

2010 DOE/NNSA Fire Safety Workshop

Flame Resistance and Arc Flash

**Review of Industry Consensus
Standards for Personal
Protective Equipment**



2010 DOE/NNSA Fire Safety Workshop

Gary S. Kephart

Environment, Safety & Health
Supervisor

Bechtel Jacobs Co LLC



Genesis of the Presentation

- Alphabet soup of standards;
 - Opportunities for confusion?
- Cross disciplinary questions
 - Can a welder assume arc flash clothing is FR?
 - Can an electrician be confident FR clothing has an arc rating?
 - Are there tasks with both arc flash and hot work hazards present?
 - What PPE makes sense for emergency responders?



FR Requirements & Standards

Rules and Standards imposing PPE for a given task / hazard such as OSHA, NFPA, ANSI.

Standard test methods for characterizing PPE/component capabilities, primarily ASTM.

[Both categories have some parallel international standards. – More on these later.]



OSHA REGULATION

The *General Duty Clause*:

“ Employer shall furnish place of employment free from recognized hazards...”

Industry consensus standards likely to be perceived as the *Standard of Care*



OSHA REGULATION

29CFR1910.132(a) [PPE]:

“...PPE for eyes, face, head, and extremities, protective clothing... shall be provided, used, and maintained... whenever it is necessary by reason of hazards... capable of causing injury...”



2010 DOE/NNSA Fire Safety Workshop

29CFR1910.269 (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... could increase the extent of injury that would be sustained...”



2010 DOE/NNSA Fire Safety Workshop

29CFR1910.269 (l)(6)(iii):

“NOTE: Clothing made from the following types of fabrics, either alone or in blends, is prohibited by this paragraph...acetate, nylon, polyester, rayon....”



OSHA REGULATION

29CFR1910.335(a)(1)(i) [Electrical]:

“ Employees working in areas where there are potential electrical hazards shall be provided with... protective equipment that is appropriate... for the work...”



Arc Flash PPE

A 1982 paper by Ralph Lee is credited as initiating attention to arc blast burn hazards as currently reflected in 2009 NFPA 70E *Standard for Electrical Safety in the Workplace.*



2010 DOE/NNSA Fire Safety Workshop

Why the Attention to Arc Flash?

- Typical 100 amp, 3-phase, 480 V industrial circuit that faults can deliver 10000-to-15000 amps until the breaker opens.
- Produces incident energy of about 12 cal/cm² at 1 ft.
- Enough to ignite typical cotton work clothes, melt synthetics; Burns often fatal.



2010 DOE/NNSA Fire Safety Workshop

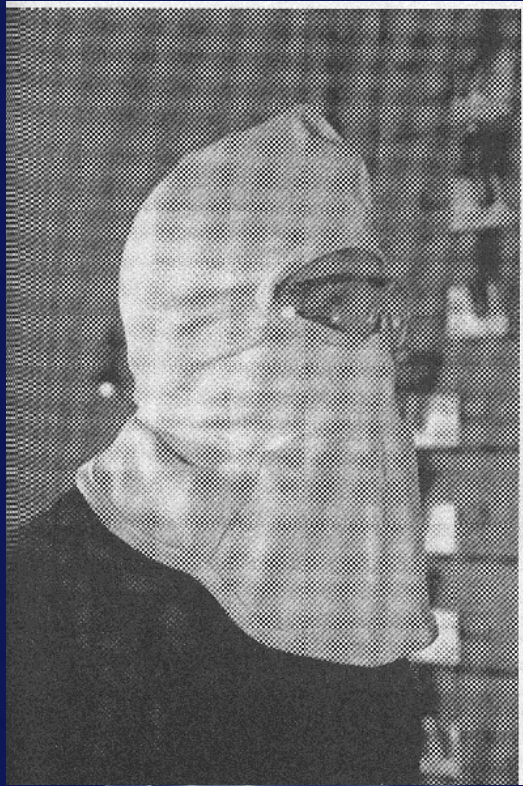
Why the Attention to Arc Flash?

- In the typical arc flash scenario, conceivable to have burn injury to about 50% of the total body surface area.
- American Burn Association statistics: 37% of burns to this much of the body surface result in fatalities.



