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electrical WORKPLACE SAFETY

EFCOG DOE ESW Arc Flash Update

Hugh Hoagland

e-Hazard

ArcWear Arc Flash & Textile Testing for PPE

ACCREDITED

Safety Facts

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Why be Concerned About Electrical Safety?

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- Personal safety
- Safety for your fellow workers
- Comply with regulations

Safety Facts

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~80 cal/cm^2 100% Cotton Ignition (07-2901)

11.1 cal/cm^2 in crotch area; some from jean ignition
Mannequin at 12" from arc source

Safety Facts

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~80 cal/cm^2 100% Cotton Ignition (07-2901)

Safety Facts

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~80 cal/cm^2 Exposure FR Jean (07-2902)

- Flame resistance in underlayers pays off in extreme incidents.
- FR uniforms that are ALWAYS on have the most impact.

Safety Facts

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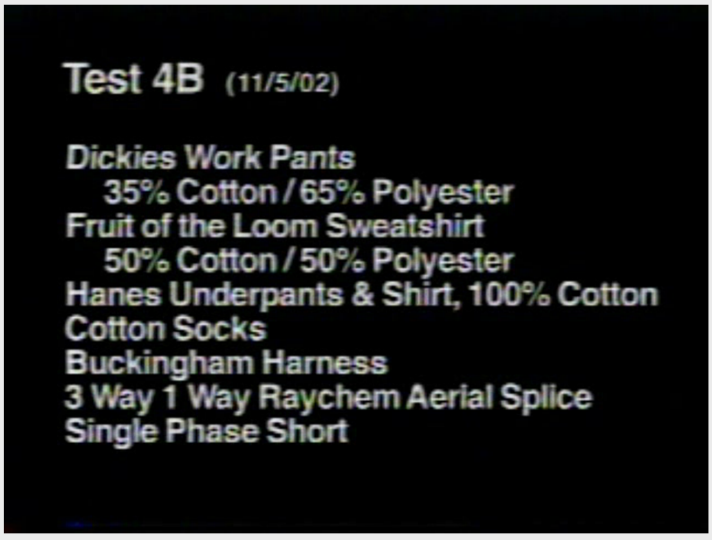
Can an Arc Get into a Bucket?



Safety Facts

Study Finding: Arc Plays a Major Role in Electrical Injuries

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Results of an electrical industry 10-year study of 120,000 workers:

- 125 electrical injuries per year
- 77% 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

U.S. Workplace Fatalities from Exposure to Electricity

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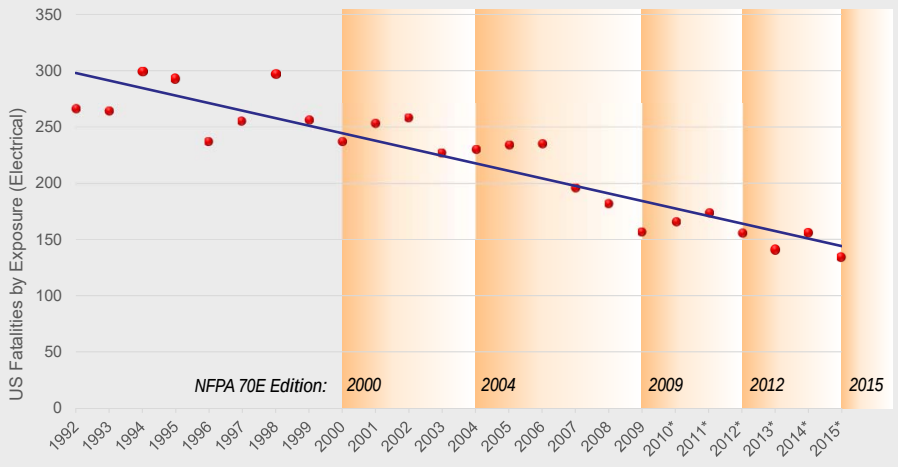

*Due to classification/coding changes, data from 1992-2010 analyzed by "contact with electrical current" and data from 2010-2014 analyzed by "exposure to electricity"

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

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Distribution of Electrical Thermal Injuries

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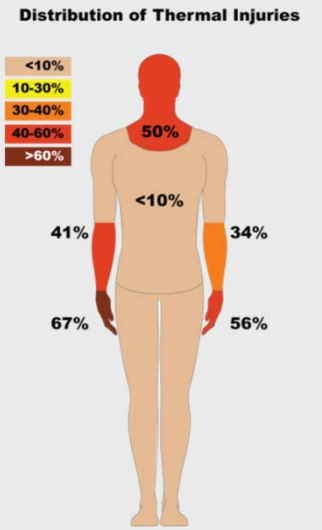
- The areas with the highest percentage imply that most are not wearing proper PPE.
- The <10% on the body does not indicate level of damage but most who have clothing ignitions will be disabled.
- Proper PPE will eliminate most of these injuries.



