Electrical Safety in the Workplace

SouthWest Electritech Services

Electrical Systems Technical Services
Objectives

- Hazards of Electricity
- Overview of statistics
- Most common violations
Hazards of Electricity

What are the Hazards of Electricity

Shock
Arc-Flash
Arc-Blast
SHOCK

- Human Body is a great conductor of electricity

- Amount of Current flow depends on:
  Type of Circuit
  Voltage & Current Potential
  The pathway thru the Body
  Duration of contact
SHOCK

Immediate
- Muscle contraction
- Vital organs (Heart, Lungs, etc.)
- Tingling
- Pain
- Breathing
- Disorientation
- Dizziness

Long term
- Memory Loss
- Nervous disorders
- Chemical imbalances
- Damage to vital organs
- Sometimes Fatal
SHOCK

Treatment

- Injury may not at first be apparent: watch for confusion, tingling, shortness of breath, or pain.

- If the person is faint or pale or shows other signs of shock, lay the person down with the head slightly lower than the trunk of his or her body and the legs elevated.

- Check the person's breathing and pulse. If either has stopped or seems dangerously slow or shallow, begin cardiopulmonary resuscitation (CPR) immediately or use an automated external defibrillators (AED).
What is an Arc-Flash?

A sudden release of electrical energy through the air, when a high-voltage gap exists and there is a breakdown between conductors. An arc flash gives off thermal radiation (heat) and bright, intense light that can cause burns. Temperatures have been recorded as high as 36,000 °F.

Measured in Calories CM²
Electrical Arc-Flash

..\Videos\video.mp4
Electrical Arc-Flash

- Arc-Flash equal to 4 times the surface temperature of the sun (Aprox 36,000º F)
  - Vaporizes metals
  - Ignites Clothing
  - Causes External Burns to the Skin

203º F – Causes cell death (3rd degree burn)
10.7 Cal/cm² causes cell death

172ºF- Onset of curable burn (2nd degree burn)
1.2 Cal/cm² Onset of 2nd degree burn
As much as 80% of all the electrical injuries are burns from an arc-flash and ignition of flammable clothing.

Over 2000 people are admitted into burn centers each year with severe burns. Average stay is 2-6 months.
If clothing ignites, clothed areas can be more severely burned than the skin and extensive 3rd degree burns may result.
Electrical Arc-Flash
Electrical Arc-Flash
The Arc-Flash is not just voltage, amperage, and the available fault current but, also the overcurrent device upstream and how quick it operates so finding the potential is not an easy calculation.

Since we cannot see the electrons flowing, how do we know what the potential is unless the potential is marked on the labels?
Electrical Arc-Flash

Arc Flash and Shock Hazard
Appropriate PPE Required

FLASH PROTECTION
Flash Hazard at 18 inches
Min. Arc Rating: 0.19 cal/cm^2
Flash Protection Boundary: 5 inches
Glove Class: 00
Clothing Category: Category 0
Nonmelting, Flammable Materials with Weight >= 4.5 oz/sq yd

SHOCK PROTECTION
Shock Hazard when cover is removed 480 VAC
Limited Approach 42 inches
Restricted Approach 12 inches
Prohibited Approach 1 inches

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Arc-Blast  What is it?  
Arcs can also produce considerable pressure waves by rapidly heating the air and creating a blast. This pressure burst can hit a worker with great force and send molten metal droplets of melted copper, aluminum and steel electrical components great distances at extremely high velocities.
Shock & Arc-Flash Statics

- Annually 4000 Non-disabling electrical contact injuries reported.
- Annually 4000 disabling electrical contact injuries reported.
- Electrocutions are the 4th leading cause of traumatic occupational fatalities.
- Each year 2,000 Plus workers are set to a burn center with electrical rated burns.
- 170 Fatalities were attributed the electrical component in 2010.

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Shock & Arc-Flash Statics

- 10-12 Serious Accidents occur daily in the US
- 1 of the serious accidents end in death
- Average cost of an Arc-Flash incident in the workplace is $2M in direct cost
- It’s estimated that the indirect cost is $5-7M
- If there are permanent disabling injuries, the cost of lifetime medical care and long term disability can cost upwards of $23M
Arc-Flash Statics

Burn Injury Chances Of Survival

% Chance of Survival

Age Range, Years

Source: American Burn Association (1991-1993 Study)
Assuming

- It is de-energized, I turned the switch off
- Nothing is going to happen, it will only take a second
- I have done this may times before, it will be fine!
- If there is an issue the overcurrent device will open the circuit
Assuming
I Turned it off – Check it!

