Electrical Safety & Arc Flash Awareness

DYMAX ENGINEERING

Presented By Rick Edel
Need for Electrical Safety

- **PERSONAL SAFETY** is of the utmost concern.

- Preventing personnel from being exposed to electricity in an uncontrolled manner, which can result in injury or death

- Personal safety is easily achievable by following a few simple guidelines
  - Developing Safety awareness
  - Paying constant attention to detail
  - **COMMON SENSE** and **ATTENTION** to detail are **MANDATORY**
Introduction

- This class is designed for those individuals and their supervisors who are required to:
  - Operate or maintain electrical distribution equipment, or who
  - Work **ON** or **NEAR** exposed electrical components of **50 Volts** or higher
A survey of 1,200 electricians found:

- 97% of respondents had experienced a shock at work
- 26% had witnessed an injury
- 58% were exposed to the possibility of an injury everyday
Objectives

- State the need for electrical safety
- Describe the effects of electrical shock on the human body
- Identify the components and effects of an Electrical Arc
- Determine the correct Personal Protective Equipment (PPE) required
“Qualified” Person – OSHA
1910.33(b)(3) (Expanded Definition)

- Trained and knowledgeable in the construction and operation of equipment or specific work method
- Able to recognize and avoid electrical hazards
- May be qualified with respect to certain equipment and methods but unqualified for others
“Qualified” Person – OSHA
Expanded Definition (cont.)

- Is thoroughly familiar with company’s electrical safe work practices
- Intends to implement them

**Exceptions:**
- Encounters specific duties in the course of on-the-job training
- A qualified person is observing and directing the person performing the work
WHY DO WE ALL NEED ELECTRICAL SAFETY
SAFETY CIRCLE

These All Compliment Each Other
Safety concerns three different areas:

- Protection of life
- Protection of equipment
- Prevention of power interruption
Electrical Safety Statistics

- Average of **4,000** non-disabling and **3,600** disabling electrical contact injuries annually in the United States.
- One person is electrocuted in the workplace every day.
- Electrocutions were the **Fourth** leading cause of traumatic occupational fatalities.
- Over **2000** workers a year are sent to burn centers with electrical-related burn injuries.
- About **8000** electrical contact injuries referred to emergency rooms annually in the United States.

Electrical Safety Statistics (cont.)

Electrocutions by Age, 1982-1994

Percent of workers Electrocuted

Age of Workers

0% 5% 10% 15% 20% 25% 30% 35%

16-19 20-24 25-34 35-44 45-54 55-64 65+
Experienced maintenance personnel and supervisors had a larger proportion of injuries; less experienced laborers also had more injuries.
A greater proportion of injuries occurred six or more hours into shift (32%)
Types of Electrical Hazards

- Electrical Shock
  - Electrocution
  - Internal and external burns

- Arc Flash
  - Potentially severe external burns

- Arc Blast
  - Pressure and sound waves
  - Shrapnel (in excess of 700 MPH)
Effects of Electric Shock

- Electricity flowing through the human body can:
  - Cause involuntary muscle reaction
  - Paralyze muscles
  - Burn tissues
  - Burn organs
Effects of Electrical Shock (cont.)

- A major factor of concern is the frequency of the current
- Most dangerous AC current frequencies are around 50 to 100 hertz (cycles)
- Results in ventricular fibrillation
- More severe burns occur above 200 hertz
- DC currents have a clamping and burning effect
- Know the factors that affect the severity of electrical shock
- Use rubber-insulating materials
Effects of Electrical Shock (cont.)

- Work with one hand as much as possible keeping the other insulated
- Try to prevent a path for the current through the chest
- Higher voltage also has an effect
- Above about 600 volts
- Resistance of skin ceases to exist
- Only resistance is internals of the body
- Above 2400 volts, burning is the major effect
- Duration of contact determines the severity
### Effects of Electric Current on the Human Body

