

Gettysburg College



Proton Accelerator Laboratory Safety Program

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I. Scope and Application

All researchers, students, or others who use the Gettysburg College Proton Accelerator Laboratory are required to comply with this document, to ensure radiation exposure to accelerator users is as low as reasonably achievable

(ALARA) and well within the limits established by the Pennsylvania Department of Environmental Protection's Bureau of Radiation Protection.

II. Responsibilities

- A. The **President of Gettysburg College** has the ultimate responsibility for radiation safety within the institution. General oversight responsibility is assigned to the **Provost of the College**.
- B. The **Environmental Health & Safety Officer** advises on matters of radiation safety policies and practices and:
 1. establishes policies on the safe use of the accelerator.
 2. ensures the accelerator is licensed/annually renewed according to state law.
 3. reviews operational procedures and annual audits of the safety program to determine compliance with Pennsylvania Department of Environmental Protection.
 4. reviews incident analyses involving the use of the accelerator to determine the cause and take necessary corrective actions to prevent reoccurrence.
 5. maintains records required to meet compliance with federal, state, and local regulations.
- C. The **Radiation Safety Officer** has a primary responsibility for implementing this safety program and:
 1. providing individual workers with training, advice, and assistance on all matters pertaining to the safe use of the accelerator (training may be designated to lab supervisors by the RSO).
 2. reviewing work practices to determine compliance with regulations and approved procedures.
 3. assuring that all required radiation monitoring and protective devices are calibrated, in place, and used appropriately.
 4. assuring the integrity of all accelerator systems through regular inspection and testing.
 5. performing incident analyses involving the use of the accelerator.
 6. maintaining calibration and training records.
 7. ensuring that all required signs and labels are applied.
 8. providing supervision and assistance for the management of emergency situations.
 9. performing an annual audit of the accelerator safety program to determine that all activities are being conducted safely and reporting findings in a written report to the environmental health & safety officer.
 10. terminates any operation involving the use of the accelerator which he/she deems unsafe.

11. has the authority to approve individuals with the requisite experience and knowledge as authorized users (laboratory supervisors).
- D. The **Accelerator Laboratory Supervisors** (*authorized users*) are those faculty members under whose instruction the particle accelerator is used. The supervisor has a primary responsibility for assuring the safe use of the accelerator, including but not limited to:
1. complying with and enforcing the accelerator safety program.
 2. assuring that all personnel are properly trained in the safe use of the accelerator.
 3. assuring that any new procedures for use of the accelerator are submitted to the radiation safety officer for review before initial testing/implementation.
 4. maintaining the required accelerator logbook, maintenance records, and circuit diagrams.
 5. performing any required radiation safety surveys and report results in the operator's logbook.
 6. reviewing in advance all lab procedures using the accelerator.
 7. maintaining records required by the radiation safety officer or the environmental health & safety officer.
- E. All **Accelerator Operators** (including accelerator laboratory supervisors and students working under their direct supervision) are responsible for:
1. following the procedures prescribed in this document for operating the accelerator. Failure to do so is a serious breach of college policy and subject to disciplinary action that might include termination of employment at the college. The procedures to be followed in the event of such action shall be in keeping with existing guidelines as stated in the appropriate handbook for faculty, administrators, staff, or students.
 2. completing the required accelerator use logbook at each time of operation.
 3. reporting any malfunction, no matter how slight, to the accelerator laboratory supervisor in charge before resuming use of the accelerator.
- F. The **Gettysburg College Safety Committee** assists the environmental health & safety officer and:
1. annually reviews the radiation safety program.
 2. conducts safety audits.

III. Training

- A. **Accelerator Laboratory Supervisors** are qualified professionals who by their educational backgrounds and work experience Gettysburg College

and the Pennsylvania Department of Environmental Protection recognize as having had the radiation training necessary to safely operate the accelerator in accordance with this document and the accelerator instruction manual.

