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# Arc Flash as it relates to AC Drives

# Five Main Topics

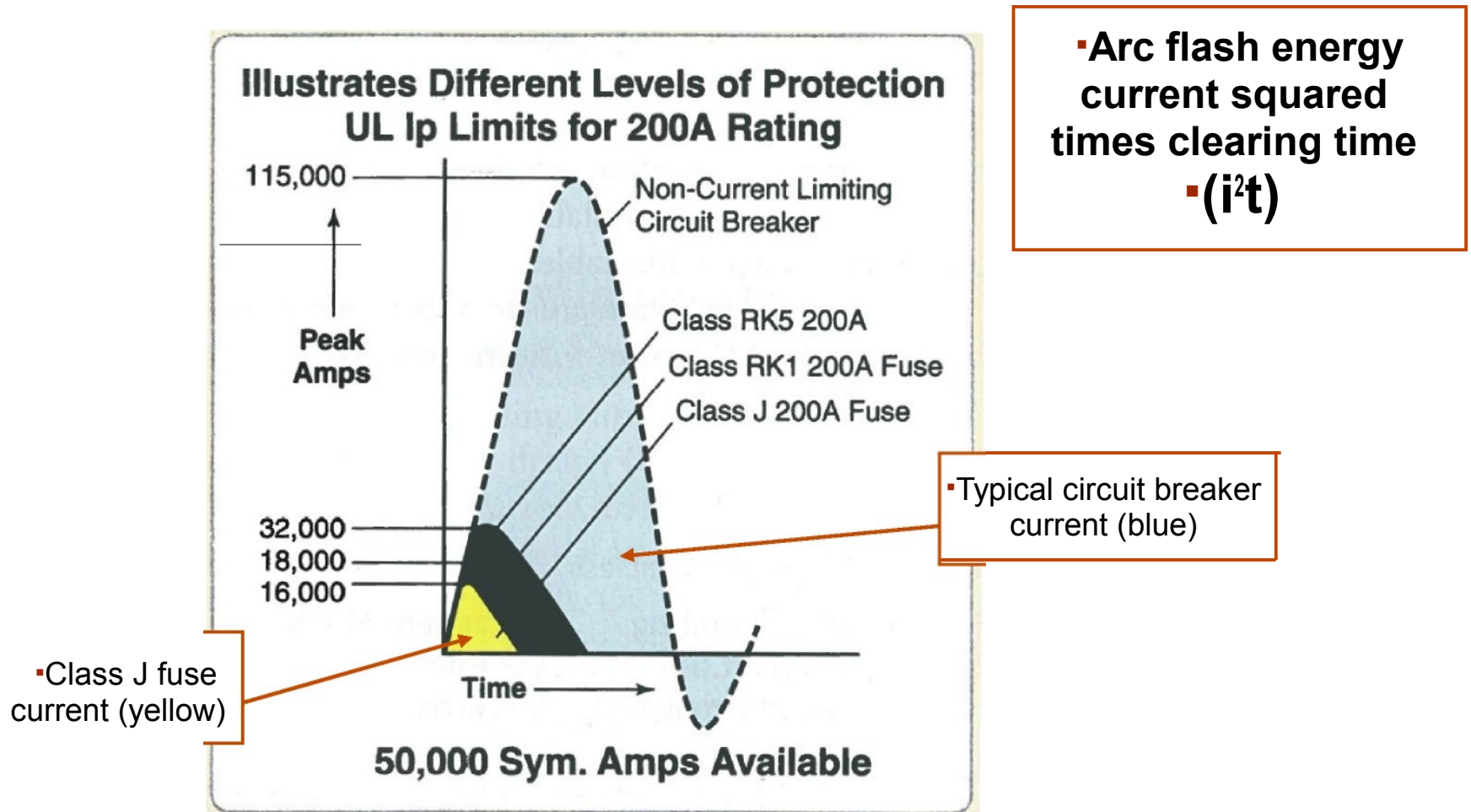
1. What is arc flash
2. OSHA, NFPA 70E
3. Codes and standards
4. Protective clothing and equipment
5. Prevention