- 110.4(A) Test Equipment Training
  - (1) Training in the proper use and selection of voltage detection tool
I Turned it off!
If you turned it off – Lock it off!

- 120.2 Lock-Out Tag-Out (Annex G)
  - Every Employee involved directly or indirectly
    - Labeled properly
    - One-Lock, One Key in the field!
I you turned it off – Lock it off!

Use the proper attachment device for the application.
LOTO Procedure

**STEP 1**
ID Energy Sources

**STEP 2**
Notify Others

**STEP 3**
Shutdown Equipment

**STEP 4**
Isolate Equipment

**STEP 5**
LOTO Equipment

**STEP 6**
Release Stored Energy

**STEP 7**
Verify Isolation

**STEP 8**
Perform Servicing

**STEP 9**
Release from LOTO

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The overcurrent device will open??

- How and when the device properly opens is based on several items...
  - The size and type of the overcurrent device
  - What is the condition of the device (has it been maintained)
  - What the installation conditions are
    - Current
    - Available Fault Current
  - What are the settings

- The Arc-Flash is not just voltage, amperage, and the available fault current but, also the overcurrent device upstream and how quick it operates
Most Common Safety Violation

2. Failure to perform hazard evaluation and recognize the potential hazards
   - No clear accurate one-line diagram
   - Condition of the Equipment
   - Using the NFPA70E Charts
   - Failure to read Chart Notes
   - Outdated or no Arc-Flash Labels
   - Improper Training and PPE
One-line Diagram

- NFPA70E 205.2
  Single Line Diagram shall be maintained in legible condition and kept current
Equipment Condition
## Table 130.7 Hazard/Risk Category Classifications and Use of Rubber Insulating Gloves and Insulated and Insulating Hand Tools—Alternating Current Equipment (Formerly Table 130.7(C)(9))

<table>
<thead>
<tr>
<th>Tasks Performed on Energized Equipment</th>
<th>Hazard/Risk Category</th>
<th>Rubber Insulating Gloves</th>
<th>Insulated and Insulating Hand Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panelboards or other equipment rated 240 V and below Parameters: Maximum of 25 kA short circuit current available; maximum of 0.03 sec (2 cycle) fault clearing time; minimum 18 in. working distance Potential arc flash boundary with exposed energized conductors or circuit parts using above parameters: 19 in.</td>
<td>0</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Perform infrared thermography and other non-contact inspections outside the restricted approach boundary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circuit breaker (CB) or fused switch operation with covers on</td>
<td>0</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>CB or fused switch operation with covers off</td>
<td>0</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Work on energized electrical conductors and circuit parts, including voltage testing</td>
<td>1</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Remove/install CBs or fused switches</td>
<td>1</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Removal of bolted covers (to expose bare, energized electrical conductors and circuit parts)</td>
<td>1</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>
Electrical Arc-Flash Labels

WARNING

Arc Flash Hazard.
Appropriate PPE Required.
Failure To Comply Can Result in Death or Injury.
Refer to NFPA 70 E.

This is all the NEC requires!
Electrical Arc-Flash Labels

⚠️ WARNING ⚠️

Arc Flash and Shock Hazard
Appropriate PPE Required

FLASH PROTECTION
Flash Hazard at 18 inches
Min. Arc Rating: 0.19 cal/cm^2
Flash Protection Boundary: 5 inches
Glove Class: 00
Clothing Category: Category 0
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SHOCK PROTECTION
Shock Hazard when cover is removed 480 VAC
Limited Approach 42 inches
Restricted Approach 12 inches
Prohibited Approach 1 inches

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BRIDGE
How do we protect the worker?

- **Prohibited Approach Boundary**: (Prohibited Space) 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.

- **Restricted Approach Boundary**: (Restricted Space) An approach limit at a distance from an exposed live part within which there is an increased risk of shock, due to electrical arc over combined with inadvertent movement for personnel working in close proximity to the live part. (Qualified Personnel only)
**Electrical Arc-Flash Labels**

- **Limited Approach Boundary**: An approach limit at a distance from an exposed live part within which a shock hazard exists. An unqualified person cannot cross this boundary unless closely supervised by a qualified person and has the appropriate PPE on.

