


Electrical Safety, the Arc-Flash Hazard, and ...

A Preview of the Coming Revision of NFPA 70E-2000

**Paul S. Hamer, P.E. – ChevronTexaco
Energy Research & Technology Company**

May 15, 2003

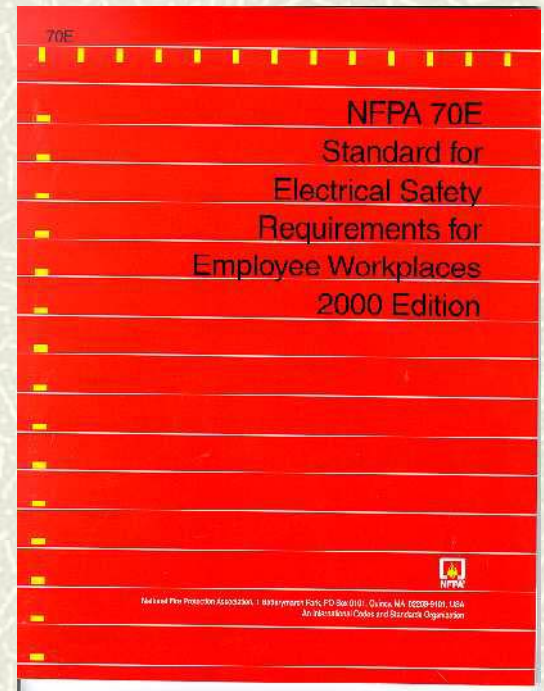


We'll cover:

- # NFPA 70E – what the standard is about, Terms and Definitions, Highlights of Requirements and changes
- # Testing and Isolation
- # Grounding
- # Job Briefings and Energized Work Permits
- # Electrical Hazards
- # Personal Protective Equipment
- # Arc-Resistant Switchgear Construction

NFPA 70E - scope

- # This standard addresses those **electrical safety requirements for employee workplaces** that are necessary for the practical safeguarding of employees in their pursuit of gainful employment
- # *The standard covers...*
 - Electric conductors and equipment installed within or on buildings or other structures, or other premises such as yards, carnivals, parking lots, and industrial substations.
 - Conductors that connect the installations to a supply of electricity.
 - Other outside conductors on the premises



Safety Related Work Practices

- # Part II of NFPA 70E-2000 covers electrical safety related work practices and procedures for employees who work on or near exposed energized electrical conductors or circuits parts ...
- # Requirements are included to protect **unqualified employees** from electrical hazards.

The NFPA – 70E Standard

This Standard is divided into four parts and a number of appendices.

- I. Installation Safety Requirements
- II. Safety-Related Work Practices
- III. Safety-Related Maintenance Requirements
- IV. Safety Requirements for Special Equipment

Appendices

(The document will be reorganized and renumbered for the next – 2003/2004 – edition)

HAZARDS ASSOCIATED WITH ELECTRICAL WORK

- #Electrical Shock
- #Arc-Flash Burns
- #Arc-Blast
- #Falls
- #Fire



LIVE PARTS

- # Existing definition of “live parts” – Electric conductors, buses, terminals, or components that are uninsulated or exposed and a shock hazard exists.
- # Definition for live parts is changing in 2004 (must start using the term *exposed live parts*):

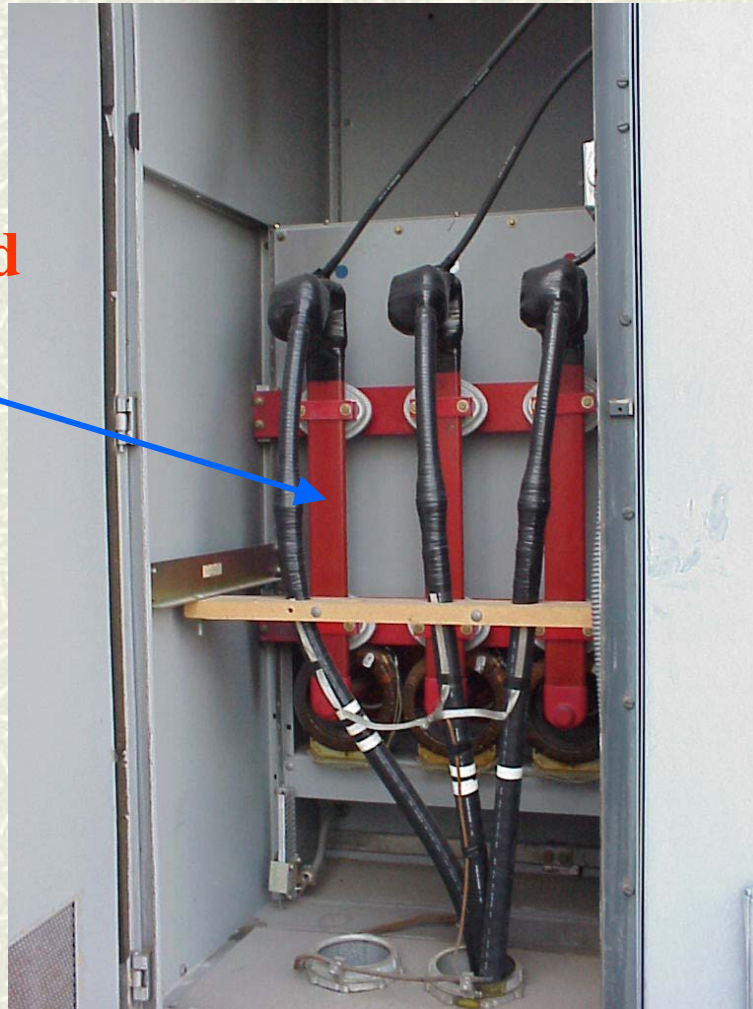
Live Parts. Energized conductive components.

Exposed. (as applied to live parts.) Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to parts that are not suitably guarded, isolated, or insulated.

- # A covered part is *not* considered insulated

This red-colored bus shown (on 15 kV switchgear) is considered “covered,” not insulated

This is an “Exposed Live Part”



With the door closed, it is an enclosure containing “live parts”

LIVE PARTS

- ⚡ **Live parts to which an employee might be exposed shall be put into an “electrically safe work condition” before an employee works on or near them**, unless an employer can demonstrate that deenergizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations.
- ⚡ Energized parts that operate at less than 50 volts to ground are not required to be deenergized if there will be no increased exposure to electrical burns or to explosion due to electrical arcs.

But, ... don't dismiss the capacity of the source and the overcurrent devices involved

Electrically Safe Work Condition:

A state in which the conductor or circuit part to be worked on or near has been **disconnected** from energized parts, **locked / tagged**, in accordance with established standards, **tested** to ensure the absence of voltage, and **grounded** if determined necessary.

QUALIFIED WORKERS

Only qualified workers are permitted to work on electrical conductors or circuit parts that have been put into an electrically safe work condition. Qualified workers:

- Are **trained** in the proper use of the special precautionary techniques, PPE, insulating & shielding materials, and insulated tools when required.
- Have the **skills and techniques** necessary for the understanding of induced, static, and impressed voltages, grounding integrity, condition of poles and structures, and circuit and equipment locations.
- Are **familiar with the decision making process** necessary to determine the degree and extent of the hazard and the personal protection equipment and job planning necessary to perform the task safely.

Personal Protective Equipment (PPE)

- # When activities are performed and will place the worker in close proximity to live parts, appropriate **personal protective equipment** must be utilized.
- # Such PPE in addition to the minimum basic requirements for electrical personnel may include:
 - **Insulating gloves with leather protectors**
 - **Arc-rated face shield or flash suit hood**
 - **Flame resistant clothing or flash suit**

LIMITED BOUNDARY APPROACH

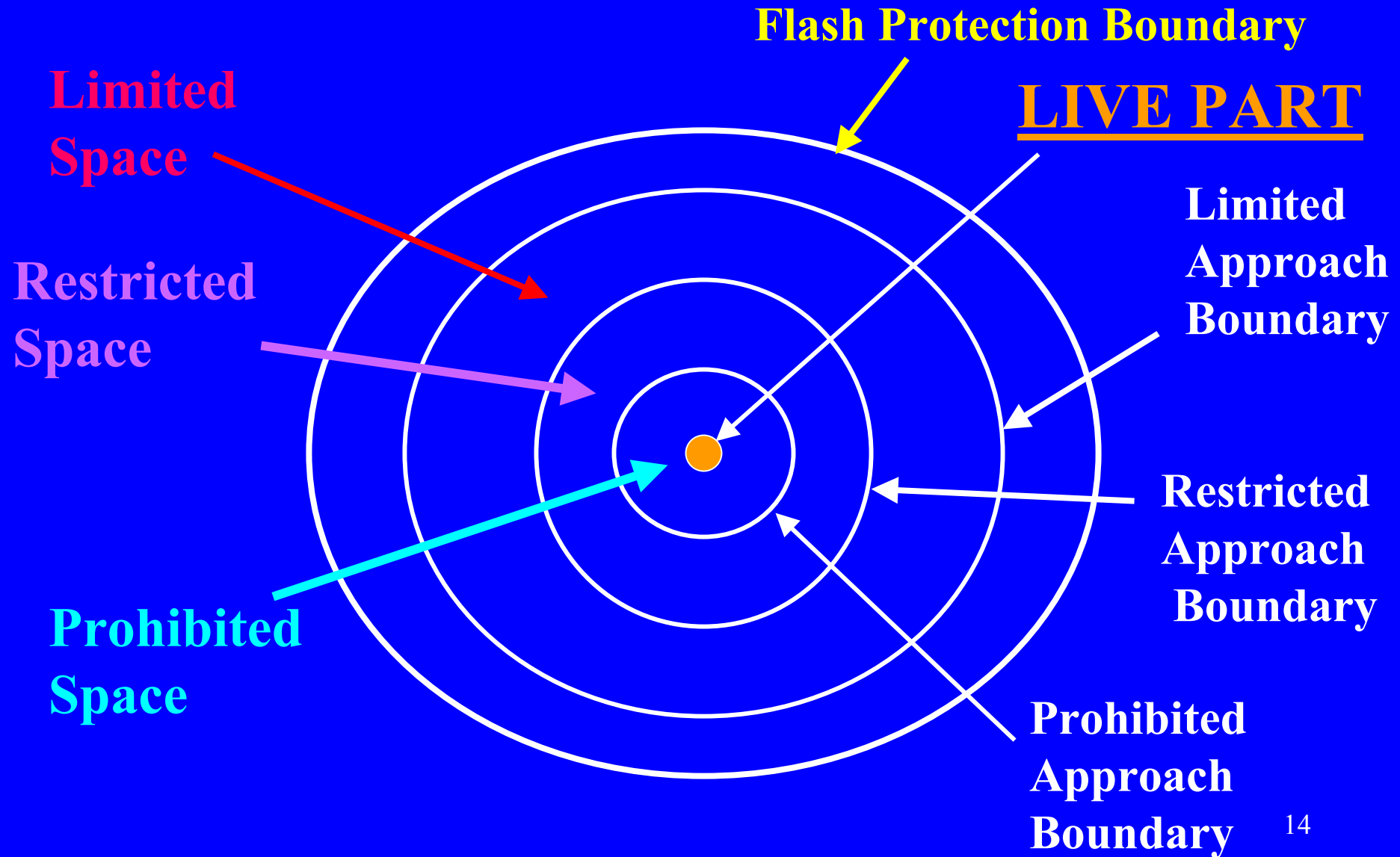
The “10 Foot Rule”... a safe “rule of thumb”...