# Arc Flash Basics



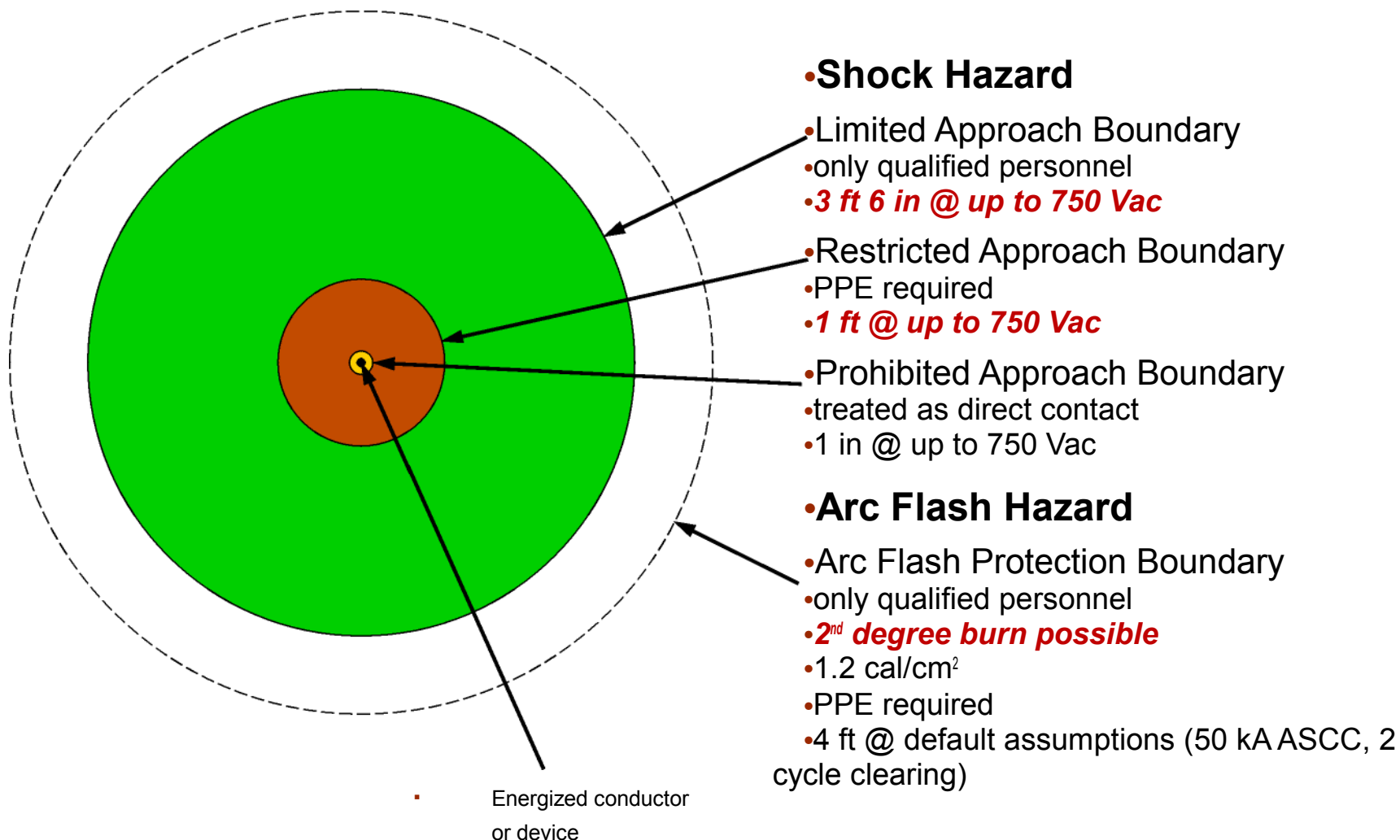
- An **arc flash** (or arc blast) is a type of electrical explosion that results from a low impedance connection to ground or another voltage phase in an electrical system
- Even without electrocution, death or dismemberment may occur through an intense arc blast, up to 35,000 F deg, and force up to 2100 psi from the intense heat rapidly expanding the air, copper & particles creating a shockwave blast. Droplets of molten metal and shrapnel can penetrate the body.

