OSC|10
Ohio Safety Congress & Expo

Arc flash update: National Fire Protection Association (NFPA) Standard 70E

435

Drake Drobnick

Wednesday, March 31, 2010 2:45 to 3:45 p.m.

Electrical
Workplace Safety

NFPA 70E Compliance
Best Practices &
ROP Changes

Hugh Hoagland

e-Hazard.com
ArcWear.com

Routine Activity

Electrical
Workplace Safety

Safety Facts

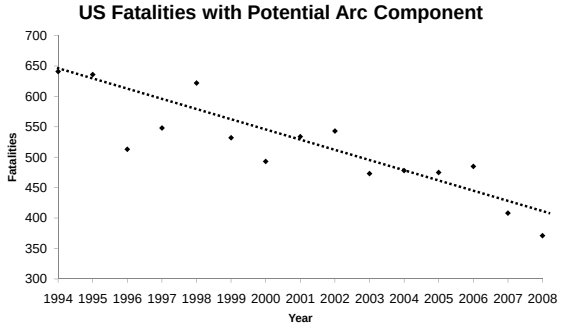
Electrical
Workplace Safety

- Electrical industry 10-year study of 120,000 workers
- 125 injuries per year
- 77% electrical arc injuries
- 21% permanent disabilities
- 2.4% fatalities

Based on ED France data, IEEE Presentation from M. Capelli-Schellpfeffer, M.D.
Electrical Trauma Research Program (University of Chicago)

Safety Facts

Electrical
Workplace Safety

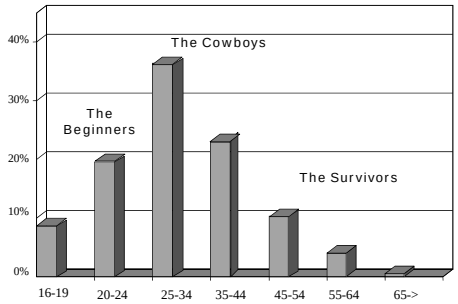


Statistics from BLS website,. Analysis by Hugh Hoagland ArcWear.com. To see calculations, visit www.arcwear.com/stats.mht.

Safety Facts

Electrical
Workplace Safety

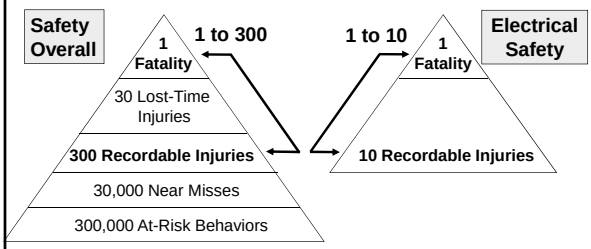
Electrocution by Age



NIOSH 98.131

Safety Facts

Electrical
Workplace Safety



Electrical Safety Program?

Electrical
Workplace Safety

An organized and planned approach that prevents injuries by using processes to do the following:

- **Eliminate hazards** **(shock/arc flash)**
- **Eliminate exposure** **(deenergize)**
- **Eliminate injuries through PPE**

Safety Program Components

Electrical
Workplace Safety

- **Policies**
- **Procedures / Standard practices**
- **Energized Work Justification (Permit)**
- **PPE**
- **Training (All Employees)**
- **Auditing**
- **Recordkeeping**

Safety Facts

Electrical
Workplace Safety

Seven habits of highly safe electrical work.

Habit 1. Always verify absence of voltage & use rubber insulating gloves & tools.

Habit 2. Establish boundaries for worker safety from shock and arc flash.

Habit 3. Always wear arc-rated daily wear and a face shield.

Habit 4. Always use a GFCI with cord & plug connected tools and extension cords.

Habit 5. When feasible create an "electrical safe work condition" which in high voltage always includes safety grounds.

Habit 6. Identify higher hazards and adopt proper PPE or engineering controls to mitigate those hazards.

Habit 7. Measure, audit and continuously improve electrical safety processes.

Habit 1: Verify Absence of Voltage & Use Rubber Insulating Gloves & Tools

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Verify Equipment is De-energized

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Workplace Safety

Verify voltage detector works properly before and after test.

Use an approved voltage detector.

