ABSTRACT

As more and more industry addresses arc flash electrical safety concerns, they are discovering high risk associated with what used to be normal maintenance tasks. In many cases, the excessively high arc flash incident energies make it so all maintenance must be done with equipment de-energized -- not always acceptable to the process industries. We will address the multiple ways to significantly lower arc flash incident energy exposure by new system design and products, retrofits, retrofits, equipment modifications, alternate protection settings, etc.

In most cases, NFPA 70E Hazard Risk Category 2 or lower can be obtained with the right methods. Several real world examples will be discussed.
Standards Covering Arc Flash

- National Fire Protection Agency (NFPA)
  - NFPA 70-2008 National Electric Code (NEC)
  - NFPA 70E-2009 Standard for Electrical Safety in the Workplace
- Occupational Safety and Health Administration (OSHA)
  - OSHA 29 CFR Part 1910
- Institute of Electrical and Electronics Engineers (IEEE)
  - 1584-2002 Guide for Performing Arc Flash Hazard Calculations

So...

What does each standard have to say about the Arc Flash Hazard?

NEC 2008 Edition

Section 110.16 Flash Protection

- Electrical equipment, such as switchboards, panelboards, 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 Arc Flash Label

Warning Sign

<table>
<thead>
<tr>
<th>DANGER</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELECTRIC ARC FLASH HAZARD</td>
</tr>
<tr>
<td>Will cause severe injury or death.</td>
</tr>
<tr>
<td>Turn OFF ALL power before opening. Follow ALL requirements in NFPA 70E for safe work practices and for Personal Protective Equipment.</td>
</tr>
</tbody>
</table>

NFPA 70E-2009

Article 100 Arc Flash Hazard

- A dangerous condition associated with the possible release of energy caused by an electric arc.
  - FPN No. 1: An arc flash hazard may exist when energized electrical conductors or circuit parts are exposed or when they are within equipment in a guarded or enclosed condition, provided a person is interacting with the equipment in such a manner that could cause an electric arc. Under normal operating conditions, enclosed energized equipment that has been properly installed and maintained is not likely to pose an arc flash hazard.
  - FPN No. 2: See Table 130.7(C)(9) for examples of activities that could pose an arc flash hazard.
  - FPN No. 3: See 130.3 for arc flash hazard analysis information

NFPA 70E-2009

130.3 Arc Flash Hazard Analysis

An arc flash hazard analysis shall determine the Arc Flash Protection Boundary and the personal protective equipment that people within the arc Flash Protection Boundary shall use.
Arc Flash Hazard Analysis and Labeling

**OSHA Code of Federal Regulations**

- 1910.269(l)(6)(i) – The employer shall train each employee who is exposed to the hazards of flames or electric arcs in the hazards involved.
- 1910.269(l)(6)(ii) – The employer shall ensure that each employee who is exposed to the hazards of flames or electric arcs does not wear clothing that, when exposed to flames or electric arcs, could increase the extent of injury that would be sustained by the employee.
- 1910.335(a)(1)(i) – Employees working in areas where there are potential electrical hazards shall be provided with, and shall use, electrical protective equipment that is appropriate for the specific parts of the body to be protected and for the work to be performed.

**IEEE C2-2007 (NESC)**

- **Section 41: Supply and communications systems**
  - General
    - The employer shall inform each employee working on or about communications equipment or electric supply equipment and the associated lines, of the safety rules governing the employee’s conduct while so engaged. When deemed necessary, the employer shall provide a copy of such rules.
    - The employer shall designate training to all employees who work in the vicinity of exposed energized circuits or apparatus that contain an energized portion, to ensure the employee has demonstrated proficiency in required tasks. The employer shall provide training to all employees who, as a result of the observance of work practices, are not following work rules.
    - Effective as of January 1, 2009, the employer shall perform an assessment to determine potential exposure to arc flash or arc flash-melting energy for employees who work on or near energized parts or equipment. If the assessment determines a potential employee exposure greater than 2.0 cal/cm² exists, the employer shall require employees to wear clothing or a clothing system that has an effective arc rating not less than the anticipated level of incident energy.

**IEEE 1584-2002**

- **1.1 Scope**
  - This guide provides techniques for designers and facility operators to apply in determining the arc-flash hazard distance and the incident energy to which employees could be exposed during their work on or near electrical equipment.
- **1.2 Purpose**
  - This guide presents methods for the calculation of arc-flash incident energy and arc-flash boundaries in three-phase ac systems to which workers may be exposed.
  - It covers the analysis process from field data collection to final results, presents the equations needed to find incident energy and the flash-protection boundary, and discusses software solution alternatives.
  - Applications cover an empirically derived model including enclosed equipment and open lines for voltages from 208 V to 15 kV, and a theoretically derived model applicable for any voltage.
  - Included with the standard are programs with embedded equations, which may be used to determine incident energy and the arc-flash-protection boundary.

