Electrical Safety

In the Research Community

Purpose

- Discuss recent changes in electrical safety requirements and others to be implemented in the future
- Discuss the lessons learned from a number of incidents that have occurred in the workplace
- The intent
  - Reduce risk of future electrical incidents
  - Reduce issues involving electrical equipment at the beam lines

Material to be discussed

- The nature of electrical hazards
- Requirements for working with barriers removed
- Review of NRTL issues for electrical equipment
- Review of common electrical safety issues on the experimental floor
- Discussion of the SLAC accident
- Review of NSLS incidents and lessons learned

Electrical Injury

- ~ 1000 fatalities per year in U.S.
- ~ 5% of all admissions to burn units are electrical in origin
- Most are occupational

Electrical Injury

Four types of injury can result from electrical accidents

- Shock to the nervous system, such as muscle contraction, breathing stoppage, and heart stoppage
- Electrical burns to tissue, which can be especially dangerous if the tissue affected includes organs or bone
- Blast from high current arcing between conductors
- Mechanical injury from reflex action, such as being thrown or falling

Electrical Shock Injury

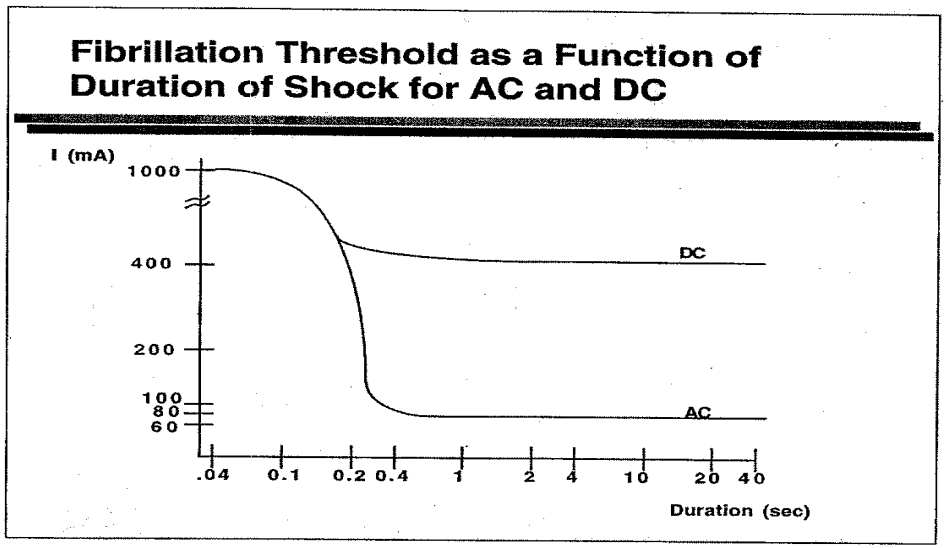
Dependent on

- Wave form (e.g. A.C. D.C., capacitive discharge)
- Current or energy
- Duration
- Current path

Physical Effects of A.C. Shock

Physical effect	Current (mA)
Tingling	~ 1
Let go threshold	~ 10
Respiratory arrest	20 – 50
Ventricular fibrillation	60 - 120

A.C./D.C. Fibrillation Thresholds



Impulse or Capacitive Discharge Shock

- Little research has been done
- 10 J has been chosen to be threshold for danger
- Over 50 J may be lethal
- Defibrillators use around 200 J
- The most significant danger is from the large dissipated energy in a shock. Can produce significant burns, especially to nerves.

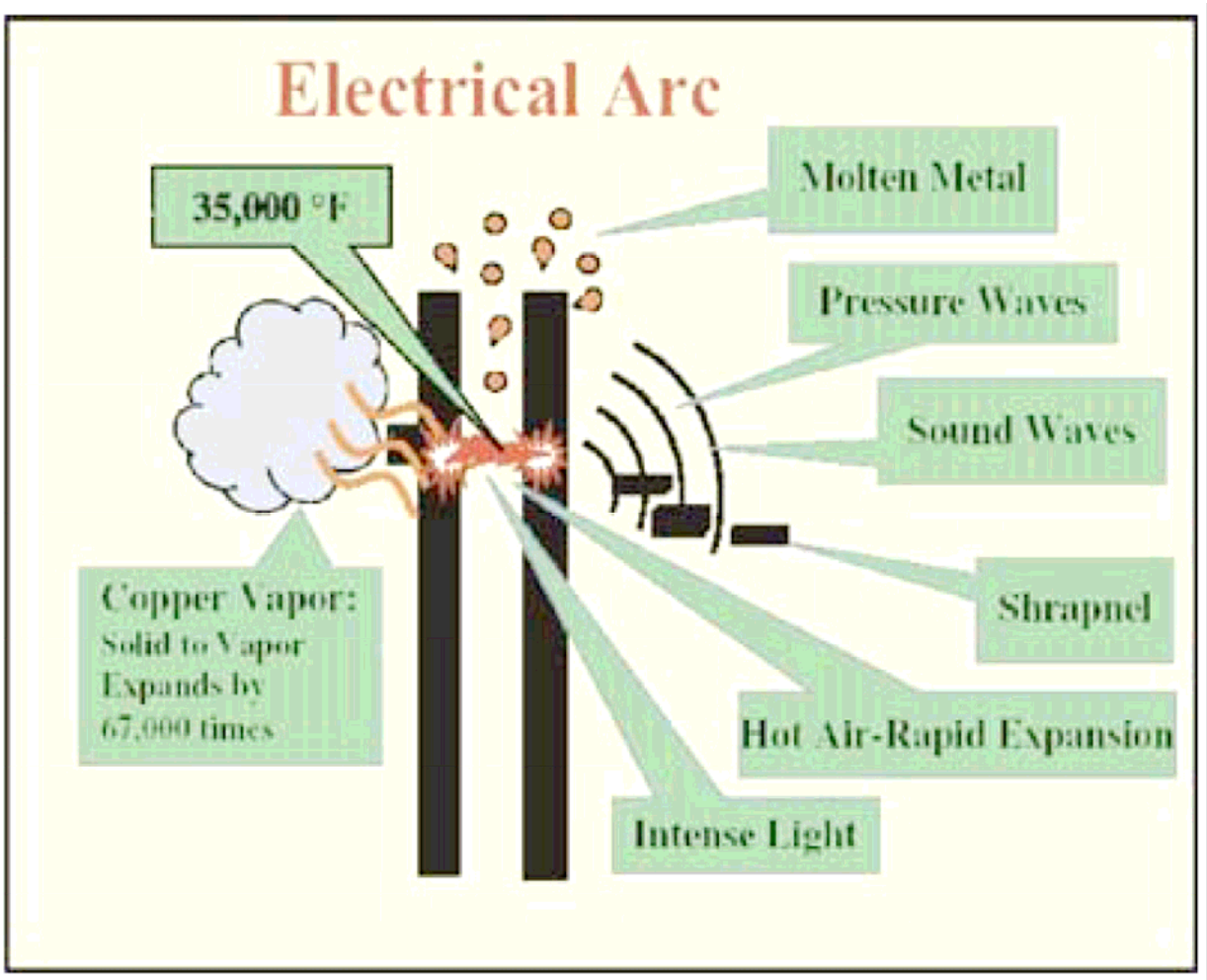
Examples of Electrical Effects

Form of Electricity	Effects
• 60 Hz A.C.	100 mA for 3 seconds – lethal
• D.C.	500 mA for ~ minute – lethal
• Carpet shock	10 A for 1 :s – harmless
• 1 MHz rf	200 mA - allowable

Arc Flash Hazards

- Arc flash – Primarily an issue at V > 240 V. a.c. and currents > 500 amps
- Type of Injury
  - high-intensity flash (eye damage)
  - superheated ball of gas and flying molten metal (skin burns and clothing can catch fire)
  - loud noise & pressure wave (hearing loss, collapsed lungs & concussion)

Electrical Arc Flash



Causes of Arc Flash Accidents

- Dust, impurities, and corrosion at contact surfaces
  - Produces heat, loosening contact and creating sparks
  - Sparks start arcs
- Sparks produced during
  - Racking of breakers
  - Replacement of fuses
  - Breakers/fuses closing into faulted lines
- Failure of insulating materials
- Snapping of leads at connections due to human, rodents or birds
- Accidental touching / dropping of tools, nuts-bolts, or metal parts

IEEE Arc Flash Tests

Figure 3. Test 4 - 22,600 - A rms, 480-V, fault initiated on line lug of size 1 starter, feeder protected by a 640-A noncurrent-limiting overcurrent protective device, and fault was cleared in 6 cycles.

IEEE Arc Flash Tests (cont)

Figure 4. Test 3 - 22,600-A rms, 480-V, fault initiated on line lug of size 1 starter, feeder protected by a 601-A current-limiting device and fault was cleared in 1/2 cycle.

IEEE Arc Flash Tests (cont)

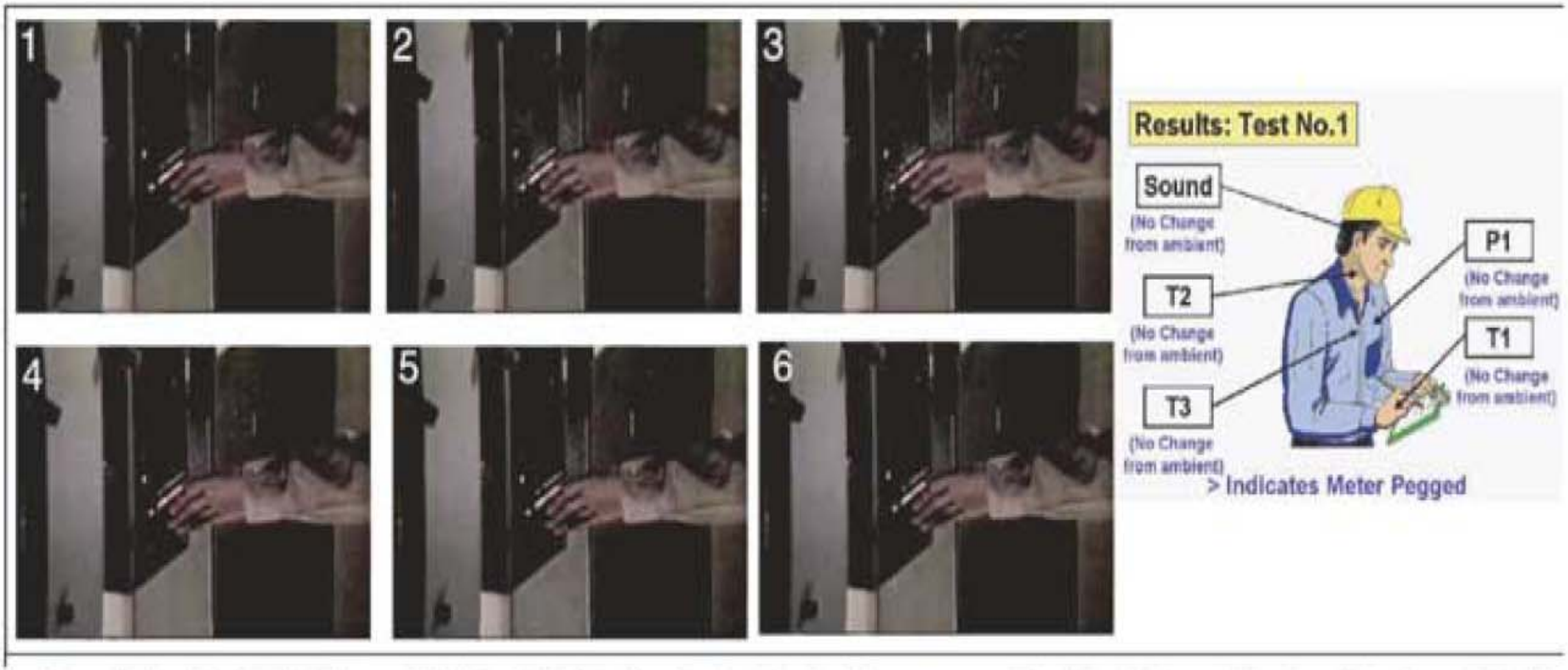


Figure 5. Test 1 - 22,600-A rms, 480-V, fault initiated on load side of a 30-amp current-limiting device in the size 1 starter, and fault was cleared in less than 1/4 cycle.

Work Practices with Barriers Removed

05/2005

National Fire Protection Association (NFPA) 70E History / Structure

- Written for OSHA (1st edition 1979)
  - National Fire Protection Association
    - Technical Committee on Electrical Safety in the Workplace
- 2004 edition = 7th revision
  - Completely reorganized
    - Work practices emphasized
    - Work de-energized emphasized
  - Added examples and definitions
- 4 Chapters
  - Work practices
  - Maintenance
  - Special equipment
  - Installation

NFPA 70E Structure

- Chapter 1: Safety Related Work Practices
  - Shock and flash protection risk analysis
    - Approach boundaries
  - Controls
    - Personal Protective Equipment (PPE)
    - Recordkeeping
    - Training

- Chapter 4: Installation Safety Requirements
  - Limited to workplace
  - Compatible with NFPA 70 (NEC)

NRTL – Second half of talk

Electrical Safety in the Work Place

Barriers Intact

- Working with NRTL listed electrical equipment
- Working with non-listed electrical equipment

Barriers Removed

- Servicing electrical equipment in a de-energized state
- Servicing electrical equipment in an energized state
  - Voltage testing or measurements
    - Outside boundaries
  - Manipulation or handling of energized parts

These Requirements Apply to Everyone Working on Energized Equipment, including LOTO Zero Energy Verification and Trouble-shooting

- NSLS Staff
- NSLS Users
- All Contractors (photocopier repairperson, beamline equipment warranty repairperson, etc.)

