Critique of Electric Shock Incident at X1

September 10, 2004
Revised November 8, 2004

Nicholas F. Gmür and W. Robert Casey

Purpose:
This critique was conducted to establish the sequence of events and determine the causal factors that resulted in the electric shock to an NSLS technician at the X1 beamline front end. An initial meeting was held 08/10/04 to gather information and to evaluate circumstances surrounding the event.

Attendees:
Mohammad Ali (DOE-BHSO)
Rich Biscardi
Mike Buckley
Nick Gmür
Ed Haas
Erik Johnson
Pat Moylan
Mike Schwarz
Emil Zitvogel

Additional information was obtained from Sue Wirick and Chris Jacobsen (SUNY/SB), Randy Church, Walter DeBoer, Al Borrelli

Sequence of Events
The utilities technician who received the shock and his supervisor were asked to relate the events leading up to the shock.

As part of the July 13-14, 2004 X-ray ring Maintenance period, cooling water hoses in the X1/X2 front end area were scheduled for replacement. This is standard for all water hoses and occurs every 2-3 years. A component located in the front end section of beamline X1 had water hoses, but the use and status of that component was unknown. The Utilities Technical Supervisor talked with a series of NSLS staff members (technician in the Electrical Controls & Diagnostics Group, supervisor in the Vacuum Group, supervisor of the Control Room) in order to locate an individual with knowledge about the unit and was led to the Local Contact (LC) for the X1A1/A2 beamline. (Note: the Electrical Controls & Diagnostics technician does not recall this discussion; he does,

however, remember discussing the shock after the event with the Control Room supervisor, and assisting in restricting personnel access and helping to assemble an electrical team to investigate.) The Utilities Tech Supervisor was told that the PBPM was associated with X1 and to get in touch with the Local Contact. It was identified as a photon beam position monitor (PBPM). The LC agreed with the supervisor to help with the hose replacement. By the time this determination had been made, the work had to be postponed until the August 10-11 Maintenance period. On August 9, the day before the Maintenance was to begin, the supervisor contacted the LC once again. The LC agreed to be available the morning of August 10. At 08:00 hrs, the LC met with the technician who was to replace the hoses. The LC, with assistance from the tech, removed the front aluminum plate of the box around the top of the PBPM. This was necessary to access the hose connection inside that box. The LC informed the tech that the PBPM motors were off (this meant that the motor power supply and motor drivers were powered down; the motor cables at the rear of the motor driver crate were disconnected). The LC also looked at and confirmed that all cables connected to the box in question were BNC cables. The LC left to obtain a step stool to assist the tech. The tech assumed that the system was in a safe configuration to begin work. The tech placed a 9/16" wrench inside the aluminum box, made contact with the nut securing one of the hoses, and received an electric shock. The tech's other hand was holding onto the aluminum foil surrounding the X1 beam pipe.

The tech immediately dropped the wrench and pulled his hands away. He informed a Utilities technician who was working nearby and the LC. The LC, in turn, informed the Control Room supervisor. The tech also informed his supervisor who was working in a mechanical equipment room. Access to the X1 beamline front end area was restricted using Caution tape. The supervisor escorted the tech to the BNL Occupational Medicine Division (~08:20 hrs) where the tech was given an examination by the medical staff, including an EKG. The tech was released and given permission to return to work.

At ~08:30 hrs, a team consisting of a departmental electrical supervisor, two Plant Engineering electricians and the departmental Head of the Electrical Section was assembled to assess the situation, determine the source of power to the beam position monitor and power the supply down. They initially locked and tagged the power supply, but later removed the supply from the beamline in order to conduct static and dynamic tests. The static test determined that the power supply could reach ~292 volts DC and ~18 mA. The dynamic test determined that the power supply reached 18-20 mA almost immediately, thus indicating the tech had been shocked in the BNL "Range B" category ('DC voltages less than or equal to 1000 VDC; with greater than 10 mA of available current' according to BNL Standard 1.5.0, 'Electrical Safety'). The ORPS Categorizer was informed of the findings.

Subsequent actions

On August 11, 2004, all NSLS photon beam position monitors were identified, status confirmed and steps taken to make sure they were safe and/or known configurations. In several instances yellow Caution tags were placed by members of the inspection team that advised the system should not be connected, and that either the beamline local

contact or the control room should be contacted. Specific actions taken at individual beamlines were as follows:

X1A 300V power supply removed, tags placed on the device in the tunnel, and on the cables out on the experimental floor

X13 Not in use, tag placed on the cables outside of the shield wall

X17 Due to lead shielding the cables could not be traced, and hence the voltages could not be measured using approved procedures. For this reason a Caution tag was placed inside the ring on the monitor further advising that it may be at a high voltage.

X21/25 Traced out and found to have electronics that can provide bias voltage. X21 had no bias. X25 used a fixed bias of 24 VDC. No tags were applied.

U14B Power supply tagged out at the power supply advising that owner or the Control Room should be contacted

At 21:30 hours on August 11, 2004, the Chair of the National Synchrotron Light Source requested that the Associate Chair for Operations, with the help of the Electrical Section Head, the Mechanical Section Head and the Operations Section Head, organize teams of electrical and mechanical personnel to examine the X-ray ring and associated front ends to assess any previously unidentified hazards and, where necessary, mitigate them. Teams were formed and conducted their surveys on August 12, 2004.

Discussion

Background Information

X1A1/A2 Beamline

- The X1A1/A2 beamline is one of ~60 operating beamlines on the X-ray ring. X1A1/A2 operations and research are administered by a Participating Research Team (PRT). This beamline uses scanning transmission x-ray microscopy for Physics, Materials Science, Chemistry, Environmental Science, Geology, Biology, Medicine and Instrumentation. The PRT members are from Brookhaven National Laboratory - Environmental Science Dept., National Synchrotron Light Source, Exxon Mobil Research and Engineering Co., SUNY @ Plattsburgh, SUNY @ Stony Brook and University of Texas. The beamline Spokesperson and the beamline Local Contact (LC) are both affiliated with SUNY @ Stony Brook.