- ⚡ An unqualified person – maintain a distance of 10 feet minimum from exposed live parts.

(also see “Limited Approach Boundary” – next slide)

- ⚡ To prevent physical contact with energized or isolated underground power lines, operate equipment or machines as follows:
 - The minimum clearance between the lines and every part of the equipment or machine or its load must be 10 feet for lines rated at 50,000 volts or below.
 - Increase the distance 4 inches for each 10 kV above 50 kV.

LIMITS OF APPROACH:



New Definitions that will be in the new edition of NFPA 70E (2004):

Limited Approach Boundary. An approach limit at a distance from an exposed live part within which a shock hazard exists.

Restricted Approach Boundary. 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 and inadvertent movement, for personnel working in close proximity to the live part.

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

APPROACH BOUNDARIES

**Nominal
System
Voltage Range**

Limited Approach Boundary

**Restricted
Approach
Boundary**

**Prohibited
Approach
Boundary**

Phase to Phase	Exposed Moveable Conductor	Exposed Fixed Circuit Part	Includes Inadvertent Movement Adder	(considered the same as making contact)
Less than 50 V	Not Specified	Not Specified	Not Specified	Not Specified
50-300 V	10 ft 0 in.	3 ft 6 in	Avoid Contact	Avoid Contact
301-750 V	10 ft 0 in	3 ft 6 in	1 ft 0 in	0 ft 1 in
751 V – 15 kV	10 ft 0 in	5 ft 0 in	2 ft 2 in	0 ft 7 in
15.1 – 36 kV	10 ft 0 in	6 ft 0 in	2 ft 7 in	0 ft 10 in
36.1 – 46 kV	10 ft 0 in	8 ft 0 in	2 ft 10 in	1 ft 5 in
46.1 – 72.5 kV	10 ft 0 in	8 ft 0 in	3 ft 3 in	2 ft 1 in
72.6 – 121 kV	10 ft 8 in	8 ft 0 in	3 ft 3 in	2 ft 8 in
138 – 145 kV	11 ft 0 in	10 ft 0 in	3 ft 7 in	3 ft 1 in

APPROACH BOUNDARIES (e.g., 480 volts)

**Nominal
System
Voltage Range**

Limited Approach Boundary

**Restricted
Approach
Boundary**

**Prohibited
Approach
Boundary**

Phase to Phase	Exposed Moveable Conductor	Exposed Fixed Circuit Part	Includes Inadvertent Movement Adder	(considered the same as making contact)
Less than 50 V	Not Specified	Not Specified	Not Specified	Not Specified
50-300 V	10 ft 0 in.	3 ft 6 in	Avoid Contact	Avoid Contact
301-750 V	10 ft 0 in	3 ft 6 in	1 ft 0 in	0 ft 1 in
751 V – 15 kV	10 ft 0 in	5 ft 0 in	2 ft 2 in	0 ft 7 in
15.1 – 36 kV	10 ft 0 in	6 ft 0 in	2 ft 7 in	0 ft 10 in
36.1 – 46 kV	10 ft 0 in	8 ft 0 in	2 ft 10 in	1 ft 5 in
46.1 – 72.5 kV	10 ft 0 in	8 ft 0 in	3 ft 3 in	2 ft 1 in
72.6 – 121 kV	10 ft 8 in	8 ft 0 in	3 ft 3 in	2 ft 8 in
138 – 145 kV	11 ft 0 in	10 ft 0 in	3 ft 7 in	3 ft 1 in



INSULATED TOOLS

- # When **working near** (i.e., within the *Limited Approach Boundary*) live parts, use insulated tools or handling equipment if the tools or handling equipment might make contact with such conductors or parts.
- # **Also use insulating gloves** with leather protectors
- # Tools must be **rated for the voltage** involved. Commercially available insulated hand tools (pliers/ screwdrivers) are typically rated up to 1000 volts A.C.

INSULATED TOOLS



**Deluxe Electricians'
Tool Box**

Note the “1000 V” mark on genuine insulated tools



EQUIPMENT / LINE STATUS

- # The **BASIC RULE**.... Consider all electrical equipment and lines **energized** until isolated, tested, locked /tagged out and grounded!
- # **Proper Work Environment** ... The preferred approach is to **De-Energize!**
- # Identify all potential voltage sources and make plans to positively control all conductors and isolating devices.

Determine all possible voltages sources: check drawings, diagrams, identification tags, etc.

ISOLATION

Testing and Verification Techniques for Isolation:

- Check for absence of voltage on molded case breakers (600 volts or less) – **test phase-to-phase and each phase to ground**
- Purchase panel boards (600 volts and less) pre-equipped with locking devices and use these devices.
- Remove fuses from low-voltage switches that have covered blades, verify there is no voltage.
- Withdraw draw-out circuit breakers to the farthest position in the cubical and completely remove if a ground and test device will be applied.
- Open isolation disconnects on circuit breakers in open air switchyards
- Do not rely on control circuit isolation for lock out purposes. Provide primary circuit isolation on circuit breakers and motor starters.

Low voltage testing

- # The “Wiggy” is not recommended.
- # The Fluke® T5-1000 is one example of a recommended voltage and current tester.
 - Has a current limiting fuse
 - Checks both DC and AC on a single voltage selection
 - It is a UL Category 3 or 4 device, depending on whether used on 1000 V or 600 V systems



Fluke T5-1000, low-voltage tester:



High voltage testing

- ⚡ Verify the voltmeter operates properly before, and after, making the actual voltage tests



High voltage testing

- ⚡ Proper PPE is required for the energy available – assume the part to be **energized** until proven otherwise



REQUIRED GROUNDING

- # To assure an Electrically Safe Work Condition
- # All switchgear buses
- # All feeders from substations
- # All open wire lines.
- # Ground all motors equipped with power factor correction capacitors.
- # Ground all motors circuits above 600 volts before working on the motor. Use a “ground and test” device or connect grounds at the load side cable connections of the circuit breaker or starter.
- # Apply grounds as if the circuit were energized.

GROUNDING

As applicable to the grounding of transmission and distribution lines and equipment.

- For employees to work on lines or equipment designated as de-energized, a “clearance” is issued and all isolating points locked and tagged and with appropriate grounds installed.
- Before any ground is installed, first test the lines or equipment for absence of voltage unless a previously installed ground is present.

CAUTION ... Grounds left on equipment when reenergized present a short circuit hazard!

- If installation of grounds at the work location is not feasible, install grounds on each side of the work location, as close to the work as possible.

EQUIPOTENTIAL GROUNDING

- # Equipotential groundings are techniques used on transmission and distribution lines – to establish a safe “work zone”
- # There are different methods used:
 - Single Point Grounding
 - Double Point Grounding
 - Remote Double Point
 - Personal Grounds
- # These techniques require hands-on training and qualification before using

Ground cluster on a 12 kV switch

- # Make sure the ground conductors are sized for the short circuit current and duration (*Ref. ASTM F 855 - check upstream protection timing*)
- # Clamps must be attached securely



EXTRA WARNING?

- # Would magnetic signs in special places help?
- # Don't take the lock off the breaker until you have the grounding lock in your hand.
- # Some work locations use a key type ground system to help with isolation and avoid problems.

Example of a magnetic sign indicating the circuit is grounded



JOB BRIEFING

- # The person in charge conducts a job briefing **before beginning work** on new installations and modifications to existing installations.
- # At least one job briefing must be conducted **before the start of each shift.**
- # Additional job briefings must be held if there are **changes** during the course of the work that could affect personal safety.
- # Use the Job Briefing Check List from the NFPA 70E-2004 proposal.

JOB BRIEFING SUBJECTS

- # Hazards associated with the job
- # Work procedures involved
- # Special precautions
- # Energy source controls
- # Personal Protective Equipment requirements
- # Work Zones.

Check and double-check the one line diagrams



Use the planning tool to prepare a “switching order”

Electrical Switching Order
No. 12924

Page 1 of 1

Date _____

Section to be Isolated
TX 137 & TX 100 @ FCC

Reason
RYTAMER PROJECT TO FIELD VERIFY ELECTRICAL ITEMS

Plants Affected
FCC PRECIPITATOR & MTBE/TAME

Plant Area Supervisor Notified (Name) and Switching Plan Reviewed _____

Step	Location	Action	Switching Sequence	Description	Date	Time	Time Completed
1.	Map Room	Change		Pins in Electrical Map			
2.	#1 PP	Change		Pins in Electrical Map			
3.	Co-Gen	Change		Pins in Electrical Map			
		CHECK LOADS	<u>TX 137</u>	<u>ACT</u>	<u>MAY 13 08</u>		
		CHECK	<u>TX 138</u>	<u>ACT</u>	<u>MAY 18 04</u>		

Planning Checklist

Identify

- | | |
|--|---|
| <input type="checkbox"/> What are the hazards? | <input type="checkbox"/> Potential for arc flash |
| <input type="checkbox"/> What voltage levels are involved? | <input type="checkbox"/> Unusual work conditions |
| <input type="checkbox"/> What skills are required? | <input type="checkbox"/> Is this a multiple-person job? |
| <input type="checkbox"/> "Foreign" voltage source present? | |

Ask

- | | |
|--|--|
| <input type="checkbox"/> Can the equipment be de-energized? | <input type="checkbox"/> Is a "standby person" required? |
| <input type="checkbox"/> Are there possible backfeeds of the circuits to be worked on? | |

Check

- | | |
|--|---|
| <input type="checkbox"/> Job plans | <input type="checkbox"/> Safety procedures |
| <input type="checkbox"/> One lines and vendor prints | <input type="checkbox"/> Vendor information |
| <input type="checkbox"/> Status board | <input type="checkbox"/> For up-to-date information on plant and vendor resources |
| <input type="checkbox"/> Individuals familiar with facility? | |

Know

- What is the job?
- Who is in charge?
- Who else needs to know? ... Communicate!

