NFPA 70E

Electrical Safety in the Work Place

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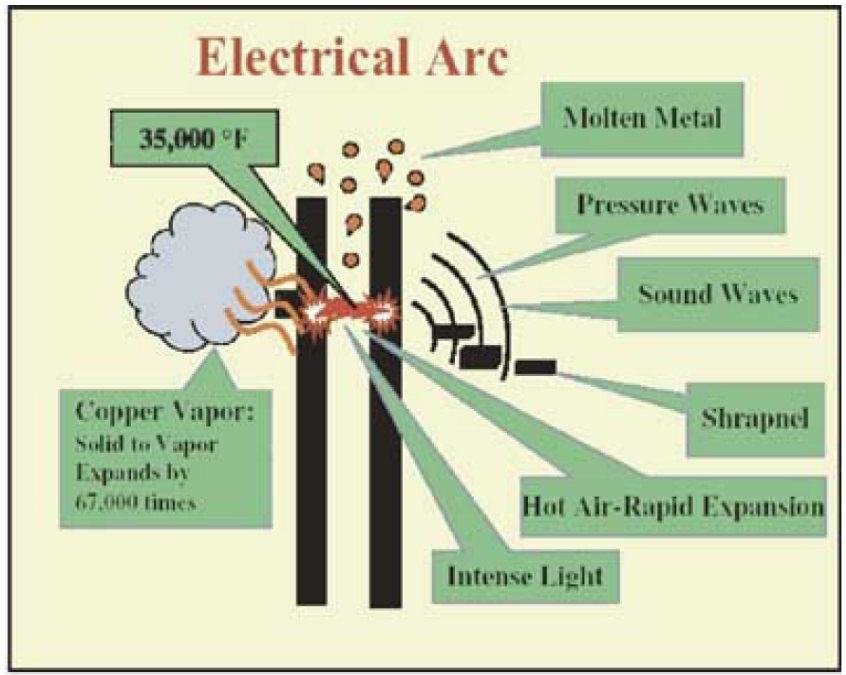
2/1/05

The “Other” Electrical Hazard

- Arc flash:
  - high-intensity flash (eye damage) and superheated ball of gas (skin burns and melting)created by electrical arcing
  - Accompanied by very loud noise and molten metal

Electrical Arc Flash

- A second-degree burn threshold, or a "just curable burn threshold," is skin temperature raised to 175°F fo 0.1 second
- A third-degree burn threshold or "incurable burn threshold," is skin temperature raised to 200°F for 0.1 second
- Eardrum damage > 720 lbs/ft^2
- Lung damage > 1728 lbs/ft^2