# Impact of Overcurrent Protection Device Selection

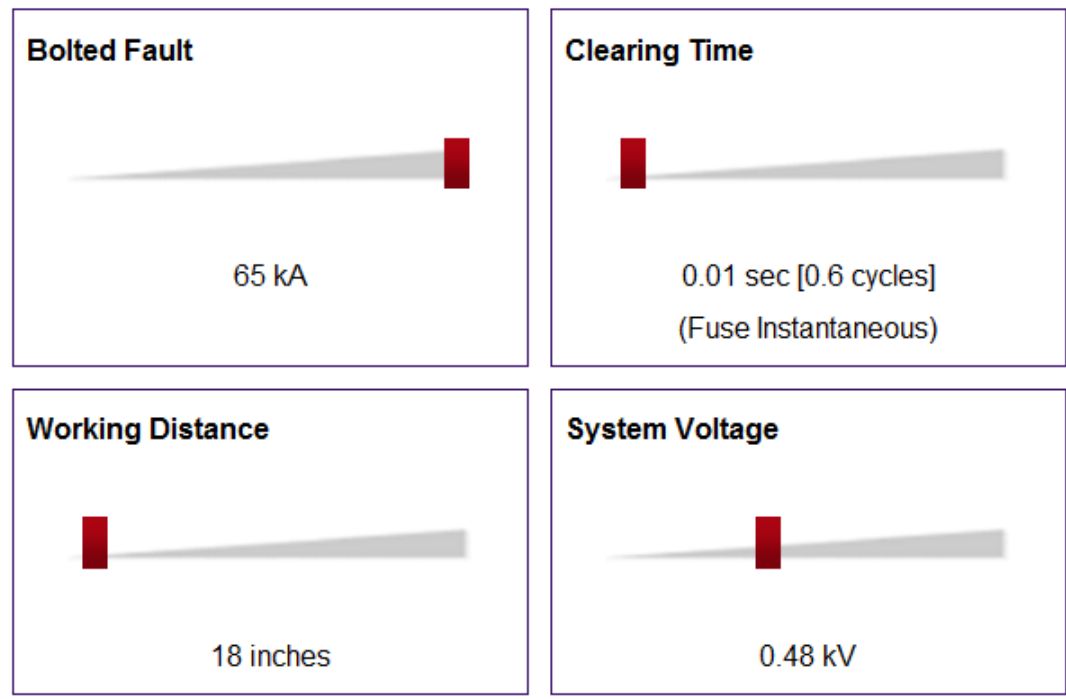


# Electrical Hazards and Approach Boundaries

## Distances from Table 130.2(C)



Equipment Type



\* **NOTE:** This is a demonstration tool only and is not meant to be used to calculate arc flash values for personnel protection.

**Results**

**Arc Boundary**

14.2 inches

**Incident Energy**

1.1 cal/cm<sup>2</sup>

**Clothing Class**

#0 - Non-melting, flammable materials



Equipment Type VFD

Bolted Fault



65 kA

Clearing Time



0.05 sec [3 cycles]  
(Typical Instantaneous Trip)

