

Electrical Safety in the Workplace

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Meet Your Presenters:

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Contents

- ▶ Dangers of Electrical Shock
- ▶ Recognizing Potential Hazards
- ▶ Safe Work Practices
- ▶ Protection Devices
- ▶ Safety Ideas



Source: www.lanl.gov

Dangers of Electrical Shock

▶ Shock

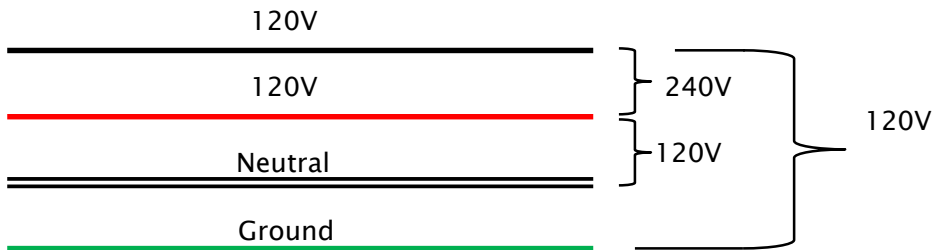
- When a circuit, electrical component, or equipment is energized, a potential shock hazard is present.
 - Touching a live wire while grounded
 - Touching a live wire and another live wire
- Electric voltage potential
 - Car Battery (12 V)
 - Electrical Outlet (120 V)
 - Clothes Dryer (220 V)
 - Utility Distribution (14,400 V)
 - Utility Transmission (500,000 V)



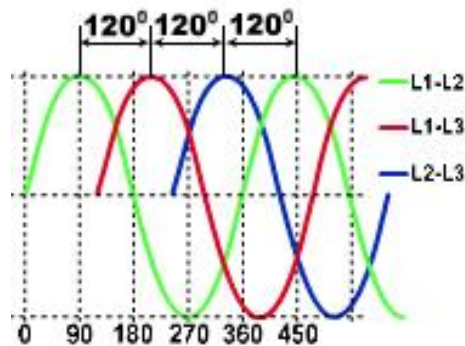
Dangers of Electrical Shock

▶ Shock

- Single-phase
 - 60 cycles per second (Hz)
 - 1 cycle = 0.017 seconds



- Three-phase



Dangers of Electrical Shock

▶ Shock

◦ Current

- Flow of electric charges (amperes)
- $I = V/R$

◦ Resistance

- Resistance to flow of current (ohms)
- $R = 1,000$ ohms (wet skin)
- $R = 100,000$ ohms (dry skin)

◦ Example:

- 120 volts @1,000 ohms
- $I = 120/1,000 = 0.12$ amps = 120 ma (milliamps)



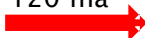
Source: www.cdc.gov

Dangers of Electrical Shock

► Shock Effects

Effects of Electrical Current in the Body (<600V, 1 second)		
Current (milliamps)		Reaction
1		Just a faint tingle.
5		Slight shock felt. Disturbing, but not painful. Most people can "let go." However, strong involuntary movements can cause injury.
6–30		Painful shock. Muscular control is lost. This is the range where "freezing currents" start. It may not be possible to "let go."
50–150		Extremely painful shock, respiratory arrest (breathing stops), severe muscle contractions. Flexor muscles may cause holding on; extensor muscles may cause intense pushing away. Death is possible.
1,000–4,300 (4.3 amp)		Ventricular fibrillation (heart pumping action not rhythmic) occurs. Muscles contract; nerve damage occurs. Death is likely.
10,000 (10 amps)		Cardiac arrest and severe burns occur. Death is probable.
15,000 (15 amps)		Lowest overcurrent at which a typical fuse or circuit breaker opens a circuit!