Power Supply

The power supply used for the X1 PBPM had the following information:
High Voltage Calibrated DC Power Supply capable of 2000 VDC
Model Number 2K20; Serial Number 301008
Manufactured by Power Designs Inc., Westbury, NY
A label was attached stating “State University of New York – PHYSICS – Stony Brook”
The power supply setting at the time of the incident was for 303 volts DC, positive output.
The supply was used to provide a 300 volt bias for the photon beam position monitor.

The history of this power supply is unclear at this point. The X1A1/A2 Spokesperson has stated, "Regarding the power supply used to bias the photon beam position monitor, my recollection (which I won't guarantee is correct) is that this power supply was originally used in the scanning photoemission microscope that used to be in operation at X1A. It
may or may not have been purchased by Stony Brook; the sticker may simply indicate that it was in use at X1A. It was certainly not hooked up to the photon beam position monitor by X1A1/X1A2 personnel operating on their own, and I believe it has been in use
in its location for at least a decade."

Photon Beam Position Monitor (PBPM)

The PBPM in use in the X1 front end had originally been designed and installed by NSLS staff. A description of the device may be found in:
E.D. Johnson and T. Oversluizen, *Compact High Flux Photon Beam Position Monitor*, Rev. Sci. Instrum. 60 (7), July 1989, pp. 1947-1950.
There are two such PBPMs currently installed at the NSLS (X1 and X13). The X1 PBPM was installed in 1989 and the X13 PBPM was installed in 1990. An earlier prototype is installed at U14B. Devices with similar function, but of a different configuration are installed at X21, X25 and X17. PBPMs are used to monitor the horizontal and vertical positions of insertion device photon beams on straight section beamlines. The LC knew that two motors were associated with the PBPM and had shut these off long before this work took place since the PBPM was not in use. The X1 PBPM operated with a 300 volt DC bias. This bias was originally supplied by a 300 volt battery which was subsequently replaced with a DC power supply. The LC was not aware that the PBPM was biased at 300 volts DC, nor was the LC aware that a power supply existed in an electronic rack near the front end of the X1 beamline to supply the PBPM. After the electric shock had occurred, a sign was found that had apparently once been taped to one side of the PBPM aluminum box (based on an imprint left on the aluminum panel) It should be noted that the sign had been positioned on the opposite side of the box from the work location of the technician on August 10. When the sign was found, it was lying face down on an adjacent piece of equipment near the PBPM. The sign reads:

CAUTION! CAUTION! CAUTION!
DO NOT OPEN COVER WITHOUT
CONTACTING X1A PERSONNEL
RE: 300VDC POWER SUPPLY

The aluminum box at the top of the PBPM had five BNC cable connections. There were no SHV connections or red high voltage cables. The X1A1/A2 LC provided the following information, "There are only 2 motors on the beam positioning monitor chamber; bpm-x and bpm-y. Bpm-x moves [the whole assembly] to the right or the left and bpm-y moves [the whole assembly] up and down. I've only ever moved them twice, once with Roger [Klaffky] and once with Steve Kramer. Both times those guys watch an orbit in the control room while I move the motors. You'd have to ask Steve [Kramer]

exactly what it is he looks at. I'm not sure. And how the blades actually "move" the beam, I'm not sure about either. Steve would also know the answer to this." The LC also stated later that X1 personnel had moved the photon blades a total of 3 times in the last 11 years to adjust the position of the beam in the X1 front end.

Maintenance Periods

Two-day ring maintenance periods are scheduled every month with longer maintenance periods scheduled during Spring and Winter. Prior to each Maintenance period supervisors are polled to submit a list of their jobs. These are entered into standard forms specifying each group (mechanical, utilities, vacuum, etc.) and the times/dates for the work to be accomplished. A meeting of supervisors is held one week before a Maintenance period begins to review the items, make any necessary changes to the schedule and to allow interaction between groups to make sure jobs go smoothly. Information from this meeting is also brought to the weekly NSLS User meeting when jobs might impact them. The replacement of the cooling water hoses to the X1 PBPM had been contained in the list of planned maintenance activities for the July and August maintenance periods under the title "change poly lines X1-2, X5-6". No discussion of this job took place during either of the meetings.

Previous Hose Replacement Maintenance in 2001

It was determined that the job described above had also been completed in April 10, 2001. In that case, the Utilities Engineer contacted the X-ray Ring Manager to determine the nature and status of the PBPM (the position of Ring Manager no longer exists in 2004). The Ring Manager contacted an electrical engineer to diagnose the system. The power supply was found. It was turned off, locked and tagged out by the electrical engineer. This was documented in the NSLS Red Tag Log Book. A Utilities tech, the same person who received the electrical shock on August 10, 2004, also tagged out the device on April 11, 2001. This tech has no recollection of the 2001 lockout/tagout. The X1 PBPM had been in place for 15 years and other hose replacements had apparently occurred. There is no recollection of how these earlier hose replacements were conducted.

