Overview

• Introduction
• Electrical Shocks
• Electrical Arcs
• Relevant Industry Standards
• Elements of an Electrical Safety Program
• Case Study
Introduction

• Gain awareness of electrical shocks including what they are, how to recognize & avoid potential hazards, & what the different approach boundaries mean.
• Gain awareness of electrical arcs, including what they are, related jargon, their causes, their results, & why they are being addressed.
• Learn about the different industry standards that address electrical safety and arc flash hazards.
• Learn about safety programs that should be or are in place regarding electrical safety.
Videos
Electrical Shocks

• What is an Electric Shock
• Typical Sources of Electrical Shock
• Shock Protection Boundaries
• Ways to Identify the Limited Approach Boundary
• Shock Protective Tools
What is an Electrical Shock

Electric Shock- Flow of Electricity Through the Body

<table>
<thead>
<tr>
<th>SHOCK</th>
<th>mA</th>
<th>Affect on a person</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5-3</td>
<td>Tingling sensation</td>
</tr>
<tr>
<td></td>
<td>3-10</td>
<td>Muscle contractions &amp; pain</td>
</tr>
<tr>
<td></td>
<td>10-40</td>
<td>“Let-go” threshold</td>
</tr>
<tr>
<td></td>
<td>30-75</td>
<td>Respiratory paralysis</td>
</tr>
<tr>
<td></td>
<td>100-200</td>
<td>Ventricular fibrillation</td>
</tr>
<tr>
<td></td>
<td>200-500</td>
<td>Heart clamps tight</td>
</tr>
<tr>
<td></td>
<td>1500+</td>
<td>Tissue &amp; organs start to burn</td>
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</tbody>
</table>
Sources of Electrical Shock

- Live Panels and Circuits
- Receptacles
- Downed Power Lines
- Worn Extension Cords
- Power Tools
- Motors and Generators
Shock Protection Boundaries
Shock Protection Boundaries

• Limited Approach Boundary
  • An approach limit from an exposed live part that has a shock hazard. Qualified personal or someone escorted by a qualified individual may enter.

• Restricted Approach Boundary
  • An approach limit from an exposed live part that has an increased risk of shock. Only a qualified personal may enter, and uses proper protection and techniques.

• Prohibited Approach Boundary
  • A distance from an exposed that is considered that same as touching the live part. Only a qualified personal using protection as if indirect contact with live part may enter the area.

Qualified Person – One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved.
Ways to Identify Approach Boundaries

- **NFPA Tables**
  - Easiest and quickest with the least amount of accuracy. Refer to NFPA 70E

- **Formula Method**
  - Formulas provided by NFPA 70E & IEEE, gives accurate approach boundaries, But time consuming, requires an engineer level of expertise and subject to human error.

- **Approach Calculator**
  - IEEE provided spreadsheet to speed up calculations. Often requires the use of an electrical engineer.

- **Software**
  - Available on the open market.

***Look AWAY on next slide if you get queasy****
Shock Damage
Shock Protective Tools

• Personal Protective Equipment (PPE)
  - Helmet, nonconductive head protection. ANSI Z89.1
  - Gloves, Insulated to the voltage of exposed area 1910.137

• Insulated Tools- Insulated to the level of voltage they’re exposed to and inspected before each use.

<table>
<thead>
<tr>
<th>Tag Color</th>
<th>Class</th>
<th>Proof Test Voltage AC / DC</th>
<th>Max. Usage Voltage AC / DC</th>
<th>Glove Tag</th>
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</thead>
<tbody>
<tr>
<td>Beige</td>
<td>00</td>
<td>2.500 / 10,000</td>
<td>500 / 750</td>
<td></td>
</tr>
<tr>
<td>Red</td>
<td>0</td>
<td>5.000 / 20,000</td>
<td>1,000 / 1,500</td>
<td>10</td>
</tr>
<tr>
<td>White</td>
<td>1</td>
<td>10,000 / 40,000</td>
<td>7,500 / 11,250</td>
<td>10</td>
</tr>
<tr>
<td>Yellow</td>
<td>2</td>
<td>20,000 / 50,000</td>
<td>17,000 / 25,500</td>
<td>10</td>
</tr>
<tr>
<td>Green</td>
<td>3</td>
<td>30,000 / 60,000</td>
<td>26,500 / 39,750</td>
<td>10</td>
</tr>
<tr>
<td>Orange</td>
<td>4</td>
<td>40,000 / 70,000</td>
<td>36,000 / 54,000</td>
<td>10</td>
</tr>
</tbody>
</table>
Electrical Arcs

- What is an Electric Arc (arc flash)?
- Incident Energy
- Arc Flash Boundary
- Personal Protective Equipment
- Causes of Electrical Arcs
- Arc Flash Hazards
- Reasons to Address Arc Flash Hazards
What is an Electric Arc (arc flash)?