Exposed to Electrical Hazards

Electrical
Workplace Safety

All voltage testers are not equal

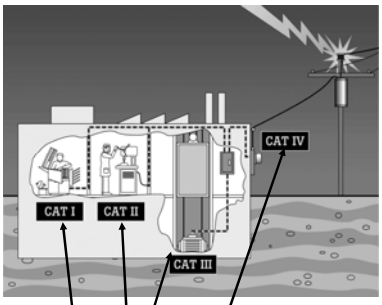
Best practice voltage detector selection

- Inherently self-protected (ohm setting)
- Checks DC and AC on a single voltage selection
- UL category III device, 1000v
  - Maximum voltage and maximum impulse
- Self-test feature

Solenoid testers are not recommended.

Right Meter for the Job
IEC 1010-1 Category locations

Electrical
Workplace Safety



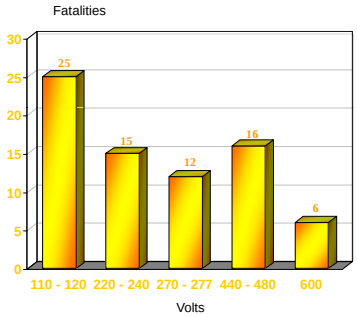
CAT III Distribution; feeders and branch circuits; permanently installed loads

CAT IV "Origin of installation"; outside and service drop, service entrance, primary overcurrent protection

Safety Facts

Electrical
Workplace Safety

U.S. Industrial Low Voltage Fatalities (Electrocution)



NIOSH 98.131

Electrical Hazards - Shock

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Right glove for the job

You must have the correct class of glove for the task.

Check the label.

Gloves Good News

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Workplace Safety

45 cal/cm²

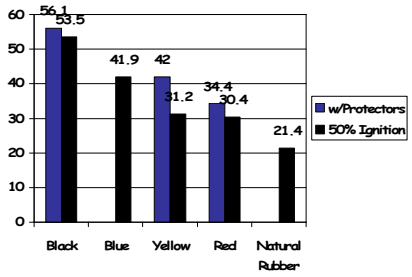
Glove Limiting Factor: Ignition

Electrical
Workplace Safety

Proposed ASTM Standard in F-18

Class 0 Rubber Glove (cal/cm²)

Electrical
Workplace Safety



Leather Protector (cal/cm²)

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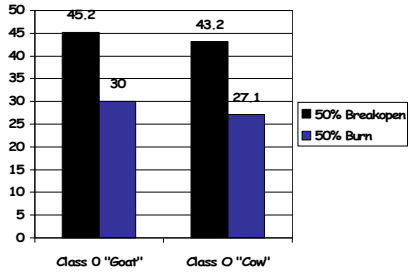


Electrical Hazards - Shock

Electrical
Workplace Safety

Shoes may be optional, but important…

EH Rated

ATSM F2413 or CAN/CSA Z 195
14kV, Test Soles only
Lower Voltage Hazard, Lower Risk Exposure
130.7(C)(7)Secondary Protection Only

DI Rated

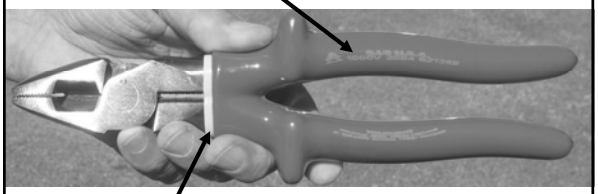
ASTM F1117, Test to ASTM F1116
20kV, Tested wet on whole shoe/boot
High Voltage, High Risk Exposure
130.5(E)(3) Required "equipment grounding near power lines."

Best Practice: Use overshoes for wet service & battery service.

Electrical Hazards - Shock

Electrical
Workplace Safety

Note the "1000 V" mark on genuine insulated tools.



Two color insulation indicator recommended

Rated insulated tools must meet the requirements of ASTM F1505.

Habit 2. Establish boundaries for worker safety from shock and arc flash.

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- There are four boundaries in the standards.
  - Shock Boundaries
    - Limited Approach Boundary (Public Safety Boundary)
    - Restricted Approach Boundary
    - Prohibited Approach Boundary
  - Arc Flash
    - Arc Flash Boundary

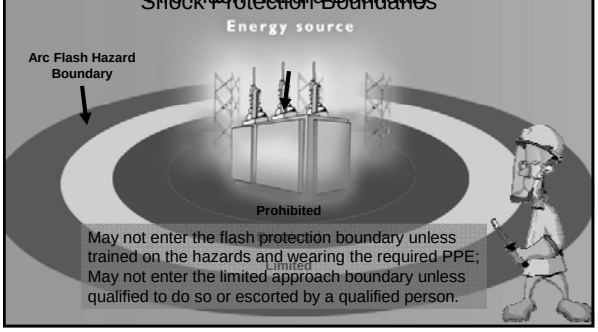
Electrical Hazards – AFH

Electrical
Workplace Safety

Two types of boundaries

Shock Protection Boundaries

Arc Flash Hazard Boundary



May not enter the flash protection boundary unless trained on the hazards and wearing the required PPE;
May not enter the limited approach boundary unless qualified to do so or escorted by a qualified person.

