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

May 23, 2014

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&Q 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 sub-systems 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 sub-systems. 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 876-1743. For escalation of effort, or for emergencies, the RadCon manager (Vashek Vylet) can be reached as follows: Office: 269-7551, Cell: 218-2733 or Home: 772-6098.

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 $10^{13} n/cm^2$. 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 protection manager (Dave Kausch) can be contacted at 269-7674.

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&Q manual and must obtain approval of one of the responsible personnel. The JLab electrical safety point-of-contact (Todd Kujawa) can be reached at 269-7006.

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 6231 of the Jefferson Lab EHS&Q manual. Use of cranes, hoists, lifts, etc. must comply with Chapter 6141 of the Jefferson Lab EHS&Q 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 functioning 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. Contact Jennifer Williams at 269-7882, in case of questions or concerns.

2.6 Cryogenic Fluids and Oxygen Deficiency Hazard

Not applicable for HPS experiment.

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 269-7344 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. Material Safety Data Sheets (MSDS) for hazardous materials in use in the Hall is available from the Hall safety warden. These are being replaced by the new standard Safety Data Sheets (SDS) as they become available in compliance with the new OSHA standards. 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 (Jennifer Williams) can be contacted at 269-7882.

2.9 Lasers

Not applicable for HPS experiment.

Chapter 3

Hall Specific Equipment

3.1 Overview

The following Hall A 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 A operations manual 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 B beamline consists of various elements necessary to transport beam with required specifications onto the production target and the beam dump, and simultaneously measure the properties of the beam relevant to the successful implementation of the physics program in Hall B.

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.

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3.3.1 Hazards

Along the beamline these various hazards can be found. These include radiation areas, vacuum windows, high voltage, and magnetic fields.

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 [1], except for special elements which are addressed in the subsequent sections. The detailed safety operational procedures for the Hall B 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 (e.g. around the HPS chicane magnets). Signs are posted by RadCon for any hot spots. Survey of the beamline and around it will be performed before work is done on the beam line or around. The connection of leads to magnets have plastic covers for electrical safety. Any work around the magnets will require de-energizing the magnets, energized magnets are noted by read flashing beacons. Any work on the magnets requires the "Lock and Tag" procedures [2] and the appropriate training, including the equipment-specific one.

Additional safety information is available in the following documents:

- EH&S Manual [2];
- PSS Description Document [3]
- Accelerator Operations Directive [4];

3.3.3 Responsible Personnel

The beamline requires both accelerator and physics personal to maintain and operate. It is very important that both groups stay in contact to coordinate any work on the Hall B beamline. The authorized personnel is shown in table 3.1.

Name (first,last)	Dept.	Call [5]		e-mail	Comment
		Tel	Pager		
F.-X. Girod	Hall-B	6002		fxgirod@jlab.org	*1st Contact*
Stepan Stepanyan	Hall-B	7196		stepanya@jlab.org	*2nd Contact*
Michael Tiefenback	Accel.	7430	757-438-4523+	tiefen@jlab.org	*Contact to Hall-B*
Hari Areti	Accel.	7187	584-	areti@jlab.org	*Contact to Physics*

Table 3.1: Hall B beamline: authorized personnel.

3.4 HPS Chicane Magnets

Dipole magnets can present magnetic and electrical hazards when they are energized. There is also hazard of an unwonted beam move due to the magnet power trip. The HPS experiment will use three magnet chicane installed on the beamline in the Hall B downstream alcove. The chicane includes the Hall B pair spectrometer magnet, an 18D36 dipole, with its vacuum chamber, and two identical H-dipoles known as "Frascati" magnets. Electron beam will pass through the magnets in the vacuum. The pair spectrometer magnet will serve as a spectrometer magnet. The two "Frascati" dipoles are to keep the deflected electron beam on the beamline to the dump. The spectrometer magnet will be powered from the Hall B pair spectrometer magnet power supply, Dthe "Frascati" magnets will be powered from so called "mini-torus" power supply, Dynapower ***.

3.4.1 Hazards

Dipole magnets can present magnetic and electrical hazards when they are energized. There is also hazard of an unwonted beam move due to the magnet power trip.

3.4.2 Mitigations

There are plastic covers on the connection panels for power leads on the magnets for electrical safety. Any work around the magnets will require de-energizing the magnets, energized magnets are noted by read flashing beacons. Any work on the magnets requires the "Lock and Tag" procedures [?]. There will be beacons installed to notify existence of the magnetic field. The magnet power supplies will be interlocked to the beam shutdown system (FSD). If any of power supplies will trip, beam delivery to Hall B will be interrupted.