B. All **Accelerator Operators** who are not designated as authorized users on the state license must work under the direct supervision of an authorized user and:

1. complete general radiation safety training which ensures the operator:
 - a. has a basic knowledge of the different types of ionizing radiation,
 - b. understands the sources of potential radiation in the Gettysburg College Proton Accelerator Laboratory
 - c. understands the risks from occupational radiation exposure,
 - d. understands the units of radiation dose,
 - e. understands the measures that can be taken to protect against exposure to radiation, including specific, procedures the college has implemented such as work practices, emergency procedures, and personal protective equipment to be used,
 - f. understands the purpose and function of monitoring equipment,
 - g. understands the applicable details of the Gettysburg College Proton Accelerator Safety Program and the accelerator instruction manual,
2. complete site-specific “hands-on” training in accelerator operation under the supervision of an accelerator laboratory supervisor, and
3. complete laboratory safety training.

When the accelerator laboratory supervisor or radiation safety officer have reason to believe that an operator who has been trained does not have the understanding and skill required to safely operate the proton accelerator, the operator must be retrained. Circumstances where retraining is required include, but are not limited to, situations where:

1. changes in the laboratory render previous training obsolete.
2. changes in the work practices, emergency response or the type of protective equipment used render previous training obsolete.
3. inadequacies in an operator’s knowledge or use of equipment indicate that the operator has not retained the requisite understanding and skill to safely operate the accelerator.

IV. Accelerator Description

The accelerator and operator controls are located in Masters Hall, Room 106 (Appendix C). This machine, model PN250, was manufactured by High Voltage Engineering Corporation, Burlington, MA. A copy of the unit instruction manual is available in the accelerator lab and contains a complete description of its construction and capabilities. All accelerator operators are required to review this in addition to any other training.

The primary radiation source is expected to be X-rays from back-streaming electrons created by the interaction of the proton beam with residual gas atoms within the acceleration tube. The accelerator tank is constructed of 1 cm thick steel lined with ¼" lead, which will stop essentially all X-rays below 250 keV.

X-rays can also be produced when the proton beam interacts with certain target materials. It is expected that the 1"-thick aluminum walls of the target chamber will prevent exposure from these potential X-rays. Actual radiation levels are determined from radiation surveys.

V. Radiation Safety Surveys

A. Initial Survey Results

An initial radiation survey conducted by Dr. Bret Crawford at full energy (250kV) showed all radiation levels to be below the 2-mR/hr standard for public radiation exposure.

A possible source of major exposure is that of neutron-producing reactions. For accelerators under 2 MeV such reactions are rare except when deuterium or tritium is used as a target or projectile. We do not have such targets, nor do we have deuterium as a source gas for the ion source for the accelerator. Therefore, there are no neutrons produced by this facility.

Another potential problem would be if the machine were used to produce electron beams. This machine is not capable of running negative voltages, so no electron beams are produced.

B. Periodic Operator Surveys

During normal operation, accelerator supervisors will monitor the lab prior to the start of the fall semester, spring semester, and summer research session to ensure radiation levels remain ALARA. Survey readings will

be recorded in the operators' logbook and reported in the annual audit to the environmental health & safety officer.

All surveys will be performed using a properly calibrated survey meter capable of measuring the x-ray radiation emitted. Survey meters will be sent out for calibration annually.

VI. Personnel Dosimetry

According to federal and state regulations, persons likely to receive radiation exposure levels at 10% or more of the annual limit of 5 Rem/year must be assigned to wear a personnel dosimeter during work with the accelerator. The initial survey conducted by Dr. Crawford indicates all exposures are below the public dose limit of 2 mRem/hr, and therefore a personnel dosimetry program will not be necessary.

VII. Accelerator Operating Procedures

The radiation safety officer shall retain the authority to modify details of the operating procedures given below as needed to maintain safe and effective use of the accelerator laboratory.

Accelerator operation is controlled by a key system. The accelerator key is kept in a combination locked box in the accelerator lab. Only accelerator laboratory supervisors know the combination to the lock box. A logbook is located at the accelerator controls. This log is completed by the accelerator operator each time the system is used. This log indicates the operator, date, time on/off, and all necessary operating parameters. This data will assist the accelerator laboratory supervisor in monitoring the accelerator system safety on a continuous basis.

No one will be allowed to perform any maintenance, repairs, or modifications until the accelerator laboratory supervisor has given permission to do so. Records of all maintenance, repair, and modifications will be maintained by the accelerator laboratory supervisor. Operation and service of the accelerator will always be in accordance with High Voltage Engineering PN250 accelerator operators' manual and with the instruction of the accelerator laboratory supervisor.