**NFPA 70E 2009**

- **Arc Flash Hazard-Definition**
  - A dangerous condition associated with the possible release of energy caused by an electric arc.
  - FPN No. 1: An arc flash hazard may exist when energized electrical conductors or circuit parts are exposed or when they are within equipment in a guarded or enclosed condition, provided a person is “INTERACTING” with the equipment in such a manner that could cause an electric arc.
  - Under normal operating conditions, enclosed energized equipment that has been properly installed and maintained is not likely to pose an arc flash hazard.
- **Arc Flash Hazard Analysis**
  - A study investigating a worker’s potential exposure to arc flash energy, conducted for the purpose of injury prevention and the determination of safe work practices, arc flash protection boundary, and the appropriate levels of PPE.
**What is an Arc-Flash?**

An arc flash starts with an arcing fault. An arcing fault can be defined as the flow of current through a path where it is not intended to flow. The current creates an electric arc plasma and releases dangerous amounts of energy.

**What is an “arc-fault”?**

An electric arc is the passage of substantial electrical current through ionized air and gasses.

**Short-Circuit Basics**

Causes of Bolted Faults
- Re-energizing without removing temporary grounds
- Incorrect connection of a parallel run of cables to a motor terminal box

**Arcing Fault**
- Faults which are not bolted.
- Poor electrical connection between conductors can cause arcing.
- Arcing results in tremendous heat.

**35,000°F**
NFPA 70E CALCS FOR FLASH PROTECTION BOUNDARY AND INCIDENT ENERGY

Common Causes of Arcing Faults

- Insulation deterioration and failure
- Work related incidents when working with tools, removing panels, taking power measurements, etc.
- Loose connections (cable terminations, transformer connections, etc.)

DEVELOPMENTS LEADING TO NFPA 70E-2004

Important Temperatures

- Skin temperature for curable burn 176°F
- Skin temperature causing cell death 205°F
- Ignition of clothing 752°F-1472°F
- Burning clothing 1472°F
- Metal droplets from arcing 1832°F
- Surface of sun 9000°F
- Arc terminals 35,000°F

Arc Flash Introduction

Numerous workers injured/death each year while working

- Protective Clothing, Non-melting (According to NFPA 70E)

NFCCALCS FOR FLASH PROTECTION BOUNDARY AND INCIDENT ENERGY

Hazard/Risk Category 1

- Protective Clothing: Arc Flash Minimum Arc-Rated Rating of 4 (Note 1)
- Protective Clothing and PPE: Arc-rated long sleeve shirt (Note 3)
- FR Clothing, Minimum Arc-Rated Rating of 8 (Note 1)

Hazard/Risk Category 2

- Protective Clothing: Arc Flash Minimum Arc-Rated Rating of 8 (Note 1)
- Protective Clothing and PPE: Arc-rated long sleeve shirt (Note 3)
- FR Clothing, Minimum Arc-Rated Rating of 8 (Note 1)

NFPA 70E-2009

Table 130.7(C)(10) PPE Requirements

<table>
<thead>
<tr>
<th>HRC</th>
<th>Energy level (cal/cm²)</th>
<th>Typical Personal Protective Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>≤ 1.1</td>
<td>Hard hat, safety glasses, Face shield, Hearing Prot., Hand Prot. &amp; Foot Prot.</td>
</tr>
<tr>
<td>1</td>
<td>1.2 to 4</td>
<td>Hard hat, safety glasses, Arc-rated coverall (Note 6)</td>
</tr>
<tr>
<td>2</td>
<td>4.1 to 8</td>
<td>Arc-rated coverall, Arc-rated jacket, Arc-rated pants (Note 3), Arc-rated gloves (AN)</td>
</tr>
<tr>
<td>3</td>
<td>≥ 8</td>
<td>Arc-rated coverall, Arc-rated jacket, Arc-rated pants (Note 3), Arc-rated gloves (AN)</td>
</tr>
</tbody>
</table>

Undergarments: Must be non-conductive items such as 100% cotton FR clothing. Shirt and pants. Alternative is currently Under Protection: Leather gloves or Leather protectors over Rubber gloves

Flash Protection: Leather work shoes or boots
### NFPA 70E Protective Clothing and PPE Table (Table 130.7(C)(10)©NFPA)

