NFPA 70E SERIES

2015 NFPA 70E - Standard for Electrical Safety in the Workplace

Significant Changes To Standard
NFPA 70E

- Requirements for safe work practices
- Addresses hazards:
  - Shock
  - Arc Flash/Blast
- Requirements for shock and arc flash boundaries
- Requirements for personal protective equipment
- Additional Training Requirements to be considered “Qualified”
- Energized Electrical Work Permit
Significant Changes in 2015 Standard

- Safety Related Maintenance Requirements 90.2(A)
- “Bare Hand Work” – Best served by “utility regulations”
- ‘Energized Work Permit’ - Definition Updated 130.2(B)(1)
- ‘Qualified Person’ re-defined to correlate with OSHA 1910.399
- Removal of “Prohibited Approach Boundary”
- New requirements for Electrical Safety Program to include condition of maintenance 110.1(B)
- Audit of field work compliance not to exceed 1 year 110.1(I)(2)
- Location, sizing, application of temporary grounding identified as part of job planning 120.3(A)
- Clarification of ‘Normal Operation’ 130.2(A)(4)
- Incident Energy vrs Clothing Category 130.5(D)
- Field Marking Requirements process changes 130.5(D)
Significant Changes in 2015 Standard

- Boundary Changes 130.6(D)
- Conductive Objects 130.6(D)
- PPE Table Changes 130.7(C)(15)(A)(a) – 130.7(C)(15)(A)(b) - 130.7(C)(15)(B)
- Removal/Redefine of ‘Category 0’ 130.7(C)(16)
- Insulated Tool requirements 130.7(D)(I)
- Barricade Requirements 130.7(E)(2)
- Risk Assessment Before Cutting or Drilling 130.10
- Host Company (Owner) responsibility 205.3
- Test instrument requirements 110.4(A)(5) – 250.4
- Battery Risk Assessment 320.3(A)(1) – 320.3(A)(1)
Safety Training Requirements

NFPA 70E ~ 110.2

- All employees who face a risk of electrical hazards.
  - Trained to understand the specific hazards.
  - Trained in safety related work practices.
  - Trained in procedural requirements for Personal Protective Equipment (PPE)
  - Trained to understand the relationship between the hazard and possible injury

- Emergency Procedures – Employs Exposed
  - Methods of release
  - Regularly Instructed In CPR & AED and verified annually
The employer shall implement and document an overall electrical safety program that directs activity appropriate to the risk associated with electrical hazards.

The electrical safety program shall be implemented as part of the employer’s overall occupational health and safety management system, when one exists.
Electrical Safety Program 110.1

Elements of the program shall include:

• Maintenance
  • Consideration of condition
• Awareness and Self Discipline
• Program Principals
  • Basis of program
  • Examples in annex ‘E’
• Control
  • How Measured and Monitored
• Procedures for Safe Work
• Risk Assessments
• Job Briefing Requirements
  • Annex ‘I’
• Audit Requirements
“Qualified” person

“A qualified person shall be trained and knowledgeable in the construction and operation of equipment or a specific work method and be trained to identify and avoid the electrical hazards that may be present with respect to that equipment or work method”
"Qualified" person

Additional requirements:

- Trained to recognize the hazards present
- Such persons shall also be familiar with
  - The use of the precautionary techniques
  - Electrical policies and procedures
  - Personal protective equipment
  - Insulating and shielding materials
  - Insulated tools and test equipment
“Qualified” person

In addition, to be permitted to work within the limited approach of exposed energized conductors and circuit parts >50Volts. shall be trained in all of the following:

- The skills and techniques necessary to distinguish exposed live parts from other parts of electric equipment
- The skills and techniques necessary to determine the nominal voltage of exposed live parts
- The minimum approach distances specified in this section corresponding to the voltages to which the qualified employee will be exposed, and,
- The decision making process necessary to be able to do the following:
  - Perform the job safety planning
  - Identify electrical hazards
  - Assess the associated risk
  - Select the appropriate risk control methods from the hierarchy of controls (110.1(G)) including proper PPE
Dangers of Electricity