Arc Flash Protection Boundary

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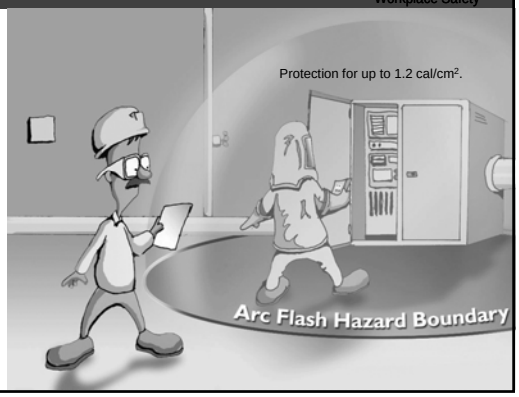

Electrical Hazards – Arc Flash

Electrical
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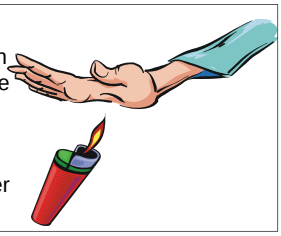
What is a Calorie?

Amount of energy required to raise the temperature of one gram of water one degree centigrade.

If you take a disposable lighter and put your palm in the hottest part of the flame for one second, you will receive about 1.2 calories per cm^2 — the onset of a second degree burn (blister burn) 175°F.



Arc Flash Protection Boundary

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Default Flash Protection Boundary

A 48" boundary may be used for basic systems:

- 50 to 600 volts maximum.
- Up to 50kA available and 2-cycle clearing time.
- Other combinations up to 100kA cycles.
- Calculations are permitted.

NFPA 70E 130.3(A)

Habit 3
Wear arc-rated daily wear & face shield

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The right stuff makes a difference

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Flash Hazard PPE

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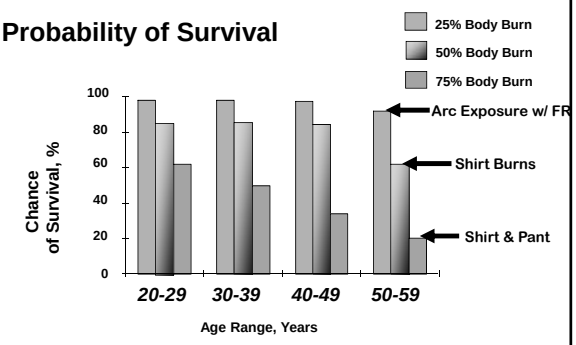
Probability of Survival



Source: American Burn Association (1991-1993 Study)

Costs of FR vs Non-FR in a Utility: A Real Example

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Two Accidents Before FR Paid & Reserve		Two Accidents After FR Paid & Reserve
Medical	$812,677	$32,707
Indemnity	$773,613	$6,035
Vocational	$9948	$1,903
Expenses	$931	$36
Total	**$1,597,229**	**$44,682**
Medical	$309,571	$9,213
Indemnity	$49,369	$1,890
Vocational	$9,999	$1,195
Expenses	$20	$10
Total	**$368,992**	**$12,309**

Source: PECO Presentation by Bill Mattiford, PES-IEEE Seminar
Accident 1: 7/29/93 Accident 2: 7/12/94 Accident 3: 6/1/95 Accident 4: 6/1/95
Accidents in FR were lightweight FR uniform. Actual results may vary.

Face shields have limits

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34 cal/cm²

Flash Hazard PPE – Clothing

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Arc Flash Protection Principles

- Layering
  - Outer layers
  - Under-layers (arc-rated or non-melting)
- Coverage
- Fit
- Maintenance of equipment
  - Laundering
    - Follow manufacturer's instructions
    - No chlorine bleach
    - No fabric softener
  - Inspect for tears and frays

Flash Hazard PPE – Clothing

Electrical
Workplace Safety

Layering Principles

NFPA 70E does not recognize non-FR layers as adding arc flash protection. Only FR layers can be counted toward the total protective calorie count.