<table>
<thead>
<tr>
<th>Hazard/Risk Category</th>
<th>Protective Clothing and PPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard/Risk Category 3</td>
<td>FR Clothing, Minimum Arc Rating of 25 (Note 1)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated long-sleeve shirt (AR) (Note 8)</td>
</tr>
<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 (AR) (Note 8)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated jacket, parka, or rainwear (AN)</td>
</tr>
<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>FR Protective Equipment</td>
</tr>
<tr>
<td></td>
<td>Leather gloves (Note 2)</td>
</tr>
<tr>
<td></td>
<td>Leather work shoes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hazard/Risk Category</th>
<th>Protective Clothing and PPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard/Risk Category 4</td>
<td>FR Clothing, Minimum Arc Rating of 40 (Note 1)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated long-sleeve shirt (AR) (Note 9)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated pants (AR) (Note 9)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated coverall (AR) (Note 9)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated arc flash suit jacket (AR) (Note 9)</td>
</tr>
<tr>
<td></td>
<td>Arc-rated arc flash suit pants (AR) (Note 9)</td>
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<td></td>
<td>Arc-rated arc flash suit hood (AR) (Note 9)</td>
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<tr>
<td></td>
<td>Arc-rated jacket, parka, or rainwear (AN)</td>
</tr>
<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>FR Protective Equipment</td>
</tr>
<tr>
<td></td>
<td>Leather gloves (Note 2)</td>
</tr>
<tr>
<td></td>
<td>Leather work shoes</td>
</tr>
</tbody>
</table>

### Notes:
1. See Table 130.7(C)(11). An Arc Rating for a garment or system of garments is expressed in calories/square inch (cal/cm²).
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.
5. The FR shirt and 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 occularly), an arc-rated flash suit hood, if required.
8. An arc flash protective face shield with a good field of view and good visibility is recommended as an alternate to a coverall (minimum arc rating of 40) for Hazard/Risk Category 4.
9. FR = As required (optional)
10. SR = Selection Required

---

### Why is an Arc Hazardous?

**Copper Vapor:**
- Solid to Vapor
- Expands by 67,000 times

**Molten Metal:**
- Intense Light
- Hot Air - Rapid Expansion
- Shrapnel

**Sound Waves:**
- Pressure Waves

---

**Bad things can happen.**
**An electric arc fault is a bad thing!**
Bad things can happen. An electric arc fault is a bad thing!

- Large Hydro in Pacific NW
- 6.9kV Swgr
- Racking in Breaker
- AF occurred
- One worker injured
- 7+ years, $10+ million
Arc Flash Injuries

Arc Blast Pressure

The pressure from an electric arc is developed from two sources:
- Expansion of the metal as it vaporizes
- Heating of air by the arc energy
- When copper vaporizes, it expands by a factor of 67,000. This accounts for the expulsion of near-vaporized droplets of molten metal from the arc (droplets could be propelled up to 10 feet).

Arc Blast Pressure Example

Inhalation Injuries

In addition to burns, an arc flash can cause inhalation injuries.
- More than a hundred known toxic substances are present in fire smoke.
- When inhalation injuries are combined with external burns the chance of death can increase significantly.

Inhalation Injuries Example

Toxic Smoke Example

DEVELOPMENTS LEADING TO NFPA 70E-2004

Burn Injuries

Burns are classified as first, second, or third degree, depending on how deeply the layers of skin (dermis and epidermis) are damaged.
A First Degree Burn is red and sensitive to touch. There is minimal skin damage and only the skin surface is involved.

Example: Sunburn

A Second Degree Burn involves the first and second layers of skin. The skin reddens intensely and blisters develop. Severe pain and swelling occur and chance for infection is present.

A Third Degree Burn causes charring of skin and coagulation of blood vessels just below the skin surface. All three layers of skin are affected. Extensive scarring usually results.

What Is a Calorie?
A calorie is the energy required to raise one gram of water one degree Celsius at one atmosphere.

At 1 second, 1.2 cal/cm² of heat energy can cause a second degree burn.

The intent of NFPA 70E regarding arc flash is to provide guidelines which will limit injury to the onset of second degree burns.
DEVELOPMENTS LEADING TO NFPA 70E-2004

The intent of NFPA 70E regarding arc flash is to provide guidelines which will limit injury to the onset of second degree burns.

Three Main Factors Affecting Incident Energy and Arc Flash

An arc flash will occur based on the intensity of the heat generated by an electrical arc accident. The heat reaching the skin of the worker is dependent on the following three factors:

Main Factors Affecting Arc Flash:
- Power of the arc at the arc location
- Distance of the worker to the arc
- Time duration of the arc exposure

Illustration of Power and Time Effects on NFPA Calculations for Arc in a Box

The following table shows how the power of the arc and/or time duration of the arc will affect incident energy when the worker distance is held constant at 18 inches from the arc flash. Note: The incident energy calculations were performed using the “Arc in a Box” equations.