Working Distance



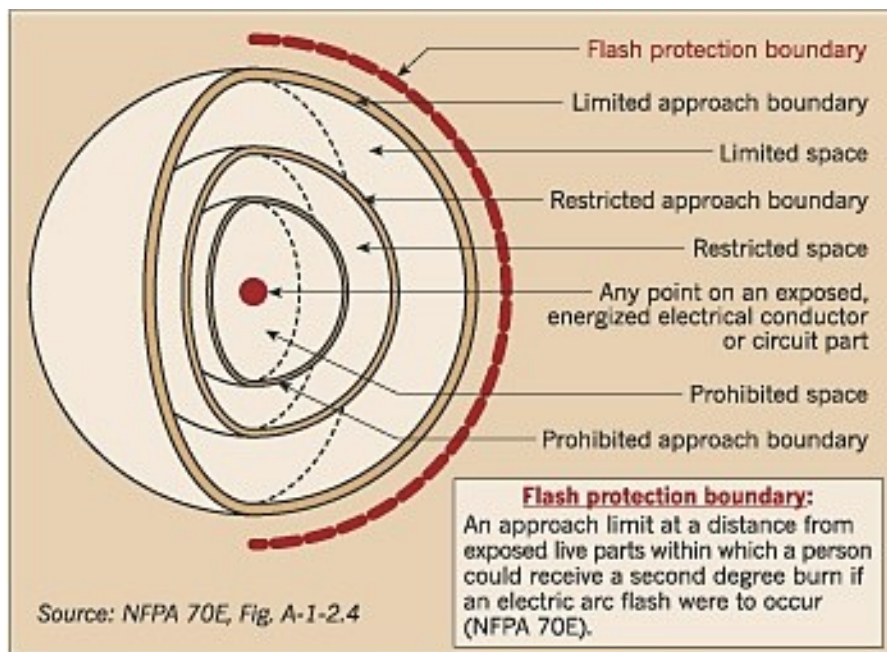
18 inches

System Voltage



0.48 kV

Calculate Arc Flash



## Results

**Arc Boundary**

42.3 inches

**Incident Energy**

5.3 cal/cm<sup>2</sup>

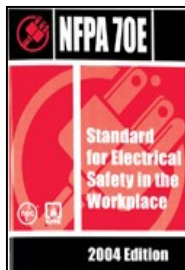
**Clothing Class**

#2 - Cotton underwear plus FR shirt and FR pants

# Electrical Workplace Safety Standards

## The OSHA / NFPA 70E mix

- OSHA sets the **functional requirements** but does not provide procedural detail (*what must be done*)
- NFPA 70E provides **procedural recommendations** for how to meet functional electrical safety goals (*how to recommendations*)
- NFPA 70E procedural provisions are based on OSHA requirements and OSHA citations reference NFPA 70E recommendations
- Thus, although OSHA is **law** and NFPA 70E is **not**, **NFPA 70E recommendations** are effectively *de facto requirements*



# OSHA - Basic facts



- OSHA – Occupational and Safety Health Administration
- Established in accordance with the Occupational and Safety Health Act of 1970
- Requires that employers provide **a place of employment free from recognized hazards that are likely to cause death or serious injury**
- Sets **personal safety requirements**
- Primarily written in **performance language**: *(what must be achieved, not how to achieve it)*

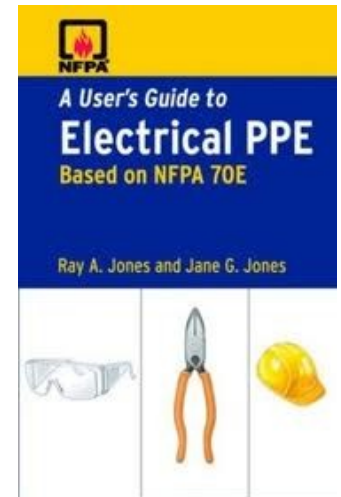


# OSHA and Workplace Electrical Safety

## One level deeper

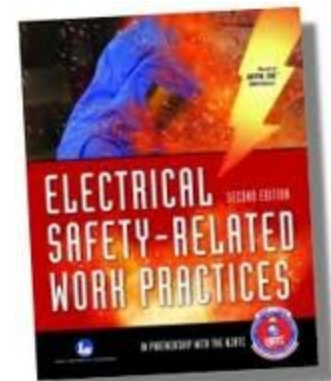


- OSHA 29 Code of Federal Regulations Part 1926
  - Construction industry
  - New installations, often temporary situations
- OSHA 29 Code of Federal Regulations Part 1910
  - General industry / general commercial sites
  - Existing installations, often maintenance or repair related
  - Sets personal protective equipment (PPE) requirements
  - Sets PPE training requirements
  - Sets safety related work practice training requirements
    - Sets lockout / tagout requirements



# NFPA 70E - Basic facts

- NFPA — National Fire Protection Association
- NFPA 70E: Standard for Electrical Safety in the Workplace (2009 Edition)
- All industries; all installations (with exceptions, e.g. utility sites)
- **Prescriptive language** — how to achieve
  - Personnel safety emphasis
  - Electrical shock hazards
  - Arc flash / arc blast hazards
- Provides specific practices and procedures
  - **Electrical work practices**
  - Maintenance procedures
  - **Electrical hazard evaluation**
  - **Personal protective equipment (PPE) evaluation and selection**