Although layered FR garments may provide protection beyond the actual calorie count, only the arc rating values of individual layers is acceptable in the total count unless the system is tested.

NFPA 70E Annex M

The Underwear Question

Electrical
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You may not have to change underwear

Arc-Rated or FR?

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Not all FR rainwear is arc rated.
Any rainwear with a melting substrate will usually increase worker injury.

Watch out for melting "FR" accessories

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These items say "FR" but melt

"FR" Acrylic

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- "FR" means nothing if not attached to a specific standard
- "FR" melting materials like acrylic are bad

Flash Hazard PPE – Clothing

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Workplace Safety

Specific Class E Hard Hat Melting Probability

Probability of Safety Glasses Melting

50% 55.8 cal/cm²

Flash Hazard PPE – Clothing

Electrical
Workplace Safety

Red Foam earplug
10% Probability of Ignition 6.7 cal/cm²

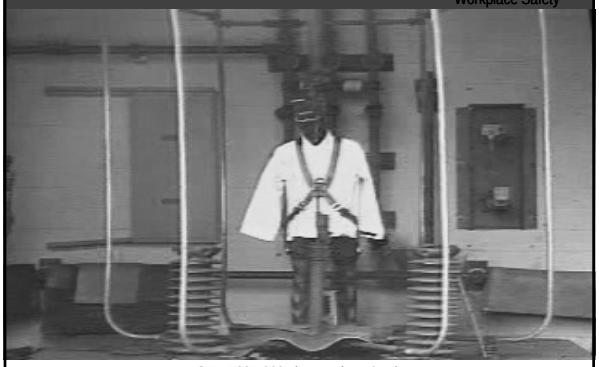
Hearing Protection Options

Dual Design combat ear plug
10% Probability of Ignition
10.7 cal/cm²

Classic Yellow
Foam Ear Plug
Probability of ignition
>50 cal/cm²
No ignition with propane torch or arc flash (does melt).

Flash Hazard PPE – Clothing

Electrical
Workplace Safety



ASTM F887-2004 is tested to 40 cal.

Leather work shoes in arc

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Workplace Safety

50-60 cal/cm²

Leather work shoes in arc

Electrical
Workplace Safety

50-60 cal/cm²

Habit 4
Always use a GFCI with cord & plug connected tools and extension cords.

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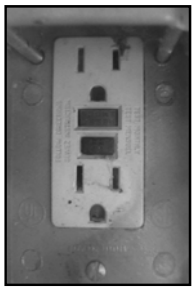
Required by OSHA: Inspect and maintain



- Inspect and test portables before each use.
- Inspect permanent GFCI's normally monthly and document
- Removed damaged GFCIs from service.
- Portable GFCI plugs into receptacle, extension cord or tool is attached.

Habit 5: When feasible create an "electrically safe work condition" which in high voltage always includes safety grounds.

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Workplace Safety

Create an Electrically Safe Work Condition

- Check drawings and identify all possible energy sources.
- Shut down equipment.
- Open disconnect switch or circuit breaker.
- Visually verify opening of contacts where possible.
- Apply lockout/tagout devices.
- Test for absence of voltage and verify operation of tester both before and after use.
- Apply grounds where necessary.

Safe Work Practices - Grounding

Electrical
Workplace Safety

GROUND the phase conductors or parts before touching them when:

- A possibility of induced voltages exists.
- There is stored electrical energy.
- Conductors or any part of the equipment may contact energized parts.

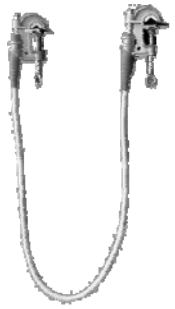
NFPA 70E 120.1(6)

NEVER ground low voltage unless engineering has determined the grounds can carry the fault current for the clearing time.

Personal Safety Grounding

Electrical
Workplace Safety

Personal Ground Sets



Ground sets must be rated for the available fault duty and inspected for:

- Cuts in the sheath,
- Damage to conductors,
- Tightness of clamps and connector strain relief devices,
- Last testing date (must be tested every three years) NFPA 70E 250.2(B).