NFPA 70E CALC FOR FLASH PROTECTION BOUNDARY AND INCIDENT ENERGY

Calculating Prospective Short-Circuit Current, \( I_{SC} \)

NFPA 70E-2004, Annex D, provides the "well known" formula that is used to calculate the short-circuit symmetrical amperes from a bolted 3-phase fault at a transformer terminals:

\[
I_{SC} = \frac{MVA_{Base} \times 10^6}{1.732 \times V_Z} \times 100 \quad (4-1)
\]
Classroom Exercise 4a: Perform a Calculation of Prospective Short Circuit Current

Problem: Using equation (4-1), calculate the prospective short circuit current for a fault at the 480 V terminals of a 1500 kVA transformer which has a nameplate impedance of 5.5%.

\[
I_{sc} = \frac{1.5 \times 10^6 \times 100}{1.732 \times 480 \times 5.5}
\]

\[
= 32,805 \text{ Amps}
\]

### NFPA 70E CALCS FOR FLASH PROTECTION BOUNDARY AND INCIDENT ENERGY

<table>
<thead>
<tr>
<th>Accident Description</th>
<th>Accident Description Continued</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employee performed some troubleshooting on 15KV Gear and determined that he did not have control power.</td>
<td>Employee crawled into the lower compartment of vertical section 6.</td>
</tr>
<tr>
<td>Customer was instructed to restore power to the 15KV B side main breaker and remove power from the A side main breaker.</td>
<td>Employee opened the shutter in the VT compartment to see if the 15 kV jumper cables were installed and connected between the CPT and VT drawers.</td>
</tr>
<tr>
<td>Employee locked out the A side main breaker and the tie breaker.</td>
<td>When Employee’s flashlight got too close to the ionized air, there was an arc flash incident.</td>
</tr>
<tr>
<td>Employee pulled the CPT drawer on the A side main on the front of the switchgear and adjusted the secondary contacts.</td>
<td></td>
</tr>
<tr>
<td>Employee visually inspected the routing of the 15 kV power cables on the A side CPT connections in the rear of the switchgear.</td>
<td></td>
</tr>
<tr>
<td>Customer was instructed to restore power to the A side main and the employee verified the control power was still not present.</td>
<td></td>
</tr>
</tbody>
</table>
**Injury Consequences**

- **Burn injuries can be fatal.**
- **Survival depends on age, health, exposure intensity and time, area of the body burned.**
- **Treatment of second degree burns requires weeks, for third degree burns it can be years.**

**The Personal Cost Is Devastating**

- **Due to disfigurement and intense pain the victim will often not want to live, depression is common.**
- **Children will likely not be able recognize the burn victim after the accident.**
- **The victim’s spouse will be traumatized, divorce is common.**

**Arc-Flash Costs: Monetary**

*National Institute for Occupational Safety and Health (NIOSH)*

> from the US Bureau of Labor Statistics

**Treating Burn Injury Is Very Expensive**

- **The cost of treatment can exceed $1,000,000 USD for a single case.**
- **Treatment can require years of skin grafting and rehabilitation.**
- **The victim may never be able to return to work.**

**Arc Flash Example**

Failed 50kA 5kV available fault current 0.5sec – FULL SPEED

**Arc Flash Example**

Failed 50kA 5kV available fault current 0.5sec – SLOW MOTION
**Arc Flash Standards and OSHA Six-Point Plan**

Four separate industry standards concern the prevention of arc flash incidents:
- NFPA 70-2008 National Electrical Code.

Compliance with the latest OSHA standards involves adherence to a six-point plan:
- A facility must provide, and be able to demonstrate a Safety program with defined responsibilities.
- Calculations for the degree of arc flash hazard.
- Correct personal protective equipment (PPE) for workers. (FR Rated Clothes, HV Gloves, Face Shield)
- Training for workers on the hazards of arc flash.
- Appropriate tools for safe working. (Grounds, rubber mats, voltage detectors, hot sticks etc.)
- Warning labels on equipment. (Arc Flash Labels with Incident Energy (cals) & appropriate PPE)

Companies will be cited and fined for not complying with these standards.

**NIOSH Data for the year 2000**

- Nonfatal injuries and illnesses = 5.7 million
- Days away cases = 1.7 million
- Fatal work related injuries = 5,920
- Days away electrical cases = 3,786
- Electrical Fatalities = 260

About 1 of every 450 nonfatal accidents involved electricity, but....

1 of every 23 deaths was caused by electricity.

**NIOSH Electrical fatalities by industry, 1992-2000.**

**Nonfatal electrical shock and burn injuries involving days away from work**

**NIOSH’s summary & conclusions from these statistics:**

- Electrical accidents are more likely to result in death than many other types of accidents.
- Contact with overhead power lines is the leading cause of on-the-job electrical death.
- The construction industry accounted for 45% of electrical deaths followed by: Agriculture (12%); Transportation (11%); Manufacturing (11%); Service (10%).

