Clothing Testing Update

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What We'll Talk About Today

- Arc Basics
- OSHA & Training Requirements
- Consensus Standards
- System Assessment
- Clothing Options
- Arc Lessons

Arc Basics

Arcs May Include Electrocution

Before

During

Electric arcs happen

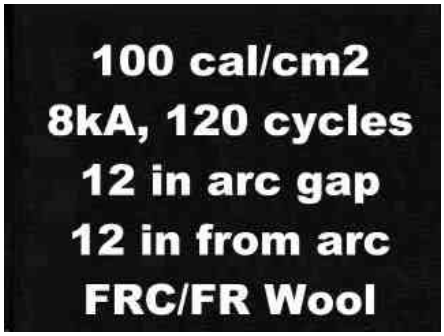
- 10 Year data 120,000 employees
- Electrical Accident rate 125/year
- 77% Electrical Arc Injuries
- 21% Permanent Disability
- 2.4% Fatalities
- >2000 arc injuries/year at this rate

IEEE Presentation from M. Capelli-Schellpfeffer, M.D.
Electrical Trauma Research Program (University of Chicago)

For more information on Arc Data contact Hugh Hoagland at 502-314-7158

OSHA Requirements
&
Training Requirements

100 cal/cm^2 Arc



Electric Generation, Transmission and Distribution

Apparel Standard

OSHA 29 CFR 1910.269 (l) (6) (i-iii)

1910.269 on Apparel

- (l)(6)(i) When work is performed within reaching distance of exposed energized parts of equipment, the employer shall ensure that each employee removes or renders nonconductive all exposed conductive articles, such as key or watch chains, rings, or wrist watches or bands, unless such articles do not increase the hazards associated with contact with the energized parts.

1910.269 on Apparel

- (l)(6)(ii) The employer shall train each employee who is exposed to the hazards of flames or electric arcs in the hazards involved.

1910.269 on Apparel

- (l)(6)(iii) The employer shall ensure that each employee who is exposed to the hazards of flames or electric arcs does not wear clothing that, when exposed to flames or electric arcs, could increase the extent of injury that would be sustained by the employee.

1910.269 on Apparel

- Note: Clothing made from the following types of fabrics, either alone or in blends, is prohibited by this paragraph, unless the employer can demonstrate that the fabric has been treated to withstand the conditions that may be encountered or that the clothing is worn in such a manner as to eliminate the hazard involved: acetate, nylon, polyester, rayon.

History of Apparel Standard

- IBEW testimony
  - 171 fatalities & 100 serious injuries in 65 clothing seemed to add to injury
  - "If. . .the 65 employees. . .had been wearing natural fiber clothing or FR clothing their accidents might have been classified as serious accidents."
- Duke Power Testing
  - 7800 Amp/10 cycle/12" Arc Gap/12" Distance from arc/clothing on racks (OSHA had 3800A)
  - Tested 4-5 oz. cotton which burned, then 11 oz. which did not. Moved to FR clothing.

Charles Williams OSHA Letter

1910.269(l)(6)(iii) applies to...personal protective clothing worn by an employee for protection against cold or rain when...exposed to the hazards of electric arcs or flames....Clothing made from untreated polyester, nylon prohibited, unless the employer can demonstrate that the clothing is worn in such a manner as to eliminate the hazard involved.

OSHA on Eye & Face Protection

- 29 CFR 1910.335(a)(1)(v) requires employees to wear protective equipment for the eyes or face wherever there is danger of injury to the eyes or face from electric arcs or flashes or from flying objects resulting from electrical explosion.

Flammability Hazard of Fabric

- Ease of ignition
- Degree & ease of flame spread
- Heat produced during burning
- Rate of heat transfer
- Ease of extinguishing the flame
- Other effects (i.e. Melting)

Employee/Employer Responsibility

- Manufacturer will not accept liability
  - Carhartt added label warning welders after lawsuit
- Employer must educate and enforce
  - Must train on hazards of electric arc and clothing.
  - Total training program should include jewelry since this is part of the standard.