NFPA 70E 250.2(B) and 250.3(B)

Habit 6 Identify greater hazards & adopt PPE or engineering controls to mitigate

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The best way to reduce hazard exposure is:

- Identify hazards;
- Remove or reduce possibility of contact through engineering controls;
- Establish mandatory safe work practices.

Hazard Assessment

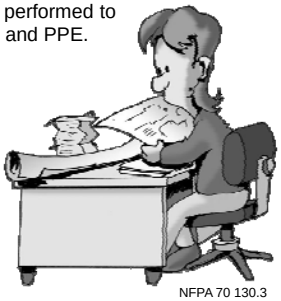
Electrical
Workplace Safety

Flash Hazard Analysis Required

Flash hazard analysis must be performed to determine protection boundary and PPE.

Must be reviewed a minimum of every five years. Updates required if major modifications or renovations.

Must consider effects of overcurrent protective devices and opening times.



NFPA 70 130.3

Hazard Assessment

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Exceptions to Performing an Analysis

Exception #1:

- *Circuit is rated at 240 volts or less, and*
- *Circuit is supplied by one transformer rated at less than 125kVA.*

Exception #2: The following default tables may be used in lieu of an analysis if you meet the table notes:

- *130.7(C)(9) Hazard/Risk Category Classifications.*
- *130.7(C)(10) Protective Clothing and PPE.*
- *130.7(C)(11) Protective Clothing Characteristics.*

NFPA 70E 130.3

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Over 40 cal/cm²?

Arc blast potential must be heavily considered when this level of protection is needed.

The preferred method is to reduce the risk level through engineering controls.

Electrical Hazards – AFH

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Reducing exposure through safety by design

- Choose arc-resistant equipment.
- Separate supply voltage from control voltage to reduce exposure.
- Reduce risk of common tasks with ports, etc.
- Design and install to easily de-energize.
- Have one line or single line drawings.
  - Keep drawings up-to-date and available.
  - Have different drawings for specific uses.
    - Panel diagrams/plans.
    - Switching diagrams.

See Annex O and 110.8 (B)(1)

Hazard Assessment

Electrical
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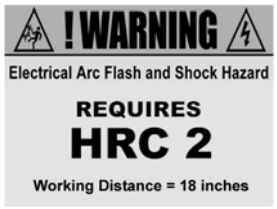
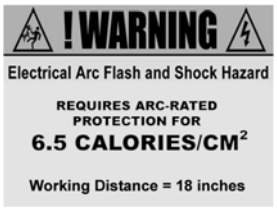
Arc Flash Hazard Labels

NFPA 70E 130.3 (C)

Equipment must be field labeled with labels displaying either the required level of PPE or the available incident energy.





Hazard Assessment

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Arc Flash Hazard Labels

May also display such information as:

- Nominal Voltage
- Shock Approach Boundary
- Arc Flash Boundary
- Working distance
- PPE (listed)
- Equipment name/ID
- Upstream device
- Date of assessment

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WARNING

Arc Flash and Shock Hazard
PPE Required
When exposed to energized components

480 VAC
42" Shock Protection Boundary
48" Arc Flash Protection Boundary
7 Cal/Cm^2 incident energy @ 18 inches

Use Class "00" insulated gloves with leather protectors, flame resistant clothing, face shield, hard hat, balaclava, leather shoes, ear canal inserts, and safety glasses

Equipment ID: Review Date:

Electrical Hazards – Arc Flash

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First, it is infrared radiation from an arc event.
1.2 cal/cm^2 electric arc in open air 12 inches away from worker.

Electrical Hazards – Arc Flash

Electrical
Workplace Safety

Second, it can be mostly arc plasma if arc is ejected.
10.2kA, 8.2 cycles, 17.3kA peak current, 34 inch distance from worker.

Electrical Hazards – Arc Flash

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Arc in a Box

Third, arc-in-a-box energy can be two to twelve times greater when the arc is an *arc in a box* situation.

Electrical Hazards – Arc Flash

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Tracking Arc

Fourth, tracking arcs are "arcs" which conduct along air and moisture between skin and clothing.

- Can cause ignition of clothing in a contact situation.
- Usually occurs at higher voltages.

