Electrical Safety in the Workplace

(D) Employee Training.

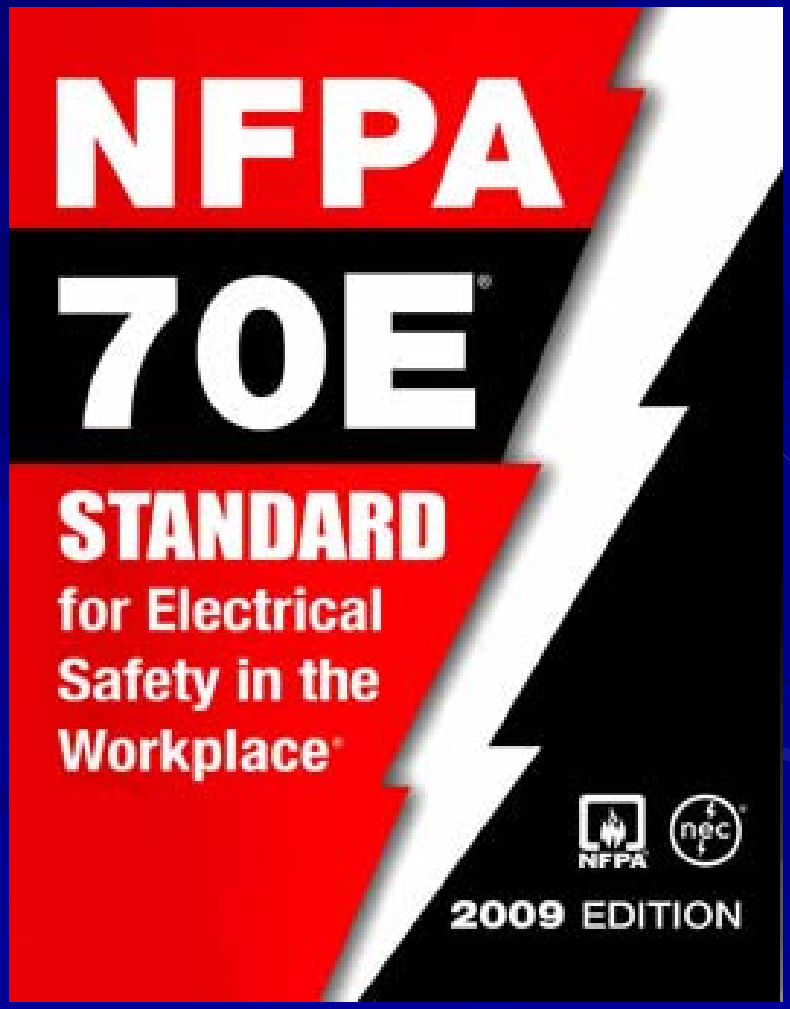
(1) Qualified Person. A qualified person shall be trained and knowledgeable of the construction and operation of equipment or a specific work method and be trained to recognize and avoid the electrical hazards that might be present with respect to that equipment or work method.

(a) Such persons shall also be familiar with the proper use of the special precautionary techniques, personal protective equipment, including arc-flash, insulating and shielding materials, and insulated tools and test equipment. A person can be considered qualified with respect to certain equipment and methods but still be unqualified for others.

(b) An employee who is undergoing on-the-job training and who, in the course of such training, has demonstrated an ability to perform duties safely at his or her level of training and who is under the direct supervision of a qualified person shall be considered to be a qualified person for the performance of those duties.

(c) Such persons permitted to work within the Limited Approach Boundary of exposed live parts operating at 50 volts or more shall, at a minimum, be additionally trained in all of the following:

(1) The skills and techniques necessary to distinguish exposed energized parts from other parts of electrical equipment
(2) The skills and techniques necessary to determine the nominal voltage of exposed live parts
(3) The approach distances specified in Table 130.2(C) and the corresponding voltages to which the qualified person will be exposed
(4) The decision-making process necessary to determine the degree and extent of the hazard and the personal protective equipment and job planning necessary to perform the task safely



FN000385/CR

Objectives

- At the end of this training the student will be able to:
  - State the hazards and physical effects of the hazards of electricity
  - State Fermilab's Policy on working on energized circuits
  - Recall the basic tenets of Fermilab's Electrical Safety Program
  - Understand the significance of NFPA 70E and why it exists
  - Understand requirements of NFPA 70E as related to the AC Power Distribution System and Utilization Equipment

Objectives

- Understand terms presented in NFPA 70E
- Understand the process and means for mitigating electrical hazards
- Understand how to protect yourself against the hazards of electrical shock
- Understand how to protect yourself against the hazards arc -flash
- Understand the importance of Single Line Electrical Diagrams (SLEDs)

Objectives

- State where to procure, how to maintain, and limitations of Personal Protective Equipment (PPE) and tools
- Describe proper methods of verification of de-energization
- Discuss the Electrical Hazard Analysis Work Permit (EHAWP) found in FESHM 9110 and 9120
- State requirements for rescue, including use of Cardiopulmonary Resuscitation (CPR)
- State requirements for Task Manager and Construction Coordinator (TM/CC) as it applies to their oversight responsibilities of subcontractors

Most Important Objectives

- Protect the Worker
- Understand the Work and the Hazard
- Identify the Shock and Flash Boundaries
- Identify the Hazard/Risk Category
- Identify What PPE Must be Worn
- Understand How NFPA 70E Helps to Figure Out All of This
- Understand Where to Go for Advice and Guidance

Why?