<table>
<thead>
<tr>
<th>Effect/Feeling</th>
<th>Current (Amps)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150lbs</td>
<td>115lbs</td>
<td>150lbs</td>
<td>115lbs</td>
<td>150lbs</td>
<td>115lbs</td>
<td></td>
</tr>
<tr>
<td><strong>Alternating Current</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>60 Hz</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slight sensation on hand</td>
<td>.0004</td>
<td>.0003</td>
<td>.007</td>
<td>.005</td>
<td>.001</td>
<td>.0006</td>
<td></td>
</tr>
<tr>
<td>Perception threshold</td>
<td>.0011</td>
<td>.0007</td>
<td>.012</td>
<td>.008</td>
<td>.0062</td>
<td>.0035</td>
<td></td>
</tr>
<tr>
<td>Shock – not painful and no loss of muscular control</td>
<td>.0018</td>
<td>.0012</td>
<td>.017</td>
<td>.011</td>
<td>.009</td>
<td>.006</td>
<td></td>
</tr>
<tr>
<td>Painful shock – muscular control may be lost</td>
<td>.009</td>
<td>.006</td>
<td>.055</td>
<td>.037</td>
<td>.062</td>
<td>.041</td>
<td></td>
</tr>
<tr>
<td>Painful shock – “let go” threshold, possibly fatal</td>
<td>.016</td>
<td>.0105</td>
<td>.075</td>
<td>.050</td>
<td>.076</td>
<td>.051</td>
<td></td>
</tr>
<tr>
<td>Painful and severe shock – breathing difficult, muscular control lost, frequently fatal</td>
<td>.023</td>
<td>.015</td>
<td>.094</td>
<td>.063</td>
<td>.090</td>
<td>.060</td>
<td></td>
</tr>
<tr>
<td>Respiratory arrest – frequently fatal</td>
<td>.030</td>
<td>.019</td>
<td>.018</td>
<td>.095</td>
<td>.179</td>
<td>.19</td>
<td></td>
</tr>
<tr>
<td>Ventricular fibrillation – probably fatal</td>
<td>.1</td>
<td>.067</td>
<td>.5</td>
<td>.34</td>
<td>.5</td>
<td>.37</td>
<td></td>
</tr>
</tbody>
</table>
Effects of Electrical Shock (cont.)

REMEMBER

More fatalities occur from **120 Volts** than from any other voltage!
Shock & Arc Flash Approach Boundaries

- **NFPA 70E – 2009 Standard for Electrical Safety in the Workplace**
  - Sets the requirements for safe work Practices
  - Establishes the requirements for:
    - Shock and arc flash boundaries
    - Incident energy
    - Flash boundary calculations
    - Requirements for personal protective equipment (PPE)
Limits of Approach

- Flash protection boundary
- Limited approach boundary
- Limited space
- Any point on an exposed, energized electrical conductor or circuit part
- Restricted approach boundary
- Restricted space
- Prohibited approach boundary
- Prohibited space
Approach Boundaries

- **Limited Approach Boundary:** Qualified or Unqualified* Persons
  * Only if accompanied by Qualified Person

- **Prohibited Approach Boundary:**
  - Qualified Persons Only
  - PPE as if direct contact with live part

- **Restricted Approach Boundary:**
  - Qualified Persons Only

- **Limited Approach Boundary:**
  - Qualified or Unqualified* Persons
  * Only if accompanied by Qualified Person

- **Flash Protection Boundary (FPB):** Must wear appropriate PPE
  FPB dependent on fault level and time duration.

**WARNING!!** The Flash Protection Boundary may be greater or less than the Shock Approach Boundary.
Shock Approach Boundaries

- Limited Approach Boundary
- Restricted Approach Boundary
- Prohibited Approach Boundary
- All are dependent on the **Voltage** to which a person will be exposed.
<table>
<thead>
<tr>
<th>Limited Approach Boundary Distance (L)</th>
<th>Nominal System Voltage (Phase to Phase)</th>
<th>&lt;300</th>
<th>300-750</th>
<th>750-2k</th>
<th>2k-15k</th>
</tr>
</thead>
<tbody>
<tr>
<td>From a Fixed Conductor</td>
<td></td>
<td>3’ 6”</td>
<td>3’ 6”</td>
<td>4’ 0”</td>
<td>5’ 0”</td>
</tr>
<tr>
<td>From a Moveable Conductor</td>
<td></td>
<td>10’ 0”</td>
<td>10’ 0”</td>
<td>10’ 0”</td>
<td>10’ 0”</td>
</tr>
</tbody>
</table>

Unqualified individuals must stay **OUTSIDE** the Limited Approach Boundary
An approach limit at a distance from an exposed live part within which a shock hazard exists

Must be “Qualified” to perform the job/task to cross

Must use insulated tools

If voltage exceeds 750 volts:

Must have an assistant or

Be accompanied by another “Qualified” person
“Qualified” Person – OSHA Expanded Definition

- To work within the Limited Approach Boundary, must be trained to:
  - Distinguish exposed energized parts from other parts
  - Determine nominal voltage of exposed energized parts
  - Determine approach distances
  - Determine degree and extent of hazard and PPE required
Restricted Approach Boundary

