# Integrating Roles Within Electric Utilities to Achieve Arc Flash Safety

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Presenters Neil Stiller & Bob Cooke



#### **Presenters**

Neil Stiller, Sr. Electrical Engineer, RPU

 30 years utility experience, primarily in substation design and construction management

Bob Cooke, Safety Manager, RPU

 39 years of professional safety experience including insurance loss control, manufacturing, construction, mining, safety consulting, and utilities.

Jointly leading the RPU Electrical Safety Standards Team; a cross-functional team from Engineering, Maintenance & Construction, Operations, and Safety departments



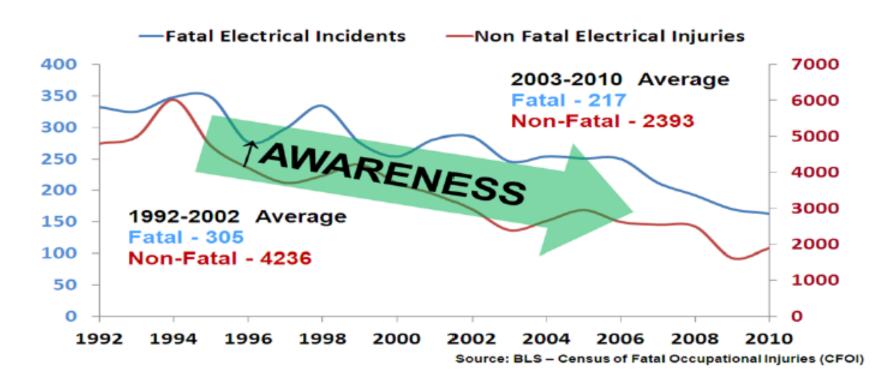
### Why it Matters...

- From 1980 to 1995, electrical injuries were the fifth highest cause of fatal injuries in the workplace, averaging 1-2 fatalities per day and non-fatal injuries every 2-3 hours.
- As of 2010, electrical injuries were the seventh largest cause of fatal injuries
- Industry stakeholder awareness is vital to the safety of electrical workers

[Source: A Guide to Establish an Arc Flash Safety Program for Electric Utilities, Clarke & Balasubramanian]



#### Awareness, Training, Action



Fatal Electrical Incidents 2011 – 2016 Average = 152 per year

[Sources: A Guide to Establish an Arc Flash Safety Program for Electric Utilities, Clarke & Balasubramanian Bureau of Labor Statistics – Census of Fatal Occupational Injuries 2011 - 2016]

### **Regulatory Framework**

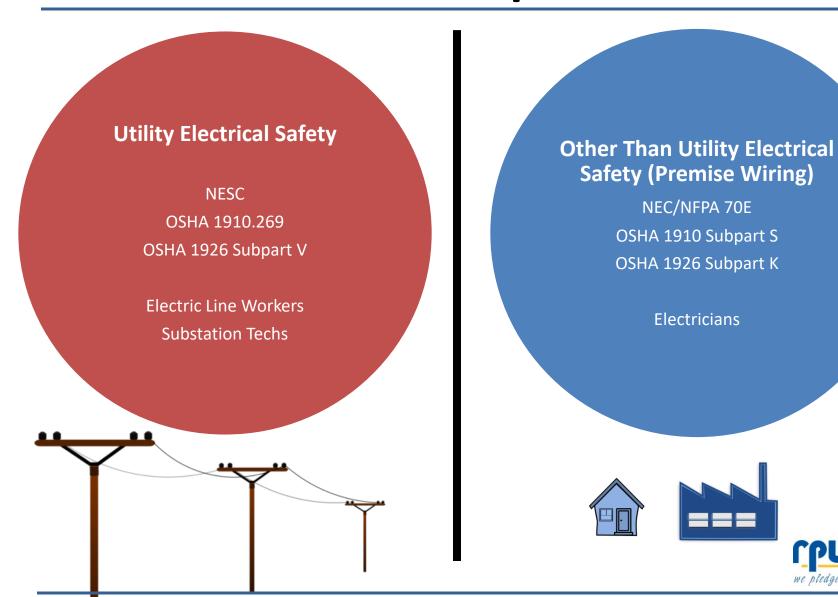
Electrical safety standards OSHA, IEEE/ANSI, NESC and NFPA-70E continue to evolve.