- Nonfatal electrical accidents are distributed more evenly across all industries than are fatalities, but construction industry is still highest. Electrical shock and electrical burns and their distribution varies widely by industry.

**Arc Flash History Timeline**

- 1968 Dow implements arc flash PPE program
- 1980 Published article on use of arc flash PPE
- 1981 Ralph Lee publishes theory for hazard calculations
- 1986 DuPont implements arc flash PPE program
- 1990 OSHA subpart S does not address arc flash details
- 1994 OSHA 1910.269 addresses clothing hazards
- 1995 DuPont undertakes arc flash R&D
- 1995 ASTM Arc Test Method development
**Arc Flash History Timeline**

- **1995** NFPA 70E defines arc flash boundary
- **1996** DuPont arc flash research published
- **1997** DuPont protective clothing research published
- **1998** ASTM standards for PPE testing
- **1999** Arc Flash rated PPE appears
- **2000** NFPA 70E expands arc flash requirements
- **2002** NEC requires arc flash hazard warning
- **2002** IEEE 1584 calculation guide published
- **2004** NFPA 70E major reorganization

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**ARC FLASH Avoidance:**
Superior Protection with the Right Products

**What Can Be Done:**
- **Engineering Studies:**
  - Arc Flash Study... (includes Arc Flash Labels)
  - Protective Device Coordination (Breaker Settings)
  - Short Circuit Study
- **Training**
- **Personal Protective Equipment**
- **Arc Flash Reduction Maintenance Switch**
- **Arc-Resistant Switchgear & Controls**
- **Remote Power Racking**

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**NFPA 70E (2009)**

**Key Features**

- Equipment shall be field marked with a label containing the available incident energy or required level of PPE. (130.4(C))
- Arc Flash Hazard Analysis shall be updated when a major modification or renovation takes place. (130.3)
- Arc Flash Hazard Analysis shall be reviewed periodically, not to exceed 5 years. (130.3)
- Hazard Risk Categories (0-4). Changes in PPE; Level 1 PPE includes face shield. (130.7(C)(10))

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**E-ESS NFPA70E Arc Flash Compliance**

**Eaton Engineering Services & Systems Arc Flash Studies**

- 70+ Power Systems Engineers
- Standardized Data Collection Templates
- Studies, Labels, Training, Recommendations

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**E-ESS ARC FLASH PROGRAM**

A calorie is the energy required to raise one gram of water one degree Celsius at one atmosphere.

At 1 second duration, 1.2 cal/cm² of incident heat energy can cause a second degree burn.

**ELECTRIC ARC FLASH HAZARD**

Will cause severe injury or death. Turn OFF ALL power before opening. Follow ALL requirements in NFPA 70E for safe work practices and Personal Protective Equipment.
**Arc Flash Hazard Analysis and Labeling**

**WARNING**

**Arc Flash and Shock Hazard**
**Appropriate PPE Required**

- 34 inch Flash Hazard Boundary
- 3 Cal/cm² Flash Hazard at 18 inches
- 10F PPE Level, 1 Layer 6 oz Nomex®, Leather Gloves, Faceshield
- 480 VAC Shock Hazard when Cover is removed
- 36 inch Limited Approach
- 12 inch Restricted Approach - 500 V Class 00 Gloves
- 1 inch Prohibited Approach - 500 V Class 00 Gloves

**Equipment Tests / Money Traps/ Hazards**

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**NFPA 70E 2009 Annex H**

**Simplified two Category FR Clothing**

- Categories 0, 1 & 2:
  - 8+ Calorie FR long-sleeve shirt
  - 8+ Calorie FR Pants

- Categories 3 & 4:
  - 40+ Cal Jacket
  - 40+ Cal Pants
  - 40+ Cal Hood

- Gloves, Faceshield/Hood, Hearing Protection
- Leather Shoes, Safety Glasses, (per hazard level)

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**Eaton Recent Arc Flash Study’s**

- Cargill
  - 179 Sites
- Georgia Pacific
  - 54 Sites
- VA Hospitals
  - 25 Sites
- Enbridge Pipeline
  - 25 Sites
- Weyerhaeuser
  - 104 Sites
- Woodbridge Group
  - 14 Sites
- GM
  - 12 Sites
- Ford
  - 10 Sites

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**Eaton Local Arc Flash Study’s**

- Asarco Copper Mines
- Sky Harbor Airport
- USAA Insurance Group
- TEP Springerville
- Wild Horse Pass Casino
- Chase Field

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**Arc Flash Incident**
Arc Flash Incident

