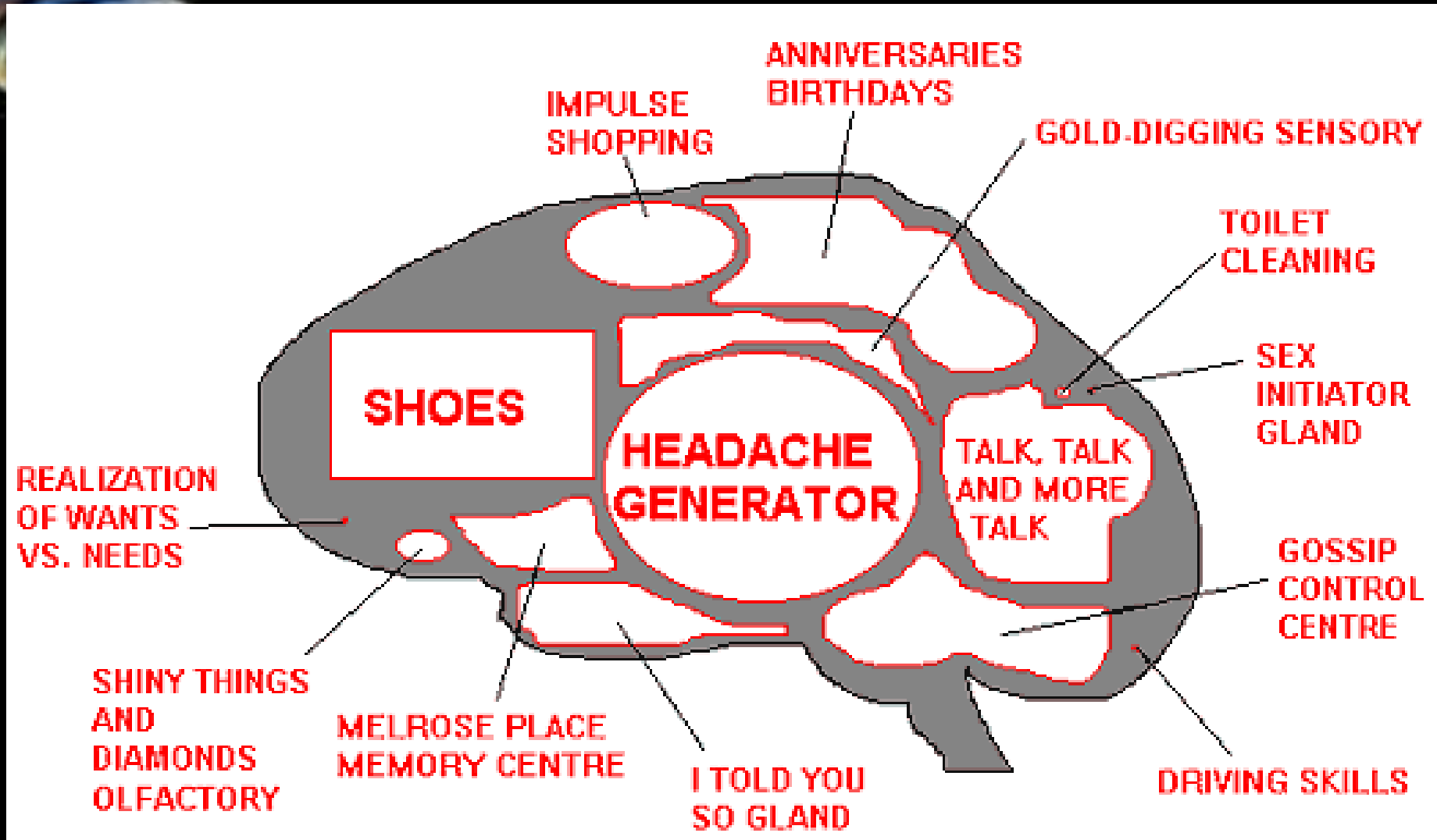
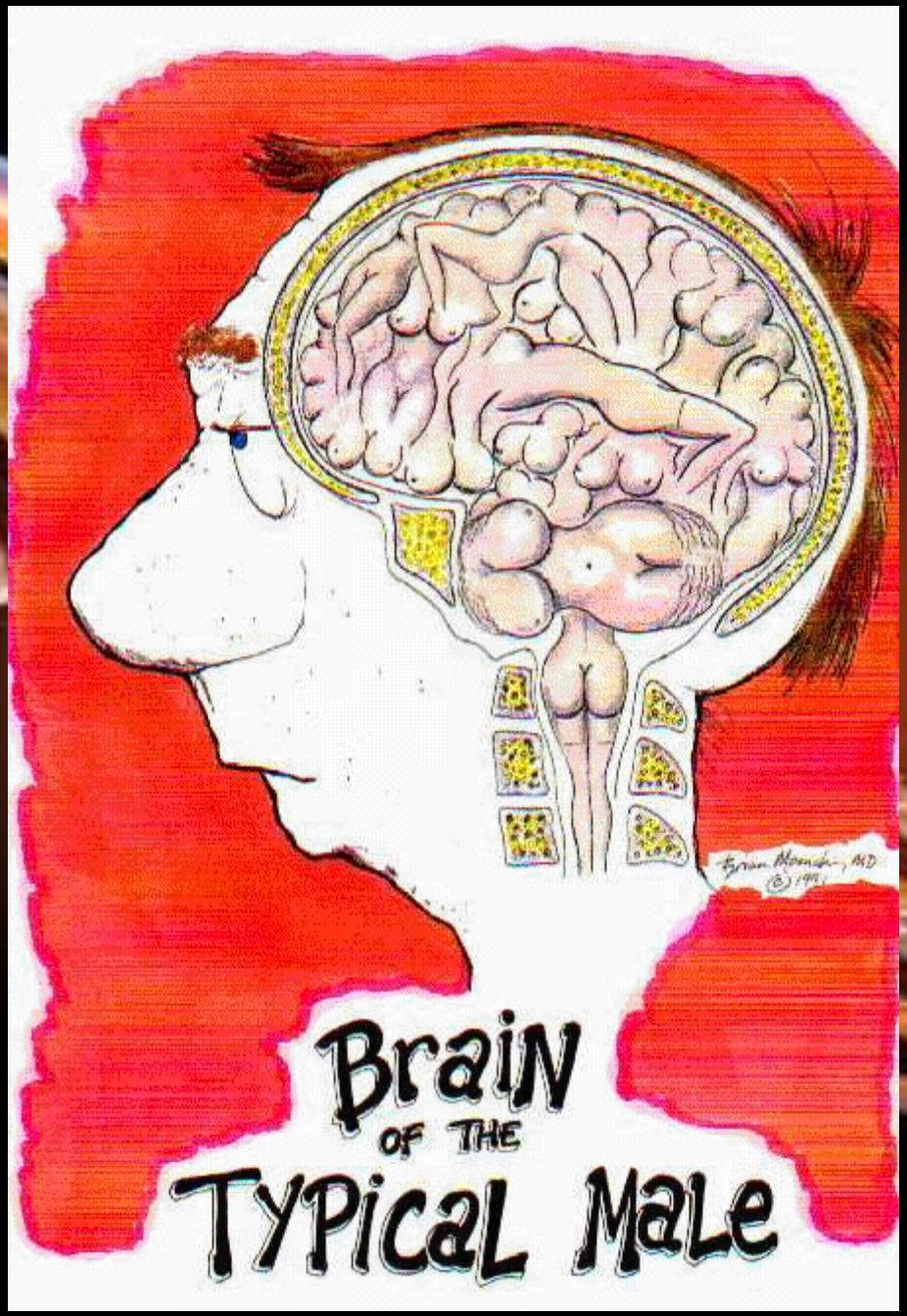
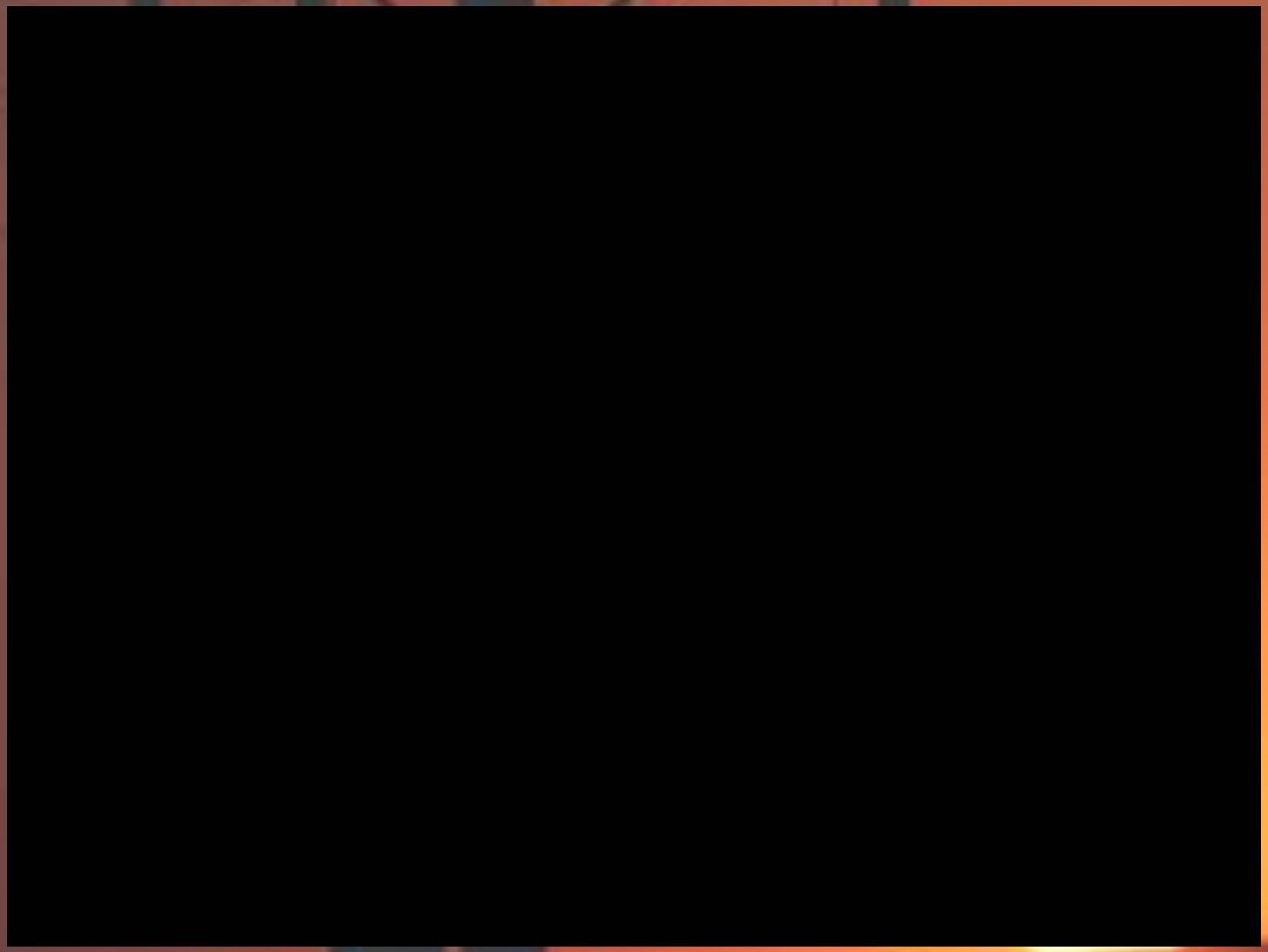


