Experiment Safety Assessment Document for E12-11-105 (PEPPo)

May 4, 2012 (v11.0)

Authorized: ____________________
Injector Program Manager

Contents

1 Introduction and Scope 2
2 PEPPo Beam line 3
2.1 Beam line Vacuum Components, Windows and Interlocks 3
2.2 Beam line Magnets 5
3 Detector Systems 5
3.1 Annihilation Detector 5
3.2 Fiber Array Detector 6
3.3 Compton Transmission Detector 7
4 Additional Issues 8
4.1 Targets and View Screens 9
4.2 Machine Protection 9
4.3.Radiation Hazards 10
4.4 Personnel Protection Issues and Controls 10
4.5 Experiment Operations 11
A PEPPo Overview Drawing 12
B. PEPPo Commissioning Readiness Review Report (2/3/2012) 13
C. Steps Taken to Address the Issues Raised by the Commissioning Readiness Review 16

1 Introduction and Scope

Jefferson Lab experiment E12-11-105 will study the feasibility of developing a beam of polarized positrons for use in future experiments. The detailed goals and plans of the experiment are presented in the proposal that was approved by the PAC.[1] It uses a specialized beam line that has been developed (reusing many components from an earlier SLAC experiment) to make these measurements. Since the apparatus is not intended to be a permanent part of the CEBAF injector, it is being treated as a “one of a kind” specialized experiment. The safety of all of the equipment and its interaction with the CEBAF injector has already been the subject of a safety review, which raised a number of issues. A copy of the report from that review is attached as Appendix B of this document.

The purpose of this document is twofold. First, it gathers in one place all of the relevant materials in preparation for a final experiment safety review, which will take place in April. Second, it serves to document for the record all of the measures being taken to ensure safe operations of the experiment.

Since PEPPo is a “one of a kind” specialized experiment, the operation of each subsystem is the responsibility of designated experts who, in turn, certify collaboration members for operation of the subsystem. The COO for the experiment describes the relevant responsibilities and procedures for operations of PEPPo. Table 1 below identifies the subsystem experts, who are also the authors of the relevant material in this document. In the remainder of this document we first review the beam line and its major subsystems, then the three detector systems used for the experiment, and finally we summarize additional experimental equipment issues. Note that the data acquisition hardware and analysis software are not discussed in this document as they present no safety issues that are not “standard” for the use of any such subsystems in CEBAF experiments.

Table 1: Subsystem Experts

Subsystem	**Subsystem Experts**
Beam line vacuum components	Joe Grames
Beam line magnets	Joe Grames
Annihilation Detector	Tony Forest
Fiber Array Detector	Paul Gueye
Compton Transmission Detector	Eric Voutier, Erica Fanchini
Data Acquisition Hardware	Alexandre Camsonne , Erica Fanchini
Data Acquisition Analysis	Erica Fanchini, Riad Suleiman

[1] See http://www.jlab.org/exp_prog/proposals/11/PR12-11-105.pdf

2 PEPPo Beam line

An overview drawing of the PEPPo experiment, with labeling used to identify all components is provided as Appendix A to this document. We provide here a summary of the three vacuum beam line regions and then discuss in detail the vacuum and magnet related safety issues.

Region 1 - After passing through a beam current monitor (IBC0L02) the electron beam is extracted using a dipole magnet (MBV0L021) through a beam line vacuum valve (VBV5D00) to the PEPPo apparatus. A short electron beam line consisting of steering coils (MBH5D00H/V, MBH5D01H/V) and quadrupole magnets (MQD5D00, MQD5D01) are used to setup the beam to a target ladder (ITG5D01), which supports a viewer and multiple production targets. Beam line viewers (ITV5D00, ITV5D01) and position monitors (IPM5D00, IPM5D01) are used to determine the beam position, angle, size and aspect ratio at the target. During the experiment the BCM and BPMs continuously monitor cw beam to the production targets.

Region 2 - The target ladder is followed by a solenoid magnet (MPC5D02) and D/D-bar spectrometer (MPD5D03). The spectrometer magnetic field is reversible so that either electrons or positrons may be transported. The spectrometer vacuum chamber includes a 2" thick steel beam dump within the first dipole followed by two 1" thick tungsten collimators (ISC5D03L, ISC5D03R) and beam line viewer (ITV5D03) after the first dipole. The collimators are independently movable "elevator doors" which define the spectrometer momentum acceptance; they are electrically isolated to a current monitoring system. The second dipole completes the chicane and includes a supplemental trim steering coil (MPD5D03A).