The radiation safety officer shall be informed of all abnormal events and departures from normal use of the accelerator, which harm or have the potential to harm humans or the environment.

A. Accelerator Start-up Procedure

(See PN-250 Instruction Book for details.)

1. Scan Operator Logbook for any anomalous running conditions.
2. Log starting date and time.
3. Log tank pressure (between 90 and 100psi). If not at appropriate pressure see *Tank Gas Filling Instructions*
4. Log vacuum level on Accelerator Tube line, left of gate valve ($<4 \times 10^{-6}$ Torr). If tube is not under vacuum, see *Vacuum System Instructions*.
5. Obtain Control Key from lock box.
6. Check that Belt Charge control (big knob in the center) is completely counter-clockwise. Turn key clockwise and toggle upward the start switch.
7. After motor has gotten up to speed (you'll hear the starting capacitor relay drop out), you are ready to turn Belt Charge knob to reach the desired terminal voltage. See Energy Calibration chart in Operator's Logbook to convert micro-amp reading of terminal-voltage meter to actual beam energy.
8. Adjust Gas control to desired gas pressure.
9. Adjust Beam (probe voltage) and Focus controls to maximize beam current.
10. Once at running energy, log beam energy, up-charge current, column current, corona current, and beam current.

B. Accelerator Shutdown Procedure

(See PN-250 Instruction Book for details.)

Emergency Shutdown

- 1. Toggle downward the Control Power switch.**
- 2. Remove key and place back in lock box.**
- 3. When safe to do so, log emergency conditions in Operator Logbook and contact the radiation safety officer.**

Normal Shutdown

1. Slowly rotate the Belt Charge control counter-clockwise taking note of the Total Charge and Voltage meters. As charge leaks off the dome, the voltage should approach zero.
2. Bring the Beam control (probe voltage) to zero.
3. Bring the Focus control voltage to zero.
4. Toggle downward the Control Power switch.
5. Remove key and place it back in lock box.
6. Log Stop time in Operator Logbook.
7. Comment on any abnormal running conditions in Operator Logbook.

C. Accelerator Tank Gas Filling/Emptying Procedures

- Fill Directly from source bottle
 1. Evacuate accelerator tank with roughing pump.
 2. Regulator on source bottle should be fully counter-clockwise.
 3. Open valves 1 and 2 (in line from source bottle to accelerator tank).
 4. Open valve on top of source bottle and slowly rotate regulator control clockwise to control flow (do not allow the line to freeze). Fill tank to 95—100 psig.
 5. Close valves 1 and 2, return regulator to fully counter-clockwise, and close valve on top of source bottle.
 6. Release pressure in gas line with pressure-relief valve.

- Fill Directly from storage tank
 1. Evacuate accelerator tank with roughing pump.
 2. Open valves 8, 7, and 4 (in line from storage tank to accelerator tank, bypassing the compressor).
 3. Slowly open valve 1 to allow gas pressures between the accelerator tank and storage tank to equalize.
 4. Once pressure has equalized, close valve 4.
 5. Open valves 3 and 5. Note: now valves 8, 7, 5, 3, and 1 are open.
 6. Start compressor.
 7. When storage tank is empty, turn compressor OFF.
 8. Close valves 1, 3, 5, 7, and 8 (all valves closed).
 9. If needed, fill from source bottle as per directions.
 10. Release pressure in gas line with pressure-relief valve.

- Empty into storage tank
 1. Evacuate storage tank with roughing pump.
 2. Open valves 8, 7, and 4.
 3. Slowly open valve 1 to allow gas pressures between the accelerator tank and storage tank to equalize.
 4. Once pressure has equalized, close valves 3 and 7.
 5. Open valves 5 and 6. Note: now valves 1, 4, 5, 6, and 8 are open.
 6. Start compressor.
 7. When accelerator tank is empty, turn compressor OFF.
 8. Close valves 1, 4, 5, 6, and 8 (all valves closed).
 9. Release pressure in gas line with pressure-relief valve.