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Regulations & Standards

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Regulations & Standards

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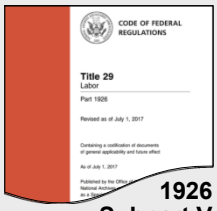
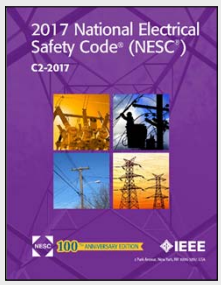
What Standards Apply?

1910.269
Electric Power: Operation & Maintenance

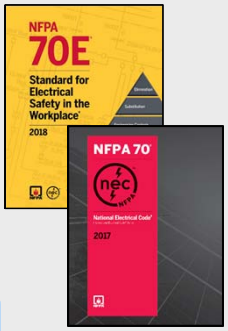


1926 Subpart V
Electric Power: Construction



How to build AND work on utility systems

Comparable Commercial Standards
70E= Work Practices
NEC=Construction



2014 Update makes OSHA Regs comparable to NESC

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Electrical Hazards & Protection Strategies

- Shock
  - **Hazards**
  - **Protection Strategies**
- Arc Flash
  - **Hazards**
  - **Protection Strategies**

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Open Air Arc

1.

- Mainly infrared radiation and some hot gases
- Most common type

20 cal/cm² electric arc in open air 12" away from worker

Ejected Arc

2.

- Arcs can be worse when they are ejected plasma

10.2kA, 8.2 cycles, 17.3kA peak current, 34" distance from worker

Electrical Hazards » Arc Flash

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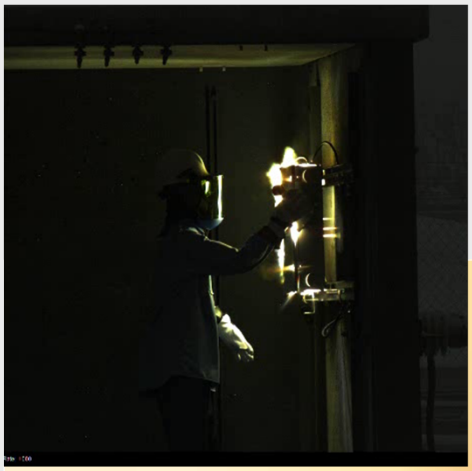
Arc-in-a-Box



- Energy can be two to twelve times greater in an *arc-in-a-box* situation

3.

Watch the disconnect door.

Electrical Hazards » Arc Flash

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"Tracking" Arc

- Arc conducts through skin and "pops out" between skin and clothing
- Can cause ignition of unrated natural fibers
- Usually occurs at higher voltages

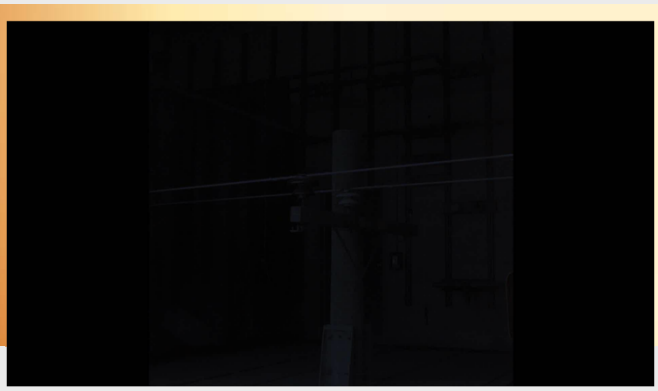
8kV, 8kA, 10 cycles Tracking Arc on power line
Unrated cotton t-shirt under 8 cal/cm² AR work shirt

4.

"Running" Arc 4kA

5.

- Starts between lines from tools or other contact
- Causes ignition of unrated natural fibers
- More like a normal arc than "tracking" arc
- May sit at insulators low current

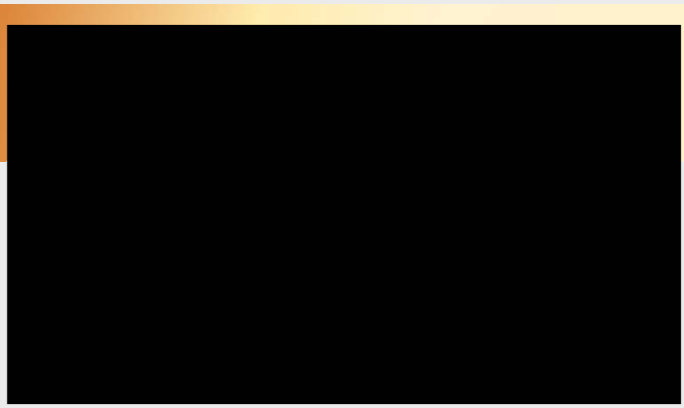


4kA Grounded and Ungrounded Insulators
Arc remained at crossarm

"Running" Arc 8kA

5.