Think

- | | |
|---|---|
| <input type="checkbox"/> About the extra event ... What if? | <input type="checkbox"/> Use the right tools and equipment, including PPE |
| <input type="checkbox"/> Lock - Tag - Test - Try | <input type="checkbox"/> Install barriers and barricades |
| <input type="checkbox"/> Test for voltage - FIRST | <input type="checkbox"/> What else ...? |
| <input type="checkbox"/> Install and remove grounds | |

Prepare for an emergency

- | | |
|---|---|
| <input type="checkbox"/> Standby person CPR trained? | <input type="checkbox"/> What is the exact work location? |
| <input type="checkbox"/> Telephone location? | <input type="checkbox"/> How is the equipment shut off in an emergency? |
| <input type="checkbox"/> Fire alarm locations? | <input type="checkbox"/> Where is the emergency equipment? |
| <input type="checkbox"/> Confined space rescue available if required? | <input type="checkbox"/> Is the required emergency equipment available? |
| <input type="checkbox"/> Emergency phone numbers? | <input type="checkbox"/> Radio communications available? |
| <input type="checkbox"/> Extinguisher? | <input type="checkbox"/> |

Job Briefing and Planning Checklist (sample)

QUESTIONS

- # The job briefing should enable each employee to answer **YES** to the following questions before beginning the job:
 - Do I thoroughly understand the job?
 - Do I thoroughly understand my role and everyone else's roles in the job?
 - Am I aware of the hazards I may possibly encounter.
 - Am I knowledgeable about all safety rules and PPE?
 - Do I have safeguards in place to protect me from unexpected events?

“Energized Electrical Work Permit”

A new requirement in the next edition of 70E

Includes:

- a) A description of the equipment/circuit and the work to be done
- b) Justification of why the work must be done energized
- c) Description of the safe work practices to be used
- d) Shock Hazard Analysis and determination of approach boundaries
- e) Flash Hazard Analysis and the Flash Protection Boundary
- f) Protective clothing and other personal protective equipment required to perform the task safely
- g) Means of restricting unqualified persons from the work area
- h) Evidence of a Job Briefing and discussion of job-specific hazards
- i) Appropriate management approvals

Energized Electrical Work Permit (cont'd)

A new requirement in the next edition of 70E

Relief from the permit requirement:

Work performed on or near live parts by **qualified persons** related to tasks such as testing, troubleshooting, voltage measuring, etc., shall be permitted to be performed without an energized electrical work permit provided appropriate safe work practices and personal protective equipment in accordance with Part II is provided and used.

HAZARDS ASSOCIATED WITH ELECTRICAL WORK

Electrical Shock

Arc-Flash Burns

Arc-Blast

Secondary hazards include

Falls

Fire

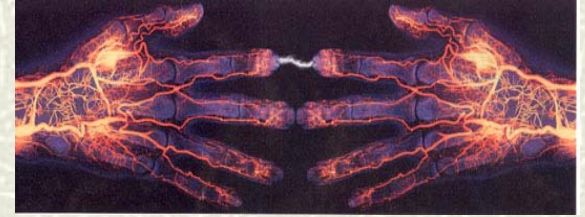
ELECTRICAL HAZARDS

- **Shock**
- **Arc-Flash**
 - Heat
 - Fire
- **Arc-Blast**
 - Pressure
 - Shrapnel
 - Sound



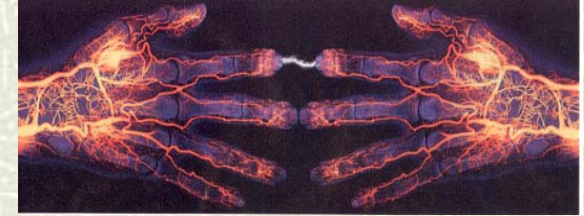
Example of an arcing fault

SHOCK



- **Over 30,000 non-fatal electrical shock accidents occur each year.**
- **Over 350 people die from electrocution each year.**
- **Electrocution remains the fourth (4th) highest cause of industrial fatalities.**
- **Most injuries and deaths could be avoided**

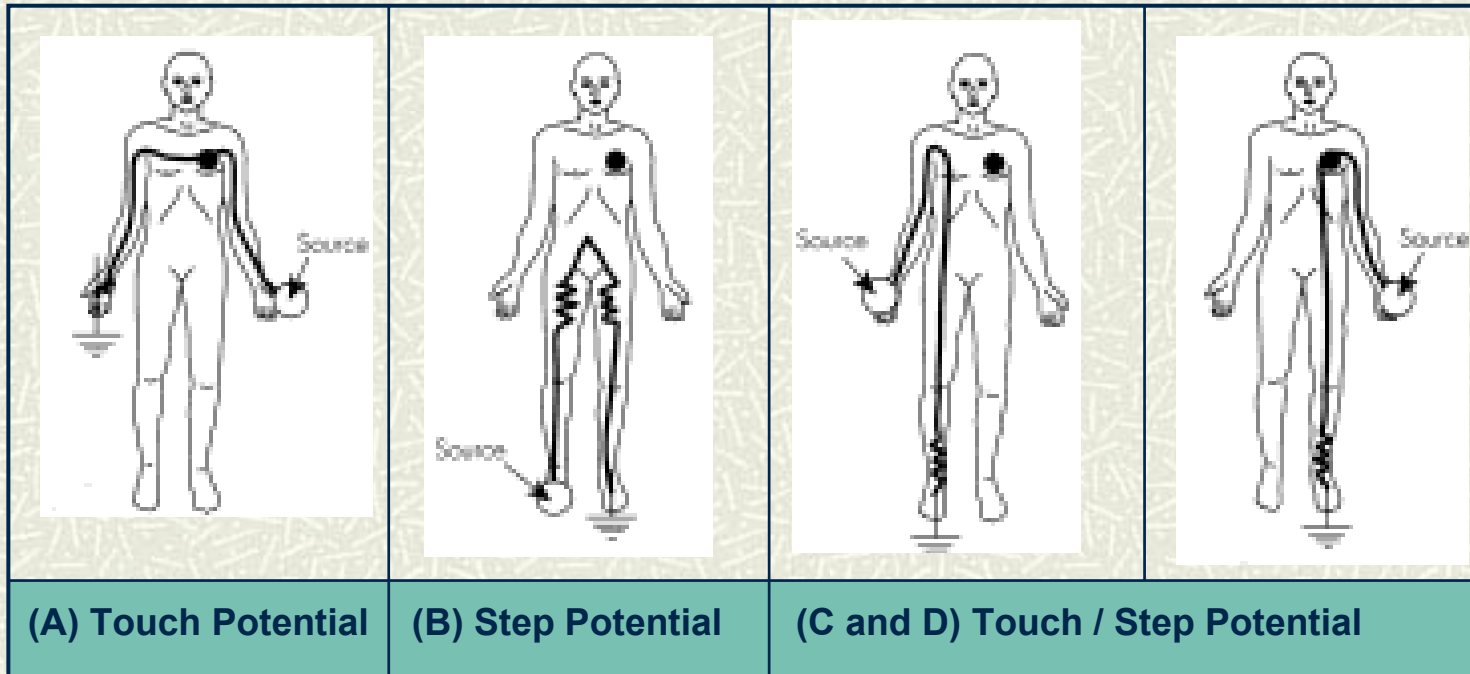
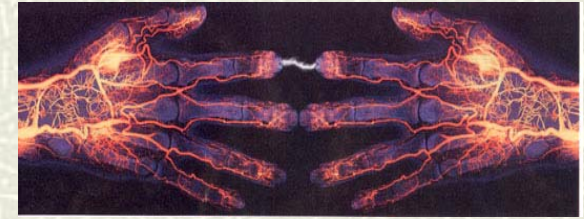
SHOCK *(Resistance Table)*



Condition	Resistance, (ohms)	
	Dry	Wet
Finger Touch	40,000 to 1,000,000	4,000 to 15,000
Hand Holding Wire	15,000 to 50,000	3,000 to 6,000
Finger-Thumb Grasp	10,000 to 30,000	2,000 to 5,000
Hand holding pliers	5,000 to 10,000	1,000 to 3,000
Palm Touch	3,000 to 8,000	1,000 to 2,000
Hand around 1 1/2 Pipe	1,000 to 3,000	500 to 1,500
Two Hands Around 1 1/2 Pipe	500 to 1,500	250 to 750
Hand Immersed		200 to 500
Foot Immersed		100 to 300
Human Body, internal, excluding skin	200 to 1,000	

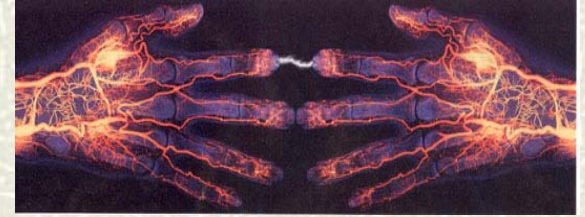
This Table was compiled from data developed by Kouwenhoven and Milnor

SHOCK



Current passing through the heart and lungs is the most serious

SHOCK



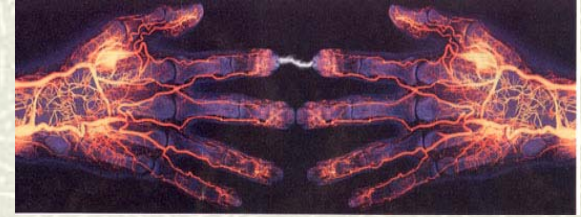
- **Human body resistance (hand to hand) across the body is about 1000 Ω**

Ohms Law: $I = V / R$ (Amps.)

