

Arc Flash the Easy Way 2023

Part 1 - Standards and Regulations



Presented By:

Jim Chastain – Jim@EasyPower.com

The presentation will start at
the top of the hour.



Arc Flash the Easy Way 2023

Part 1 - Standards and Regulations



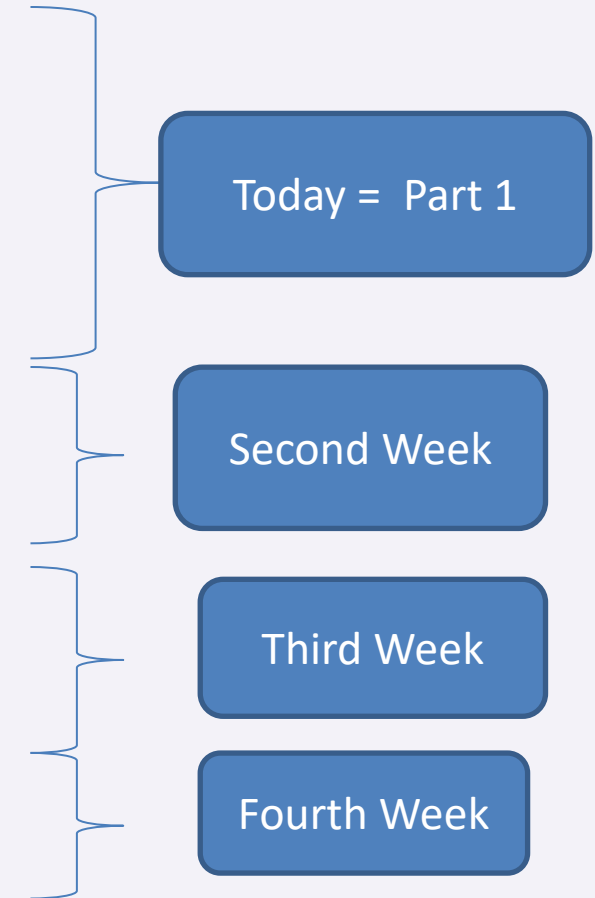
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Series Agenda

- Arc Flash is a safety hazard
- Organizations *and* Regulations Involved in Electrical Safety
 - OSHA
 - Consensus standards - rules & methods
 - NFPA
 - IEEE
 - CSA
- Arc Flash Study - initial phase
 - Data Collection
 - System Modeling
- Updated IEEE 1584-2018
- Arc Flash Study - analysis phase
 - Short Circuit Study
 - Protective Device Coordination
 - Arc Flash Hazard Assessment
- Examples, Reports, Labels
 - Mitigation
 - Comparing Results



Poll Questions

- Where do you currently stand with respect to NFPA-70E compliance?
- What area of the study present the greatest challenge?

Presentation Sourcebook

Featured Downloads



FREE Intro to Grounding Analysis

This comprehensive and valuable resource will help you understand the need for arc flash analysis.

FREE Arc Flash Safety Book | A \$70 value!



PDF



PDF

Practical Solution Guide to Arc Flash Hazards

This valuable resource will walk you through the steps for implementing an arc flash safety program as part of your overall safety program.

All Downloads



PDF

FREE Arc Flash Study Spec



PDF

FREE Arc Flash Labeling Guide



Links

Safety Program Resources

Case Study

- Electrician replacing air filters - routine PM.
- Large Forced-Cooled VFD cabinets.
- 2000 kVA - 480 VAC
- First filter replaced with no incident.
- Heard strange noise from another drive.

Case Study

- Located source as a specific drive section.
- He opened the door.
- Tremendous explosion.
- Died soon after hospital arrival.

Case Study - What Happened

- Electrician was NOT electrocuted.
- Died as the result of burns from an arcing fault.
- Initiated by the simple act of opening the cabinet door - which allowed a loosely connected phase cable to fall onto a ground (or another phase) initiating an arcing fault.
- Arc Flash is our focus today.

