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Revision: 00
Revision Date: 6/30/03

COLLIDER-ACCELERATOR DEPARTMENT

Title: OSH Initial Assessment Review for Accelerator Experiments

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Group: ESHQ

Approvals

Signature on File ______________________ Date:________________

ESH&Q Division Head

Signature on File ______________________ Date:________________

Collider-Accelerator Department Chairman

(Indicate additional signatures)

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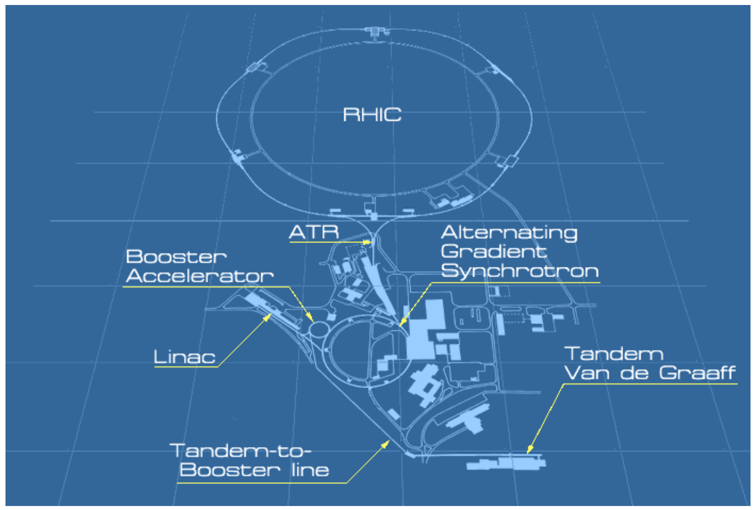
BROOKHAVEN NATIONAL LABORATORY
INITIAL ASSESSMENT FORM

<table>
<tr><td>ID:</td><td colspan="2">C-A-OSH-EXP</td><td>Revision 00</td></tr>
<tr><td>Work Area Name:</td><td colspan="3">Accelerator Experiments</td></tr>
<tr><td>Work Area Description:</td><td colspan="3">LINAC, TVDG, Tandem to Booster, Booster, AGS, AtR, RHIC.

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<tr><td>Dept./Div.:</td><td colspan="3">Collider-Accelerator Department (C-AD)</td></tr>
<tr><td>Dept. Code:</td><td colspan="3">AD</td></tr>
<tr><td>Building(s):</td><td colspan="3">912, 919, 1005, 1002, 1004, 1008, 1010</td></tr>
<tr><td>Point of Contact:</td><td colspan="3">Building 912, Building Manager F. Kobasiuk
Building 919, Building Manager, J. Benante
Building 1005, RHIC Ring, Building Manager J. Benante
Building 1002, Building Manager F. Kobasiuk
Building 1006, Building Manager F. Kobasiuk
Building 1008 RHIC Ring, F. Kobasiuk
Building 1010 RHIC Ring, F. Kobasiuk</td></tr>
<tr><td>Originally Prepared by:</td><td>Peter Cirnigliaro</td><td>Original Reviewers:</td><td>E. Lessard
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<tr><td>Initial Release Date:</td><td>6/30/03</td><td></td><td></td></tr>
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General Information for Accelerators and Experimental Areas

Primary areas are areas where beam is fully enclosed. During running periods, this includes the Tandem van de Graaff, Tandem to Booster line (TTB), Linac, Booster, AGS, AGS to RHIC line (AtR), RHIC and RHIC interaction regions. It also includes the SEB port, the switchyard and the beam lines (A, B, C and D) up to the target stations housed in Building 912. Primary areas also include Building 927, which encloses the FEB port that gives rise to the U, V and upstream portion of the W lines. The U and V lines are used for high-intensity proton experiments using fixed targets and are considered primary areas. All primary areas are fully enclosed by shielding or fences. They are generally arranged as shielded areas with interlocked gates.

Secondary beam lines are beam enclosures that extend beyond the primary lines. They are normally labeled A1, A2, C1, C4, etc. They are not necessarily fully enclosed; that is, they may not have a barrier on the roof. They are generally arranged as fenced areas with interlocked gates. The radiation hazard in secondary areas is less than primary beam areas. Secondary areas are enclosed in larger structures referred to as experimental halls. The five-acre structure, Building 912, houses all primary slow-extracted-beam lines that give rise to thirteen secondary beam-lines. Building 919 houses a secondary beam line that arises from the fast extracted beam.

A strict radiation hazard classification scheme for beam lines was adopted by the Collider-Accelerator Department, or its predecessors, in the 1970s and it is delineated in C-AD OPM Procedure 9.1.11. This guideline prescribes the radiological controls, interlocks, enclosure types, and access and sweep requirements for beam lines.

Fixed Target Experimental Areas, Buildings 912 and 919

Building 912, the AGS Experimental Building, is a large structure and the functional focus of the fixed target accelerator program. This building is a high-bay steel-frame construction, covers 16,350 m^2 (more than 4 acres), with a form approximating two contiguous rectangles, one 64 m by 150 m, the other 61 m by 116 m. These areas are further delineated as East Experimental Area (EEA), East Experimental Building Addition (EEBA), North West Experimental Area (NWF,A), Target Building, East Experimental Building Addition Annex (EEBAA) and North Experimental Building Addition (NEBA). The area houses the G Superperiod of the AGS, the Slow External Beams including the switchyard, and all of the Slow External Beam experimental setups.