$$\begin{aligned} I &= 480 \text{ volts} / 1000 \Omega \\ &= \mathbf{0.48 \text{ amps (480 mA)}} \end{aligned}$$

The National Electrical Code® considers 6 mA to be the safe upper limit for shock protection (Class A device per UL 943, *Standard for Ground-Fault Circuit Interrupters*)

SHOCK



Current Flow, Not Voltage causes Electric Shock

- # 0.5 - 3 mA - Tingling sensations
- # 3 - 10 mA - Muscle contractions and pain
- # 10 - 40 mA - “Let-go” threshold
- # 30 - 75 mA - Respiratory paralysis
- # 100 - 200 mA - Ventricular fibrillation
- # 200 - 500 mA - Heart clamps tight
- # 1500 + mA - Tissue and Organs start to burn

Note: Reaction will vary with frequency and time of exposure

ARC-FLASH



- As many as 80% of all electrical injuries are burns resulting from an arc-flash and ignition of flammable clothing
- Arc temperature can reach 35,000°F - this is four times hotter than the surface of the sun
- Fatal burns can occur at distances over 10 ft.
- Over 2000 people are admitted into burn centers each year with severe electrical burns
- An Arc-Flash also contains molten metal



Typical Arc Test

**Non-FR Shirt &
Pants
12 inch arc gap
Exposed surface
12 inches from
the arc center line**

Arc Test Exposure

15 kA

3 kV

10 cycles

12 inch arc gap

Arc Test Consequences

Cotton Shirt Ignites

*Consequences:
3rd degree burns
on most of the
torso and face*



Arc test of flame-resistant (FR) material versus cotton flannel

- # FR material flares and then extinguishes
- # Cotton flannel ignites immediately and continues to burn



Arc-Flash



Skin Temperature	Time of skin temperature	Damage caused
110 °F	6 Hours	Cell breakdown starts
158 °F	1 sec.	Total cell destruction
176 °F	0.1 sec	Curable burn
200 °F	0.1 sec	Incurable 3rd degree burns

Skin Temperature Tolerance Relationship

FLASH HAZARD ANALYSIS

- # A **flash hazard analysis** must be done before a person approaches any exposed electrical conductor or circuit part that has not been placed in an electrically safe work conditions.
- # The **Flash Protection Boundary** will establish the need for PPE to cross that boundary.
- # **Flame Resistant clothing and PPE** is used by the employee based upon the incident energy associated with the task.

FLASH HAZARD ANALYSIS – definition:

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 and the appropriate levels of PPE.

(in the next edition of NFPA 70E)

FLASH PROTECTION BOUNDARY (to become more stringent in NFPA 70E-2004)

- ⚡ At 600 volts or less The flash boundary shall be 4.0 feet.
- ⚡ Or the flash boundary may be alternatively using information and formulas outlined in NFPA 70E.
- ⚡ At voltage levels above 600 volts, **the flash protection boundary is the distance at which the incident energy level equals 1.2 cal/cm² (New 2004 definition)**
- ⚡ For situations where fault clearing time is 0.1 second (or faster), the flash protection boundary is the distance at which the incident energy level equals 1.5 cal/cm² **(no longer applicable in 2004)**

ARC-BLAST (its effect on workers is the next frontier of investigation)



- **An arc fault develops a “Pressure Wave”**
- **Sources of this blast includes:**
 - Copper expands **67,000 times** its original volume when vaporized
 - Heat from the arc, causes air to expand, in the same way that thunder is created from a lightning strike
- **This may result in a violent explosion of circuit components and thrown shrapnel**
- **The blast can destroy structures, knock workers from ladders, or across the room**

LEFT HAND RULE FOR DISCONNECTS

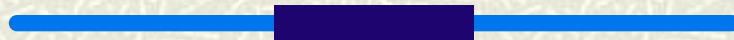
- # The “Left Hand rule” as applied to breakers and disconnects simply states that using your left hand to energize or deenergize a breaker or disconnect will place you as far from the source as you can get.



Position yourself away from the Arc Blast Path!

Electrical Safe Work Practices

Personal Protective Equipment



HAZARD/RISK CATEGORY CLASSIFICATION (From NFPA 70E-2000)

Refer to Table 3-3.9.1 Hazard Risk Category Classifications.

- **Hazard Risk Category (0-4)**
- **Voltage Rated Gloves (Yes or No)**
- **Voltage Rated Tools (Yes or No)**

Refer to Table 3-3.9.2 Protective Clothing

- **Protective Clothing and Equipment**
- **Hazard Risk Category**
- **Protective Systems for Hazard/Risk Category (-1 to 4)**

Protective Clothing and Equipment	Protective Systems for Hazard/Risk Category						
	Hazard/Risk Category Number	-1 (Note 3)	0	1	2	3	4
Untreated Natural Fiber	-	-	-	-	-	-	-
a. T-shirt (short-sleeve)	X				X	X	X
b. Shirt (long-sleeve)			X				
c. Pants (long)	X	X	X (Note 4)	X (Note 6)	X	X	X
FR Clothing (Note 1)	-	-	-	-	-	-	-
Long-sleeve Shirt			X	X	X (Note 9)	X	
Pants			X (Note 4)	X (Note 6)	X (Note 9)	X	
Coverall			(Note 5)	(Note 7)	X (Note 9)	(Note 5)	
Jacket, Parka, or Rainwear			AN	AN	AN	AN	
FR Protective Equipment	-	-	-	-	-	-	-
Flash Suit Jacket (2-Layer)							X
Flash Suit Pants (2-Layer)							X
Head Protection	-	-	-	-	-	-	-
Hard Hat			X	X	X	X	X
FR Hard Hat Liner					X	X	
Eye Protection	-	-	-	-	-	-	-
Safety Glasses	X	X	X	AL	AL	AL	
Safety Goggles				AL	AL	AL	
Face Protection—Double-Layer Switching Hood				AR (Note 8)	X	X	
Hearing protection (ear canal inserts)				AR (Note 8)	X	X	
Leather Gloves (Note 2)			AN	X	X	X	
Leather Work Shoes			AN	X	X	X	

PPE Hazard/Risk Categories



Also see Appendix “F” in NFPA 70E (page 75)

Legend:

Notes:

Protective clothing:

- # For most low-energy work (240 volts or below), natural-fiber, non-melting clothing is adequate; some higher risk tasks require FR clothing
- # Most work on or near systems rated 480 volts and above requires at least one layer of flame-resistant (FR) clothing worn over natural-fiber clothing
- # High-energy tasks require FR flash suits and flash suit hoods worn over FR clothing

PPE-related proposals for NFPA 70E-2004:

Melting. Clothing made from flammable synthetic materials that melt at temperatures below 315°C (600°F), such as acetate, nylon, polyester, polypropylene, and spandex, either alone or in blends with each other, shall not be used.

NOTE: These materials will melt as a result of arc-flash exposure conditions, form intimate contact with the skin, and aggravate the burn injury.

Proposals for NFPA 70E-2004 (cont'd):

Flammability. Clothing made from non-melting flammable materials, such as cotton, wool, rayon, or silk shall be permitted for Hazard/Risk Categories 0 and minus 1 if it is determined by flash hazard analysis that the exposure level is 2 cal/cm^2 , or below, and that the fabric will not ignite under the arc exposure hazard to which it will be exposed ...

Notes on “flammability” proposal

NOTE 1: Non-FR Cotton, polyester-cotton blends, nylon, nylon-cotton blends, silk, rayon, and wool fabrics are flammable. These fabrics can ignite and continue to burn on the body resulting in serious burn injuries.

NOTE 2: Rayon is a cellulose-based (wood pulp) synthetic fiber that is a flammable, but non-melting material.

Example: 240 V Panelboard

TASK	HRC	GLOVES	TOOLS
Operate CB or fused switch with covers off	0	N	N
Work on live parts, including voltage testing	1	Y	Y
Remove bolted covers (to expose live parts)	1	N	N

Example: 600 V MCC (w/ proposed 2004 changes to NFPA 70E-2000)

TASK	HRC	GLOVES	TOOLS
Operate starter with door open	2	N	N
Diagnostic testing (considering interference)	2	Y	Y
Remove bolted covers (to expose live parts)	4	N	N

Example: 600 V Metal-Clad Switchgear (proposed 2004 changes to NFPA 70E-2000)

TASK	HRC	GLOVES	TOOLS
Operate CB with door open	2	N	N
Diagnostic testing (considering interference)	2	Y	Y
Insert or remove (rack) CB	4	N	N

“Racking in” a 480 V CB – (with the 2004 edition of NFPA 70E, HRC 4 PPE will be required)



Table 3-3.9.1 Hazard Risk Category Classifications -- (Excerpt from NFPA 70E-2000)

Task (Assumes Equipment is Energized, and Work is Done Within the Flash Protection Boundary)	Hazard/ Risk Category	V-rated Gloves	V- rated Tools
Metal Clad Switchgear, 1 kV and above	-	-	-
Work on energized parts, including voltage testing	4	Y	Y
Work on control circuits with energized parts 120 V or below, exposed	2	Y	Y
Work on control circuits with energized parts >120 V exposed	4	Y	Y
Insertion or removal (racking) of CBs from cubicles, doors open	4	N	N
Application of safety grounds, after voltage test	4	Y	N

“Racking in” a 15 kV CB



Arc-Resistant Switchgear Considerations:

See ANSI/IEEE C37.20.7-2001, EEMAC G14-1-1987 (Canada), and IEC 60298-1990

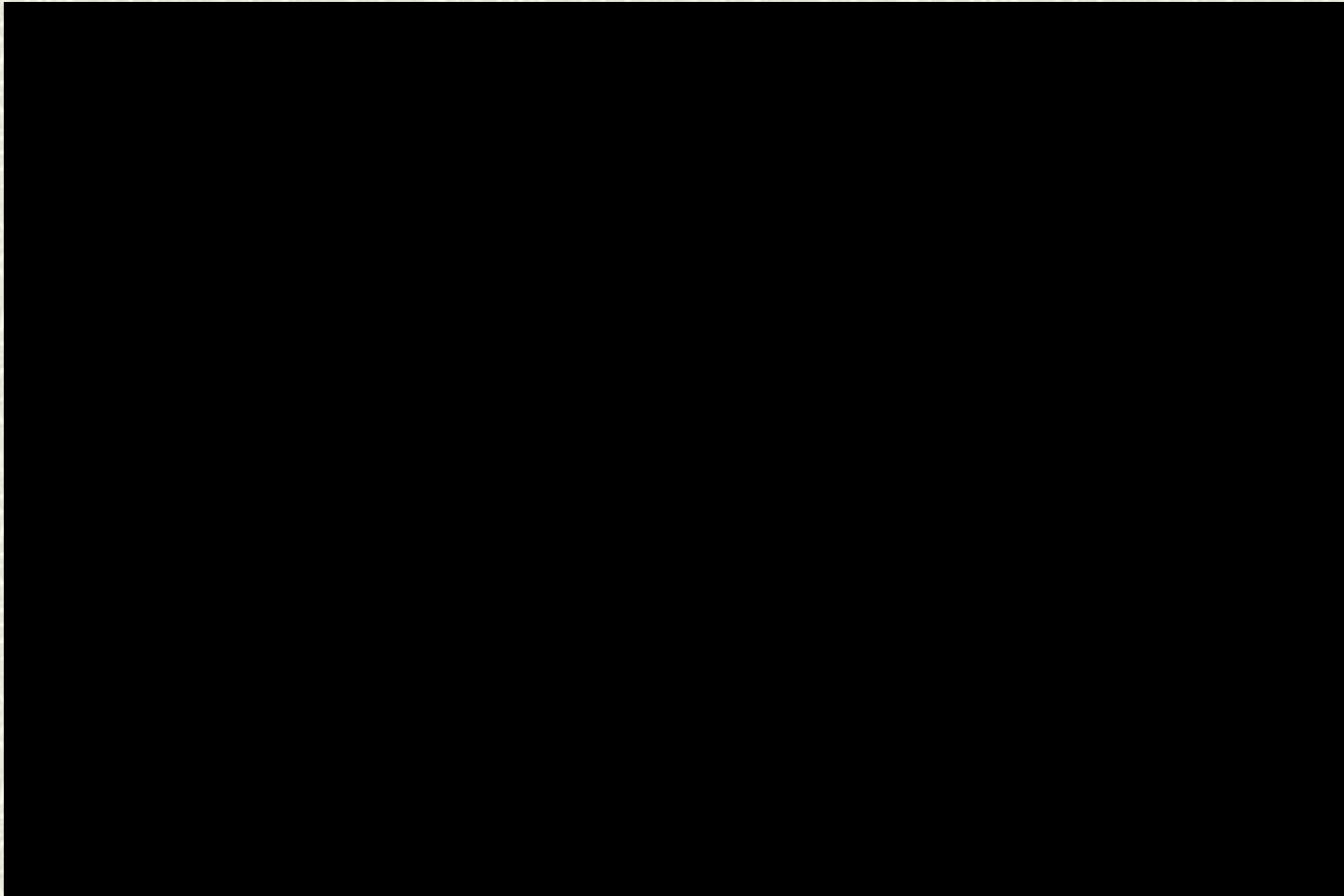
- EEMAC Type “A” (IEEE Type 1) – arc-resistant construction for employee working at the front of the switchgear only
- EEMAC Type “B” (IEEE Type 2) – features of Type A, plus arc-resistant construction at the back and sides
- EEMAC Type “C” (IEEE Type 2C) – features of Types A and B, plus arc-resistant construction between compartments within the same cell or between cells

Video clips of arc-resistant tests:

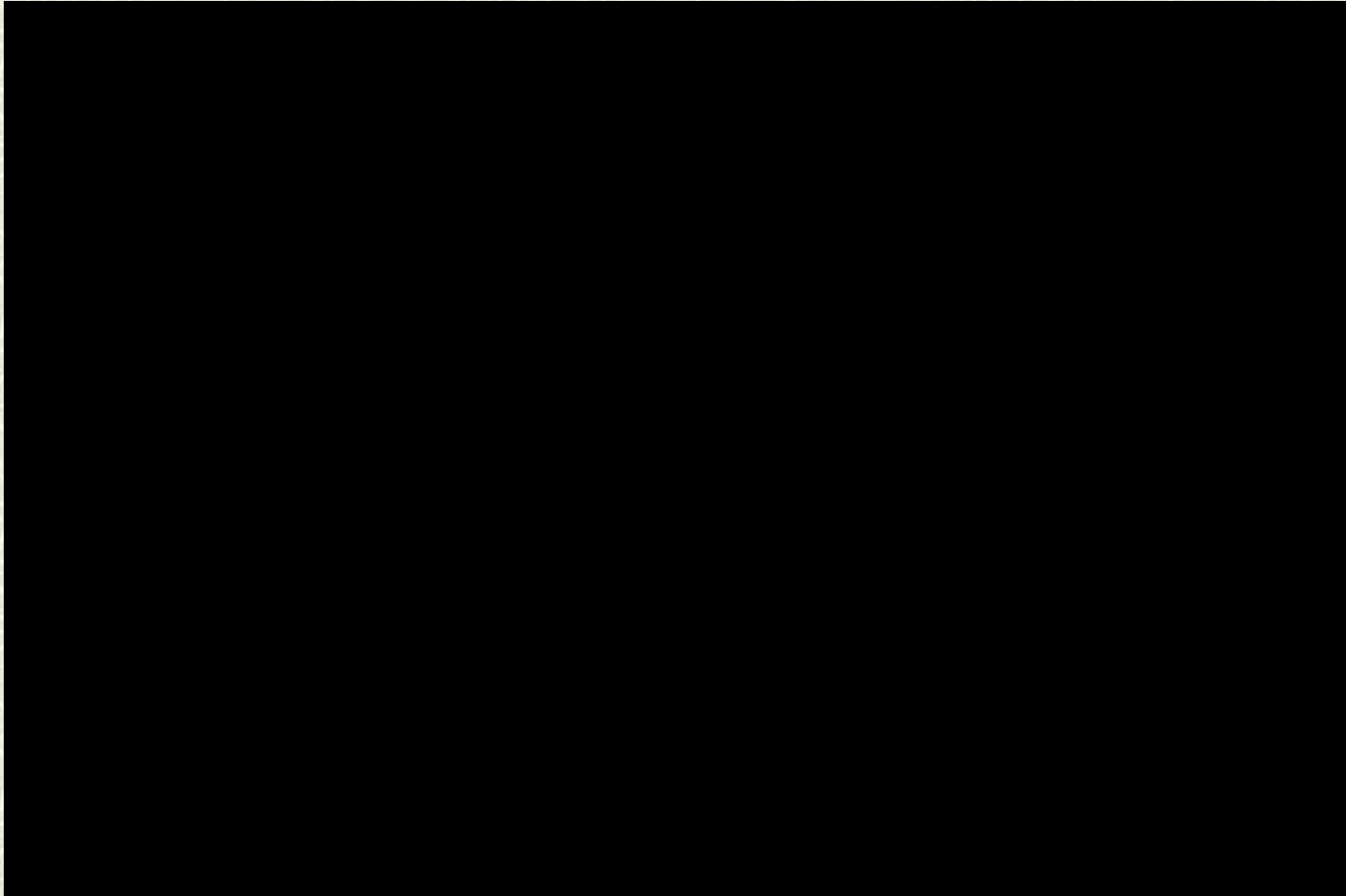
Load-interrupter switchgear applied at 15 kV and 40 kA short circuit availability:

- # First video is an unsuccessful test of equipment not of arc-resistant design
- # Second video is of arc-resistant switchgear

Arc Resistant Switchgear - Unsuccessful test:



Arc Resistant Switchgear - Successful test:



Arc-Resistant Switchgear Considerations:

Advantages:

- When **all doors are closed and secured**, do not need to use flame-resistant or arc-rated PPE
- Also avoids direct exposure to the “blast” hazard

NFPA 70E-2004 may address the “arc-resistant approach” in a Note to the tables (pending approval of a Tentative Interim Amendment)

Disadvantages:

- Special building construction may be required
- When performing required voltage testing or grounding (doors open), PPE is needed
- Only beginning to become available for medium-voltage motor controllers and load-interrupter switches
- Not yet available for low-voltage switchgear and motor control centers, where many incidents occur

Arc-Resistant Switchgear Considerations:

There are alternative approaches:

- # Deenergize prior to doing the task
- # Remote operation of circuit breakers (e.g., open/close through a “mimic” panel)
- # Remotely operated circuit breaker “racking” devices (motor driven)

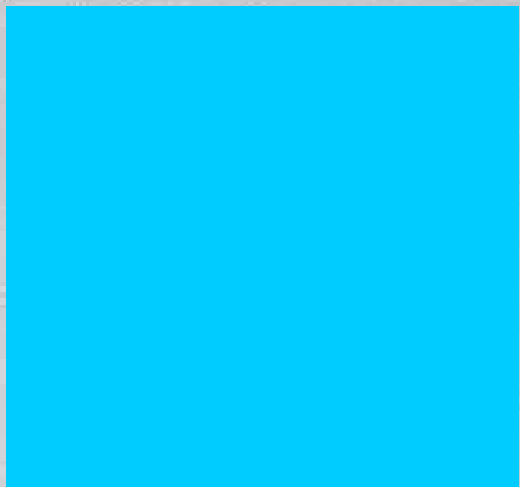
PPE at 480 volts?

- # At some MCCs you can use an arc-rated Face Shield for an 8 cal/cm² exposure...

Only if the fault current available at the point of work is less than 15 kA for 0.2 sec, or 32 kA for 0.1 sec (time duration of exposure is dependent on “upstream” CB setting and characteristics). This is accordance with calculation methods of the new IEEE Std 1584-2002.

ARC-RATED FACE SHIELD

FLASH PROTECTION ARC SHIELD



PPE at 480 volts?

- # Where will you need to use a flash suit and flash suit hood (40 cal/cm² rating)?

If the fault current available at the point of work is less than 50 kA for 0.33 sec, 86 kA for 0.2 sec, or 180 kA for 0.1 sec (time duration is dependent on “upstream” CB setting and characteristics). This is in accordance with the calculation methods of the new IEEE Std 1584-2002.

FLASH SUIT HOOD

FLASH PROTECTION ARC HOOD



CLOTHING / APPAREL

- # Use clothing, including undergarments, made from materials **that will not increase the extent of an injury** sustained during a flame or arc event.
- # The EMPLOYER must ensure that conductive articles are not worn in close proximity to, or within reaching distance of, live parts.