120 ma



Shock Effects

▶ Shock

- Magnitude
 - 120 ma @1 sec $\approx$ 1,200 ma @0.1 sec (6 cycles)
- Duration
- Path

▶ Burns

- Temperatures as high as 35,000°F have been reached in arc-blasts.
- A person 2 feet away from a 25,000-amp arc feels a force of about 480 pounds on the front of the body.



Source: www.tva.gov

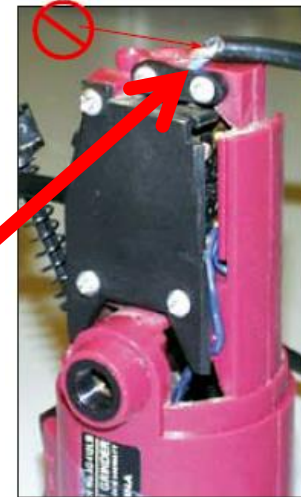


Electrical burn on hand and arm.

Source: www.cdc.gov

Recognizing Potential Hazards

- ▶ Undersized wiring
 - Wire gauge too small
 - Extension cords
- ▶ Exposed electrical parts
 - Cover is removed
 - Electrical terminals exposed

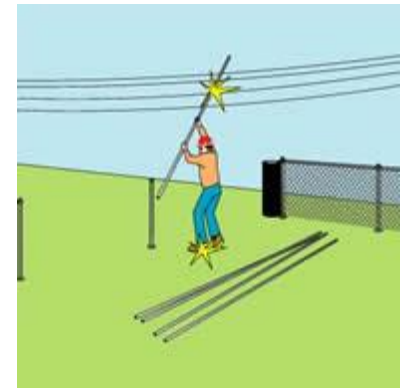


Source: www.cdc.gov

Recognizing Potential Hazards

- ▶ Overhead power lines
 - NEC Table 110.34(E), Elevation of Unguarded Live Parts Above Working Space

Voltage	Meters	Feet
601–7,500	2.8	9
7,501–35,000	2.9	9.5
Over 35,000	2.9 + 9.5mm/kV>35KV	9.5 + 0.37in/kV>35KV

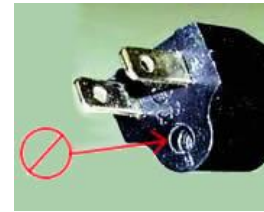


Poll Question

- ▶ Which is the most deadly of the following electrical phenomena?
 - a) Voltage
 - b) Amperage
 - c) Wire gauge

Recognizing Potential Hazards

- ▶ Defective insulation
 - Inspect cords for cracking, fraying, and other signs of wear, or faults in the cord insulation.
- ▶ Improper grounding
 - Inspect the plug for cracks and for missing, loose or faulty prongs.



Source: www.cdc.gov

Recognizing Potential Hazards

▶ Overloaded circuits

- NEC Article 310.15 (A)(3) Ampacities for Conductors Rated 0–2000 Volts, Temperature Limitation of Conductors.
- No conductor shall be used in such a manner that its operating temperature will exceed that designated for the type of insulated conductor involved.



Source: www.cdc.gov

Recognizing Potential Hazards

▶ Wet conditions

- Easy path for electrical current
- NEC 2011 ARTICLE 310.10 (C) Conductors for General Wiring, Uses Permitted, Wet Locations
 1. Be moisture-impervious metal-sheathed
 2. Be types *W* (MTW, RHW, RHW-2, TW, THW and so on)
 3. Be of a type listed for use in wet locations

Recognizing Potential Hazards

- ▶ Damaged tools and equipment
 - Check for damaged switches and ones with faulty trigger locks.
- ▶ Improper personal protective equipment (PPE)
 - Never wear clothing made from synthetic materials.
 - Required clothing
 - Long sleeve shirt
 - Long pants
 - Safety glasses