IEEE Test

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 Test 3

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 Test 1

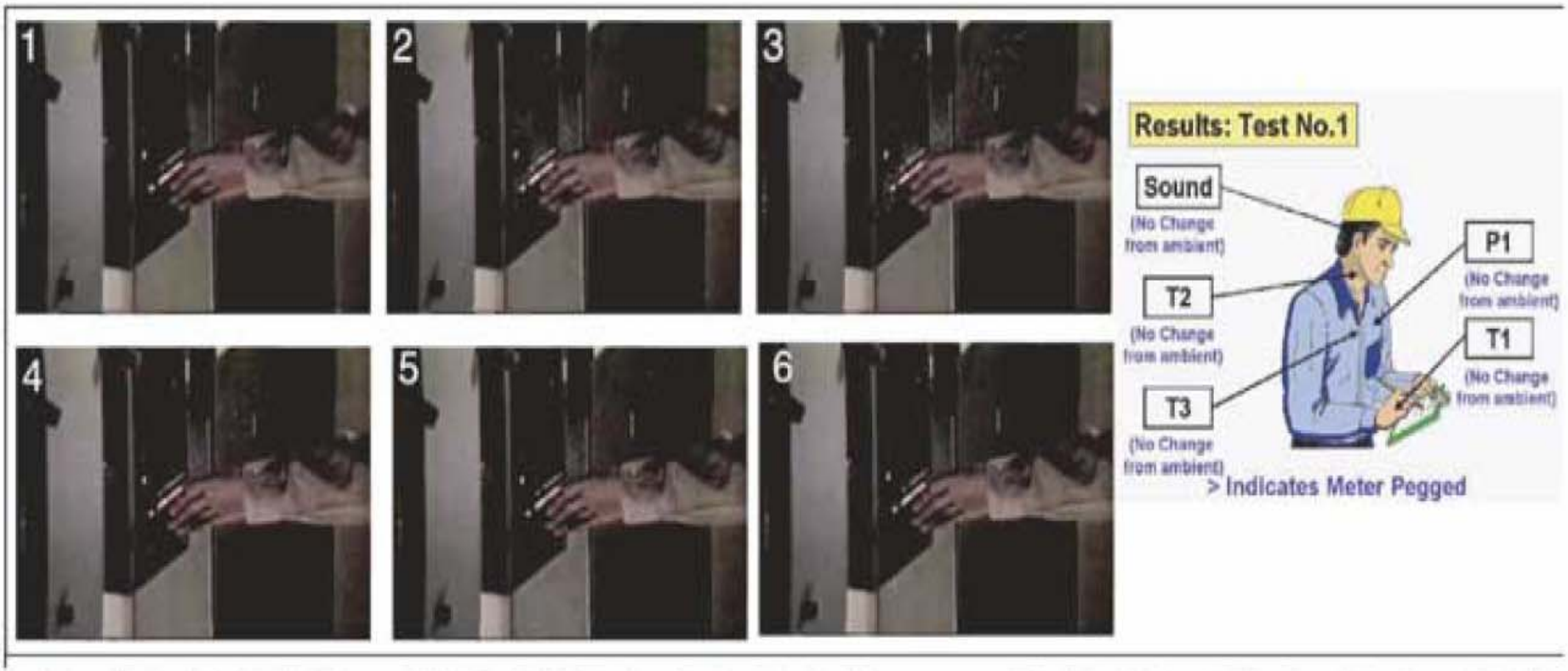


Figure 5. Test 1 - 22,600-A rms, 480-V, fault initiated on load side of a 30-amp current-limiting device in the size 1 starter, and fault was cleared in less than 1/4 cycle.

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

RISK

- 5 to 10 arc-flash injuries per day in US
  - Injuries require treatment in special burn center
  - Does not include hospital treated injuries

ESH Coordinators Meeting

Stanford Linear Accelerator Center (SLAC) Contractor Hospitalized After Arc Flash