# NEC® Article - 110.16 Flash Protection

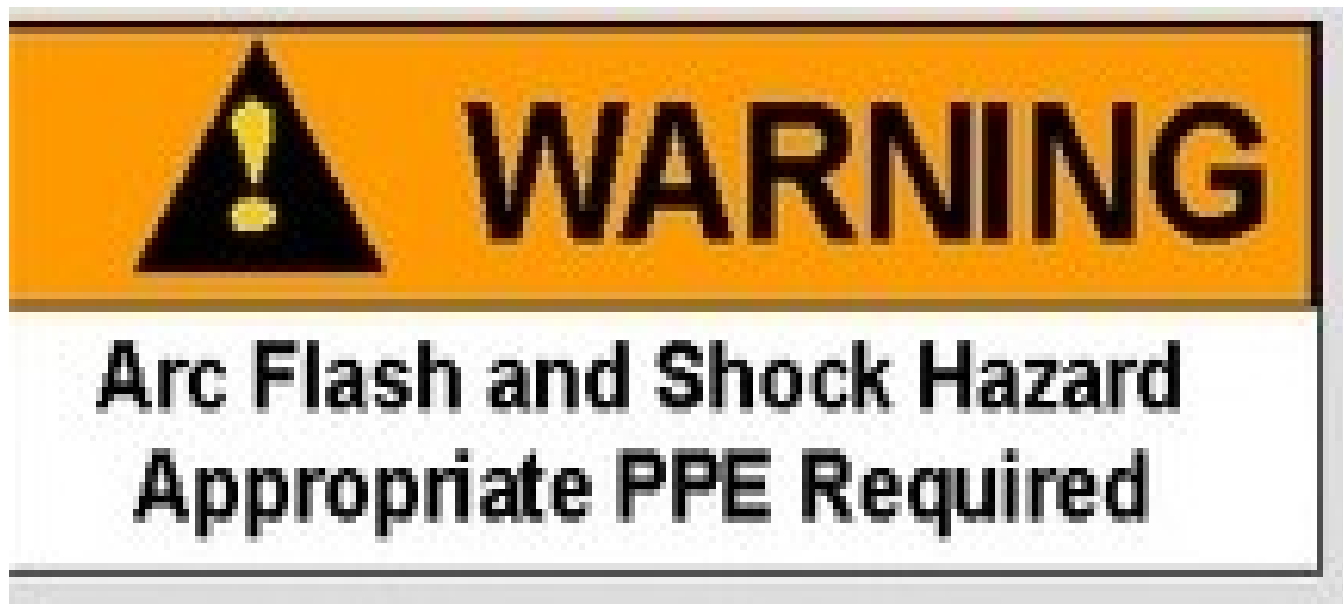
- **Equipment such as** switchboards, panel boards, **industrial control panels**, meter socket enclosures, and **motor control centers** that are in other than dwelling occupancies and are likely to require examination, adjustment, servicing, or maintenance while energized **shall be field marked to warn “qualified persons” of potential electric arc flash hazards.**
- The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

# NEC® Article - 110.16 Flash Protection

- FPN No. 1: NFPA 70E-2009, Standard for Electrical Safety in the Workplace, provides assistance in determining severity of potential exposure, planning safe work practices, and selecting personal protective equipment.
- FPN No. 2: ANSI Z535.4-1998, Product Safety Signs and Labels, provides guidelines for the design of safety signs and labels for application to products.




# Arc Flash Hazard Labels




- The following arc flash label would suffice in meeting the requirements of NEC Article 110.16 but may not suffice in meeting NFPA 70E – 2009.



# Arc Flash Hazard Labels

- Equipment Labeling. Equipment shall be field marked with a label containing the available incident energy or required level of PPE. Below is an example of NFPA70E recommended label warnings.

 <b>WARNING</b> 	
<b>Arc Flash and Shock Hazard</b>	
<b>Appropriate PPE Required</b>	
21 inch	Flash Hazard Boundary
1.58 cal/cm <sup>2</sup>	Flash Hazard at 18 inches
Class 1	FR Shirt & Pants
480 VAC	Shock Hazard when cover is removed
00	Glove Class
42 inch	Limited Approach (Fixed Circuit)
12 inch	Restricted Approach
1 inch	Prohibited Approach
<b>Bus: 1DPB Prot: CB ATS-2 N</b>	
 Electrical Reliability Services, Inc. 3150-B East Birch Street Brea, California 92821 (714)961-2888	
Job#: 300xxxx	Prepared on: August 27, 2004
Warning: Changes in equipment settings or system configuration will invalidate the calculated values and PPE requirements	

 <b>DANGER</b> 	
<b>NO PPE AVAILABLE</b>	
<b>ENERGIZED WORK PROHIBITED</b>	
334 inch	Flash Hazard Boundary
144 cal/cm <sup>2</sup>	Flash Hazard at 18 inches
Dangerous!!!	No FR Class Found
480 VAC	Shock Hazard when cover is removed
00	Glove Class
42 inch	Limited Approach (Fixed Circuit)
12 inch	Restricted Approach
1 inch	Prohibited Approach
<b>Bus: MDS Prot: MDS MAIN</b>	
 Electrical Reliability Services, Inc. 3150-B East Birch Street Brea, California 92821 (714)961-2888	
Job#: 300xxxx	Prepared on: August 27, 2004
Warning: Changes in equipment settings or system configuration will invalidate the calculated values and PPE requirements	

▪ 27'.8"

# NEC® Definition - Motor Control Center

- An assembly of one or more enclosed sections having a common power bus and principally containing motor control units.