Source: www.cdc.gov

Recognizing Potential Hazards

▶ Arc Flash Hazard

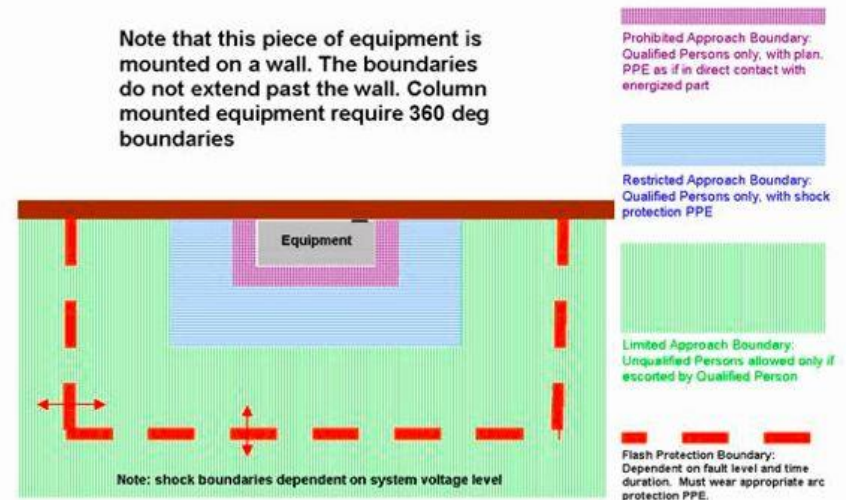
- Temperature of the arc terminals can reach approximately 35,000°F.
- Shrapnel propelled in excess of 700 miles-per-hour.
- Deafening loud noise
- OSHA 29 CFR 1910.132
Personal Protective Equipment
 - (d)(1) requires [evaluating](#) the workplace for electrical hazards and [selecting](#) and requiring the use of appropriate PPE to protect employees (ASTM F1506).
 - (f) requires PPE [training](#) (how to wear, remove, maintain).



Safe Work Practices

► Arc Flash Hazard

- NFPA 70E:2012 Standard for Electrical Safety in the Workplace, Article 130 Work Involving Electrical Hazards
 - Determine **severity** of potential exposure (**>50V**).
 - Article 130.4 (C) Shock Protection Boundary
 - Article 130.5 (B) Incident Energy Analysis, (C) labeling
 - Annex D Incident Energy and Flash Protection Boundary Calculation Methods
 - IEEE Std. 1584 - 2002, Guide for Performing Arc-Flash Hazard Calculations



Source: www.nasa.gov

= 1.2 cal/cm²

Safe Work Practices

▶ Arc Flash Hazard

- NFPA 70E:2012 Standard for Electrical Safety in the Workplace, Article 130 Work Involving Electrical Hazards
 - Instruction on safe work practices (alertness, illumination, clothing, tools).
 - Select personal and other protective **equipment**.
 - Article 130.5 (B) Incident Energy Analysis, labeled



- **Table H.3(b) in Annex H (cal/cm^2)**

or

- Table 130.7(C)(15)(a) Hazard/Risk Category (0-4), Gloves/Tools



- Table 130.7(C)(16) Protective Clothing and PPE



- Table 130.7(C)(14) Protective Clothing Standards



Source: www.cdc.gov

Safe Work Practices

► Arc Flash Hazard

◦ Table 130.7(C)(15) Hazard/Risk Category Classifications

◦ Not valid if:

- Task not listed
- Available fault current exceeds listed
- Device clearing time exceeds listed

Tasks Performed on Energized Equipment	Hazard/Risk Category
Metal clad switchgear, 1 kV through 38 kV Parameters: Maximum of 35 kA short circuit current available; maximum of up to 0.2 sec (12 cycle) fault clearing time; minimum 36 in. working distance Potential arc flash boundary with exposed energized conductors or circuit parts using above parameters: 422 in.	
Perform infrared thermography and other non-contact inspections outside the restricted approach boundary	3
CB operation with enclosure doors closed	2
Reading a panel meter while operating a meter switch	0
CB operation with enclosure doors open	4
Work on energized electrical conductors and circuit parts, including voltage testing	4
Work on control circuits with energized electrical conductors and circuit parts 120 V or below, exposed	2
Work on control circuits with energized electrical conductors and circuit parts >120 V, exposed	4
Insertion or removal (racking) of CBs from cubicles, doors open or closed	4
Application of temporary protective grounding equipment, after voltage test	4
Removal of bolted covers (to expose bare, energized electrical conductors and circuit parts)	4
Opening hinged covers (to expose bare, energized electrical conductors and circuit parts)	3
Opening voltage transformer or control power transformer compartments	4