Work Planning

Water hose replacement is considered to be Skill of the Worker activity by qualified NSLS Utilities personnel. The Maintenance Periods section above provides some information regarding work planning. The NSLS Maintenance and Repair Tracking Information (MARTI) database is used to track routine maintenance activities within the NSLS and provides feedback to responsible persons when scheduled activities are due. It also provides capability for the responsible person to identify any special requirements or procedures associated with the task. There is a general procedure associated with all water and air hose replacements tracked in MARTI entitled, "PM Procedure for Air and Water (Lines) Hoses", revision dated 1 March 1999. The procedure states that water and air hoses must be replaced every 2-3 years and provides a color coding sequence for this replacement; there is no specific reference to the X1/X2 hoses in this PM procedure. MARTI also provides periodic reminders to the Utilities Supervisor of preventive maintenance work that needs to be completed. In addition, the Utilities Engineer

maintains task sheets that provide him with a record of maintenance that has occurred during that hose replacement cycle. The Utilities Engineer meets regularly with the Utilities Technical Supervisor to plan work and meets weekly with his technicians to plan out the week's work. This weekly meeting is also used to plan work that will take place during each ring's two-day maintenance shutdown and to anticipate any problems and plan for them ahead of time so that the maintenance schedule proceeds smoothly. Safety considerations and requirements are typically discussed at this meeting. (One recent example would be the need to obtain a Work Authorization to remove lead shielding in order to access some cooling water hoses.) The replacement of the X1 water hoses was discussed at the weekly meeting prior to the initial scheduled maintenance and the work was assigned to a specific technician. There was no specific discussion of electrical hazards or the need for lock-out of the power source. It was noted that the owner of the component would need to be identified before the hose could be replaced.

Equipment Responsibilities

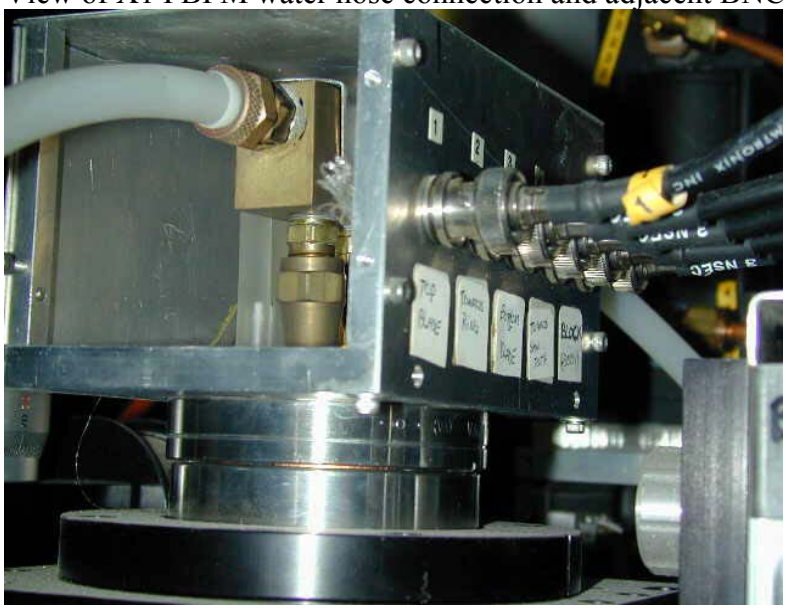
The NSLS maintains equipment responsibilities lists for the major groups at the NSLS. The Mechanical System Responsibilities List includes item #1.11.1.2.5, "X1 Insertion Device Front End Beam Position Monitor"; no engineer or technician name is associated with this entry. This item is not listed in the Electrical & Control Systems Responsibilities List. There was no clearly identifiable "owner" for the PBPM. As stated above, the PBPM in use at X1 was originally designed, built and installed by NSLS staff. If electrical or mechanical repairs had to be made to the unit, NSLS staff would conduct these repairs. X1A personnel only use the signals when they moved the PBPM, 3 times in the last 11 years. They also controlled two motors which positioned the sensor blades of the PBPM, used to locate the horizontal and vertical outer edges of the photon beam. The LC was not knowledgeable of the details of the device, did not know that the PBPM was biased to 300 VDC, and did not know about the power supply itself. The LC stated, "That chamber historically has been shared by X1 and the feedback, vacuum and water cooling guys. We have always maintained the software to move the motors and controllers to drive the motors and the Light Source guys worry about the beam positioning parts. So ownership is a gray area." The LC reported observing five BNC cable connections made to the aluminum box at the top of the PBPM. Based on NSLS facility training, the LC interpreted that BNC-terminated cables were not to be used for voltages greater than 50 V; and therefore assumed that the BNC-terminated cables were used for low voltage signals[1]. One BNC cable did have a small piece of red tape, partially hidden from view, attached to it ~24" away from the connection to the box. It is not known when or by whom the red tape had been installed. As noted in the footnote, an NSLS Electrical Safety Inspection Committee had placed red

[1] The NSLS adopted a conservative standard two years ago requiring that red-jacketed RG-59B/U cable be used for voltage applications greater than 50 volts, even though BNC connectors and standard signal cable are rated up to 500 V. Inspections were performed at all beam lines to enforce this standard, but in a number of cases because of length of cable run, exceptions to the red high voltage cable requirement were permitted with the proviso that the end of the cable be identified with red tape.

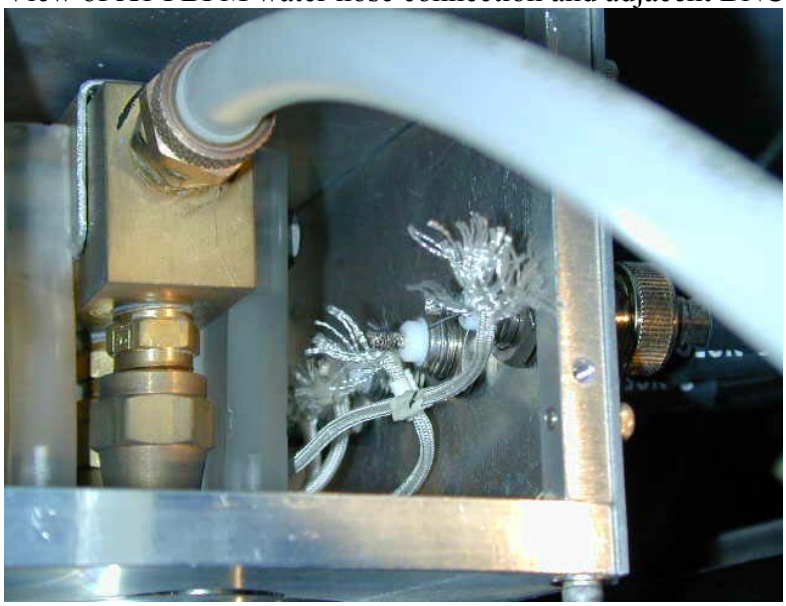
tape on beamline signal cable used above 50 volts as part of a survey performed in 2002, but they reported that they had not affixed tape to any cables within the ring during these inspections. It should be noted that the use of red tape to identify high voltage is a common technique among electricians. However, the LC neither saw this tape, nor would have recognized its meaning.