## ▪ ARTICLE 312

- Cabinets, Cutout Boxes, and Meter Socket Enclosures

- 312.1 Scope. This article covers the installation and construction specifications of cabinets, cutout boxes, and meter socket enclosures

# NEC® Article 409.2- Industrial Control Panel

An assembly of two or more components consisting of one of the following:

- (1) Power circuit components only, such as motor controllers, overload relays, fused disconnect switches, and circuit breakers
- (2) Control circuit components only, such as pushbuttons, pilot lights, selector switches, timers, switches, control relays
- (3) A combination of power and control circuit components

These components, with associated wiring and terminals, are mounted on or contained within an enclosure or mounted on a sub-panel. The industrial control panel does not include the controlled equipment.

# Electrical Safety — Who's Responsible

## Employer responsibilities

- Establish / provide safety related work practices / procedures
- Safety awareness and self-discipline
- Safety measurement and monitoring controls
- Specific written safety **procedures**
- Hazard **assessments**
- Personal protective equipment (select and provide)
  - Job briefings
  - Safety **auditing**
  - Establish / provide **training**
  - Safety related work practices
  - Emergency procedures
    - Release of victims from electrical contact
    - Resuscitation methods
  - Knowledge of equipment specific electrical hazards
  - Proper use of PPE
  - Proper use of insulated tools and test equipment

▪ **Employer**  
▪ **Formal procedures,  
documentation and training**

# Electrical Safety — Who's Responsible

## Employee responsibilities

- Cultivate and maintain an earnest safety **attitude**
- Be alert to potential safety hazards —**think** proactively
- Implement all established safety practices, procedures, and policies —exercise **diligence**
- Never make assumptions, when not sure, **verify intension and status**
- Don't cut corners or skip steps —be **meticulous**
- Conscientiously **utilize prescribed PPE** without exception

**▪ Employee**  
**▪ Attitude is vital**  
**▪ Ardent implementation is critical**

# NEC® Definition

## NFPA 70 National Electrical Code®, 2011 Edition

Qualified Person. One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received **safety training to recognize and avoid the hazards involved.**

FPN: Refer to NFPA 70E®-2009, *Standard for Electrical Safety in the Workplace*, for electrical safety training requirements.

# Qualified Person

## NFPA 70 E Standard for Electrical Safety in the Workplace, 2009 Edition

Qualified Person. A qualified person shall be:

Trained and knowledgeable of the construction and operation of equipment or a specific work method

**Trained to recognize and avoid the electrical hazards** that might be present with respect to that equipment or work method.

# Qualified Person

## NFPA 70 E Standard for Electrical Safety in the Workplace, 2009 Edition

The employer shall document that each employee has received the training required. This documentation shall be made when the employee demonstrates **proficiency** in the work practices involved and shall be maintained for the duration of the employee's employment. The documentation shall contain each employee's name and dates of training.

# Safety Principle

## De energize power unless infeasible

- OSHA 29 CFR 1910.333(a)(1)
- Live parts to which employees may be exposed shall be de energized before the employee works on or near them, unless the employer can demonstrate that de energizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations.
- Turning power off is always the preferred choice of action.

- Inconvenience  $\neq$  Infeasibility
- Higher cost  $\neq$  Infeasibility
- Increased time  $\neq$  Infeasibility
- Valid exceptions:
  - Powering down creates a greater hazard
  - Trouble shooting / measurement only possible in energized state (However, repair must be performed de energized)



# Safety Principle No

## Ensure an electrically safe work condition

- Electrically safe work condition - A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked / tagged in accordance with established standards, tested to insure the absence of voltage, and grounded if determined necessary.

- Procedural steps:

1. Identify power sources (e.g. review drawings / documentation)
2. Disconnect all power sources
3. Visually verify disconnection (when possible)
4. Implement approved lock out / tag out procedure
5. Confirm electrically safe status (e.g. voltmeter measurement)
6. Ground equipment as needed (e.g. capacitive energy storage)

# Backup Safety Strategy

What to do when energized work can't be avoided

- Obtain an Energized Work Permit
- Plan the work
- Hold preparatory meetings as required
- Clearly define goals and responsibilities for all involved
- Insure that all assigned personnel are properly qualified
  - Follow established practices and procedures
    - Don't cut corners
    - Don't skip steps
    - Don't make assumptions – verify!
    - Always use appropriate PPE
  - Use only appropriate tools and test instruments



# Arc Flash Risk Categories and PPE

Based on Table 130.7(C)(10)