- IEEE Std. 1584 issued in 2002, recently updated 2018
- NESC 2007 code called for utility assessment by January 2009
- NESC 2012 code added secondary voltage systems 1000 volts and less
- NFPA-70E-2018 added selecting arc-rated clothing using energy analysis methods
- OSHA 1910.269/1926 Subpart V (applicable to electric utility) require analysis, provision of information to field crews and PPE selection/use based on analysis
- OSHA 1910 Subpart S/1926 Subpart K (applicable to premises wiring) references older version of 70E, OSHA Interpretation 2006-10-18 indicates violation may be citable

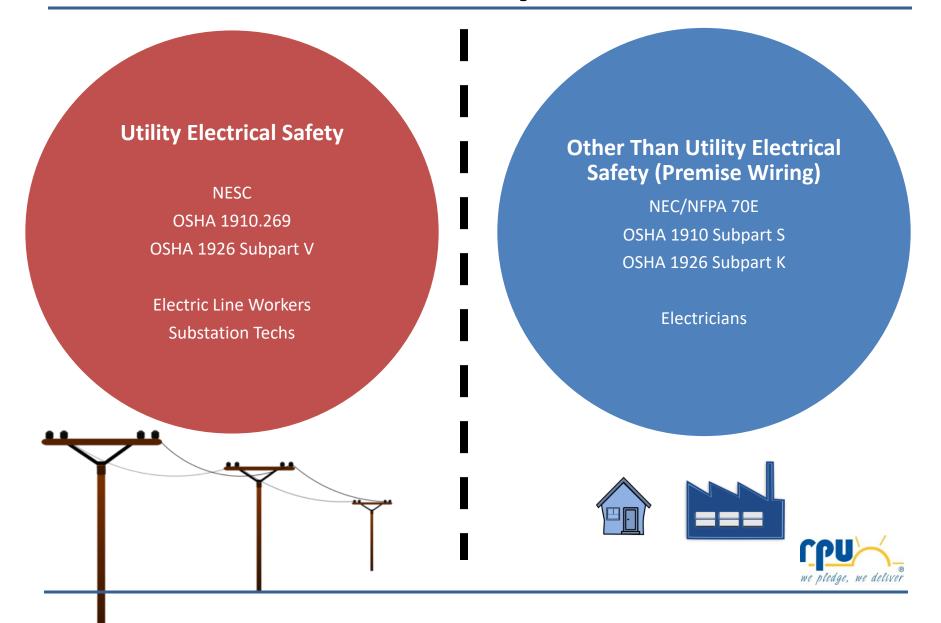
While NFPA-70E is not directly applicable to electric utility work, language across standards is becoming more aligned and consistent.



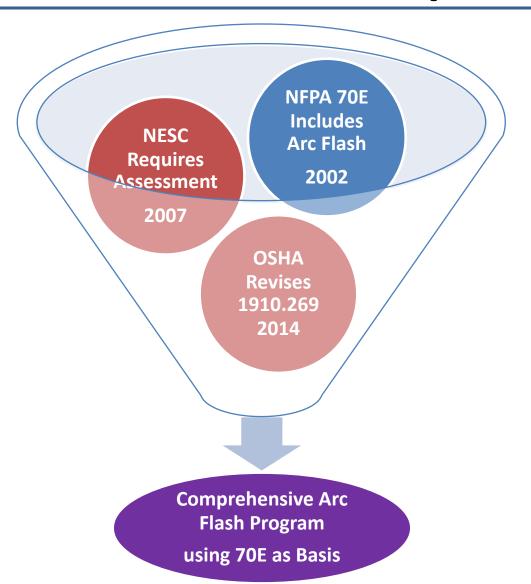
#### **Prior to Arc Flash Emphasis**



### **Prior to Arc Flash Emphasis**



# As a Result of Arc Flash Emphasis





#### Example of NFPA 70E's "Global Effect"

#### PPE Category

1

Minimum arc rating between 4 and 8 cal/cm<sup>2</sup>

- · Arc rated, flame-resistant long sleeve shirt and pants or coveralls
- Arc rated face shield with wrap-around guarding or hood
- Arc rated jacket, parka, rain wear or hard hat liner (as needed)
- · Flame-resistant hard hat
- · Flame-resistant safety glasses or goggles
- · Hearing protection (ear canal inserts)
- Heavy duty leather gloves (optional leather gloves protectors with insulating rubber gloves)
- Leather work shoes (as needed)