FOOTNOTE: The "Put Oil into the Car" and "Be Quiet During the Game" glands are active only when the "SHINY THINGS AND DIAMONDS" OLFactory has been satisfied or when there is a shoe sale.

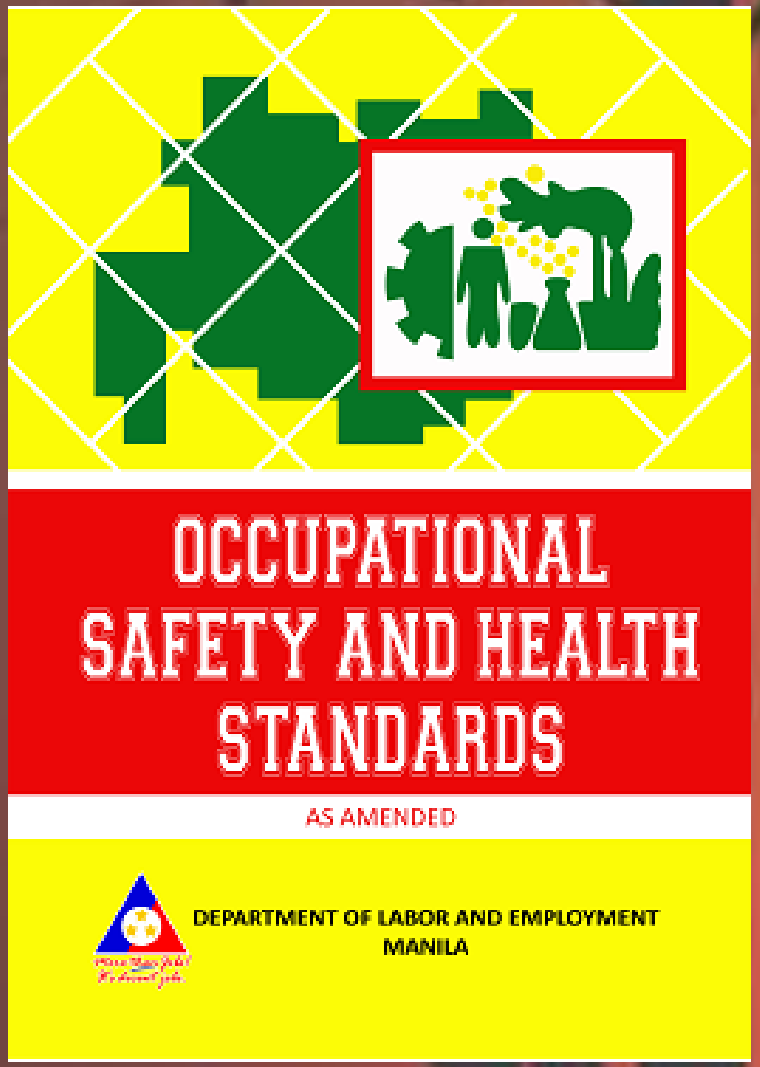

Brain
OF THE
TYPICAL MALE


ELECTRICAL SAFETY
NFPA 70E
(ARC FLASH)
FRUMENCIO T. TAN
Accredited Safety Consultant



What Does an Electrician Do?

- Reading blueprints
- For safety, electricians follow the Philippine Electrical Code (OSHS)
- Connecting all types of wires and circuit breakers, outlets, and a host of other components
- Regular assessments of electrical equipment and electrical systems
- Work involves adding and replacing wires, fuses, circuit breakers, connections
- Test electrical devices


OCCUPATIONAL
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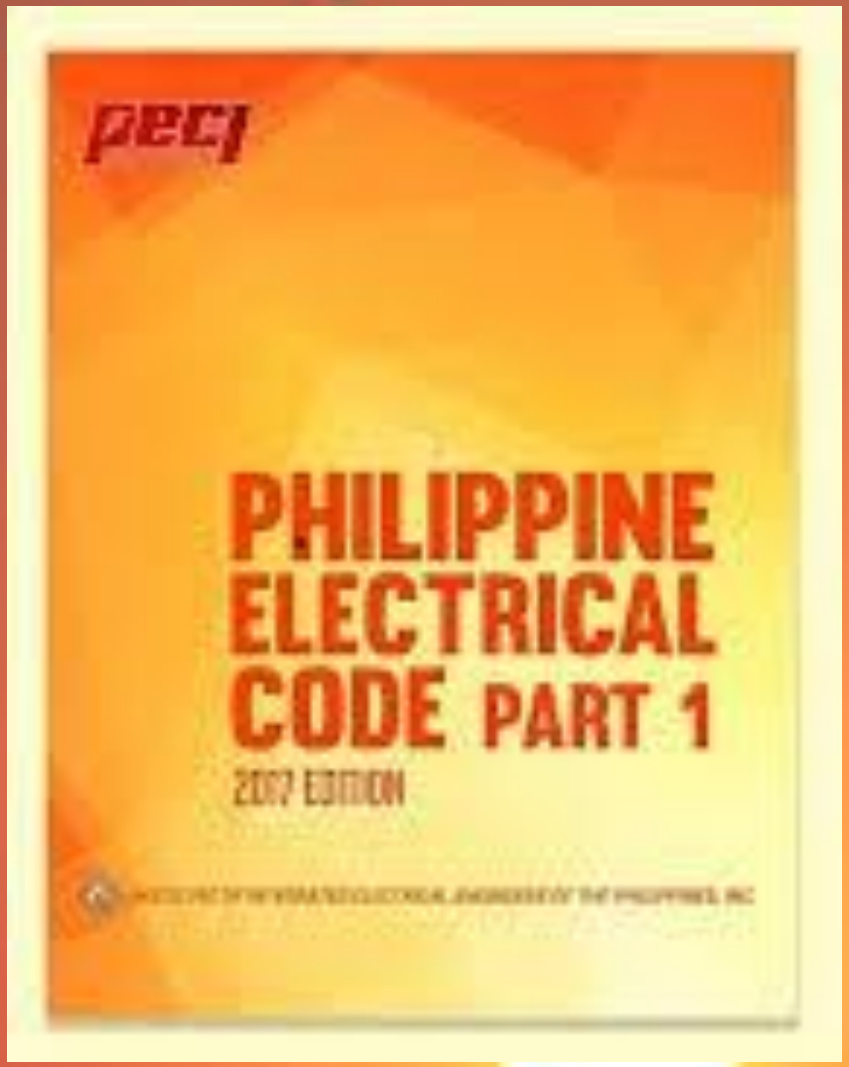
STANDARDS
AS AMENDED
DEPARTMENT OF LABOR AND EMPLOYMENT
MANILA


PECI
PHILIPPINE
ELECTRICAL
CODE PART 1
2017 EDITION

NFPA 70E®

Standard for Electrical Safety in the Workplace®

2018

ESH Coordinators Meeting

Stanford Linear Accelerator Center (SLAC) Contractor Hospitalized After Arc Flash