	<i>Hazard / Risk Category</i>	<i>Covers Arc Rating Range*</i>	<i>Clothing</i>	<i>Other PPE</i>	<i>Clothing/ PPE Min Arc Rating*</i>	
➔	0	0 - 1.2	Non melting material >4.5 oz/yd	safety goggles hearing protection leather gloves	na	▪Goal ←
	1	1.2 - 4	FR shirt and pants or FR coverall	Cat 0 gear + hard hat leather shoes	4	
	2	4 - 8	FR shirt and pants or FR coverall	Cat 1 gear + face shield or arc flash hood	8	
	3	8 - 25	FR shirt and pants or FR coverall and arc flash suit	Cat 1 gear + flash suit jacket flash suit pants flash suit hood	25	
	4	25 - 40	FR shirt and pants or FR coverall and arc flash suit	Cat 1 gear + flash suit jacket flash suit pants flash suit hood	40	

\* cal / cm<sup>2</sup> **ABB**

# Typical PPE Requirements

Hazard/Risk Category	Eye protection, ear canal inserts, long sleeve shirt and pants	Arc rated clothing	Face & Head Protection	Flash Suit Hood
0	✓			
1	✓	✓	✓	
2	✓	✓	✓	
3	✓	✓	✓	✓
4	✓	✓	✓	✓

# Typical Protective Clothing

Hazard/Risk Category	Clothing Description	Required Minimum Clothing Arc Rating
<b>0</b>	Non-melting, flammable material with fabric weight of at least 4.5 oz/yd <sup>2</sup>	Not applicable
<b>1</b>	Arc-rated FR shirt + FR pants <u>or</u> FR coveralls	4 calories/cm <sup>2</sup>
<b>2</b>	Arc-rated FR shirt + FR pants <u>or</u> FR coveralls	8 calories/cm <sup>2</sup>
<b>3</b>	Arc-rated FR shirt + FR pants <u>or</u> FR coveralls, <u>and</u> Arc-rated flash suit, the layered system must meet the required minimum rating.	25 calories/cm <sup>2</sup>
<b>4</b>	Arc-rated FR shirt + FR pants <u>or</u> FR coveralls, <u>and</u> Arc-rated flash suit, the layered system must meet the required minimum rating.	40 calories/cm <sup>2</sup>

# Shock Hazard and Rubber Glove Ratings

Per ASTM D120

<i>Class</i>	<i>Color</i>	<i>Max Voltage AC / DC</i>	
00	Beige	500 / 750	
0	Red	1,000 / 1,500	★ ▪ Good for most low voltage industrial work
1	White	7,500 / 11,250	
2	Yellow	17,000 / 25,500	
3	Green	26,500 / 39,750	
4	Orange	36,000 / 54,000	

▪ Always wear leather protector gloves over rubber gloves!

# FR Rated Clothing

- Limit the 'Incident Energy' level of the arc flash to 1.2 cal/cm<sup>2</sup> against the worker's chest.
- Look for a label that states:
  - 1506 approval (ASTM F1506)
  - Arc rating of the garment
- All materials in the garment should be FR Rated:
  - Thread
  - Buttons
  - Insulation
  - Zippers, etc.



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# FR Clothing Can Be Layered

- Increases level of protection.
- May be lighter than a single heavy garment.
- Manufacturer must provide the new combined arc rating afforded by layering.



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# When Purchasing PPE

- Tell the supplier that you need arc flash rated PPE and clothing.
- PPE must have some resistance to:
  - Flame
  - Ignition
  - Melting.
- obtain PPE from a known and trusted supplier



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▪ *Not all FR clothing is tested to ASTM F1506*

# Synthetic Clothing

- Synthetic clothing that melts ***shall not*** be worn, such as:
  - Acetate
  - Nylon
  - Polyester
  - Polypropylene
  - Spandex

# Arc Flash Rated PPE

ASTM F1506 is the certification for arc flash resistant clothing.

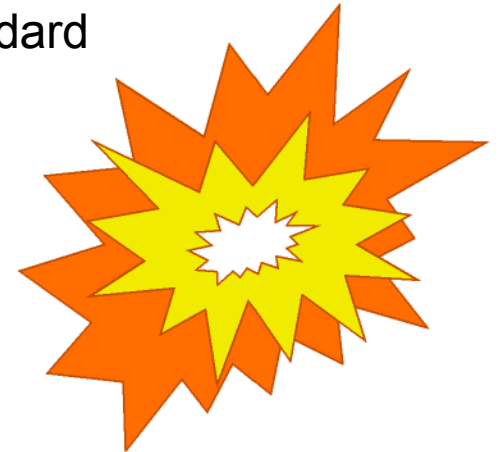
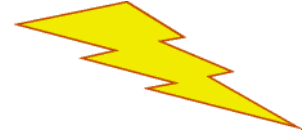
- Required minimum clothing:
  - Non-melting, flammable material,
  - Fabric weight of at least 4.5 oz/yd.
- PPE must also provide arc flash protection:
  - Face shield
  - Gloves, etc.