Figures

View of X1 PBPM water hose connection and adjacent BNC cables



View of X1 PBPM water hose connection and adjacent BNC cables



View of wrench used in attempt to disconnect water hose

Causal Factor Analysis

The causal analysis for this incident was conducted utilizing "TapRooT®", a commercial causal analysis process supported by computer software. Members of the BNL Quality Management Office (QMO) were invited to assist the committee members in this effort. Additional BNL staff members were also asked to participate. The Causal Factor committee consisted of:

Mohammad Ali (DOE-BHSO),
Ron Beauman,
Rich Biscardi,
Mike Buckley,
Bob Casey,
Joe Curtiss (SHSD),
Nick Gmür,
Ed Haas,
Frank Marotta (F&O),
Ed Sierra (QMO),
Emil Zitvogel

The time line established by this team for this incident is given in Appendix A. Causal Factors are designated in the time line by the symbol “CF” and were established by the committee in its deliberations. Causal Factors are considered judgments or actions that directly led to the incident. Each Causal Factor is individually evaluated using the "TapRooT®", methodology to determine the Apparent Causes. Six Causal Factors were selected and are discussed below. Note that a number of Causal Factors were determined to have the same Apparent Causes. To simplify the explanations below, Apparent Causes

are, for the most part, discussed only once with the Causal Factor they are most closely allied with. Corrective Actions associated with Apparent Causes are indicated.

Causal Factor #1: Tech assumes system in safe configuration to begin work

Discussion:

The Utilities technician requested assistance from the X1A1/A2 Local Contact (LC) to gain access into the PBPM box in order to replace the cooling water hose. The LC knew that motors were associated with the operation of the PBPM and knew these were off and their signal/power cables were disconnected. The technician was informed by the LC that the PBPM motors were off. The LC further observed that the signal/power cables leading to the PBPM box had BNC connectors and inferred that this meant <50 volts. The LC was not aware of the power supply and was not aware that the PBPM was biased at 300 VDC. The LC and the tech removed one of the faceplates. At this point the technician assumed that conditions to access the box were safe based on the actions of and the information from the LC. The tech did not ask if the box was safe for access and did not request that the power to the system be locked out. The LC also assumed that it was safe for work. The LC was uninvolved in previous maintenance on the PBPM and was unaware that Lockout/Tagout of the power source was performed in 2001.

Using the TapRooT® methodology, the following apparent causes were selected by the Critique Committee for this Causal Factor:

Apparent Cause # 1 - There was no procedure that the LC or utilities group could refer to place the PBPM in a safe configuration prior to replacing the hose.
(See Corrective Action #2)

> Basis: Neither the LC nor the Utilities tech knew how to render the component safe for maintenance, nor was there any information available to refer to for this purpose.

Apparent Cause # 2 - The communication between the tech and the LC was incomplete.
(See Corrective Actions #4, #9)

> Basis: There was no discussion between the tech and the LC regarding the conditions within the box and whether additional actions, such as Lockout/Tagout were needed. The tech assumed that the PBPM box was safe to access based on the actions of the LC; and the LC assumed that the workers knew how to do the work safely. The tech did not directly ask if conditions were safe nor was a request made to verify that conditions were safe.

Apparent Cause # 3 - The instruction and briefing provided by the supervisor to the tech performing the work needed improvement.
(See Corrective Actions #4, #6)

> Basis: The Utilities group met and discussed the replacement of water hoses in the X1 beamline. Since no one had knowledge of the component, the supervisor visited the beam line to examine the component and discussed this issue with a number of individuals. He eventually consulted with the X1A1/A2 LC about the device (the PBPM) and she agreed to help in the replacement of the hose. The tech was instructed to work with the LC. There was no discussion of the BNC cables that entered the PBPM box and no instruction to determine LOTO requirements prior to the beginning of the work.

Apparent Cause # 4 - The use of Lockout/Tagout needed improvement.
(See Corrective Action #6)

> Basis: The tech assumed conditions were safe based on the actions and information given by the LC. Tech did not ask or seek confirmation that power was off. LOTO was not applied as it had been previously. The tech is LOTO trained and qualified, and should have taken steps to ensure that all high voltages were locked and tagged prior to the beginning of work.

Causal Factor #2: X1A1/A2 LC not aware that PBPM biased at 300 VDC nor aware of location of power supply in electronic rack at front end of X1 beamline

Discussion:

The power supply for the high voltage bias on the PBPM was located at the bottom of a rack at the upstream end of the X1A1/A2 beamline (outside the shield wall) and labeled as SUNY-SB equipment (a member of the beamline Participating Research Team). It should be noted that other equipment in the rack is NSLS equipment. The LC was not aware that the power supply was associated with the PBPM and was also not aware that the PBPM was biased at 300 VDC. A manual describing equipment is available: http://xray1.physics.sunysb.edu/~micros/beamline/beamline.pdf
This documentation refers to beam position determinations based on signals from the X1 PBPM; however, there is no mention of the PBPM power supply or the bias voltage. Discussions with the PRT Spokesperson indicated that the PRT saw themselves as infrequent users of the equipment and not as the responsible party for it. The manual was intended to describe the software and motor positions to aid in movement of the PBPM. The LC had utilized read-outs from the PBPM indicating the position of the synchrotron beam in the X1A beam pipe. The LC was also aware of a Step-Pak stepper motor power supply and controller (for two motors) that adjusted the PBPM position. These devices were seldom used and normally off with the signal/power cables disconnected. The LC recalls collaborating with NSLS accelerator staff on three occasions in moving the PBPM in order to locate the synchrotron beam. The LC was not knowledgeable about the power supply and its hazards.