- We Care About Your Safety
- We Want to Provide a Safe Work Environment
- We Want to Continue to Avoid Injuries
- Required to Comply with NFPA 70E Requirements
- Consequences are Unacceptable

Consequences of an Arc-Flash Incident

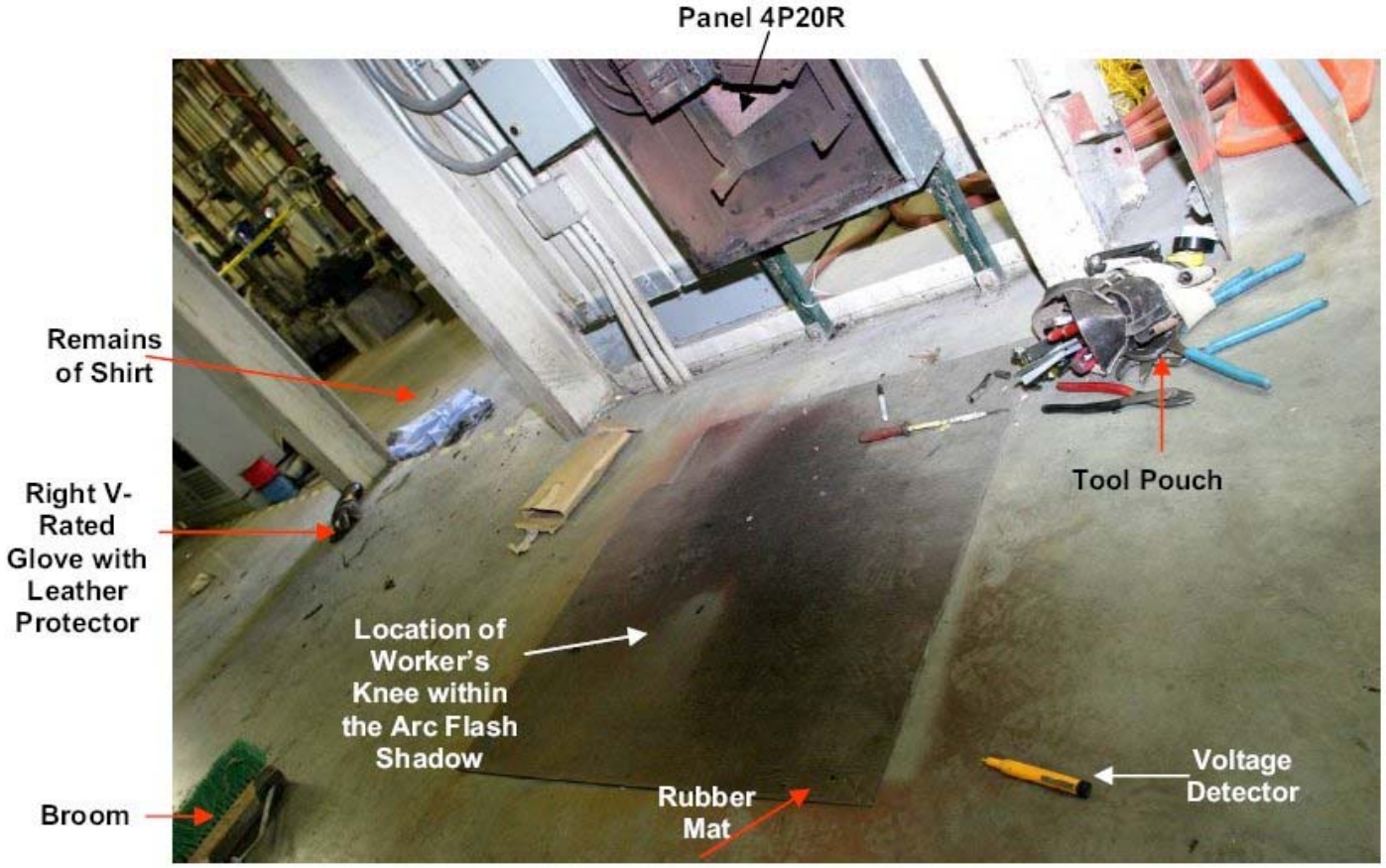


Figure 2-3. The insulating mat with the outline of BSE-1's knee in the arc flash shadow