System Assessment

Arc Energy Theory

- Current available (Amps ground fault or phase-to-phase)
- Duration of arc (cycles)
- Length of the arc (~6" max 480V)
- Distance from the arc (s^2)
- Arc voltage (70A-20kA arc voltage = 400-425V Westinghouse Protective Relay Book)
- Arc directionality (2-12X arc-in-a-box)

For more information on Arc Data contact Hugh Hoagland at 502-314-7158

Arc Directionality Test Video

Action Steps

- Assess your workplace
- Assess any provided clothing (include rainwear)
- Train your employees on arcs & clothing
- Ensure proper use of Lockout/Tagout

Three Worst Places for a Fault

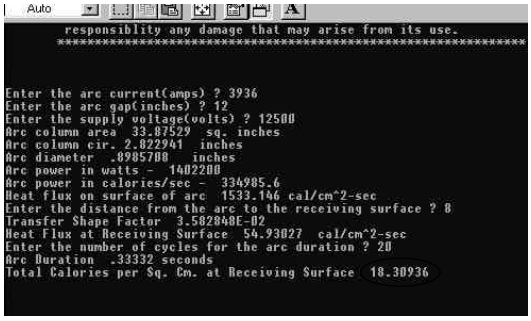
- Uninterruptable Network (typical secondary system in large city downtown area)
  - 100kA and up
  - no definite clearing times
  - sees fault as load
- Motor Control Centers (power plants, industrial)
  - 10-40kA typical with 20 cycle + clearing times
- Metal Clad Switchgear (typically in substations, etc.)
  - often on secondary side with fault current availability
  - many deaths here
  - improper use of testing equipment
  - breaker failure

Assessment Steps

- Working distance (min. 12" unless physically impossible)
- Arc energy potential (hot spots)
- Assess at substations, down-line, and secondary
- Use software to determine cal/cm^2
- Determine clothing requirements from manufacturer or best available test data
- Determine where normal clothing is unacceptable, using latest OSHA recommendations, and provide additional protection for "hot spots" (i.e. switching jacket/raingear and hood/faceshields)

Heat Flux Calculator

Heat Flux Calculator



100% Cotton Electric Arc Data

- Data provided by OSHA (8kA)
  - 5.2 oz. Blue Twill 4.6 cal/cm^2
  - 6.2 oz. White Fleece 6.4 cal/cm^2
  - 6.9 oz. Blue Twill 5.3 cal/cm^2
  - 8.0 oz. Black Twill 6.1 cal/cm^2
  - 8.3 oz. White Sateen 11.6 cal/cm^2
  - 11.9 oz. Tan Duck 11.3 cal/cm^2
  - 12.8 oz. Blue Denim 15.5 cal/cm^2
  - 13.3 oz. Blue Denim 15.9 cal/cm^2
    - » Source "Testing Update on Protective Clothing & Equipment for Electric Arc Exposure" IEEE Paper No. PCIC-97-35.

Consensus Standards

ASTM Ignition Standard F1958-99

- Used for testing ignition of non flame resistant clothing
- Data on several fabrics
- Probability of ignition
- Measures arc not flame resistance
- No *official* OSHA stance

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F1958-99 Setup

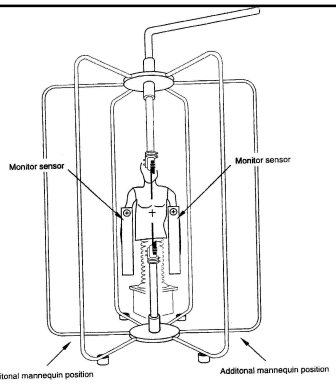


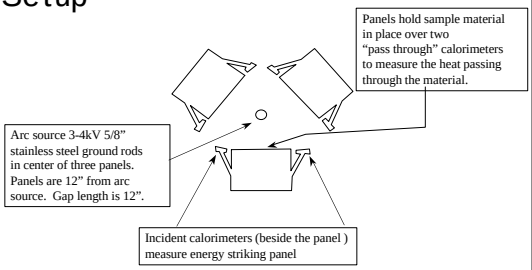
Figure 3
Supply Bus and Arc Electrodes

ASTM Protection Standard F1959-99

- For FR materials
- Determines an ATPV (Arc Thermal Performance Value)
- No *official* OSHA stance
- Very useful in determining protective levels of single and multiple layers

F1959-99 Setup

OHT Panel Testing (Top View)



Note: Two of the panels are replaced with mannequins for Mannequin testing. The third panel is removed for Mannequin testing to facilitate dressing the mannequins.