Control Requirements for Work on Exposed Conductors Depends on Hazard Range & Type of Work

- 4 Hazard Ranges at BNL – A, B, C, D
- 4 types of work
  - Positively de-energized (cord and plug)
  - Positively de-energized (LOTO)
  - Voltage measurements of energized conductors (Troubleshooting and LOTO zero energy check)
  - Manipulation (work with energized conductor with tools) NOT ALLOWED AT BNL

BNL Electrical Hazard Ranges

- **Range A**:
  - ac and/or dc voltages ≤ 50 V; or
  - All ac sources < 10mA rms available current; or
  - All dc sources < 60mA available current

Does not apply to electrical sources with potential for instantaneous release > 10 J

- **Range B**: **> range A**
  - ≤ 250 Vac rms or ≤ 1000 Vdc

  NSLS limits: ≤ 240 Vac rms or ≤ 750 Vdc

- **Range C**: **> range B**
  - ≤ 600 Vac rms or ≤ 6000 Vdc

- **Range D: > range C**

"Range A"
No Special Requirements

- ac and/or dc voltages ≤ 50 V; or
- All ac sources < 10mA rms available current; or
- All dc sources < 60mA available current

- **Does not apply to electrical sources with potential for instantaneous release > 10 J**

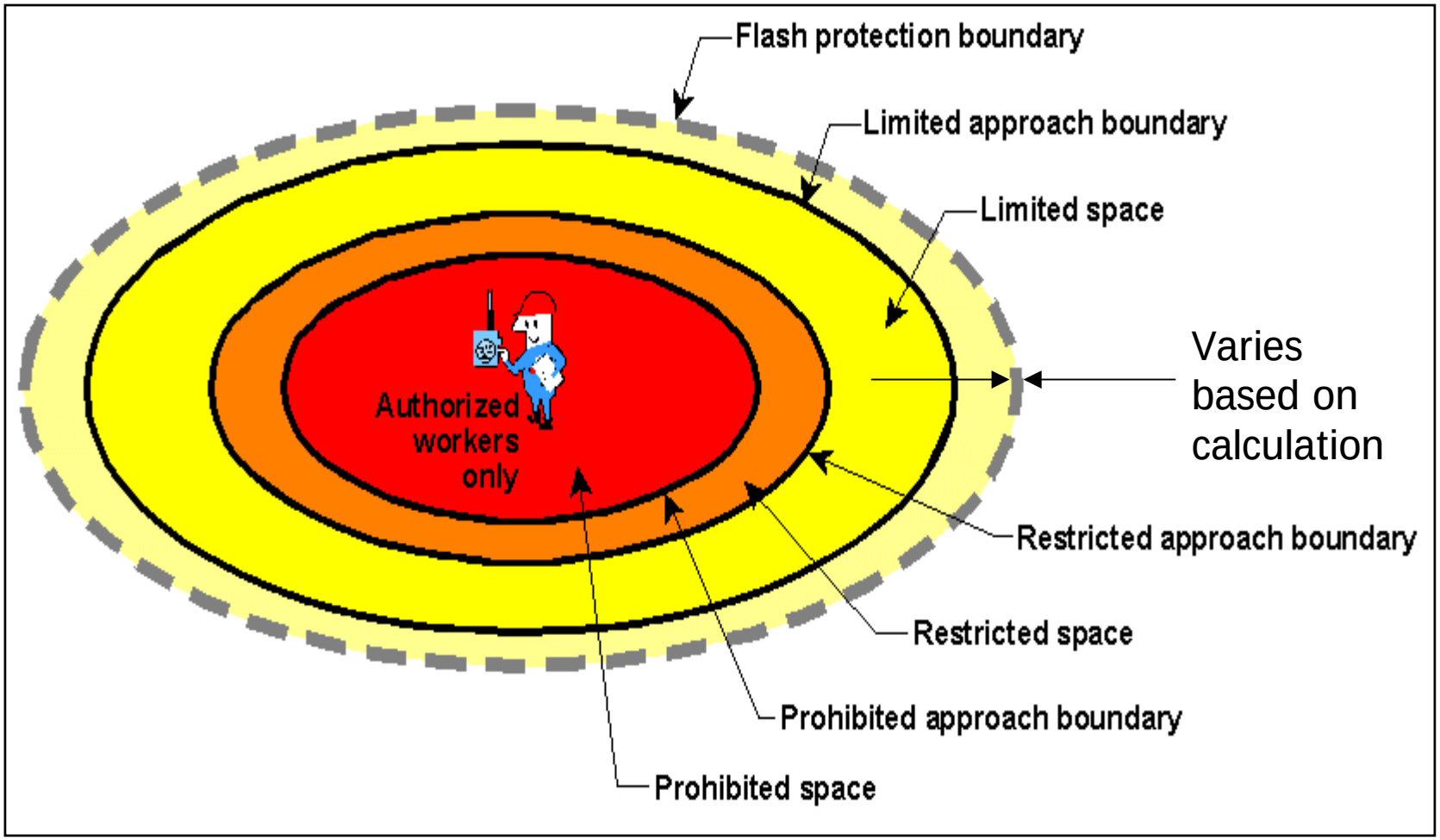
Control Zone for Arc Flash "Range B"

- Flash Protection Boundary
  - Second degree burn risk distance
  - Range B is 4' 0" based on NFPA 70E table – can be determined by calculation
  - Requires arc flash protective clothing
    - Type of protective clothing determined by task

Control Zones for Shock Protection "Range B"

- Limited Approach Boundary
  - Range B is 3' 6"
  - Working "near" energized conductors
  - Qualified personnel authorized by supervisor or escorted
- Restricted Approach Boundary
  - Range B is 1"
  - Still working "near" energized conductors
  - Only qualified personnel authorized by supervisor
- Prohibited Approach Boundary
  - Range B is Avoid Contact
  - Working "on" energized conductors
  - Only qualified personnel authorized by supervisor
- Distances for these various zones are defined in ESH Standard 1.5.0.

Control Zones for Energized Conductors With Barriers Removed



Range B Work Requirements
Greater than "Range A" and ≤ 250 Vac rms or ≤ 1000 Vdc
NSLS limits: ≤ 240 Vac rms or ≤ 750 Vdc

- Whenever possible – work positively de-energized
  - Remove plug from outlet and maintain direct control
  - Or lock-out/tag-out power source using LOTO procedure

- Voltage Testing (trouble-shooting or LOTO zero energy verification)
  - Energized work permit
    - Protective clothing and equipment
    - Control zone and other controls identified in permit
  - Training
    - Electrical safety I
    - LOTO authorized training
    - PPE orientation
    - Task specific training
  - Authorization of supervisor
- **Manipulation of energized conductors not allowed**

Requirements for Range B Measurements

Troubleshooting & LOTO Zero Energy Verification

- Voltage Rated Gloves & Leather Glove Protectors (500 Vac/750 Vdc)
- Denim Cotton Jeans
- Flame Resistant Long Sleeve Shirt (≥4 cal/cm^2)
- Natural Fiber Undergarments
- Hard Hat
- Safety Glasses (non-conductive)
- Training
- Category III or IV Multimeter
- Energized Work Permit

“Range B”
Voltage Testing / LOTO Verification PPE

Hard Hat & Safety Glasses

- ANSI Z89.1 Hard Hat
- ANSI Z87.1 Safety Glasses

Flame Resistant Shirt for “Range B”

- No bleach
- No products containing hydrogen peroxide
- No starch or fabric softener
- Dry clean or machine wash
- Tumble dry

Voltage Rated & Leather Protector Gloves for "Range B" Class 00

- 500 Vac/750 Vdc
- Shelf life one year (stamped)
- 6 Month retesting & cleaning period (controlled by Al Boerner)
- Inspect before each use
- Must wear leather protectors over v-rated gloves

Denim Cotton Jeans

Personal Protective Equipment (PPE) Determined by Arc Flash Analysis

- PPE requirements are determined through use of NFPA 70E tables or an approved calculation
- BNL PPE requirements are currently based on NFPA 70E tables and are conservative for range B
- Calculations will be made for BNL systems
  - The risk may be small for systems of less than 240 volts with limited fault current
  - Any system over 240 volts probably has the capability to have significant arc flash event

Obtaining a LOTO Zero Energy Verification Energized Work Permit

- Go to NSLS PRM 1.5.0 and download the Generic Energized Work Permit for LOTO Zero Energy Verification.
- The responsible supervisor shall have the authorized persons read the permit and sign page two, and the supervisor shall also sign page two.
- The supervisor keeps the original and sends a copy to the NSLS ESO.

Obtaining a Troubleshooting Energized Work Permit

- Go to NSLS PRM 1.5.0 and download the Energized Work Permit for Troubleshooting.
- Review work with the NSLS ESO.
- The NSLS ESO adds limits and controls to the permit and signs page one.
- The responsible supervisor shall have the authorized persons read the permit and sign page two, and the supervisor shall also sign page two.
- The supervisor keeps the original and mails a copy to the NSLS ESO.

Exemption to "Range B" PPE Requirements

Troubleshooting Equipment Connected to 120 Volt Receptacle by an AWG 16 or 14 line cord at least 3 feet Long, or AWG 12 at least 6 feet Long*

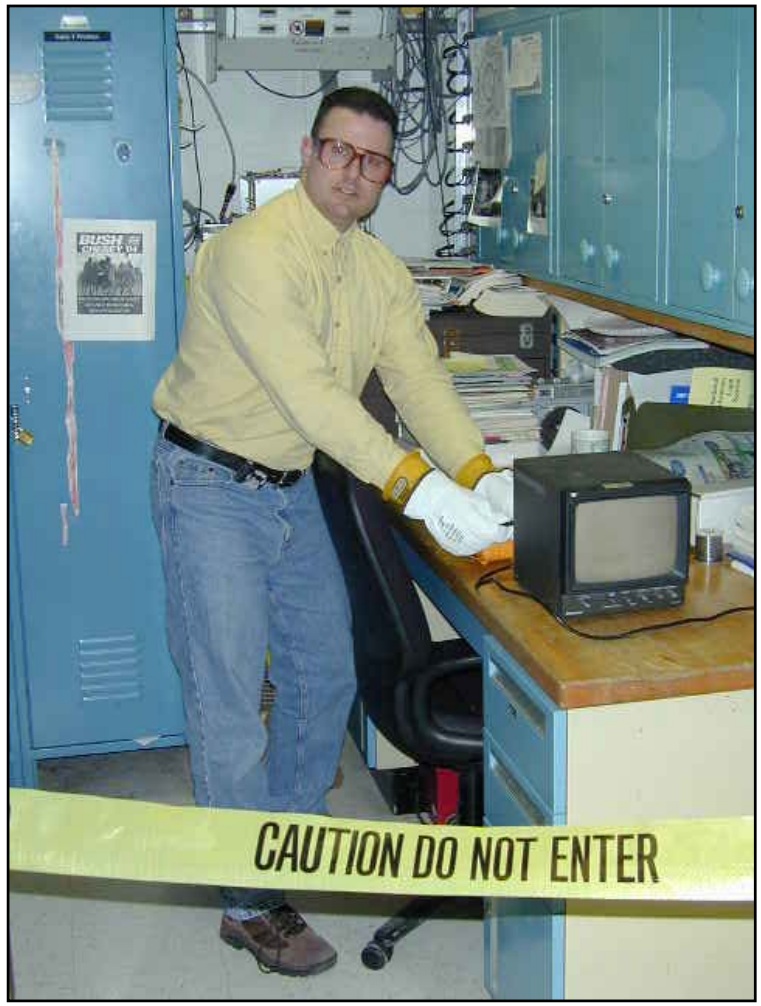
No Flame Resistant Clothing and No Hard Hat Required

- Natural fiber long-sleeve shirt & pants (denim not required)
- Natural Fiber Undergarments
- Non-conductive safety glasses
- Voltage rated gloves and leather glove protectors
- Category III Multimeter
- Energized work permit for troubleshooting

* If the equipment has a shorter cord, then an extension cord may be used in conjunction with the equipment cord to provide the required circuit length.