#### **PPE Category**

2

Minimum arc rating between 8 and 25 cal/cm<sup>2</sup>

- Arc rated, flame-resistant long sleeve shirt and pants or coveralls
- Arc rated, face shield with wrap-around guarding or flash suit hood, with balaclava
- · Arc rated jacket, parka, rain wear or hard hat liner (as needed)
- · Flame-resistant hard hat
- · Flame-resistant safety glasses or goggles
- · Hearing protection (ear canal inserts)
- Heavy duty leather gloves (optional leather gloves protectors with insulating rubber gloves)
- · Leather work shoes (footwear)

#### **PPE Category**

3

Minimum arc rating between 25 and 40 cal/cm<sup>2</sup>

- Arc rated, flame-resistant long sleeve shirt and pants and coveralls (selected so that the system arc rating meets the required minimum)
- Arc rated arc flash suit including jacket, pants, hood (rating level as required)
- Arc rated gloves (rating level as required)
- Arc rated jacket, parka, rain wear or hard hat liner (as needed)
- · Flame-resistant hard hat
- · Flame-resistant safety glasses or goggles
- Hearing protection (ear canal inserts)
- Heavy duty leather gloves (optional leather gloves protectors with insulating rubber gloves)
- Leather work shoes (footwear)

#### **PPE Category**

4

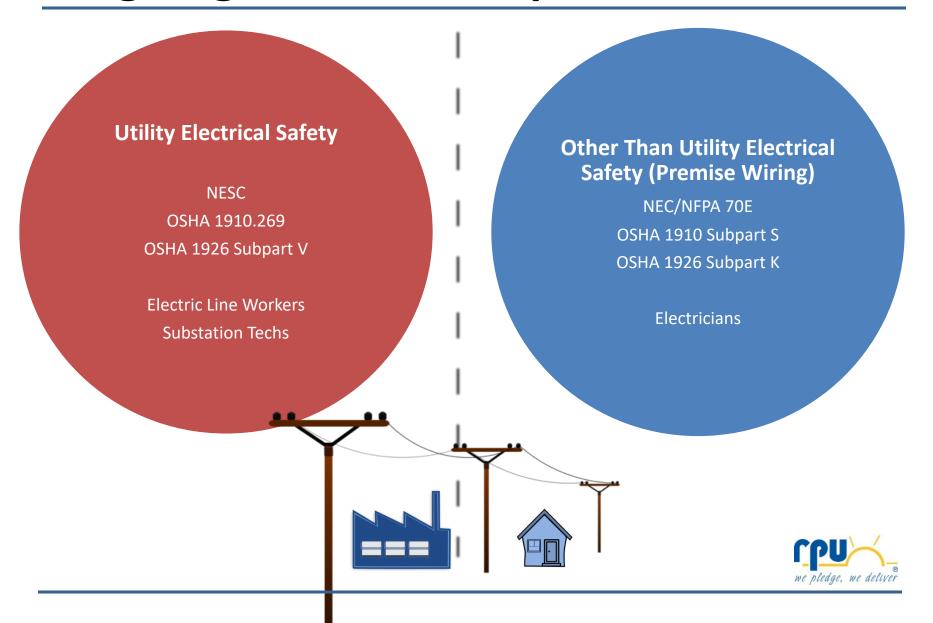
Minimum arc rating 40 cal/cm<sup>2</sup>