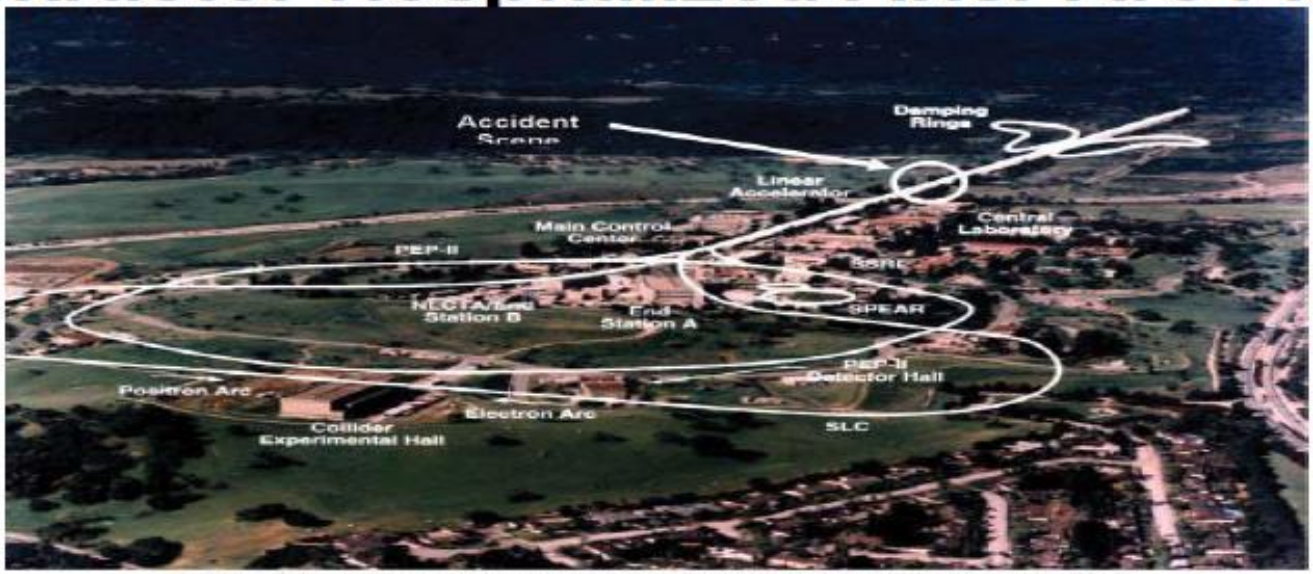


Figure 1-1. Stanford Linear Accelerator Center with Accident Scene Marked

Accident Description
October 11, 2004

- SLAC Supervisor directs subcontractor electrician to install breaker in live 480 volt dist. panel.
- Supervisor did not obtain required working “EEW” permit.
- The electrician wore a short sleeved cotton/polyester shirt, leather gloves over Voltage (V) rated gloves, safety glasses, and a hardhat.
- When the accident occurred, the electrician had connected phases B and C and was in the process of connecting phase A.

Scene Immediately After the Accident

Figure 2-1. Scene immediately after the accident

Insulating Mat With Outline of Knee in Arc Flash Shadow

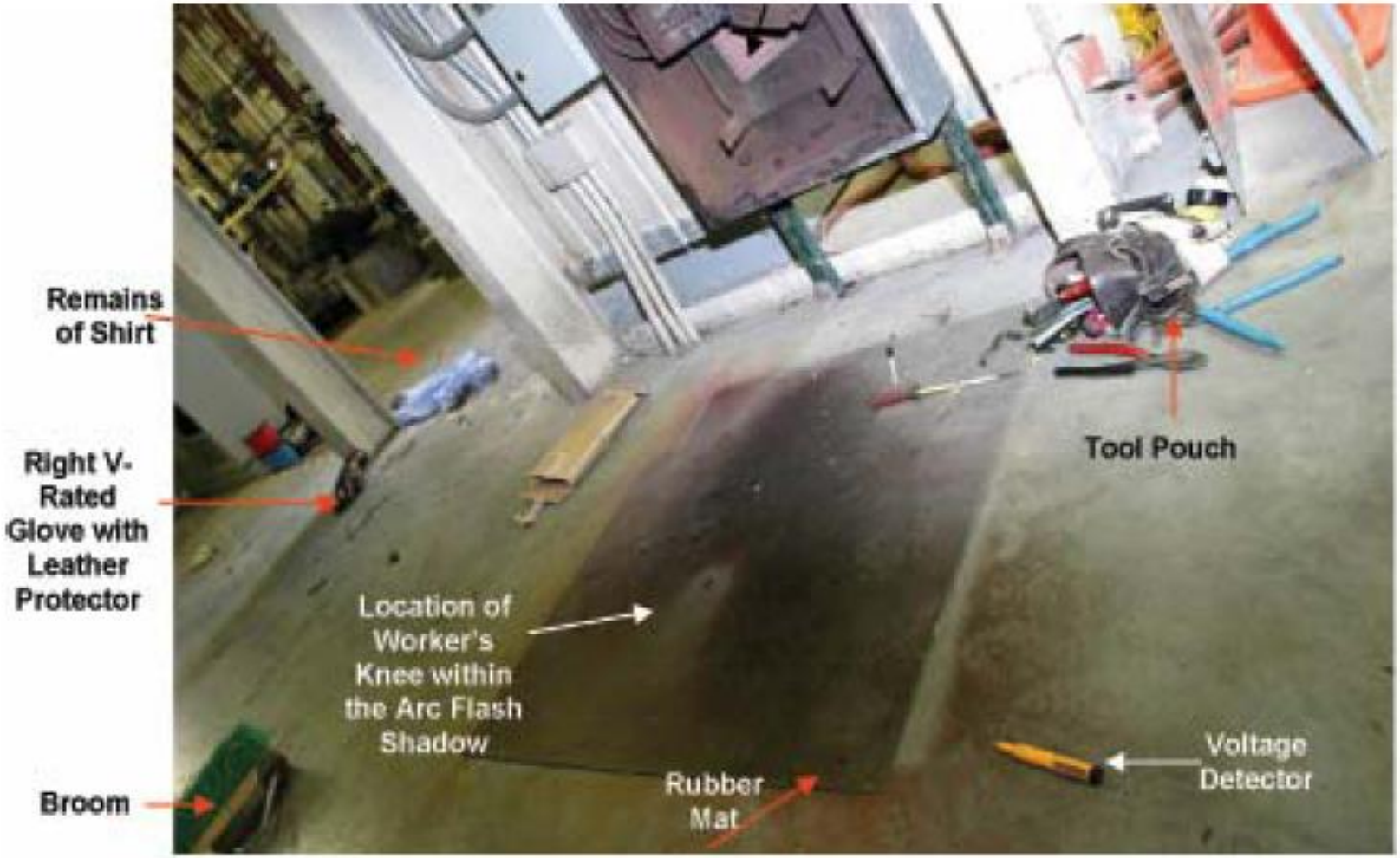


Figure 2-3. The insulating mat with the outline of BSE-1's knee in the arc flash shadow

Screwdriver Used When Arc Flash Occurred

Figure 2-9. Closeup of the screwdriver the Board believes BSE-1 was using when the arc flash occurred

Burned Glove

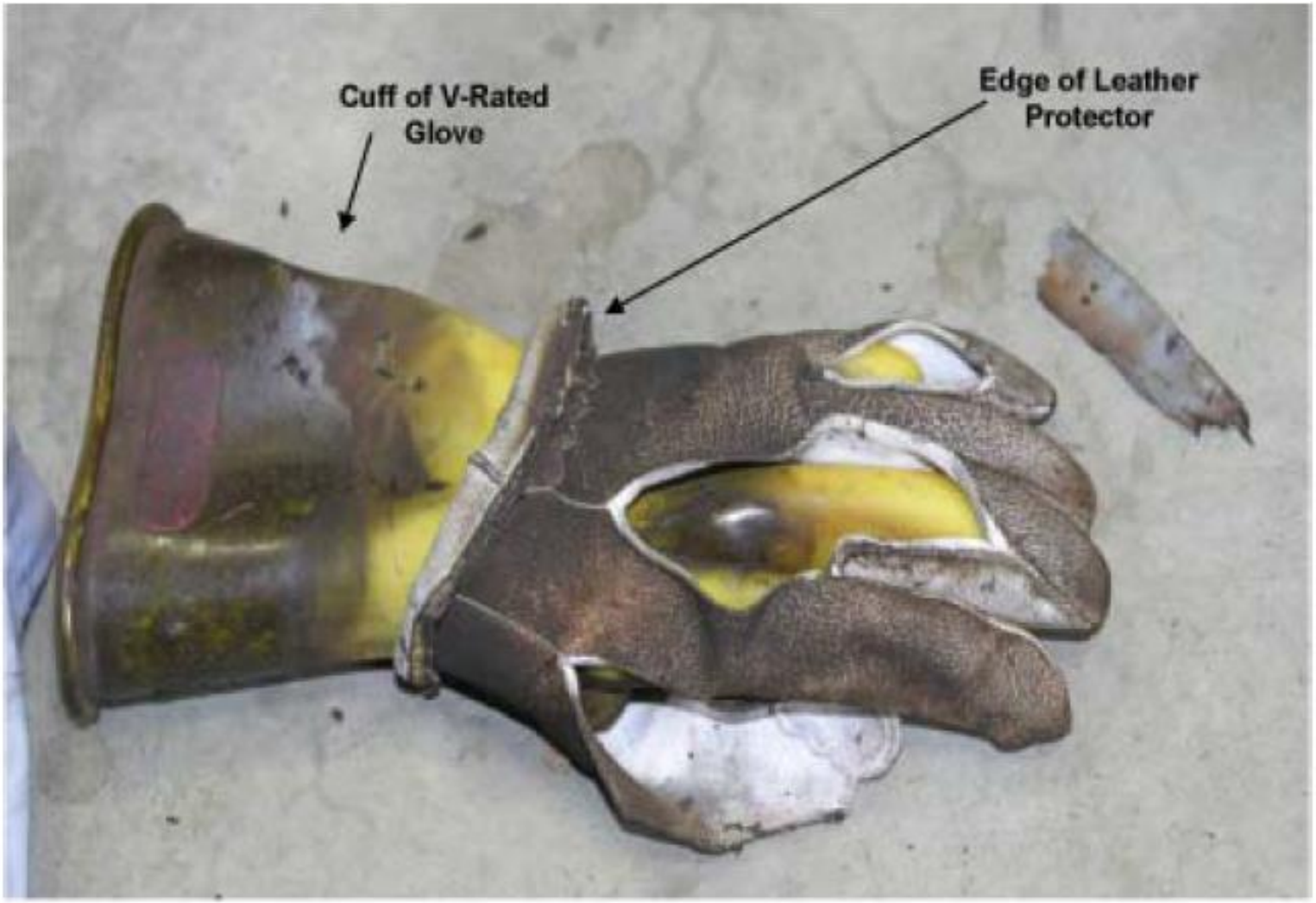


Figure 2-8. Closeup of one of BSE-1's burned gloves

Burned Shirt & Flash-damaged PPE & Tools

Figure 2-6. BSE-1's burned shirt and his flash-damaged PPE and tools

Required Equipment for 480

Figure 3-5. Worker wearing the eye and hearing protection to be worn under the double-layer switching hood