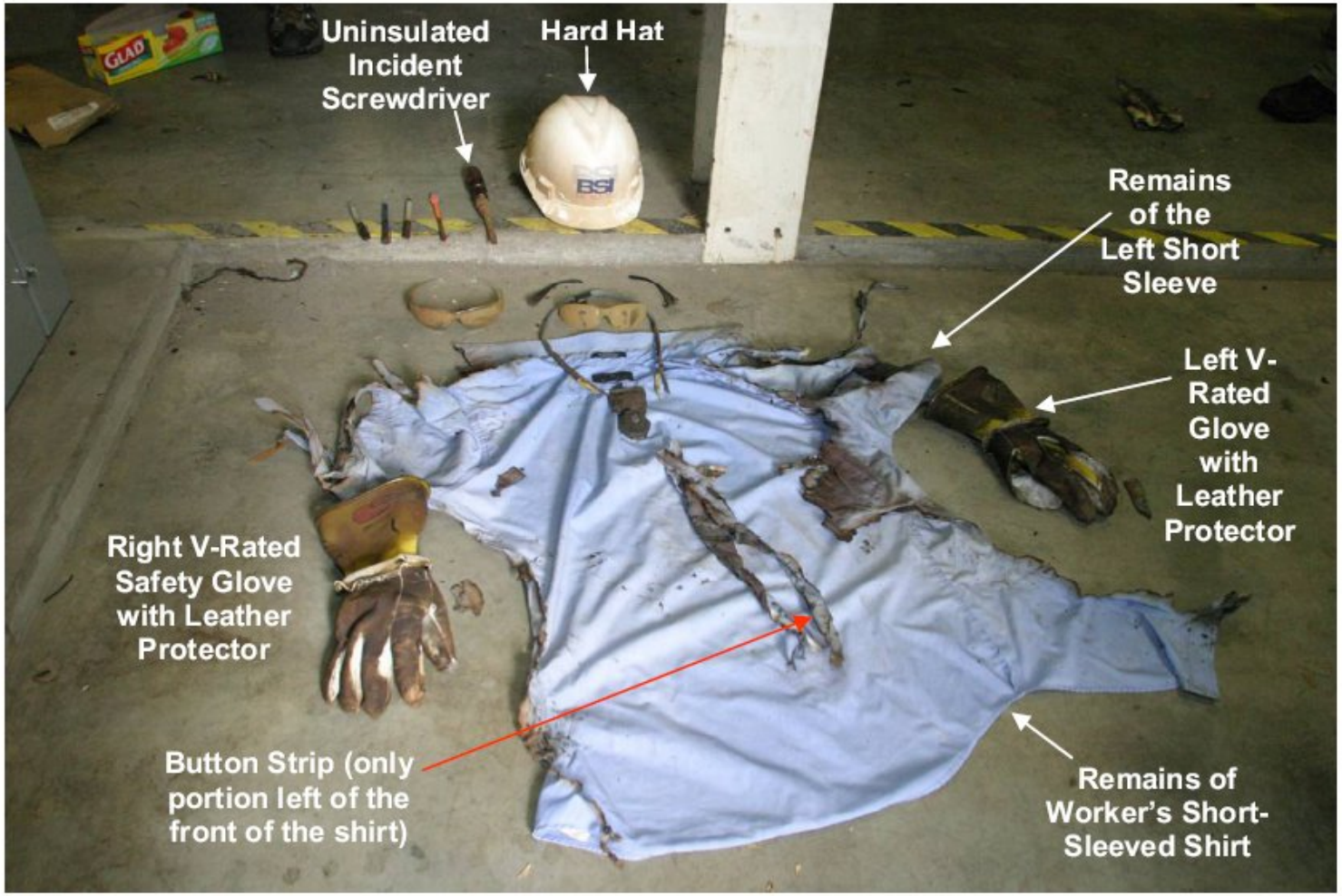


Figure 2-6. BSE-1's burned shirt and his flash-damaged PPE and tools

Some Statistics

- 286 Fatalities and 4,100 cases of lost time injuries due to electrical shock or electrical burns each year from 1992-1998
  - 98% of the fatalities due to electrical shock
  - 38% injuries were due to arc flash burns
- 239 construction workers electrocuted in 2010
- 5 to 10 arc flash explosions occur daily in the US
- Financial costs can be staggering
  - Can exceed $13 Million for one incident
- Programmatical costs for Fermilab would be astronomical

Hazards of Electricity

Familiar to Most of You But They Bear Repeating

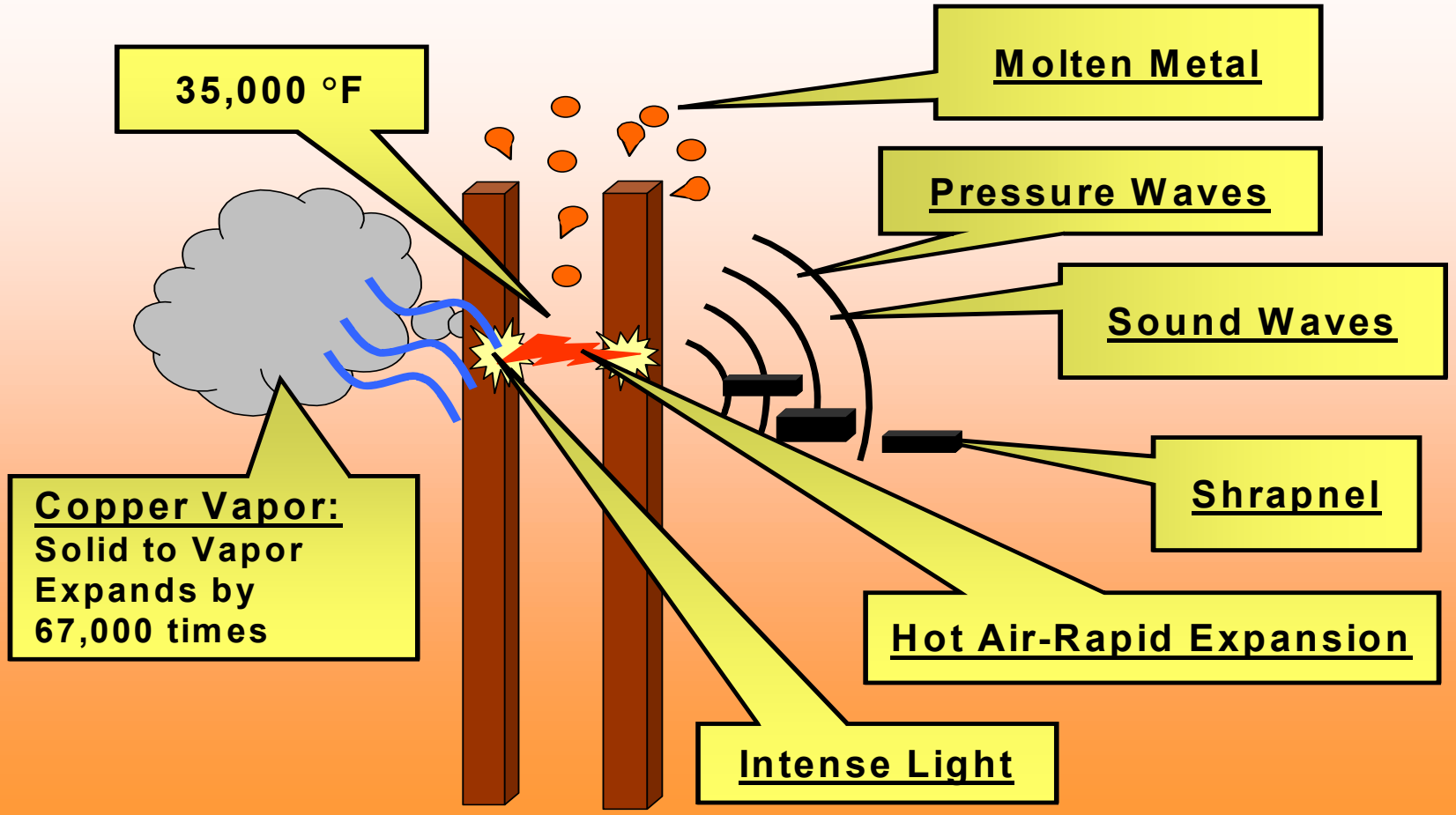
Hazards of Electricity

- Electric Shock
  - Electric Current through Body – Electrocution and Burns
- Arc-Flash
  - Burns due to high heat and molten metal
  - Fire Ignition
- Arc-Blast
  - Hearing loss due to blast explosion
  - Lacerations/Punctures from blast debris
  - Percussion force
  - Explosion

Arc-Flash

- Electric current passes through air, between a “Hot” conductor and ground, or between “Hot” conductors
- Temperatures can reach 35,000 Degrees F three times the surface temperature of the sun
- Exposure can easily cause skin burns & ignite clothing
- Clothing or PPE that Burns and Melts is a Real Problem

Electrical Arc



Arc Flash Video

Mitigation of Electrical Hazards

- Work De-Energized
- Engineer Out the Hazard
- Follow Electrical Safe Work Practices
  - Employ Lockout/Tagout of Hazardous Electrical Energy Sources
  - Use Voltage Insulating PPE and Equipment
  - Use PPE for Arc-Flash Protection
  - Use Ground Fault Circuit Interrupters

Fermilab's Electrical Safety Program

- Electrical systems and equipment and all design, construction, installation, inspection, testing, and operational activities shall be in accordance with established electrical safety standards
- Electrical work activities at Fermilab are preferentially performed on de-energized circuits
- Implementation of Lockout/Tagout (LOTO) procedures is central to our Program
- See a Problem? Tell Somebody!