- Moved past insulators without delay



8kA Grounded and Ungrounded Insulators
Arc moved through crossarm

Electrical Hazards – Arc Flash

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"Running" Arc

5.

- Starts between lines from tools or other contact
- Causes ignition of unrated natural fibers
- More like a normal arc than "tracking" arc
- May sit at insulators

Wet Area "looks" better

Exposure to outside

Electrical Hazards » Arc Flash

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Arc Blast
40 cal/cm^2 "Limit" Removed from NFPA 70E

Pressure wave caused by the rapid heating of air

- Strips outer shell electron of air and metal; super heated air becomes plasma
  - Vaporized metal accounts for little of blast; most metal is molten
- ***Function of fault current and containment, not incident energy***
- Limited data for calculating

40-50 kA arc blast can:
- Create 165 dB sound wave
- Blow a person several feet away
- Explode parts

20 kA, 10 cycle <6 cal/cm²

Watch disconnect door & mannequin.

Watch for the arm flying!

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Wind Beneath my Wings or a Hurricane?

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Recent studies show:

Although arc blast is a function of fault current, containment is more critical factor

18 kA, 1 cycles Door Open 3kV 8kA 1 cycle Door Closed

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Common Places for a Fault

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Padmount Switching

- Clearing time varies
- Substantial fault current
- Arc-in-box
- Burns in some accidents > 6 ft away

Common Places for a Fault

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480v Motor Control Centers (MCCs) often have:

- 10-40+ kA
- 20+ cycle clearing times

Arc flashes are more common in low voltage equipment due to busbar spacing

Common Places for a Fault

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Meter Bases and Meter Banks

- Higher fault currents of secondary side
- Longer clearing times if phase to phase
- Shorter clearing times if phase to ground since the lower voltages tend to self-extinguish when they go through zero

Meter de-energized but clip fell into energized meter below

Common Places for a Fault

Low Voltage Testing

- Higher fault currents of secondary side
- Longer clearing times if phase to phase
- Phase-to-ground often clears ½ cycle self-extinguishing at zero
- Drawing arc phase-to-phase
- Common scenario is testing on primary voltage (i.e. 4160V to 13800V with a low voltage meter)

Two workers exposed

Racking Power Circuit Breakers

- **Wear proper PPE**
- **Follow proper procedures**
- **Adequately maintain**

40 Cal Arc Flash Gear

40 Cal Arc Flash Gear

Front

Back

Arc Flash Hood

Equipment Damage

Severe damage to cubicles in the area of the fire and to cables above

Equipment Damage
Breaker Cubicle Remains

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SCE&G A SCANA COMPANY

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Arc-Rated Personal Protective Equipment

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Arc-Rated PPE

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The Right Stuff Makes a Difference

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Arc-Rated PPE

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Probability of Survival

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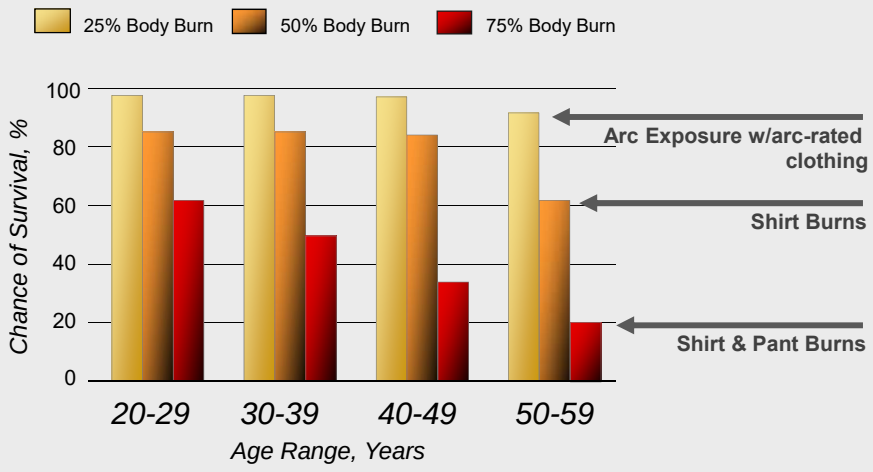

Source: American Burn Association (1991-1993 Study)

SCE&G 40 Cal Arc Flash Gear

40 Cal Arc Flash Gear

Front

Back

Arc Flash Hood

Equipment Damage

Severe damage to cubicles in the area of the fire and to cables above

Equipment Damage
Breaker Cubicle Remains

Dangerous Clothing Characteristics

- Flammable
- Melting

Clothing not permitted:

- Acetate, acrylic, nylon, polyester, polyethylene not permitted unless arc tested in blends
- Melting materials are prohibited by NFPA 70E and OSHA 1910.269
- Beware of popular undergarments