Region 3 - Following the spectrometer is the final beam line segment consisting of steering coils (MCS5D03H/V, MCS5D04H/V) and a solenoid magnet (MPT5D04) to focus electrons or positrons toward the Compton polarimeter reconversion target (ITG5D04). Beam line viewers (ITV5D03A, ITV5D04) are used to locate the beam position and size/aspect ratio, and finally a Faraday cup (IFY5D04) may measure beam current and stop the beam upstream of the 0.010" thick aluminum exit window. Three air-side detectors located around the beam line are described in Section 3: the Annihilation Counter (IAC5D03), the Fiber Array Detector (IFA5D04) and the Compton transmission polarimeter (ICP5D05).

2.1 Beam line Vacuum Components, Windows and Interlocks

Vacuum Components – The PEPPo apparatus is a single beam line isolated from the CEBAF injector by a vacuum valve. The beam line pipes and chambers are fabricated from stainless steel with ultra-high vacuum quality specifications and mated together with metal gaskets and ConFlat (CF) flanges. A modest amount of aluminum, copper, tungsten and low out-gassing ceramic Macor are used in the production target, collimators and vacuum windows. The vacuum window hazard is discussed in the next section. The beam line is evacuated through an isolation pump out port using a turbo pump and finally by four ion pumps providing combined 135 L/sec pump speed. A residual gas analyzer (RGA) is used to leak check the beam line. To date the beam line has been entirely leak free and is maintained at ~1E-9 Torr.

Vacuum Window Hazard – Three identical style vacuum windows (3” diameter) are used on the PEPPo apparatus; two are used in conjunction with the Annihilation counter detectors and one is used for the exit vacuum window. Each is fabricated by epoxying a 0.010” thick aluminum disk between a pair of 4.5” CF copper gaskets. The window design has been evaluated by the Engineering Division and approved by their Design Authority. Sample windows have been tested experimentally; and the 0.010” thick window ruptured at approximately 184 psig of pressure, significantly above the operation load. All files related to the PEPPo Thin Windows are located on DocuShare in the folder entitled “PS-PHY-11-003 Thin Windows for Peppo Experiment” (https://jlabdoc.jlab.org/docushare/dsweb/View/Collection-15625/Document-49364). Upon recommendation of the safety review (see Appendix B) we explored the consequence of radiation damage to the epoxy seal by radiation dosing additional test windows in the FEL 10 MeV beam dump. Two windows dosed in excess of 70kRad were tested and neither failed to 170psi.

Injector Vacuum Hazard – The PEPPo beam line vacuum is continuously monitored via the power supply (Injector Digitel Power Supply #8) of the four PEPPo ion pumps. A read back greater than the Injector specification threshold of ~10^{-7} Torr will automatically close the PEPPo vacuum valve (VBV5D00) as well as the nearest upstream (VBV0L01B) and downstream (VBV0L03A) injector vacuum valves. Closing the injector vacuum valves also generates and FSD which turns the beam off. The vacuum valves will not reopen while the interlock threshold is exceeded.

SRF Vacuum Hazard – SRF cavities are located both upstream (cryo-unit 0L02) and downstream (cryomodule 0L03) of the PEPPo beam line. Elevated vacuum levels due to the PEPPo beam line are mitigated by intervening differential pump (DP) stations comprised of valve-interlocked ion pumps and non-evaporable getters. These stations are located downstream of the cryounit (VDP0L01, VDP0L01A, VDP0L01B) and upstream of the cryomodule (VDP0L03A, VDP0L03B, VDP0L03). Sudden vacuum rise to atmosphere resulting from a broken vacuum window is mitigated by a fast vacuum valve at the entrance of cryomodule 0L03 however there is no such valve at the exit of cryounit. The initial safety review recommends (see Appendix B) a similar fast valve after the cryounit. Because it is logistically prohibitive to perform this task prior to the PEPPo experiment as scheduled measures are taken to reduce the risk of damaging the cryounit by a sudden vacuum event. The existing vacuum windows have been thoroughly tested, vacuum hardware interlocks to the PEPPo beam line have been implemented and a BCM FSD to limit beam power has been successfully commissioned.

Vacuum Component Collision Hazard – A beam line viewer (ITV5D04) and Faraday cup (IFY5D04) occupy the same physical vacuum space when inserted. To prevent a vacuum collision and possible vacuum leak an anti-collision hardware interlock circuit is implemented. The interlock uses dedicated limit switches to detect when either element is retracted thereby preventing concurrent insertion.

2.2 Beam line Magnets

Beam line magnets are used to steer and focus the electrons and positrons through the vacuum chambers.