- An approach limit at distance from an exposed live part within which there is increased risk of shock due electrical arc-over

<table>
<thead>
<tr>
<th>Nominal System Voltage (Phase to Phase)</th>
<th>&lt;300</th>
<th>300-750</th>
<th>750-2k</th>
<th>2k-15k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted Approach Boundary Dimension (R)</td>
<td>Avoid Contact</td>
<td>1’ 0”</td>
<td>2’ 0”</td>
<td>2’ 2”</td>
</tr>
</tbody>
</table>
To cross the Restricted Approach Boundary, qualified persons must:

- Have a plan that is documented and approved by authorized management
- Use appropriate personal protective equipment
- Be certain that no part of the body enters the prohibited space
Prohibited Approach Boundary

- An approach limit at a distance from an exposed live part within which work is considered the same as making contact with the live part.

<table>
<thead>
<tr>
<th>Nominal System Voltage (Phase to Phase)</th>
<th>&lt;300</th>
<th>300-750</th>
<th>750-2k</th>
<th>2k-15k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prohibited Approach Boundary Dimension (P)</td>
<td>Avoid Contact</td>
<td>0’ 1”</td>
<td>0’ 3”</td>
<td>0’ 7”</td>
</tr>
</tbody>
</table>
To cross the Prohibited Approach Boundary, qualified persons must:

- Have specialized training and experience to work on energized conductors
- Have a documented work plan approved by authorized management justifying the need to work that close.
- Use appropriate personal protective equipment
Two Types Of Major Electrical Faults

- Bolted Faults
- Arcing Faults
Bolted Faults

- Low impedance and high current
- Energy is contained by the conductor (bus or cable)
- Cleared quickly by circuit breakers or fuse
- Arcing is confined within the circuit breaker or fuse
- Usually no damage to equipment
- Relatively low safety risk to personnel
Arcing Faults

- High impedance (air) results in lower current
- Persist longer and propagate
- High release of heat and blast energy
- Are very destructive and dangerous to personnel
Causes Of Faults

What causes these types of faults?

Bolted faults (low impedance and high current)

- Commonly caused by
  - Improper connections after maintenance
  - Installation errors
Causes Of Faults

- Arc faults (high impedance, low current)
  - Commonly caused by
    - Careless cover or device removal
    - Foreign object (tool) dropped into equipment
    - Misalignment of moving contacts (parts failure)
    - Dirt contamination or dielectric breakdown
    - Entry of foreign body (rodent, snake, squirrel)
Characteristics Of Faults

- Arcing fault incident energy produced is
  - Greater at higher bolted fault current levels
  - Reduced by dynamic impedance (air)
  - And increased by the time duration of the arc
Characteristics Of Faults

- The most controllable factor in reducing the incident energy is time.
- Current flow in an arcing fault is approximately half that of the bolted fault current (impedance of air).
- Fuses or circuit breakers are the first line of defense in reducing arcing fault incident energy.
- Calculating arc fault incident energy is a very complex engineering task.
An Arcing Fault
Electrical Arcs

- One of the hottest things on earth
- Kills up to 8 feet, burns up to 20 feet
- Size of arc is independent of voltage
- Amount of short circuit current available determines size of arc
- Responsible for about 75% of all industrial electrical injuries
- **Arcs on low voltage systems can be just as dangerous as arcs on medium & high voltage systems**
Components of Electrical Arcs

- Copper Vapor: Solid to Vapor Expands by 67,000 times
- Molten Metal
- Pressure Waves
- Sound Waves
- Shrapnel
- Hot Air-Rapid Expansion
- Intense Light
- 35,000 °F
Components of an Electric Arc

- Temperature of the arc
- Intense Light
- Pressure Waves
- Sound Waves
- Shrapnel
- Molten Metal
- Hot Air – Rapid Expansion
Arc Flash Hazard
Arc Flash Hazard

- A dangerous condition associated with the release of energy caused by an electric arc
- Arc flash / blasts occur extremely quickly
- Arc flash / blasts are normally initiated by a person
- Changes material into a vapor
- Releases energy in the form of light, heat, sound, and UV radiation
- Can cause serious injury to individuals close to the source of the fault not wearing proper PPE
- Damage is a function of Incident Energy density which is a function of the distance from the source
Some Temperature Data

- Temperature at arc terminals: 35,000° F
- Temperature of sun’s surface: 9,000° F
- Temperature of metal droplets: 1,800° F
- Curable burn temperature: 145° F
- Temperature of burning clothing: 1,400° F
- Clothing ignition temp.: 700° F to 1,400° F
- Cell death temperature (0.1 sec): 200° F
Arc Flash Simulation