PPE for Troubleshooting 120 Vac Line Cord Equipment

- Natural fiber long-sleeve shirt & pants
- Natural fiber undergarments
- Non-conductive safety glasses
- Voltage rated gloves and leather glove protectors
- Category III Multimeter
- Energized work permit for troubleshooting



Seek to Perform Troubleshooting Outside of the Outermost Boundary

- Applies to plug and cord equipment only
  - Unplug equipment
  - Remove cover
  - attach meter probes
  - Step back 4 feet
  - Plug equipment in
  - Read meter
  - Unplug equipment
  - Remove meter
  - Install covers

"Range C" is Greater than "Range B" and ≤ 600 Vac rms or ≤ 6000 Vdc

- All work in Range C at NSLS is performed by BNL electricians – **no NSLS staff or users are authorized for Range C voltage measurements**
- Voltage testing requires
  - Higher hazard category protective clothing
  - Energized work permit
  - Two person rule (safety watch)
- Manipulation never allowed

Required Equipment for voltage measurements in "Range C"

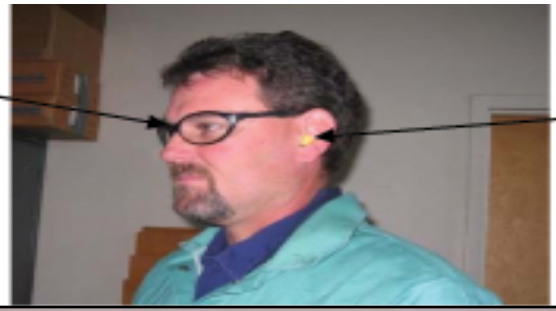


Figure 3-5. Worker wearing the eye and hearing protection to be worn under the double-layer switching hood

Figure 3-4. Worker wearing the correct protective clothing and PPE

Circuit Breaker and Fused Switch (Disconnect) Operation With Covers on (≤ 600V ac rms)

- Safety Glasses
- Natural Fiber Long Sleeve Shirt
- Natural Fiber Long Pants
- Look Away & Stand to the Side of Device if Possible

NSLS Electrical Safety Warning Label

Future Label

! WARNING	
Arc Flash and Shock Hazard Appropriate PPE Required	
_____ inches	**Flash Hazard Boundary**
_____	**cal/cm^2 Flash Hazard at 18 inches**
Category _____	**Type of required PPE**
208 VAC	**Shock Hazard when cover is removed**
00	**Glove Class**
42 inch	**Limited Approach**
1 inch	**Restricted Approach**
Avoid contact	**Prohibited Approach**

Summary of Electrical Safe Work Practices

- No requirements for Range A
- Manipulation of energized parts greater than range A is PROHIBITED
- Always LOTO equipment before installation, maintenance or repairs if you will have to address unprotected conductors
- If you perform LOTO zero energy verification, or troubleshoot on exposed energized parts greater than range A
  - you must wear protective equipment
  - need a energized work permit
  - be qualified and authorized by your supervisor.
- Range C LOTO zero energy verification must be performed by BNL electricians

NSLS Electrical Safety Requirements PRM 1.5.0 & 1.5.1

- BNL ESH Standard 1.5.0 & 1.5.1
- Includes NFPA 70E requirements
- Protective clothing requirements
- Training requirements
- Energized Work Permit

Integrated Safety Management and Electrical Safety

- ISM stresses work planning to ensure:
  - Definition of scope of work
  - Identification & control of hazards
  - Authorization to do work

Addressed through screening and work permits as needed

- Qualified workers

Addressed through training program, includes supervisor OJT

2005 NSLS User Meeting
Electrical Safety Workshop

NRTL's

Nationally Recognized Testing Laboratories

Nationally Recognized Testing Laboratories

- History
- Program outline
- Application to BNL
- Proper equipment assembly
- Common User mistakes
- Illustrations

NRTL History

- OSHA (1971) adopts existing consensus standard
  - ANSI
  - NFPA

- Requirements for:

‘Approved’, ‘Listed’, or ‘Labeled’ equipment.

- Need definition

More History

- 29 CFR 1910.7: NRTL Program (1988)
  - OSHA Directorate of Science, Technology, and Medicine (1 of 8)
  - Mission
    - Prevent accidents – workplace product safety
    - Recognize private testing laboratories
      - Defined testing scope
      - Program elements
        - Testing
        - Product certification
        - Manufacturer inspection

NRTL Program: OSHA Language

- OSHA regulations require electrical equipment to be
  - Accepted
  - Approved
  - Certified
  - Listed
  - Meet the requirements of
  - Otherwise determined to be safe
  - Tested
- 37 product approval requirements
- NRTL Program defines ‘Approval’

Why does this apply to BNL?

OSHA Subpart S – Electrical

- 29CFR 1910.303(a) ***General Requirements***
  - All workplace equipment must be approved

OSHA NRTL Approval References (partial list)

- 29 CFR 1910.28 – *Scaffolding*
- 29 CFR 1910.36 – *Exit door design*
- 29 CFR 1910.66 – *Powered platforms*
- 29 CFR 1910.106 – *Flammable liquids*
- 29 CFR 1910.107 – *Spray finishing (flam mat)*
- 29 CFR 1910.108 – *Dip tanks (flam mat)*
- 29 CFR 1910.109 – *Explosives*
- 29 CFR 1910.165 – *Fire detection systems*
- 29 CFR 1910.253 - *Welding*

NRTL Program Elements

- NRTL's
  - Independent organizations
    - 18 companies
  - Recognized by OSHA
    - Specific testing and certification scope
    - Application process
  - Provide product safety testing and certification

Product Testing

- Testing
  - Meet appropriate consensus-based product safety standards
  - ~ 600 recognized test standards
  - Organizations:
    - American National Standards Institute (ANSI)
    - American Society for Testing and Materials (ASTM)
    - Underwriters Laboratories (UL)
    - Factory Mutual Research Corporation (FMRC)

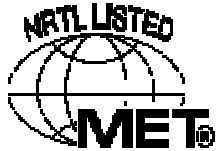
Partial NRTL List

- Applied Research Laboratories (ARL)
- Canadian Standards Association (CSA)
- Communication Certification Laboratory (CCL)
- FM Global (formerly Factory Mutual) (FM)
- MET Laboratories (MET)
- NSF International (NSF)
- TUV America (TUVAM)
- Underwriters Laboratories (UL)
- Wyle Laboratories (WL)

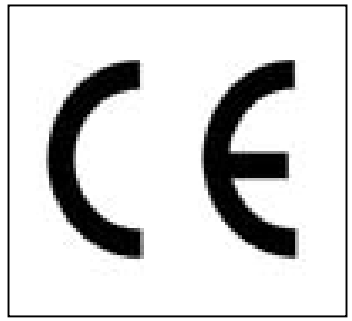
Product Certification

- Certification
  - Listing
  - Product meets applicable standard
  - Manufacturer labels product
  - Manufacturer monitoring:
    - Facility inspection
    - Representative sampling
    - Use of certification mark

NRTLs - Examples of Certification Marks



European Union CE Mark



NOT an NRTL certification mark

BNL Requirements: Purchases

- New equipment purchases must be NRTL accepted, certified, listed, or labeled

Exception: Custom made equipment that no NRTL certifies need not be listed if:

- It is determined to be safe for its intended use by the manufacturer; and
- That determination is made on the basis of test data; and
- The test data is kept by BNL.

BNL Requirements; Homemade Equipment

- Homemade equipment must be:
  - Inspected and certified as safe by the BNL Authority Having Jurisdiction (AHJ)
- BNL AHJ's
  - BNL Electrical Safety Officer
  - NSLS Electrical Safety Officer
  - 3 NSLS Electrical Safety Engineers

Homemade Equipment Inspections

- Robust enclosure
- Proper grounding
- Made from NRTL listed parts
- Proper strain relief and grommets
- No exposed conductors
- Fused
- Proper gauge double insulated wire
- Heating effects
- Arcing effects
- Wire bending & connection space
- Suitability of use

NSLS Legacy Equipment

- Much BNL made equipment
- Much purchased equipment – No NRTL certification
- NSLS AHJ's inspection and certification
  - Training ongoing today
  - Could be just inspection (no testing)
  - Lists
  - Labels
  - Might be certified by UL to list and label
  - 5 year program

NSLS User Experience

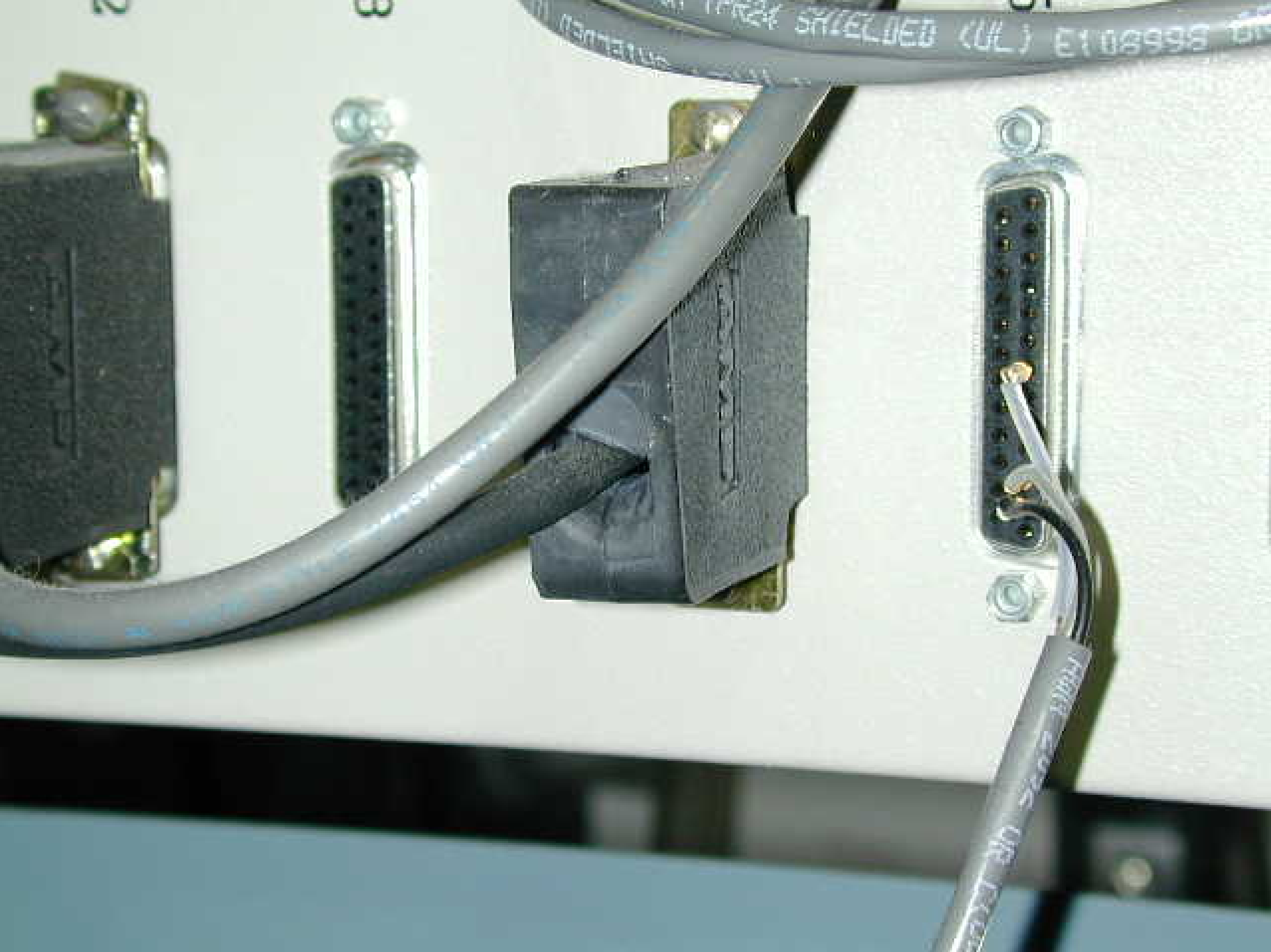
- Scientists assemble needed components
  - Assembled from available parts
  - Assembled to function not to code
  - Limited experience with accepted practice and design

- Typical mistakes
  - Poor/inappropriate connections
  - Poor grounding
  - Undersized conductors
  - Improperly insulated conductors (double insulated power)
  - Poor feed through / strain relief
  - Inadequate enclosure / exposed conductors
  - No fusing


DISABLE OUT
FUSE
FUSE
FUSE


OUTPUT CURRENT
AMPS HERTZ
25.0 60
14.4 60
12.5 60
10.0 60
8.3 60
7.2 60
MAX. 15 AMPS/RECEPTICAL


SCILLATOR
33FW
.955 MHZ
3260
TRON LABORATORIES INC.
NORWALK, CT
MADE IN USA


SHIELDED (UL) E108998


J6
MTR INTLK
J7
RING CRASH
J8
CONTROL RM
GAP LMT SWS
J10
BIT I/O
J3
GAP MICRO
J5
MTR DRV
J4
PLTFM MICRO
J1
J2
X29 MGU
Control Chassis