Arc Flash - Hazards

Release of energy from an electric arc causing: Arc Flash; Arc Blast

Heat from 35,000° F arcs igniting clothing and causing **burns of the skin.**

Projectiles of molten metal exceeding 700 mph as **shrapnel penetrating the body.**

Toxic Gas from vaporized metal oxide dust forming **poisonous airborne particles.**

Pressure of electrodes vaporizing at 67,000 times at 2000 PSF **collapsing lungs.**

Sound level of 160dB causing permanent hearing damage and **ruptured eardrums.**

Light intensity of 1,000,000 lux causing blurry vision and **permanent eye damage.**

* Arc rated PPE only protects against the thermal effects of an arc flash.

Arc Blast Pressure

- Ralph Lee paper *Pressure Developed by Arcs, 1987*
- Not directly related to Incident Energy
- Calculated from Arc Current
 - Pressure = $11.58 * I_{arc} / D^{0.9}$
 - Where impulse pressure wave ~
 - Pressure in pounds per square foot
 - D = distance from arc in feet
 - I_{arc} = arc current in kA
 - Not presently covered in NFPA 70E or IEEE 1584
 - Case: 480 vac; arc current 42kA; electrician thrown 25 feet away
 - Approx 260 lb/ft²

WORKPLACE ELECTRICAL INJURIES: 2003 - 2019

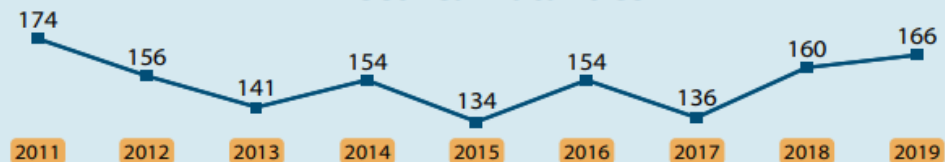
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FATAL ELECTRICAL INJURIES IN 2019

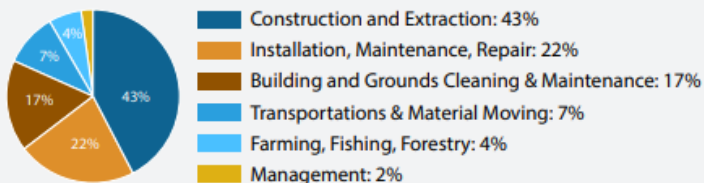
According to the Bureau of Labor Statistics, 2019 had the most recorded fatal electrical injuries since 2011. There was a 3.75% increase in fatal injuries over 2018.

Nonfatal electrical injuries involving days away from work totaled 1,900 in 2019.

Electrical Fatalities



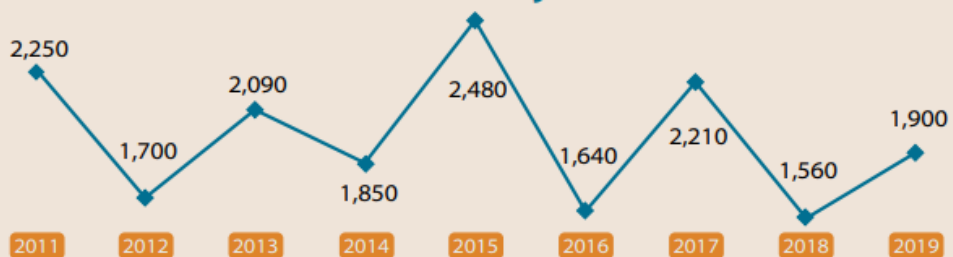
Occupations Involved in Electrical Fatalities



Fatality Rate

The construction industry had the **highest rate** of fatal electrical injuries (**0.7 / 100,000**) followed by **utility (0.4 / 100,000)**. All industries had 0.1 fatalities per 100,000 workers.