- Where a flashover of electric current that leaves its intended path and travels through the air to another conductor or ground
- Serious injury or death is typical for a human in close proximity of an arc flash.
What is an Arc Flash Hazard?

NFPA 70E Article 100 “…Informational Note No. 1: The likelihood of occurrence of an arc flash incident increases when energized electrical conductors or circuit parts are exposed or when they are within equipment guarded or enclosed condition, provided a person is interacting with the equipment in such a manner that could cause an electric arc. An arc flash incident is not likely to occur under normal operating conditions when enclosed energized equipment has been properly installed and maintained.
Causes of Electrical Arcs

• Dust
• Dropping Tools
• Accidental Touching
• Condensation
• Material Failure
• Corrosion
• Faulty Installation
Arc Flash Hazards

- Burns - Non flame resistance clothing can melt onto the skin
- Intense Light - Damage eyesight
- Flying objects - Molten metal
- Blast pressure - Upwards of 2,000 lbs/ft²
- Sound Blast - Can reach over 140dB
- Heat - upwards of 35,000°F
- Toxic fumes
Arc Flash Hazards

- Light so bright it can damage vision
Arc Flash Hazards

• Shrapnel Wounds

Material and molten metal can hit the body at over 700 miles per hour.
## Arc Flash Hazards

- **Hearing Damage**

<table>
<thead>
<tr>
<th>Source</th>
<th>Decibels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arc blast at 2 feet</td>
<td>145</td>
</tr>
<tr>
<td>Jet engine at 200 feet</td>
<td>132</td>
</tr>
<tr>
<td>Pain threshold</td>
<td>130</td>
</tr>
</tbody>
</table>
Key Factors for Severity

- Distance from the worker to the fault
- Time for the fault to clear
- Power of the arc
Incident Energy

• Measure of thermal energy from an arc fault. cal/cm²
• Common Distance is 12” to 18”
• 2nd Degree burn occurs at 1.2 cal/cm²
Arc Flash Boundary

- Farthest established boundary from the live device
- Distance someone will be exposed to a curable second degree burn
- There are no common distances between equipment

- 2\textsuperscript{nd} degree or less burns if unprotected
- 2\textsuperscript{nd} degree or greater burns if unprotected
Personal Protective Equipment

• Should be used as the Last Line of Defense
  • Helmet and Gloves
  • Flame Resistant Clothing- To protect the skin from burns. See 1910.335(a)(1)(i)
  • Arc Suppression Blanket- Used as a barrier, for protection between the worker & the potential arc fault location. See 1910.335(a)(2)(ii)
  • Masks- to protect the eyes and face. See 1910.335(a)(1)(v)

arcflashppc.com
Personal Protective Equipment

Standard Work Attire
Protection Rated for 4 cal/cm²
Protection Rated for 25 cal/cm²
Protection Rated for 40 cal/cm²

** NO SYNTHETIC MATERIAL **
Reasons to Address Electrical Hazards

1. Injury/Death Prevention
   • We work in an industry with significant electrical hazards.
   • In 2016 there were 5,190 workplace fatalities (991 in construction) and 2.9 million nonfatal workplace injuries (OSHA statistic).

2. Business Case
   • Litigation and lost opportunity have significant impacts on our company.
   • Our safety metrics are critical to the vitality of our business.

3. Workplace Satisfaction
   • Quality of life and productivity are improved when safe work practices are consistently employed.
Probability of Surviving Burns

- 25% Body Burn
- 50% Body Burn
- 75% Body Burn

American Burn Association
Break Time
Relevant Industry Standards

I. OSHA 29 CFR 1910.269
II. OSHA 1926 Subpart S
III. NESC
IV. NFPA 70
V. NFPA 70E
VI. IEEE 1584
OSHA General Duty Clause

• Sect. 5(a)(1)
  "each employer shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to employees."