D. Vacuum System Procedures

There are two pumping stations: one for the Acceleration Tube to the left of the gate valve, one for the remainder of the beam line to the right of the gate valve. The latter includes the target chamber. The accelerator may be operated with the target chamber up to air, so long as the gate valve is closed. The gate valve is interlocked with the vacuum meters such that both lines have to be $<5 \times 10^{-5}$ Torr for the gate valve to open. If either pressure rises, the gate valve will close automatically. However, since the gate valve may not close fast enough to protect the turbo pumps and/or Acceleration Tube, one should not rely on the interlock. **Always double check vacuum pressures before making a change to the vacuum system.**

1. Check that the gate valve is closed (upper panel of control rack). If not, close it.
2. Turn on vacuum pressure meters (power switch is at the rear of the Gauge Controller).
3. Press CHAN to scroll through the 4 thermocouple gauges (1 = A.Tube, 2=Chamber, 3,4 = not used) and the 2 penning gauges (1 = A. Tube, 2 = Chamber). The thermocouple gauges read pressures $>10^{-3}$ Torr. The penning gauges read pressures $<10^{-3}$ Torr. If up to air, you should read 760 Torr on the appropriate thermocouple gauge. If not, press the ATM button to recalibrate the thermocouple.
4. Double check that the line you wish to evacuate is closed up. If so, press START on the relevant Pump Control Box (left box = A. Tube). This will start the turbo pump and its associated backing pump.
5. When the thermocouple gauge falls into the 10^{-2} to 10^{-3} Torr range, press CHAN to the relevant penning gauge and press EMIS. You may have to wait and press EMIS again, possibly several times, until the penning gauge measures a current.
6. Log Start time in Operator Log.

Bringing a vacuum line up to air:

1. Press CHAN on the Gauge Controller to monitor the beam line you wish to bring up to air.
2. Press EMIS to turn OFF the penning gauge.
3. Press the START button on the relevant Pump Control Box (left box = A. Tube). The green light above the button will go out, but the pump will continue to spin as it slowly winds down. Once the pressure is high enough, the vent valve will be automatically opened.
4. Log Stop time in Operator Log.

Maintenance on the Gettysburg College Proton Accelerator will be performed in house by or under the direct supervision of the authorized users identified on the state license.

Most maintenance problems are described in the Model PN Positive Ion Accelerator Instruction Book (HVI-368, High Voltage Engineering Corporation, Burlington, MA) or in the Gettysburg College Proton Accelerator Laboratory Maintenance Logbook.

Whenever maintenance is performed, including pre-semester and annual preventative maintenance as described below, details should be logged in the GCPAL Maintenance Logbook.

Preventative Maintenance Inspection Chart

Station	Component	Action
Daily		Log only abnormal conditions.
Generator	Tank	Check buffer gas and replenish to 100psi if below 90psi.
All Stations	System	Inspect by eye and ear for signs of wear or abnormal operation. Check tank-cooling water.
Pre-Semester		Log in Maintenance Logbook.
All Stations	System	Check-run using Operator's Procedure. Check for signs of abnormal noise. Check mechanical pump oil. Check turbo pump cooling fans.
Annually (pre-summer) Generator	Belt	Log in Maintenance Logbook. Inspect for frayed sides, burns, deterioration, and replace if necessary.
	Motor	Check freedom of rotation; replace bearings if needed.
	Alternator	Check freedom of rotation; replace bearings if needed. Lightly oil alternator mount screws.
	Belt Chg. Ass'y	Remove, clean, inspect screen; replace if worn.
	Term. Collector	Remove, clean, inspect screen; replace if worn.

	Column Resistors	Remove, clean, inspect for broken and/or loose resistors, good contact. Replace as necessary.
	Gradient Bars	Clean bars.
	Column	Clean and inspect insulators.
	Accelerator Tube	Check spark gaps and tube clips.
	Tube Connectors	Check for position.
	Tank	Blow out, check surfaces and repair burned areas.
	Terminal Shell	Clean and polish.
	Terminal	Inspect electronics for signs of excessive heating.
	Ion Source Circuit	Inspect for signs of wear or burning. Retune before closing up.
Vacuum Sys.	Mechanical pumps	Total yearly hours run from Operator Logbook. Check oil.
	Turbo pumps	Total yearly hours run from Operator Logbook.
Operator Cntrl.	Control Cabinet	Open and blow out. Visually inspect for loose and/or burned contacts. Log annual hours run.
	Accelerator base	Open and blow out. Visually inspect for loose and/or burned contacts.
Beam Optics	Steerers	Inspect for evidence of excessive heating.
	Quads	Inspect for evidence of excessive heating.