Electrical Hazard - Class 2 Magnets (MPC5D02, MPD5D03, and MPT5D04): Three normal conducting magnets are powered by Class 2 power supplies in the Injector Service Building. Protective shields and signage cover all exposed leads and are inspected by the Accelerator Division Safety Officer prior to operation. Each magnet is individually grounded. Removal of protective barriers requires LOTO of the 220VAC wall plug power to the supply.

Electrical Hazard - Class 1 Magnets: Approximately 13 normal conducting air core dipole and quadrupole magnets are powered by Class 1 CEBAF style 10A/35V CEBAF style trim power supplies. Magnets are individually controlled and limited in current by a series resistor where necessary. Magnet software controls are used in the Alarm Handler and archived.

Magnet Over-Temperature Hazard (MPC5D02, MPD5D03, and MPT5D04): These high current magnets are individually protected from overheating by LCW flow interlocks and temperature Klixon interlocks required for the power supply permissive. Magnet software controls are used in the Alarm Handler and archived.

3 Detector Systems

In this section we review each of the three detector systems used as part of the PEPPo experiment and summarize the safety-related issues.

3.1 Annihilation Detector

The main purpose of the annihilation counter detection system is to indirectly confirm the presence of positrons by detecting in coincidence the 511 keV photons produced in the experiment when positrons annihilate inside a target. The annihilation counters for PEPPo consist of a pair of NaI(Tl) detectors located perpendicular to the beam line viewer positioned to detect the back-to-back photons emitted either in coincidence or individually.

Electrical hazard: Each detector consists of a 2x2 in. crystal mounted on a photomultiplier tube that is packaged in a standard housing by ORTEC (their part # 905-3). The operational high voltage is supplied via standard HV cables with SHV connectors. The power supplies are located in the injector service building. An additional ground connection is built-in through the mechanical assembly that attaches the detectors to the PEPPo beam line.

Vacuum hazard: The detectors are mounted inside a cylindrical tube bolted on the 6-way cross located at the exit of the spectrometer. They are separated from the beam-line vacuum by thin aluminum windows out of the direct view of the beam. Safety issues related to these windows are addressed in section 2.1.

(Un)mounting procedure: Manipulating the detectors at the vacuum windows requires appropriate PPE (safety goggles, hearing protection) and *training* by an expert. Before beginning any such manipulation the valve to the PEPPo beam line must be closed to prevent inadvertent venting of the injector vacuum that would result if a vacuum window ruptured. In addition, the HV power supplies must be turned off whenever the detectors are being handled. Whenever the detectors are removed from the beam line protective blanks are put in place.

3.2 Fiber Array Detector

The purpose of the fiber array detector is to provide a measurement of the electron and positron beam profiles at the entrance of the Compton transmission polarimeter. The device is a modified version of the beam profiler used for the Hall B two-photon exchange experiments. It consists of a 16x16 array of 30 cm long, 1mm^2 fibers oriented along the two axes of the plane perpendicular to the beam direction.

Electrical hazard: Each fiber plane is connected to a 16 pixel multi-anode photomultiplier tube (Hamamatsu H8711) operating at about 800 V. The power supplies are located upstairs, in the injector service building, and HV is supplied to each PMT via RG-58C/U cables with an SHV connector at one end and a specific 2-pin connector at the PMT end. An additional ground connection is provided via the mechanical support that attaches the detector to the polarimeter table.

Vacuum hazard: In data taking mode, the detector is located at the exit of the vacuum section of the PEPPo beam line, about 5 cm after a thin aluminum vacuum window. The mechanical assembly of both the window and of the detector prevent any direct interaction. Safety issues related to this window are addressed in section 2.1.

(Un)mounting procedure: Manipulating the detector near the vacuum window requires appropriate PPE (safety goggles, hearing protection) and training by an expert. Whenever such manipulations are done, the valve to the PEPPo beam line is closed to prevent inadvertent venting of the injector vacuum in the event of a window rupture, and the HV

power supplies are set off. Whenever work near the detector occurs a protective blank is put in place over the vacuum window, which is otherwise normally uncovered.

Detector motion: The detector can be inserted or retracted from the beam line within a motion perpendicular to the beam direction. This motion is provided by an actuator mechanically attached to the polarimeter table and remotely controlled by specific PEPPo experts. The system assembly design prevents any interaction with the beam line.

3.3 Compton Transmission Detector

The operation of the PEPPo polarimeter relies on the Compton absorption of polarized photons inside a polarized target. Polarized photons are generated from the interaction of a polarized electron or positron beam inside a 2 mm tungsten target at the entrance of the polarimeter. The photon beam is then analyzed by passing it through a 7.5 cm long iron target polarized to 7% by a 2.3 T magnetic field provided by a solenoid. Transmitted photons are measured in a 3 x 3 CsI(Tl) crystal array located at the exit of the analyzing magnet. The full detector assembly is complemented with 5 plastic scintillating paddles (2 above the polarimeter, and 3 below) that serve as a cosmic ray trigger.

