain inert gases.

3.13.2 Mitigations

Analysis of ODH hazards and gas filling procedures for these three detectors are discussed in their respective Operational Safety Procedures.

Voltages must be set to zero before disconnecting HV cables from the detectors. HV cables must be disconnected before replacing PMTs or bases.

3.13.3 Responsible Personnel

Maintenance of the gas Cherenkov detectors is systems is routinely performed by the Hall C technical staff and the university groups that built them. Shift personnel are not expected to be responsible for maintaining the detector gas systems (see Table 3.10 for the names of persons to be contacted in case of problems).

Name (first,last)	Dept.	Call [8]		e-mail	Comment
		Office	Cell		
Tech-on-Call	Hall-C	W.B.			*Contact*
Jack Segal	Hall-A/C	7242	Web [10]	segal@jlab.org	
Donal Day	UVA			donal@jlab.org	NGC/CER
Garth Huber	U. of Regina			huberg@jlab.org	HGC

Table 3.10: Responsible personnel for gas Cherenkov detectors.

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