IX. Record Keeping

A. Training Records

The radiation safety officer will maintain records of all employees who have attended radiation training. Training dates, times, locations, and participants will be included in the annual audit submitted to the environmental health & safety officer.

B. Operator Logbook and Maintenance Records

The Operator Logbook and maintenance records for the proton accelerator shall be maintained in the Gettysburg College Proton Accelerator Laboratory.

C. Annual Program Audits

The environmental health & safety officer will maintain records of annual audits of the Gettysburg College Proton Accelerator Safety Program, including results of periodic radiation surveys.

Appendix A

Proton **Accelerator Operator** Safety Training Certification

By signing this certification form at a training session, you acknowledge that you are aware of the Gettysburg College Proton Accelerator Laboratory Safety Program and the policies and procedures applicable to the safe operation of the High Voltage Engineering PN250 Proton Accelerator, and you have attended a training session by the radiation safety officer or his/her designate.

I have received training in the use of the High Voltage Engineering PN250 Accelerator.

This training included the following topics:

- knowledge of the different types of ionizing radiation
- sources of potential radiation in the Gettysburg College Proton Accelerator Laboratory
- risks from occupational radiation exposure
- units of radiation dose
- measures that can be taken to protect against exposure to radiation, including specific procedures the college has implemented such as work practices, emergency procedures, and personal protective equipment to be used
- the purpose and function of monitoring equipment
- applicable details of the Gettysburg College Proton Accelerator Safety Program and the accelerator instruction manual

Name: _____

Signature: _____

Today's Date: _____

Accelerator Laboratory Supervisor's Name: _____

Name of Trainer: _____

Signature of Trainer: _____

Today's Date: _____

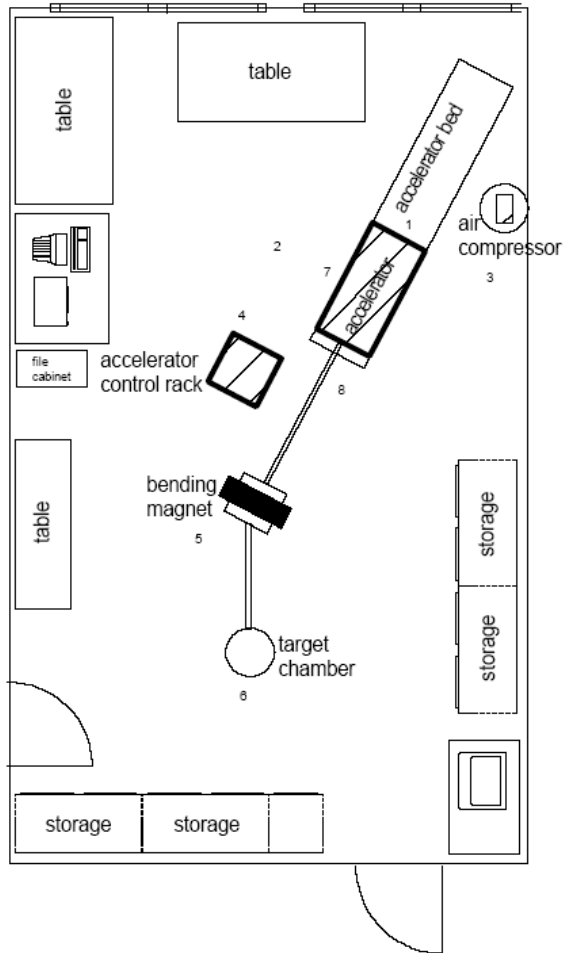
Appendix B
Radiation Survey Report

Spring _____ Summer _____ Fall _____

Has the instrument operated since completion of the last survey report? _____ Y _____ N
(If Answer is No, a survey report is not necessary)

Operating Energy _____ keV Beam Current _____ μ A Vacuum Pressure _____ Torr

Surveyor _____ Date _____



Location	Description	Survey Reading ($\mu\text{R/hr}$)
1	Back of Tank	
2	One meter from Control Side of Tank	
3	One meter from Compressor Side of Tank	
4	Control Rack	
5	Bending Magnet	
6	Target Chamber	
7	Surface of Tank	
8	Accelerator Output	

Appendix C

Accelerator Lab Facility Layout