Using the TapRooT® methodology, the following apparent causes were selected by the Critique Committee for this Causal Factor:

Apparent Cause # 5 - There was no procedure that the LC or utilities group could refer to place the PBPM in a safe configuration prior to replacing the hose.
(See Corrective Actions #1, #5)

Basis: The work was commenced without an understanding of the hazards or the steps necessary to place the component in a safe state. There were no procedures within the Utilities Group for this device, and the X1A beamline operations manual included only information about PBPM beam position readouts.

Apparent Cause # 6 - The instruction and training provided to the Local Contact needs improvement
(See Corrective Actions #5, #11)

Basis: Although the Local Contact has day-to-day responsibility for the beam line, the LC was not knowledgeable of the hazards associated with a component in the beam line's front end. As is discussed in another section, it is not clear that the LC was the proper person to provide access to this device. The LC reported that she assumed she was helping in the hose replacement.

Basis: The NSLS facility specific safety training module discusses the requirement to limit of use cables with BNC connectors to <50 V AC or DC. The module does not include information that already existing cables with BNC connectors might have higher voltages and should be evaluated before working around exposed conductors.

Apparent Cause # 7 - The Local Contact was not qualified to assume responsibility for placing the PBPM in a safe state.
(See Corrective Actions #1, #5)

Basis: The LC was not knowledgeable of the hazards and the methods to safely secure the device. In addition, the LC was not qualified to lock and tagout electrical hazards. While the LC's R2A2 stated, "Ensures that all beam line activities are planned and conducted in accordance with NSLS work planning requirements," this was not done due to lack of knowledge of the PBPM.

Causal Factor #3: Caution sign found laying face down near box

Discussion:

The Caution sign that had originally been fixed to one side of the PBPM box gave clear warning of the potential hazards within the box and would have clearly alerted the tech

and the LC of the shock hazard. It is not known who posted the sign or when it was posted. It is also not known when the sign had fallen off the component. The sign was originally taped onto the side of the PBPM box that faced the inside of the X-ray ring (visible from the inner ring walkway) and was not visible from any other location. In addition, the tape holding the sign had degraded over time and eventually the sign had fallen off, facing down on an adjacent component so no one could read it or know that it was a warning sign.

Using the TapRooT® methodology, the following apparent causes were selected by the Critique Committee for this Causal Factor:

Apparent Cause # 8 - The manner in which the warning sign was affixed did not adequately consider the radiation environment of the X-ray ring.
(See Corrective Action #3)

> Basis: The warning sign was affixed on one face of PBPM aluminum box using adhesive tape. Over time, the tape degraded in the high radiation environment and the label fell off. This is a known condition that needs to be addressed in equipment or signs placed in this environment.

Apparent Cause # 9 - The placement of the original warning sign was inadequate.
(See Corrective Action #3)

> Basis: The location of the original warning sign was visible from one side and would not have provided adequate warning to workers who began work on the side opposite the sign.

Causal Factor #4: The requirement implemented previously to lock and tag out the power supply to the PBPM was not documented and resulted in a loss of historical information.

Discussion:

Replacement of the X1 PBPM cooling water hoses had been conducted in April 2001. At that time, the Utilities Engineer had asked the X-ray Ring Manager (a position that no longer exists) about the device since the engineer was unfamiliar with that device. The Ring Manager knew that it was a PBPM and contacted an electrical engineer to examine the device. The Electrical Engineer determined that the PBPM was biased at 300 VDC, located the power supply, turned it off, and locked and tagged out the power supply. As required by BNL policy, the Utilities tech performing the hose replacement also applied LOTO prior to the job[2]. The 2001 LOTO information (names, dates, component name,

[2] The tech who applied the LOTO in 2001 was the same tech who accessed the PBPM in August 2004 and received the electrical shock. He does not recall that he had applied a LOTO previously when performing this work.

red tag number) is listed in the NSLS Control Room Red Tag Logbook. However, the 300 VDC bias hazard and the LOTO requirement to mitigate the hazard were not documented elsewhere by the Utilities group as a reminder and were forgotten. In 2004, the hose replacement was again scheduled. The previously-identified X1 PBPM 300 VDC hazards were not remembered by either the Utilities Engineer, the supervisor, or the Utilities tech. The Utilities Tech Supervisor, based on discussions with the Utilities Engineer, searched for personnel with knowledge of the device to assist in the hose replacement, including the Vacuum Group supervisor, the Control Room supervisor and a Controls & Diagnostics technician. The Control Room supervisor recognized the device as being the PBPM used by X1 personnel and directed the supervisor to the X1A1/A2 Local Contact.

The NSLS MARTI database is used to track items requiring periodic maintenance and can be used to note special requirements associated with a job. The procedure associated with hose replacement contains instructions regarding replacement frequency and colors for various types of hoses, but contains no safety instructions regarding hose replacement for this device and does not identify knowledgeable people. This procedure would have been an excellent vehicle to capture the LOTO requirements utilized in 2001.

Using the TapRooT® methodology, the following apparent causes were selected by the Critique Committee for this Causal Factor:

Apparent Cause # 10 - The communication and documentation system for ensuring that established safety requirements associated with maintenance are documented and carried forward needs improvement
(See Corrective Actions #1, #5, #7)

> Basis: An important safety requirement correctly identified and used in a maintenance activity was not successfully incorporated into work instructions and was subsequently forgotten.

Causal Factor #5: Based on NSLS specific training LC believed BNC cables used for <50V.