Safe Work Practices

▶ Arc Flash Hazard

- NFPA 70:NEC-2011 Article 110.16 Arc-Flash Hazard Warning identifies the minimum arc flash **warning label** requirements.
 - Potential arc-flash hazard while energized
 - Clearly visible
 - Other than dwelling units
- NFPA 70:NEC 2014 - 110.21(B) Marking has **three marking requirements [NEW]** for hazard labels
 - Labels shall adequately warn of the hazard using effective words, colors or symbols.
 - Labels shall be permanently affixed and cannot be handwritten (with exception).
 - Labels must be durable to last in the environment.



Source: Mille Mega Power Solutions

Safe Work Practices

▶ Arc Flash Hazard

- NFPA 70E:2012 Article 130.5 (C) labeling requirements.

- The nominal system voltage,
- Arc flash boundary, and
- **One** of the following:
 - Available incident energy and corresponding working distance
 - Engineering analysis method
 - Required level of PPE
 - If table method is used
 - Highest hazard/risk category for the equipment



Source: Mille Mega Power Solutions

Poll Question

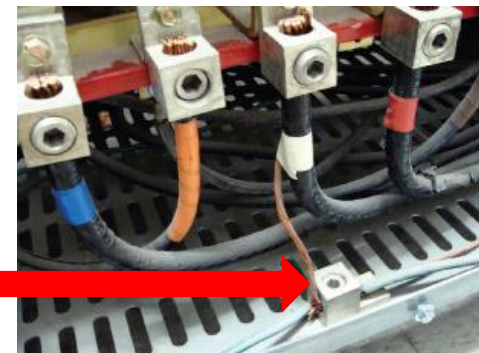
- ▶ What are the major hazards from arc flash?
 - a) High temperature
 - b) Shrapnel
 - c) Deafening loud noise
 - d) All of the above

Safe Work Practices

- ▶ NEC: 2014 - 240.87 Arc Energy Reduction (**NEW!**)
 - Where the **highest** continuous current trip setting for which the actual overcurrent device installed in a circuit breaker **is rated or can be adjusted** is 1,200 amperes or higher then (A) and (B) shall apply.
 - Limits applicability to Frame N and higher switchgear
 - (A) Documentation - as to the location of the circuit breakers
 - (B) Method to Reduce Clearing Time - **One** of the following or approved equivalent means shall be provided:
 - (1) Zone-selective interlocking
 - (2) Differential relaying
 - (3) Energy-reducing maintenance switching with local status indicator
 - (4) Energy-reducing active arc flash mitigation system
 - (5) An approved equivalent means