Electrical Hazard - Class 2 Magnet Power Supply (MPA5D05): The normal conducting magnet is powered by Class 2 power supply in the Injector Service Building. Protective shield and signage cover all exposed leads and is inspected by the Accelerator Division Safety Officer prior to operation. The magnet is grounded. Removal of the protective barriers requires LOTO of the 220VAC wall plug power to the supply.

Magnet Overtemperature Hazard (MPA5D05): This high current magnet is protected from overheating by requiring both an LCW flow interlock and temperature Klixon interlock for the power supply permissive. Magnet software controls are used in the Alarm Handler and archived.

Electrical hazard (detectors): Each crystal, supplied by the Monokristal company (Kharkov, Ukraine), is connected to a Hamamatsu R6236-100 photomultiplier tube operating in the range 1000-1500 V with custom amplified bases requiring ±12 V supply. The scintillating paddles are equipped with Photonis XP2282 photomultiplier tubes operating in the range 1700-2000 V with standard bases. High and low voltage power supplies are located upstairs in the injector service building. HVs are supplied to the PMTs via standard HV cables equipped with SHV connectors. Low voltage is supplied via a single specific 2 pins shielded LEMO cable, and is distributed internally to each PMT. An additional ground connection is provided by the polarimeter support table through specific ground cables connection.

Detector motion: The polarimeter assembly (analyzing magnet + calorimeter + surrounding shielding hut) can be translated forward/backward in the z-direction via a hydraulic jack. This system can be operated only by specifically trained and designated experts.

Mechanical stops in each direction limit the amplitude of the motion to a safe position. Additionally, the motor is contained into a bucket to prevent the dispersion of any eventual oil leak. By default, the operation of the polarimeter motion is physically disabled via the disconnection of the motor to electrical power.

Detector protection: In order to prevent excessive radiation exposure of the calorimeter, a fast shut-down system has been installed that shuts down the beam when the electron beam current (as measured using the beam current monitor upstream of the PEPPo branch exceeds a pre-set current limit (typically set to a few nanoAmps) during operations without a production target. A description of this system is presented in section 2.1. The Faraday cup at the end of the PEPPo beam line provides an additional safety protection and its always inserted in the beam line unless PEPPo operations require its removal.

4 Additional Issues

We summarize in this section all additional experimental equipment issues associated with PEPPo. In particular the extension of machine protection systems to include possible beam-related accident scenarios involving things like window burn-through in the PEPPo apparatus. Table 2 below summarizes the measures in place and further information is provided in the subsections that follow.

Table 2. List of machine protection issues and controls.

Issues (Type of Control)	**Controls**
Area Prompt Radiation (Engineered)	Evaluation of prompt radiation during commissioning
Material Activation (Administrative Monitoring and Engineered Rapid Access)	Evaluation of activation during commissioning
Excessive beam energy (Engineered)	Cathode power supply taps limit beam energy Undesired extraction energy detected by beam loss at 5MeV dipole
Excessive beam current (Engineered)	Use CW inhibit (software) when possible - ALARA Use of cavity current monitor FSD interlock (hardware)
Loss of vacuum due to thin vacuum window failure (Engineered Control)	Mechanical and thermal engineering analysis performed Mechanical failure testing Engineering approval acceptance Evaluation of vacuum quality during commissioning Valve hardware interlock to upstream/downstream ion pumps
Degrade beam line vacuum (Engineered)	Evaluation of vacuum quality during commissioning Valve hardware interlock to upstream/downstream ion pumps
Overheat high current magnets (Engineered)	LCW cooling circuit interlocked to power supply Thermal contact interlocked to power supply
Overheat Faraday cup (Engineered)	LCW cooling circuit interlocked to FSD (hardware)
Radiation damage CsI crystals (Administrative)	ALARA principle during commissioning with temporary shielding
Radiation damage scintillator	ALARA principle during commissioning placing detector in retracted

fibers (Administrative)	position

4.1 Targets and View Screens

The PEPPo vacuum beam line uses standard chromium oxide (Chromox) viewers and a target ladder that has five positions; retracted, viewer, and three tungsten (>99.99%) foils ranging in thickness from 0.1 – 1 mm.