2010 DOE/NNSA Fire Safety Workshop

NFPA 70E (2009)



“Employees shall wear FR clothing whenever there is possible exposure to an electric arc flash above the threshold incident-energy level for a second-degree burn (1.2 cal/cm^2).”



NFPA 70E

Identifies five classes of electrical scope with PPE requirements based on arc flash hazard / risk.

PPE Minimum **Arc Rating** in cal/cm^2
Arc Ratings of 4, 8, 25, and 40 cal/cm^2 commensurate with the hazard.



Handbook for Electrical Safety in the Workplace

“ During an arcing fault, electrical energy is converted to several other forms of energy. NFPA 70E does not define equipment for protection from the other forms of energy that are generated by an arcing fault...”



2010 DOE/NNSA Fire Safety Workshop

Handbook for Electrical Safety in the Workplace

“ Although arc-rated FR clothing provides protection from the thermal energy associated with an arcing fault, it should be considered to provide no protection from shock.”



2010 DOE/NNSA Fire Safety Workshop

ANSI Z 49.1:2005

*Safety in Welding,
Cutting, and Allied
Processes*

[American Welding Society]



2010 DOE/NNSA Fire Safety Workshop

ANSI Z 49.1

- Clothing shall be selected to minimize the potential for ignition, burning, trapping hot sparks, or electric shock.
- Clothing shall provide sufficient coverage, and be made of suitable materials, to *minimize* skin burns caused by sparks, spatter, or radiation.



ANSI Z 49.1 - advisory

- Clothing treated with flame resistant materials may lose some of its protective characteristics after repeated washing...
- Materials which can melt and cause severe burns should not be used...
- Frayed clothing is particularly susceptible to ignition... and should not be worn...



2010 DOE/NNSA Fire Safety Workshop

Additional Standards Imposing FR PPE

NFPA 1971, 2007

Standard on
Protection
Ensembles for
Structural Fire
Fighting and
Proximity Fire
Fighting

NFPA 2112, 2007

Standard on Flame-
Resistant Garments
for Protection of
Industrial Personnel
Against Flash Fire



Additional Standards Imposing FR PPE

Both NFPA 1971 and NFPA 2112 set minimum thermal protective performance (TPP) ratings for fabric or composite layers to protect the wearer from potential to receive a second degree burn. [flashover versus arc flash as the hazard orientation.]



Key FR Terminology

The Stoll Curve –

US Navy research published in 1969 relates tissue tolerance to heat to provide conversion between 2nd degree burn threshold and ΔT on a calorimeter and ΔmV on a thermocouple.

Subsequently adopted as “baseline” for several ASTM FR test methods.



Key FR Terminology

Thermal Protection Performance Rating – Standard method assesses transmission of BOTH radiant and convective heat through material (e.g., turn-out composite). Output tracing is overlaid on the Stoll Curve and intersection is the TPP rating for that test specimen expressed in cal/cm^2 .



Key FR Terminology

Arc Thermal Performance Value (ATPV)—
The incident thermal energy on the fabric at which there is 50% probability the wearer will suffer onset of 2nd degree burns. TPP for the special case of electric arc, expressed in cal/cm².



Key FR Terminology

Energy of break-open threshold (E_{BT})—
The incident thermal energy for which the fabric has 50% probability of break-open (holes) evidenced in the innermost layer.



Key FR Terminology

Arc Rating -

This value describes performance in exposure to electric arc; derived from the ATPV or from E_{BT} if it occurs below ATPV. Labels on arc-rated PPE should include the rating, in cal/cm^2 .



FR Materials Standards

ASTM F1506-08

Standard Performance
Specification for Flame-
Resistant Textile
Materials for Wearing
Apparel for Use by
Electrical Workers
Exposed to Momentary
Electric Arc and Related
Thermal Hazards.

This is the governing
ASTM standard for
Flame Resistant (FR)
clothing (referenced by
NFPA 70E). Requires:
(1) afterflame and char
length meet ASTM
D6413 and (2) arc
thermal performance
tested i a w ASTM
F1959.



2010 DOE/NNSA Fire Safety Workshop

ASTM F1506

Requires FR apparel to contain a label indicating that it meets the standard's performance specifications, care instructions, fiber content, and arc rating (APTV or E_{BT})



FR Materials Standards

ASTM
F1959/F1959M-06
Standard Test Method
for Determining the
Arc Rating of
Materials for
Clothing

This test method is used to measure the arc rating of materials intended for use as flame resistant clothing for workers exposed to electric arcs that would generate heat flux rates from 2 to 600 cal/cm².