Electric Shock

Arc Flash

Arc Blast
### By The Numbers

<table>
<thead>
<tr>
<th>How Often</th>
<th>Number</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>4,000</td>
<td>Non-Disabling electrical contact injuries</td>
</tr>
<tr>
<td>Annual Average</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3,600</td>
<td>Disabling electrical contact injuries</td>
</tr>
<tr>
<td>Every Day</td>
<td>1</td>
<td>Person is electrocuted in the workplace</td>
</tr>
<tr>
<td>Electrocutions are</td>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Leading cause of traumatic occupational fatalities</td>
</tr>
<tr>
<td>Each year</td>
<td>+2,000</td>
<td>Workers are sent to burn centers with electrical burns</td>
</tr>
</tbody>
</table>

- An average of one person is electrocuted in the home every 36 hours
- Electrocution is fourth in work related fatalities with a majority of these incidents occurring at 600 volts or less
- There are four main types of electrical injuries:
Electrocution and Shock

Factors that determine severity of electric shock

- Amount of current
- Path of current
- Duration of shock
- Body Resistance
- Voltage
- Frequency
- AC or DC
## Current Magnitudes

<table>
<thead>
<tr>
<th>CURRENT A/C</th>
<th>PHYSIOLOGICAL PHENOMENA</th>
<th>FEELING OR LETHAL INCIDENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>60Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1mA</td>
<td>None</td>
<td>Imperceptible</td>
</tr>
<tr>
<td>1mA</td>
<td>Perception threshold</td>
<td></td>
</tr>
<tr>
<td>2-10mA</td>
<td>Sensation of shock</td>
<td>Not painful, muscle control maintained</td>
</tr>
<tr>
<td>5mA</td>
<td></td>
<td>Ground Fault Circuit Interrupter Operates</td>
</tr>
<tr>
<td>10-20mA</td>
<td>Paralysis Threshold of Arms</td>
<td>Cannot release hand grip, victim may be thrown clear</td>
</tr>
<tr>
<td>20-50mA</td>
<td>Respiratory Paralysis</td>
<td>Breathing Stoppage (frequently fatal)</td>
</tr>
<tr>
<td>50-100mA</td>
<td>Fibrillation Threshold (0.5%)</td>
<td>Heart action discoordinated (probably fatal)</td>
</tr>
<tr>
<td>100-200mA</td>
<td>Fibrillation Threshold (99.5%)</td>
<td></td>
</tr>
<tr>
<td>&gt;200mA</td>
<td>Tissue Burning</td>
<td>Non fatal unless vital organs are burned</td>
</tr>
</tbody>
</table>

## DC Current

<table>
<thead>
<tr>
<th>DC Current</th>
<th>Physiological Phenomena</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4 mA</td>
<td>Perception Threshold</td>
</tr>
<tr>
<td>4-15 mA</td>
<td>Surprise</td>
</tr>
<tr>
<td>15-80 mA</td>
<td>Reflex Action</td>
</tr>
<tr>
<td>80-160 mA</td>
<td>Muscular Inhibition</td>
</tr>
<tr>
<td>160-300 mA</td>
<td>Respiratory Failure</td>
</tr>
<tr>
<td>&gt;300 mA</td>
<td>Usually Fatal</td>
</tr>
</tbody>
</table>
Typical Human Resistor Values

<table>
<thead>
<tr>
<th>Current path</th>
<th>Resistance of body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand - hand</td>
<td>1000Ω</td>
</tr>
<tr>
<td>Hand – foot</td>
<td>750Ω</td>
</tr>
<tr>
<td>Hand – feet</td>
<td>500Ω</td>
</tr>
<tr>
<td>Hand - chest</td>
<td>450Ω</td>
</tr>
<tr>
<td>Hands - chest</td>
<td>230Ω</td>
</tr>
<tr>
<td>Hands - posterior</td>
<td>300Ω</td>
</tr>
</tbody>
</table>