Figure 3-4. Worker wearing the correct protective clothing and PPE

Circuit Breaker Panel

Accident Analysis

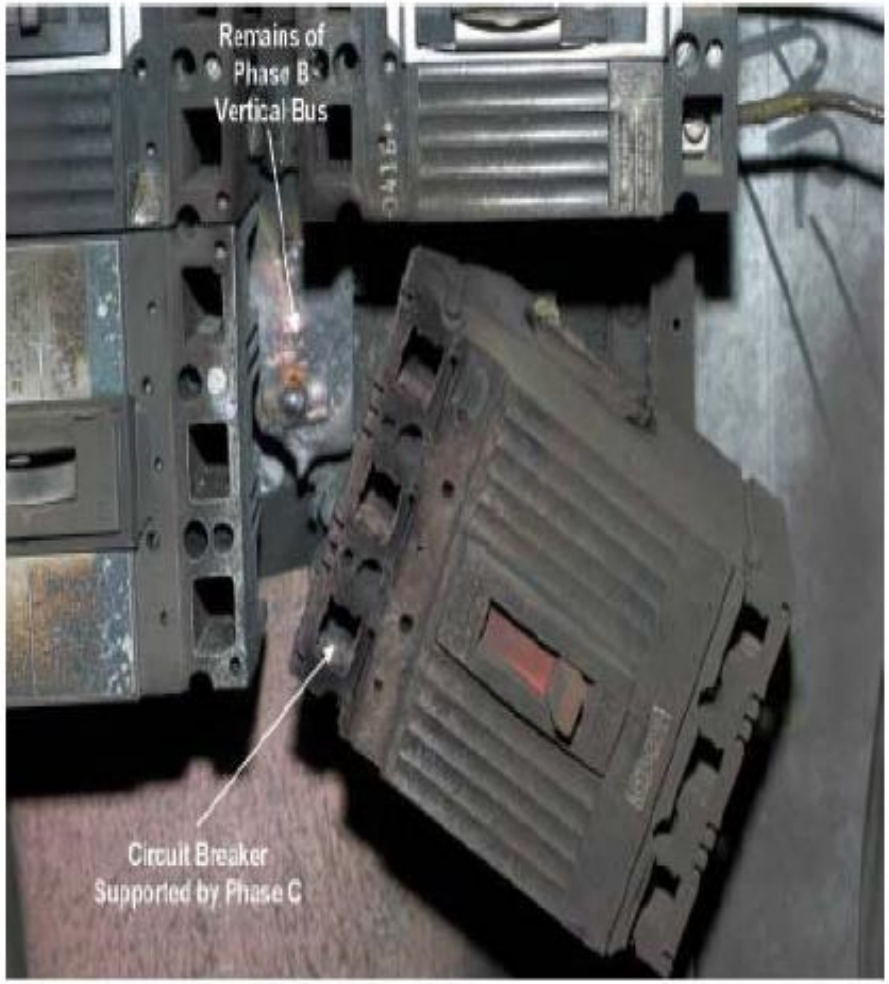


Figure 2-10. Closeup 1 of the damaged circuit breaker panel

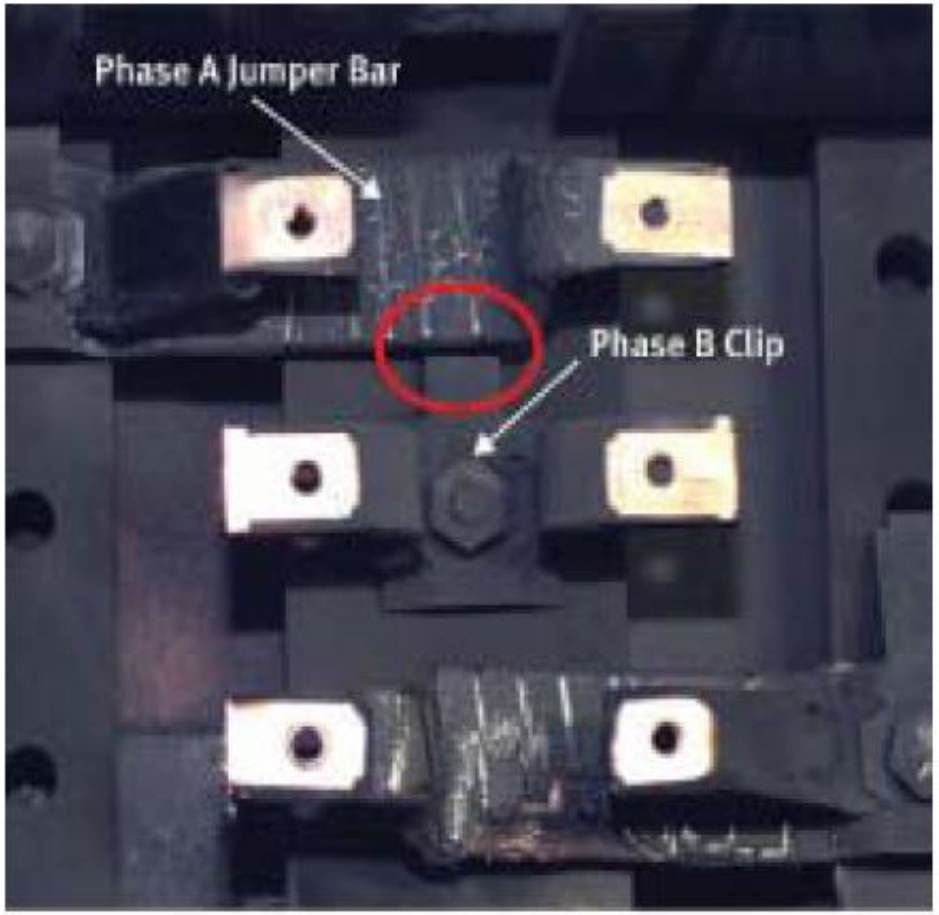
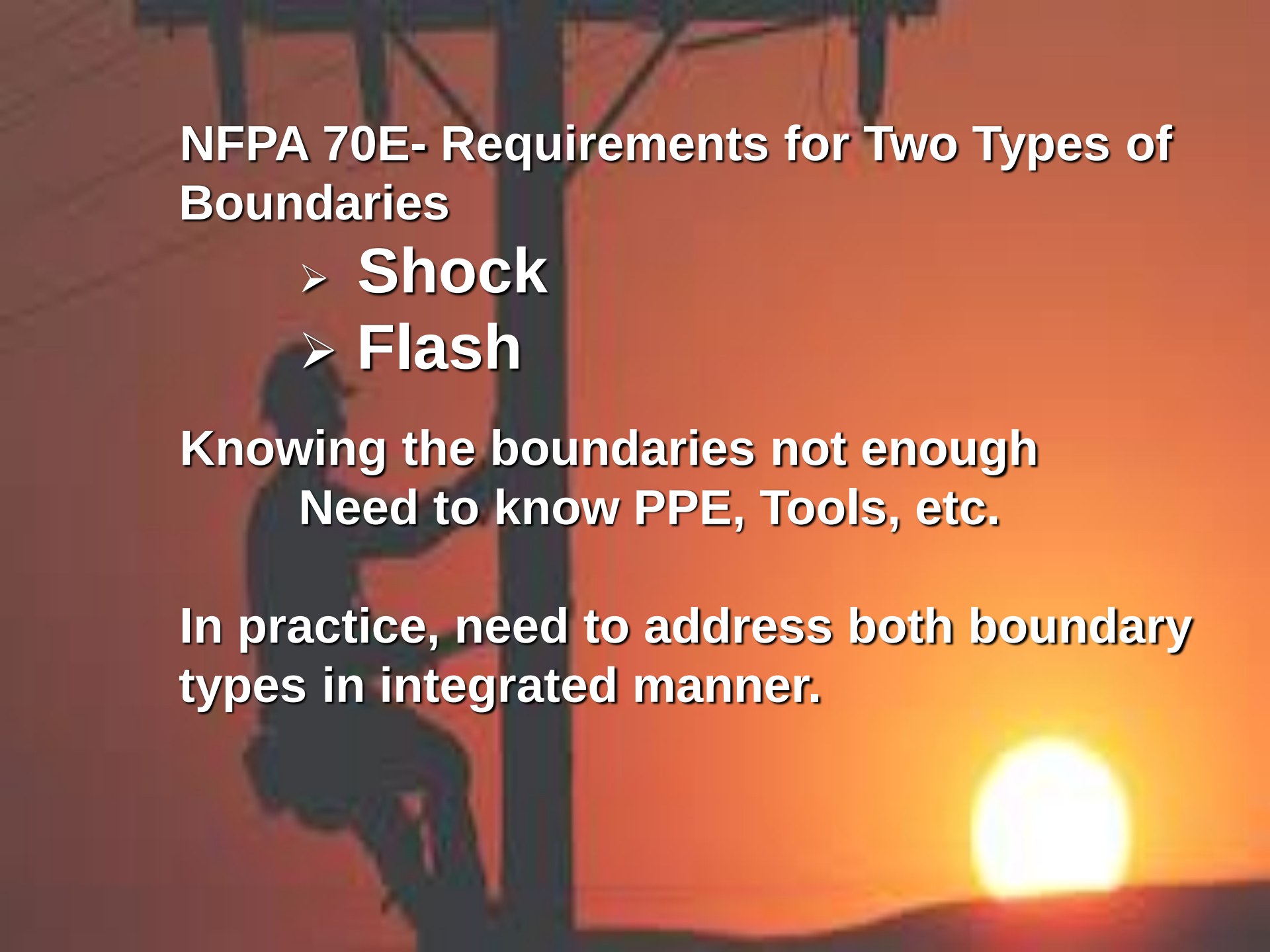