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# Hazard Reduction via Design

- Shock Hazards
- Covers and barriers
- Remote monitoring
- Arc Flash Hazards
- Covers and barriers
- Remote monitoring
- Door mounted keypad
- Overcurrent protective device (OCPD) selection
- Current limiting fuses vs. circuit breakers
- Clearing time is critical
- $I^2t$  let through provides a hazard measurement standard
- Circuit breaker zone selective interlocking
- Maintenance switching
- High impedance grounding systems
- Phase to ground faults (not phase to phase)



# Covers and Barriers



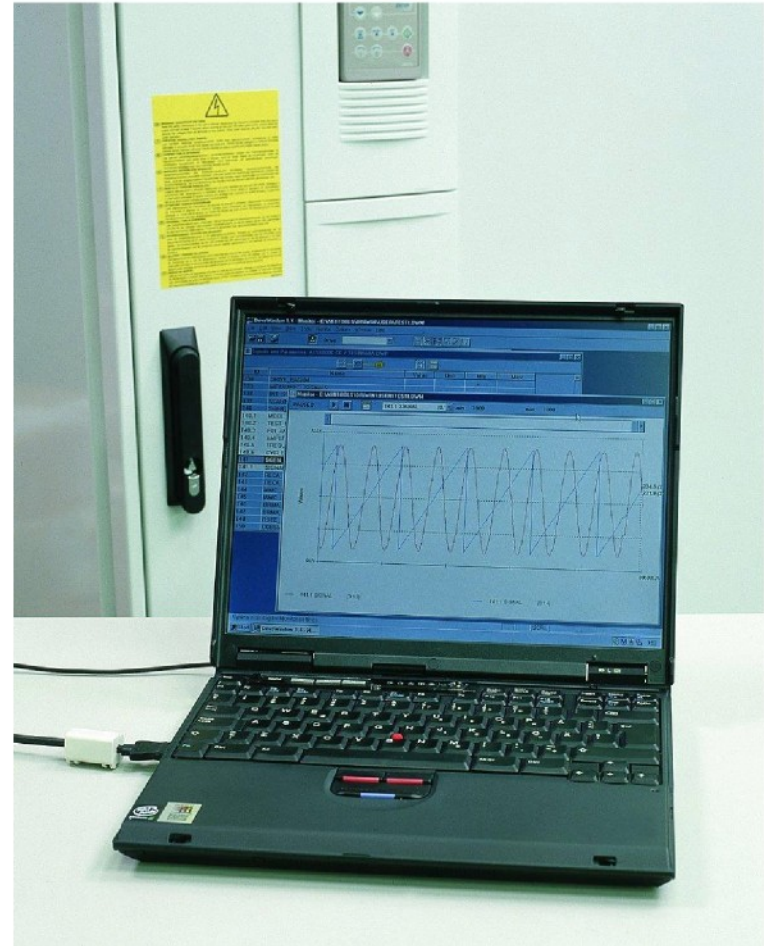
- **No shock hazard.**
- **Reduced arc flash hazard tools can't 'fall in'.**

# Some elements to consider regarding arc flash related to AC drives

- 1. Arc flash analysis is required to evaluate the available short circuit current to the facility and the individual panels within the facility. A new analysis is required after a change in the power distribution system.
- 2. Available certified & maintained personal protection equipment (PPE)
- 3. Proper warning labels applied to panel or drive
  - Defined personal safety boundary areas
  - Required personal protection equipment (PPE)
- 4. Current limiting line reactors are sometimes beneficial to lower the available short circuit current levels at installation point
- 5. Ultra-fast clearing time of an arc flash fault is essential. Techniques include: fast acting current limiting fuses, coordinated circuit breakers and optical arc flash detection relay control systems. A dedicated flash control system can be stand alone on a feeder circuit and does not have to be part of a coordinated system. Flash relay sensors can trigger by either a light flash only or light flash plus fault current to minimize nuisance trips.

# Remote Monitoring & Door Mounted Keypads

Smart flexible tools - Basically keep the door closed.



Doors closed — no shock or arc flash hazards!

Power and productivity  
for a better world™