- 480 Volt System
- 22,600 Amp Symmetrical Fault
- Motor Controller Enclosure
- 6-Cycle Arcing Fault (0.1 sec)
What are the hazards as you approach electrical equipment to perform work?
Intense light and heat
Debris and Molten Metal
Wireway cover hits worker
Intense smoke and flames
NFPA 70E - 2009

- Standard for Electrical Safety in the Workplace

- Addresses hazards:
  - Shock
  - Arc Flash

- Does not assess blast hazard

- Requirements for shock and arc flash boundaries

- Incident Energy and flash boundary calculations

- Requirements for personal protective equipment (PPE)
Arc Flash Hazard Analysis

- **NFPA 70E – ARTICLE 130.3**
  - A flash hazard analysis shall be done in order to protect personnel from the possibility of being injured by an arc flash.
  - Shall determine the Flash Protection Boundary and the Personal Protective Equipment (PPE) required.
  - Calculations can be performed using equations contained in:
    - NFPA 70E “Standard for Electrical Safety in the Workplace” or
    - IEEE-1584 “IEEE Guide For Performing Arc-Flash Hazard Calculations”
Arc Flash Hazard Analysis (cont.)

- Determines Trip Time for Each Protective Device based on Arcing Fault Current (Based on Maintained Equipment)
- Calculates Incident Energy at Working Distance
- Calculates Arc Flash Boundary
- Determines Required PPE
- Is Used to Generate Warning Labels
Flash Hazard Analysis Example

- A low-voltage power circuit breaker had not been operated or maintained for several years
  - The lubrication had become sticky or hardened
  - Circuit breaker could take several additional cycles, seconds, minutes, or longer to clear a fault condition

- Flash hazard analysis is performed
  - Based on what the system is supposed to do – 5 cycles (.08 seconds) clearing time
  - Unintentional time delay, due to sticky mechanism
  - Breaker clears in 30 cycles (.5 seconds)
Flash Hazard Analysis Example

- **Arc/Flash situation**
  - 20,000-amp short-circuit
  - 480 volts
  - 3-inch arch gap
  - The worker is 18 inches from the arc
  - With a 5 cycle clearing time for a 3-phase arc, incident energy is **3.79 cal/cm²** – **Category 2**

- Due to a sticky mechanism, with a 30 cycle clearing time
  - Incident energy is **38.64 cal/cm²** – **Category 4**

- The worker could be seriously injured because he/she was under protected

- Most common cause of opening delay
  - Improper lubrication of circuit breakers

- Maintenance is extremely important to an electrical safety program
Flash Protection Boundary

- Distance at which the need for Flame Resistant (FR) clothing and Personal Protective Equipment (PPE) is required

- This requirement applies to ANY person within the Flash Protection Boundary (FPB)

- The FPB is the distance at which the exposure or incident energy equals 1.2 calories / cm²

- The FPB and FR required are either taken from NFPA 70E or calculated.
WARNING
Arc Flash and Shock Hazard
Appropriate PPE Required

34 inch Flash Hazard Boundary
3.46 cal/cm² Flash Hazard at 18 inches

Class 1 VR Gloves-Tools, Proper Clothes, Safety Glasses, Hardhat

480 VAC Shock Hazard when cover is removed

42 inch Limited Approach
12 inch Restricted Approach
1 inch Prohibited Approach

Flash Boundary – 4 ft. or calculated

Bus Name: PP-MCC-G81, Prot Device: PP-PDP-G71-6

Warning label provides boundary information
For systems that are 600 volts or less the Flash Protection Boundary shall be **4.0 ft**

- Based on available bolted fault current not exceeding 300 kA cycles (5000 ampere seconds)

- Otherwise the Flash Protection Boundary shall be calculated

- **WARNING!!** The Flash Protection Boundary may be greater or less than the Shock Approach Boundary
Where it has been determined that work will be performed within the flash protection boundary:

- The flash hazard analysis shall determine
- And the employer shall document
- The **Incident Energy** exposure of the worker
Incident Energy (cont.)

NFPA 70E – 2009 defines incident energy as:

The amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. One of the units used to measure incident energy is calories per centimeter squared (cal/cm$^2$)
This incident energy exposure level shall be based on the **Working distance of the employee’s face and chest areas** from a prospective arc source for the specific task to be performed.
1.2 cal/cm² - Second Degree Burn (Just Curable)

3 cal/cm² - 1% probability ignition of light weight cotton shirt.