View Screen Current Limit Hazard – View screen ITV5D00 is configured as a standard beam line viewer where the beam mode is automatically reduced 0.15% duty factor limiting average current to ~nanoAmps. View screens ITV5D03, ITV5D03A and ITV5D04 are configured as a cw safe viewers without limit on duty factor so they may be inserted during positron production. Damage to the viewer in electron mode is mitigated by limiting the beam current using the BCM threshold w/ 1nA sensitivity connected to the FSD system. Damage to the viewer in positron mode is mitigated by dumping the electron beam upstream of the cw safe viewers with the spectrometer in positron mode. Additionally, cw beam operation requires the Beam Loss Monitor (BLM) connected to the FSD system be used, preventing unnecessarily high current to a viewer.

Target Heating Hazard – The PEPPo target ladder will heat up due to collisional (dE/dx) energy loss when cw beams of energy up to 8MeV are incident on production targets. A conservative evaluation of target ladder heating using a finite element modeling code was performed by the Engineering Division. The results indicate beam power deposition to the target ladder should be limited to 1.1 Watt in order to maintain the target ladder assembly below 150 deg C. The maximum allowable beam current was then calculated as a function of beam energy using Geant4 for each target to be used and is summarized in Appendix B of the COO. For each target and beam energy configuration the BCM receiver FSD interlock threshold will be set accordingly to turn the beam off in the event the administrative beam current limit is exceeded.

4.2 Machine Protection

Hardware interlocks based upon acceptable and/or calibrated thresholds are used to protect the machine. In some cases the hardware interlock results in a fault of the Fast Shutdown (FSD) system. The list of machine protection and associated interlock is summarized in Table 3. Unless noted, operator intervention is required to clear the hardware interlock and/or FSD fault.

Table 3: List of machine protection issues and the associated FSD interlocks

Machine Protection (Type of Control)	**Interlock**
Beam Line Vacuum (Engineered Control)	When the PEPPo vacuum exceeds about 1E-7 Torr (ion pump power supply current >100µA) the PEPPo experiment valve VBV5D00 closes and will not re-open.
Beam Line Vacuum (Engineered Control)	When the PEPPo vacuum exceeds about 1E-8 Torr (on pump power supply current >100µA) the nearest injector valves 0L01B and 0L03A close, also resulting in an FSD fault.
Beam Current (Power) (Engineered Control)	When the beam current exceeds an administratively defined threshold (beam cavity monitor IBC0L02 calibrated against Faraday Cup #2 IFY0L03) a FSD fault results. The cavity receiver has a resolution of ~1 nA.
Beam Energy (Power) (Engineered Control)	When the beam energy is increased by the cryounit the maximum allowable value is limited by the cryounit cathode power supply taps.
Beam Loss at Extraction (Engineered Control)	When the beam loss monitor (BLM) positioned to detect beam loss at the extraction vacuum chamber exceeds threshold a FSD results. This fault occurs when the beam energy does not match the desired extraction dipole magnet (MBV0L021) setting.
PEPPo Faraday Cup LCW (Engineered Control)	When the LCW flow required for operation of the PEPPo Faraday Cup IFY5D04 is below threshold (measured about 0.5 GPM) a FSD fault results.
PEPPo High Current Magnets LCW (Engineered Control)	When the LCW flow (Proteus flow meter) through a PEPPo high current magnet (MPC5D02, MPD5D03, MPT5D04, MPA5D05) is below threshold the corresponding power supply current faults to zero current.
PEPPo High Current Magnets Temperature (Engineered Control)	When the temperature sensor (Klixon) of a PEPPo high current magnet (MPC5D02, MPD5D03, MPT5D04, MPA5D05) is above threshold the corresponding power supply faults to zero current.

4.3.Radiation Hazards

Radiation safety has been explicitly addressed in the Radiological Safety Analysis Document (RSAD) developed by the RadCon group for experiment E12-11-105. The experiment will be run within the controls identified in that document, and all collaboration members will have read and signed the RSAD prior to taking shifts, as described in the Conduct of Operations for the experiment.

4.4 Personnel Protection Issues and Controls

Table 4, below summarizes the personnel protection issues and controls in place. The Conduct of Operations document for the experiment provides further details.

Table 4. List of personnel protection issues and controls.