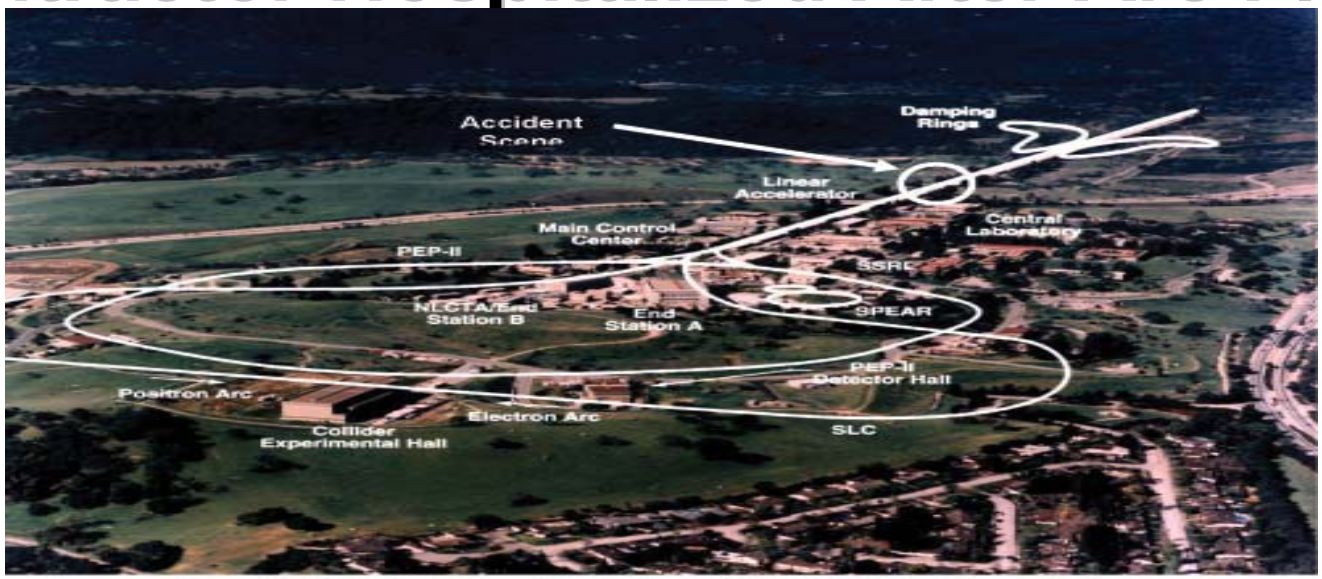


Figure 1-1. Stanford Linear Accelerator Center with Accident Scene Marked

Presented by Ed Sierra
Laboratory Lessons Learned Coordinator
Quality Management Office