ASTM F1959/F1959M-06

- Heat transport response through the test specimen when exposed to the heat energy from an electric arc is assessed versus the Stoll curve.
- “Material response to an electric arc is indicated by...: breakopen, melting, dripping, charring, embrittlement, shrinkage, and/or ignition.



FR Materials Standards

ASTM F1958/F1958M

Test Method for
Determining the
Ignitability of Non-
flame-Resistant
Materials for
Clothing by Electric
Arc Exposure
Method Using
Mannequins

This standard parallels
F-1959 but with full
garments tested on
mannequins rather
than material
specimens mounted
on test stands.



2010 DOE/NNSA Fire Safety Workshop

More FR Standards

ASTM F1891 – 06

Standard Specification for
Arc and Flame
Resistant Rainwear

ASTM F2178 – 08

Determining the Arc
Rating and Standard
Specification for Eye or
Face Protective
Products

ASTM F887 – 05

Standard Specifications
for Personal Climbing
Equipment (includes an
arc test *followed by* a
drop test)



2010 DOE/NNSA Fire Safety Workshop

More FR Standards

ASTM F1002 – 06

Performance Specification
for Protective Clothing
for Use by Workers
Exposed to Specific
Molten Substances and
Related Thermal
Hazards (e.g., foundry
work)

ASTM F1449 – 08

Standard Guide for
Industrial Laundering of
Flame, Thermal, and
Arc Resistant Clothing
(Criteria when garments
should be removed
from service)



More FR Standards

ASTM F2302 - 08

Standard
Performance
Specification for
Labeling
Protective
Clothing as Heat
and Flame
Resistant.



2010 DOE/NNSA Fire Safety Workshop

Yes There's More

IEC 61482 – 2:2009

Live Working – Protective Clothing Against the Thermal Hazards of an Electric Arc.

ISO 6942:2002

Protective Clothing – Protection Against Heat and Fire – Method of Test: Evaluation of Materials and Material Assemblies When Exposed to a Source of Radiant Heat.



Yes There's More

ISO 9185:2007

Live Working –
Protective Clothing
– Assessment of
Resistance of
Materials to Molten
Metal Splash.

- ISO 11612:2008

Protective Clothing –
Clothing to Protect
Against Heat and
Flame.



Overlaps & Challenges

- Both arc flash and flashover protection standards share same end-point: survivable 2nd degree burn injuries.
- Consequently they also share same critical constraint: PPE **MUST** always accompany other **PREVENTIVE** measures and controls.



Overlaps & Challenges

- Real-world work environments often present mixed hazards. Some PPE not available or no established spec for flame resistance.
- NEC and NFPA invoke AHJ involvement in these determinations; Although technical decisions, they may also involve worker emotions & perceptions.



Overlaps & Challenges

- Real-world work environments often present mixed hazards. Some PPE not available or no established spec for flame resistance.
- Outcome of such decisions needs to be carefully communicated; Very difficult NOT to send **mixed messages**, even with best intention to *do the right thing*.



Overlaps & Challenges

- Metal jewelry and synthetic undergarments may both invite informal or don't-ask/don't-tell approaches -- as incursions on worker privacy, religion, etc.
- Important that the workers recognize that non-compliance can carry very significant and painful costs.



Overlaps & Challenges

- Arc-Rated PPE IS Flame Resistant; May or may not be suited to hot work or other non-electrical scopes.
- HOT-Work coveralls and associated PPE is NOT necessarily arc-rated; Likely *NOT* appropriate for electrical scope.



Overlaps & Challenges

- Industrial Laundry processes may be compatible with all PPE in-service but onus is on the employer to assess (and document) laundry compatibility.
- Tracking number of laundry cycles can be accomplished, but ...



Overlaps & Challenges

- Emergency Responders: Where scope of hazards can't be readily predicted, turn-out gear is a great compromise.
- Challenge then is to make sure wearers and incident commanders appreciate capabilities and limitations of the PPE.



Open Issues

- Arcing electrode orientation (horizontal or vertical) impacts incident energy level. Some orientations may exceed ASTM method energies.
- Open air arc-flash model probably underestimates energy from enclosures or in vaults.