Role of Overcurrent Protection

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Decreases in "let through" time equaling Arc Flash Protection Boundary and Incident Energy level reductions

26.8 inches
800 amp Circuit Breaker opening in 6 cycles

5.28 inches
800 amp Class-L Opening in ½ cycle

1.61 inches
30 amp Class RK-1 opening in ¼ cycle or less

Mitigation

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May be able to reduce arc flash hazard on existing systems:

- Ensure proper interrupting rated overcurrent protective devices
- Upgrade clearing devices to current-limiting
- Eliminate circuit breaker short-time delays and set instantaneous settings as low as possible
- Install isolation transformers

Electrical Hazards – AFH

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Retrofit of power CB with a maintenance switch to allow temporary reduction of available energy.

Door mounted.

Breaker mounted.

Maintenance Reduces Risk

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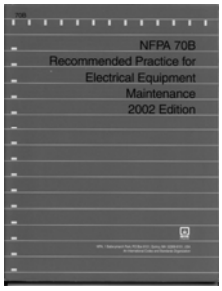
NFPA 70B

NFPA 70B requires power circuit breakers be calibrated on an interval required by the manufacture or every three to five years.

Breaker maintenance and calibration are critical to arc flash protection.



NFPA 70E 205.3 Overcurrent Device

Electrical Hazards – AFH

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Putting distance between worker and hazard

Universal
Remote Power
Racking

Eaton

CBS Nuclear

Electrical Hazards – AFH

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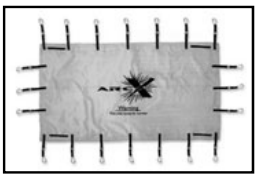
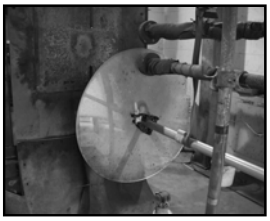
Reducing the arc hazard



Arc blast blankets can reduce energies reaching the worker



SafetyShield can reduce energies reaching the worker by attachment to a hotstick

Arc Blanket ASTM F2676

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Arc Forces

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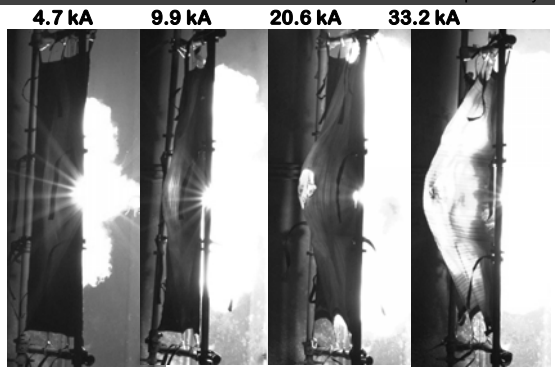

Shield Hotstick Work

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Bad Day at the Office for Electricians

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~80 cal/cm² Exposure 100% Cotton Jean Ignition (07-2901)

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Workplace Safety

11.1 cal/cm² in crotch area Some from jean ignition
Mannequin at 12" from arc source

~80 cal/cm² Exposure 100% Cotton Jean Ignition (07-2901)

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~80 cal/cm² Exposure FR Jean 07-2902

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- Flame Resistance pays off in under layers in extreme incidents
- FR uniforms that are ALWAYS on have the most impact.

Flash Hazard PPE – Clothing

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Indura® UltraSoft® Shirt Indura® Denim Jean vs. Non-FR Cotton

Flash Hazard PPE – Clothing

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40 cal/cm² suit - no 2nd degree burns
HRC 2 - received 2nd and 3rd degree burns

Laundering can be critical

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L: Clean R: 100 ml hydraulic oil
~20 cal/cm^2

Arc Goggle - Carbon Balaclava Now meets ASTM F2178

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Goggle at 37 cal/cm^2 and 42 cal/cm^2

Worst accident?

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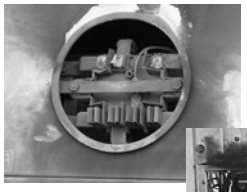

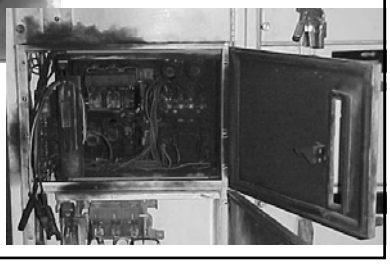

Sometimes....