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Layering Principles

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Non-AR underlayers allowed *only if* non-melting (i.e. cotton, wool, silk, leather)

- Does not increase protection value

In real-life: Cotton undergarments may add some protection but may also ignite, causing serious burns

Layers of AR garments *may* offer increased protection

- Layers must be tested as a system to provide increased rating

8 cal/cm² coverall
\+ 4 cal/cm² shirt
≠ 12 cal/cm² system

Non-AR outer layers ***prohibited*** over AR layers

Arc-rating of outer layer does *NOT* impact rating of AR underlayers

8 cal/cm² shirt
w/ 5 cal/cm² high-vis vest
= 8 cal/cm² rating value

See Arcwear.com for 2-Layer Test Results list

NFPA 70E 130.7(C)(9), Annex M

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Free Layering Data

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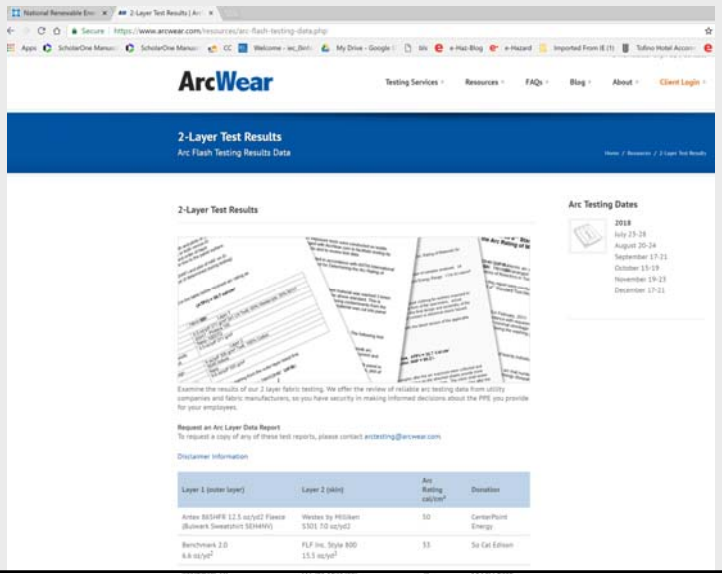

Use Hard Hats & Safety Glasses

50% Probability of Specific Class E Hard Hat Melting = 48 cal/cm²

50% Probability of Safety Glasses Melting= 55 cal/cm²

Adding a Balaclava Hood to Face Shield

(No safety glasses)

Front Testing	Back Exposure	60° Angle Exposure
		
10.9 cal/cm²	30 cal/cm²	12.8 cal/cm²

Arc Rating (ATPV)

balaclava, shield and safety glasses can be used for up to 12 cal/cm² if the properly rated system is used

Arc-Rated PPE

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ArcGoggle w-Balaclava

Arc Rating (ATPV) = 38.6 cal/cm²

Arc-Rated PPE » Equipment

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Hearing Protection

Ear Plug Type		Probability of Ignition
Dual design combat		10% at 10.7 cal/cm²
Yellow foam		>50 cal/cm² (does melt)
Red foam		10% at 6.7 cal/cm²
Best Practice — Silicone		>50 cal/cm² (no melting)

All hearing protection adequate under AR balaclava or AR hood

Required inside AFB NFPA 70E 130.7(C)(5) Muffs may be acceptable if arc-tested

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Glove Arc Ratings

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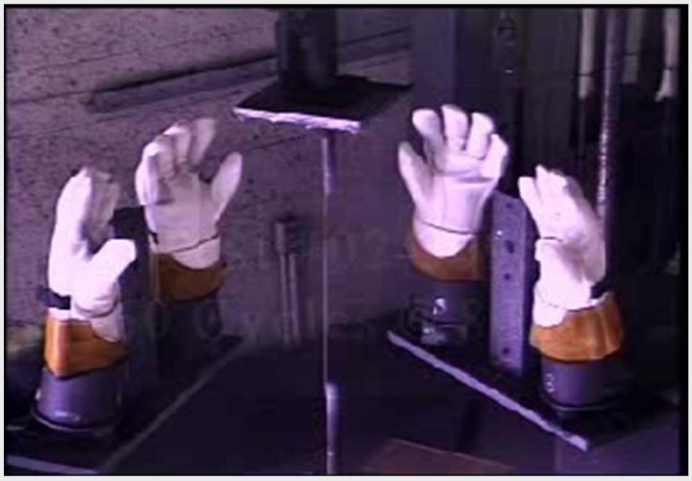

45 cal/cm²

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Simplified and Fool-Proof PPE Program

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Use the *Two-Category Approach* (Annex H.2)