Fermilab's Program

- FESHM 9100 – Overall Program
- FESHM 9110 – Utilization Equipment Safety
- FESHM 9120 – AC Electrical Power
- FESHM 9130 – Cable Trays
- FESHM 9140 – Exposed Electrical Bus
- FESHM 9150 – HV Coaxial Connectors
- FESHM 9160 – Low Voltage, High Current
- FESHM 9170 – AC Power Back Up Systems
- FESHM 9180 – Safe Work Practices and PPE
- FESHM 9190 – Grounding Requirements
- FESHM 2100 – Lockout Tagout

Energized Work

Diagnostic or Manipulative

What is Energized Work?

- Any activity On or Near exposed energized conductors where a hazard exists from contact or equipment failure that can result in electric shock, arc flash burn, or arc blast.

- Working On - Coming in contact with live parts with the hands, feet, or other body parts, with tools, probes or with test equipment

- Working Near – Inside the Limited Approach Boundary

Diagnostic Energized Work

- Inspection, testing, voltage and/or current measurements, phase alignment, troubleshooting, circuit and signal tracing, thermal imaging, etc. that are performed on or near exposed live parts within the Limited Approach Boundary
- Verification Associated with LOTO
- Performed by Qualified Persons Utilizing Appropriately Rated Measurement Equipment and Required PPE.

Manipulative Energized Work

- Making, tightening or breaking of energized electrical connections or the replacement, removal, or addition of electrical or mechanical components

- Examples include:
  - Replacing a duplex outlet, light switch, fluorescent fixture ballast, fuses, circuit breakers
  - Drilling or punching holes in a panelboard
  - Pulling conductors into a panelboard

Fermilab Policy for Energized Work

- Do Not work on energized electrical equipment unless absolutely necessary
- Diagnostic Energized Work is allowed only when the diagnostic activity is not feasible with the circuit de-energized
- Manipulative Energized Work is prohibited at Fermilab unless it can be demonstrated that de-energization introduces additional or increased hazards or is infeasible due to equipment design or operational limitations
- Directorate Approval Required for Manipulative Energized Work
- These policies and NFPA 70E apply to both the equipment of the AC Power Distribution system and to Utilization Equipment
- Infeasible is not Inconvenient

NFPA 70E
Electrical Safety in the Workplace

NEC - OSHA - NFPA 70E

- NEC – National Electric Code NFPA 70
- OSHA 1910 and 1926
  - Subparts S and K Relate to Electricity
- NFPA 70E – Electrical Safety in the Workplace

NFPA 70E Organization

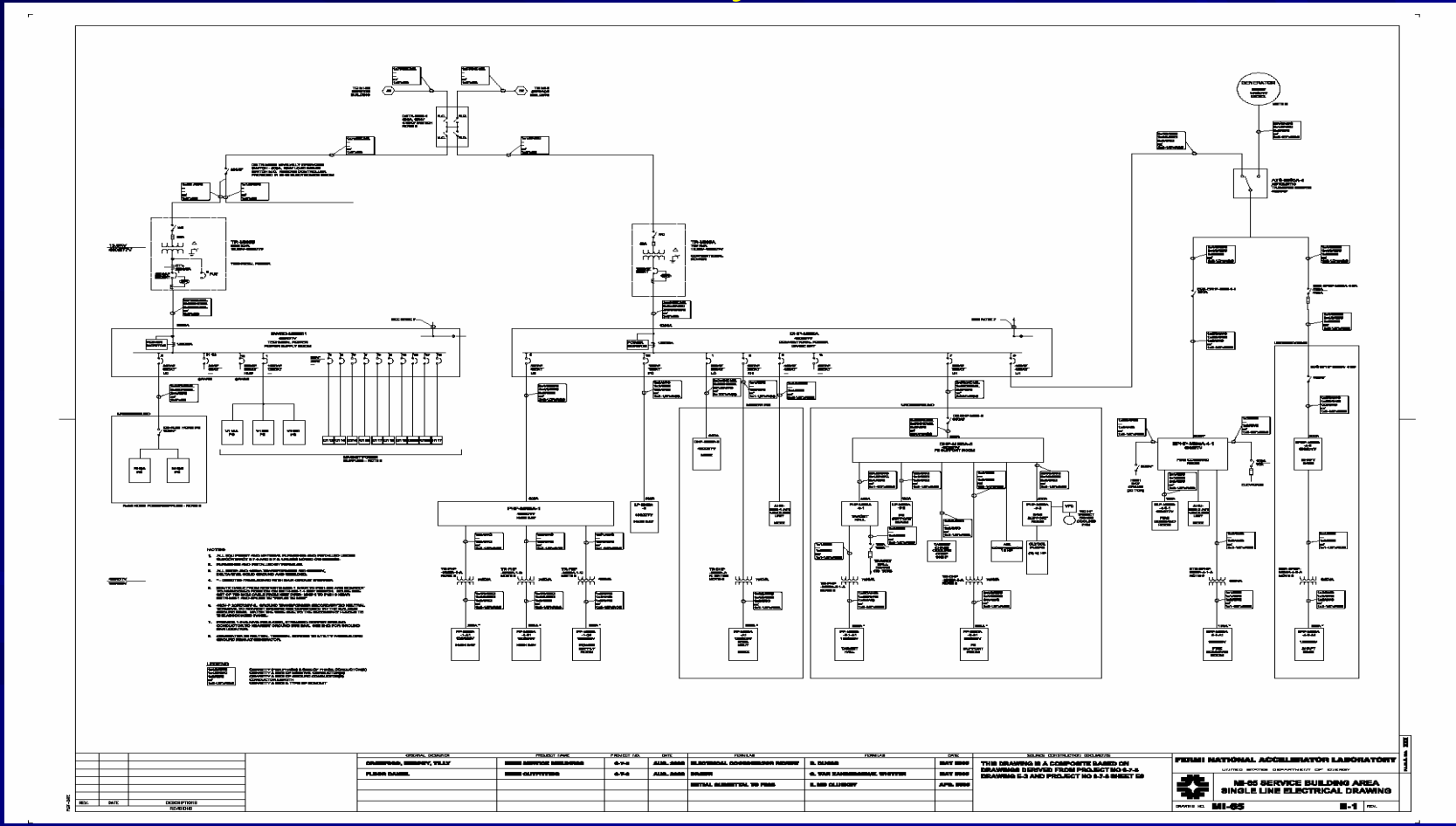
- 4 Chapters and 13 Annexes
- Chapter 1 “Safety Related Work Practices”
  - Article 100 - Definitions
  - Article 110 - General Requirements
  - Article 120 - Establishing an Electrically Safe Work Condition
  - Article 130 - Working On or Near Live Parts
- Chapter 2 “Safety Related Maintenance Requirements”
- Chapter 3 “Safety Requirements for Special Equipment”
- Chapter 4 “Installation Safety Requirements”