Safe Work Practices

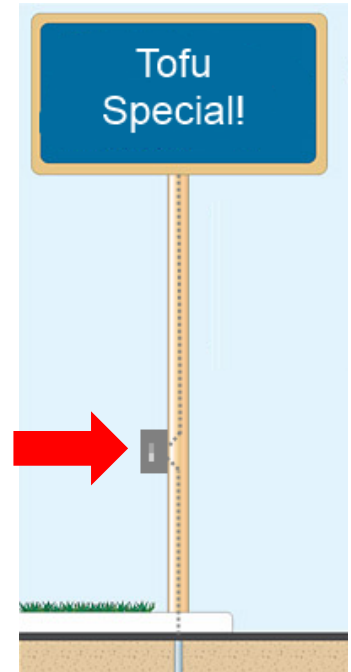
- ▶ NEC: 2014 **NEW** requirements
 - 110.26 Spaces About Electrical Equipment
 - Egress requirements now apply to smaller equipment.
 - Reduced to 800 amps from 1200 amps.
 - 450.10 Transformer Grounding (A) Dry-Type Transformer Enclosures
 - A common terminating (terminal) bar is now required in the transformer.
 - For primary equipment grounding conductors and supply-side bonding jumpers.
 - 517.17, 700.27, and 701.27 Selective Coordination for Overcurrent Protection
 - Broadens scope of application to ground faults and short circuits (not just overloads).
 - Requires design by engineer level competency.



Source: Electrical Service Solutions, Inc.

Safe Work Practices

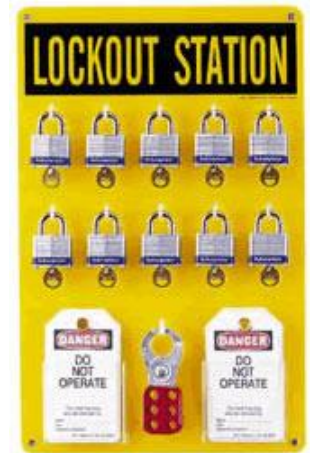
- ▶ NEC: 2014 **NEW** requirements
 - 600.6 Disconnects for Electric Signs and Outline Lighting (A) Location (1)
 - The disconnect location should be the point that the conductors enter the sign.
 - Assures that all of the conductors inside the enclosure are de-energized by the disconnect.
 - 700.16 Emergency Illumination
 - Emergency illumination must be provided to illuminate the indoor service or building disconnecting means.
 - So that an injured electrician can be easily located by first responders.



Safe Work Practices

▶ OSHA 29 CFR 1910.147 Lockout/Tagout

- (c)(1) Energy control program
 - Requires energy control procedures, employee training and annual inspections.
- (c)(2)(i, ii) Control devices
 - Lockout, unless **not capable** (means of attaching a lock).
 - Lockout, unless you can **prove** tagout system will provide full employee protection.
- (c)(9) Notification of employees
 - Notify **affected** employees before applied and after removed.
- (d)(6) Verification of isolation
 - Prior to starting work, the **authorized** employee **shall verify** that isolation and deenergization of the machine or equipment have been accomplished.



Protection Devices

▶ Circuit Breakers

- Low-voltage (<600 volts)
 - Molded case, insulated case, or metal frame.
 - Trips by bimetallic strips, magnetic (solenoid), and hydraulic magnetic technology.
- Medium-voltage (>1,000 volts and <72.5 kV)
 - Trips by instantaneous overcurrent, time overcurrent, and overvoltage.
 - Metal-clad switchgear (image at right)
 - Metal-enclosed switchgear



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Protection Devices

▶ Fuses

- Cheaper than circuit breakers.
- Clears heavy fault currents in less time.
 - Often delay for minutes
- Current-limiting
 - Silver or copper strip fuse elements.
 - Reduced cross-sectional areas heat up and melt very quickly.
 - Can clear a fault within 1/2 cycle (0.008 sec).