4 cal/cm² - FR (Fire Rated) shirt and FR pants or FR coverall

8 cal/cm² - Cotton underwear plus FR shirt and FR pants

40 cal/cm² - Cotton underwear plus FR shirt and FR pants plus multi-layer flash suit
Warning Labels

- **NEC® 2005 110.16 Flash Protection.** Switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers 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.

- FPN No. 1: NFPA 70E-2004, *Electrical Safety Requirements for Employee Workplaces*, provides assistance in determining severity of potential exposure, planning safe work practices, and selecting personal protective equipment.

Example of a Warning Label

![Warning Label Image]

**WARNING**

Arc Flash and Shock Hazard
Appropriate PPE Required

**FLASH PROTECTION**

- Flash Hazard at 18 inches
- Min. Arc Rating: 6.92 cal/cm^2
- Flash Protection Boundary: 52 inch
- Glove Class: 00
- Clothing Category: Category 2
  - FR shirt & pants, hard hat, safety glasses, face shield, earplugs, leather gloves & shoes

**SHOCK PROTECTION**

- Shock Hazard when cover is removed 480 VAC
- Limited Approach 42 inch
- Restricted Approach 12 inch
- Prohibited Approach 1 inch

FG-M110

March 02, 2006
Burns

- Burns suffered in electrical accidents are of three basic types:
  - Electrical Burns
  - Arc Burns
  - Thermal Contact Burns
Burns (cont.)

- **Electrical Burns**
  - Tissue damage (whether skin deep or deeper)
  - Body is unable to dissipate heat
  - Electrical burns are slow to heal

- **Arc Burns**
  - Similar to heat burns from high temperature sources
  - Can burn flesh
  - Can ignite clothing at distances of 10 feet or more
**Thermal contact burns**

- Caused by skin contact with the hot surfaces of overheated equipment
- Check for overheating with a non-contact infrared thermometer
- The human body survives in a narrow temperature range around **98.6°F**
- At **110°F**, body’s temperature equilibrium breaks down in about 6 hours
- Total cell destruction at **158°F** for 1 sec.
- “Second degree” 176 skin temp for .1 sec.
- Incurable “third degree” burn at **200°F** for more than one tenth (1/10th) of a sec.
Burns (cont.)

Clothed areas can be burned more severely than exposed skin.

So, the message is:

Wear clothing that won’t catch fire!
A typical way that a person would get 75% of their body burnt is when their clothing ignites.

Source: American Burn Association (1991-1993 Study)
Arc Blast

- Can be great enough to hurl people or objects considerable distances
- Can cause falls and other injuries
- Can be damaging to human ears
  - *Eardrum Rupture Threshold: 720 lbs/ft²*
  - *Lung Damage Threshold: 1728 – 2160 lbs/ft²*
Arc Blast (cont.)

- Comes from:
- Near instantaneous expansion of air by arcs passing through it at 35,000° F
- Expansion of vaporized conductors
- Copper expands by a factor of 67,000 times in vaporizing
- Sound levels have been documented above 165 db during arc blast tests
- Almost twice the acceptable daily exposure level
Arc Blast (cont.)
Arc Blast (cont.)
Arc Blast (cont.)
Arc Blast (cont.)
Shock-Arc-Blast Summary

- Each has its own unique characteristics
- Each requires special protective measures
- Best way to avoid exposure to these hazards

!!! DON’T DO HOT WORK !!!
Shock-Arc-Blast Summary

- More fatalities occur from 120 volts than any other voltage
- The following can increase safety and decrease injuries and fatalities:
  - Knowledge of CPR and first aid
  - Proper use of PPE
  - Qualified Personnel
  - Limiting access to electrical equipment
Determine the Appropriate PPE
Items **NOT** to be worn

- Conductive jewelry and clothing such as:
  - Watchbands, bracelets, rings, necklaces, metallized aprons
  - Clothes with conductive threads
  - Metal headgear
  - Unrestrained metal glasses
  - Etc.
Personal Clothing

- Wear long sleeve natural fiber (cotton or wool) clothing or flame-resistant (FR) clothing

- The following are appropriate types of PPE where needed
  - Non-melting or untreated natural fiber clothing
  - Flame Resistant (FR) clothing
  - Do Not wear synthetic fiber clothing
  - Untreated synthetic fabrics can melt into the body or ignite
  - Data shows that ignition of clothing is a major component of burn injuries
  - Flammable clothing ignition almost always results in 3rd degree (incurable) burns
Personal Clothing (cont.)