Building 919 is also named the "g minus 2" experiment. It is a metal shell building with 1,490 m^2 of floor area. It includes light shops and labs, a compressor room to process gases such as hydrogen, helium, and neon to pressures up to 4000 psi. Building 919 also has a building crane. The current function of this space is to house the dormant g-2 experiment, which consists of a cryogenic storage ring, and associated detectors and controls.

Not surprisingly all of the hazards indigenous to high energy physics are represented in Buildings 912 and 919: high currents to 5000 A dc, high voltage to 500 kV dc, high radiation to 100,000 rem/hr (10^3 Sv/hr) within the highly protected primary beam lines, the high flammability/explosion and cryogenic hazards associated with liquid hydrogen targets, plus standard industrial hazards such as: rigging, 6 bridge cranes 4 at 40 tons, 1 at 25 tons, 1 at 10 tons; occasional welding; large mechanical hazards associated with moving equipment; mechanical hazards from vacuum equipment; small radiation sources for testing equipment; magnetic fields; toxic materials used for counting gases; confined spaces; and many types of counting gases that are either flammable or inert, which represents an oxygen deficiency hazard. Experiments at C-AD change from year to year. Therefore, the 912 experiment floor will serve to define a class of activities for the purposes of defining all experiments at C-AD.

The RHIC Collider, Buildings 1005, 1002, 1006, 1008, 1010

The RHIC Collider consists of two beams circulating in opposite directions around a pair of superconducting magnet rings in a 3.8 kilometers circumference tunnel. The machine is designed to collide beams at six locations where experiments can be carried out. Each ring is capable of accepting either protons or ions from deuterons up to gold; therefore, the Collider can contain experimental beams of protons, ions or a combination.

Protons are accelerated up to a final energy of 250 GeV and gold ions to 100 GeV per nucleon (GeV/u). Two major detector facilities, STAR and PHENIX, have been constructed at the six and 8 o'clock locations, respectively. Smaller experiments, BRAHMS and PHOBOS, have been installed at the 2 and 10 o'clock locations, respectively. Four and 12 o'clock intersecting regions remain for future development. The Collider beam stops are located in the Collider tunnel. The Collider experiments include all of the hazards associated with the fixed target programs with the stipulation that oxygen deficient hazards are more common due to the extensive use of liquid helium and liquid nitrogen.

Detailed Process and Hazard Descriptions for Accelerators and Experimental Areas

IONIZING RADIATION HAZARDS

The external radiation hazard is due to loss of beam at a single point inside an enclosure with potential exposure of personnel from radiation that penetrates through thin shielding. Inadvertent beam losses are not rare events, they may happen several times per shift. For example, power to a bending magnet may be disrupted. In the collider-accelerator complex, beam faults are detected with area radiation monitors and addressed immediately, and operators re-tune the beam or reduce intensity according to established OPM procedure. Additionally, personnel are protected during a fault by appropriate shielding and by barriers such as fences that keep people at a safe distance.

The design goal for the ion accelerators is no more than 20 mrem per fault. C-A Department OPM procedures prohibit more than four faults at a given location in one hour. Because shielding is relatively inexpensive, beam faults typically produce a fraction of a mrem exposure. Offsite risk from inadvertent beam loss at the accelerators is insignificant.

Sweep procedures are used to remove people from an enclosure prior to the onset of operations with beam. Once the beam is on, interlocked gates protect people from contact with the beam hazards directly.

Accidental exposure of workers to contamination is rare and may happen if a target fails during high-intensity proton operations. Because there is a relatively minor inventory of dispersible radioactivity in a failed target, there is no impact to public. That is, experience shows the majority of radioactivity will be firmly entrained in the target metal and will not become airborne.

Targets are designed and fabricated to withstand the quasi-static and dynamic thermal stresses from a high-intensity pulsed beam. If a target is heated slowly enough and uniformly enough, then it will not break. Our experience with contamination events is that the severity of contamination is negligible. That is, significant internal exposures to radioactive materials have not occurred over the past 40 years of operations at C-A facilities.

Several primary beam areas such as the Linac, Booster Ring, AGS Ring, Switchyard and Target Caves are High Radiation Areas during shutdown or maintenance days. The residual radiation level may be greater than 100 mrem per hour in these areas, and up to 50,000 mrem per hour at targets. Generally, there are not high levels of radiation all over the area; it is usually at hot spots such as the center of magnet gaps. In order to control radiation exposure during maintenance periods in these locked enclosures, individuals are trained and authorized. Additionally, job-specific radiation work permits are used to control work in High Radiation Areas.

The C-AD has a limited number of beta and gamma emitting sources. These are available to be loaned as needed. Care is taken to ensure sources brought into the C-AD facilities are not lost, as this might result in unnecessary exposure and widespread contamination if a source is damaged. Sources are not allowed to be taken into an uncontrolled area nor away from the C-AD complex.

The C-AD HP Office is contacted if sources are moved within the complex. Sources owned or brought into the complex are leak checked by the HP Office annually, or a valid certificate of a leak check accompanies the source.

Environmental radiation-protection issues include:

- Sky-shine, which is high-energy radiation interacting in the sky above the accelerators that gets reflected back to the ground in the form of low-energy radiation
- Induced radioactivity in cooling water and fire-protection water
- Cooling tower emissions of radioactive gases to air
- Induced radioactivity in air
- Induced radioactivity in beam-line components that later enter a waste stream
- Induced radioactivity in soil

Procedures and systems have been established to eliminate environmental emissions, or reduce them to a level of no significant impact.