• Sect. 5(b)
  "each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to this Act which are applicable to his own actions and conduct."
OSHA 29 CFR 1910.269

• Covers the Operation & Maintenance
  • Electrical Power Generation
  • Control
  • Transformation
  • Transmission
  • Distribution Lines
  • Equipment
OSHA 1926 Subpart S

• Safety & Health Regulation for Construction
  • OSHA 1910.335(a)(1)(i) (which links to 1910.132(d) ) requires employers to assess their working environment and identify electrical or any other hazards that are present, inform employees of the presence of any such hazards, provide employees with personal protective equipment (PPE), and train employees on the proper use of this PPE.
NESC

• National Electric Safety Code
• Published by IEEE
• Sets the ground rules for practical safeguarding
  • During installation
  • Operation
  • Maintenance of electric supply
  • Communication lines
  • Associated equipment
• National Electrical Code
  • Addresses installation of electrical/signaling/communication
    • Conductors
    • Equipment
    • Raceways
  • For public/private premises, automobiles and recreation vehicles

• Not for watercraft, railways, aircraft
NFPA 70E

• Standard for Electrical Safety in the Workplace
  • Safety Related
    • Work practices
    • Maintenance requirements
    • Special equipment
  • Guidance
    • Hazard identification
    • Risk assessment
    • Selecting PPE
    • Safe working condition
    • Employee training
IEEE 1584

• Guide for Performing Arc Flash Hazard Calculations
  • Provides techniques
    • Determining arc-flash boundaries
    • Calculating incident energy
  • Updated in 2018
    • 1800 tests performed
Elements of an Electrical Safety Program

- Purpose
- Principles
- Typical Table of Contents
- How is it Measured and Monitored
- Common Procedures
- Training Requirements
- Documentation Requirements
Purpose

• Provide comprehensive on-site training to high-risk workers & management

• Develop Understanding & Requirements
  • OSHA Sub Par S
  • NFPA 70
  • NFPA 70E

• Reduce/Eliminate Electrical Safety Hazards in the Workplace

• Guidelines
  • Qualifications for personnel
  • Job planning
  • Management/Personal responsibilities
Principles

1. Inspect/evaluate Electrical Equipment
2. Maintain Electrical Equipments Insulation & Enclosure Integrity
3. Plan Every Job & Document First-Time Procedures
4. Provide an Electrically Safe Condition
5. De-Energize
6. Anticipate Unexpected Events
7. Identify & Minimize the Hazard
8. Assess People's Abilities
How it is Measured and Monitored

- Electrical Safety Auditing
  - Electrical Safety Program: Frequency shall not exceed three years
  - Field Work: To insure the safety program is being followed.

- Audits will be Documented
Common Procedures

• Purpose of Task
• Qualifications
• Hazardous Nature & Extent of Task
• Limits of Approach
• Safe Work Practices
• Personal Protective Equipment (PPE)
• Insulated Materials and Tools
• Special Precautionary Techniques
• Lockout/Tagout Procedure
• Audits
Training Requirements

• Safety Training
• Type of Training
  • Classroom
  • On-the-job
• Emergency procedures
• Employee Training
  • Qualified Person
  • Unqualified Person
  • Retraining
• Training Documentation
Documentation Required

- Each Employee has Received Training
  - Demonstrates proficiency
- Documentation shall contain the content of the training
Arc Flash Case Study

• Replacement of 480V Low Voltage Power Circuit Breaker
• To be racked in with bus energized
• Re-furbished breaker had slightly mis-aligned neutral stab.
• As breaker racked in, neutral stab bends and contacts load-side phase stab.
• Nothing noticed by electrician as breaker racked in (with breaker open)
• Old-style 480V breaker with manual close – pump up handle until breaker closes.
• Resulting Fault Causes Primary Fuses To Open
Before the Fault Occurred...

- Arc-Flash Study done and equipment labeled
- PPE determined and workers trained
- ~39kA bolted fault current, ~24kA arcing fault current
- Primary fuse opens in 0.8 seconds
- Incident Energy (IE) of 88 cal/cm² at 18" working distance.
- 28” measured distance, worker to arc
- Estimated Incident Energy of 50 cal/cm²
Arc Flash Case Study

Because of Training, Warning Labels and PPE:

• Electricians wearing 100 cal/cm² flash suits

• Outcome:
  • First-Aid Case – minor 1st degree burn from loose face shield
  • Second person not injured
QUESTIONS?