- Safety glasses or goggles
- Arc-rated face shield
- Leather work shoes
- Leather gloves
- Hard hats (Class E)
- Hearing protection
- Flash suit jacket, pants, and hood
How Flame-Resistant (FR) Clothing Provides Protection

- Does not ignite & burn or drip
- Resists break-open
- Maintains a barrier to isolate the worker from the thermal exposure
- Traps air between the worker and the barrier to provide additional insulation from the exposure
- Reduces burn injury
- Increases survivability
- Helps preserve the quality of life
Manufacturer & manufacturer tracking code

Care Instructions

Fabric fiber content

Garment size

Meets F1506 Fire Retardant Standards

Lists ATPV (Arc Thermal Performance Value) in calories per square centimeter
Hazard/Risk Category 0

| Protective Clothing, Nonmelting (according to ASTM F 1506-00) or Untreated Natural Fiber | Shirt (long sleeve) |
|FR Protective Equipment| Pants (long) |
| | Safety glasses or safety goggles (SR) |
| | Hearing protection (ear canal inserts) |
| | Leather gloves (AN) (Note 2) |

2. If rubber insulating gloves with leather protectors are required by Table 130.7(C)(9), additional leather or arc-rated gloves are not required. The combination of rubber insulating gloves with leather protectors satisfies the arc flash protection requirement.
### Hazard/Risk Category 1

<table>
<thead>
<tr>
<th>FR Protective Equipment</th>
<th>Arc-rated long-sleeve shirt (Note 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR Clothing, Minimum Arc Rating of 4 (Note 1)</td>
<td>Arc-rated pants (Note 3)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated coverall (Note 4)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated face shield or arc flash suit hood (Note 7)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated jacket, parka, or rainwear (AN)</td>
</tr>
<tr>
<td></td>
<td>Hard hat</td>
</tr>
<tr>
<td></td>
<td>Safety glasses or safety goggles (SR)</td>
</tr>
<tr>
<td></td>
<td>Hearing protection (ear canal inserts)</td>
</tr>
<tr>
<td></td>
<td>Leather gloves (Note 2)</td>
</tr>
<tr>
<td></td>
<td>Leather work shoes (AN)</td>
</tr>
</tbody>
</table>

2. If rubber insulating gloves with leather protectors are required by Table 130.7(C)(9), additional leather or arc-rated gloves are not required. The combination of rubber insulating gloves with leather protectors satisfies the arc flash protection requirement.

3. The FR shirt and pants used for Hazard/Risk Category 1 shall have a minimum arc rating of 4.

4. Alternate is to use FR coveralls (minimum arc rating of 4) instead of FR shirt and FR pants.

7. A face shield with a minimum arc rating of 4 for Hazard/Risk Category 1 or a minimum arc rating of 8 for Hazard/Risk Category 2, with wrap-around guarding to protect not only the face, but also the forehead, ears, and neck (or, alternatively, an arc-rated arc flash suit hood), is required.
## Personal Protective Equipment

### Hazard/Risk Category 2

| FR Clothing, Minimum Arc Rating of 8 (Note 1) | Arc-rated long-sleeve shirt (Note 5) |
| FR Protective Equipment | Arc-rated pants (Note 5) |
| | Arc-rated coverall (Note 6) |
| | Arc-rated face shield or arc flash suit hood (Note 7) |
| | Arc rated jacket, parka, or rainwear (AN) |
| | Hard hat |
| | Safety glasses or safety goggles (SR) |
| | Hearing protection (ear canal inserts) |
| | Leather gloves (Note 2) |
| | Leather work shoes |

2. If rubber insulating gloves with leather protectors are required by Table 130.7(C)(9), additional leather or arc-rated gloves are not required. The combination of rubber insulating gloves with leather protectors satisfies the arc flash protection requirement.

5. FR shirt and FR pants used for Hazard/Risk Category 2 shall have a minimum arc rating of 8.

6. Alternate is to use FR coveralls (minimum arc rating of 8) instead of FR shirt and FR pants.

7. A face shield with a minimum arc rating of 4 for Hazard/Risk Category 1 or a minimum arc rating of 8 for Hazard/Risk Category 2, with wrap-around guarding to protect not only the face, but also the forehead, ears, and neck (or, alternatively, an arc-rated arc flash suit hood), is required.
### Hazard/Risk Category 2*