Electrical Injuries



Please share this free resource to save lives



www.facebook.com/ESFi.org



www.twitter.com/ESFIdotorg



www.youtube.com/ESFIdotorg

Risk Trade-off for Electrical Hazards

**Low
Frequency**



- 0.16% of Lost Time Injuries due to electrical hazards¹
- 3.6% of occupational fatalities¹

**High
Consequence**



- 7th leading cause of occupational fatality¹
- 1-2% of total injuries, but 28-52% of total medical costs²
- (*study at one utility*)
- 2nd most costly workers comp claim³

¹Cawley, J.C., Brenner, B.C., *Occupational Electrical Injury Statistics for the US, 2003-2009*, Conference Record, 2012 IEEE IAS Electrical Safety Workshop, January 30-February 3, 2012, Daytona, FL

²Wyzka, R and Lindroos, W., *“Health Implications of Global Electrification”*, Annals of the New York Academy of Sciences, vol 888, October 30, 1999, pp 1-7

³“Work Related Electrical Injuries”, *From Research to Reality*. Liberty Mutual Research Foundation, Winter 2010

Overlapping Standards for Electrical Safety

Federal Regulations

OSHA

Consensus Standards

NESC – Electric Utility
NFPA 70 (NEC) Construction
NFPA 70E General Industry
Z462 General Canadian Ind.

Guides & Methods

IEEE 1584 –Guide for
Performing Arc Flash Hazard
Calculations

OSHA - Occupational Safety and Health Administration

General Duty Clause: (SEC. 5. Duties)

‘Each employer SHALL furnish to each of his employees ... a place of employment which are free from *RECOGNIZED HAZARDS* that are causing or likely to cause death or serious physical harm to his employees;’

The employer shall assess the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of personal protective equipment (PPE).

If such hazards are present, or likely to be present, the employer shall:

- Select, and have each affected employee use, the types of PPE that will protect the affected employee from the hazards identified in the hazard assessment;
- Communicate selection decisions to each affected employee; and,
- Select PPE that properly fits each affected employee.

OSHA

OSHA CFR 1910 - Occupational Safety & Health Standards

- **Subpart I** - Personal Protective Equipment
 - PPE necessary for hazards capable of causing injury to the body.
- **Subpart S** - Electrical (NFPA 70E)
 - Safety requirements necessary for safeguarding of employees in their workplace.
- **Subpart R** - Special Industries
 - 1910.269 - Electric Power Generation, Transmission, and Distribution.

OSHA CFR 1926 - Safety & Health Regulations for Construction

- **Subpart K** - Electrical Standards for Construction (NFPA 70E , NPFA 70)
 - Safety requirements for safeguarding of employees involved in construction work.

OSHA - Consensus Standards

OSHA 29 CFR Section 1910.3(b)(1) addresses the historical relationship between the Act and the National Fire Protection Association (NFPA):

*“The relevant legislative history of the Act indicates congressional recognition of the **American National Standards Institute** and the **National Fire Protection Association** as the major sources of national consensus standards. National consensus standards adopted on May 29, 1971, pursuant to section 6(a) of the Act are from those two sources.”*

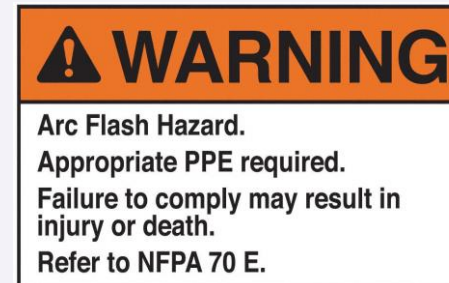
Employers following consensus standards meet OSHA requirements.

NFPA 70 - National Electrical Code

Practical safeguarding of persons and property from electrical hazards.

Covers the installation and removal of electrical equipment (construction).

110.16 Arc-Flash Hazard Warning. Electrical equipment, such as switchboards, switchgear, panelboards, industrial control panels, meter socket enclosures, and motor control centers, that is in other than dwelling units, and is likely to require examination, adjustment, servicing, or maintenance while energized, shall be field or factory marked to warn qualified persons of potential electric arc flash hazards.

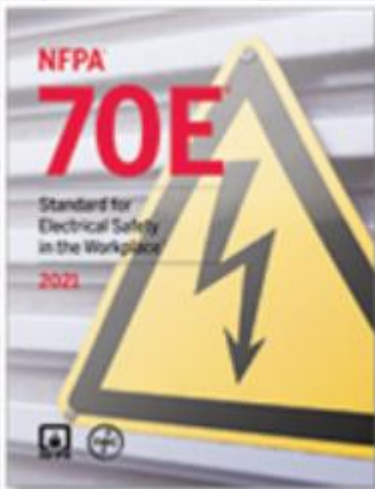


Informational Note: [NFPA 70E, Standard for Electrical Safety in the Workplace](#), provides guidance, such as determining severity of potential exposure, planning safe work practices, arc flash labeling, and selecting personal protective equipment.