3.4.3 Responsible Personal

The chicane magnets will be maintained by the Hall B engineering group.

Name	Dept.	Phone	email	Comments
Tech-on-call	Hall-B			1st contact
D. Tilles	Hall-B		tilles@jlab.org	2nd contact

Table 3.2: Personal responsible for the HPS chicane.

3.5 Target Systems

The HPS target system consists of several solid material foils mounted on a target ladder. The bottom edge of the foils mounted on the ladder is free-standing so there is no thick support frame to trip the beam when the target is inserted. Target position is adjustable vertically allowing different targets to be inserted. The support frame on the beam-right side of the target is made thin enough to prevent excessive flux of secondaries and radiation damage to the silicon detector in the event of an errant beam caused, for example, by an chicane magnet trip which will move beam to the right.

3.5.1 Hazards

There are hazards related to moving the target frame into the beam or overheating the target foils. The stepping motor linear actuator will be operated using EPICS controls, GUI for operation of the target will have preset coordinates for each target foil. The tungsten targets are intended to operate with beam currents up to 500 nA, which produce strong local heating. The strength of tungsten drops by an order of magnitude with temperature increases in the range of 1000 C. In addition, the material re-crystallizes above this range, which increases the tendency for cracking where thermal expansion has caused temporary dimpling.

3.5.2 Mitigations

There will be limit switches (hard stops) that will prevent motion of the target ladder outside of allowed range if EPICS set values are wrong. To keep the temperature rise less than about 1000 degrees is accomplished by selecting an adequately large beam spot area. There will be overall beam current limit of 500 nA for the experiment.

3.5.3 Responsible Personal

The target system will be maintained by the Hall B engineering group.

Name	Dept.	Phone	email	Comments
Tech-on-call	Hall-B			1st contact
D. Tilles	Hall-B		tilles@jlab.org	2nd contact
C. Field	SLAC		sargon@slac.stanford.edu	contact

Table 3.3: Personal responsible for the target.

3.6 Vacuum Systems

The Hall B vacuum system consists of three segments, all interconnected. The beam transport line consisting of 1.5 to 2.5 inch beam pipes, the Hall B tagger magnet vacuum chamber, and the set of vacuum chambers through the HPS detector system. Only tagger vacuum chamber has a large window, 8 inches over 30 ft Kevlar-Mylar composite window. There is a 2.5 in diameter 7 mil Kapton window at the end of the HPS detector vacuum system, before the shielding wall, that is normally unaccessible. The vacuum in the system is provided by a set of rough, turbo, and ion pumps and it is maintained at the level of better than 10^{-5} Torr.

3.6.1 Hazards

Hazards associated with the vacuum system are due to rapid decompression in case of a window failure. Loud noise can cause hearing loss. Also, there is a hazard related to SVT coolant leakage into analyzing magnet vacuum chamber that will degrade the vacuum and may damage readout electronics if leak is extensive.

3.6.2 Mitigations

All personal working in the vicinity of the tagger vacuum chamber window are required to wear ear protection. Warning signs must be posted in that areas. For mitigation of a possible coolant leakage, cooling system will be interlocked with the beamline vacuum system and cooling system pressure gage. In an event of a leak, system will be shutdown and valves will be closed.

3.6.3 Responsible Personal

The vacuumsystem will be maintained by the Hall B engineering group.

Name	Dept.	Phone	email	Comments
Tech-on-call	Hall-B			1st contact
D. Tilles	Hall-B		tilles@jlab.org	2nd contact

Table 3.4: Personal responsible for the vacuum system.

3.7 Silicon Tracker

The silicon vertex tracker (SVT) is a compact six layer tracking system, less than a meter long, which uses silicon microstrip detectors to measure charged particle momentum and decay vertex positions. Each layer, top or bottom, consists of axial and stereo silicon sensors. The SVT is divided into top and bottom sections to avoid direct interactions with the beam and degraded electrons, and it resides in vacuum, to eliminate beam gas backgrounds. The first three layers can be moved close to the beam, to maximize acceptance for heavy photons. A cooling system removes heat from the electronics, and cools the sensors to improve their radiation hardness. The sensors are readout with onboard sensors which pass signals to Front End boards for digitization and transmission out of the vacuum enclosure.