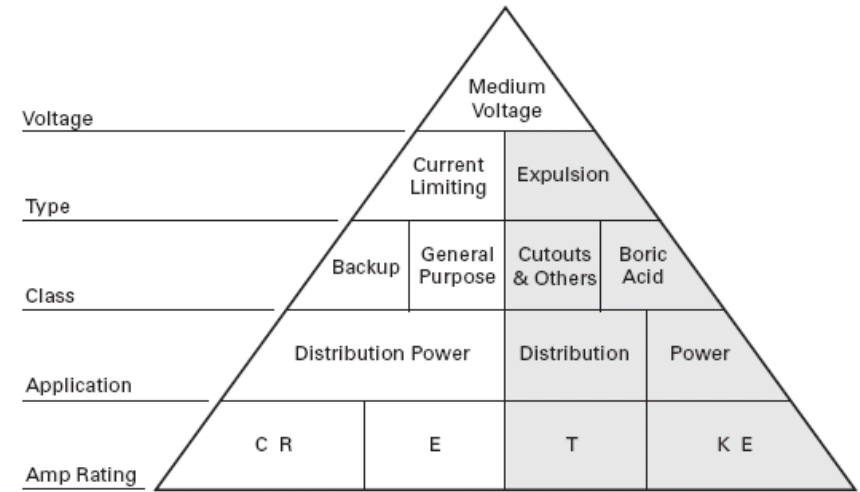


Image courtesy of Norberg @ chfuses.com

Protection Devices

▶ Fuses

- Non-current limiting (expulsion)
 - Metal arcing rod with one end attached to a silver fusible element and the other end attached to a spring.
 - Spring retracts the rod and the arcing action decomposes the surrounding boric acid.
 - Arc is extinguished **only** at the zero switching current point of the AC sine wave.
 - This may take 1 to 2 AC cycles and during this period no significant current limitation occurs.

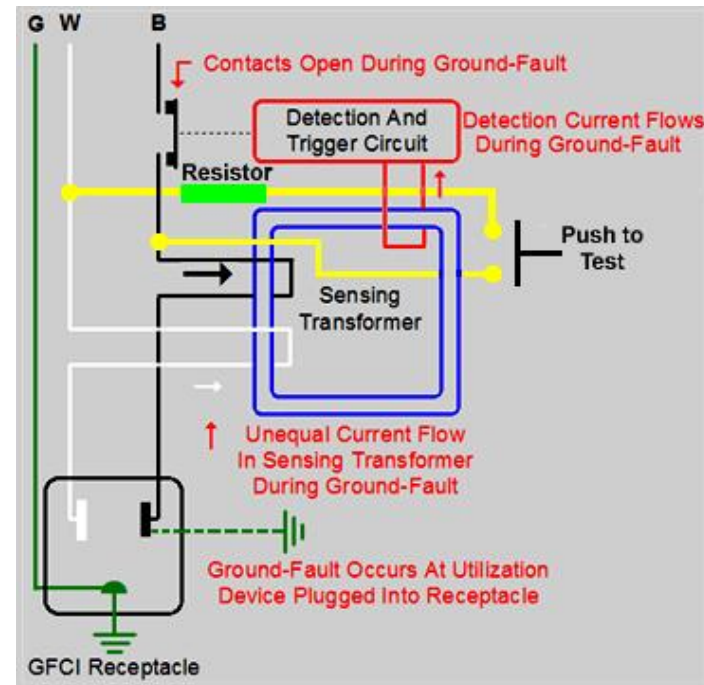


Image used with permission of Cooper Bussmann

Protection Devices

▶ Ground-Fault Circuit Interrupter (GFCI)

- Protects **people** directly, equipment indirectly
 - Minimizes shock ($< 5\text{ma}$)
- Receptacle, circuit breaker, or portable types
- Test once per month
 - Always use test lamp



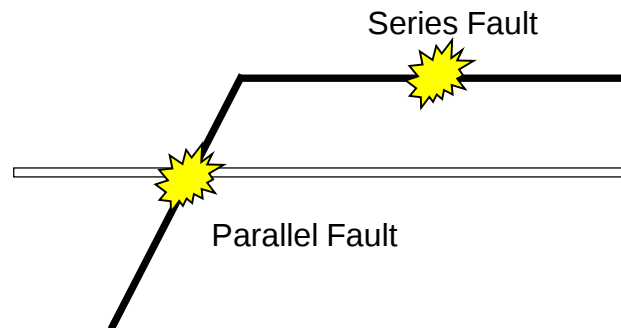
Protection Devices

▶ Ground-Fault Circuit Interrupter (GFCI)