Discussion:

As a part of the required training for Local Contacts, the X1A1/A2 LC had completed the NSLS "Sci/Tech Staff Safety Module" (LS-ESH-SCITECH) on 06/20/2003 and "Electrical Safety I" (TQ-ELECSAF1) on 06/20/2003. The NSLS Sci/Tech training has a specific section on 'Electrical Safe Work Practices' that addresses the use of cables with BNC connectors. The LC interpreted the instruction in the training "Do not use BNC connectors for applications > 50 V AC or DC", to mean that all cables with BNC connectors would have voltage <50 volts and was therefore not concerned with the electrical cables leading into the top of the PBPM.

Using the TapRooT® methodology, the following apparent causes were selected by the Critique Committee for this Causal Factor:

Apparent Cause # 11 - The "Sci/Tech Staff Safety Training Module" needs improvement
(See Corrective Action #11)

> Basis: The NSLS facility-specific safety training module limits the use of BNC cables and connectors for applications to <50 V AC or DC. The module does not include information that already existing BNC cabling might have higher voltages and should not be assumed to carry voltages only < 50 V. In addition, the training should include information regarding the red-tape warning tags that are used to identify non-red high voltage cable carrying more than 50 volts.

Causal Factor #6: Equipment responsibility not adequately assigned for PBPM

Discussion:

The Utilities Supervisor had considerable difficulty identifying who was responsible for the X1 PBPM. Coordination of maintenance activities had been simpler previously when a Ring Manager existed who could identify equipment and responsible people. The Ring Manager position was eliminated in reorganization within the department and now determination of the responsible person resided solely with the supervisor. The department list of equipment and responsible persons that could have been consulted was incomplete and did not have a responsible person identified for the PBPM. Specific ownership of the X1 PBPM was also unclear to the X1A1/A2 LC. Although the PRT provided the power supply for the chamber bias, the equipment had been designed, built and installed by the NSLS, and was used by X1 staff members in conjunction with NSLS operations.

Using the TapRooT® methodology, the following apparent causes were selected by the Critique Committee for this Causal Factor:

Apparent Cause # 12 - The assignment of responsibility for the X1 PBPM was inadequate.
(See Corrective Actions #1, #5)

> Basis: The responsibility for placing the X1 PBPM in a safe state for maintenance was not assigned. The lack of this information created a significant difficulty for the utilities group.

Corrective Actions
The following Corrective Actions are recommended to address the apparent causes of this incident. It is understood that management will receive additional reports which may augment this set of recommendations.

Corrective Action 1
Review current lists for department systems and components, and ensure that the lists:

- Include all equipment
- Identify all equipment with potential hazards
- Assign a person to be responsible for placing those systems or components in a safe configuration for maintenance.

Corrective Action 2
Develop procedures as necessary for placing equipment with potential hazards in a safe configuration for maintenance.

Corrective Action 3
Establish a department policy for affixing warning signs to equipment.

Corrective Action 4
Ensure that department processes for authorizing work are adequate and compliant with the Laboratory Subject Area, "Work Planning and Control for Experiments and Operations", and the tenets of DOE's Integrated Safety Management.

Corrective Action 5
Establish lists for beam line systems and components, and ensure that the lists:

- Include all equipment
- Identify all equipment with potential hazards
- Assign a person to be responsible for placing those systems or components in a safe configuration for maintenance.

Corrective Action 6
Ensure department compliance with BNL Lock-out Tag-out requirements.

Corrective Action 7
Augment the Maintenance and Repair Tracking Information (MARTI) (or its successor), as necessary, to ensure that safety instructions applicable for maintenance activities are included for each component.

Corrective Action 8
Ensure that legacy BNC terminated cables used above 50 V (AC or DC) are properly identified and recognizable by users and staff.

Corrective Action 9
The Associate Chairs will conduct meetings with their line staff to discuss this incident to assure awareness of the causal factors and lessons learned.

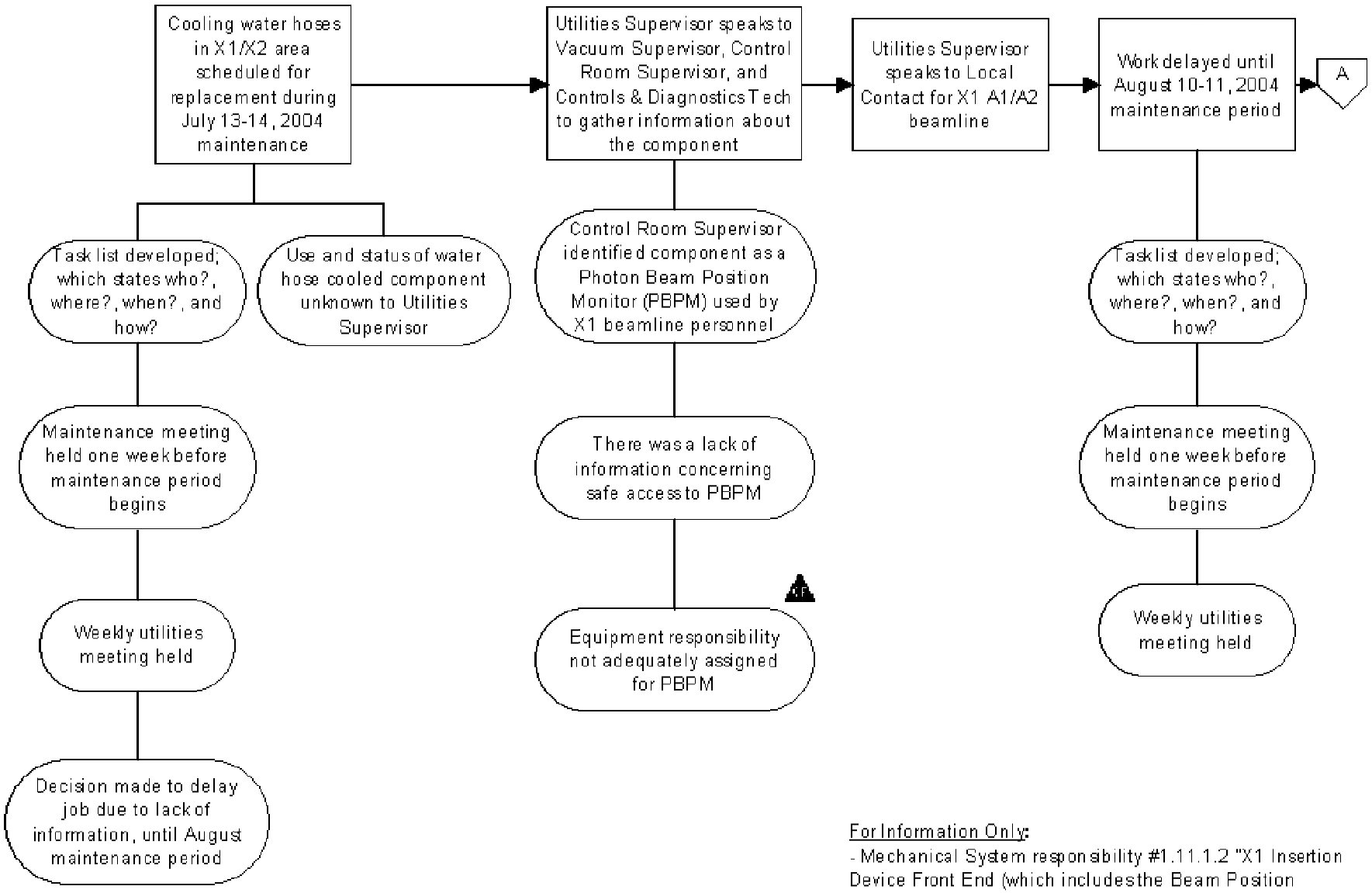
Corrective Action 10
Ensure that job-training assessments (JTA's) are current and complete for all departmental staff.