<table>
<thead>
<tr>
<th>FR Clothing, Minimum Arc Rating of 8 (Note 1)</th>
<th>Arc-rated long-sleeve shirt (Note 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arc-rated pants (Note 5)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated coverall (Note 6)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated arc flash suit hood (Note 10)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated jacket, parka, or rainwear (AN)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FR Protective Equipment</th>
<th>Hard hat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Safety glasses or safety goggles (SR)</td>
</tr>
<tr>
<td></td>
<td>Hearing protection (ear canal inserts)</td>
</tr>
<tr>
<td></td>
<td>Leather gloves (Note 2)</td>
</tr>
<tr>
<td></td>
<td>Leather work shoes</td>
</tr>
</tbody>
</table>

2. If rubber insulating gloves with leather protectors are required by Table 130.7(C)(9), additional leather or arc-rated gloves are not required. The combination of rubber insulating gloves with leather protectors satisfies the arc flash protection requirement.

5. FR shirt and FR pants used for Hazard/Risk Category 2 shall have a minimum arc rating of 8.

6. Alternate is to use FR coveralls (minimum arc rating of 8) instead of FR shirt and FR pants.

10. Alternate is to use a face shield with a minimum arc rating of 8 and a balaclava (sock hood) with a minimum arc rating of 8 and which covers the face, head and neck except for the eye and nose areas.
## Personal Protective Equipment

### Hazard/Risk Category 3

<table>
<thead>
<tr>
<th>FR Clothing, Minimum Arc Rating of 25 (Note 1)</th>
<th>Arc-rated long-sleeve shirt (AR) (Note 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arc-rated pants (AR) (Note 8)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated coverall (AR) (Note 8)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated arc flash suit jacket (AR) (Note 8)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated arc flash suit pants (AR) (Note 8)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated arc flash suit hood (Note 8)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated jacket, parka, or rainwear (AN)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FR Protective Equipment</th>
<th>Hard hat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FR hard hat liner (AR)</td>
</tr>
<tr>
<td></td>
<td>Safety glasses or safety goggles (SR)</td>
</tr>
<tr>
<td></td>
<td>Hearing protection (ear canal inserts)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated gloves (Note 2)</td>
</tr>
<tr>
<td></td>
<td>Leather work shoes</td>
</tr>
</tbody>
</table>

2. If rubber insulating gloves with leather protectors are required by Table 130.7(C)(9), additional leather or arc-rated gloves are not required. The combination of rubber insulating gloves with leather protectors satisfies the arc flash protection requirement.

8. An alternate is to use a total FR clothing system and hood, which shall have a minimum arc rating of 25 for Hazard/Risk Category 3.
### Hazard/Risk Category 4

<table>
<thead>
<tr>
<th>Personal Protective Equipment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FR Clothing, Minimum Arc Rating of 40 (Note 1)</td>
<td></td>
</tr>
<tr>
<td>Arc-rated long-sleeve shirt (AR) (Note 9)</td>
<td></td>
</tr>
<tr>
<td>Arc-rated pants (AR) (Note 9)</td>
<td></td>
</tr>
<tr>
<td>Arc-rated coverall (AR) (Note 9)</td>
<td></td>
</tr>
<tr>
<td>Arc-rated arc flash suit jacket (AR) (Note 9)</td>
<td></td>
</tr>
<tr>
<td>Arc-rated arc flash suit pants (AR) (Note 9)</td>
<td></td>
</tr>
<tr>
<td>Arc-rated arc flash suit hood (Note 9)</td>
<td></td>
</tr>
<tr>
<td>Arc-rated jacket, parka, or rainwear (AN)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FR Protective Equipment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard hat</td>
<td></td>
</tr>
<tr>
<td>FR hard hat liner (AR)</td>
<td></td>
</tr>
<tr>
<td>Safety glasses or safety goggles (SR)</td>
<td></td>
</tr>
<tr>
<td>Hearing protection (ear canal inserts)</td>
<td></td>
</tr>
<tr>
<td>Arc-rated gloves (Note 2)</td>
<td></td>
</tr>
<tr>
<td>Leather work shoes</td>
<td></td>
</tr>
</tbody>
</table>

2. If rubber insulating gloves with leather protectors are required by Table 130.7(C)(9), additional leather or arc-rated gloves are not required. The combination of rubber insulating gloves with leather protectors satisfies the arc flash protection requirement.