HAZARDOUS OR TOXIC MATERIAL HAZARDS

Although the dominant shield materials are concrete and iron, lead shielding is sparsely found throughout the complex. In any handling operation, routine industrial hygiene procedures are followed. In case of fire, some lead may be heated and released in smoke. People would be expected to stay out of smoke if a fire occurs, thus exposure to lead vapors is not considered a hazard.

Materials Safety Data Sheets are used by personnel who work with hazardous chemicals. Personnel are also trained in Hazard Communication. The range of materials is typical for an industrial complex of this size. The hazards from these materials are in the "routinely accepted" category and pose minor hazards within the complex. In particular, hazardous and toxic materials pose no significant impact off-site.

Uranium shield block is used to accommodate both shielding and space requirements in Building 912. The high density of uranium allows one to fit the beam-line shielding within the building confines whereas iron, concrete or heavy concrete would require more space than is available.

The toxicological hazard from depleted uranium is greater than the radiological hazard. The maximum credible intake in a fire at C-AD was determined to be 13.5 mg; however, this intake would not likely to lead to kidney impairment, which is expected to occur for intakes greater than 30 mg. The committed effective dose equivalent from inhalation of 13.5 mg of U (uranium dioxide, Class Y) is 0.8 rem.

It was concluded that toxic hazard from fire in Building 912 was low. An external fire would not reach the uranium shield block. The probability of renal injury or significant radiation dose was determined to be extremely remote. That is, the probability of occurrence could not be distinguished from zero.

The intersecting regions at STAR, PHENIX, BRAHMS, and PHOBOS contain solid beryllium beam pipes. These pipes are physical protected to prevent damage and direct access by personnel to them. Beryllium and beryllium containing materials and are controlled through the Laboratory Beryllium Use Review Form (BURF) process. The metal poses little or no immediate hazard in solid form; however, inhaling particulate containing beryllium may cause a serious, chronic lung disease called Chronic Beryllium Disease (CBD) in some individuals.

FLAMMABLE OR COMBUSTIBLE MATERIAL HAZARDS

Welding gases and flammable/explosive gases in experimental detectors is widely used and stored according to National Fire Protection Association codes and standards applicable to experimental installations. Gases are stored in compressed gas cylinders which meet DOT specifications. Large quantities of stored gas are forbidden in accelerators and experimental areas, and staff and users are generally limited to using 100 to 200 lb. cylinders inside of buildings. No offsite threats to the public are expected should a cylinder fail.

Combustible loading of beam lines consists of magnets, power and control cables, and beam diagnostic equipment. None of the materials are highly flammable, and with the possible exception of small amounts of control cable, all are expected to self extinguish upon de-energizing of electric power. Induced radioactivity is deeply entrapped in magnets and concrete shielding, and is not dispersible in a fire. No off-site threats to the public are expected from a fire.

The personnel risks associated with the fire hazard are considered low considering the type of building construction, the available exits, the fire detection systems, the fire alarm systems, and the relative fire-safety of the components and wiring. The fire protection of some buildings is improved by the installation of sprinkler systems, and some experimental equipment has fire suppression. Emergency power and lighting is available in all parts of the complex and travel distances to exits do not present a problem.

The maximum travel distance from any point to an exit is less than 300 feet and therefore within the allowable distance. The smoke detection systems, emergency lighting, non-flammable construction where possible and fire suppression where appropriate make the experimental structures acceptable.

ELECTRICAL ENERGY HAZARD

Hazards leading to personnel injury include electrical shock and high current arcing. Electrical shock presents the greatest hazard. High voltages are present in many parts of the accelerator complex. These areas include: the main magnet power supply, other magnet power supplies, kicker systems, rf systems and their power supplies, experimental area equipment, and, the most commonly encountered, ac distribution systems from 480 V 3-phase down to the 208/120 volt local distribution systems.

Regardless of the voltage involved, high current systems may create arcs capable of causing severe flash burns, direct burns, or molten metal splattering. Even though circuit breakers may actuate, the short-circuit capability of many systems is many tens of thousands of amperes and severe damage or injury can occur before the breaker trips.

Procedures and proper equipment design are used to reduce the potential for electric shock. Accidents are eliminated or minimized by the application of proper equipment design and design reviews, quality assurance programs, component and equipment testing and personnel training.

Electrical hazards pose only minor on-site impact potential and negligible off-site impact potential.

OXYGEN DEPLETION HAZARDS

Oxygen depletion hazards (ODH) occur when an enclosed space is designed into a facility or experimental structure. With the exception of the RHIC tunnel, RHIC compressor buildings and Building 919, the accelerators, transfer lines and experimental areas do not have sources of cryogenic fluids in which a large volume of cryogenic liquid can be released to create an ODH. Fixed-target experimental areas where ODH may occur are typically man-size, walk-in trenches throughout the experimental areas. In order to eliminate the potential for loss of life or injury, certifications/permits are required for entry inside confined spaces at the accelerator complex, and where appropriate, atmosphere-testing prior to entry, entry procedures, alarming oxygen monitors, escape packs, exhaust fans and posting are also used.

There is no impact on the public or the environment for ODH.

MAGNETIC FIELD AND ELECTROMAGNETIC RADIATION HAZARDS

High direct current magnetic fields may be present in accelerator and experimental area magnets, particularly spectrometer magnets. Limits of exposure are such that the whole body is not allowed in fields greater than 600 gauss on a daily basis (8-hour time-weighted average), and the extremities are not allowed in fields greater than 6000 gauss (8-hour time-weighted average). Other hazards associated with strong magnetic fields are reaction with heart pacemakers or other medical implants and the potential physical injury of carrying ferrous objects near a strong field. Areas with strong magnetic fields are fenced and posted with appropriate warnings. Cardiac pacemaker wearers are not allowed to be exposed to fields greater than 5 gauss.