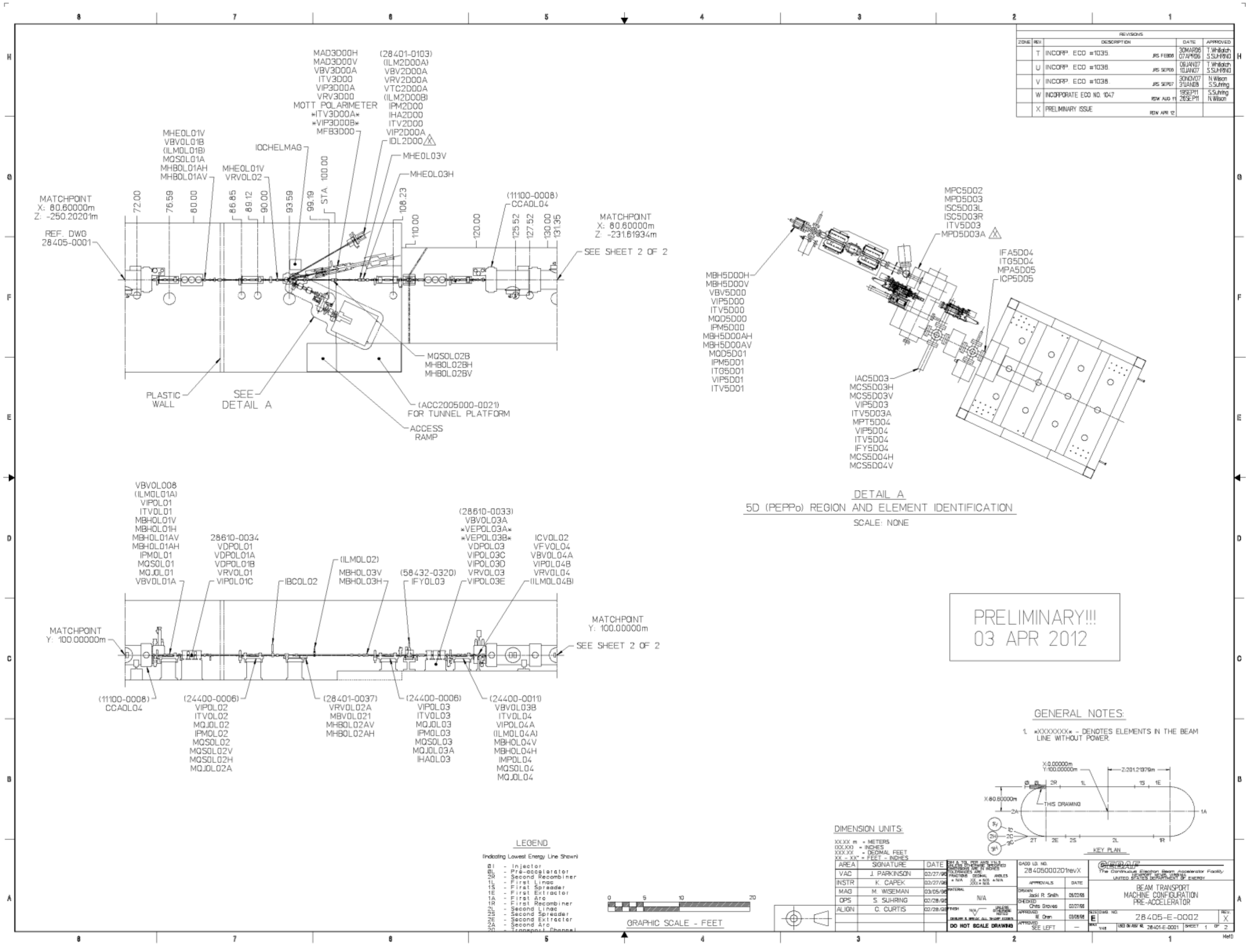
Task (Type of Control)	Controls
Work in tunnel (Administrative)	SAF 100 – General EH&S SAF 103 – Oxygen Deficiency Hazard SAF 132A – Tunnel Awareness Training SAF 132 – Tunnel Awareness Walkthrough SAF 801 – Radiation Worker I SAF 801kd – Tunnel Radiation Work Permit
Work near thin vacuum windows (Administrative)	Hearing protection signs posted Earplugs provided Protective covers in place to prevent accidental puncture
Work near painted lead bricks (Administrative)	Lead storage signs posted SAF 136 lead training and PPE used for handling
Work near Class 2 magnets (Administrative)	Magnet leads protected by enclosure Class 2 power supply signs posted
Work with hydraulic jack (Administrative)	System normally de-energized Training required to power and use hydraulic jack Pinch hazard signs posted
Work with detector high voltage (Administrative)	Training required to de-energize detectors prior to handling High voltage safe connectors used
Work with ion pump high voltage (Administrative)	Training required to de-energize ion pumps prior to handling High voltage safe connectors used

4.5 Experiment Operations

This document contains information relevant to the safe operation of the PEPPo experiment. It is, of course, also necessary to disseminate the information contained in this document effectively to all staff and users who need to know the information and rules of conduct delineated here and in the "Conduct of Operations" for PEPPo. To this end the following steps will be taken.