3.7.1 Hazards

Hazards to personnel include the high voltage which biases the sensors, and the low current which powers the readout electronics.

Hazards to the SVT itself include mechanical damage, radiation damage, and overheating. Hazards to the vacuum system could arise from excessive SVT outgassing or coolant leaks. SVT mechanical damage could occur if the top sensors are accidentally driven into the bottom sensors.

Radiation damage could occur in the SVT if the sensors are driven too close to the beam, the beam moves into the sensors, the beam interacts upstream to produce excessive radiation, or excessive beam currents create more radiation than can be tolerated.

Overheating can occur in the SVT if the cooling system is performing inadequately or if a cooling system leak develops.

3.7.2 Mitigations

Hazards to personnel are mitigated by turning off HV and LV power before disconnecting cables or working on the sensors and internal electronics. Hazards to the Hall B vacuum system have been mitigated by extensive testing of all components to ensure low-outgassing rates, construction of the SVT and electronics in a clean room, and tests of the cooling system to high pressures to prove leak-tightness. The coolant used, water glycol, would not cause irreparable damage to the vacuum system if a leak occurred. If the system pressure increases, the coolant supply is halted.

Possible mechanical damage has been mitigated by designing the channels which hold the sensors to touch before any modules would touch. Software limits and limit switches on the motion controllers also prevent the sensors from moving into each other and too close to the beam.

Radiation damage from the beams is mitigated in several steps. First, beam size and halo must conform to beam requirements before beams are passed through the detector. Second, the beams are centered between the top and bottom sections of the SVT. Third, an upstream collimator is aligned with the "centered" beam position to intercept the beam if it moves off nominal position. Fourth, beam halo monitors sense a rise in backgrounds if the beam moves off nominal position, activating the FSD and removing the power permissive to the SVT. Fifth, precision movers position the SVT layers precise and safe distances from the beam . Finally, beam currents and target thicknesses are carefully chosen to avoid over-radiating the silicon sensors.

Overheating is mitigated by requiring good coolant flow, proper coolant temperature, good vacuum (assuring no coolant leakage), and sensor temperature in range in the interlock for SVT HV and LV power.

3.7.3 Responsible Personal

Name	Dept.	Phone	email	Comments
Tim Nelson	SLAC			First contact
Omar Moreno	UCSC			Contact
Sho Uemura	SLAC			Contact
Per Hansson	SLAC			Contact

Table 3.5: Personal responsible for the silicon tracker.

3.8 Electromagnetic Calorimeter

The Electromagnetic Calorimeter (ECal) consists of 442 lead-tungstate ($PbWO_4$) crystals with avalanche photodiode (APD) readout and amplifiers enclosed inside a temperature controlled enclosure. There two identical ECal modules positioned above and below of the beam plane. In order operate calorimeter modules high voltage and low voltage are supplied to each channel. The high voltage is < 450 V and < 1 mA. The required low voltage is ± 5 V for preamplifier boards.

3.8.1 Hazards

Hazard associated with this device are electrical shock or damage to the APDs if enclosure is opened without HV on.

3.8.2 Mitigations

Always turn HV off before opening the enclosure or disconnecting HV cables.

3.8.3 Responsible Personnel

The authorized personnel is shown in table 3.6.

Name (first,last)	Dept.	Call [5]		e-mail	Comment
		Tel	Pager		
Stepan Stepanyan	Hall-B	7196		stepanya@jlab.org	*1st Contact*
Raphael Dupre	ORSAY	7252		dupre@ipno.in2p3.fr	*2nd Contact*

Table 3.6: HPS calorimeter: authorized personnel.

Bibliography

[1] EPICS Documentation. WWW page. URL http://www.epics.org/. see also http://www.aps.anl.gov/asd/controls/epics/EpicsDocumentation/WWWPages/EpicsDoc.html.

[2] JLab. *EH&S Manual*. URL http://www.jlab.org/ehs/ehsmanual/.

[3] JLab. *Personnel Safety System (PSS) manual*. URL http://www.jlab.org/accel/ssg/user_info.html.

[4] *Accelerator Operations Directive*. URL http://opsntsrv.acc.jlab.org/ops_docs/online_document_files/ACC_online_files/accel_ops_directives.pdf. *URL is available inside JLab site.*

[5] Jefferson Lab, (12000 Jefferson avenue, Newport News, VA 23606). URL http://www.jlab.org. Telephone numbers: (757)-269-XXXX, Pager numbers: (757)-584-XXXX.