- Bathrooms
- Near sinks
- Spray washers
- Vending machines
- Drinking fountains
- Safety showers
- Eyewash stations
- Swimming pools (including lights and fans)
- Outdoors
- Pits
- Hoistways
- Elevator car tops
- Escalator and moving walk wellways
- Machine rooms
- Aircraft hangars
- Construction sites
- Fountains (with exceptions)
- Commercial garages/service bays
- Vehicle tire inflation and vacuum machines

Protection Devices

- ▶ Arc-Fault Circuit Interrupter (AFCI)
 - Protects **materials** directly, people indirectly.
 - Mainly from fires caused by arcs.
 - Normal arcs do not cause tripping.
 - 2014 NEC 210.12 AFCI Protection **[NEW]**
 - **(A) Lodging guest rooms/suites with cooking**
 - **(C) Dormitories**



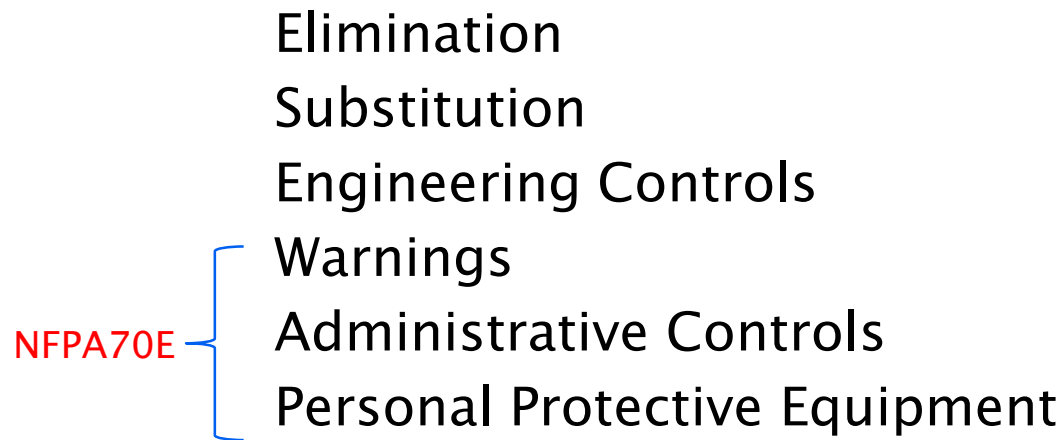
Source: www.cpsc.gov

Poll Question

- ▶ One of these things is not like the others:
 - a) AFCI
 - b) GFCI
 - c) Circuit breaker

Safety Ideas

- ▶ ANSI Z10-2005 Occupational Health and Safety Management Systems
 - Hazard Control Methods



Safety Ideas

- ▶ ANSI Z10-2005 Hazard Control Methods
 - **Elimination** (during design)
 - Move break area from switchgear room
 - **Substitution** (less hazardous equipment)
 - Reduce transformer size
 - Current-limiting fuses
 - Smart motor control centers
 - **Engineering Controls** (automatically reduces risk)
 - High resistance grounding
 - Remote racking for draw-out circuit breakers

Source: Landis Floyd, DuPont

Safety Ideas

▶ ANSI Z10-2005 Hazard Control Methods

- Warnings
 - Visible/audible signs, barriers, labels
- Administrative Controls
 - Hazard assessments
 - Lockout/tagout
 - Audits
 - Equipment maintenance
- Personal Protective Equipment
 - Available
 - Effective
 - Easy-to-use