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Your PPE

The only thing between you and this is…

Meter base 480V Phase to Phase

Electrical
Workplace Safety

Bring it together: A Common Approach

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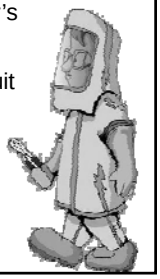
Category 2 – 8 cal/cm²

- Safety glasses
- Arc-rated 8 cal/cm² shirt and pants or coveralls
- Hard hat (Class E)
- Face shield or hood
- Hearing protection
- Gloves
- Leather work shoes
- For 2* add balaclava hood or flash hood

Category 4 – 40 cal/cm²

- Same as Level 2 plus switcher's suit
- Flash suit hood



PPE – Standards

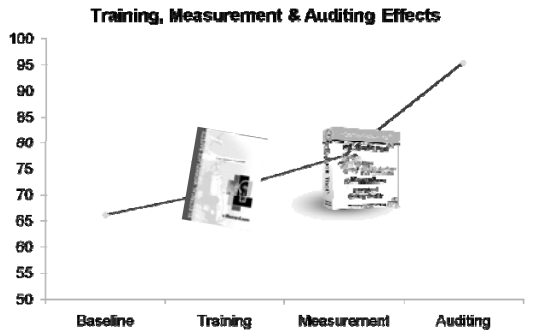
Electrical
Workplace Safety

- Clothing
  - ASTM F1506
- Rainwear
  - ASTM F1891
- Goggles, Hoods and Face shields
  - ASTM F2178
- Fall Protection Exposed to Electric Arc
  - ASTM F887
- Blankets
  - ASTM F2676

- Gloves
  - ASTM D120
  - Proposed Arc Standard
- Insulated Tools
  - ASTM F1505
- Work Shoes
  - EH (Electrical Hazard)
    - ASTM F2413, 14kV, Dry Test Soles only
  - DI (Di-Electric)
    - ASTM F1116, 20kV, Wet near top of shoe

Habit 7. Measure, audit and continuously improve electrical safety processes.

Electrical
Workplace Safety



The Effects of Training, Goal Setting, and Knowledge of Results on Safe Behavior: A Component Analysis, Robert A. Reber and Jerry A. Wallin, The Academy of Management Journal, Vol. 27, No. 3 (Sep., 1984), pp. 544-560

Emergency Response Training

Electrical
Workplace Safety

- **Qualified employees**
- **First-aid (1910.151)**
- **BBP (1910.1030)**
- **CPR/AED**

Optimize Hierarchy of Controls

Electrical Workplace Safety

- **Eliminate the hazard**
  - **de-energize, lockout, visualize, verify**
- **Engineering controls**
  - **design it out**
- **Administrative controls**
  - **labeling, training, safe work practices, work plans and permits**
- **Personal protective equipment**

Things to do, Review

Electrical Workplace Safety

- Conduct Hazard Analysis/Selective Coordination study
- Determine a hazard mitigation strategy
- Update Single Line Drawings
- Develop Electrical Safety Program
- Select PPE
- Train employees
- Label equipment
- Audit for compliance
- Review program annually

Gap Analysis

Electrical Workplace Safety

Where Should You Begin?

- Determine your program's goal.
- Assess your current state.
- Understand where gaps exist.
- Plan to bridge gaps.
- Use external resources when necessary.
- Implement program.
- Audit to determine compliance.

Cost Justification

Electrical Workplace Safety

- Workers' Compensation Expenses
  - Indemnity and medical
- Governmental Citations
- Corporate Image
- Insurance Premium Increases
- Investigation Expenses
- Equipment Down-time
- Criminal Prosecution

NFPA 70E 2012 ROP Changes

Electrical Workplace Safety

- Term FR removed replaced with Arc Rated
- Term Protection removed from Arc Flash Boundary
- Term "Working On" means intentional contact
- New shock and task tables for DC
- 3 yr. re-training requirement
- Task table (C)(9) includes columns for specific notes and AFB
- PPE tables (C)(10)-(11) combined
- AED training required for first aid

NFPA 70E 2012 ROP Changes

Electrical Workplace Safety

- HRC 2* Removed
- Balaclava required for all HRC 2 tasks
- New minimum labeling requirements
  - Incident Energy (Working Distance) OR
  - Arc rating of clothing (Cal/cm^2)
  - Arc Flash Boundary
  - Nominal voltage
  - Date of assessment
- Removed installation requirements from Article 320 Battery Rooms

NFPA 70E 2012 ROP Changes

Electrical
Workplace Safety

- Deleted D.8 formula
- New Annex H choices
- Calculation method required for new installations starting 2012
- IEEE 1584 Exception removed

Questions?

Electrical
Workplace Safety

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