NFPA 70E - Electrical Safety in the Workplace

Standard for Electrical Safety in the Workplace

Helps companies and employees avoid workplace injuries and fatalities due to shock, electrocution, arc flash, and arc blast, and assists in complying with **OSHA 1910 Subpart S** and **OSHA 1926 Subpart K**.



Chapter 1 - Safety Related Work Practices

Chapter 2 - Safety Related Maintenance Requirements

Chapter 3 - Safety Requirements for Special Equipment

Not Covered by NFPA 70E but still use EasyPower

- Installations in ships, watercraft, rolling stock, aircraft mobile homes
- *Installations of communications equipment*
- Utilities generating or transmission of electric energy
- Federal lands, military bases, Native American reservations
- Equipment in dwelling units do not require labels

NFPA 70E changes

- Updated on 3-year cycle
 - 2009 edition included several modifications
 - Compatible with NFPA 70
 - Definitions to clarify references and nomenclature
 - 2012 evolved to meet safety needs of employer & employee
 - Hazard identification vs risk assessment
 - 2015 refined ‘hazard analysis’ vs ‘risk assessment’
 - HRC tables no longer valid, changed label content
 - Eliminated ‘Prohibited Approach’ boundary & “bare hand work”
 - 2018 moved tables for PPE standards moved to ‘Informational Tables’
 - Employer still responsible for determining validity of PPE manufacture’s claims
 - (Misunderstandings about Label content still prevalent)

NFPA 70E 2021

- Article 110 revised general requirements for safety programs, practices, and procedures.
- Arc resistant equipment tables updated
- Safety related requirements involving capacitors
- Calculation methods updated to reference IEEE 1584-2018

NFPA 70E - Safety Related Work Practices

Article 100 Definitions

Article 105 Application of Safety-Related Work Practices and Procedures

Article 110 General Requirements for Electrical Safety-Related Work Practices
(modifications 2021)

Article 120 Establishing an Electrically Safe Work Condition

Article 130 Work Involving Electrical Hazards

NFPA 70E - Application

Article 105 Application of Safety-Related Work Practices and Procedures

Identifies responsibilities of the **employer** and those of the **employee**.

Employer:

- Provide safety-related work procedures.
- Training employees in the practices.
- Supervise the employees, audit, and document.

Employee:

- Apply the work procedures.
- Comply with training and demonstrate ability.

NFPA 70E - General Requirements

Article 110 General Requirements for Electrical Safety-Related Work Practices

110.1 - Electrical Safety Program

110.2 - Training Requirements

110.3 - Host and Contract Employers' Responsibilities

110.4 - Test Instruments and Equipment

110.5 - Portable Cord- and-Plug-Connected Electric Equipment

110.6 - Ground-Fault Circuit-Interrupter (GFCI) Protection

NFPA 70E

- Prime directive:
 - ‘Thou shall not work on hot equipment.’
 - Electrically safe working conditions. (ESWC)
- Even when this is ‘company policy,’ it does not eliminate the need to do an arc flash risk assessment.
- PPE must be worn to test system and verify voltage removed.

NFPA 70E - Electrically Safe Work Condition

Article 120 Establishing an Electrically Safe Work Condition

120.1 - Lockout/Tagout Program.

120.2 - Lockout/Tagout Principles.

120.3 - Lockout/Tagout Equipment.

120.4 - Lockout/Tagout Procedures.

120.5 - Process for Establishing and Verifying an Electrically Safe Work Condition.



Lockout/Tagout - Locks and tags for control of exposure to electrical hazards.

NFPA 70E - Work Involving Electrical Hazards

Article 130 - Work Involving Electrical Hazards

Defines situations which an ESWC must be established.

Describes situations requiring energized electrical work.

Requirements for working safely with energized electrical equipment.

