Electrical Safety and High Energy Physics

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Electrical Hazards in High Energy Physics

- High Voltage detector components
  - Generally low current, mostly represent a “startle hazard”
- High current power supplies
  - Possible burns from shorting items across terminals
- Stored energy
  - Possible burns from shorting, internal damage
What determines the hazard?

- Voltage
- Current
- Duration
- Energy
What determines the Damage?

\[ I = \frac{V}{R} \]

\[ P = I \times V \]

\[ E = P \times t \]

Circuit → Voltage → Current → Energy

Path → Resistance → Waveform → Damage

Environment → Duration → Determines Immediate Impact

Immediate Impact → Damage Done
Injury from R&D Equipment

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Injury from R&D Equipment
Typical Examples

- magnet lab generator
- electroplating supply
- computer power supply
- computer circuits
- CRT monitor
- photon detector
Results of Electric Injury

- Burn from tool across terminals for a low voltage, high current device
Results of Electric Injury (cont.)

- High Voltage breakdown of skin with entrance/exit wounds
Results of Electrical Injury (cont).

- Arc Flash Burns:
Protecting from hazards

- **Engineering controls**
  - Keep the hazard isolated
  - Interlocks

- **Administrative Controls**
  - Personnel Protective Equipment (PPE)
  - Procedures (application of Lock Out Tag Out)
When/What protection is necessary?

- Codes and Standards specify when/where protection is required:
  - In the US:
    - OSHA
    - NEC
    - NFPA-70E
    - DOE Electrical Safety Handbook
  - Also Facility standards and procedures
US: NFPA-70E Standard for Electrical Safety in the Workplace

- Must protect against both electric shock and possible arc flash
- Preferred method is to de-energize the equipment
- Special procedures for testing, troubleshooting, voltage measuring, and similar activities on energized parts
- Permit with special procedures for other activities on energized parts
NFPA-70E: Shock Protection

- Triggered when working “on or near” exposed energized parts:
  - Over 50V
  - On = tool or body part touching
  - Near = any activity within the “limited approach boundary” (voltage dependent)

- Requires all body parts within the “Prohibited Approach Boundary” to be insulated against the voltage
Limited and Prohibited Approach Boundaries for Electrical Shock

- Voltage dependent:
  - Prohibited = point where the voltage could jump the air gap
  - Limited = larger region, activity in this region could result in accidental contact
- Example:
  - 120V: Limited = 42 inches; Prohibited = contact
  - 480V: Limited = 42 inches; Prohibited = 1 inch
Arc Flash Protection Boundary

- Boundary set at point where energy of arc may just cause a 2\textsuperscript{nd} degree burn (blistering)
- Depends on many factors (e.g. current, duration)
- May be larger than Limited Approach Boundary for Shock
What does that give us?

- New labels on equipment:
  - Arc Flash hazard labels
More arc flash labels
Equipment Inspection Labels

- All electrical equipment must be listed for use by a Nationally Recognized Testing Laboratory (NRTL) or other agency certified by the local Authority Having Jurisdiction (AHJ)
Is this enough for the HEP community? NO!

- Good for shock hazard.
- Not enough for burn hazards:
  - NFPA-70E and IEEE-1584 give formulas for 60 Hz AC systems only!
  - Nothing about capacitor Banks
  - Nothing about high current low voltage power supplies
  - Nothing about RF systems
DOE Electrical Safety Handbook

- Only 2 out of 11 chapters applicable to HEP:
  - Chapter 9: Enclosed Electrical/Electronic Equipment
  - Chapter 10: Research and Development
- Gives guidelines for construction
- Limited guidance for protection
Where does that leave the HEP Community?

- Each facility has needed to develop guidance to ensure worker safety
- Hazards may not be recognized
- Standards not uniform
Six US Facilities
Where do we go from here?

- Capitalize on the expertise in the HEP community to develop standards for situations and equipment not covered by existing codes (e.g. RF, capacitor banks)
- Use forums like this one to work towards uniform standards
Initial steps

- The DOE Electrical Safety Handbook is a step in this direction.
- Efforts are underway to establish an international committee under ISA to develop standards for High Energy R&D Electrical Systems.
High-Power Research and Development Electrical Systems Standards Committee

- Scope
  - To develop standards, recommended practices, technical reports and related information documenting design, fabrication, installation, operation, and maintenance of high power electrical systems, and their associated control, monitoring, safety, and protection systems for national and international research programs in accelerators, pulsed power applications, and high power lasers.

- From the 2005 R&D Electrical Safety Meeting and Workshop held at SLAC March 28-31