- **Flash Protection Boundary**: An approach limit at a distance from exposed live parts within which a person could receive a second degree burn if electrical arc flash were to occur.
Equipment Ratings and Labels

“electrical equipment… is likely to require examination, adjustment, servicing or maintenance while energized, [it] shall be field marked with a Label…”

NO SAFE PPE EXISTS
ENERGIZED WORK PROHIBITED

FLASH PROTECTION
- Flash Hazard at 18 inches
- Min. Arc Rating: 86 cal/cm²
- Flash Protection Boundary: 327 inches
- Glove Class: 00
- Clothing Category: Dangerous!
- No FR Category Found

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

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Electrical Arc-Flash Labels

NFPA70E Annex C
110.2 (C) Emergency Procedures

“Employees exposed to shock hazard and those employees responsible for taking action in case of emergency shall be trained in the methods of release of victims from contact with exposed energized electrical conductors or circuit parts. Employees shall be regularly instructed in methods of first aid and emergency procedures, such as approved methods of resuscitation, if their duties warrant such training. Training of employees in approved methods of resuscitation, including CPR and AED shall be certified by the employer annually.”

Survival rates with an AED are as high as 74%, without an AED are just 5%.
110.2 (D) Employee Training

(1) (a,b) qualified vs. unqualified worker
- Skills and techniques necessary to distinguish exposed energized parts and nominal voltage
- Decision making skill to determine hazard, requirements of the hazard and perform the task safety (Annex F)

(1) (c) On the job training on the skill required for the specific task
NFPA 70E 2012

- 110.2(D) Training (OSHA1910.132(f) (1),(2),(3)&(4))
  - (3) Retraining
    (a) If the Supervisor or annual inspection indicates employee is not complying with safety-related work practices
    (b) New Technology, new equipment or new procedures
    (c) Employing practices not normally used
110.2(E) Training Documentation
- Each Employee as detailed in section (D)
- Proof of proficiency at work practice
- Documentation and log of training with dates
NFPA 70E 2012

130.5

Arc Flash Hazard Analysis

- Shall determine the arc flash boundary and the PPE within the arc flash boundary – Key word **shall**
- Shall be updated when a major modification or renovation take place
- Reviewed periodically **not to exceed** five years
What makes up the information on Arc-Flash/Shock Hazard labels?

- Amperage/Current rating
- Maximum available fault current at that point in the system.
- Time it takes the overcurrent device to open.
- This is used to calculate the PPE and approach distances
Electrical Arc-Flash Labels
Electrical Arc-Flash
Equipment Ratings and Labels

- NFPA 70E section 130.5
  The date that the fault current calculation was performed should be on the label. The arc flash hazard analysis shall be updated when a major modification or renovation takes place. It shall be reviewed periodically, not to exceed 5 years, to account for changes in the electrical distribution system that could affect the results of the arc flash hazard analysis.
205.3 General Maintenance Requirements
“Electrical equipment shall be maintained in accordance with manufacturers’ requirements…..”

205.4 General Maintenance Requirements
“Overcurrent protective devices shall be maintained in accordance with the manufacturers’ instructions and industry consensus standards. Maintenance, tests and inspections shall be documented.”

- Follow 205.1 “Must be qualified”
- Use Standards NFPA70B, NETA-ATS,NEMA AB 4, UL 489, PEARL
- Use of Non-Tested and Reconditioned overcurrent devices from questionable resellers/dealers could end in big issues! Use of accredited PEARL Member Organizations insure quality tested equipment...
- Electrical Preventive Maintenance Program is a must!
NFPA 70E 2012

Maintenance Requirements:
IR Scan Annual

Testing of equipment (months)
Switchboards 12-24
Panelboards 12-24
Circuit Breakers 12-36
Transformers 12-36
Cables 12-36
NFPA 70E 2012

- Maintenance of Fuses (225.1)
  - Fuse holders shall not be modified, fuses in good working order, replaced with like kind.
NFPA 70E 2012

- Maintenance of Circuit Breakers (225.2, 225.3)
  - Study by the IEEE
  - When considering the life of a CB, 77% of molded case circuit breaker failed to open as designed over the life of the equipment. Why?
    - Improper application
    - No Maintenance
What are we exposed to?
What is behind the cover?
What is behind the cover?
What is behind the cover?
What is behind the cover?
What is behind the cover?
NFPA 70E 2012