This includes items such as rings, metal watch bands, unrestrained metal-framed eyewear (with the 2004 Edition of NFPA 70E, metal-framed eyewear will be, discouraged, if not prohibited), metal dangling jewelry and key chains.

“EVERYDAY” WORK CLOTHING

All Hazard/Risk Category 1 & 2 tasks listed in Table 3-3.9.1

Flame Resistant (FR) coveralls of minimum ATPV of 5 (4 in the 2004 edition) worn over an untreated cotton T-shirt, or an untreated natural fiber long sleeve shirt, with untreated natural fiber pants.

ELECTRICAL “SWITCHING” CLOTHING

All Hazard/Risk Category 3 & 4 Tasks

Insulated FR coveralls (with a minimum ATPV of 25, independent of outer layers) worn over untreated natural fiber long sleeve shirt with untreated denim cotton blue jeans) regular weight, minimum 12 oz/yd² fabric weight., worn over an untreated cotton tee shirt. ...OR

ELECTRICAL “SWITCHING” CLOTHING

All Hazard/Risk Category 3 & 4 Tasks

A FR rain suit worn over the FR coveralls or FR shirt/slacks (and cotton underneath) – layer combination must have been tested and passed a 40 cal/cm² without breakthrough of the innermost FR layer

Flash suit hood and rainwear using recent technology

- # Hood and rainwear briefly flare up
- # Flames extinguish



ATPV in cal/cm² – Level of Protection (there's something wrong with the 15 cal/cm² kit photo – can you spot it?)



Flame-Resistant Rainwear

Should individual suits be available for every person? Arguments for:

- Correct size and fit.
- Hygiene concerns eliminated
- Storage & protection is easy
- Cost approximately \$200 to \$250 each



Suitable for arc flash protection – not for petrochemical fire protection.

Example of “HRC 4” clothing system



NFPA 70E CHANGES

- # Keep an eye open for changes in the 2004 edition of NFPA 70E – (see <http://www.nfpa.org>)
 - Technical Committee ballot May 2003
 - Report on Comments (ROC) published Summer 2003
 - NFPA approval November 2003
 - NFPA Standards Council approval January 2004
 - New Edition available ~ April 2004
- # Adapt your PPE practices to reflect the changes approved by NFPA

EYE PROTECTION

- # Wear approved safety glasses, with non-conductive side shields, at all times when working on or near potentially energized conductors or exposed live parts.
- # But, ... safety glasses only provide minimal protection from arc-flash energy.
- # Eye protection for electrical workers needs to protect the worker from ultraviolet radiation as well as impact.
- # Where are your side shields now?
- # Goggles and / or face shields may also be required.

Safety glasses – plastic frame with side shields are recommended (left)



HAND PROTECTION

- # Insulating rubber gloves with leather protectors must be worn any time an employee is working with energized, or potentially energized, conductors or equipment.
- # Rubber gloves with protectors must be worn any time an employee is using live-line tools or test probes.
- # Rubber gloves with protectors must be worn during the installation or removal of grounds.
- # Use only gloves dielectrically tested within the previous six (6) months
- # Inspect gloves and air test them before each use.
- # Heavy leather gloves provide good arc-flash protection.

INSULATING RUBBER GLOVES

CLASS	MAXIMUM USE VOLTAGE (AC)	TEST VOLTAGE (AC)
00	500 Volts	2,500 Volts
0	1,000 Volts	5,000 Volts
1	7,500 Volts	10,000 Volts
2	17,000 Volts	20,000 Volts
3	26,500 Volts	30,000 Volts
4	36,000 Volts	40,000 Volts

Cal OSHA requirement (Title 8, 2320.2)

- # Approved insulating rubber gloves are required when working on exposed live parts with voltages in excess of 250 volts to ground (e.g., all 480 volt systems and 277 volt lighting circuits).

Rubber Gloves & Protectors



Glass 00

High Dexterity



Glass 0 and 00

Glove Kit



Glass 2

Glove Kit

Class 0 (1000 V) Insulating Rubber Gloves, with Leather Protectors



Class 2 (17 kV) Insulating Rubber Gloves, with Leather Protectors



GLOVE STORAGE

- # Store gloves in an approved glove bag or an equivalent protective location.
- # Do not store gloves folded or inside-out
- # If possible, store gloves with the cuffs down.

PROPER SIZE GLOVE

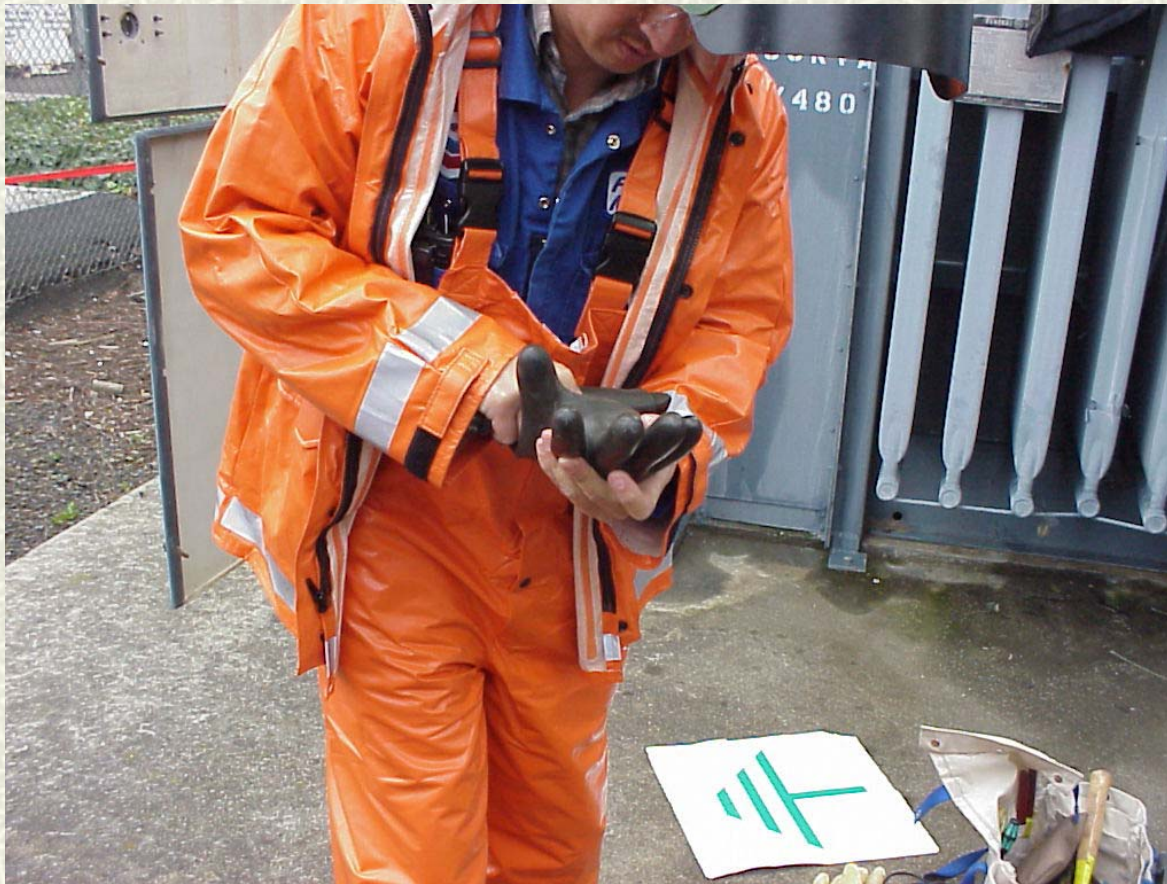


For Class 0 and 00 insulating gloves, use a tape measure to find the circumference of your hand around the palm.

8” means your Class 0 and 00 glove is size 8. For Class 2 gloves add $\frac{1}{2}$ size to allow for dexterity.

For example, 8” means your Class 2 glove size is $8 \frac{1}{2}$.

“Air test” of insulating rubber gloves – prior to each use



TESTING OF RUBBER GOODS

Insulating Rubber Gloves

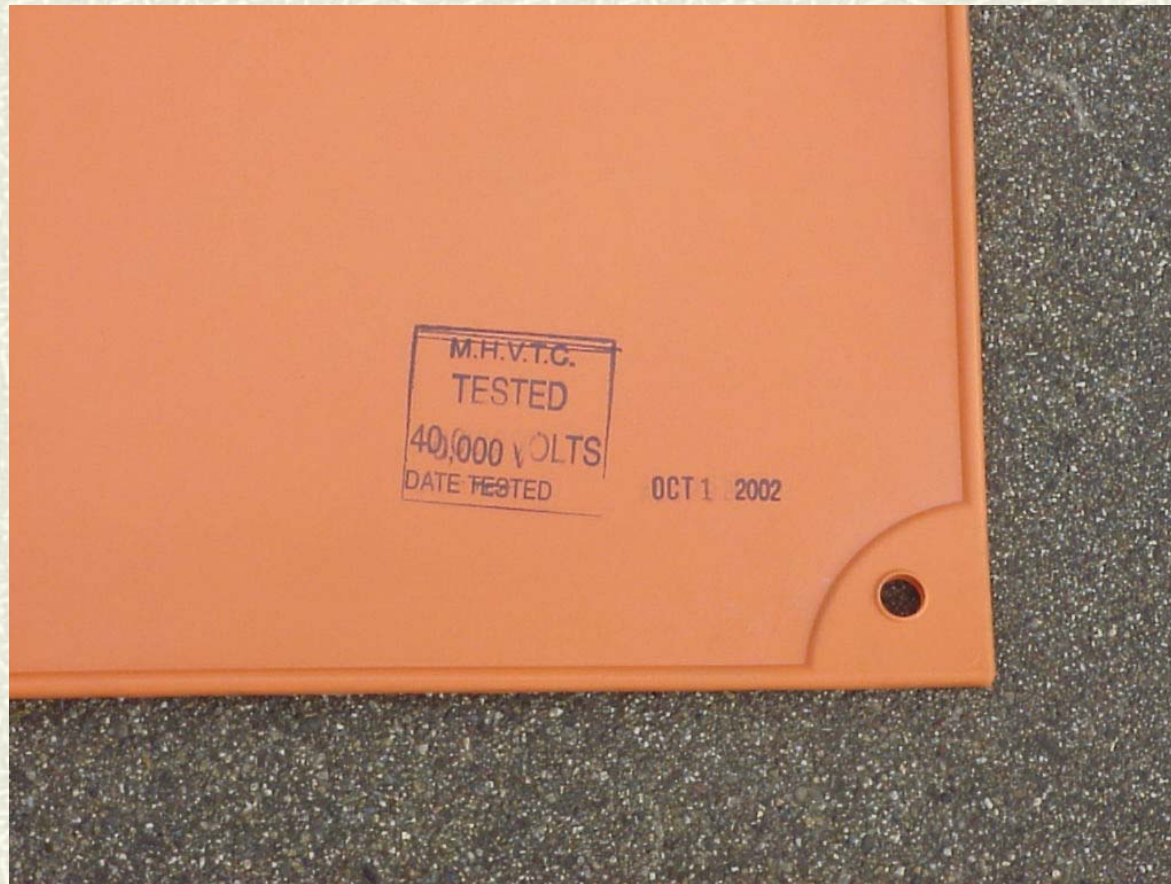
- Dielectrically test before first use and every 6 months thereafter.
- Visually inspect and air test by the employee at the beginning of each use.
- Dielectrically test before the next use, if they might have been damaged.