Accidental contact with the HV battery of a hybrid car, a photovoltaic array, DC charging station. If the insulation is faulty, it is possible that the following current flows:
Hand – to – Hand

\[ I = \frac{E}{R} = \frac{288\text{V}}{1000\text{ohm}} = 0.288\text{A} = 288\text{mA} \]
First Aid

Some basic first aid practices

This section is not intended to replace first aid training
Immediate Response

Contact Release

• Shall be trained in methods of *safe release*
• Annual refresher requirement
First Aid Training

OSHA 1910.269 (b)

“When employees are performing work on or associated with exposed lines or equipment energized at 50 volts or more, persons trained in first aid including cardiopulmonary resuscitation (CPR) and (AED) shall be trained and available” AND anybody working inside the limited approach.

“At a fixed location (i.e. shop, plant, etc.), ensure that enough people are trained in first aid so that a victim can be reached within four minutes. At remote fixed locations where this may not be possible, then all of the individuals working must be first aid trained”
First Aid, Emergency Response, and Resuscitation.

(a) Employees responsible for responding to medical emergencies shall be trained in first aid and emergency procedures.

(b) Employees responsible for responding to medical emergencies shall be trained in cardiopulmonary resuscitation (CPR). Refresher training shall occur annually.

(c) Employees responsible for responding to medical emergencies shall be trained in the use of an automated external defibrillator (AED) if an employer’s emergency response plan includes the use of this device. Refresher training shall occur annually.

Training Verification.

Employers shall verify at least annually that employee training required by this section is current.

Documentation.

The employer shall document that the training required by this section has occurred.
Response to Electric Shock

**IMMEDIATE** - Confusion, amnesia, headache, breathing stops, heart stops, burn

**SECONDARY** - Paralysis, muscular pain, vision abnormalities, swelling, headache, and cardiac irregularities

**LONG RANGE** - Paralysis, speech/writing disorders, loss of taste, and other disorders as a result of nerve tissue damage
Electrical Burns

Most common shock-related, nonfatal injury

Occurs when you touch electrical wiring or equipment that is improperly used or maintained

Typically occurs on the hands

Very serious injury that needs immediate attention
Arc Flash

- An arc flash occurs when electrical current passes through air
- This most often occurs in power systems when:
  - Making or breaking a circuit
  - Bridging an insulating air gap with a more conductive object
- The heat generated can be devastating:
  - A fire usually burns at 800-1000 degrees
  - Steel melts at around 1,800 degrees
  - The surface of the sun is estimated to be about 7,000 degrees
  - An arc flash can be up to 36,000 degrees! That’s 20 times the temperature that steel melts and 5 times as hot as the sun!
- This extreme heat causes other hazards
Arc Flash Hazards

Heat – An arc flash can be up to 36,000 degrees

- FR clothing can minimize extent of burns
- FR clothing is available up to 100 Cal/cm²

Ultraviolet (UV) light

- Can cause damage to retinas, possible causing blindness
- Coating on eye protection is designed to filter out some of the UV light
Arc Flash Hazards

Pressure

- When copper vaporizes it expands to 67,000 times the volume of solid copper.

- The air in the vicinity of the arc is heated and expands rapidly.

- A study conducted by Dr. Ralph Lee revealed that a 10kV – 100kA arc created a pressure of 400 lbs/ft² at a distance of 3.3 feet! This is about 10 times the pressure a conventional wall is built to withstand so such an arc could destroy a conventional wall from 40 feet away!
Arc Flash Event 10-15-2012

Circumstance:
A Facility associate was changing a breaker in a 480 volt MCC panel. When connecting the wire to the lug, the energized line wire grounded causing an arc blast / flash. Panel was identified as a HRC 2.

The associate sustained no injury due to following electrical safety work practices. DMAT’s training and foresight prevented a serious injury during high risk work.