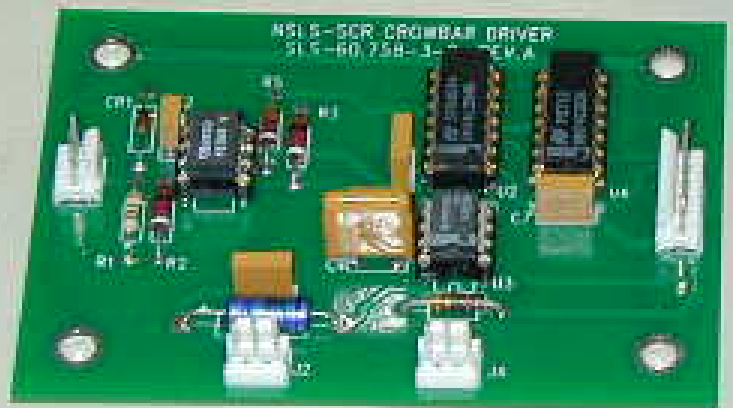

10 Amp
16 Amp
eramic (F)
ANGE
50/60 Hz

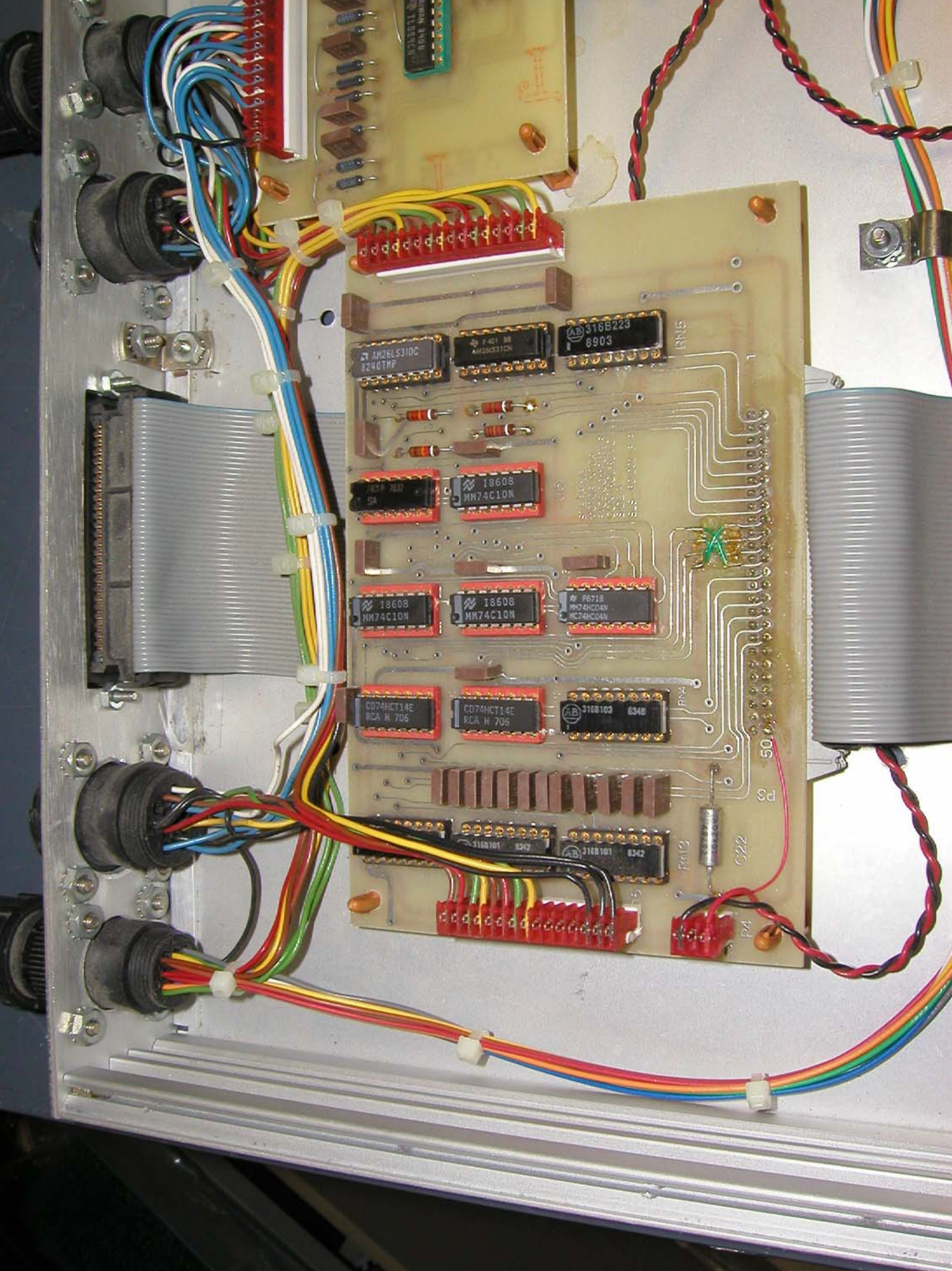

COMPUTER PRODUCTS
POWER CONVERSION
+ COM - AC AC
PM301
OUTPUT
±15V 350MA
INPUT
50/60 HZ 115 VAC 210 MA
9125
COMPONENT TYPE CUSTOM RECTIFIER


1
240V~
OUTPUT
10A
2
CRYDOM
SOLID-STATE RELAY
ASSEMBLED IN MEXICO
D2410
4
INPUT
3-32V
+3
D24J
L36

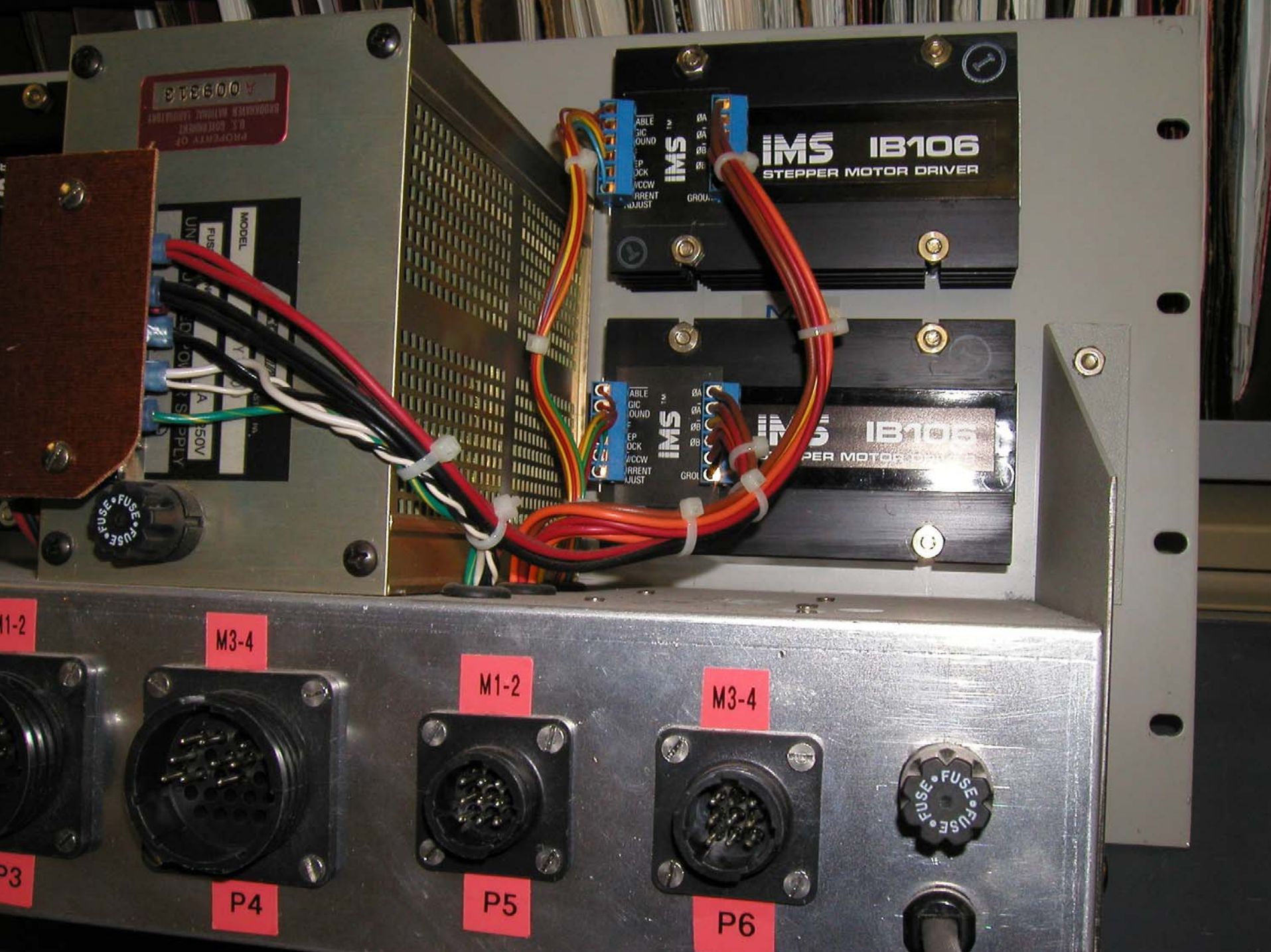

MONO TANK 2
WHITE BEAM STOP
MIRROR TANK
VALVE 1
CONTROLLER 1
ACUUM OK
ACUUM FAULT
CLOSE
RESET
valve 3
CONTROLLER 2
CUUM OK
CUUM FAULT
OPEN
CLOSE
valve 4
CONTROLLER 3
OPEN
CLOSE


CHT RESISTANT DIRECT BURIAL
CSA NRTL/C 75C

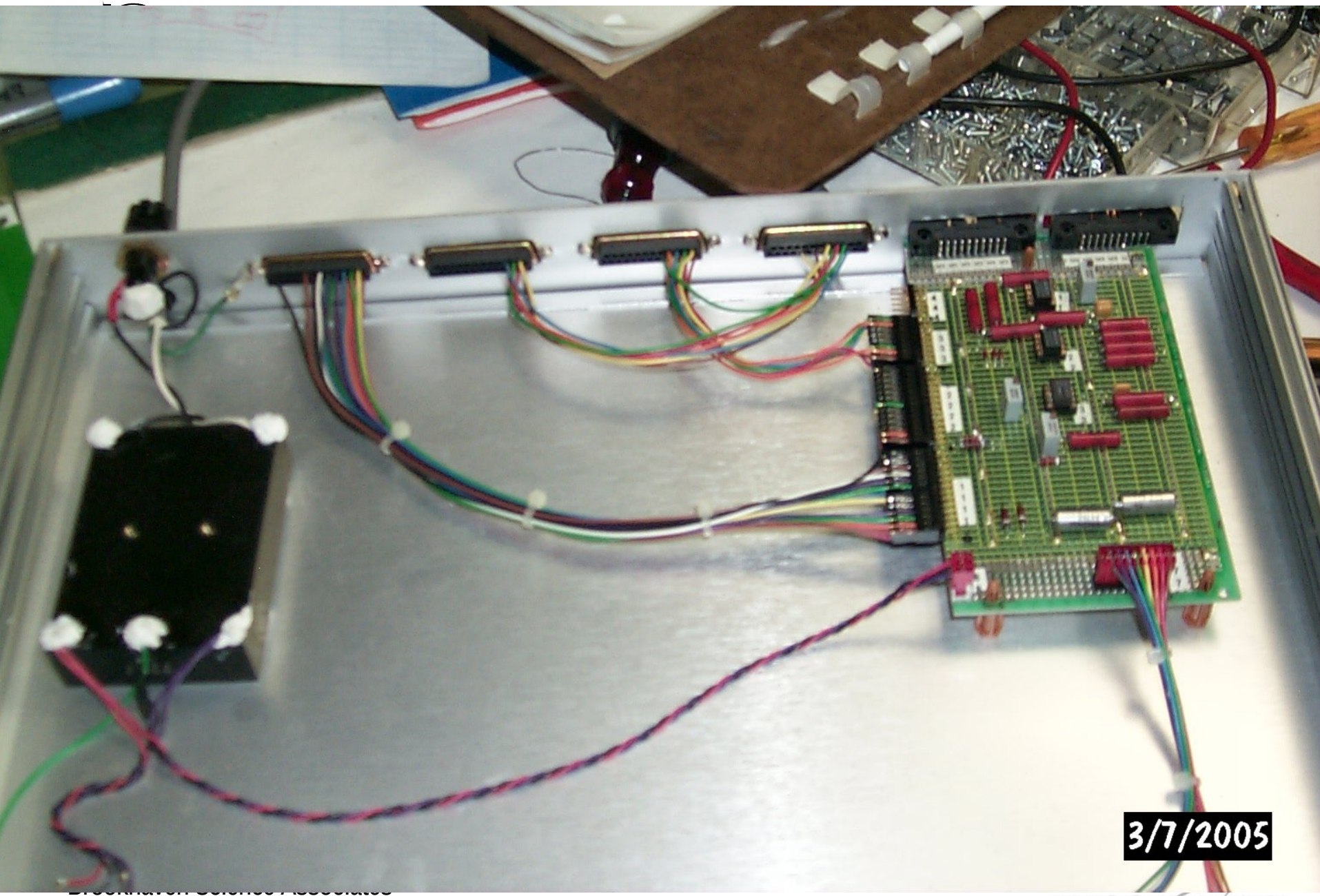

NSLS-SCR CROWBAR DRIVER


AM26LS31DC
8240TMP
316B223
8903
I8608
MM74C10N
I8608
MM74C10N
P8718
MM74HC04N
MC74HC04N
CD74HCT14E
RCA H 705
CD74HCT14E
RCA H 705
316B103
6348
316B101
8342
316B101
8342
RN5
RN4
RN3
C22
P4
50
Sd


IMS IB106
STEPPER MOTOR DRIVER
M1
IMS IB106
STEPPER MOTOR DRIVER
PROPERTY OF
U.S. GOVERNMENT
BROOKHAVEN NATIONAL LABORATORY
A009313
MODEL
FUSE • FUSE • FUSE
M1-2
M3-4
P1


IMS IB106
STEPPER MOTOR DRIVER
M1-2
M3-4
P3
P4
P5
P6
FUSE
FUSE
FUSE
FUSE


PACKAGED POWER
+ COM AC AC
PM342
OUTPUT
5V 1000 MA
INPUT
115 VAC 50/60 HZ 115 MA
Power Products
Division of Computer Products, Inc.
M3-4
M1-2
M3-4
M1-2
206838-1 8345