Training

Understanding Arc-Flash

- Existing and Proposed Standards
- Determining Safe Approach Distance
- Methods for Calculating Prospective Short Circuit Current
- IEEE Standard 1584 & NFPA 70E Methods for Calculating Flash Protection Boundary Distance and Incident Energy Value

Flash Protection Boundary And Limits Of Approach

- Determining Hazard Risk Category
- Selecting Protective Clothing and the PPE Matrix
- ATPV Values for Common Types of Garments
- Practical Methods for Reducing Arc-Flash Hazard
- Eaton can award 0.8 CEUs for the successful completion of this training.
Definitions of Boundaries and Spaces

- The closer you approach an exposed, energized conductor or circuit part, the greater the chance of an inadvertent contact and the greater the injury that an arc flash will cause. NFPA 70E-2004, Annex C©NFPA defines approach boundaries and work spaces. The diagram on the next slide illustrates these.

### Approach / Flash Protection Boundaries

#### Qualified Person (OSHA 29CFR1910) (Cont.)
- Know what precautions to take to work safely, including:
  - how to carry out lockout/tagout procedures
  - how to manage and maintain a safe work area
  - how to use protective grounds
- Know how to use PPE
- Know how to use insulating and shielding materials
- Know how to use insulated tools

#### FLASH PROTECTION BOUNDARY AND LIMITS OF APPROACH

Qualified Person (OSHA 29CFR1910) (Cont.)

- Note: A qualified person must be certified by his employer before working on or near energized equipment, (1910.269a2vii) and must have his or her qualifications reviewed annually. (1910.269a2iii)

#### FLASH PROTECTION BOUNDARY AND LIMITS OF APPROACH

Work intentionally performed on or near energized equipment or circuits is limited by standards and regulations, such as those issued by OSHA.

- Only qualified persons may work on energized electric circuits. (1910.333c2)
- Only qualified persons may perform tests on electric circuits or equipment. (1910.334c1)
- Only qualified persons may work on or with exposed lines or parts of equipment. (1910.26911)
Only qualified persons may work in areas containing unguarded, uninsulated energized lines or parts of equipment operating at 50 volts or more. (1910.269l1)

Live parts to which an employee 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. (1910.333)

Minimize Risk with Good Safety Practices

- De-Energize Equipment versus “Working It Live” unless increased hazards exist or infeasible due to design or operational limitations.
- Switching remotely (if possible)
- Closing and tightening door latches or door bolts before operating a switch.
- Standing to the side and away as much as possible during switching operations.

Solution That Reduce Arc Flash Hazards

- Label Equipment & Train Personnel
- Minimize Risk with Good Safety Practices
- Reduce Available Fault Current
  - if you can maintain fast clearing times
- Faster Clearing Time
- Move People Further Away
- Redirect Blast Energy
- Prevent Fault

Bad – Exposed Back of Neck
Good – All of Body Protected

Using the proper tools and equipment (Line side of Main)
PRACTICAL METHODS FOR REDUCING ARC FLASH HAZARDS

Minimize Risk with Good Safety Practices
Using the proper tools and equipment (Load side of Main).

PRACTICAL METHODS FOR REDUCING ARC FLASH HAZARDS

Equipment Alternatives
- Current-Limiting Breakers / Fuses - Reduces the clearing time which reduces the incident energy.
- Metal-Clad Switchgear - Structural design reduces the possibility of arcing faults within the enclosure.
- Arc Resistant Switchgear - Structural design includes robust design and pressure relief vents, which redirect the blast away from the worker.

ARC FLASH Avoidance: Superior Protection with the Right Products

What is PPE?  
Personal Protective Equipment  
It is worn by everyone. Police officers, professional athletes, construction workers, chefs and everyone in between.

ARC FLASH Avoidance: Superior Protection with the Right Products

Electrical PPE

ARC FLASH Avoidance: Superior Protection with the Right Products

Arc-flash Reduction Maintenance Switch (ARMS)
- Used to reduce the trip delay of LV circuit breakers while performing maintenance.
- Enabled with the circuit breaker door closed by a door mounted lockable switch.
- Preserves coordination under normal conditions (not enabled continuously).