January 26, 2005

Accident Description 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

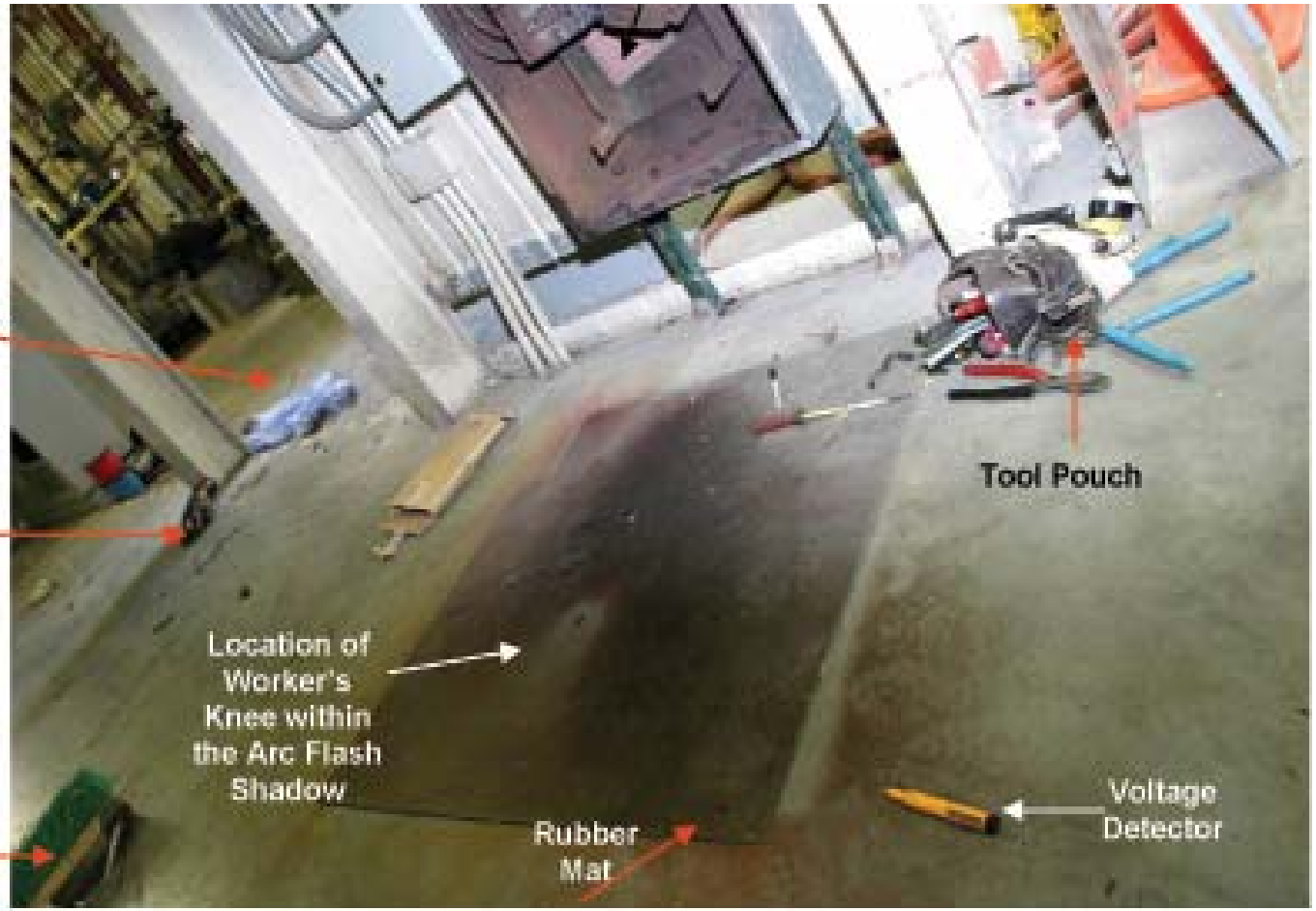


Figure 2-3. The insulating mat with the outline of BSE-1's knee in the arc flash shadow