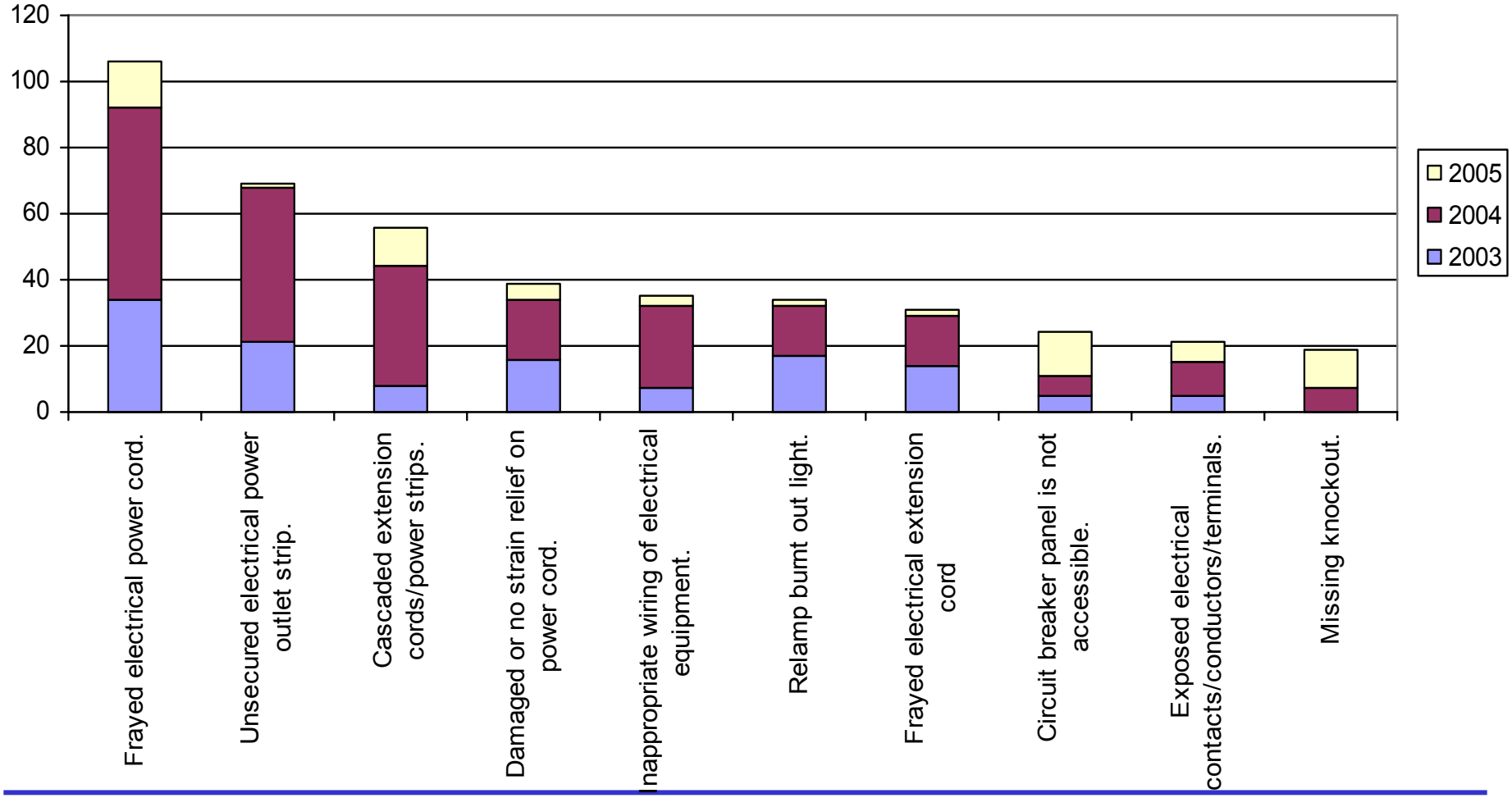

3/7/2005

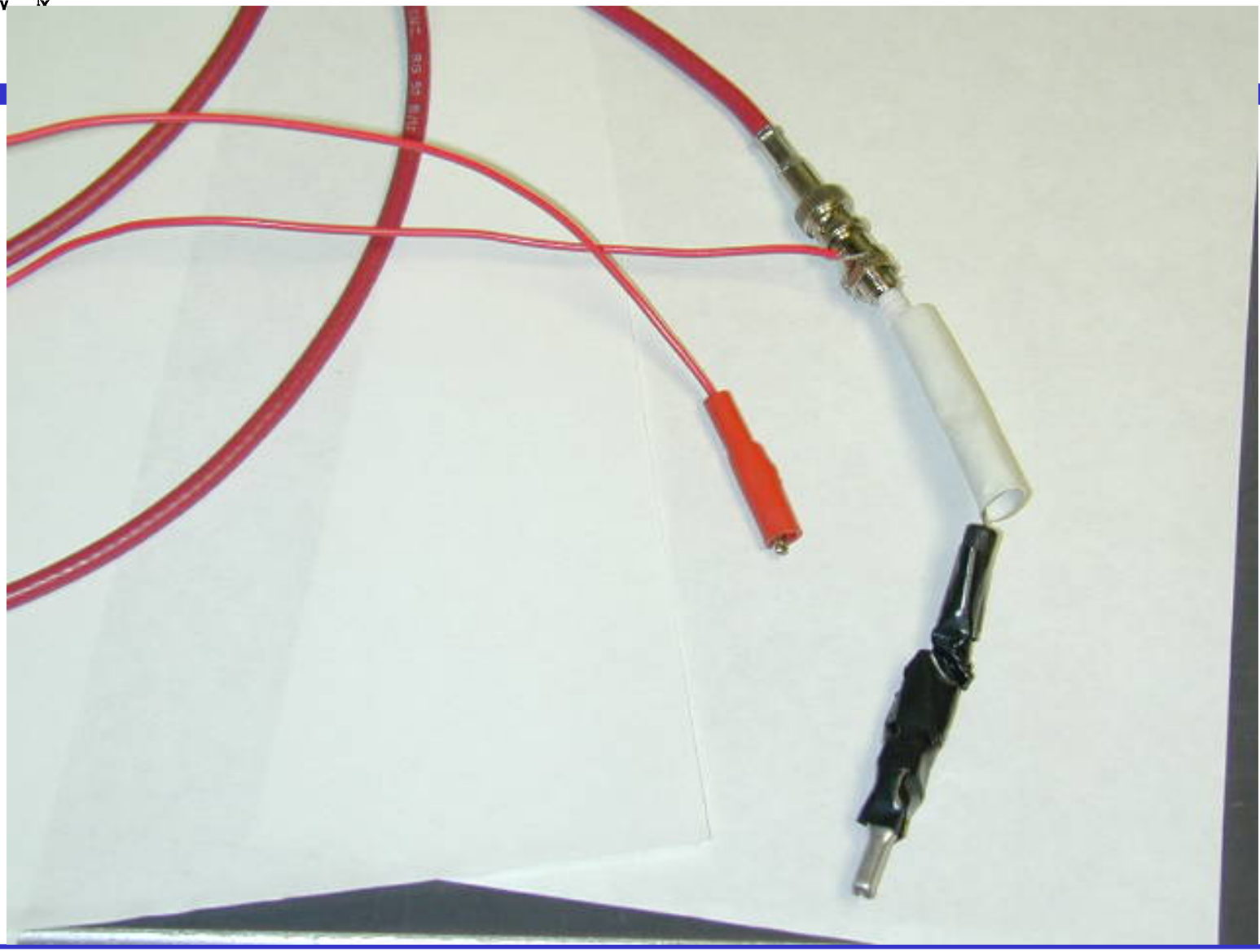

White/Blanc
RTV 102
Silicone Rubber Adhesive Sealant
Scellant adhésif au caoutchouc de silicone
General Purpose
Pour Usage Général

Electrical Findings from Safety Inspections

- Beam lines and experimental floor inspected four times per year
- PRT and beam line staff responsible for correction
- Tracked until closed out
- Focused electrical safety inspections have been conducted twice in last three years

Types of Electrical Findings 2003 - 2005





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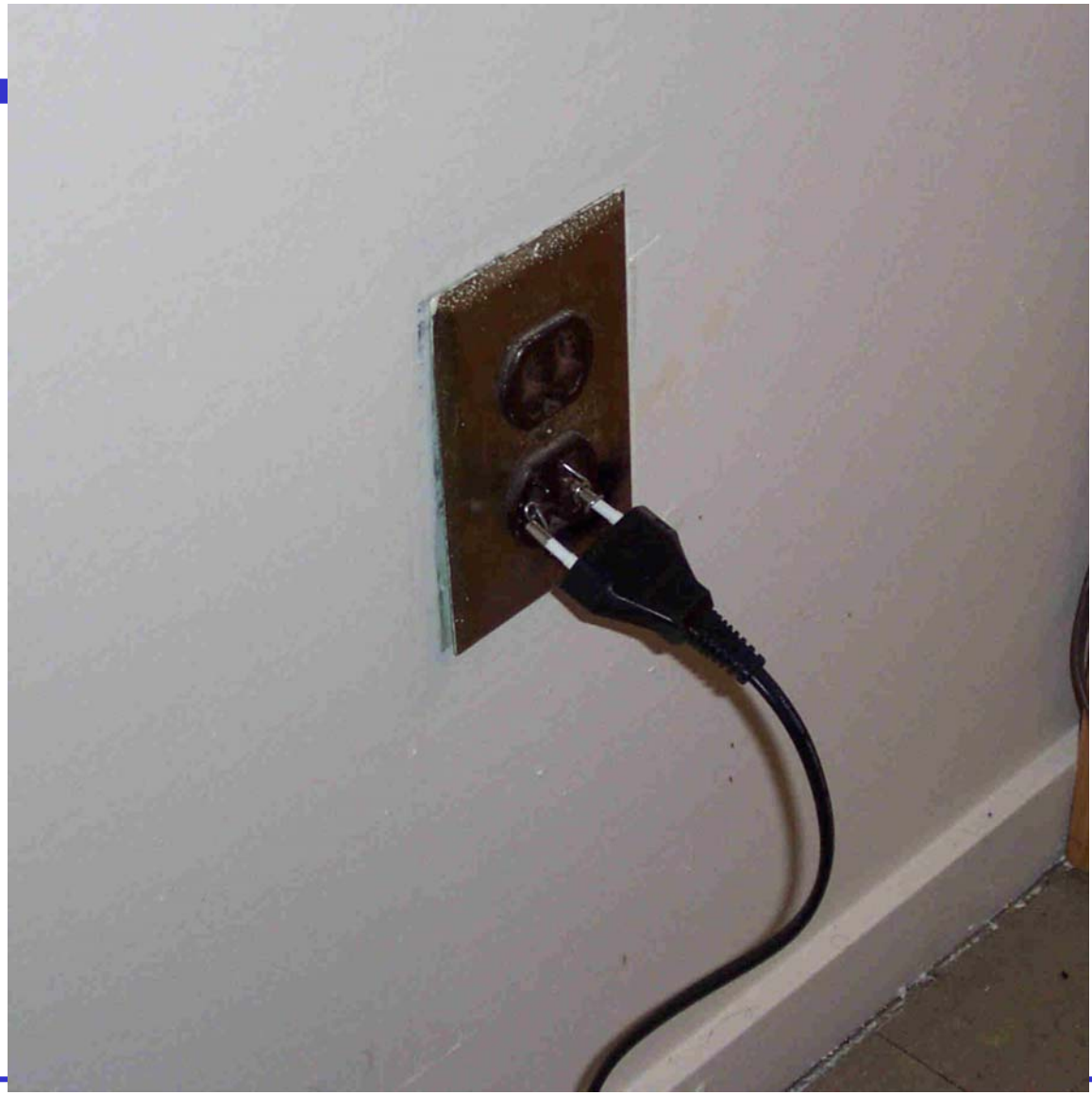


Review of SLAC Accident

Description of SLAC Accident October 11, 2004

- SLAC Supervisor directs subcontractor electrician to install breaker in live 480-volt dist. panel
- Supervisor did not obtain required working “Hot” permit
- The electrician wore a short-sleeved cotton/polyester shirt, leather gloves over Voltage (V)-rated gloves, safety glasses, and a hardhat
- When the accident occurred, the electrician had connected phases B and C and was in the process of connecting phase A

Scene Immediately After the Accident

Figure 2-1. Scene immediately after the accident

Insulating Mat With Outline of Knee in Arc Flash Shadow

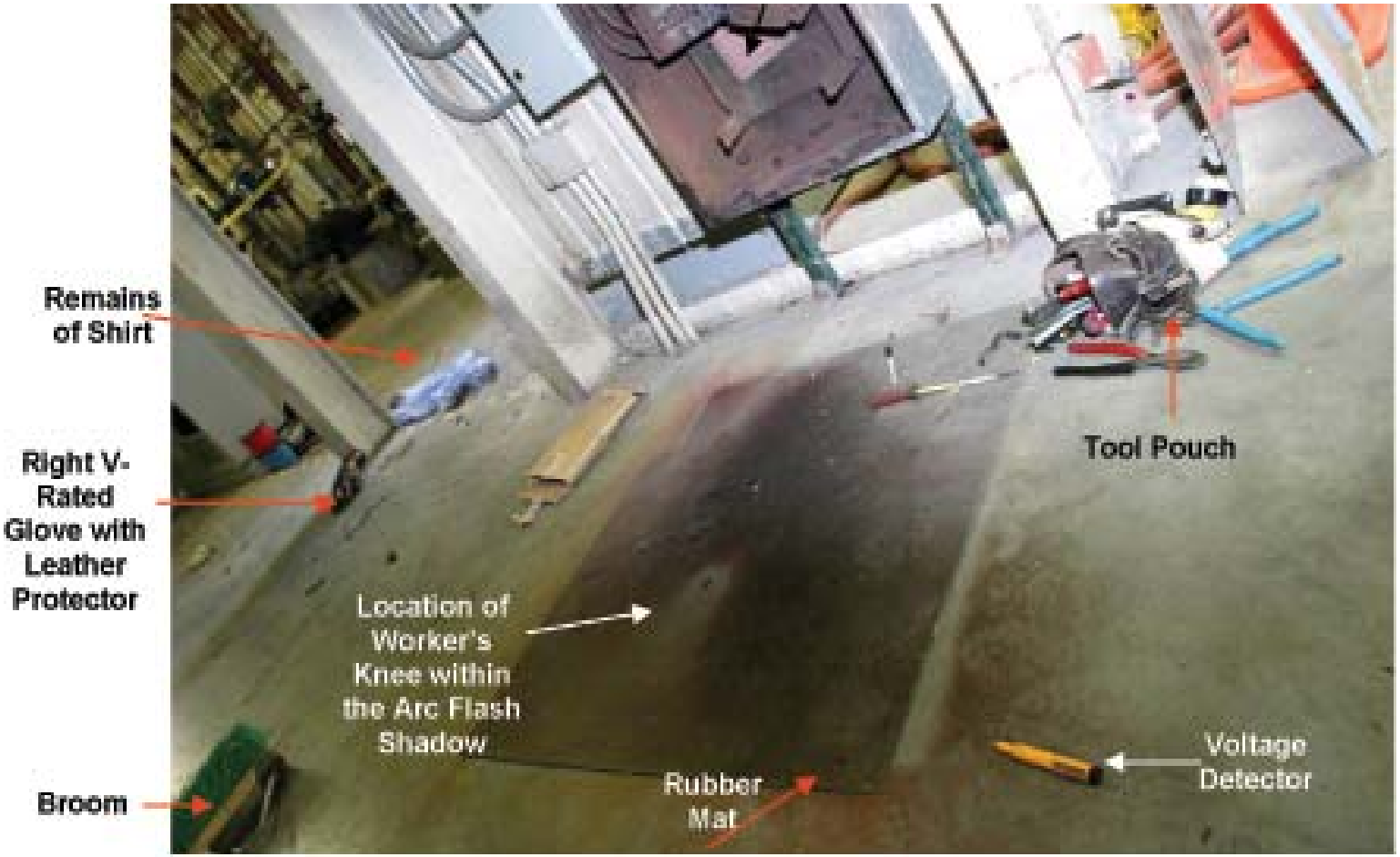


Figure 2-3. The insulating mat with the outline of BSE-1's knee in the arc flash shadow