- 205.5

Spaces About Electrical Equipment, clearances per NEC
What do we see in 2015

- Removal of HRC 0 from Tables
- Elimination of Prohibited Approach Boundary
- Revised Tables for PPE Arc Flash 130.7
- Emphasis on Risk Reduction Expanded
  (NEC 2014 changes NEC 240.87)
<table>
<thead>
<tr>
<th>Task</th>
<th>Equipment Condition – Note 2</th>
<th>Arc Flash Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perform infrared thermography and other non-contact inspections</td>
<td>Any</td>
<td>No</td>
</tr>
<tr>
<td>outside the restricted approach boundary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading a panel meter while operating a meter switch</td>
<td>Any</td>
<td>No</td>
</tr>
<tr>
<td>Normal operation of a circuit breaker (CB), switch, contactor or</td>
<td>• The equipment is properly installed;</td>
<td>No</td>
</tr>
<tr>
<td>starter</td>
<td>• The equipment is properly maintained;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• All equipment doors are closed and secured;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• All equipment covers are in place and secured; and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• There is no evidence of impending failure.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• The equipment is not properly installed;</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>• The equipment is not properly maintained;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Properly maintained;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Equipment doors are open or not secured;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Equipment covers are off or not secured; or</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• There is evidence of impending failure.</td>
<td></td>
</tr>
<tr>
<td>Work on energized electrical conductors and circuit parts,</td>
<td>Any</td>
<td>Yes</td>
</tr>
<tr>
<td>including voltage testing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Removal or installation of CBs or switches</td>
<td>Any</td>
<td>Yes</td>
</tr>
<tr>
<td>Removal or installation of covers for equipment such as wireways,</td>
<td>• The equipment is properly installed;</td>
<td>No</td>
</tr>
<tr>
<td>junction boxes and cable trays that does not expose bare,</td>
<td>• The equipment is properly maintained; and</td>
<td></td>
</tr>
<tr>
<td>energized electrical conductors and circuit parts</td>
<td>• There is no evidence of impending failure.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• The equipment is not properly installed;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• The equipment is not properly maintained;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• There is evidence of impending failure.</td>
<td>Yes</td>
</tr>
<tr>
<td>Equipment</td>
<td>Category</td>
<td>Arc-Flash Boundary</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
<td>----------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Panelboards or other equipment rated 240 V and below Parameters: Maximum of 25 kA short-circuit current available; maximum of 0.03 sec (2 cycles) fault clearing time; working distance 18 inches</td>
<td>1</td>
<td>600 mm (2 ft)</td>
</tr>
<tr>
<td>Panelboards or other equipment rated &gt; 240 V and up to 600 V Parameters: Maximum of 25 kA short-circuit current available; maximum of 0.03 sec (2 cycles) fault clearing time; working distance 18 inches</td>
<td>2</td>
<td>900 mm (3 ft)</td>
</tr>
<tr>
<td>600-V class motor control centers (MCCs) Parameters: Maximum of 65 kA short-circuit current available; maximum of 0.03 sec (2 cycles) fault clearing time; working distance 18 inches</td>
<td>2</td>
<td>1.5 m (5 ft)</td>
</tr>
<tr>
<td>600-V class motor control centers (MCCs) Parameters: Maximum of 42 kA short-circuit current available; maximum of 0.33 sec (20 cycles) fault clearing time; working distance 18 inches</td>
<td>4</td>
<td>4.3 m (14 ft)</td>
</tr>
</tbody>
</table>
240.87 Arc Energy Reduction

- Title was changed from “Noninstantaneous Trip” to “Arc Energy Reduction” and section was revised for usability and formatted into subdivisions.
- Revision clarifies that this rule applies only to circuit breakers that are intentionally delayed under short-circuit conditions and that these circuit breakers do not have an instantaneous trip settings.
- No override setting higher than the potential arc current.
- A limitation to the size of breaker (1200 ampere) required to comply with this section was added.
- Two additional methods for reducing arc energy were added to the list of methods:
  - Energy-reducing active arc-flash mitigation system.
  - An approved equivalent means.
240.87 Arc Energy Reduction

Relative clearing times for electronic circuit breaker trip functions:

- **50 ms**: Energy-Reducing Maintenance Switch
- **100 ms**: Instantaneous Trip
- **150 ms**: Zone Selective Interlocking
- **Short Time Delay**: Short Time Delay

*Courtesy of Eaton Corporation*
240.87 Arc Energy Reduction
For Further information on

Short Circuit Analysis
Coordination Study
Arc Flash Hazard Analysis
Arc Flash Training
Technical Services
Field Testing Services
Distribution Equipment

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