(there are similar requirements for insulating sleeves and blankets)

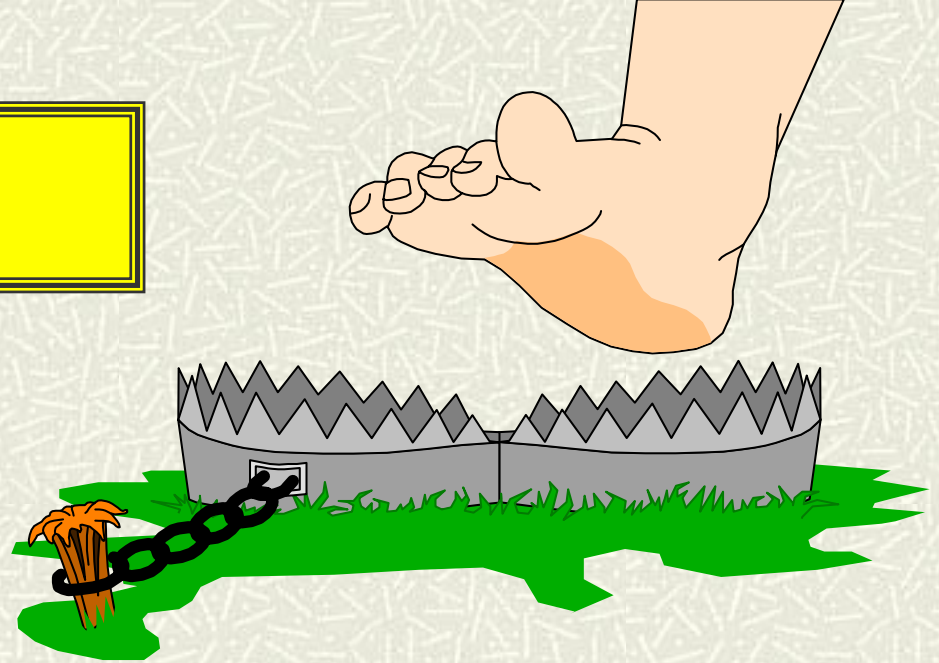
Insulating Rubber Blanket with clips



Class 4 (36 kV rated) Insulating Rubber Blanket test stamp

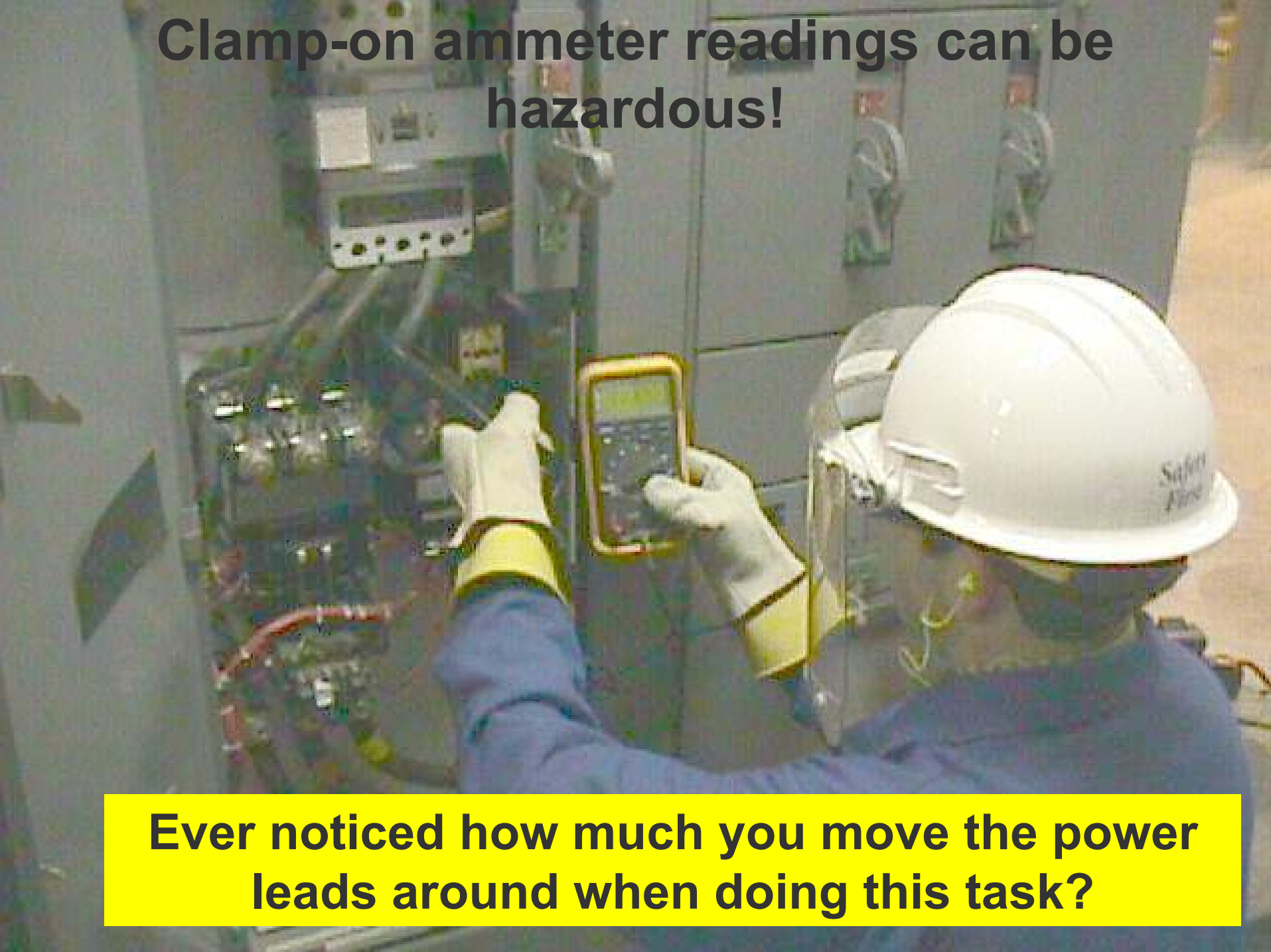


Foot Protection



- ⚠ Avoid wearing shoes and boots constructed with conductive materials extending outside of the sole, e.g., staples and nails.
- ⚠ Several manufacturers make foot apparel with a stamp showing that the shoe is electrical-rated. (ER) This indicates that the shoe will withstand about 1000V only when new at the factory.

Clamp-on ammeter readings can be hazardous!



Ever noticed how much you move the power leads around when doing this task?

FACE PROTECTION -

FACE SHIELD

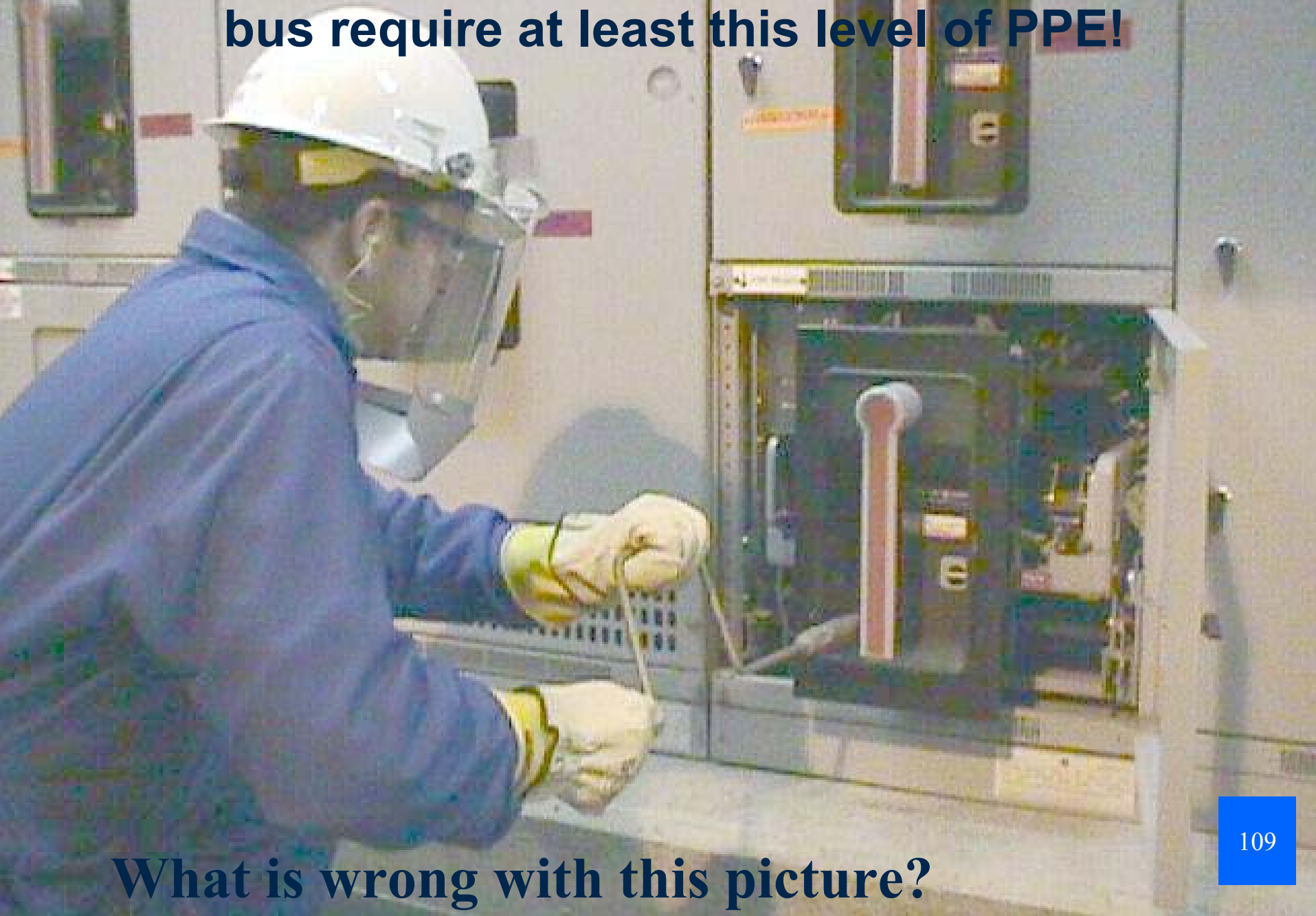
- Not just any face shield will do.
- It takes a special type to provide protection against energy radiation from an arc