Some General Article 100 Definitions

- Qualified Person
  - One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training on the hazards involved
- Electrically Safe Work Condition
  - The equipment is de-energized and free of hazardous electrical energy.
  - See Article 120.1 for Details of the Process

Electrical Single-Line Diagram (SLED)

Block diagram of major elements of a local AC Power Distribution System



NFPA 70E Requirements

Article 130

Article 130 - Working on or Near Live Parts

- Working on or near live parts must be justified
- Diagnostic Energized Work is allowed when the diagnostic activity is not feasible with the circuit de-energized
- Manipulative Energized Work is prohibited at Fermilab unless it can be demonstrated that de-energization introduces additional or increased hazards or is infeasible due to equipment design or operational limitations.
  ** Requires Directorate Approval **

Article 130 Requirements

- A Permit is Required for Energized Work
  - But Diagnostic Work is not subject to permit
  - FESHM 9110 & 9120 EHAWP is our Permit
- Boundaries for Shock and Arc-Flash
- Hazard/Risk Categories (HRCs)
- Determination of the degree of protection required to safeguard workers involves both a Shock and Arc-Flash Hazard Analysis

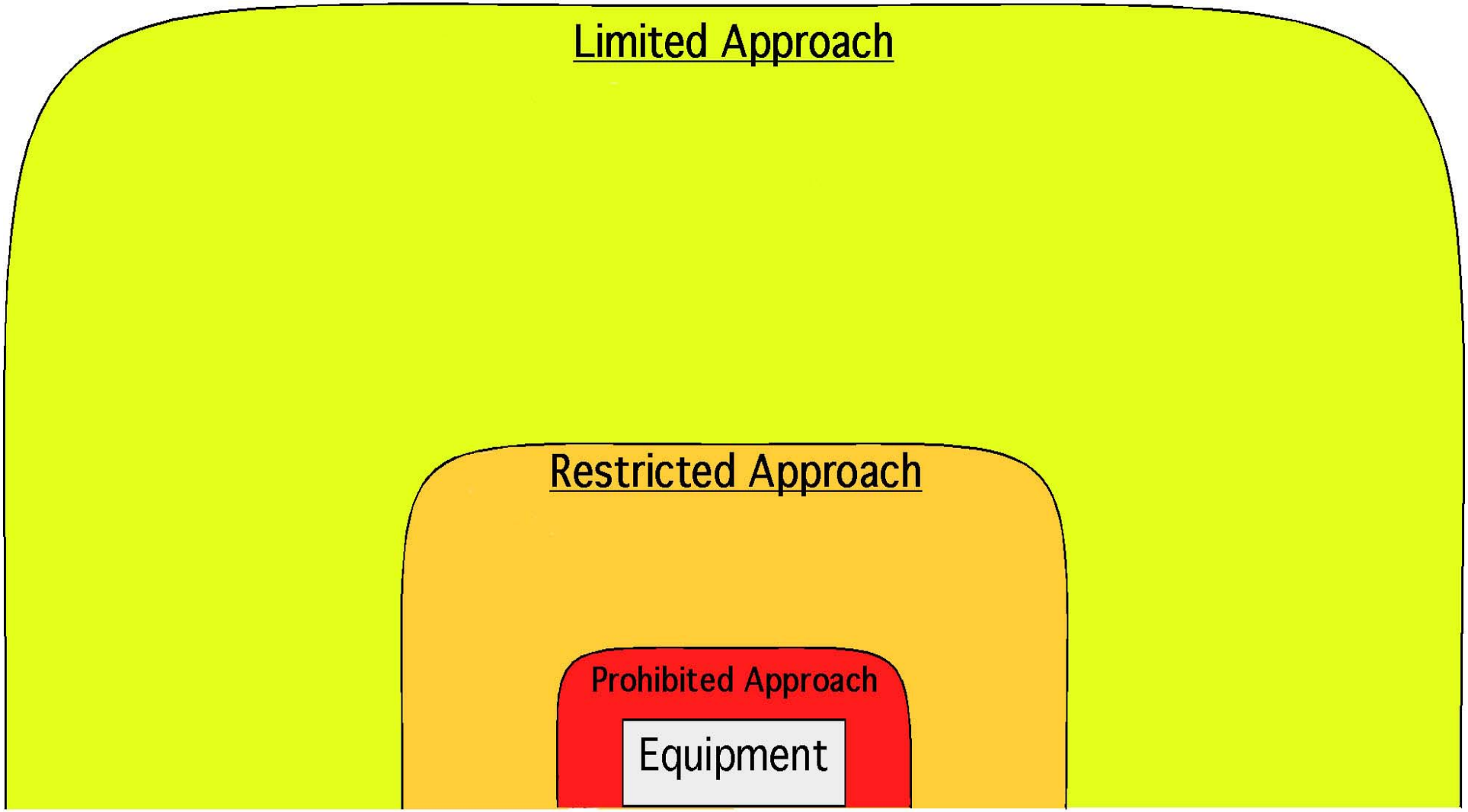
Shock Hazard and Protection

It Helps to Consider this Aspect of 70E
Separate from the Arc-Flash Hazard

Shock Hazard and Protection

- There is No One Solution for Protection from Shock, but Really Pretty Simple
  - Degree of protection is determined primarily by system voltage and distance from the energized part