ASTM F1506

- Requires vertical flame test
- New version requires arc rating
- Arc Rating in label designated as ATPV or E_{BT}
- OSHA has considered this as minimum compliance

ASTM F-1891-99a Rainwear Standard

- Not a Pass/Fail Standard
- Gives levels of protection
- Must still eliminate melting fabrics
- Not all FR rainwear is acceptable
- ATPV (Arc Thermal Performance Value)
- E_{BTAS} (Energy Breakopen Threshold Above Stoll)
- Useful in determining protective levels of single & multiple layers

NFPA 70E-2000

- "Selection of FR clothing and Protective Equipment...includes shirts, pants, coveralls, jackets, and parkas worn ... by workers...exposed to momentary electric arc...Arc and flame resistant rainwear...included"
- Job Specific Table
- Or Use In Depth Hazard Analysis
- 5 Levels of Protective Clothing

NFPA 70E-2000

- L0 Untreated Cotton (0-2 cal/cm^2)
- L1 FR Shirt and FR Pants or Denim Jeans (min. 5 cal/cm^2)
- L2 Cotton Underwear plus FR Shirt and FR Pants (min. 8 cal/cm^2)
- L3 Cotton Underwear plus FR Shirt and FR Pants plus FR Coverall (min. 25 cal/cm^2)
- L4 Cotton Underwear plus FR Shirt and FR Pants plus Double Layer Switching Coat and Pants (min. 40 cal/cm^2)

ANSI 107-1999

- 1995 BLS Census of Fatal Occupational Injuries, 25% vehicle/worker fatalities occur between 6PM and 6AM with 9% full-time workforce on duty.
- Class 3: Traffic exceeding 50 mph, hwy work
- Class 2: Traffic exceeding 25 mph blocked hwy work
- Class 1: Traffic not exceeding 25 mph clear separation from all traffic (parking attendants)
- Standard is $38 from ISEA at (703) 525-1695 or see http://www.safetycentral.org

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Clothing Options

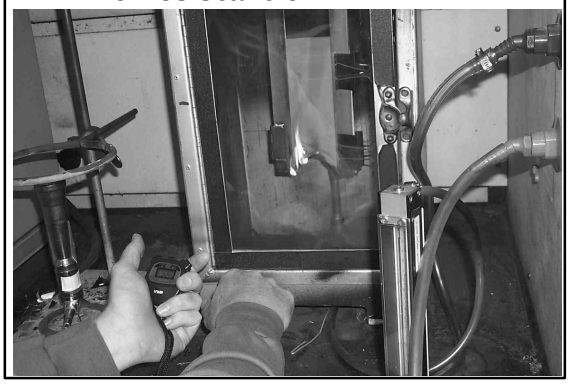
Flame Resistant Materials

- Natural Fibers Treated with Flame Retardant Chemicals
  - Proban, Banox
  - Indura, Banox Plus
  - Dale ANTIFLAME, Pyrovatex
  - ZirPro-Treated Wool (Victor Woolens, Ullfrotte, Devold)
- Natural Fibers Blended with Synthetics and Treated with Flame Retardant Chemicals
  - BanWear, Indura TufStuf, Nomex Rayon, Aramid Wool, Kermel/Lenzing
- Natural Fibers/Synthetics that Retard Flame
  - FireWear, Valzon
- Synthetics with Flame Resistant Properties
  - Nomex, PBI/Kevlar, Kermel, Kevlar, Conex, Other Aramids

Non-Flame Resistant Materials

- Cotton (in underlayers with no ignition risk
- Wool (best in underlayers)
- Silk (best in underlayers)

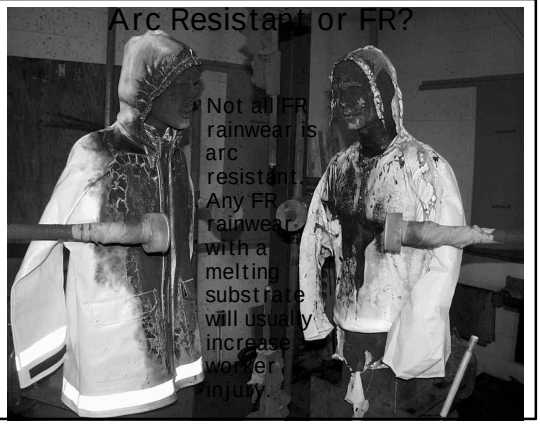
Arc Resistant or FR?



Arc Resistant or FR?

- FTM 191A-5903 developed by US Gv't
- Textiles NOT coated materials
- Until F-1891 NO consensus specifications for rainwear
- Individual companies specified this test and rainwear companies tested
- Problem: FR rainwear MELTS away and extinguishes

Arc Resistant or FR?