High magnetic fields are routinely encountered by the public in conjunction with Magnetic Resonance Imaging. Lower level magnetic fields are routinely encountered in the home due to AC power use.

Many areas contain high power rf systems that generate large fields of electromagnetic radiation in the frequency range of a few hundred kilohertz to a few hundred megahertz. These systems, for proper operation of the accelerator, are thoroughly shielded to prevent leakage radiation, thus minimizing this hazard. Leakage of radio-frequency radiation from electronic equipment is controlled by using RFI gaskets. The rf stations in the rings may be powered when the rings are accessible, but local barriers are used to restrict personnel access.

Exposure of personnel to magnetic fields and rf radiation is in compliance with SBMS requirements. Access to the rings is prohibited when the main magnets are powered; when necessary, access is permitted for personnel authorized via a Class D working hot permit. Static or remnant magnetic fields present in ring and transport magnets do not warrant special controls other than appropriate warning signs.

There are no off-site or environmental impacts associated with magnetic fields and electromagnetic radiation at the ion accelerators.

THERMAL ENERGY HAZARDS

Heat sources such as soldering irons and vacuum heating blankets exist in several areas of the accelerator complex. Skin contact with heat sources may cause burns. These hazards are mitigated by safety reviews and compliance with SBMS requirements; for example, shielding or posting warnings near hot surfaces. This hazard is limited in scope and poses no hazard outside the complex.

CRYOGENIC TEMPERATURE HAZARDS

Cryogenic liquids exist in several areas of the accelerator complex. Skin contact with cryogenic materials due to spills or splashes may cause freezing or "cryogenic burns." These hazards are mitigated by safety reviews and compliance with SBMS requirements; for example, requiring the use of gloves and splash goggles when handling open containers of cryogenic fluids. This hazard is limited in scope and poses no hazard outside the complex.

KINETIC ENERGY HAZARDS

Kinetic energy hazards are associated with motorized materials handling equipment and with the operation of hand and shop tools. These hazards are mitigated by safety reviews and compliance with SBMS requirements; for example, machine guarding. This hazard is limited in scope and poses no hazard outside the complex.

POTENTIAL ENERGY HAZARDS

Potential energy hazards are those associate with compressed gases and vacuum windows, as well as those associated with hoisting and rigging operations. These hazards are mitigated by safety reviews and compliance with SBMS requirements; for example, by designing pressure and vacuum vessels to the ASME code, and by setting requirements for the training and qualification of operators, riggers, inspectors, and trainers who use cranes, forklifts, man lifts, hoists, in-plant powered industrial trucks, and rigging equipment.

This hazard is limited in scope and poses no hazard outside the complex.

Controls in-Place or Planned Controls

IONIZING RADIATION HAZARDS

A. Direct Radiation

Possible Consequences:

- Accidental external radiation exposure from beam faults producing greater than 20 mrem
- No impact to public

Potential Initiators:

- Shield degradation
- Failure to follow both the design procedure and fault study procedure for new shields
- Loss of shield configuration control
- Barrier failure
- Person defeats barrier
- Door interlock failure
- Failure to respond to radiation alarms

Hazard Mitigation:

- Fault studies of shielding
- Shield drawing configuration control
- Radiation Safety Check-off List completed prior to operating machines or beam lines where shields have been modified
- Fence and barrier inspection by operators during sweep procedure
- Formal design reviews for radiation safety for all shield modifications
- Facility specific training for all personnel and Users
- Formal job assessments
- Conduct of Operations procedures and training records
- Formal OPM procedures for MCR Operator response to radiation alarms
- PAAA enforcement
- Radiation shielding and barriers designed to reduce the worst case accident exposure to less than 20 mrem per event
- A dual, independent, fail-safe protection system to control access to High Radiation Areas
- Radiation monitors to alarm in the Main Control Room and to turn the beam off if unusual radiation levels occur
- A loss monitor system and fast-beam interrupt system primarily designed to protect equipment and unwarranted soil-shield activation
- A system of radiation work permits
- Radiation Worker training
- Work planning

B. Contamination

Possible Consequences:

- Accidental internal uptake of radioactive material
- No impact to public

Potential Initiators:

- Failure to follow the design review procedure for targets
- Failure to follow rules for entry or work in Contamination Areas
- Improper target fabrication
- Target intensity limit exceeded
- Target temperature interlock failure

Hazard Mitigation:

- Radiation Safety Committee review of targets
- Mechanical engineering design review of targets
- Target intensity limits approved by Radiation Safety Committee and promulgated by operations procedures
- Radiation Safety Check-off List completed by responsible parties and concurred on by MCR Operations Coordinator prior to sending beam to targets
- Operators trained on procedure that lists the individual target intensity limits for each running period
- Air-flow barriers on doors leading to potentially contaminated target caves
- No HVAC in beam lines or target caves except at NSRL where beam intensity is low
- Contamination worker training for all potentially affected personnel
- Formal job assessments
- Conduct of Operations procedures and training records
- Water-cooled targets
- Target design which accounts for dynamic and quasi-static thermal stresses
- Fail-safe target temperature interlocks
- Contamination surveys at target gates
- A system of radiation work permits
- Work planning

HAZARDOUS OR TOXIC MATERIAL HAZARDS

Possible Consequences:

- Accidental exposure leading to personnel injury
- Un-permitted environmental release
- Negligible off-site impact

Potential Initiators:

- Cooling pipe break on systems with ethylene glycol
- Oil leak from capacitors, transformers, pumps, motors