Shock Protection Boundaries



Shock Protection Boundaries

- Limited Approach Boundary
  - Distance from an exposed live part within which a shock hazard exists
  - Note that this Boundary is significant to Fermilab's definition of Energized Work

Shock Protection Boundaries

- Restricted Approach Boundary
  - Distance from an exposed live part within which there is an increased risk of shock due to electrical arc over, combined with inadvertent movement, for personnel working in close proximity to the live part
- Prohibited Approach Boundary
  - Distance from an exposed live part within which work is considered the same as making contact with the live part

Shock Protection

- Shock Hazard Analysis
  - Defined at 130.2 (A)
- Shock Protection Boundaries
  - Defined at Table 130.2 (C)

  - You are Responsible for Establishing, Maintaining, and Communicating to Others the Extent of these Boundaries

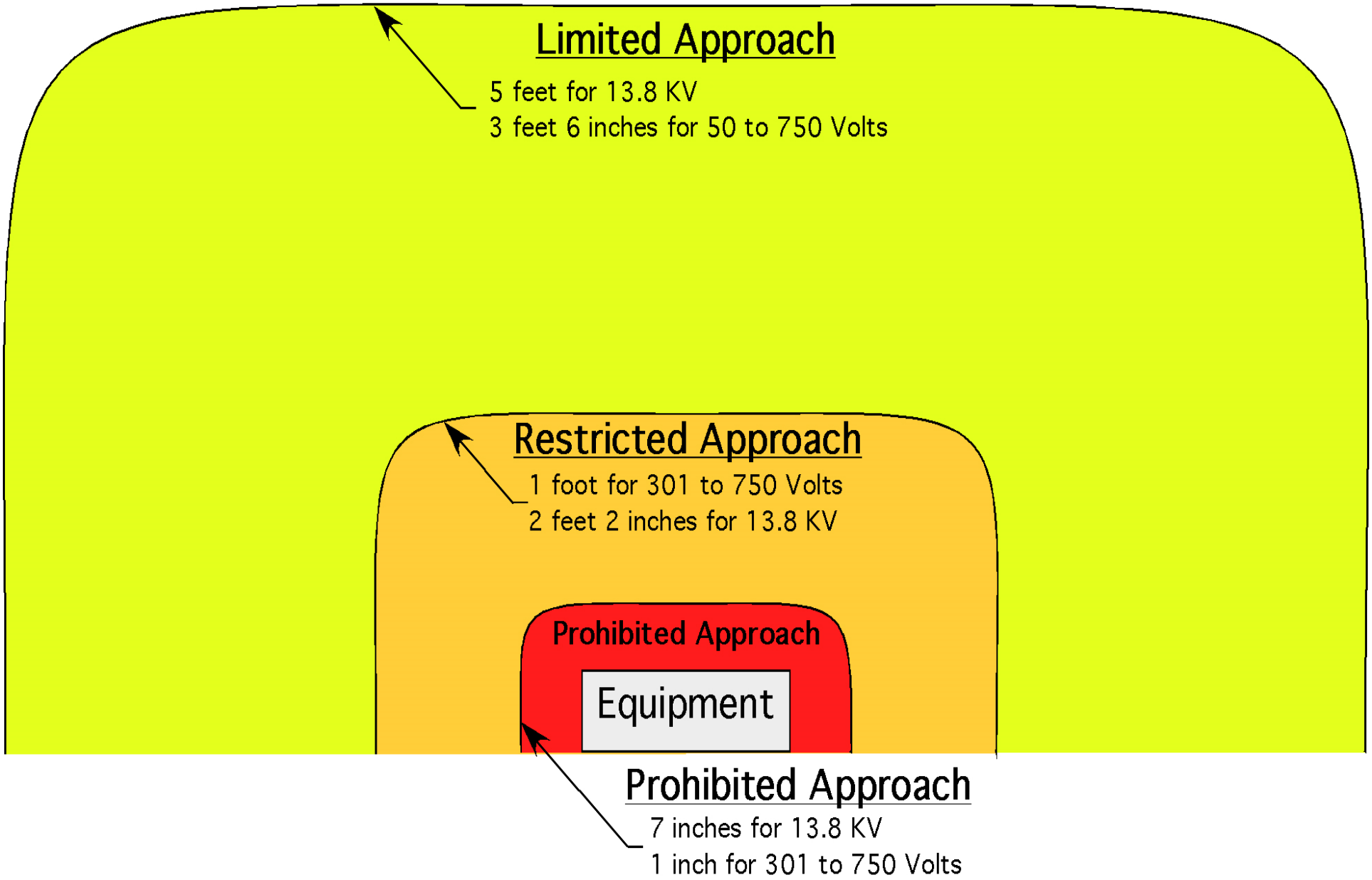
Table 130.2 (C)

Table 130.2(C) Approach Boundaries to Live Parts for Shock Protection. (All dimensions are distance from live part to employee.)

Nominal System Voltage Range, Phase to Phase[2]	Limited Approach Boundary[1]		Restricted Approach Boundary[1]; Includes Inadvertent Movement Adder	Prohibited Approach Boundary[1]
	Exposed Movable Conductor[3]	Exposed Fixed Circuit Part		
Less than 50	Not specified	Not specified	Not specified	Not specified
50 to 300	10 ft 0 in.	3 ft 6 in.	Avoid contact	Avoid contact
301 to 750	10 ft 0 in.	3 ft 6 in.	1 ft 0 in.	0 ft 1 in.
751 to 15 kV	10 ft 0 in.	5 ft 0 in.	2 ft 2 in.	0 ft 7 in.
15.1 kV to 36 kV	10 ft 0 in.	6 ft 0 in.	2 ft 7 in.	0ft 10 in.
36.1 kV to 46 kV	10 ft 0 in.	8 ft 0 in.	2 ft 9 in.	1 ft 5 in.
46.1 kV to 72.5 kV	10 ft 0 in.	8 ft 0 in.	3 ft 3 in.	2 ft 2 in.
72.6 kV to 121 kV	10 ft 8 in.	8 ft 0 in.	3 ft 4 in.	2 ft 9 in.
138 kV to 145 kV	11 ft 0 in.	10 ft 0 in.	3 ft 10 in.	3 ft 4 in.
161 kV to 169 kV	11 ft 8 in.	11 ft 8 in.	4 ft 3 in.	3 ft 9 in.
230 kV to 242 kV	13 ft 0 in.	13 ft 0 in.	5 ft 8 in.	5 ft 2 in.
345 kV to 362 kV	15 ft 4 in.	15 ft 4 in.	9 ft 2 in.	8 ft 8 in.
500 kV to 550 kV	19 ft 0 in.	19 ft 0 in.	11 ft 10 in.	11 ft 4 in.
765 kV to 800 kV	23 ft 9 in.	23 ft 9 in.	15 ft 11 in.	15 ft 5 in.