130.1 - General

130.2 - Electrically Safe Work Conditions

130.3 - Working While Exposed to Electrical Hazards

130.4 - Shock Risk Assessment

130.5 - Arc Flash Risk Assessment

130.6 - Other Precautions for Personnel Activities

130.7 - Personal and Other Protective Equipment

NFPA 70E - Working Exposed to Electrical Hazards

De-energized Work (Electrically Safe Work Condition)

- Disconnect from energized parts.
- Verifying absence of voltage.
- Ensure equipment cannot be re-energized.

Energized Work

(110.4)

Allowed on voltage <50 volts

Permitted when de-energizing introduces additional hazards:

- Interruption of life-support equipment.
- Deactivation of emergency alarm systems.
- Shutdown of hazardous location ventilation equipment.

Permitted when task is infeasible in a de-energized state:

- Performing diagnostics and testing.
- Equipment that is an integral part of a continuous process.

Normal Operating Condition (110.4(D))

- Equipment properly installed (per manufacture's instructions)
- Equipment is properly maintained (per mfgr)
- Equipment used in accordance to manufacture's instructions
- Equipment covers, doors in place and secured
- No evidence of impending failure

NFPA 70E - Energized Electrical Work Permit (130.2)

Required when management has authorized work in an area where the equipment is not in an Electrically Safe Work Condition.

- Description of the circuit.
- Description of the work.
- Justification for the work.
- Description of the safe work practices.
- Results of the shock risk assessment.
- Results of the arc flash risk assessment.
- Means employed to restrict the access.
- Evidence of completion of a job briefing.
- Energized work approval.

ENERGIZED ELECTRICAL WORK PERMIT	
PART I: TO BE COMPLETED BY THE REQUESTER:	
1. Description of circuit equipment/job location:	MAIN SWG Switchgear
2. Description of work to be done:	Work on energized parts, including voltage testing
3. Justification of why the circuit/equipment cannot be de-energized or the work deferred until the next scheduled outage:	_____
Requester/Title _____	Date _____
PART II: TO BE COMPLETED BY THE ELECTRICALLY QUALIFIED PERSONS DOING THE WORK:	
1. Detailed job description procedure to be used in performing the above described work:	Check when complete <input type="checkbox"/>
2. Description of the Safe Work Practices to be employed:	<input type="checkbox"/>
3. Results of the shock risk assessment:	
a. Voltage to which personnel will be exposed	13.8 kV <input type="checkbox"/>
b. Limited approach boundary	5' - 0" <input type="checkbox"/>
c. Restricted approach boundary	3' - 1" <input type="checkbox"/>
d. Necessary shock, personal, and other protective equipment to safely perform assigned task	<input type="checkbox"/>
V-rated Gloves: Yes, Class 2	V-rated Tools: Yes <input type="checkbox"/>
4. Results of the arc flash risk assessment:	
a. Available incident energy	40.7 cal/cm ² at Work Distance: 1' - 6" <input type="checkbox"/>
b. Necessary arc flash personal and other protective equipment to safely perform the assigned task	<input type="checkbox"/>
Do not Work on Energized Equipment!	
c. Arc flash boundary	56' - 0" <input type="checkbox"/>
5. Means employed to restrict the access of unqualified persons from the work area:	<input type="checkbox"/>
6. Evidence of completion of a job briefing, including discussion of any job-related hazards:	<input type="checkbox"/>
7. Do you agree the above-described work can be done safely? <input type="checkbox"/> Yes <input type="checkbox"/> No (If no, return to requester.)	
Electrically Qualified Person(s) _____	Date _____
Electrically Qualified Person(s) _____	Date _____
PART III: APPROVAL(S) TO PERFORM THE WORK WHILE ELECTRICALLY ENERGIZED:	
Manufacturing Manager _____	Maintenance/Engineering Manager _____
Safety Manager _____	Electrically Knowledgeable Person _____
General Manager _____	Date _____

NFPA 70E - Shock Risk Assessment

130.4 - Shock Risk Assessment

- Identify exposure to the potential electrical shock hazards.
- Estimate the potential severity of a shock injury.
- Estimate the likelihood of occurrence of this injury.
- Determine if protective measures are required.
- Determine the appropriate protective measure to use.