ARC FLASH Avoidance: Superior Protection with the Right Products

ARM™ – Retrofit for Low Voltage Circuit Breakers
- Door Mounted Components
- Breaker Mounted Components
**Practical Methods for Reducing Arc Flash Hazards**

**Multiple Settings Groups**
- Similar to LV maintenance switch, only for MV applications
- Used to reduce the trip delay of medium-voltage relays while maintenance is being performed on equipment
- Requires relay with multiple settings groups capability, such as the Cutler-Hammer FP-5000

**Medium Voltage ARMS Using FP-5000 – Group Settings**

**Network Protectors**

**FlashGard® MCC**
The Ultimate Arc Fault preventive solution

**ARC FLASH Avoidance:** Superior Protection with the Right Products

**The FlashGard™ Bucket**
- Features:
  - Specially designed Stab Assembly
  - Designed to fit tightly with the labyrinth vertical bus bar making it virtually arc free
  - 480 Volt isolation via stab shutter
  - Extendable and Retractable power stab – up to 400 Amp Stab
  - Allows you to engage or disengage the stab with the vertical bus while the door is closed keeping you at a safe distance while performing this operation
  - RotoTract™ assembly – No over torque
  - Special screw design spins free at the end of travel in either direction preventing over torque of the mechanism
  - Status Indication
    - Stab position indication
    - Stab shutter position indication
**FlashGard ® Door Accessories**

Remote Racking “wired” Accessory
- Accessory to perform RotoTract racking safely behind NFPA Arc Flash boundaries
- 120 VAC motor driven
- Mounts to RotoTract Mechanism
- Wired pendant station for “rack-in”/“rack-out” operation.
- Momentary Jog
- Mounting offset bracket to clear device panel

**ARC FLASH Avoidance: Superior Protection with the Right Products**

How it works
- Internal Shutter Indicator
  - Open
  - Closed
- Bucket Position
  - Indicator
  - Connected
  - Test
  - Withdrawn
- Breaker must be open to access racking tool receiver

**APPLICATIONS**

Fiber Optic Arc Mitigation Devices
- Fiber Optic Arc Mitigation Devices
  - Able to Distinguish Between Light from Fault and Background Lighting
  - Fast Acting Relay Trips Breaker Instantaneously
  - European Design (Vaasa, ABB, Ètc.)
  - SEL, iGard & Eaton

**APPLICATIONS**

Fiber Optic Arc Mitigation Devices
- UL Listing Issues
  - NO INDUSTRY STANDARD exists for the design, application, or performance for these systems.
  - On January 27, 2010, Underwriters Laboratories held a meeting to address this issue. UL clearly stated in the January meeting that they do NOT recognize any arc flash detection (light detection) systems.
**APPLICATIONS**

**Fiber Optic Arc Mitigation Devices**

- Other Issues with these Devices
  - Eaton will not utilize these devices to reduce PPE Requirement calculated in an Arc Flash Study. No test standard to justify engineering calculation for arc flash study.
  - Other arc mitigation devices like GE Arc Vault also would have UL issue.
  - Can install in Non-Listed Assemblies
  - May be utilized as a “back-up” system.

**Safety Related Solution Offerings**

- Infrared Scanning Windows for LV/MV Assemblies

**Remote Switching: Chicken Switch**

- Without
- With

**Remote Racking of MV Breakers - VCP-W 5/15 kV Swgr – New Swgr**

Remain physically outside the flash protection boundary.

**ARC FLASH Avoidance: Superior Protection with the Right Products**

- Remote Racking
- Remote Racking – Eaton’s Universal Design for Retrofit Applications
  - LV or MV
  - Any breaker
    - Air-Magnetic
    - Vacuum
    - Vacuum Replacement
    - SF6
  - 1-2 high MV & 1-4 high LV
  - Flashgard MCC
AmpGard Motor Operated Iso Switch

- New Optional Accessory For Remote Operation Of Ampgard Isolation Switch And Increased Operator Safety.
- Temporarily Mounts To Front Of Starter Door Equipped With Mounting Provisions.
- Operation By Control Station Connected To Motor Operator Via 25-foot Cable.

Motor Operated Iso Switch

Arc initiated in breaker compartment
2000A or 3000A breaker with Vent

Arc-Resistant Switchgear

- Redirects Arc Energy and Particulates

Arc-Resistant Switchgear with Vent

5/15 kV Arc Construction

Substations Without Main Secondaries AFL Retrofit

LV Arc Resistant Switchgear - Testing

Test @ 60KA / 50kV
Arc initiated in breaker compartment
Plenum Design
March 2008 - PASS

No arc flash out of the front of the gear
Substations Without Main Secondaries

- Pri Fuse Only = 594 Calories
- Pri Bkr Only= 289 Calories
- Pri. Bkr + Maint. Switch= 7.5 calories

Substations Without Main Secondaries

- Retrofill Primary Fuse with Mini Vac Bkr
- Sense at 480V Txmr-Trip Primary
- Use Group Settings for ARMS
- Many Variations
- Must Meet ANSI C37.59

Substations Without Main Secondaries

Retrofill Primary Fuse with Mini Vac Bkr
Sense at 480V Txmr-Trip Primary
Use Group Settings for ARMS
Many Variations
Must Meet ANSI C37.59

ARC FLASH Avoidance:
Superior Protection with the Right Products

- MV AMPGARD
- MV VCP-W
- I/R Windows
- FlashGard Motor Control Centers
- Door Mounted Metering and Controls
- Thru-Door racking capability
- High Impedance Transformers
- High Resistance Grounding

ASTM F1506 Standard

ASTM F1506-02a - Standard Performance Specification for Textile Material for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards, 2002a

- Developed to give min performance specs for protective clothing.
- Major requirement being that the fabric is flame resistant.
- Results must be reported to the end user as an Arc Rating on a garment label.