Figure 3-3. Close up of jumper bar and clip with the believed location of the fault circled in red

Identified Key Deficiencies

- A Pre Work Hazards Analysis form was not completed
- There was no approved Energized Electrical Work Permit
- No one in the SLAC management chain had been informed of the decision by the supervisor to install the circuit breaker in an energized panel
- The workers did not wear the appropriate flame resistant clothing, and all required PPE
- The SLAC safety officials were not involved
- The subcontractor laborer was not trained to be a backup for the electrician



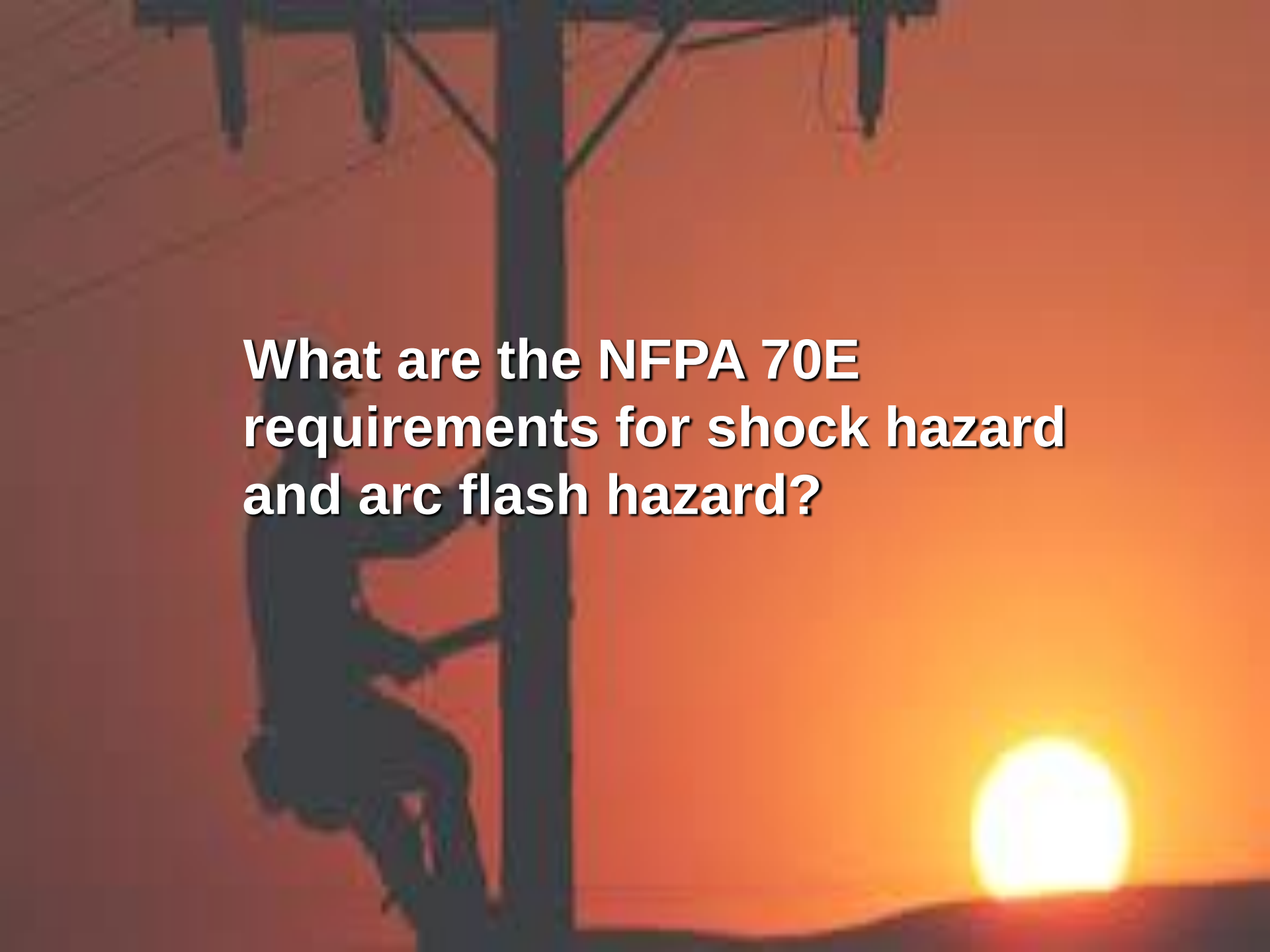
NFPA 70E- Requirements for Two Types of Boundaries

- **Shock**
- **Flash**

Knowing the boundaries not enough

Need to know PPE, Tools, etc.

In practice, need to address both boundary types in integrated manner.


What are the NFPA 70E requirements for shock hazard and arc flash hazard?

NFPA 70E Boundaries

Shock Protection Boundaries

Limited Approach Boundary

entered only by qualified persons or unqualified persons escorted by qualified person

Restricted Approach Boundary

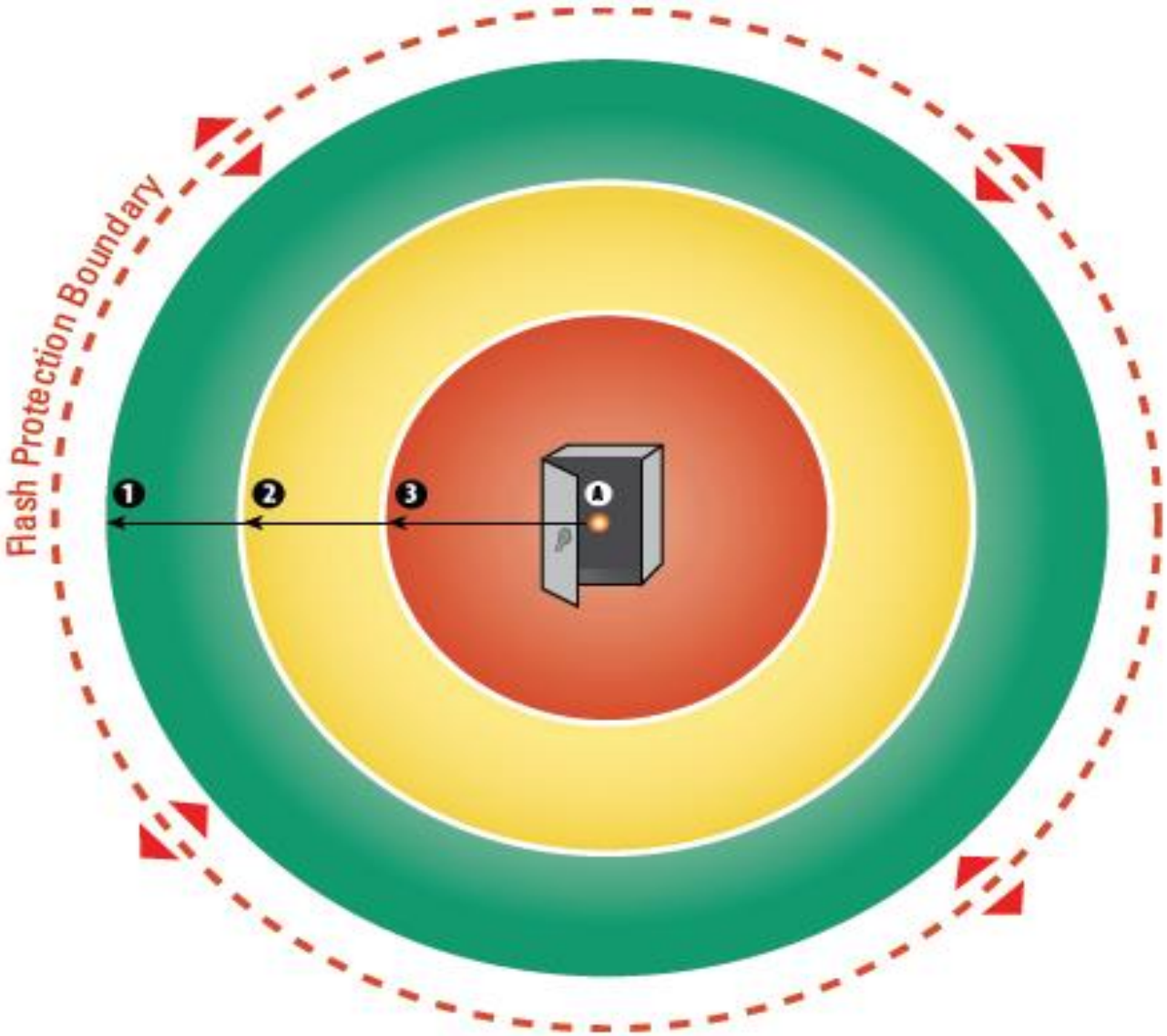
entered only by qualified persons required to use shock protection techniques and equipment