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

Rainwear Data (8kA)

- ArcBasic™ PVC/Nomex® Int. Or. 10 oz/yd^2 ATPV=5-17 cal/cm^2 E_{BTAS}= >30
- ArcShield™ Neoprene/Nomex® 10 oz/yd^2 ATPV= 10-12 cal/cm^2 E_{BTAS} = 40
- ArcLite™ PVC/Nomex®/Kevlar® 8.5 oz/yd^2 ATPV= 7-16 cal/cm2 E_{BTAS} = 33-36
- ArcBreeze™ Breathable Nomex® 8.5 oz/yd^2 ATPV= 15 cal/cm^2 E_{BTAS} = 19
- ArcTuff™ PVC/Nomex®/Kevlar® 8.5 oz/yd^2 ATPV=8-17 cal/cm^2 E_{BTAS} = 30-38
- PetroLite™ PVC/Nomex®/Kevlar® 8.5 oz/yd^2 ATPV=7 cal/cm^2 E_{BTAS} = 38

For more information on Arc Data contact Hugh Hoagland at 502-314-7158

Switching Jacket Data

- Steel Grip 10 oz. Nomex®/6 oz. Nomex®
  ATPV= 18 cal/cm^2
  - Add 9 oz Orange Indura® shirt layer
    ATPV= 61 cal/cm^2
- Steel Grip 12 oz Dale/5 oz. Dale
  ATPV= 38 cal/cm^2 (12 oz Dale 28 cal/cm^2)
  - Add 9 oz Orange Indura® shirt layer
    ATPV= 59 cal/cm^2
- Oberon Arc 15, 31, 50, 100

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NEW Switching Coat 70E Data

- Class 3 (9.2 oz system)
  4.5 oz. Navy Nomex®/1.5 oz. E-89/3.2 oz. Navy Nomex®
  Arc Rating (E_{BT})= 27cal/cm^2
- Class 4 (10.7 oz. System)
  4.5 oz. Navy Nomex®/2X 1.5 oz. E-89/3.2 oz. Navy Nomex®
  Arc Rating(ATPV)= 39.9 cal/cm^2
- [100 cal] (22 oz. System)
  7.7 oz Tufweld® /6X 1.5 oz. E-89/ 7.7 oz Tufweld®
  Arc Rating(E_{BT})= 97.6 cal/cm^2
- These systems are available from
  Steel Grip (800) 397-8390

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Rainwear For Switching Data

- FR Layering - 4.5 oz. Nomex®
  - ArcLite™ PVC/Nomex®/Kevlar®
    7.5 oz/yd^2 Yellow
    ATPV= 40 cal/cm^2
  - ArcTuff™ PVC/Nomex®/Kevlar®
    8.5 oz/yd^2 Fluorescent Orange
    ATPV= 29 cal/cm^2
- ArcTuff™ /t-shirt E_{BT}=34 cal/cm^2

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Layered Wool and Electric Arc

- 12 oz. FR cotton over 13 oz. non-FR wool. Arc Rating= 40 cal/cm^2
  - » Calculations must stop when FR layer breaks open for non-FR materials
- 6 oz. meta-aramid over 13 oz. FR wool Arc Rating=41 cal/cm^2
  - » One of the highest values for a 2 layer system on record.
- 8 oz./yd^2 FR cotton over 8.1 oz./yd^2 FR wool Arc Rating=21 cal/cm^2

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Wool as underwear

- 6 oz/yd^2 knitted FR wool Arc Rating= 13 cal/cm^2
- 9 oz/yd^2 knitted FR wool Arc Rating= 21 cal/cm^2

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Shirt Layering Data

- T-Shirts
  - 4.6 oz. Nomex®/6 oz. FireWear ® White LaCoste Knit ATPV=18.2 cal/cm^2
  - 4.6 oz. Nomex®/6 oz. FireWear ® Navy Knit E_{BT}=17.7 cal/cm^2
  - 6.0 oz. Nomex®/6 oz. FireWear ® Navy LaCoste ATPV=19.3 cal/cm^2
  - 6.4 oz Dale ANTIFLAME® FRC over 5.5 oz Devold® FRC ATPV = 12.5 cal/cm^2
  - 8 oz Dale ANTIFLAME® FRC over 8 oz Devold® FR Wool ATPV = 20 cal/cm^2

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Rainwear and Flashfire

Tests with 6 oz. Nomex coverall and cotton underwear

- Neoprene Nomex® 11 oz.
  - 13.5% body burn excluding hands & face
- Breathable Nomex® 8.5 oz.
  - 3.5% body burn excluding hands & face
- Nomex Coverall 6 oz.
  - 60% body burn
- FR Neoprene Nylon
  - >68% body burn