The Screwdriver Used by the Worker

Figure 2-9. Closeup of the screwdriver the Board believes BSE-1 was using when the arc flash occurred

Burned Glove

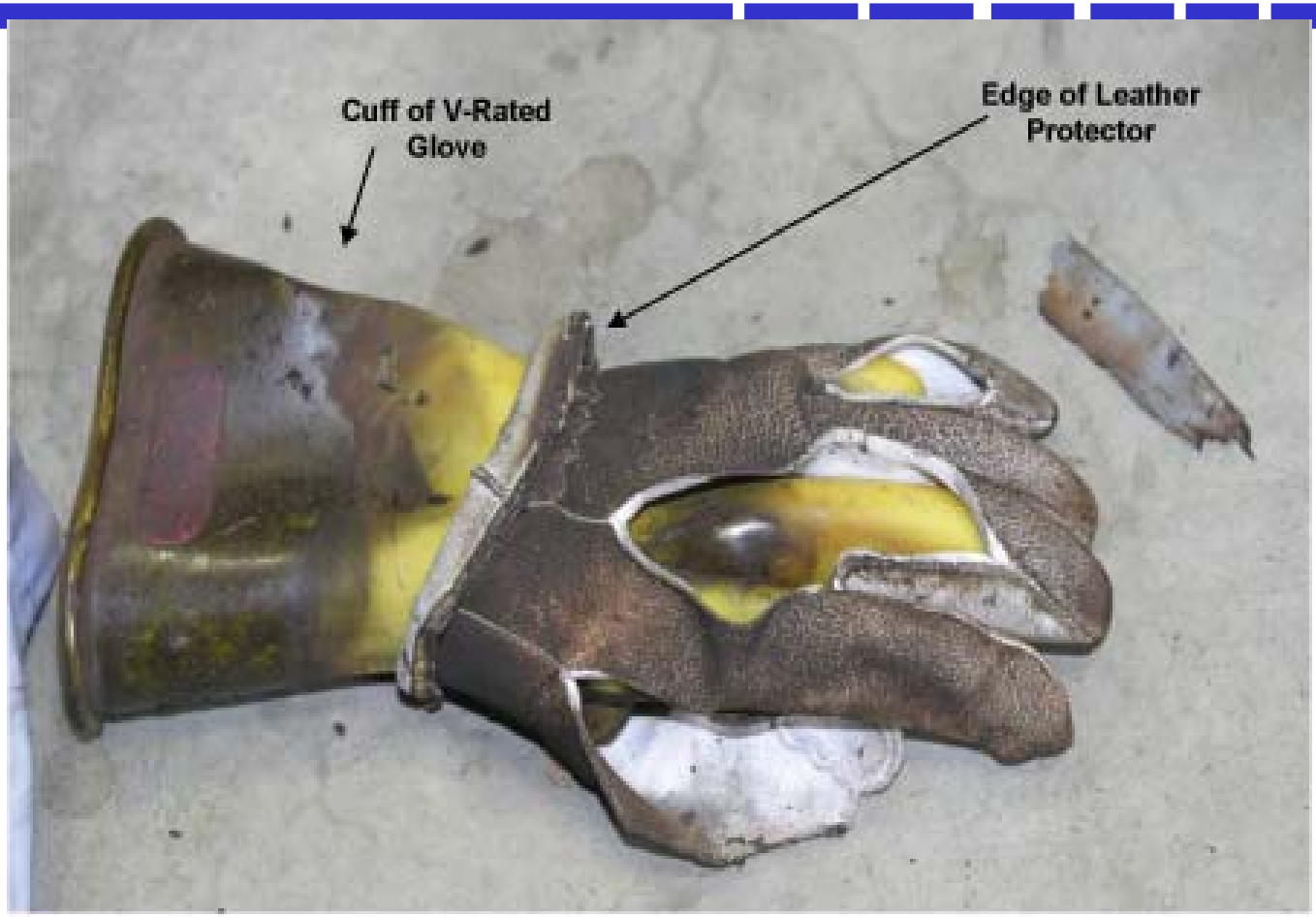


Figure 2-8. Closeup of one of BSE-1's burned gloves

Burned Shirt & Flash-damaged PPE & Tools

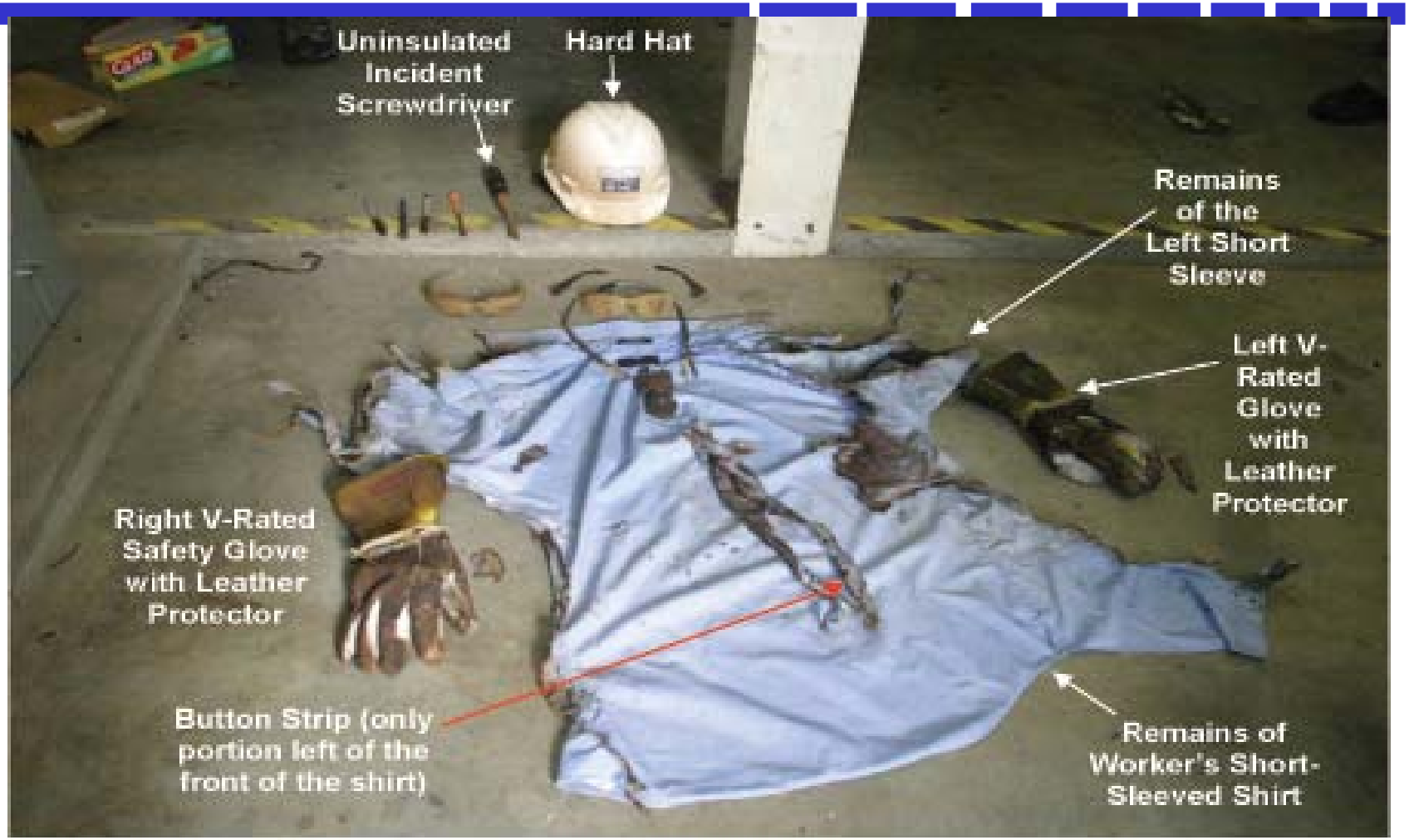


Figure 2-6. BSE-1's burned shirt and his flash-damaged PPE and tools

PPE Protection

- Demo test

Required Equipment for 480

Figure 3-5. Worker wearing the eye and hearing protection to be worn under the double-layer switching hood

Figure 3-4. Worker wearing the correct protective clothing and PPE

Circuit Breaker Panel

Accident Details

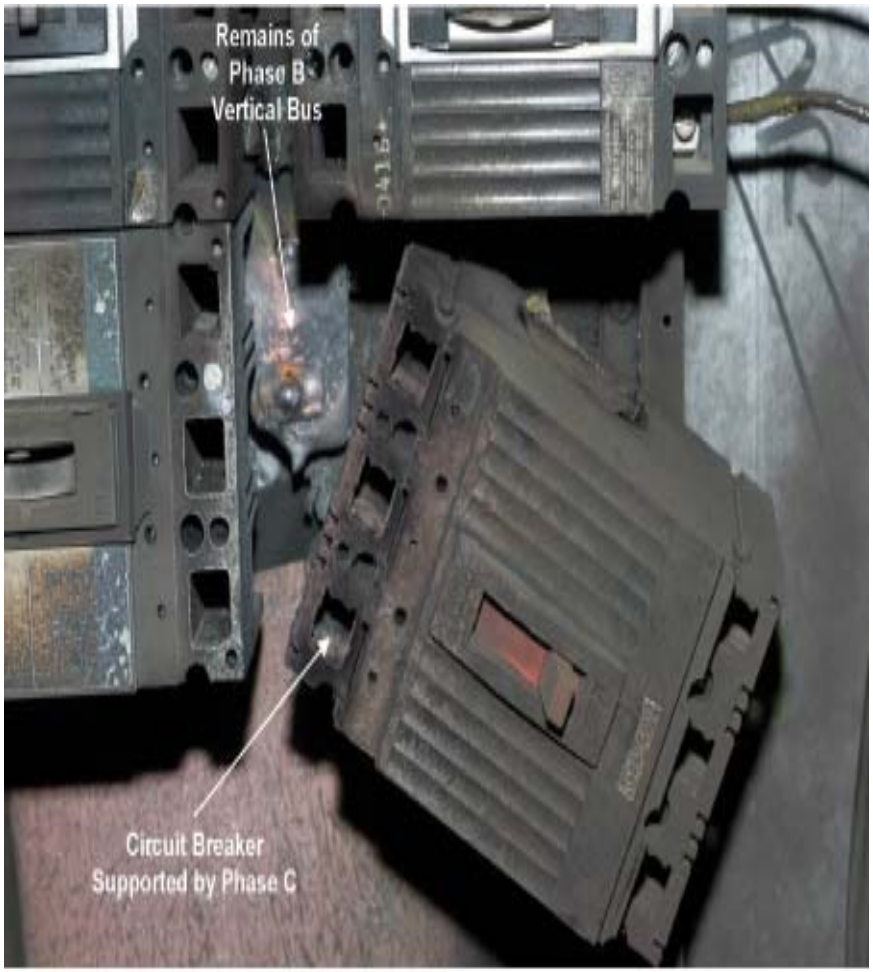


Figure 2-10. Closeup 1 of the damaged circuit breaker panel

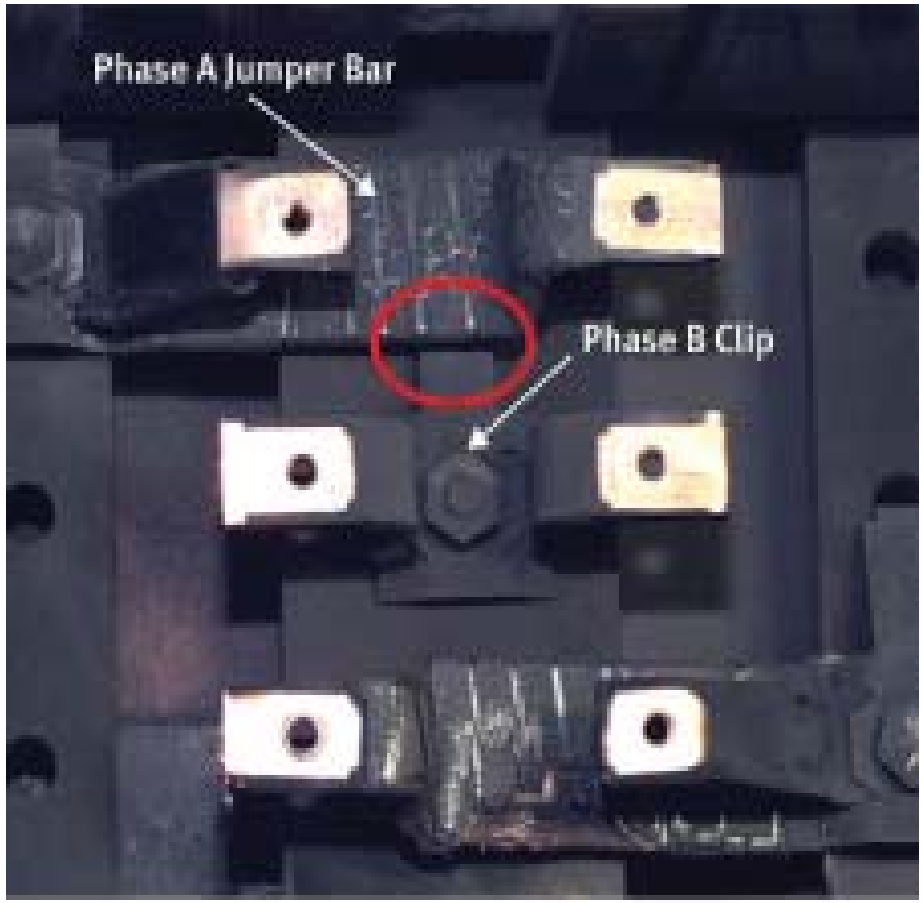


Figure 3-3. Close up of jumper bar and clip with the believed location of the fault circled in red