Prohibited Approach Boundary

entered only by qualified persons requiring same protection as if direct contact with live part

Flash Protection Boundary

linear distance to prevent serious injury from a potential arc flash



1. Limited Approach Boundary
2. Restricted Approach Boundary
3. Prohibited Approach Boundary
4. Energized Part

Shock Hazard Approach Boundaries
(from NFPA 70E)

Column Number (1)	(2)	(3)	(4)	(5)
Nominal System Voltage Range	**Limited approach Boundary**		**Restricted Approach Boundary**	**Prohibited Approach Boundary**
Phase-to-Phase	**Exposed Movable Conductor**	**Exposed Fixed Circuit Part**	**Includes Inadvertent Movement Adder**	**Includes Reduced Inadvertent Movement Adder**
	Energized Part to Employee - Distance in feet - Inches			
50 V and less	Not Specified	Not Specified	Not Specified	Not Specified
Over 50 V, not over 300 V	10 ft. 0 in.	3 ft. 6 in.	Avoid Contact	Avoid Contact
Over 300 V, not over 750 V	10 ft. 0 in.	3 ft. 6 in.	1 ft. 0 in.	0 ft. 1 in.
Over 750 V, not over 15 kV	10 ft. 0 in.	5 ft. 0 in.	2 ft. 2 in.	0 ft. 7 in.
Over 15 kV, not over 36 kV	10 ft. 0 in.	6 ft. 0 in.	2 ft. 7 in.	0 ft. 10 in.

Flash Hazard - NFPA 70E

Article 130.3

130.3 Flash Hazard Analysis.

Flash hazard analysis shall be done before a person approaches any exposed electrical conductor or circuit part that has not been placed in an electrically safe work conditions."

What is required?

1. Determine Flash Protection Boundary

2. Determine the Personnel Protective Equipment

Flash Hazard

How?

1. Determine Flash Protection Boundary:

Calculate using Isca & clearing time

(or use tables - many qualifiers)

(or default to four feet - 600 V or less)

2. Determine the Personnel Protective Equipment :

A. Calculate incident energy exposure level for distance of worker's face and chest from the possible arc source (18" typical - considers the head and torso but not the hands and arms).

B. Select appropriate PPE for incident energy.

Flash Hazard Analysis

Flash Protection Boundary Calculations

1) (600 V or less) Distance formula based on fault available and clearing time of overcurrent protective device: (0.1 sec)

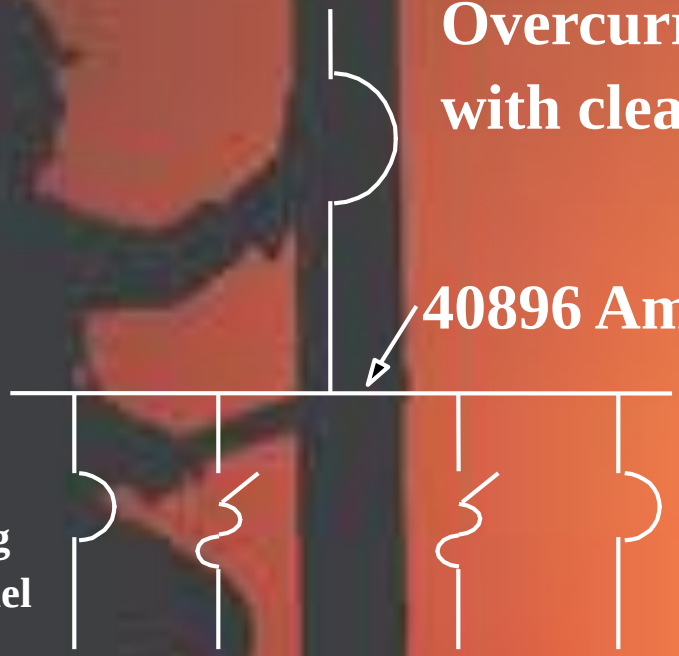
$$D_C = [2.65 \times MVA_{bf} \times t]^{1/2}) \text{ ft}$$

where $MVA_{bf} = 1.73 \text{ (Isca) (Voltage)} \times 10^{-6}$

2) (> 600 V) Distance based on where incident energy level is 1.2 or 1.5 cal/cm^2

Flash Hazard Analysis -Example 1

- ***Flash Protection Boundary*** Calculation
  Circuit using non-current limiting circuit breaker



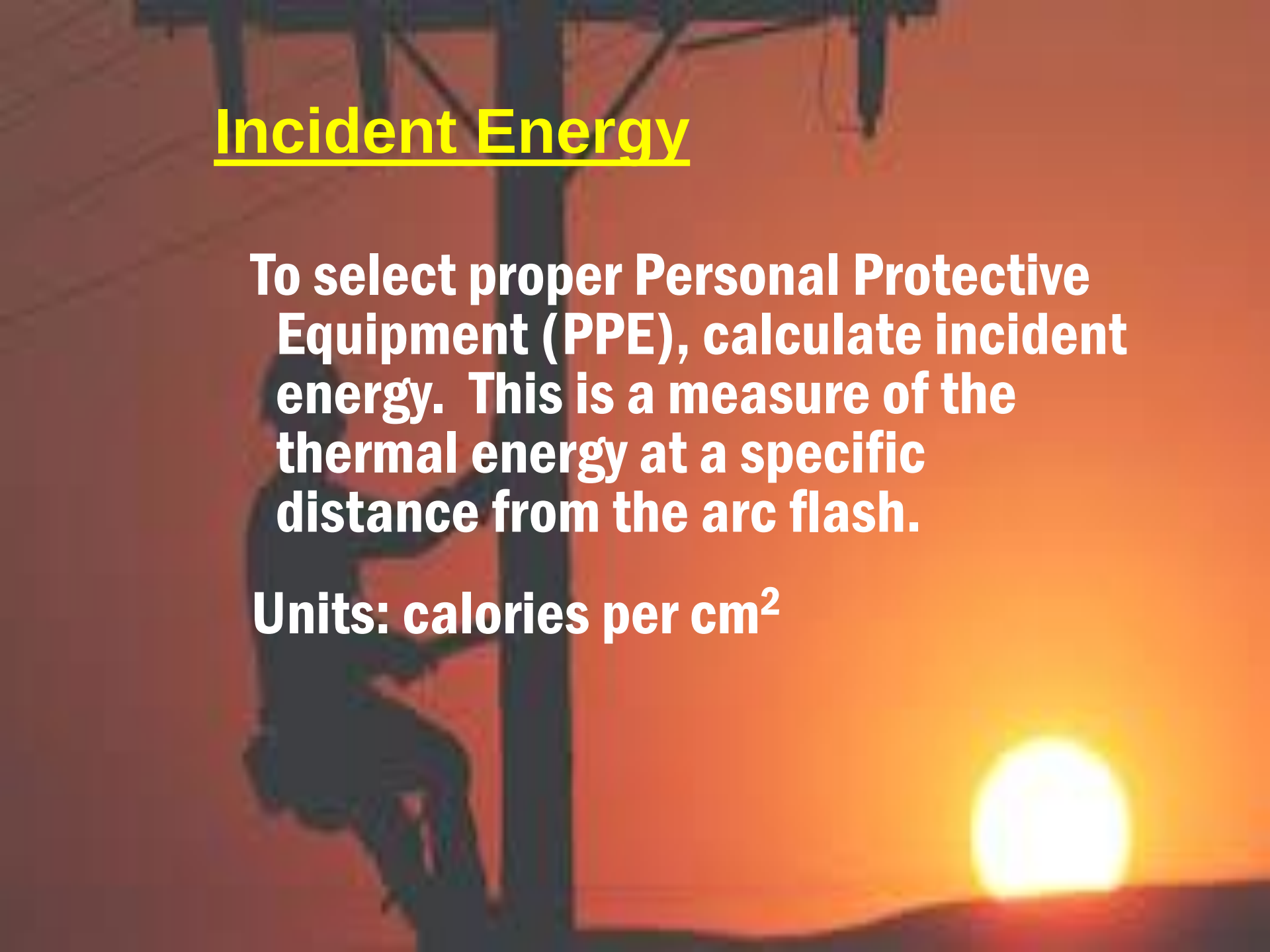
Answer

D_C = 3 ft

MVA= 33.999

Flash Hazard Analysis

Flash Protection Boundaries **need to be calculated for all levels of fault current.**



Incident Energy

To select proper Personal Protective Equipment (PPE), calculate incident energy. This is a measure of the thermal energy at a specific distance from the arc flash.

Units: calories per cm^2

A Calorie is the amount of heat energy needed to raise the temperature of one gram of water by one degree Celsius.