- Arc rated, flame-resistant long sleeve shirt and pants and coveralls (selected so that the system arc rating meets the required minimum)
- Arc rated multi-layered flash suit jacket (selected so that the system arc rating meets the required minimum)
- Arc rated flash suit pants (rating level as required)
- Arc rated flash suit hood (rating level as required)
- Arc rated gloves (rating level as required) (optional leather gloves protectors with insulating rubber gloves)
- · Arc rated jacket, parka, rain wear or hard hat liner (as needed)
- · Flame-resistant hard hat
- Flame-resistant safety glasses or goggles
- Hearing protection (ear canal inserts)
- Leather work shoes (footwear)

- Category 0 is discontinued
- Alignment with 1910.269 PPE categories still a work in progress



#### **Ongoing Arc Flash Emphasis**



#### **Assessment and Beyond**

The arc flash assessment is just one piece of the arc flash safety program:

- Maintaining the assessment to current standards
- Periodic review of arc flash calculations
- Arc flash mitigation solutions clearing time, fault current, work distance or isolation
- Employee training
- Equipment labeling
- PPE selection and maintenance
- Maintaining protective devices



#### **Assessment and Beyond**

Various utility departments contribute to the overall understanding and mitigation of arc flash hazards.



#### Substation, T&D or Plant Crews

- Workers desire to know the hazards
- Input and implementation of new work methods
- Pivotal buy-in of comfortable daily-wear PPE
- Contributions to accurate field records, equipment data, etc.



### **Regulatory Compliance Staff**

- Tracking of evolving standards and regulations
- Input on interpretation of requirements
- Key input on day to day work method questions



#### **Engineering and GIS Staff**

- Input on interpretation of requirements
- Technical assessments
- Creation of useful information summaries
- Creation and maintenance of GIS data sharing tools
- Engineered risk mitigation solutions



# **Safety Trainers**

- Identifying qualified internal and external trainers and evaluators
- Translating information into training guides and other training materials
- Beyond the classroom/competency based training: Evaluating worker skills through periodic demonstration (RPU uses Field Performance Requirements checklists)
- Scheduling training
- Managing training records



#### **Procurement**

- Coordinating PPE garment sourcing
- PPE garment laundry requirements and service contracts



#### **Operations**

- Revising operating procedures and keeping them current
- Offer operational solutions to mitigate work zone risk
  - Outage vs. hot work
  - Safety Clearance and Hot Line Order procedures



"What is the arc hazard here?" (exhaustive modelling) Vs.

"What is the arc hazard at all places with this relay or fuse protective device?" (category modelling)

Not necessarily a new approach, but one that is infrequently discussed.

Inspired by a 2008 paper published by United Services Group, Elk River MN \*

<sup>\* &</sup>quot;A Time-Current Curve Approach to Arc-Flash Hazard Analysis", J. Avendt, United Services Group, Elk River, MN, July 2008



- This approach calculates arc-flash energy allowed by a relay or fuse across a range of fault currents.
- Calculation results can be tabulated for reporting narratives and training
- Results can be joined with fault studies of a feeder
- Can be reported via GIS database tools

<sup>\* &</sup>quot;A Time-Current Curve Approach to Arc-Flash Hazard Analysis", J. Avendt, United Services Group, Elk River, MN, July 2008



#### <u>Advantages</u>

- Aligns well with standardized fuse or relay curve implementations
- Arc hazard calculations can be performed without exhaustive distribution system modeling.
- Results can be easily tabulated for training aids.
- Common work scenario hazards can be rapidly evaluated for work planning, safety procedure development, or PPE selection.



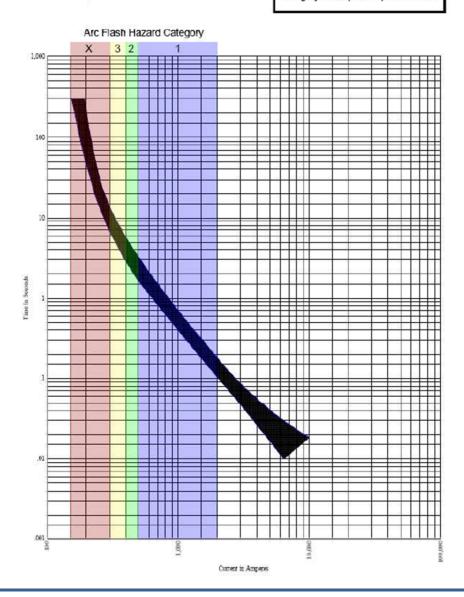
#### **Disadvantages**

- System re-configuration can change available fault current at a work site, possibly pushing the arc hazard across a PPE category threshold.
- Certain work scenarios may require a very case specific assessment.
- Unique fuse or relay applications may not be reflected in the standardized approach.