Face Protection - Face Shield

- # Use an arc rated face shield.
- # Be careful not to use a standard face shield that is used for grinding -- It might just melt!
- # What's wrong with this picture (if it's supposed to be a HRC 2 system)?



Racking 480 volt circuit breakers on and off the bus require at least this level of PPE!



What is wrong with this picture?

LIVE LINE TOOLS

- # A test schedule must be established that provides visual inspection for defects and contamination.
- # Tools must be waxed (with approved insulating wax) and then dielectrically tested every two years (24 months).
- # A visual inspection for defective hardware attachments, cracks, deformities, contamination, proper operation, and cleanliness must be performed before use of the tool each day.

WORK ZONES

- # Work Zones may be required to safeguard personnel from potential hazards.
- # **Barricades** in conjunction with **safety signs** are used to limit or prevent access to work areas where hazards may exist.
- # Appropriate identification makes employees more aware of the hazards in their work areas.

Establish a clear “Work Zone”



Plastic yellow chain can be used to establish a “work zone” around the exposed live parts of line reactors



AREA PROTECTION

- # Areas accessible to qualified employees only
 - If the work exposes energized or moving parts that are normally protected then **display danger signs**.
 - When working in a restricted section that adjoins other such sections, the qualified employee must **mark** the work area conspicuously and **place barriers** to prevent accidental contact with live parts in adjacent sections.
 - When qualified people determine the size of the work zone, they should consider the types and size of conductive materials and equipment to be used in the area.

ELECTRICAL HAZARD TAPE

- # Electrical hazard barricade tape is intended to be used as a temporary hazard warning.
- # “Temporary” may be defined as during the period of construction, remodeling, maintenance, repair, or demolition of buildings, structures, or equipment.
- # The recommended color is red and the red tape be imprinted with wording such as “**Danger --- Do Not Enter**”



ENCLOSED SPACES

- # Enclosed (or “confined”) spaces are manholes, unvented vaults, tunnels, etc. that can be entered by employees.
- # Employees who enter enclosed spaces or serve as attendants must be trained in the following.
 - The hazards of enclosed space entry
 - Enclosed space entry procedures
 - Enclosed space rescue procedures.
- # Employees must be provided equipment to ensure prompt and safe rescue.

12 kV Underground pullbox for cables

– would be a “confined space entry”

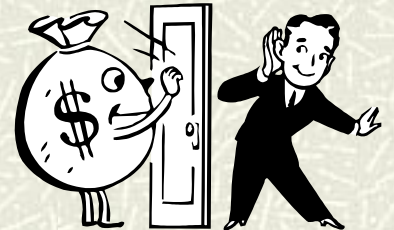
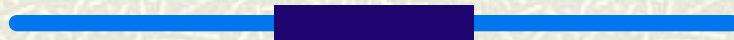


UNDERGROUND ELECTRICAL FACILITIES

- The following are additional requirements for work on underground electrical installations in manholes and/or vaults.
 - Use ladders or other climbing devices to enter or exit manholes or vaults that exceed 4 feet in depth.
 - Equipment used to lower materials and tools must be capable of supporting the weight and inspected prior to use.
 - Attendant must be in the immediate vicinity of the manhole opening and trained in CPR, first aid, enclosed space hazards & rescue techniques.
 - Rescue equipment must be present at the worksite.

Electrical Safe Work Practices

Conclusion & Summary



KEY SAFE PRACTICES

- ⚡ It is not deenergized until it has been placed in an “Electrical Safe Work Condition”.
 - ⚡ isolated,
 - ⚡ locked,
 - ⚡ tagged,
 - ⚡ tested,
 - ⚡ and grounded
- ⚡ Hold job briefings before start of work
- ⚡ Use personal protective equipment
- ⚡ Establish a work zone

KEY SAFE WORK PRACTICES

- ⚡ Follow your lockout tagout policy
- ⚡ Apply safety grounds before start of work
- ⚡ Observe minimum approach distances
- ⚡ **Test before you touch – ALWAYS!**

Coming to the Bay Area! – mark your calendar...
2004 Electrical Safety Workshop



11th
Annual
Electrical Safety
Workshop
February 10-13
Oakland, California

Additional information:

- # Job Briefing and Planning Checklist details
- # Head protection
- # Hand and power tools

Job Briefing and Planning Checklist (sample)

APPENDIX G: JOB BRIEFING CHECKLIST

Planning Checklist

Identify

- | | |
|--|---|
| <input type="checkbox"/> What are the hazards? | <input type="checkbox"/> Potential for arc flash |
| <input type="checkbox"/> What voltage levels are involved? | <input type="checkbox"/> Unusual work conditions |
| <input type="checkbox"/> What skills are required? | <input type="checkbox"/> Is this a multiple-person job? |
| <input type="checkbox"/> "Foreign" voltage source present? | |

Ask

- | | |
|--|--|
| <input type="checkbox"/> Can the equipment be de-energized? | <input type="checkbox"/> Is a "standby person" required? |
| <input type="checkbox"/> Are there possible backfeeds of the circuits to be worked on? | |

Check

- | | |
|--|---|
| <input type="checkbox"/> Job plans | <input type="checkbox"/> Safety procedures |
| <input type="checkbox"/> One lines and vendor prints | <input type="checkbox"/> Vendor information |
| <input type="checkbox"/> Status board | <input type="checkbox"/> For up-to-date information on plant and vendor resources |
| <input type="checkbox"/> Individuals familiar with facility? | |

Know

- What is the job?
- Who is in charge?
- Who else needs to know? ... Communicate!

Think

- | | |
|---|---|
| <input type="checkbox"/> About the extra event ... What if? | <input type="checkbox"/> Use the right tools and equipment, including PPE |
| <input type="checkbox"/> Lock - Tag - Test - Try | <input type="checkbox"/> Install barriers and barricades |
| <input type="checkbox"/> Test for voltage - FIRST | <input type="checkbox"/> What else ...? |
| <input type="checkbox"/> Install and remove grounds | |

Prepare for an emergency

- | | |
|---|---|
| <input type="checkbox"/> Standby person CPR trained? | <input type="checkbox"/> What is the exact work location? |
| <input type="checkbox"/> Telephone location? | <input type="checkbox"/> How is the equipment shut off in an emergency? |
| <input type="checkbox"/> Fire alarm locations? | <input type="checkbox"/> Where is the emergency equipment? |
| <input type="checkbox"/> Confined space rescue available if required? | <input type="checkbox"/> Is the required emergency equipment available? |
| <input type="checkbox"/> Emergency phone numbers? | <input type="checkbox"/> Radio communications available? |
| <input type="checkbox"/> Extinguisher? | <input type="checkbox"/> |

IDENTIFY

- What are the hazards?
- What voltage levels are present?
- What skills are required?
- Foreign voltage source present?
- Potential for Arc Flash?
- Unusual work conditions?
- Is this a multi-person job?
- What is the Flash Protection Boundary?
- What are the Shock Protection Boundaries?
- What is the available incident energy?

ASK

- Can the equipment be de-energized?
- Is a “standby person” required?
- Are the possible backfeeds of the circuits to be worked on?

CHECK

- Job Plans
- One line and vendor prints
- Status boards
- Individuals familiar with facility?
- Safety procedures
- Vendor information
- For up-to date information on plant and vendor resources.

KNOW

- ❑ What is the job?
- ❑ Who is in charge?
- ❑ Who else needs to know? ... Communicate!

THINK

- ❑ About the extra event ... What if?
- ❑ Lock – Tag – Test – Try
- ❑ Test for voltage – FIRST
- ❑ Install and remove grounds
- ❑ Use the right tools and equipment.
Including PPE
- ❑ Install barriers and barricades
- ❑ What else ... ?

PREPARE FOR AN EMERGENCY

- Standby person CPR trained
- Telephone location?
- Fire alarm location?
- Confined space rescue available if required?
- Emergency phone numbers?
- Extinguisher?
- What is the exact work location?
- How is the equipment shut off in an emergency?
- Where is the emergency shut off equipment?
- Is the required emergency equipment available?
- Radio Communications available?

Head Protection - Hardhat

The ANSI standard Z89.1 was rewritten in 1997.

(Keep hardhats clean and do not alter in any way except for company approved markings)

Class G

General

Class E

Electrical

Class C

Conductive

Description Former Class	General service, A	Utility service, B	No voltage C
Electrical	2,200 VAC,	20,000 VAC,	None
Impact	40 Foot-pounds	40 Foot-pounds	40 Foot-pounds

Type 1 helmet. Protects from top of head blow only

Type 2 helmet. Protect from off-center and top of head

HAND AND POWER TOOLS

- # Any cord and plug connected equipment *not supplied* by premises wiring must:
 - Be equipped with a cord containing an equipment grounding conductor connected to the frame and to ground at the other end. **OR**
 - Be of the double-insulated type **OR**
 - Be connected to the power supply through an isolating transformer.
- # Ground-fault circuit interrupters are required!