Either

ARC 2 or **ARC 4**

ARC 2:
8 cal/cm²

ARC 4:
40 cal/cm²

Arc-Rated PPE

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Match Your Arc Flash Study

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< 1.2 cal/cm²	1.2 - 12 cal/cm²	> 12 cal/cm²
	Arc-rating must be ≥ estimated incident energy	
✓ Eye Protection ✓ Hearing Protection ✓ Natural Fiber Long Sleeve Shirt & Pant *or* Coverall ✓ Leather footwear	✓ Eye protection ✓ Hearing protection ✓ Hard hat	
As Needed ✓ Face Shield ✓ Leather, AR *or* VR Gloves	Head: ✓ Rated face shield *with balaclava* *or* ✓ Rated arc flash hood	✓ Rated arc flash hood
Best Practice: Minimum Daily Wear	Body: ✓ Rated shirt, long sleeve *and* ✓ Rated pants *or* ✓ Rated coverall	*or* ✓ Rated arc flash suit
	Hands: ✓ Heavy-duty leather *or* ✓ Rated gloves *or* ✓ Rubber insulating gloves w/leather protectors (SR)	✓ Rated gloves *or* ✓ Rubber insulating gloves w/leather protectors (SR)
	Feet: ✓ Leather footwear	
	Rated Outerwear (AN)	

Table 130.5(G)

Arc-Rated PPE

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Look for Arc Rating and PPE Conformity per ANSI 125

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Check the Label

Vertical Flame Test (ASTM D6413) *Not Adequate*

Garments must meet ASTM F1506 which specifies a rating for:

EBT = **E**nergy **B**reakopen **T**hreshold **or** **ATPV =** **A**rc **T**hermal **P**erformance **V**alue

ASTM F1506

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- Pros
  - Special Class for Disposables
  - Has Arc Rating
  - Several Fabrics
  - Meets NFPA 70E by default.
- Cons
  - Requires FR thread and most require FR zipper
  - None certified disposable to ASTM F1506

ANSI/ISEA 203

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- Pros
  - Eliminates melting materials which can pass vertical flame criteria
  - Full Scale Flash Fire Test
  - Addressed a real issue
- Cons
  - No arc flash option
  - Deferred to ASTM F1506 but may offer arc flash option if F1506 doesn't address issues of thread and zippers which are either covered or little of the garment

Not Using Arc-Rated Undergarments?

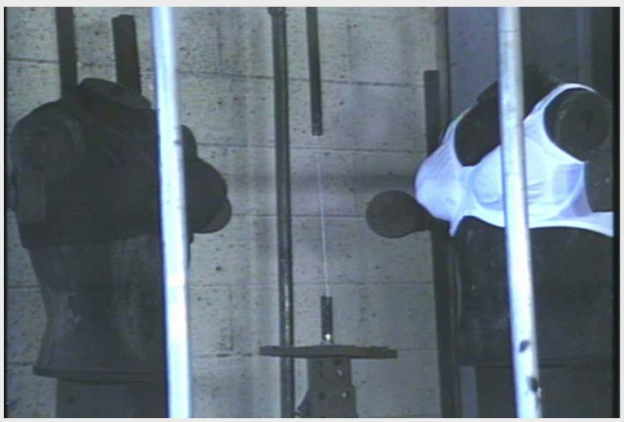
Silk long underwear

- Arc-rated undergarments are available
- If outer layer does not break open or ignite, non-melting undergarments have tested well
- You cannot count non-AR layers as adding protection without testing

- **Cotton**
  - May use for under-layers when no breakopen risk
  - Is an ignition risk in tracking arc

- **Silk**
- **Wool**

Arc-Rated vs. Cotton Bra



ArcStore.com

Arc-Rated PPE

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The Right PPE is Vital

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ASTM F887 is tested to 40 cal.

Arc-Rated PPE

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BEWARE: "FR" Melting Safety Vests, Coats, etc.

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"FR" Windguard

BEFORE AFTER

These may LOOK the same.

ANSI 107 & F1506 vs. ANSI 107 "FR"

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Arc-Rated Winter Wear a Must if Exposed

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Laundering Can Be Critical

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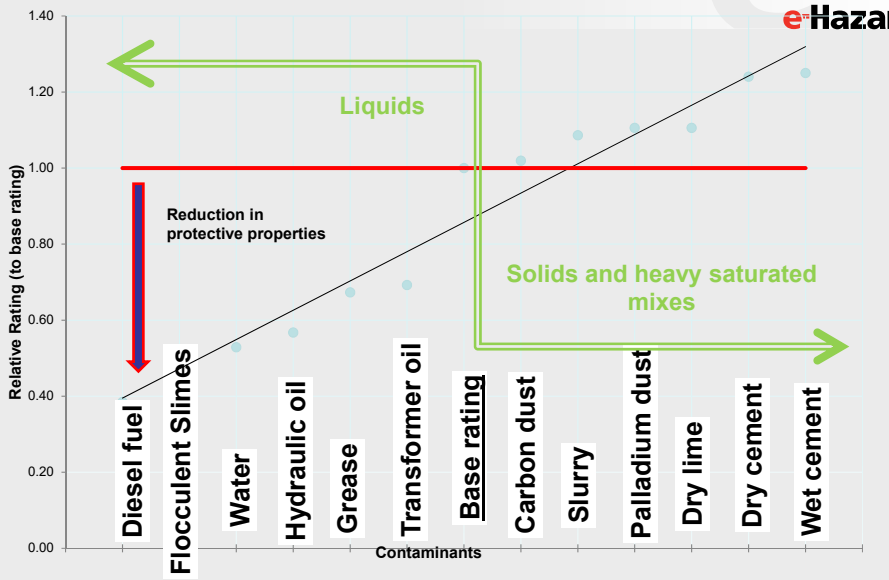
Clean 100 ml hydraulic oil