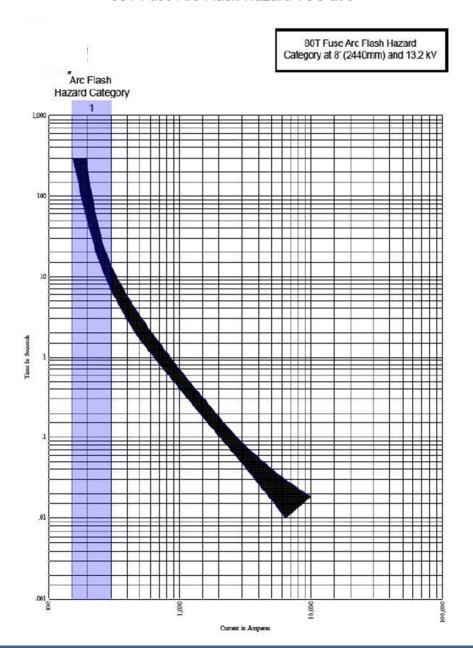
#### 80T Fuse Arc-Flash Hazard TCC at 15"

80T Fuse Arc Flash Hazard Category at 15" (381mm) and 13.2 kV





#### 80T Fuse Arc-Flash Hazard TCC at 8'





#### **Analysis Parameter Choices**

- Standard fuses speed / size / series combinations
- Standard relay curves / tap / time dial
- Working distances for standard situations
- IEEE 1584 2-second criteria
- EPRI research regarding arc sustainability below 240V



#### **Working Distance Choices**

- Standardize within the utility for usual work
  - o 18" or 16" or other for glove work?
  - o 8' or 7' for hot stick work?
- Customize to other work situations?
- Switchgear racking
  - O With or without remote operator?
  - Are the breaker stabs near or far from the worker?



#### IEEE 1584 2-second criteria

"If the device clearing time is longer than two seconds, consider how long a person is likely to remain in the location of the arc flash. It is likely that a person exposed to an arc flash will move away quickly if it is physically possible and two seconds is a reasonable maximum time for calculations. A person in a bucket truck or a person who has crawled into equipment will need more time to move away."



# Escape motion away from the arc?

- Lineman ducking down into the fiberglass bucket of the line truck – Fiberglass bucket becomes a shield.
- Lineman climbing a pole escape movement is quite restricted.
- A worker that is on their feet at or near unobstructed padmounted equipment – escape movement is easy.
- A worker who is on their knees or have otherwise closely positioned their body in the equipment – escape movement is quite restricted.



# Arc sustainability below 240V

Research publications conducted by utilities and EPRI have built a growing industry consensus that arcs on 120/208 V or 120/240 volt systems are non-sustaining.

- Test result arc duration span 0.2 9 cycles for utility 120/240 transformers and meter sockets.
- EPRI research found faults self-cleared in less than one cycle for 11 of 14 tests on 120/208 equipment.
- Self-sustainability was largely dependent on arc gap distance less than ½ inch or phase to phase bridging.



#### Arc sustainability below 240V

#### **Research Sources:**

 208-V Arc Flash Testing: Network Protectors and Meters, EPRI project 1022218, T. Short, c/o EPRI and Pacific Gas & Electric, September 2010

- An Investigation of Low Voltage Arc Flash Exposure, IEEE Paper No. ESW2013-30, A. Smoak and A. Keeth, c/o Southwestern Electric Power Co., 2013
- Low-Voltage Arc Sustainability, IEEE, M. Eblen and T. Short, c/o
   MLE Engineering and EPRI, 2017