Definition of Arc Rating

Arc Rating
- Previously the Arc Thermal Performance Exposure Value (ATPV)
- Minimum incident thermal energy on a fabric or material that results in sufficient heat transfer through the fabric or material to cause the onset of a second degree burn based on the energy transmitted through the clothing.
- Arc Rating is expressed in cal/cm². This energy is related to the Stoll curve.
- The Arc Rating is an average of 20 tests performed using the ASTM F1995-99 standard.
Layering of FR Clothing

Layering of Clothing
- Layering significantly increases the level of protection.
- Two thin layers are better than one thick layer.
- Layer of air acts as a "buffer zone" between layers of flame resistant fabrics.
- Some multi-layer testing has been done by various fabric manufacturers and ASTM Task Groups (varies dramatically with different two-ply systems.)

The single layer and multi-layer ratings for two FR fabrics are shown as an example below:

<table>
<thead>
<tr>
<th>Product / Style</th>
<th>Fabric Description</th>
<th>ATPV (cal/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INDURA® Ultra Soft®</td>
<td>Fabric Description</td>
<td></td>
</tr>
<tr>
<td>Style 301</td>
<td>7oz (237g/m²) Shifting Twill</td>
<td>8.7</td>
</tr>
<tr>
<td>Style 801</td>
<td>13oz (440g/m²) Heavyweight Sateen</td>
<td>21.8</td>
</tr>
</tbody>
</table>

Multi-Layered Systems

<table>
<thead>
<tr>
<th>Product / Style</th>
<th>Fabric Description</th>
<th>ATPV (cal/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INDURA® Ultra Soft®</td>
<td>Fabric Description</td>
<td></td>
</tr>
<tr>
<td>Systems 301</td>
<td>7oz (237g/m²) over 301</td>
<td>27.2</td>
</tr>
<tr>
<td></td>
<td>13oz (440g/m²) Heavyweight Sateen over 301, 7oz (237g/m²)</td>
<td>51.5</td>
</tr>
</tbody>
</table>

Wear life & Laundering of FR Clothing

- Expected Lifetime and Effects of Cleaning
- Wear life is affected by laundering.
- Industrial laundering will create more wear on a garment than home laundering.
- Garments manufacturer’s provide the expected lifetime based on use and laundering.
  - FireWear - Inherently flame resistant, a characteristic that cannot be degraded by laundering. Expected wear life of 18 to 30 months when worn and home laundered once per week.
  - Nomex IIIa - Inherently flame resistant, a characteristic that cannot be degraded by laundering. Expected wear life of 36-48 months.
  - Indura Cotton - Cotton fabric made flame resistant through an ammonia cure process. Expected wear life of 12 to 18 months when worn and home laundered once per week.

Laundering Instructions for Indura Garments

Washing
- Wash Garments inside out
- Do not overload washer
- Use high water level
- Wash at temperature necessary to clean garment (Maximum 165 °F, or 74 °C)
- Use recommended amount of quality detergent. (Phosphate can be used)

Laundering Instructions for Indura Garments

Washing
- Do not use chlorine bleach
- Do not use tallow soap: (One containing animal fats)
- For optimum results use an acid sour.
- Softened water provides the best results
**Laundering Instructions for Indura Garments**

**Drying**
- Dry garments inside out.
- Do not use extreme heat or leave in for long periods. (Maximum stack temperature 165°F, or 74°C)
- Remove garment when slightly damp. Complete drying on a hanger.
- Garments may be line dried.

**Pressing**
- Press garment to remove wrinkles.
- Use cotton setting.

**Specialized Arc Flash Protective Equipment**

**Flash Suits / Switching Coats**
- Two-Layer Flash Suit.
- ATPV = 42 cal/cm²
- Use: Hazard/Risk Category 4

**ARC FLASH Avoidance:**

Superior Protection with the Right Products

**We do we go from here?**
1. Power System Studies
   - Arc Flash Hazard Study
   - Protective Device Coordination
   - Short Circuit Study
   - Updated Plant One-Line
   - Arc-Flash Hazard Labels
2. Power Systems Training Program
   - Understanding Arc-Flash
   - Electrical & Arc-Flash Safety
3. Institute PPE Program
4. Vigilantly enforce Safety & PPE Program… Everyday

**Thank You!**

We sincerely thank you for your time!