Beware: DEET is flammable

- Common dirt increases protection
  - non-flammable mining dusts, etc.
- Wet contaminants reduce protection
  - water, sweat, non-flammable liquids
- Flammable contaminants eliminate protection
  - diesel, transformer oil, etc.

Published IEEE Contamination Study Summary Graph



Arc-Rated PPE

DEET on Arc Rated Clothing?

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On Left:
Di-**e**thyl-**e**thyl-**T**oluene (DEET)
A "combustible liquid"
Deep Woods Off (heavy application)
7 sec afterflame could equal lung burns

On Right:
Permethrin water-based application

Best Practice:
- Water-based Permethryn on clothing
- DEET wipes on exposed skin only

Arc-Rated PPE

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Tuck, Button and Roll

- In this test at about 10 cal/cm² the t-shirt readily ignites on the untucked shirts.
- Tucked in shirts do not normally ignite until about the breakopen level near 20 cal/cm².
- Tuck in shirts, button all buttons and roll down sleeves before doing energized work.

Arc-Rated PPE

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Disposable Arc-Rated Materials for Dirty Applications

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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 bleach
    - No fabric softener
  - Inspecting for tears and frays

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Always Wear Required Level of PPE

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

Developing ASTM F2676 and F3272

Designation: F2676 – 16

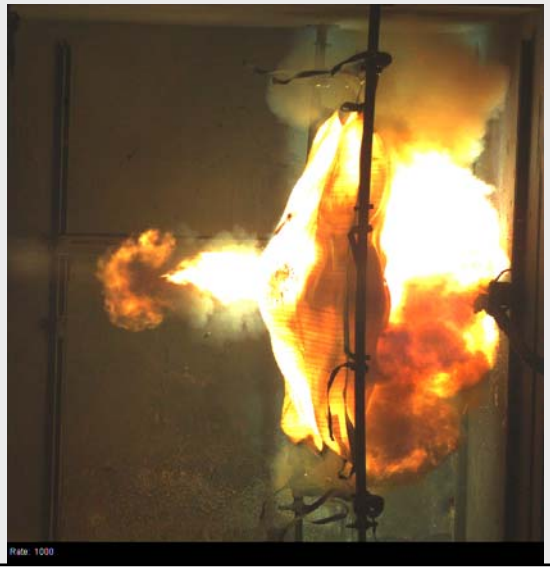
Standard Test Method for
Determining the Protective Performance of an Arc Protective Blanket for Electric Arc Hazards[1]