Screwdriver Used When Arc Flash Occurred

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

Burned Glove

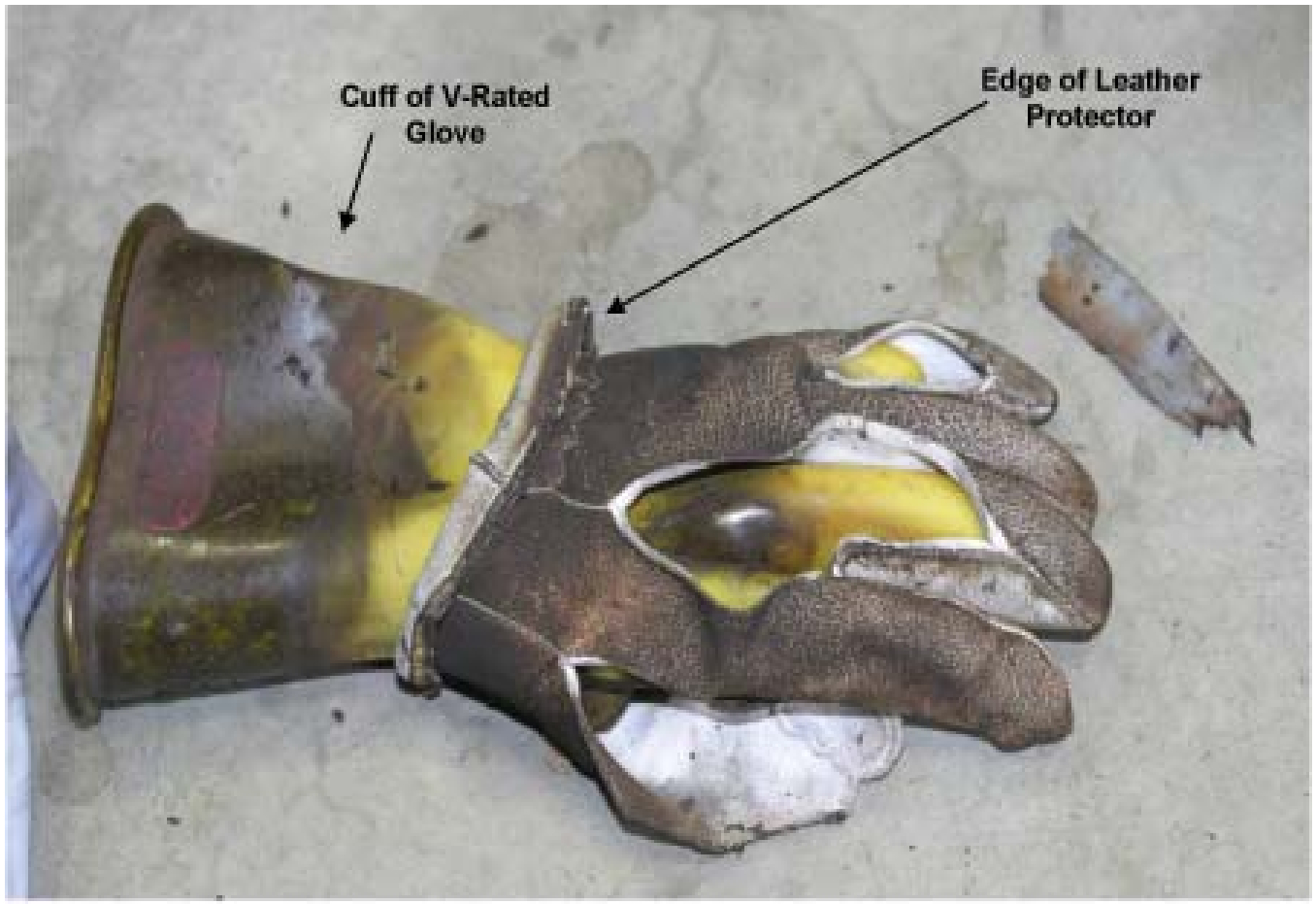


Figure 2-8. Closeup of one of BSE-1's burned gloves

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

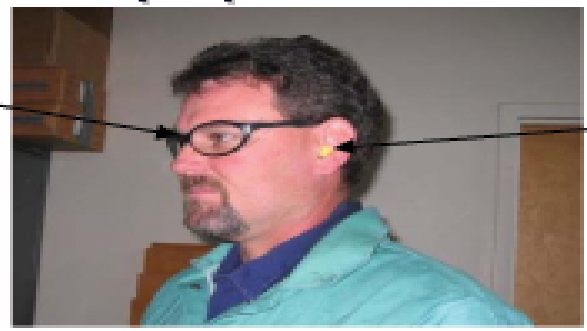


Figure 3-5. Worker wearing the eye and hearing protection to be worn under the double-layer switching hood