- Unsafe practices for handling hazardous and toxic materials
- Fire near uranium shield blocks
- Damage to beryllium beam pipes

Hazard Mitigation:

- Approved line organization procedures and training for hazardous waste handling
- Hazard Communication training
- Labeling of pipes
- Annual inventory of chemical and hazardous materials
- Annual inventory, inspection and tracking all PCB containing devices
- Annual inventory of tanks containing oil
- Annual inspection of transformer yards
- Annual inspection of tanks
- Specific hazard training (e.g., Beryllium, asbestos)
- Limiting the amount of hazardous materials in process
- Work planning

FLAMMABLE OR COMBUSTIBLE MATERIAL HAZARDS

Possible Consequences:

- Loss of life or severe injury
- Damage to components or facilities
- Impact on the physics program due to fire-related interruptions
- Insignificant impact on the environment due to releases as a result of fire

Potential Initiators:

- The common initiators in an accelerator fire are damaged or improperly connected electrical cables
- Less common initiators are failed capacitors in pulse-forming networks, improper fusing of electronics boards or failed motor starter circuits
- Ignition of flammable gases in the experiments
- Ignition of flammable liquids in the experiments

Hazard Mitigation:

- Sprinklers or other protection systems for high-value experimental equipment
- High sensitivity fire detection systems
- Selection of materials that reduce the potential for flame spread
- Emergency exhaust ventilation systems
- The use of strategically located exits and audible alarms to reduce the potential for loss of life during an emergency
- Elimination of potential ignition sources in experimental areas
- On-site fire/rescue organization
- Emergency planning and drills
- Limits on flammable gas or liquid inventory and on flow rates in the experiments

- Requirements for safety review of experiments or accelerator modifications
- Compliance with the Life Safety Code, NFPA 101, Chapters 1-6
- Compliance with the DOE Orders 420.1A, Facility Safety, and 440.1A, Worker Protection Management for DOE Federal and Contractor Employees
- Use of fire wire fire-detection systems on experimental equipment
- Electrical energy interlocks tripped by heat or smoke detectors
- Regular maintenance of electrical equipment
- Using containers that meet the criteria of Underwriters Laboratories or Factory Mutual for flammable materials
- Identifying and posting hazardous locations for flammable or combustible materials storage or use
- Written procedures to temporarily impair fire detection or fire protection systems
- Using a fire watch and a permit for cutting and welding activities
- Work planning

ELECTRICAL ENERGY HAZARD

Possible Consequences:
- Electrocution death and injury
- Electrical arcing and molten-metal spray injury
- No impact to public

Potential Initiators:
- Unsafe practices

Hazard Mitigation:
- Approved line organization procedures and training for specific tasks involving electrical safety issues
- Control zones around energized parts with signs and barriers
- Procedures and training
- Use of permits to work hot
- Performance of a job safety-analysis in order to identify and mitigate the hazard of electrocution
- Lock out and tag out procedures
- Equipment and training to isolate the source of energy in the system
- Use of a safety watch or two-man rule where appropriate
- Not allowing Users to work on power distribution or connection to electrical power
- Work planning

OXYGEN DEPLETION HAZARDS

Possible Consequences:
- Asphyxiation

Potential Initiators:

- Inadvertent entry into ODH areas

Hazard Mitigation:

- Posted Confined Spaces in accordance with SBMS requirements
- Posted ODH areas in accordance with SBMS requirements
- Written procedures for purging the hazardous gases from the experimental equipment
- Determining the O_2 level using an oxygen meter prior to entry
- Fixed O_2 meters and alarms in ODH areas
- Escape packs where appropriate
- Exhaust fans
- Design reviews and functional testing of the ODH alarm system before operations
- Work planning

MAGNETIC FIELD AND ELECTROMAGNETIC RADIATION HAZARDS

Possible Consequences:

- Reaction with medical implants
- Magnetic pull of heavy metal object through persons hand and into magnet iron with resultant crush type-injury of hand
- Hyperthermia (rf)
- Cataracts (rf)
- Lenticular opacities (rf), laser

Potential Initiators:

- Inadvertent exposure to stray magnetic field near spectrometer magnet or other large magnet
- Exposure to rf radiation from rf device or light from a laser

Hazard Mitigation:

- Areas with strong magnetic fields are fenced and posted with appropriate warnings
- Magnets such as large spectrometer magnets undergo an environmental review before turn on to ensure signs and postings are present and to ensure loose ferrous objects are not present
- Routine measurement of magnetic fields around spectrometer magnets on the experimental floor to ensure fencing and posting are located appropriately
- Design reviews and functional testing before operations
- Doors to the facilities are posted with warnings for persons wearing a cardiac pacemaker
- Local barriers are placed around rf stations in the accelerators
- RFI gaskets are used on equipment to prevent rf radiation leakage
- Routine monitoring for rf radiation to determine if gaskets are effective
- Eye protection during laser operations

- Interlocks on lasers
- Work planning

THERMAL ENERGY HAZARDS

Possible Consequences:

- Burns
- Fires

Potential Initiators:

- Contact with hot surfaces of machinery
- Contact with soldering irons
- Improper protective clothing for cutting and welding operations

Hazard Mitigation:

- Posting and guarding hot surfaces
- Review of installation and operating procedures by the safety committees
- Design reviews and functional testing before operations
- Cutting and welding conducted by trained personnel only
- Boundaries for cutting and welding are posted
- Cutting and welding permit
- Work planning

CRYOGENIC TEMPERATURE HAZARDS

Possible Consequences:

- Burns

Potential Initiators:

- Spills of cryogenic liquids
- Contact with cold lines associated with liquid nitrogen or other cryogenic fluids

Hazard Mitigation:

- Insulation on cold surfaces
- Review of installation and operating procedures by the safety committees
- Design reviews and functional testing before operations
- PPE such as goggles and face shields
- Work planning

KINETIC ENERGY HAZARDS

Possible Consequences:

- Physical injury (e.g., eye injury, broken bones, hearing loss, fatal injury, etc.)