Each blanket is taken to failure if possible

All testing occurs suspended in a vault

Electrodes are extended for worst case exposure

Failure point captured on timed high speed video camera



Arc Blankets Can Save Lives

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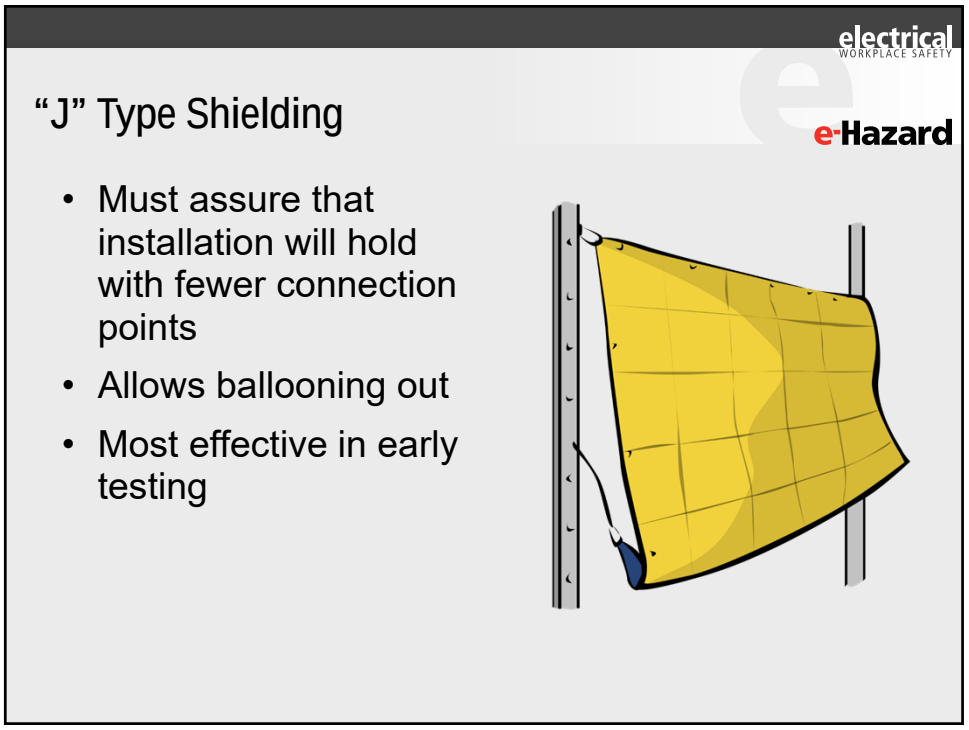
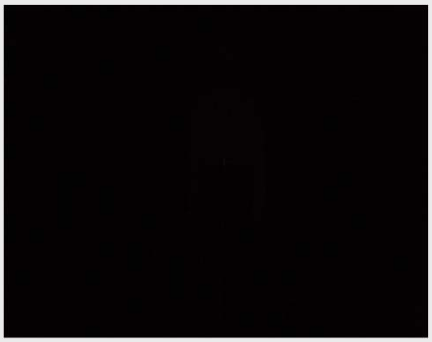
AR Garments with and without Arc Blanket
40kA, 15 cycles

Cable Splice Failure

Cable Splice Failure non-AR, no blanket

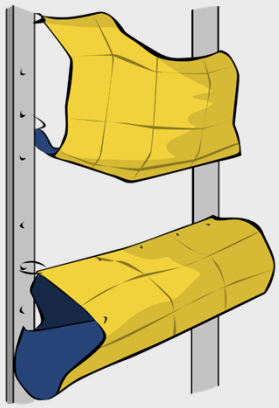


"J" without securing



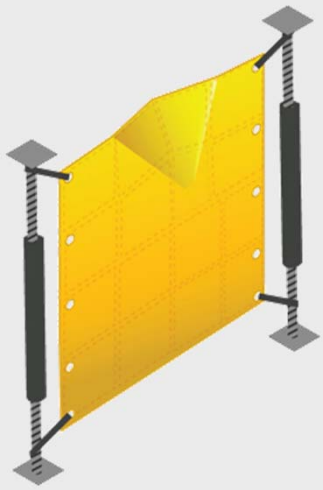
"C" Clamshell Installation

- Double or single
- Sometimes used with loose wrap
- Often used over cable splices



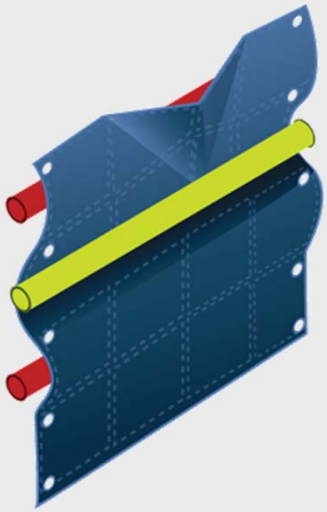
Wall Installation

- Wall method is the tested method
- Test occurs with ALL connection points connected
- Stations can be moved in arc, recommend permanent installation



Woven Method

- Cover back two cable spices, leaving front splice open for work
- Negative is possible disturbing of cables
- Wall mounted cable splices with others in close proximity



Wrapped

- Not manner tested in standard
- May act as firecracker
- Not recommended to disturb Cable
- Requires over rated blanket
- Loose wrap with securing

Wrapped

Permanent installations in mixed use

Cube Installation

- Installation with dielectric pipe
- Provides protection to the area worker using
- Protection from splices, transformers etc.
- Can be used for contractor protection or shared use protection for non-electrical workers (communication, etc.)

Temporary Installation in Mixed Use

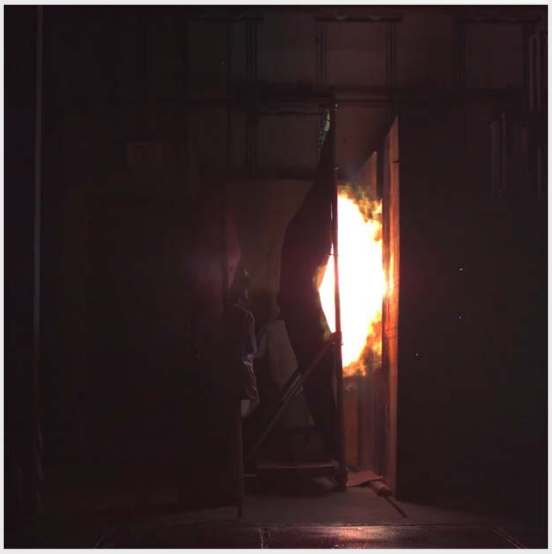
Tested for Worker Protection near open equipment