Corrective Action 11
Revise NSLS Sci/Tech Staff Safety and NSLS Safety training modules to clarify information regarding BNC terminated cables and their potential high voltage use.

Appendix A

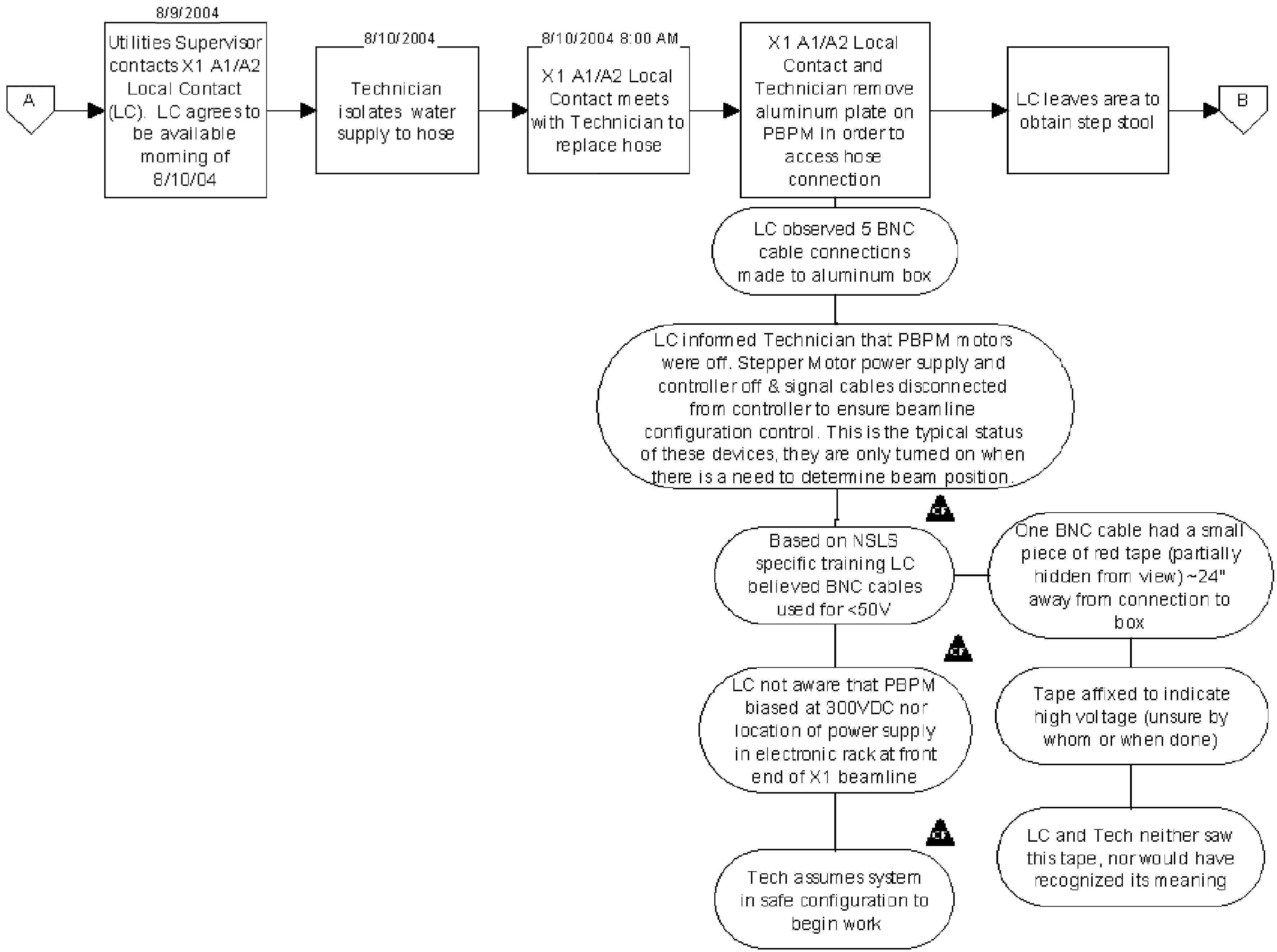
The following three pages show the time line developed using the TapRooT® format.