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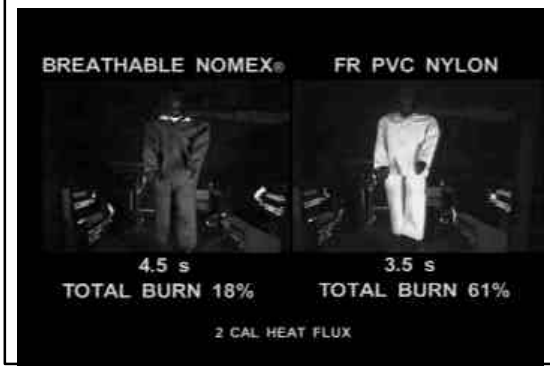
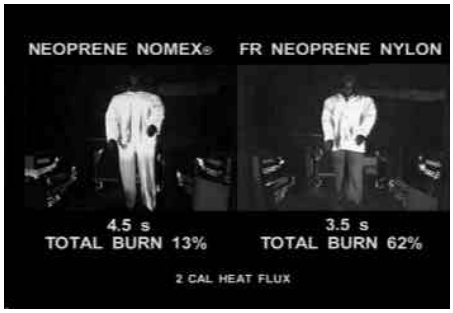
The Melting Substrate Problem



Melting Substrate Problem 2



NASCO PetroLite™

ASTM 1930 3.5 second, 2 cal/cm^2/s

Face Protection and the Arc

Faceshield Materials

- Early Data
  - Clear Polycarbonate Faceshield 1.2 cal/cm^2
  - Gold Reflective UV Absorbing Polycarbonate Faceshield 7 cal/cm^2
- Latest Data
  - Slight tint no 2º burn at 47 cal/cm^2
  - Very dark shields no 2º burn at 100 cal/cm^2

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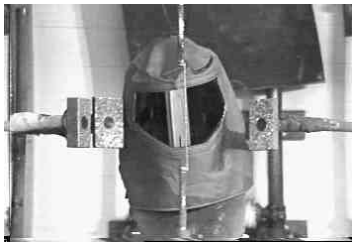
Proposed ASTM Eye, Face & Head Protection Test Method



48 cal/cm^2 arc at facial plane. Faceshield closer to arc.

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Visibility of the new shield

Inside w/ overhead lighting

Without Shield | Through Shield with hood

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Clothing Program Implementation

Program Options

- All FR
  - This option is the safest
  - FR Jeans are very protective
  - BanWear/Indura TufStuf Coveralls & Jackets ATPV = ~50 cal/cm^2
- FR/Non-FR Mixture
  - Many utility workers wear jeans and non-FR t-shirts
  - Risks & Benefits

Enforcement Options

- Supervisor clothing checks
- Continuous education program
- Color, label or logo identification system
- Uniform program the most easily enforceable

Things I learned from the electric arc AFTER kindergarten

FR Clothing is not invincible.

Choose it for the application

Gloves and Sleeves have shown good results

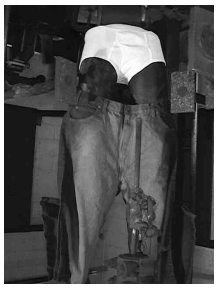
Flannel is always bad!

Some wool does well in the arc

The Underwear Question

- Four pairs of jeans exposed to 12.3kA/10 cycles/12 in. gap/12 in. distance with briefs underneath.
- Each was a 13.7 opsy jean (WearGuard).
- Both Fruit of the Loom and Munsingwear briefs displayed no sign of scorching, melting or ignition. They were totally protected by the non-igniting outer shell.

You may not have to change underwear



Watch out for melting elastic

How could you miss it?

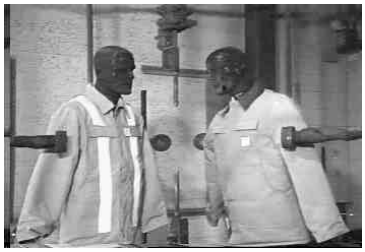
Watch out for melting "FR" accessories

These items are all FR but melt

When something we like doesn't work there MAY be a solution

FR wool-aramid vs. Cotton sweatshirt 20 cal/cm^2

Traditional clothing has risks but there ARE alternatives



FRC/FR Wool vs. non-FR Cotton/polyester-nylon ~20 cal/cm^2

Watch out for minimum standards

Both pass FR standards.

The right PPE is vital