All Shift personnel are required to read and sign this document and the PEPPo COO and send verifying email to both experiment spokespersons: Joe Grames (grames@jlab.org) and Eric Voutier (voutier@jlab.org).

A PEPPo Overview Drawing



B. PEPPo Commissioning Readiness Review Report (2/3/2012)

Review Panel: H. Areti, M. Bevins, D. Higinbotham, K. Mahoney, K. Welch

The Director of Operations has charged the panel to review the readiness of PEPPo beam line's readiness for commissioning. The focus is to be on machine and personnel protection and commission plan.

The panel viewed this charge in two respects. One, to evaluate whether the commissioning of PEPPo has a potential to adversely affect the nuclear physics program and two, to evaluate whether the commissioning plan has identified and adequately mitigated or plans to mitigate harm to personnel and machine.

The committee commends the PEPPo team for providing material well in advance of the review and for very informative presentations.

At the outset, the panel recommends that PEPPo experiment be treated just like any physics experiments in the halls. This means that PEPPo documentation should follow the guidelines provided for the experimental halls and should have documents controlling the Conduct of Operations (COO), Experiment Safety Assessment Document (ESAD) and Radiation Safety Assessment Document (RSAD) with appropriate signatures and distribution.

Finding (Fast Valves)
During the presentation, it was not clear whether the cryomodules are protected by fast valves in case of vacuum breach in the PEPPo beam line. There was some doubt as to whether these fast valves protecting SRF components are in place or not.
Recommendation
Verify whether the fast valves protecting SRF components exist or not. If they do not, address the measures to be taken to protect SRF components in case of vacuum breach in the PEPPo beam line. Note that the lack of fast valves can adversely affect the electron gun. Lack of fast valves or equivalent protection is a show stopper. An additional recommendation is to evaluate the Mott and PEPPo beamline valve opening/closing for operations and provide guidelines to the operators. All administrative procedures should be part of the COO.

Finding (Positron Beam line vacuum)
The positron line vacuum valve is not interlocked with the FSD system.
The loss of vacuum for the positron line is detected by gauges/pumps outside of the positron line. If the positron line valve is closed, and the P line has poor vacuum, one can open the p-line valve, spoiling the vacuum in the main injector line(s).
Recommendation
Consider FSD interlock for poor vacuum in the positron beam line

Finding (Vacuum Window)
How rad hard is the epoxy used to fabricating the window? Can the epoxy still hold the vacuum integrity after prolonged exposure to radiation?
Recommendation
This could be tested with a sample window prior to PEPPo commissioning and pressure testing the sample window. An additional recommendation is to consider a Havar window which can give you a higher safety margin for the same effective thickness

Finding (Machine Protection)
The PEPPo beamline has more components than the Mott beamline. Since the beam current could be up to 4 microAmperes, the beamline components should be protected from beam induced damage.
Recommendation
Evaluate the scenarios from beam loss and ensure that appropriate machine protection is either in place or will be added (e.g. BLMs)

Finding (Magnets)
PEPPo beam line contains a magnet that bends the beam (almost a z bend in the vacuum chamber). The field of the magnet can extend to the CEBAF beam line. If the magnet was left on, the field will affect the electron beam during CEBAF operations.
Recommendation
At its highest field setting, determine whether this magnet being on affects CEBAF beam. If it does, provide means of mitigation (engineering control – shielding, interlock with the PEPPo beam line valve or admin control – operational procedure).
Joe Grames has clarified that the magnet power supplies are indeed Class 2 and potential hazards have been already mitigated.

Finding (Targets and Ladder)
The targets are in vacuum. The thermal bond between any target and the aluminum ladder consists of washers and is likely to be inadequate for heat dissipation and can damage the targets.
Recommendation
Evaluate whether the present design can adequately remove the heat from the targets. If not, consider a good thermal bonding between the targets and the ladder and provide a heat dissipation mechanism whereby the ladder radiates the heat outside the vacuum chamber. Consult with Dave Meekins who has extensive experience in target design. If the beam hits the aluminum ladder, it can damage the ladder. A different ladder design (instead of a solid aluminum plate, a fork like design) may be considered. This redesign may not be necessary provided there are beam loss monitors to protect the PEPPo beamline.