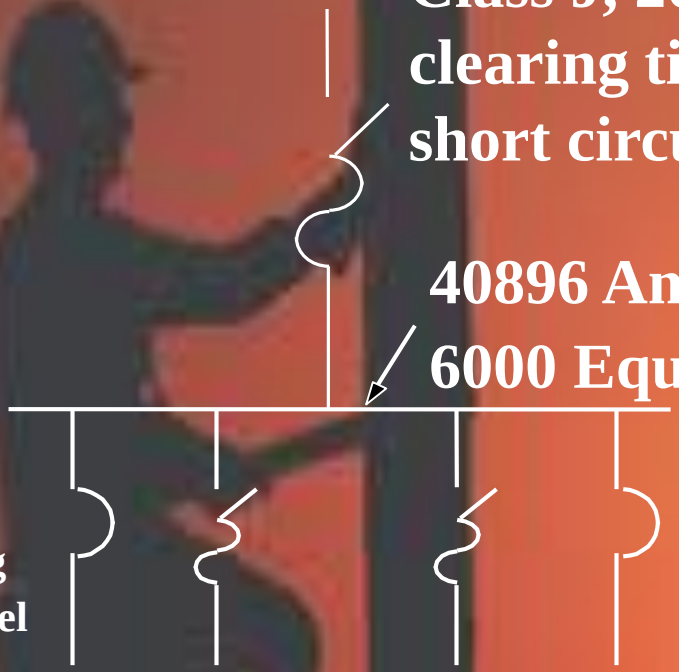
ARC-FLASH METRICS

Energy (E)	=	Power (P)	× Time (t)	
Power (P)	=	Volts (V)	× Amps (I)	
Calories (E)	=	Volts (V)	× Amps (I)	× Time (t)
1 Calorie	=	4.1868 watt-seconds		
1 Joule	=	1 watt-second		

Flash Hazard Analysis - Example 2

- ***Flash Protection Boundary*** Calculation

  Circuit using current limiting fuses



Class J, 200 A fuse clearing time of 1/4 cycle under short circuit conditions. (0.004 sec)

40896 Amperes Available

6000 Equivalent RMS Let-Through

480 Volt, 3 phase Main Lug Only Panel

MVA=4.98

Answer

D_C = .23 ft

INCIDENT ENERGY (cal/cm^2)	RESULTS/EXAMPLE
0.0033	Amount of energy the sun produces in 0.1sec. on the ground's surface at the equator.
1	Equivalent to a finger tip exposed to a cigarette lighter flame for one second
1.2	Amount of energy that will instantly cause 2nd degree burns to bare skin
4	Amount of energy that will instantly ignite a cotton shirt
8	Amount of energy that will instantly cause incurable 3rd degree burns to bare skin

INCIDENT ENERGY (cal/cm²)	HAZARD RISK CATEGORY
0 to 1.2	0
1.21 to 4	1
4 .1 to 8	2
8.1 to 25	3
25.1 to 40	4

PPE :

Hazard Risk Category 0

Hazard Risk Category 1

Hazard Risk Category 2

Hazard Risk Category 3

Hazard Risk Category 4

What determines the severity of an Arc Flash?

- *Available short circuit current*
- *System voltage*
- *Arc gap*
- *Distance from the arc*
- *Opening time of overcurrent*
- *protective device (OCPD)*

Common Causes

- ***Worn or broken conductor insulation***
- ***Exposed live parts***
- ***Loose wire connections***
- ***Improperly maintained switches and circuit breakers***
- ***Obstructed disconnect panels***
- ***Water or liquid near electrical equipment***
- ***High voltage cables***
- ***Static electricity***
- ***Damaged tools and equipment***

DATA	EX. 1 - FUSE	EX. 2 - CIRCUIT BREAKER
Fault Current (I_{sc})	43.7 kA	43.7 kA
Flash Protection Boundary (D_C)	12 inches	34 inches
Incident Energy (E_{MB})	1.27 cal/cm^2	10.54 cal/cm^2
Hazard Risk Category	1	3

Flash Hazard Analysis

70E-2004 P. 100

Incident Energy Calculation

Formula:

$$E_{MB} = 1038.7\ D_B^{-1.4738}\ t_A[0.0093F^2-.3453F+5.9675]\ cal/cm^2$$

E_{MB} = Incident Energy (cal/cm^2)

D_B = Distance, (in.) *[for Distances $\geq$ 18 inches]*

t_A = Arc Duration, (sec.)

F = Bolted Fault Short Circuit Current [16KA to 50kA]

Flash Hazard Analysis - Example 1

Incident Energy Calculation @ 18”

Circuit using non-current limiting circuit breaker

Overcurrent protective device with clearing time of 6 cycles

40896 Amperes Available

Answer

E_{MB} = 10.92 cal/cm^2

Flash Hazard Analysis

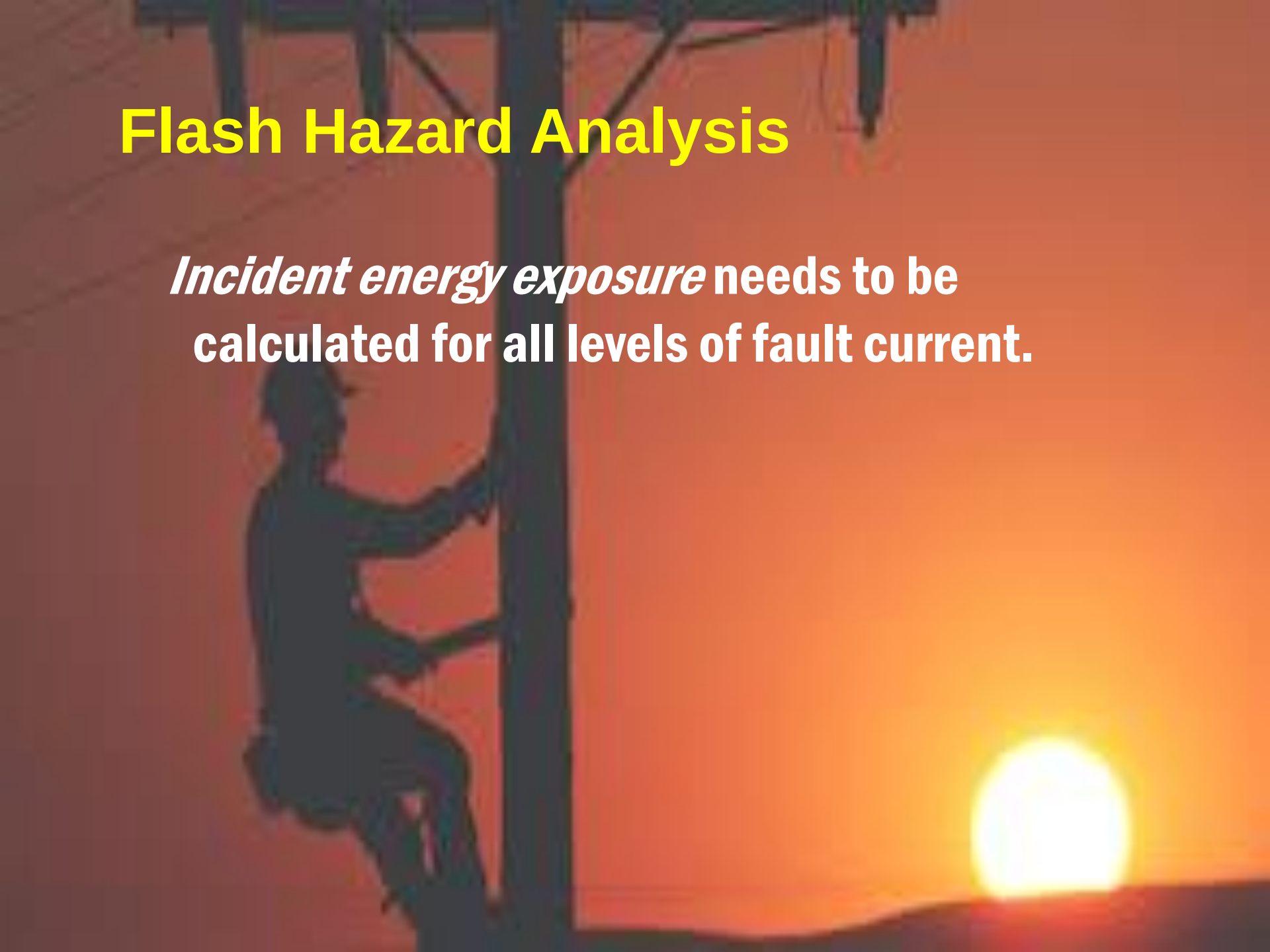
Incident Energy Calculation @ 18”

Example 1: **40896 amps** of available fault current, 480 volt 3 phase system, **Non-current limiting** overcurrent device **6 cycle (0.1 sec) opening time**.

$$E_{MB} = 1038.7\ D_B^{-1.4738}\ t_A[0.0093F^2-.3453F+5.9675]$$

$$E_{MB} = 1038.7\ (18)^{-1.4738}(.1)\ [0.0093(41)^2- .3453(41)+5.9675]$$

$$E_{MB} = 10.92\ cal/cm^2$$



Flash Hazard Analysis

Incident energy exposure needs to be calculated for all levels of fault current.