Identified Key Deficiencies from Investigation Report

- **A Pre-Work Hazards Analysis was not conducted**
- **There was no approved Electrical Hot Work Permit**
- **No one in the SLAC management chain had been informed of the decision by the supervisor to install the circuit breaker in an energized panel**
- **The workers did not wear the appropriate flame resistant clothing, and all required PPE**
- **The SLAC safety staff were not involved**
- **The subcontractor laborer was not trained to be a backup for the electrician**

Conclusion of BNL Review Conducted in November following Incident

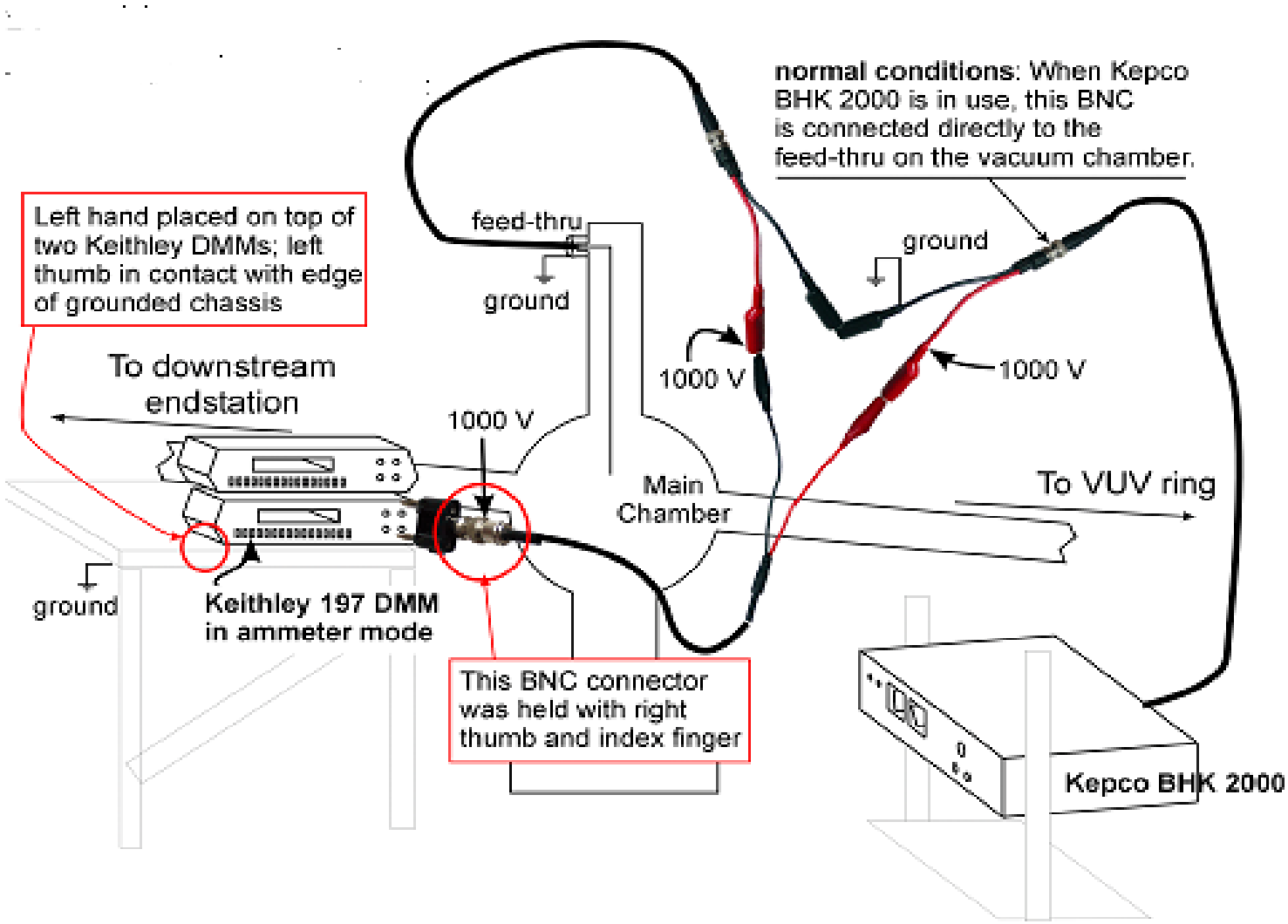
- Working on or near energized conductors rarely done except for testing and verification
- Most significant finding – lack of use of protective equipment for voltage verification and test at 480 V a.c.
- Testing of equipment at lower voltages may not always use proper gloves

Review of Electrical Incidents and Lessons Learned

Incident 1 -May 2002

User modifies electrical connections to address an operational issue and accidentally energizes BNC connector to 1000 V DC - he experiences electrical shock.

Energized BNC Connector to 1000 V (100 mA) DC



Lessons learned

- **Do Not Work on or near live electrical parts**

  The electrical configuration that was established had several exposed and energized surfaces above 50 volts.

- **Have Significant Changes Reviewed Before Implementation**

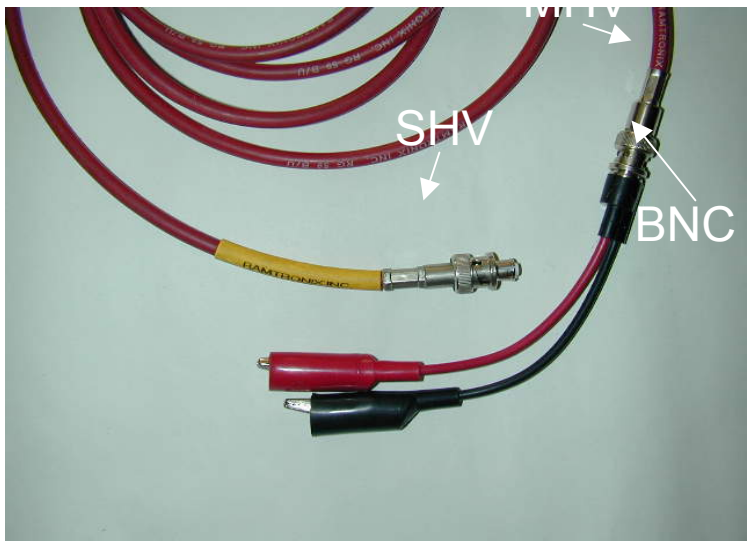
  Configuration control is very important. Always review significant changes that take place in the workplace and at beam lines.

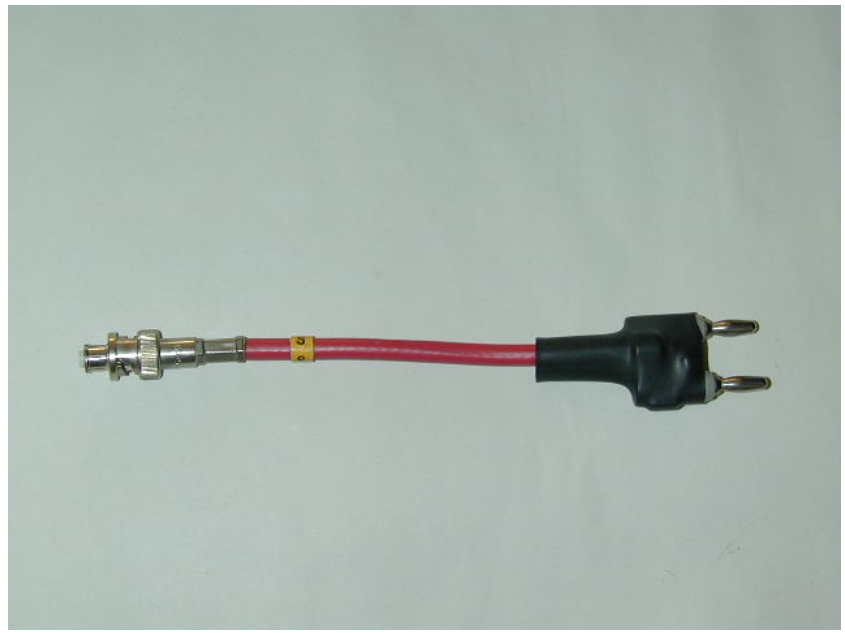
- **Report electrical shocks immediately to the Control Room (x2550).**

Revised NSLS Policy for New Equipment

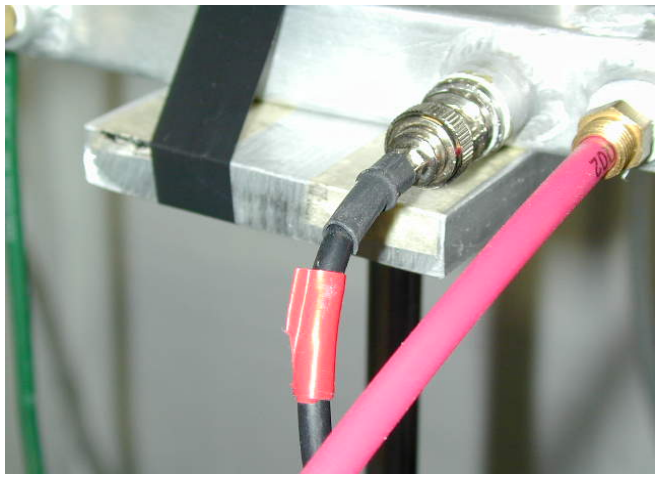
- BNC and MHV connectors are limited to 50 volts or less
- Eliminate BNC breakouts and banana jacks for system with greater than 50 volts
- For systems greater than 50 volts, only red jacketed cables shall be used (RG59 up to 5kV, RG213 up to 20 kV)
- For systems greater than 50 volts and up to 5 k volts, only SHV or approved equivalent connectors shall be used
- For systems greater than 5 k volts, only approved connectors shall be used

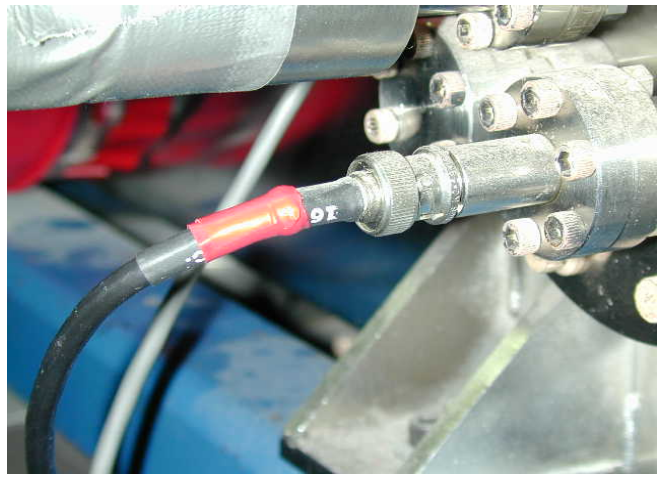
Eliminate High Voltage Breakouts

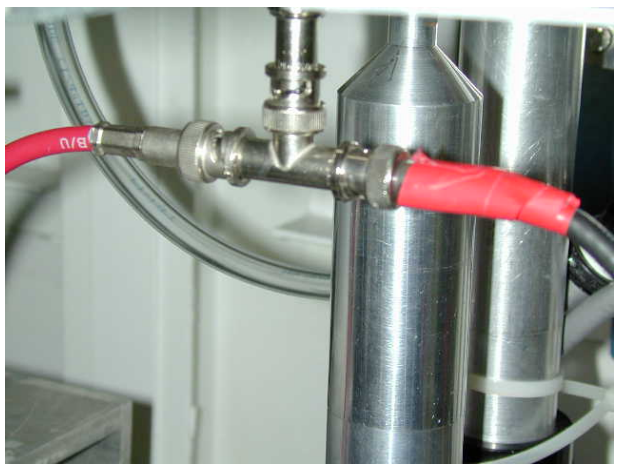




Grandfathered Item Identification







Incident # 2 - May 2004

In an effort to change polarity, two users reverse electrical connections of cable at 1000 V DC power supply and accidentally energize outer shell of SHV connectors. Unsafe condition exists for ~ 5 days and carries on to 2 subsequent experiments.