NFPA 70E - Shock Approach Boundaries

Not related to arc flash or incident energy.

Applicable when approaching exposed energized electrical conductors.

May be greater than, less than, or equal to the arc flash boundary.

Limited Approach Boundary

An approach limit within which a shock hazard exists.

Restricted Approach Boundary

An approach limit within which an increased likelihood of electric shock.

NFPA 70E - Shock Approach Boundaries

Limited Approach Boundary - Approach limit for an **unqualified** person.

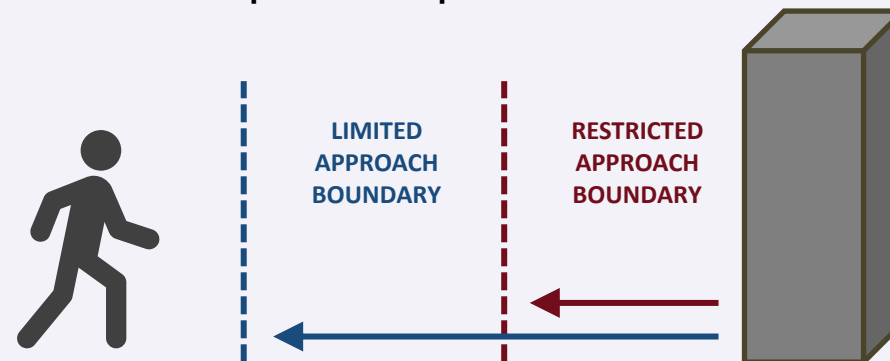
Unless:

- Advised of possible hazards by a qualified person.
- Continuously escorted by a qualified person.

Restricted Approach Boundary - Approach limit for a **qualified** person.

Unless:

- Qualified person is using personal and other shock protective equipment.
- Energized conductors are insulated from the qualified person.



NFPA 70E - Arc Flash Boundary

- **Boundary, Arc Flash** Article 100 definitions
 - When an arc flash hazard exists, an approach limit from an arc source at which incident energy equals 1.2 cal/cm^2 (5 J/cm^2).
 - Informational Note: According to the Stoll skin burn injury model, the onset of a second degree burn on unprotected skin is likely to occur at an exposure of 1.2 cal/cm^2 (5 J/cm^2) for one second.

NFPA 70E - Arc Flash Risk Assessment

130.5 - Arc Flash Risk Assessment

- (A) General
- (B) Estimate of Likelihood and Severity
- (C) Additional Protective Measures
- (D) Documentation
- (E) Arc Flash Boundary
- (F) Arc Flash PPE
- (G) Incident Energy Analysis Method
- (H) Equipment Labeling

NFPA 70E - Arc Flash Risk Assessment

Estimate likelihood of occurrence and potential severity:

- Consider design of the electrical equipment
- Consider operating condition and condition of maintenance.

(condensed Table 130.5(C))

<u>Task</u>	<u>Condition</u>	<u>Likelihood</u>
Non-Contact Inspections	Any	No
Work Within Energized Equipment	Any	Yes
Operation of Closed Equipment	Normal	No
Insertion or Removal Equipment Parts	Abnormal	Yes

But wait What if...?

Arc flash risk assessment reveals..

- Older facility
- Elevated incident energy
- Frequent C/B operation
- Open/Close procedure
 - Operator stand to the side
 - Not face panel
 - PPE on hand and arm, hearing protection



panel

NFPA 70E - Arc Flash Risk Assessment

Determine if protective measures are required:

- Appropriate safety-related work practices.
- Arc flash boundary.
- PPE to be used within the arc flash boundary.

Document:

- Results of the arc flash risk assessment shall be documented.

NFPA 70E - Arc Flash Boundary

Arc Flash Boundary:

(130.5 (C))

- All body parts within must be protected.
- Distance at which incident energy is 1.2 cal/cm^2 .

Two acceptable methods to determine:

(130.5(F))

- Arc Flash PPE Category Table Method.
- Incident Energy Analysis Method.