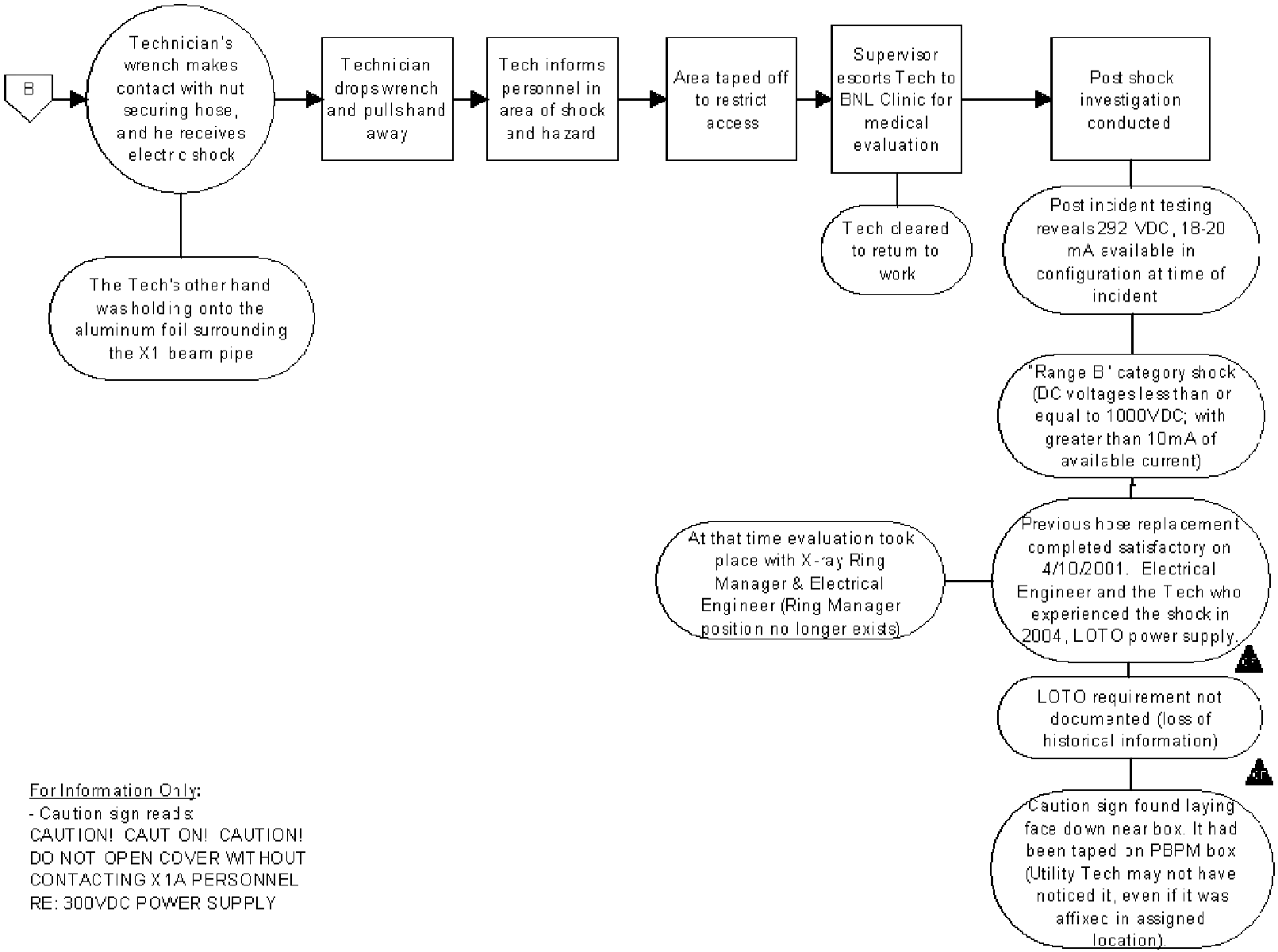
X1 Electrical Shock Incident at NSLS



For Information Only:

- Mechanical System responsibility #1.11.1.2 "X1 Insertion Device Front End (which includes the Beam Position Monitor)" lacks engineer/technician name.
- PBPM not listed in any other Responsibilities List.
- Stony Brook label on power supply.


A
8/9/2004
Utilities Supervisor contacts X1 A1/A2 Local Contact (LC). LC agrees to be available morning of 8/10/04
8/10/2004
Technician isolates water supply to hose
8/10/2004 8:00 AM
X1 A1/A2 Local Contact meets with Technician to replace hose
X1 A1/A2 Local Contact and Technician remove aluminum plate on PBPM in order to access hose connection
LC leaves area to obtain step stool
B
LC observed 5 BNC cable connections made to aluminum box
LC informed Technician that PBPM motors were off. Stepper Motor power supply and controller off & signal cables disconnected from controller to ensure beamline configuration control. This is the typical status of these devices, they are only turned on when there is a need to determine beam position.
Based on NSLS specific training LC believed BNC cables used for <50V
One BNC cable had a small piece of red tape (partially hidden from view) ~24" away from connection to box
LC not aware that PBPM biased at 300VDC nor location of power supply in electronic rack at front end of X1 beamline
Tape affixed to indicate high voltage (unsure by whom or when done)
Tech assumes system in safe configuration to begin work
LC and Tech neither saw this tape, nor would have recognized its meaning



For Information Only:
- Caution sign reads:
CAUTION! CAUTION! CAUTION!
DO NOT OPEN COVER WITHOUT
CONTACTING X1A PERSONNEL
RE: 300VDC POWER SUPPLY