PPE Used and Identified on the panel label
- Class 00 gloves with outer leather protectors
- Cotton undershirt
- Cotton long sleeve shirt
- FR HRC rated outer clothing
- Cotton pants
- Ear plugs
- Hard hat with arc flash shield.
Flash Hazard Analysis

There are several methods used to determine the incident energy of an arc flash event:

- Use the tables from the NFPA 70E (Recently Updated)
  - The tables have limitations (Notes section)
  - They make several assumptions
  - Best used as a temporary solution
  - ‘in lieu of’

- Use the NFPA 70E equations (Lee method)
  - Simple, can be done by hand using a calculator
  - Spread Sheet

- Use the IEEE 1584 equations
  - Most accurate method, but very complicated

- Purchase a software suite (SKM, ETAP, EasyPower, to name a few)
  - Very expensive but easy to use

- Contract someone else to do it
  - Probably the best solution for smaller companies
### Table 130.7(C)(15)(A)(a) Arc Flash Hazard Identification for Alternating Current (ac) and Direct Current (dc) Systems

<table>
<thead>
<tr>
<th>Task</th>
<th>Equipment Condition*</th>
<th>Arc Flash PPE Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading a panel meter while operating a meter switch</td>
<td>Any</td>
<td>No</td>
</tr>
</tbody>
</table>
| Normal operation of a circuit breaker (CB), switch, contactor, or starter | All of the following:  
The equipment is properly installed  
The equipment is properly maintained  
All equipment doors are closed and secured  
All equipment covers are in place and secured  
There is no evidence of impending failure  
One or more of the following:  
The equipment is not properly installed  
The equipment is not properly maintained  
Equipment doors are open or not secured  
Equipment covers are off or not secured  
There is evidence of impending failure | No/Yes |
| For ac systems: Work on energized electrical conductors and circuit parts, including voltage testing | Any                                                                            | Yes                    |
| For dc systems: Work on energized electrical conductors and circuit parts of series-connected battery cells, including voltage testing | Any                                                                            | Yes                    |
| Voltage testing on individual battery cells or individual multi-cell units | All of the following:  
The equipment is properly installed  
The equipment is properly maintained  
Covers for all other equipment are in place and secured  
There is no evidence of impending failure  
One or more of the following: | No/Yes |
Electrical equipment such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling units and that are likely to require examination, adjustment, servicing, or maintenance while energized shall be field-marked with a label containing all the following information:

1. Nominal system voltage
2. Arc flash boundary
3. At least one of the following:
   - Available incident energy and the corresponding working distance, or the arc flash PPE category in Table 130.7(C)(15)(A)(b) or Table 130.7(C)(15)(B) for the equipment, but not both
   - Minimum arc rating of clothing
   - Site-specific level of PPE
NFPA 70E 2012

‘...shall be field marked, with all label containing... all the following’

At least one of the following:
- Incident Energy & Working Distance
- Clothing HRC Rating
- Required PPE
- Highest Equipment HRC

Nominal System Voltage

Arc Flash Boundary

NEC REQUIREMENTS FOR LABELING
Personal Protective Equipment
Personal Protective Equipment

Shock Protection

- Exposed, Energized Electrical Conductor or Circuit Part
- Prohibited Approach
- Restricted Approach
- Limited Approach
Personal Protective Equipment

Flash Protection
Arc Thermal Performance Value (ATPV) is defined as the arc incident energy required to cause the onset of second-degree burn and is represented in cal/cm². This rating is the result of a testing procedure (ASTM F-1959) that measures the amount of thermal protection a FR fabric would give a wearer if the person were exposed to an electric arc.