Note: For Arc Flash Protection Boundary, see 130.3(A).
1. See definition in Article 100 and text in 130.2(D)(2) and Annex C for elaboration.
2. For single phase systems, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.
3. A condition in which the distance between the conductor and a person is not under the control of the person.
The term is normally applied to overhead line conductors supported by poles.

Shock Protection Boundaries



Limited Approach Boundary

- Limited Approach Boundary (LAB)
  - 3 feet 6 inches for 50 to 750 Volts
  - 5 feet for 13.8 KV
  - 15 feet 4 inches for 345 KV
- Occupancy generally limited to Qualified Workers
- Unqualified persons may enter if advised of hazards and continuously escorted
- Appropriately rated insulated tools and/or equipment must be used if they might (likely) make accidental contact with exposed live parts

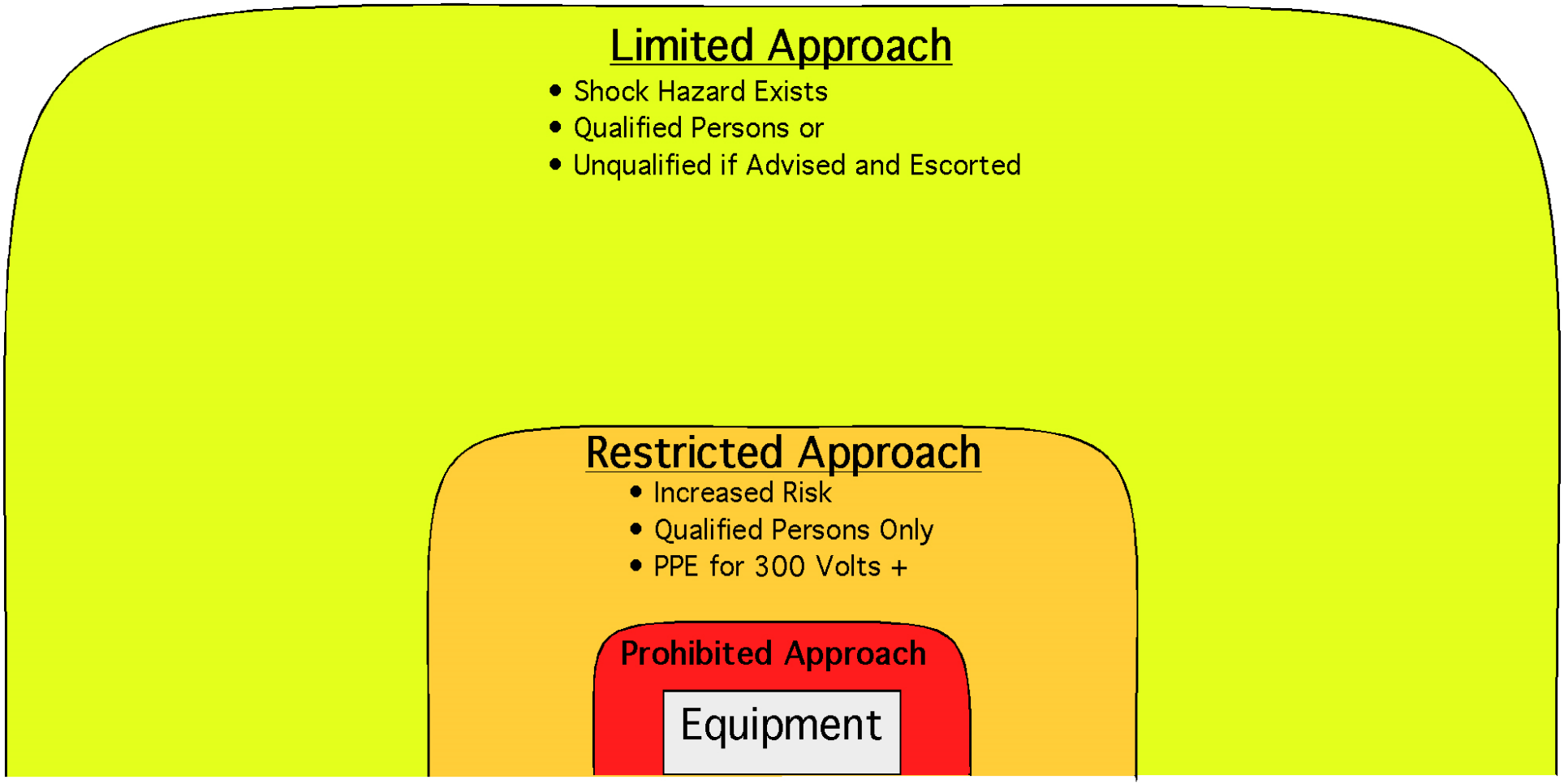
Restricted Approach Boundary

- Restricted Approach Boundary (RAB)
  - Avoid Contact for 50 to 300 Volts
  - 1 foot for 301 to 750 Volts
  - 2 feet 2 inches for 13.8 KV
- Occupancy only by Qualified Workers
- May not cross boundary with conductive objects
- No uninsulated part of the body may cross this boundary
- For voltages greater than 300 Volts, must wear PPE for shock protection, such as insulating gloves and insulating sleeves

Prohibited Approach Boundary

- Prohibited Approach Boundary (PAB)
  - Avoid Contact for 50 to 300 Volts
  - 1 inch for 301 to 750 Volts
  - 7 inches for 13.8 KV
- For 50 to 300 Volts, wearing of PPE for shock protection is advised if body contact with exposed live parts is likely

Shock Protection Boundaries



Prohibited Approach

- Same As Contact
- Qualified Persons Only
- PPE for 300 Volts +
- PPE for Less Than 300 Volts if Contact Likely