9. The total clothing system consisting of FR shirt and pants and/or FR coveralls and/or arc flash coat and pants and hood shall have a minimum arc rating of 40 for Hazard/Risk Category 4.
Rubber Insulating Gloves, Sleeves, & Leather Protectors
# Rubber Insulating Gloves, Sleeves, & Leather Protectors

<table>
<thead>
<tr>
<th>Class</th>
<th>Color</th>
<th>Maximum use voltage phase-to-phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>Beige</td>
<td>500 V</td>
</tr>
<tr>
<td>0</td>
<td>Red</td>
<td>1,000 V</td>
</tr>
<tr>
<td>1</td>
<td>White</td>
<td>7,500 V</td>
</tr>
<tr>
<td>2</td>
<td>Yellow</td>
<td>17,000 V</td>
</tr>
<tr>
<td>3</td>
<td>Green</td>
<td>26,500 V</td>
</tr>
<tr>
<td>4</td>
<td>Orange</td>
<td>36,000 V</td>
</tr>
</tbody>
</table>

**NOTE:** It’s the color of the **Label** not the color or the glove itself!
**Rubber Insulating Gloves, Sleeves, & Leather Protectors (cont.)**

- **ALWAYS** wear leather protectors over your gloves

**WARNING** Do not wear leather Protectors alone

- **DO NOT** wear watches, rings, jewelry, or sharp objects while wearing rubber gloves or sleeves

- Rubber gloves should be longer than the end of the protector by at least 1” multiplied by the glove’s class number
Rubber Insulating Gloves, Sleeves, & Leather Protectors (cont.)

- For Class 00 and Class 0 gloves, the distance shall be not less than ½”
- **ALWAYS** keep the gauntlets up
- **ALWAYS** wear rubber gloves right side out (serial number and size to the outside)
- **ALWAYS** inspect gloves and sleeves at least once a day (more frequently if used without leather protectors)
- Inspections should be performed using the inspection procedures described in the latest edition of ASTM Standard F1236
Rubber Insulating Gloves, Sleeves, & Leather Protectors (cont.)

- **DO NOT** use rubber gloves or sleeves showing signs of:
  - Physical damage (punctures, cuts, abrasions)
  - Chemical deterioration (swelling, softness, stickiness)
  - Ozone deterioration or other irregularities

- **ALWAYS** check inside for any debris that may have fallen in

- Leather protectors must also be inspected when inspecting rubber gloves
Gloves must be electrically retested at least once every six (6) months as described in the most recent edition of ASTM Standard F496.

Sleeves must be electrically retested at least once every twelve (12) months.

Gloves have a twelve (12) month shelf life from the test date stamped on the glove.

Gloves can be used for six (6) months after being placed in service and then must be retested.
Insulated Hand Tools

When test instruments are used for the testing for the absence of voltage on conductors or circuit parts operating at 50 volts or more, the operation of the test instrument shall be verified before and after an absence of voltage test is performed.

- 70E 110.9(A)(4)
Tools shall be insulated to a rating higher than the voltage being worked on.

**DO NOT** assume that it is rated for use as an insulated device.

Some handles are covered only for comfort *NOT* for electrical safety.
When working inside the Limited Approach Boundary, use:

- Insulated tools and handling equipment
- Care to protect insulation on tools
- Insulated fuse-handling equipment to remove or install fuses
- Only non-conductive ropes and hand lines
Functions performed by one authorized person are usually confined to:

- Visual inspections
- Preventative maintenance on auxiliary equipment (battery cells).

All other functions require two or more persons present, at minimum.

- All switching operations require a spotter
- Located within sight but away from the affected area
When performing maintenance or switching operations

At least one of the personnel should have CPR training (Heart Saver Level)

When it is required to have unqualified personnel (security, building maintenance, etc.) in a substation

They should have received basic electrical safety awareness training

OR have their activities monitored by a qualified person.

Any entry into a substation usually requires an entry in the log book.
Summary

- Electrical accidents are usually attributable to unsafe or careless situations or acts

- Report unsafe conditions to safety coordinator or supervisor

- Avoiding electrical hazards requires common sense & attention to detail

- Hazards can be planned for, worked around, reduced or removed
Summary (cont.)

- Primary cause of accidents is carelessness
- Safety is everyone’s responsibility
- Report unsafe conditions
- Know and use proper safety measures
Ten Principles to Ensure Personal Safety

1. **Commitment** to safety
2. **Plan** every job
3. **Train for** unexpected events
4. **Be** aware
5. **Use** the right tool
Ten Principles to Ensure Personal Safety

6. **Use** procedures as tools

7. **Isolate** the equipment

8. **Identify** and minimize a hazard

9. **Protect** yourself

10. **ASK** questions
“Safety starts with Awareness”

“Awareness starts with YOU!”
Questions / Discussion