Safety Ideas

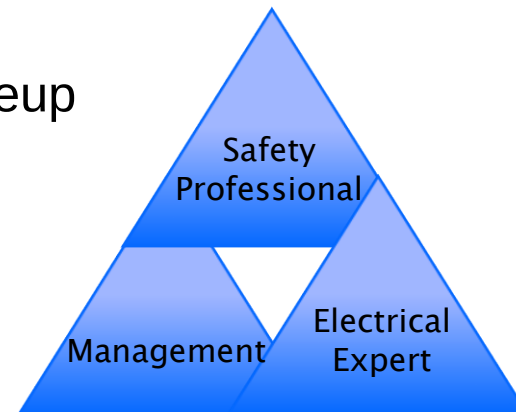
▶ Forming a Safety Committee

◦ Duties

- Safety policy meets all applicable OSHA regulations.
- Routine inspections of all equipment and work processes.
- Investigate all workplace accidents and safety violations.

◦ Keys to Success

- Management Support
- Cross-Company Committee Makeup
- Clear Committee Goals



Safety Ideas

- ▶ Turn it off!
 - OSHA 1910.333(a)(1) Selection and use of work practices
 - Live parts to which an employee may be exposed shall be **deenergized** before the employee works on or near them, **unless** the employer can **demonstrate** that deenergizing introduces additional or increased hazards or is **infeasible** due to equipment design or operational limitations.
 - Focus on the rule, not the exception.



Source: California Division of Occupational Safety and Health

Source: [Jim White, training director for Shermco Industries](#)

Safety Ideas

- ▶ Perform field safety audits.
 - What is inspected, can be expected.
- ▶ Train your employees.
 - OSHA 1910.332 Electrical Training
 - Anyone who **performs** work on such systems
 - Anyone who **supervises** workers who do such work
 - Anyone who **works around** the equipment **(NEW)**
 - Shall receive training on the Electrical Safety-Related Work Practices.
 - De-energizing equipment
 - Application of locks and tags
 - Distinguish exposed live parts from other parts
 - Determine the nominal voltage of exposed live parts



Source: www.sxc.hu

Source: [Jim White, training director for Shermco Industries](#)

Safety Ideas

- ▶ Electrical workers must meet definition of a *qualified person*.
 - OSHA 1910.399 Definitions applicable to this subpart
 - Has received training.
 - Has *demonstrated* skills and knowledge.
- ▶ Assess the hazards.
 - OSHA 1910.132(d)(1) Personal Protective Equipment
 - Hazards are present.
 - Hazards that are *likely to be* present.
 - Must produce a certification of hazard assessment document.

Source: [Jim White, training director for Shermco Industries](#)



Safety Ideas

- ▶ Conduct job briefings.
 - Hazards that may be encountered.
 - What Personal Protective Equipment (PPE) is to be used.
 - Emergency contact numbers and procedures.
 - Any extraction procedure or other emergency procedure that may be needed.
 - What work is being done in the area.
 - If any work is being done on the circuit you are working on.



Safety Ideas

- ▶ Personal Protective Equipment (PPE) use must be enforced.
 - OSHA 1910.335(a)(1)(i) Safeguards for personnel protection.
 - 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.
- ▶ Employees cannot perform energized work if unable to do so safely.
 - A worker can be impaired by alcohol, illness, lack of sleep, or over-the-counter medications.
- ▶ Never tell someone to do something you know is unsafe.

Source: [Jim White, training director for Shermco Industries](#)



Poll Question

- ▶ How valuable has this Webinar been to you?
 - a) Not valuable at all
 - b) Slightly valuable.
 - c) Moderately valuable.
 - d) Very valuable.
 - e) Extremely valuable

- ▶ What topics would you like to see in future webinars?

Additional Resources

- ▶ [Electrical Safety Foundation International](#)
 - *Never Assume* Electrical Safety Series
- ▶ National Institute for Occupational Safety and Health (NIOSH)
 - [Arc Flash Awareness](#)
- ▶ IEEE Industry Application Society (IAS)
[Electrical Safety Workshop](#)

Questions?

▶ Contact Information:

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- Websites:

- http://www.pseg.com/business/small_large_business/index.jsp
- <http://www.njcleanenergy.com/>