Finding (Radiation)
Present Rapid Access to the injector may need to be evaluated.
Radcon Response from K. Welch
Radcon (K. Welch) will provide an RSAD. The RSAD will only really need to address two issues.
(1) Prompt radiation - no issues in the region of the injector, since normal shielding and

segmentation mitigate this. At the NE stub, Pavel has calculated worst case accident scenario to be 200 mrem/h. The scenario would be a burn through, somewhere in the transport upstream of the target. This is well below our limit of 15 rem/h for what we assume would be an instantaneous loss that is shut down quickly. For normal operating conditions, the levels are inconsequential. *Note: This evaluation assumes the PSS is configured such that beam transport out of the Injector is not possible. The May PEPPo run requires the North Linac to be in straight-ahead mode, which permits beam operations up to the in-line dump.*
(2) Residual activation - no significant residual activation is expected. However, Radcon will reconfigure rapid access to have a probe near the T1 target (ATLis submitted). Radcon will monitor for neutrons with the existing probe, and do a spot check for activation at some point after running > 7 MeV. (Requires PEPPo and Radcon coordinate this activity). Radcon will also provide guidance for disassembling the target assembly. Target disassembly will require a radiation survey.

Radcon may need to provide a CARM in the NE stub. A determination will be made after consultation with the Vashek and Pavel.

Findings (Operational Procedures)
The protection of multiple insertions devices and detectors is completely administrative.It is understood that the present MCC protocols allows only a restricted set of non-operators to manipulate the injector beamline.
Recommendation
There should be clearly written procedures and chains of command. It is recommended to develop operational restrictions (similar to the experiments).

Recommendation (FSD General)

BCM needs a new FSD input assignment.
Verify MPS BLM protection where the positron beam line separates out from the main beam line.

Review FSD masking procedures for commissioning of the beamline and for running the PEPPo as an experiment.

C. Steps Taken to Address the Issues Raised by the Commissioning Readiness Review

Issue	Task Status (Responsible Individual)
RR#1 – Provide an approved RSAD, ESAD, COO	RSAD released (KW) COO v10.0 submitted 4/13/12 for readiness review ESAD v10.0 submitted 4/13/12 for readiness review
RR#2 – Address SRF vacuum protection before and after LSD	The (slow) vacuum valves at the entrance to the PEPPo beamline and nearest Injector upstream and downstream beamline has been interlocked to the PEPPo vacuum; closure of the Injector vacuum valves results in a fast shutdown (FSD) fault to turn the beam off. This vacuum interlock configuration along with administratively controlled injector current limitations imposed by the BCM FSD interlock are the proposed ALARA principle conditions, the alternative to installing an SRF fast valve
RR#3 – Interlock PEPPo valve to PEPPo vacuum	Valve now interlocked to close on a FSD signal; PEPPo vacuum is an input to the FSD (RL)
RR#4 – Investigate radiation hardness of thin vacuum window epoxy	Test windows have been made (PA) and the FEL has provided a dose test-bed. An initial vacuum test of two windows was completed (PA). They were then put in the FEL dump (BL/JG/KW) and exposed to radiation. At the end of the exposure the dosed windows were removed (BL) and the dosimeters were read (KW). Both windows have been exposed to at least 70kRad and tested to 170psi without failing.
RR#5 – Implement machine protection	MPS BLM protection at positron branch (JG), FSD BCM protection (JG), and VAC interlock protection (RG) have all been implemented.
RR#6 – Ensure PEPPo magnet operation does not impact NP program	An administrative control of spectrometer wall plug power during NP operation has been implemented (JG)
RR#7 – Provide target thermal analysis and proposed restrictions	Collisions energy loss (dE/dx) of electrons of 2-8 MeV kinetic energy in PEPPo tungsten targets 0.1-1mm have been calculated (SG). Target ladder information was provided (JG/DM) to JF who has completed an engineering thermal analysis using ANSYS finite element modeling to determine power of 1.1W is acceptable for <150C temperature rise. Corresponding beam currents have been calculated and summarized in the COO.
RR#8 - Evaluate rapid access	The RSAD developed indicates that rapid access following standard procedures is appropriate (KW)
RR#9 - Develop operational procedures	The PEPPo FSD mask configuration has been identified and reviewed through discussions with KM (YW). The new mask is similar to the existing standard Injector FSD mask with the exception of a) adding the BCM FSD input and b) masking both the P1 of the 0L03 and 0L04 modules which will be locked out to ensure the beam energy cannot exceed the maximum of that produced by the cryounit.

Note: Black text for task status denotes completion; red denotes additional work or reviews that are required before all issues have been addressed. A key to the names in the table is provided on the following page.

Key to names in Table:

BL = Bob Legg;
DI = Denny Insley;
DM = Danny Machie;
FEL = FEL Group staff
HA = Hari Areti;
JG = Joe Grames;
JF = Josh Feingold;
KM = Kelly Mahoney;
KW = Keith Welch;
LC = Larry Cardman;
PA = Phil Adderley;
RG = Rick Gonzales;
RL = Ron Lauze;
SG = Serkan Golge;
YW = Yan Wang;