### **Example Impact of Arc duration**

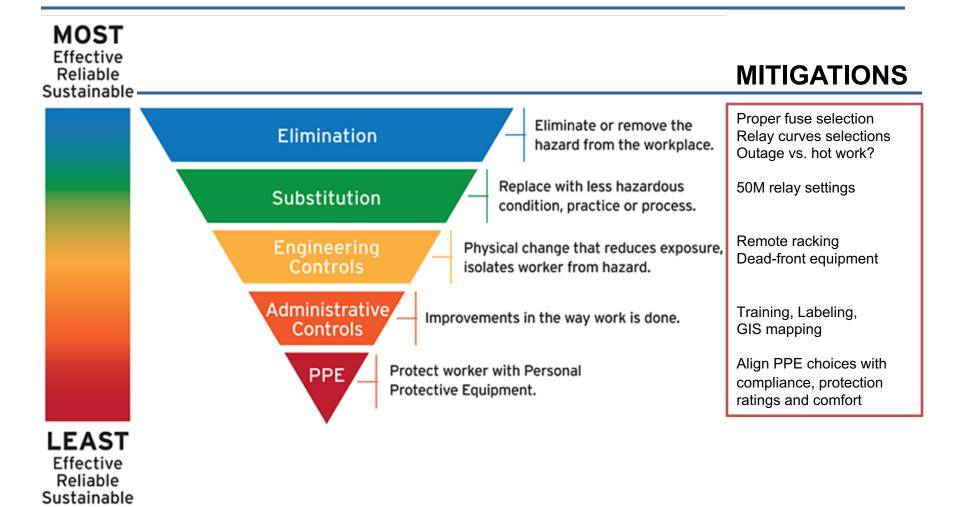
There is a brief arc at voltages below 240 V, so there is heat. Select the arc duration carefully.

A 750 kVA padmounted transformer 120/208 Volt with  $Z_T = 4.5\%$  Standard Bay-O-Net & current limiting primary fuse combination

Arc Duration	Energy at 18"	PPE Category
Full clearing time (36 sec.)	1048 cal/cm <sup>2</sup>	Category 4 Extreme Danger
15 cycles (0.25 sec.)	8.5 cal/cm <sup>2</sup>	Category 3
10 cycles (0.167 sec.)	5.7 cal/cm <sup>2</sup>	Category 2



#### **Hierarchy of Hazard Controls**





### **RPU Experience with 50M relay**

Low threshold instantaneous trip

- Setting selection 1,500 amp 50MP
   1,000 amp 50MN
- Simplified incorporation into work practices

The relay applies 50M when disabling reclose via SCADA

RPU calls this non-reclose with AF protection

Understand response protocols for inadvertent circuit breaker tripping during maintenance work

Yes, you will get a few nuisance trips.



# **RPU Experience with Info Sharing**

#### Labeling of appropriate equipment

- Compliance requirement for some scenarios
- Can be helpful even if not a requirement
- Equipment suitable for labeling

#### Alternatives to labeling

- GIS attributes on mobile device maps\*\*
- Utility Standards publications
- Other training aids are a work in progress...



#### **RPU Experience with PPE**

#### Garment ratings application

- Align compliance, protective ratings, and comfort with apparel management programs
- Examine paradigms to wearable PPE
  - Daily wear uniforms (ratings AND laundering)
  - Hardhats ... E-rated
  - Hot weather, cold weather ... COMFORT boosts compliance!
  - Hi-visibility vests, rain gear ... Arc rated
  - Fall protection harnesses



# **Layering Arc Rated Clothing**

- Layering can offer lighter weight or cooler alternative protection - *True*
- Just add the garment ratings together False
- Layered garments must be tested as a system True
- Manufacturers & Testing Labs offer test results for layering garments – *True*

arctesting@arcwear.com

https://bulwark.com/calculator

NFPA 70e Annex M for guidelines and test methods



# **RPU Experience with Training**

- Difficult at best to find trainers who are competent in the eyes of the trainees, committed to regulatory requirements <u>and</u> a skilled teacher
- Other Training Options
  - Electronically delivered training
  - Train the Trainer internal SMEs
- Driven by needs of the work
- Understanding worker behaviors boosts durable improvement
- Charts, tables and other training aids
  - Watch out for overload
  - Keep it real and practical
  - Mobile devices as a positive tool
- Classroom + Demonstrating skills



# **Questions - Discussion**