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

Circuit Breaker Panel

Incident Circuit Breaker Supported Only by Phase C Connection

Accident Analysis

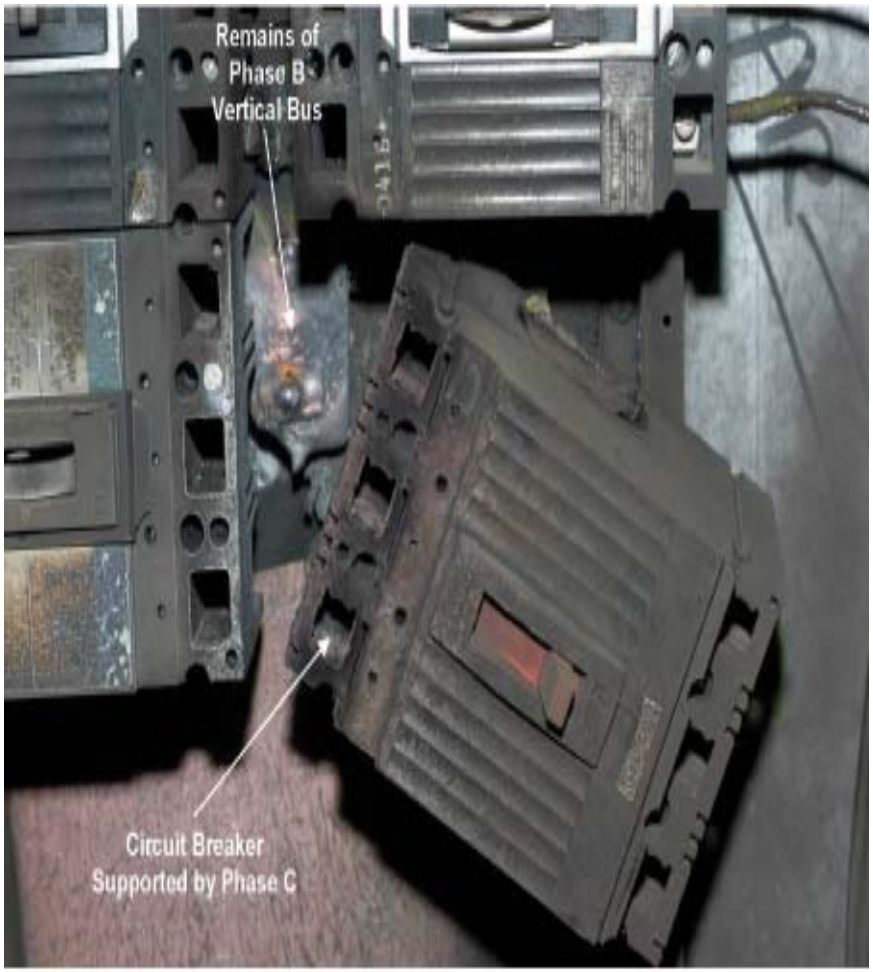


Figure 2-10. Closeup 1 of the damaged circuit breaker panel

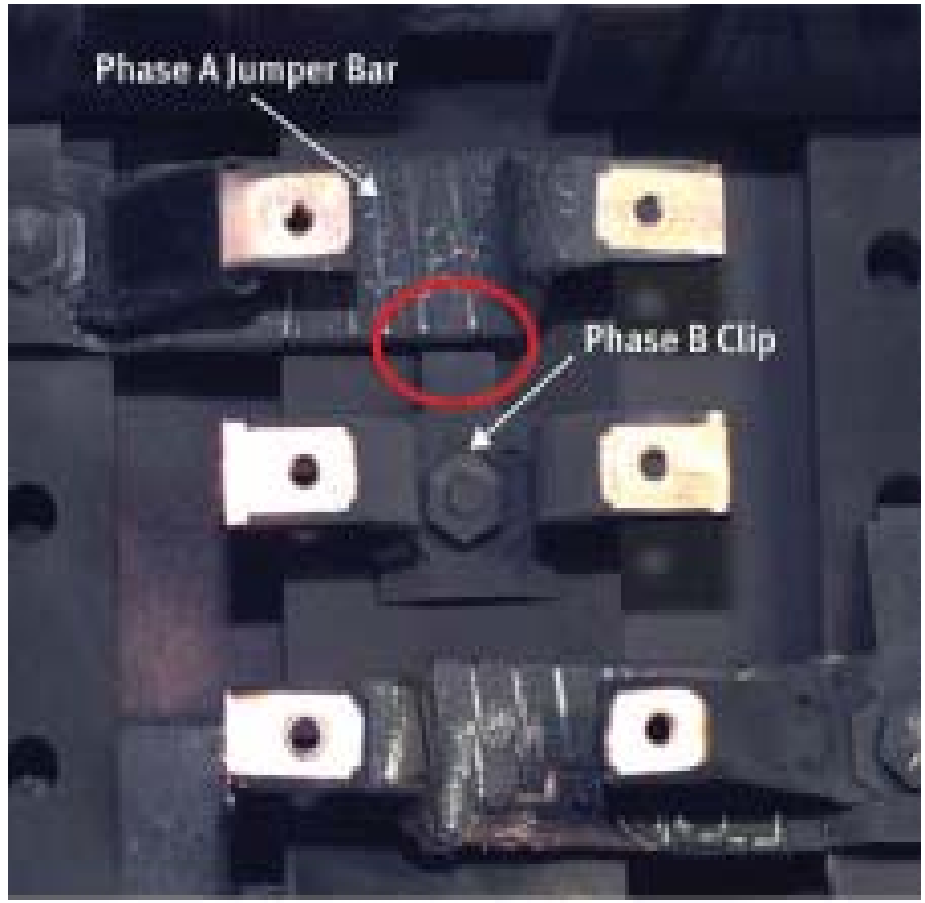


Figure 3-3. Close up of jumper bar and clip with the believed location of the fault circled in red

Identified Key Deficiencies

- **A Pre-Work Hazards Analysis form was not completed**
- **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 officials were not involved**
- **The subcontractor laborer was not trained to be a backup for the electrician**

The DOE Investigation Board Concluded:

- **Unsafe conditions and operations have become an accepted part of the everyday way of doing business.**
- **Rigorous safety oversight, which should have elevated these issues for correction, is frowned upon and given very low priority.**
- **Within some divisions and departments at SLAC, the ISM Core Functions and Guiding Principles are not being followed and have effectively no impact because operations are placed above safety concerns.**
- **SLAC's emphasis on the scientific mission as a means to secure funding from the Office of Science and compete with other laboratories reached the supervisors level as direction to "just get the job done."**

- DOE has begun aggressive compliance with
  - NFPA 70E PPE requirements
  - NEC labeling requirements
- DOE Audit in Spring

BNL conducted audit in Nov.

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

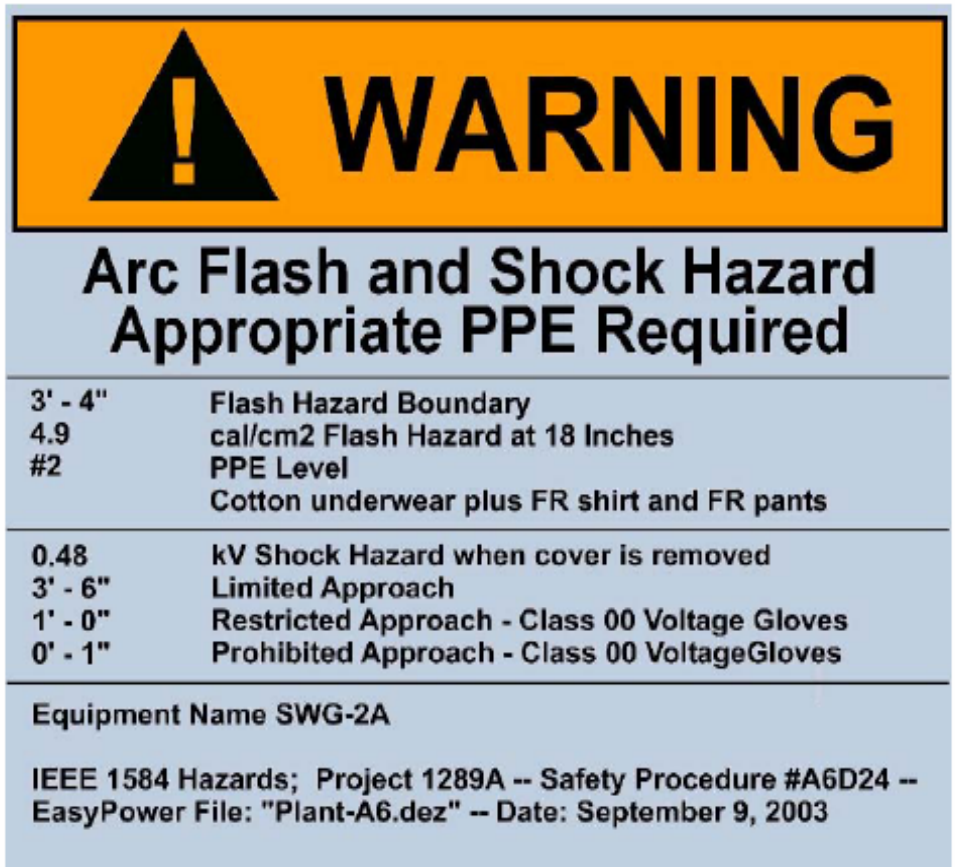
DOE/BNL Expectations

- We must be in compliance with 70E now
- Major DOE review of electrical safety planned for spring

PPE based on NFPA 70E Arc Flash Analysis

- Table method or calculation is required by NFPA 70E prior to allowing work
- The hazard 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
- PPE requirements currently based on NFPA table

Types of Label



Reducing the Risk

- Preventive maintenance to minimize arc flash potential
- Work Hot only when unavoidable and only under permit
- Wear all PPE required by permit
- NFPA 70 E Tables must be used until calculation is performed
- Initially, all breaker panels will be labeled
- Panels rated 208 volts or less may not require protective clothing, but analysis has not been performed
- All locations where workers are exposed will be analyzed
- BNL will be identifying circuits to reduce fault current
  - Fuses can be added
  - Smaller transformers can be used