Alternatively, the material may have an EBT (Energy Break-open Threshold) rating. EBT is defined as the average of the 5 highest incident energy exposure values below the Stoll curve where the specimen did not exhibit break-open. EBT is reported when ATPV cannot be measured due to FR fabric break open.
## Typical Protective Clothing

### Basic Electrical PPE Category – 0

<table>
<thead>
<tr>
<th>Protective Clothing – Nonmelting or Untreated Natural Fibers =&gt; 4.5 oz/yd²</th>
<th>Shirt - Long Sleeve Pants – Long</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR Protective Equipment</td>
<td>Safety Glasses Hearing Protection – Ear Canal Insert Leather Gloves – (AN)</td>
</tr>
<tr>
<td>PPE Level</td>
<td>0 to 1.2 Cal / cm²</td>
</tr>
</tbody>
</table>
Typical Protective Clothing

<table>
<thead>
<tr>
<th>Hazard Risk Category – 2</th>
</tr>
</thead>
</table>
| **FR Minimum Arc Rating of 8** | **Arc Rated Long Sleeve Shirt**  
**Arc Rated Pants**  
**Arc Rated Coverall**  
**Arc Rated Face Shield and Balacava**  
**Arc Flash Suit Hood**  
**Arc Rated Jacket, Parka or Rainwear (AN)** |
| **FR Protective Equipment** | **Hard Hat**  
**Safety Glasses or Safety Goggles (SR)**  
**Hearing Protection (Ear Canal Inserts)**  
**Leather Gloves**  
**Leather Work Shoes** |
## Typical Protective Clothing

### Hazard Risk Category – 4

| FR Minimum Arc Rating of 40 (Note 1) | Arc Rated Long Sleeve Shirt (AR) (Note 9)  
|                                      | Arc Rated Pants (AR) (Note 9)  
|                                      | Arc Rated Coverall (AR) (Note 9)  
|                                      | Arc Rated Flash Suit Jacket (AR) (Note 9)  
|                                      | Arc Rated Flash Suit Pants (AR) (Note 9)  
|                                      | Arc Rated Flash Suit Hood (Note 9)  
|                                      | Arc Rated Jacket, Parka or Rainwear (AN) |

| FR Protective Equipment | Hard Hat  
|                        | FR Hard Hat Liner (AR)  
|                        | Safety Glasses or Safety Goggles (SR)  
|                        | Hearing Protection (Ear Canal Inserts)  
|                        | Arc Rated Gloves (Note 2)  
|                        | Leather Work Shoes |
Employees shall wear rubber insulating gloves where there is a danger of arm and hand injury from electrical shock and burns due to contact with live parts.

Gloves used shall be of the appropriate voltage class.
Glove selection

Glove size is important to ensure a proper fit and dexterity

Size is inches around the palm of your hand

Leather Protectors:
- Required for penetration protection
- *If gloves used without, then must be re-tested prior to next use*
<table>
<thead>
<tr>
<th>Class Color</th>
<th>Proof Test Voltage AC / DC</th>
<th>Max. Use Voltage AC / DC</th>
<th>Rubber Molded Products Label</th>
<th>Insulating Rubber Glove Label</th>
<th>Insulating Rubber Dipped Sleeve Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 Beige</td>
<td>2,500 / 10,000</td>
<td>500 / 750</td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>0 Red</td>
<td>5,000 / 20,000</td>
<td>1,000 / 1,500</td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>1 White</td>
<td>10,000 / 40,000</td>
<td>7,500 / 11,250</td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>2 Yellow</td>
<td>20,000 / 50,000</td>
<td>17,000 / 25,500</td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>3 Green</td>
<td>30,000 / 60,000</td>
<td>26,500 / 39,750</td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>4 Orange</td>
<td>40,000 / 70,000</td>
<td>36,000 / 54,000</td>
<td></td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
Glove Testing

Gloves are required to be lab tested:
- Prior to first use
- Every six months
- Prior to next use if used without protectors

The tests include:
  ◦ Dielectric test at voltage on previous chart
  ◦ Air test
  ◦ Cleaning
  ◦ Visual inspection

(Courtesy Reed City Power Line)
Glove inspection

Gloves shall be inspected prior to each use

The inspection should include:

Visual inspection checking for:

• Cracks
• Punctures
• Ozone damage
• Snags
• Embedded material
Digital measuring instrument

Display
The Display shows the digital digits and the unit.

Control Keys
Setup, save measurement results, etc.