Potential Initiators:

- Mis-operation of power tools
- Pressure testing with inappropriate vessels or piping
- Inadvertent contact with rotating or moving machinery
- Improper rigging of apparatus or shielding

Hazard Mitigation:

- Machine guards
- Only trained personnel allowed to operate tools or perform rigging operations
- Written procedures or supervisory participation in large equipment moves or pressure tests
- Critical lift review and approvals as per SBMS
- Design reviews and functional testing before operations
- Work planning

POTENTIAL ENERGY HAZARDS

Possible Consequences:

- Physical injury (e.g., eye injury, broken bones, hearing loss, etc.)

Potential Initiators:

- Release of stored energy associated with compressed gases
- Puncture of a vacuum window
- Improper hoisting operation

Hazard Mitigation:

- All equipment is designed to applicable codes and standards
- Operation and design reviewed by safety committees
- Vacuum window covers
- Design reviews and functional testing before operations
- Training and adherence to procedures by operators of compressed gas systems
- Only trained personnel allowed to perform hoisting operations
- Written procedures or supervisory participation in large equipment moves
- Work planning

Training Requirements

IONIZING RADIATION HAZARDS

- Radiological Worker I (HP-RWT002)
- General Employee Radiation Training (HP-RWT001)
- Users Training for Fixed Target Areas (AGS)
- Users Training for Collider
- Radiobiology Users Training
- Collider-Accelerator Access (AD-CA_ACCESS)

HAZARDOUS OR TOXIC MATERIAL HAZARDS

- Users Training for Fixed Target Areas (AGS)
- Users Training for Collider
- Radiobiology Users Training
- Collider-Accelerator Access (AD-CA_ACCESS)
- General Employee Training (HP-V-001)

FLAMMABLE OR COMBUSTIBLE MATERIAL HAZARDS

- Users Training for Fixed Target Areas (AGS)
- Users Training for Collider
- Radiobiology Users Training
- Collider-Accelerator Access (AD-CA_ACCESS)
- General Employee Training (HP-V-001)
- Emergency Planning and Response (GE-EMERGPLAN)

ELECTRICAL ENERGY HAZARD

- Electrical Safety I (TQ-ELECSAF1)
- Electrical Safety Work Practices (AD-ELECSAFETY)
- Lockout/Tagout Affected Worker (HP-OSH-151A-W)
- Department Specific Lockout Tagout (AD-LOTO-OJT)
- Users Training for Fixed Target Areas (AGS)
- Users Training for Collider
- Radiobiology Users Training
- Collider-Accelerator Access (AD-CA_ACCESS)
- General Employee Training (HP-V-001)

OXYGEN DEPLETION HAZARDS

- Oxygen Deficiency Hazard (TQ-ODH)
- Users Training for Fixed Target Areas (AGS)
- Users Training for Collider

- Collider-Accelerator Access (AD-CA_ACCESS)
- General Employee Training (HP-V-001)

MAGNETIC FIELD AND ELECTROMAGNETIC RADIATION HAZARDS

- Static Magnetic Fields (TQ-SMF)
- Users Training for Fixed Target Areas (AGS)
- Users Training for Collider
- Radiobiology Users Training
- Collider-Accelerator Access (AD-CA_ACCESS)
- General Employee Training (HP-V-001)

THERMAL ENERGY HAZARDS

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- Users Training for Collider
- Radiobiology Users Training
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- General Employee Training (HP-V-001)

CRYOGENIC TEMPERATURE HAZARDS

- Cryogen Safety (HP-OSH-025)
- Users Training for Fixed Target Areas (AGS)
- Users Training for Collider
- Radiobiology Users Training
- Collider-Accelerator Access (AD-CA_ACCESS)
- General Employee Training (HP-V-001)

KINETIC ENERGY HAZARDS

- Users Training for Fixed Target Areas (AGS)
- Users Training for Collider
- Radiobiology Users Training
- Collider-Accelerator Access (AD-CA_ACCESS)
- General Employee Training (HP-V-001)

POTENTIAL ENERGY

- Confined Space Entry (HP-OSH-016)
- GE-81 - Fall Protection-Qualified
- Stop Work Procedure Training (GE-STOPWORK)

- Crane Safety (HP-Q-010)
- Crane Operator Practical (HP-Q-010)
- Users Training for Fixed Target Areas (AGS)
- Users Training for Collider
- Radiobiology Users Training
- Collider-Accelerator Access (AD-CA_ACCESS)
- General Employee Training (HP-V-001)

Regulatory Determination of Process
(Identify Applicable OPMs; See OPM 1.10.4.a, Flow Down Matrix for Higher Level Documents)

IONIZING RADIATION HAZARDS

- 2.5 Operational Safety Limits/Accelerator Safety Envelope for AGS, Booster and Linac
- 2.5.1 Accelerator Safety Envelope Parameters for C-A Tandem Van de Graaff
- 2.5.2 RHIC Accelerator Safety Envelope Parameters
- 4.1 C-A Complex Access Control Procedures for Primary Beam Enclosures
- 9.1.1Procedure for Obtaining Review by C-A Radiation Safety Committee
- 9.5.1 C-A ALARA Policy and Responsibilities
- 9.1.15 Guideline for Radiological Review Criteria for C-A Experiments and Procedures