Modified High Voltage Power Supply Resulting in 1 kV on Ground Shielding

Lessons learned

Management of change in equipment or component configuration is necessary to provide a safe working environment. It is very important to emphasize to visiting users in BLOSA training that changes in equipment at a beam line should not be made unless review and approval by responsible staff have been provided.

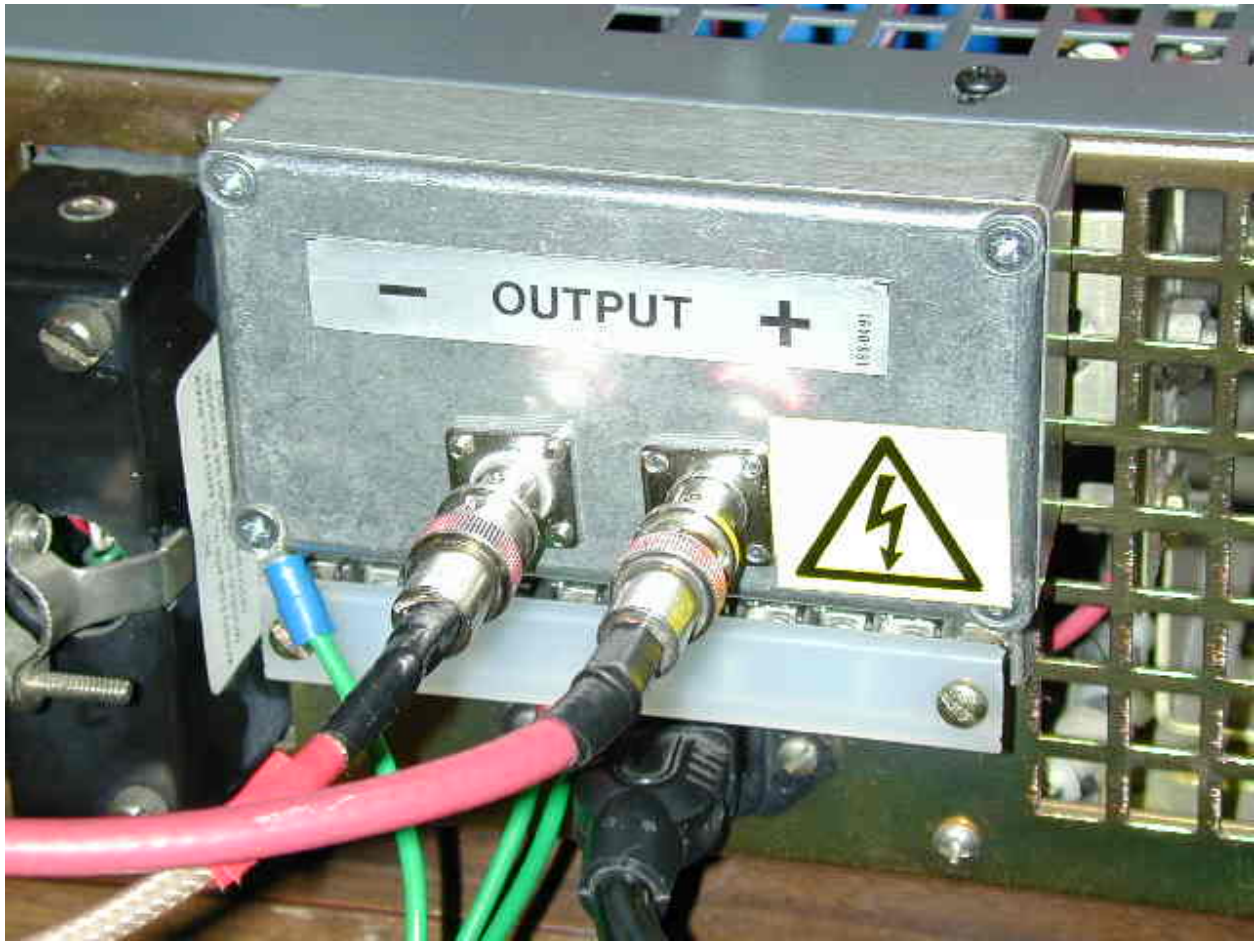
Lessons learned (cont.)

Support and oversight of visiting users by the PRT and NSLS plays an important role in providing a safe work place, particularly for inexperienced users who may not fully understand the requirements and expectations for safe work at the NSLS.

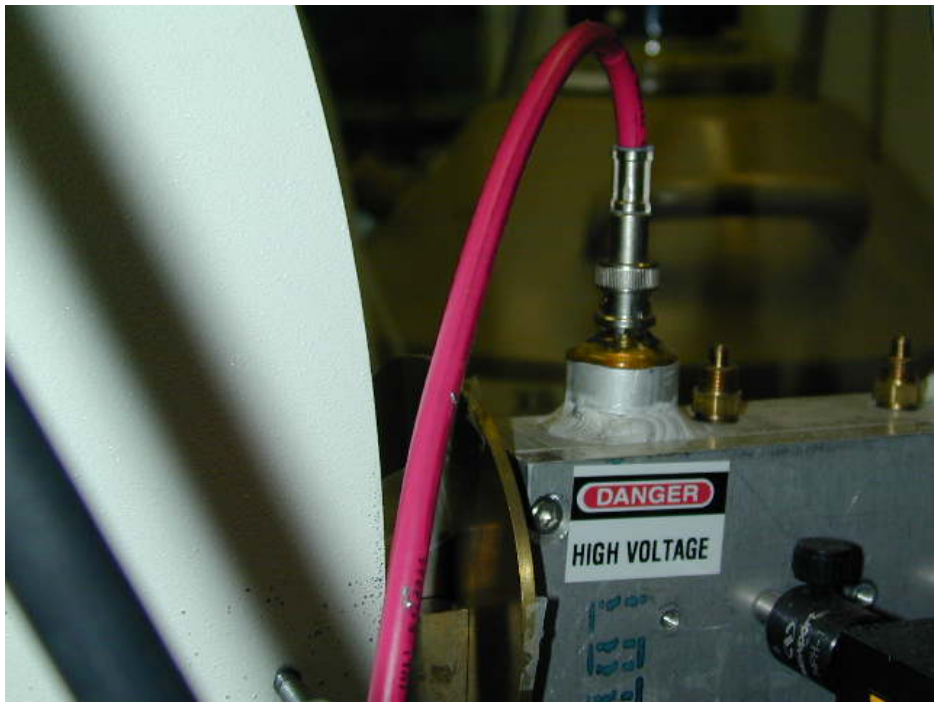
Focused Inspection

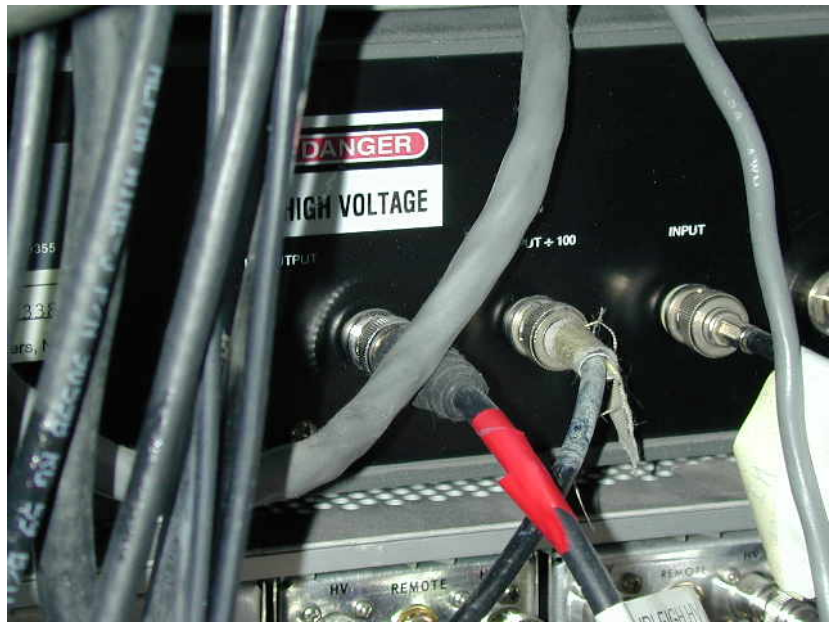
- Identify high voltage power supplies with banana jack outputs and terminal blocks that lend themselves to be easily reconfigured.
- Excess or retrofit these supplies with SHV bulkheads.

Banana Jack Retrofit



Label High Voltage Equipment (>600 V)





International Label for Equipment With Potentially Lethal Voltages >50 V and <=600 V

Incident # 3 (July 2004)

Member of beam line staff touches spectrometer and feels tingle - spectrometer was floating at 115 volts AC (7 mA) due to improper grounding of European style outlet on voltage converter.

Local Contact Feels Tingle

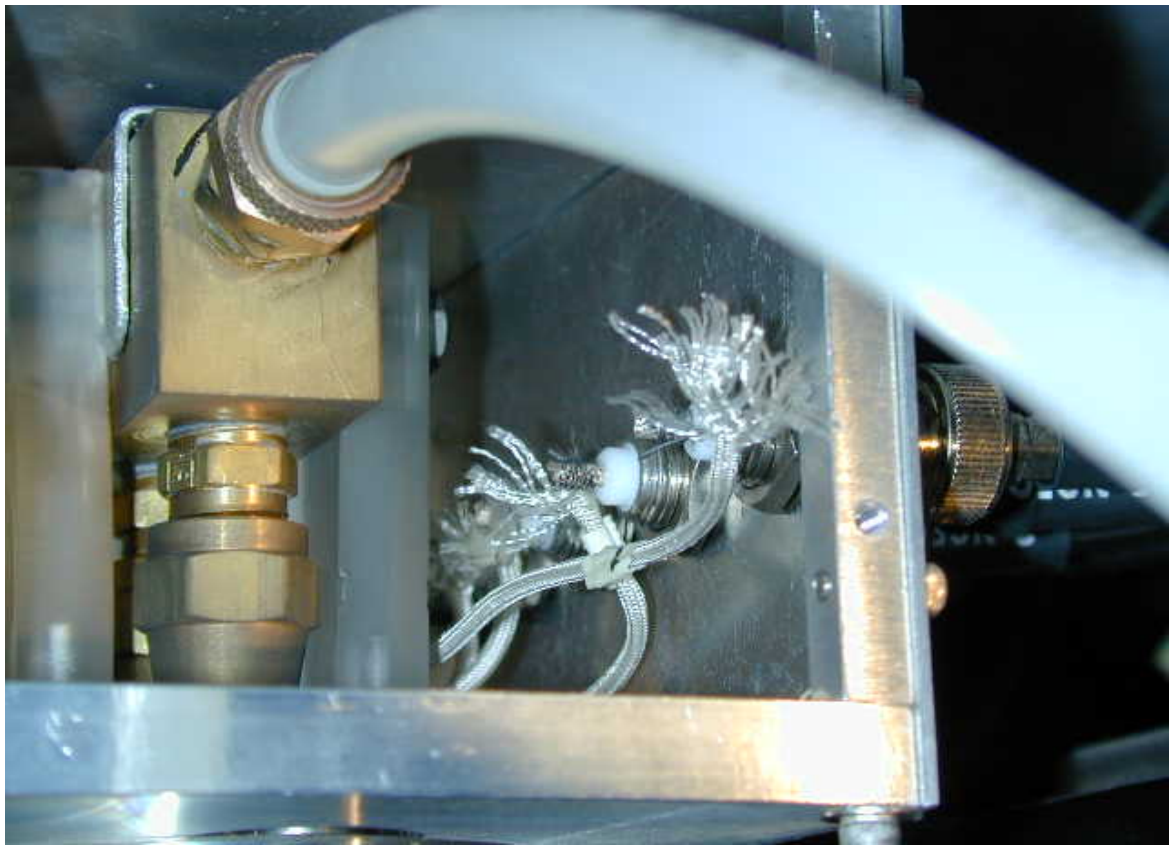
- The European style female connections on the face of the converter did not have a sufficient ground contact for the spectrometer's European style male connector to mate properly.
- The converter did not have a NRTL approval rating such as an UL listing.

NRTL Approved Voltage Converter (Quick 220® Power Tap adapter by Diamond H. Company, LLC)

Incident # 4 -August 2004

A member of a PRT and a NSLS tech remove the front plate to a beam line component for maintenance. Neither is aware of energized surfaces within box and tech receives 300 V DC (20 mA) electrical shock when he begins work.

Interior of beam position monitor



Lessons learned

Ensure that all beam line and facility equipment with significant hazards has clear ownership and a responsible person. It is important that all hazardous equipment has someone designated to maintain safe configuration, including appropriate warning signs, and to act as a contact for questions concerning hazards, operation, maintenance, and troubleshooting.

Lessons learned (cont.)

- Make sure that personnel assigned to conduct a work activity are knowledgeable of hazards (work planning)
- Be cautious with equipment that has no readily identifiable responsible person. “Legacy” equipment with unclear ownership may have hazards that have been long forgotten. Work should not proceed on these systems until their function, hazards and operation are understood.

Lessons learned (cont.)

All electrical equipment must be deenergized before work may begin on the system. You must assure that the power supply is deenergized, locked, and tagged out and confirmed safe before work begins. Make no assumptions.

Corrective Actions for 300 V Shock

- Identify all equipment requiring LOTO before maintenance
- Identify responsible person for equipment
- Verify that equipment is properly labeled
- Develop LOTO procedures for maintenance on identified equipment