Selector switch for adjusting the measuring method

Connectors
- Voltage measurement
- Resistance measurement
- Continuity test

A
Current > 1A

mA μA
Current < 1A

COM
Reference Ground

V Ω
Voltage measurement
Resistor measurement
Continuity test
Electrical test equipment Inspection

- Visually check meter for:
  - UL listed (or equivalent)
    - Double insulated

Probes should be inspected for:
- Shrouded connectors, finger guards
- Insulation not melted, cut, cracked, etc.
- Probe tips: not loose or broken off
Finally, ensure the meter and leads are rated for the installation category you will be working in.
Hot stick / Shotguns

Insulated tools for working on energized parts
Wood PVC or fiberglass

Inspected for:
- Integrity
- Cleanliness
- Insulation

Tested every 2 years if primary means of protection
Job Brief

Before starting each job, the employee in charge shall conduct a job briefing with the employees involved.

Documented Job Briefs

- Energized Work Permit
- Complex LOTO
- Contractors onsite

The briefing shall cover such subjects as:

- Hazards associated with the job
- Work procedures involved
- Special precautions
- Energy source controls
- Personal Protective Equipment Requirements
There are three forms of hazardous energy control:

- Individual employee control
  (Removed By Amendment To The OSHA Act)
  - Ex-Clean/Inspect
  - No lock required if disconnect is visible
- Simple lockout/tagout
  - Qualified person performing lockout for sole purpose of work
  - Not required to be written for each application
- Complex lockout/tagout
  - Written plan
  - Designated person in charge
  - Documented Job Brief
Energized Electrical Work Permit

**Justification**
- Per Table 130.2(C)
- Per Table 130.7(C)(10)
- Per Table 130.7(C)(9)(a)
- Per Table 130.2(C)

2 Qualified persons must agree it is safe

**Authorization**
2015 LIMITS OF APPROACH
## NFPA 70E Approach Boundaries

From NFPA 70E (2012) 130.4

### Alternating Current (AC) Shock Protection Boundaries

<table>
<thead>
<tr>
<th>Voltage Range</th>
<th>Limited</th>
<th>Movable</th>
<th>Fixed</th>
<th>Restricted</th>
<th>Prohibited</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-50 VAC</td>
<td>Not Specified</td>
<td>Not Specified</td>
<td>Not Specified</td>
<td>Not Specified</td>
<td></td>
</tr>
<tr>
<td>51-300 VAC</td>
<td>10’0”</td>
<td>3’6”</td>
<td>Avoid Contact</td>
<td>Avoid Contact</td>
<td></td>
</tr>
<tr>
<td>301-750 VAC</td>
<td>10’0”</td>
<td>3’6”</td>
<td>12”</td>
<td>1”</td>
<td></td>
</tr>
</tbody>
</table>

### Direct Current (DC) Shock Protection Boundaries

<table>
<thead>
<tr>
<th>Voltage Range</th>
<th>Limited</th>
<th>Movable</th>
<th>Fixed</th>
<th>Restricted</th>
<th>Prohibited</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-100 VDC</td>
<td>Not Specified</td>
<td>Not Specified</td>
<td>Not Specified</td>
<td>Not Specified</td>
<td></td>
</tr>
<tr>
<td>100-300 VDC</td>
<td>10’0”</td>
<td>3’6”</td>
<td>Avoid Contact</td>
<td>Avoid Contact</td>
<td></td>
</tr>
<tr>
<td>301-1000 VCD</td>
<td>10’0”</td>
<td>3’6”</td>
<td>12”</td>
<td>1”</td>
<td></td>
</tr>
</tbody>
</table>
Trained and competent
You are not 10 foot tall and bulletproof!
There is no substitute for experience
BE SAFE!!!
National Safety Technology

Kevin D. Reside
National Safety Director / Arc Flash Specialist

BOX 381
Walled Lake, MI 48390

248-757-0627 (P)
248-598-1861 (F)
248-461-7070 (C)
517-6-SAFETY (P)
877-711-5409

kreside@national-safety.net
www.national-safety.net

US NAVY RETIRED - Disabled Veteran Owned