Flash Hazard - NFPA 70E Article 130

To enter or work within Flash Protection Boundary:

shall do flash hazard analysis

employer shall document incident energy exposure of worker

worker shall use appropriate flame resistant (FR) clothing and personal protective equipment (PPE) for level of incident energy exposure

Hazard Risk Category	Required Minimum Arc Rating of PPE (cal/cm²)	Typical Protective Clothing Systems Clothing Description	Minimum Flash Protection Boundary (in.)
0	N/A	1 layer of non-melting, flammable fabric with weight of at least 4.5 oz/yd²	6
1	4	1 layer of a FR shirt and FR pants or FR coverall	15
2	8	1 or 2 layers of FR shirt and FR pants with conventional cotton underwear	45
3	25	2 or 3 layers of FR shirt, FR pants plus FR coverall cotton underwear	60
4	40	3 or more layers of FR shirt, FR pants plus multi-layer flash suit	~120

Derived from NFPA 70E Table 130.7(C)(11)

Safety Principles

“Training, Planning and Writing Procedures”

- **Plan every job**
- **Anticipate Unexpected Results**
- **Use Procedures as Tools**
- **Identify the Hazard**
- **Assess People’s Abilities**

Safety Principles

“Providing an Electrically Safe Work Condition”

- **Use the Right Tool for the Job**
- **Isolate the Equipment**
- **Protect the Person**
- **Minimize the Hazard**
- **Audit these Principles**

Hazard/Risk Analysis

Hazard/Risk Analysis is a decision making process required to:

evaluate circuit information drawings

determine the degree and extent of hazards

job planning necessary to safely perform task

determine **Shock** "***Approach Boundaries***" requirements

determine "***Flash Protection Boundary***" requirements

determine ***"Incident Energy Exposure"***

determine appropriate Personal Protective Equipment (PPE) based on the potential hazards present

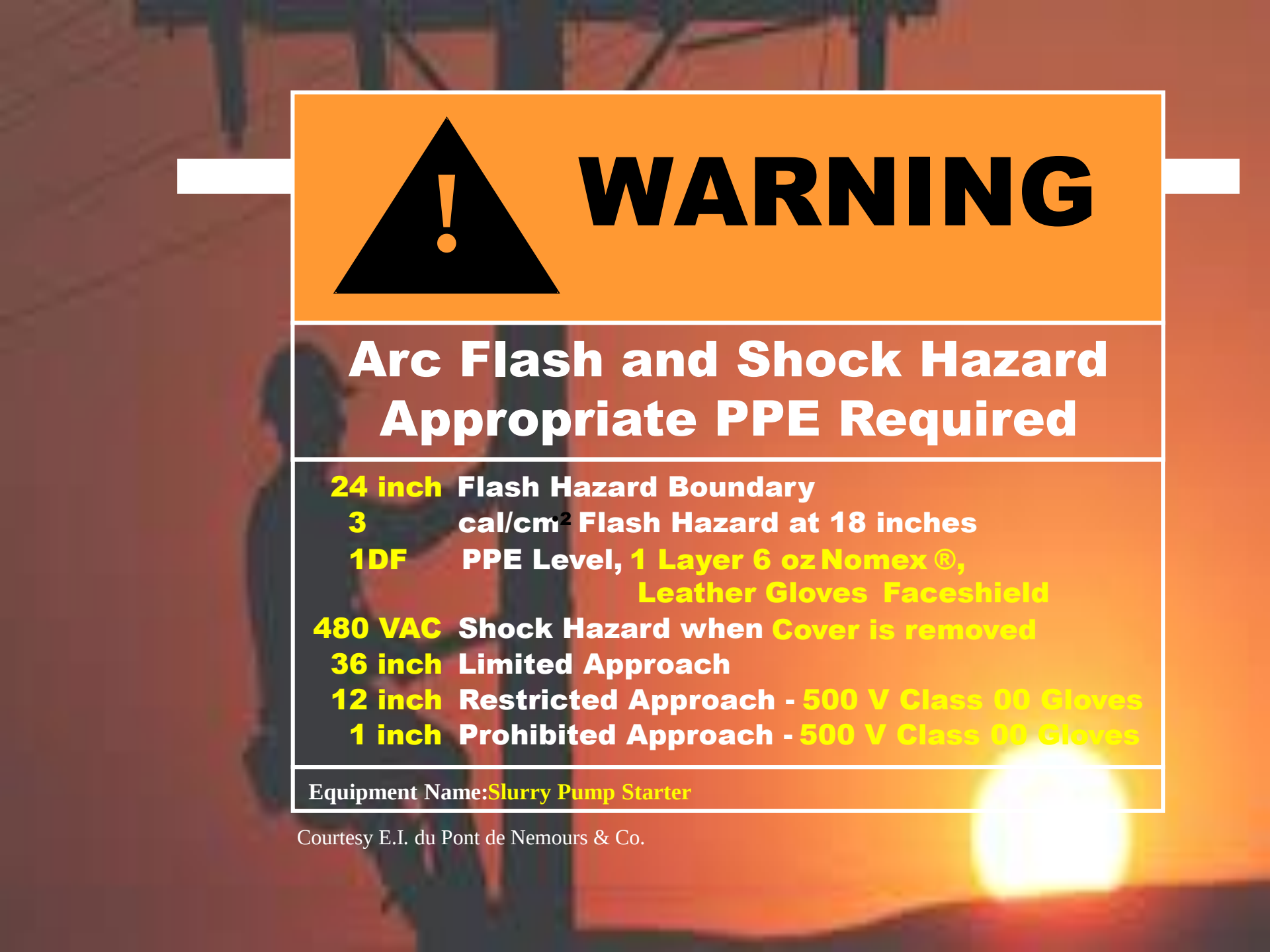
evaluate personnel qualifications

Flash Protection. Electrical equipment, such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers, that are in other than dwelling occupancies, and are likely to require examination, adjustment, servicing, or maintenance while energized shall be field marked to warn qualified persons of potential electric arc flash hazards. The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

FPN No. 1: NFPA 70E-2004, *Standard for Electrical Safety in the Workplace*, provides assistance in determining severity of potential exposure, planning safe work practices, and selecting personal protective equipment.

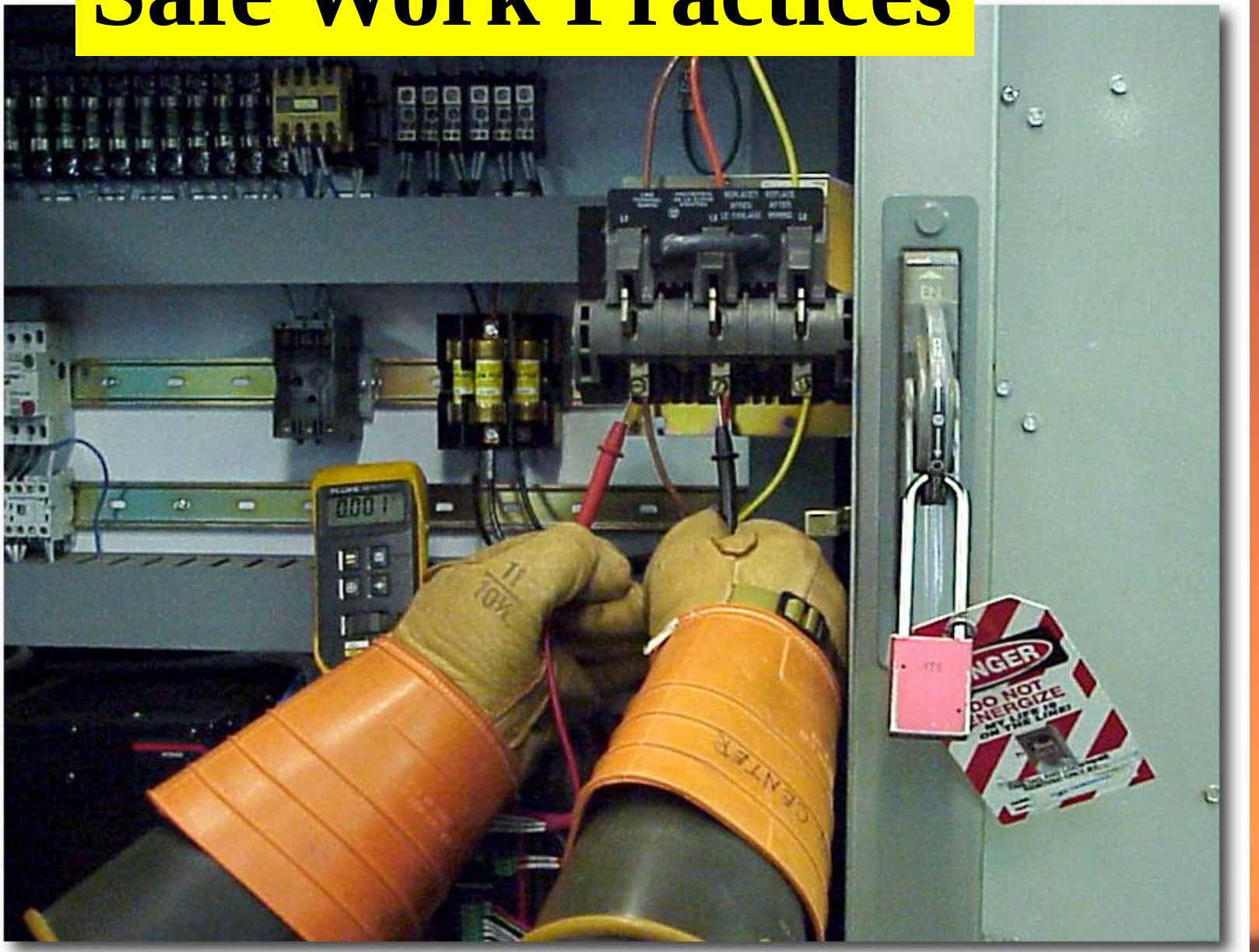
FPN No. 2: ANSI Z535.4-1998, *Product Safety Signs and Labels*, provides guidelines for the design of safety signs and labels for application to products.

Preferred Label Approach



Courtesy E.I. du Pont de Nemours & Co.

Safe Work Practices




SAFETY
IS NO ACCIDENT

SIMPLE RULES TO FOLLOW

- DO NOT GUESS
- FOLLOW PEC
- USE PROPER INSTRUMENTS
- ALWAYS USE SAFETY DEVICES
- LOCKING & TAGGING PROCEDURE
- EEW PERMIT
- ARC FLASH ANALYSIS
- JHA
- NEVER WORK ALONE
- USE DANGER SIGNS

Final Advice

Treat electricity with
the respect it demands,
and it will serve you
efficiently and effectively


funny fuse


THANK YOU ALL!