HAZARDOUS OR TOXIC MATERIAL HAZARDS

- 1.8 Hazard Communication Procedure
- 8.24 Use of Beryllium
- 9.2.1 Procedure for Reviewing Environmental , Health and Safety Aspects of an Experiment

FLAMMABLE OR COMBUSTIBLE MATERIAL HAZARDS

- 1.9 Fire Safety Program
- 2.5 Operational Safety Limits/Accelerator Safety Envelope for AGS, Booster and Linac
- 2.5.1 Accelerator Safety Envelope Parameters for C-A Tandem Van de Graaff
- 2.5.2 RHIC Accelerator Safety Envelope Parameters
- 9.2.7 Design Of Experimental Flammable Gas Systems

ELECTRICAL ENERGY HAZARD

- 1.5 Electrical Safety Implementation Plan
- 2.6 Lockout Tagout Procedure for Personnel Entry into the AGS or Booster Ring
- 9.2.3 Procedure for Chief Engineers to Certify the Conformance of Devices
- 9.3.4 Review and Approval of Electrical Equipment Built In-House
- 9.2.1 Procedure for Reviewing Environmental , Health and Safety Aspects of an Experiment

OXYGEN DEPLETION HAZARDS

- 3.15 Response to Low Oxygen Alarm in ODH Class 0 and 1 Areas
- 4.44 Operation of PASS

- 12.11 Oxygen Deficiency Hazard Response (Tandem)
- 9.2.1 Procedure for Reviewing Environmental , Health and Safety Aspects of an Experiment

MAGNETIC FIELD AND ELECTROMAGNETIC RADIATION HAZARDS

- 9.2.1.d Threshold Limit Values For Magnetic Fields
- 9.2.1 Procedure for Reviewing Environmental , Health and Safety Aspects of an Experiment

THERMAL ENERGY HAZARDS

- 9.3.1 Procedure for Reviewing Conventional Safety Aspects of a C-A System
- 9.2.1 Procedure for Reviewing Environmental , Health and Safety Aspects of an Experiment

CRYOGENIC TEMPERATURE HAZARDS

- 7.1.39 Cryogenic Group Lockout/Tagout
- 9.6.1 Cryogenic System Review
- 9.2.1 Procedure for Reviewing Environmental , Health and Safety Aspects of an Experiment

KINETIC ENERGY HAZARDS

- 1.17 C-A Hearing Conservation Program
- 8.25 Material Handling and Lifting Safely: Equipment and Procedures
- 9.2.1 Procedure for Reviewing Environmental , Health and Safety Aspects of an Experiment

POTENTIAL ENERGY

- 1.6 Mechanical System(s) Safety Implementation
- 2.6 Lockout Tagout Procedure for Personnel Entry into the AGS or Booster Ring
- 8.14 Confined Space Entry Procedure
- 9.2.1 Procedure for Reviewing Environmental , Health and Safety Aspects of an Experiment

Assessment from Workers Health Surveillance
(Review Injury Statistics for Area from SHSD Spread Sheet and Injury Report)

Hazard Description	1 Injury/Illness Description	3 Number of Injuries/Illness 2000-2002	4 Number of Critiques for year 2000-2002	5 Number of Occurrences for year 2000-2002	6 Injury Sum add columns 3,4 and 5
Ionizing Radiation Hazards	0	0	0	0	0
Hazardous Or Toxic Material Hazards	0	0	2	1	3
Flammable Or Combustible Material Hazards	0	0	2	0	2
Electrical Energy Hazard	0	0	1	1	2
Oxygen Depletion Hazards	0	0	0	0	0
Magnetic Field And Electromagnetic Radiation Hazards	0	0	0	0	0
Thermal Energy Hazards	0	0	0	0	0
Cryogenic Temperature Hazards	0		0	0	0
Kinetic Energy Hazards	0	0	0	0	0
Potential Energy	0	0	0	0	0

Risk Assessment
(Using Risk Matrix, Table 1)

Hazard ID	Risk Level Scale
Ionizing Radiation Hazards	**2**
Hazardous Or Toxic Material Hazards	**1**
Flammable Or Combustible Material Hazards	**3**
Electrical Energy Hazard	**2**
Oxygen Depletion Hazards	**2**
Magnetic Field And Electromagnetic Radiation Hazards	**1**
Thermal Energy Hazards	**1**
Cryogenic Temperature Hazards	**2**
Kinetic Energy Hazards	**1**
Potential Energy	**2**

Risk Metrics

List hazards; rank them using Tables 1 and 2; multiply the scores to get a Relative Risk Level.

Hazard ID	1	2	3	4	
	Scope Scale	Risk Level Scale	Compliance Scale	Injury Sum	Relative Risk Level, Product of columns (0=1) 1-4
Ionizing Radiation Hazards	3	2	4	0	24
Hazardous Or Toxic Material Hazards	3	1	3	3	27
Flammable Or Combustible Material Hazards	3	3	2	2	36
Electrical Energy Hazard	3	3	2	2	36
Oxygen Depletion Hazards	3	2	2	0	12
Magnetic Field And Electromagnetic Radiation Hazards	3	1	1	0	3
Thermal Energy Hazards	3	1	1	0	3
Cryogenic Temperature Hazards	3	2	1		6
Kinetic Energy Hazards	3	3	1	0	9
Potential Energy	3	2	2	0	12

Hazard Minimization Opportunities for Accident Prevention

(Select the four highest Overall Risk Levels from Section 8)

1. Electrical Energy Hazards
2. Flammable or Combustible Material Hazards
3. Hazardous or Toxic Materials

On October 2, 2002 Derek Lowenstein, C-A Department Chair, charged an ad hoc Electrical Safety Review Committee to review non-compliances reported in external and internal assessments. The Committee determined that LOTO log books are not always used to record LOTO and that it was a time-consuming task to associate a given LOTO tag with a particular logbook entry at C-AD. The Committee determined that alternate web-based LOTO systems appear to be potentially useful for tracking individual LOTOs, for tracking LOTO evolutions, and for issuing LOTO tags. The ad hoc Committee also determined that used LOTO tags and stubs should be destroyed after use; again to avoid the appearance of non-compliance.