Circuit Breaker Operation With Covers on (≤ 600V ac rms)

- Safety Glasses
- Natural Fiber Long Sleeve Shirt
- Natural Fiber Long Pants

Stand to the side

Circuit Breaker Trips

- When a circuit has been de-energized by a protective device, do not manually re-energize the circuit without first investigating the cause. Do not perform repetitive manual re-closing of breakers or replacing of fuses.

- BNL electrical protocols allow **ONE attempt** to manually re-close a breaker that has tripped. If the breaker trips again after this attempt, the cause of the trip must be investigated by a qualified person (Contact Al Boerner #5990 or an OPCO).

Fused Switch Operation With Covers on (≤ 600V ac rms)

- Safety Glasses
- Natural Fiber Long Sleeve Shirt
- Natural Fiber Long Pants

Stand to the side

Do you work on or near energized circuits?

- Do you trouble-shoot energized circuits?
- Do you confirm zero energy state for lock-out/tag-out?
- At NSLS, no work above 240 v ac is approved (except for electricians) and no work directly on an energized circuit except with approved test probe.

Voltage Testing / LOTO Verification

50 < (Vac rms) ≤ 240 & ≥ 10 mA rms available current; or
50 < (Vdc) ≤ 1000 & ≥ 60 mA available current; or
Sources capable of an instantaneous release of ≥ 10 J of energy

- Voltage Rated Gloves
- Voltage Rated Tools
- Denim Cotton Blue Jeans
- Flame Resistant Long Sleeve Shirt (≥4 cal/cm^2)
- Hard Hat
- Safety Glasses (non-conductive)
- Training (see next slide)
- Generic Energized Work Permit (see John Aloi)
- Use stamped Category III or IV Multimeter

Training & Qualifications

- BNL Electrical Safety I (TQ-ELECSAF1)
- BNL LOTO Authorized Employee (HP-OSH-151B-W)
- NSLS PPE Orientation
- Person Must be Qualified By Their Supervisor to Perform Task

Voltage Testing / LOTO Verification

50 < (Vac rms) ≤ 240 & ≥ 10 mA rms available current; or
50 < (Vdc) ≤ 1000 & ≥ 60 mA available current; or
Sources capable of an instantaneous release of ≥ 10 J of energy

- **Required PPE**

Meter Requirements
CAT III or CAT IV

Current Status

- We have purchased and received 15 sets of flame resistant shirts. Future purchases will be line responsibility
- We have purchased, but not received 15 sets of voltage rated gloves. Future purchases will be managed through Al Boerner. Gloves must be tested every 6 months.
- We will maintain 2 complete sets of PPE in the control room for authorized personnel listed on a electrical “on or near” permit. (Primarily for users)
- John Aloi has been providing initial training for use of PPE
- We have authorized separate generic work permits for trouble-shooting and LOTO verification for work < 240 Vac which must be used for all NSLS work of this type.

Where Can I Buy the Proper PPE?

- **FR SHIRTS:**
  - Working Class Clothes
  - http://www.workingclassclothes.com/FRwrkshirt.htm
  - INDURA Arc Rating 6.3 cal/cm^2 (KHAKI) {$35.95 each} or {≥ 5 $29.95 each}
- **GLOVES:**
  - Chris Zubyk at BBP 610-827-0138
  - 500 volt rated kits: cotton liner, yellow v-rated gloves, leather gloves & bag $45.00
  - 500 volt gloves only $25.00
  - Test $5.00/pair

Where Can I Buy the Proper PPE?

- **HARD HAT:**
  - BNL Stock K70330
- **NON-CONDUCTIVE SAFETY GLASSES:**
  - NSLS Stockroom #K63408 or BNL stock #K63450, safety glasses must be compliant with ANSI Z87.1 (stamped Z87), do not use chemical splash protection goggles - (they will melt during an arc flash).