NFPA 70E - Arc Flash Boundary

Arc Flash Boundary Table Method:

(Table 130.7 C 15 a)

	<u>Max</u> <u>Voltage</u> (V)	<u>Max</u> <u>Fault Current</u> (kA)	<u>Max</u> <u>Clearing Time</u> (s)	<u>Arc</u> <u>Flash Boundary</u> (ft)
Panelboards	240	25	0.03	1.58
Panelboards	600	25	0.03	3.00
MCC	600	65	0.03	5.00
MCC	600	42	0.33	14.0
Switchgear	600	35	0.50	20.0
Other	600	65	0.03	5.00
Motor Starter	7200	35	0.24	40.0
Switchgear	15000	35	0.24	40.0
Other	15000	35	0.24	40.0

NFPA 70E - Arc Flash PPE

Use one method to select Arc Flash PPE:

- Incident energy analysis method.
- Arc Flash PPE category method.

Either, but not both, methods permitted on a single piece of equipment.

Incident energy analysis not permitted to specify an arc flash PPE category.

NFPA 70E - Arc Flash PPE (uses Table 130.7 C 15 c)

Arc Flash PPE Category Method:

(Table 130.7 C 15 a)

	<u>Max Voltage</u> (V)	<u>Max Fault Current</u> (kA)	<u>Max Clearing Time</u> (s)	<u>Minimum Working Distance</u> (in)	<u>Arc Flash PPE</u> (Category)
Panelboards	240	25	0.03	18	1
Panelboards	600	25	0.03	18	2
MCC	600	65	0.03	18	2
MCC	600	42	0.33	18	2
Switchgear	600	35	0.50	18	4
Other	600	65	0.03	18	2
Motor Starter	7200	35	0.24	36	4
Switchgear	15000	35	0.24	36	4
Other	15000	35	0.24	36	4

NFPA 70E - Arc Flash PPE (130.5 F)

Incident Energy Analysis Method

- Based on the working distance of the person.
- Requires an extensive calculation.
- Allows for a more precise determination of PPE.

No specific method of incident energy calculation mandated.

Available calculation methods provided in Informative Annex D.

NFPA 70E - Arc Flash PPE

PPE Selection with Incident Energy Analysis Method:

(Table 130.5 G)

Incident Energy 1.2 cal/cm² to 12 cal/cm²

- Arc-rated clothing equal to or greater than the estimated incident energy
- Long-sleeve shirt and pants or coverall or arc flash suit
- Arc-rated face shield and arc-rated balaclava or arc flash suit hood
- Arc-rated outerwear, heavy-duty gloves, arc-rated gloves
- Hard hat, safety glasses, hearing protection & leather footwear

Incident Energy greater than 12 cal/cm²

- Arc-rated clothing equal to or greater than the estimated incident energy
- Long-sleeve shirt and pants or coverall or arc flash suit
- Arc-rated arc flash suit hood, outerwear, gloves
- Hard hat, safety glasses, hearing protection & leather footwear


* Arc-Rated PPE provides a 50 % probability of protection from second-degree burns.


NFPA 70E - Equipment Labeling (130.5 H)

Equipment likely to require examination or maintenance while energized.

Marked with a label containing:

- System Voltage
- Arc Flash Boundary
- At least one of the following:
 - Incident energy and working distance
(or arc flash PPE category, but not both)
 - Minimum rating of clothing
 - Site-specific level of PPE

 WARNING
ARC FLASH HAZARD
Nominal system voltage _____
Arc flash boundary _____
Available incident energy _____
Working distance _____
Minimum arc rating of clothing _____

 WARNING
ARC FLASH HAZARD
Nominal system voltage _____
Arc flash boundary _____
Working distance _____
PPE category _____

Demonstration

Arc Flash Paradox Example

“Counter-intuitive nature of arc flash”

01 Paradox.dez

Arc Flash Paradox

- In the same system you can have low arcing current but high Incident Energy, it all depends on the time to clear the arc.
- Take away - you cannot just look at a piece of equipment and ascertain the arc flash hazard.

Thank you for attending today

- Questions?
- Track announcements and other webinar postings on www.EasyPower.com
- Visit web site to access ‘Demo’ copy of software
- Join us next week for “Part 2 -Data Collection & System Modeling”