The Committee also determined that up to date one-line drawings are needed in order to ensure that the correct protective equipment is chosen when working hot. The Committee clarified that verifying a LOTO is working hot if the testing equipment is manipulated by hand. The committee determined that the Department lacks a written grounding plan for accelerators and beam lines. These issues and other issues associated with training were addressed in the ad hoc Committee's recommendations, and are identified as an opportunity for an injury reduction initiative.

The C-A Department has taken a proactive approach to fire safety. A review of the fire alarm panels in some facilities requires updating and replacement. The department has submitted an ADS for such improvements. The fire alarm panel in building 930 is scheduled for replacement this year.

The Department has implemented the International Labor Organization Guidelines for Occupational Safety and Health Managements Systems, ILO-OSH-2001. These guidelines enhance ISM principles with additional principles that are similar to the ISO 14001, which is used for the Environmental Management System. These additional principles promote worker participation and continual improvement, which in turn increases worker protection. It is expected that this new management system will provide a means of continual improvement in the handling of hazardous or toxic materials. Through enhanced communication, personnel are continually made aware of changes to policies and procedures concerning the handling of toxic or hazardous materials so work may proceed in a safe and environmentally conscientious manner.

Injury/Illness Reduction Initiatives

Hazard ID	New OPM, Inspection Process, or Other Mechanism	ATS , ADS Number or Reference
Electrical Energy Hazards	Review electrical safety issues at C-A through an Ad Hoc Electrical Safety Review Committee.	ATS-1425
	Review and implement appropriate corrective actions recommended by Office of Independent Oversight during an Electrical Safety Review at C-AD.	ATS-1425.2
	Implement corrective action recommended by the Ad Hoc Committee; for example, implement a Web Based LOTO data entry/Tag system.	ATS-1425.1.8
Flammable and Combustible Hazards	Update of C-AD Accelerator Safety Envelopes for managing response to fire alarms.	OPM 2.5
	Perform and review emergency response drills at C-A.	ATS-1382
	Replace various Fire Alarm Panels in building 930	ADS-AA2D0076
Hazardous or Toxic Materials	Perform and review emergency response to drills that may include environmental risks.	ATS-1382
	EMS Review Record of Decision	ATS-1272
	Reviews and Audits of the CAD EMS.	ATS-1714
	Implementation of ILO-OSH-2001	OPM 1.10.4

The Risk Matrix (Table 1)

↑ ***Consequence Level***

High	Low Risk – Acceptable *(Risk level 2)*	Medium Risk- Unacceptable *(Risk level 3)*	High Risk- Unacceptable *(Risk level 4)*	High Risk- Unacceptable *(Risk level 4)*
Medium	Extremely Low Risk - Desirable *(Risk level 1)*	Low Risk – Acceptable *(Risk level 2)*	Medium Risk- Unacceptable *(Risk level 3)*	High Risk- Unacceptable *(Risk level 4)*
Low	Extremely Low Risk - Desirable *(Risk level 1)*	Extremely Low Risk - Desirable *(Risk level 1)*	Low Risk – Acceptable *(Risk level 2)*	Medium Risk- Unacceptable *(Risk level 3)*
Extremely Low	Extremely Low Risk - Desirable *(Risk level 1)*	Extremely Low Risk - Desirable *(Risk level 1)*	Extremely Low - Desirable *(Risk level 1)*	Low Risk – Acceptable *(Risk level 2)*
	Extremely Unlikely ($<10^{-4}$/y)	**Unlikely (Between 10^{-4}/y and 10^{-2}/y)**	**Anticipated(Note) Medium (Between 10^{-2}/y and 10^{-1}y)**	**Anticipated (Note) High (Above 10^{-1}y)**

Likelihood of Occurrence →

Definition of Consequence Levels

- Extremely Low: Will not result in a significant injury or occupation illness or provide a significant impact on the environment.
- Low: Minor onsite with negligible or no offsite impact. Low risk events are events that may cause minor injury or minor occupational illness or minor impact on the environment.
- Medium: Medium risk events are events that may cause considerable impact onsite or minor impact offsite. Medium risk events may cause deaths, severe injuries or severe occupational illness to personnel or major damage to a facility or minor impact on the environment. Medium risk events are events from which one is capable of returning to operation.
- High: High-risk events may cause serious impact onsite or offsite. High-risk events may cause deaths or loss of facility/operation. High-risk events may cause significant impact on the environment.

Note: 10CFR835 may require limits that are more stringent for anticipated events.

Risk Metrics (Table 2)

List hazard, rank them using the scale below, four being the most significant.

Scale	Scope of Hazard Impact Scale	Outcome of Compliance Failure Scale
1	Unnoticeable (Low)	Minimal
2	Only one work area (Low)	Record keeping, warning only
3	Organization wide (Moderate)	Department Penalty
4	Impact Outside of the organization (High)	Civil /Criminal Penalty, fine