Temporary Wall

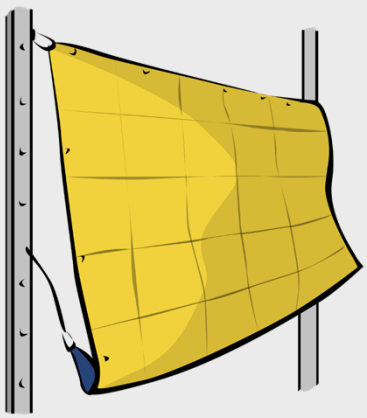
Temporary Installation in Mixed Use

- MCC and Switchgear test set up test to evaluate this installation method for personnel protection.
- Simple design, can be installed in many above ground applications
- Implication that arc cube would also work well if properly designed and installed.

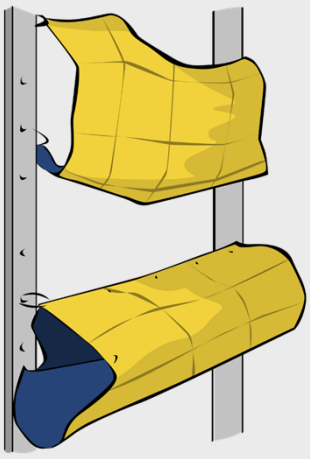
Test 35kA 10 cycles, 1000 V



Attachment to Tray and other Assemblies



"J" Installation on struts



"C" Installation on struts

Actual Installation

Loose-Wrap each splice with a J-Installation Overtop Best Practice

Safety Cycle™

Electrical Safety: A Comprehensive Approach

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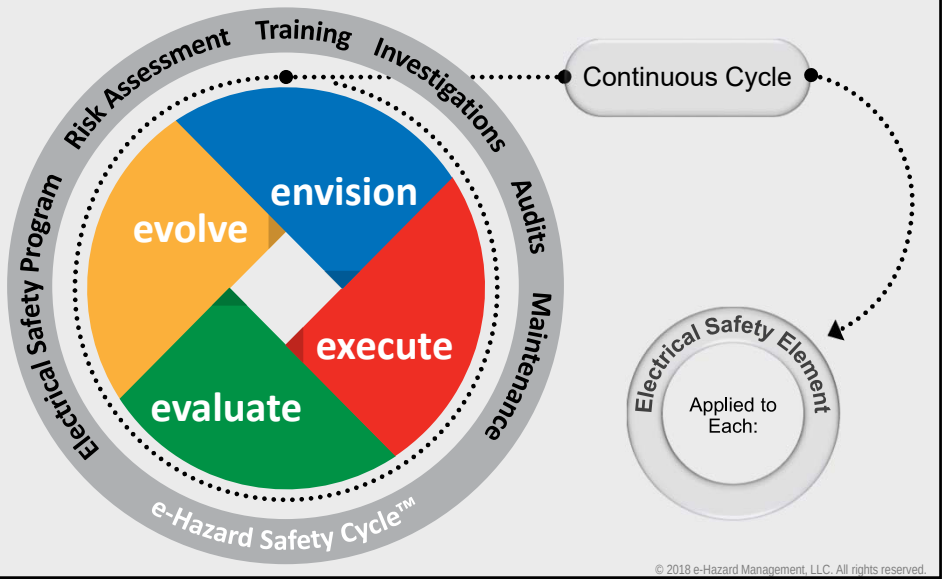

Arc-Rated PPE

electrical WORKPLACE SAFETY

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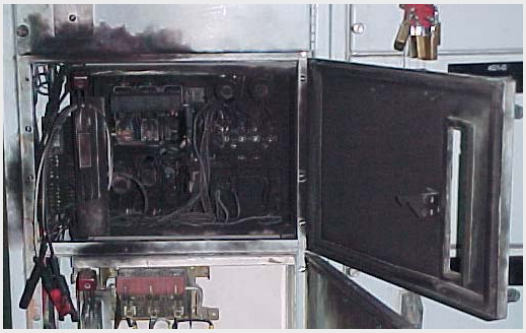
e-Hazard

Arc Flash Hazard

Both delivered similar energies to the worker. Each worker wore arc-rated clothing.
Which would cause the worst accident?



Arc-Rated PPE

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e-Hazard

Does It Really Work?

Sometimes….

The only thing between you and this is…

PPE

Arc-Rated PPE

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Protective Clothing after a 480 Volt Flash

Arc-Rated PPE

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Does It Really Work?

Wore the required PPE

Received no injuries

Questions?
Want More Information

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