Approach Boundaries

- Limited Approach Boundary
  - Restricts the approach of unqualified persons
- Restricted and Prohibited Approach Boundaries
  - Restricts the approach of qualified persons

Shock Protection Boundaries and PPE
Fermilab Summary for NFPA 70E

System Voltage Range Phase to Phase	Limited Approach Boundary (Fixed Parts) (LAB)	Restricted Approach Boundary (RAB)	Prohibited Approach Boundary (PAB)	Shock Protection Insulating PPE
50 to 300 Including 120, 277 and 120/208	3 Ft 6 In	Avoid Contact	Avoid Contact	LAB - None RAB - Wear/Use if Contact Likely PAB - Wear/Use if Contact Likely
301 to 750 Including 480/277	3 Ft 6 In	1 Foot	1 Inch	LAB - None RAB - Must Wear PAB - Must Wear
751 to 15K Including 13.8K	5 Feet	2 Ft 2 In	7 Inches	LAB - None RAB - Must Wear PAB - Must Wear
345K to 362K	15 Ft 4 In	9 Ft 2 In	8 Ft 8 In	LAB - None RAB - Must Wear PAB - Must Wear

Within the Limited Approach Boundary	Non-Qualified Worker Allowed Within Only if Advised and Escorted by a QW. Insulated Equipment/Tools if Contact Likely.
Within the Restricted Approach Boundary	Only Qualified Worker Allowed Within. May Not Cross Into with Conductive Objects. Conductive Objects Prohibited. Body Parts Must be Insulated.
Within the Prohibited Approach Boundary	Consider Activity as Same as Working On.

PPE and Equipment for Shock Protection

- PPE
  - Insulating Gloves, Matting, and Blankets
- Tools
- Insulated Tools, Hot Sticks, Static Discharge Sticks, Rescue Tools
- ALWAYS Inspect Before Use and Maintain as Required
- Keep the Tools and Equipment Clean

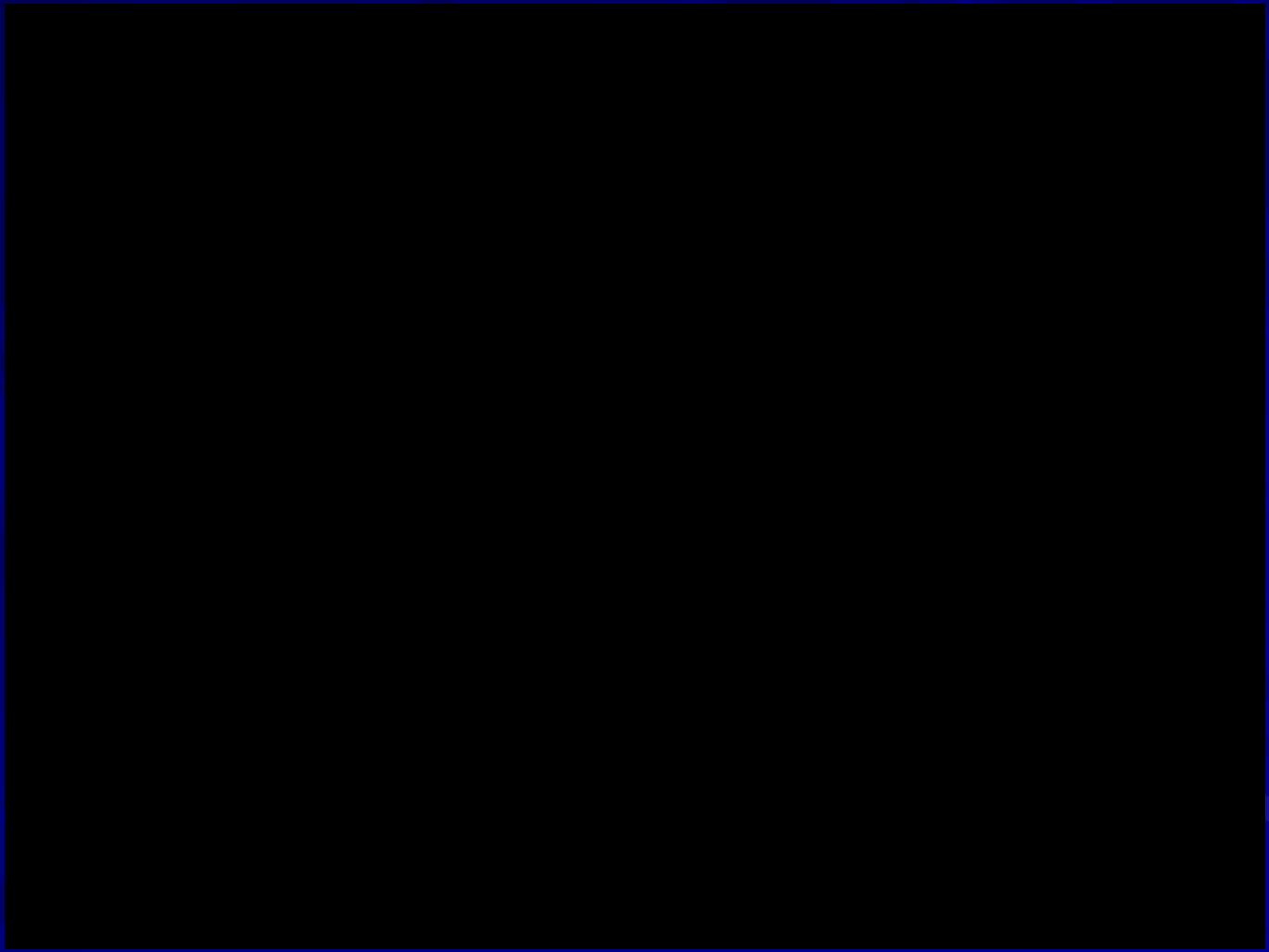
Electrically Insulating Gloves

- Glove Classes by Use Voltage

Class 00	500 volts	**Class 0**	**1,000 volts**
Class 1	7,500 volts	Class 2	17,000 volts
Class 3	26,500 volts	Class 4	36,000 volts

- Procure Through the ESH&Q Section
- Use Leather Protectors with Gloves
- Gloves must be tested after every 6 months of use through Fermilab's program (April 1 and October 1 are Scheduled Exchange Dates)

Gloves2



Courtesy of Salisbury

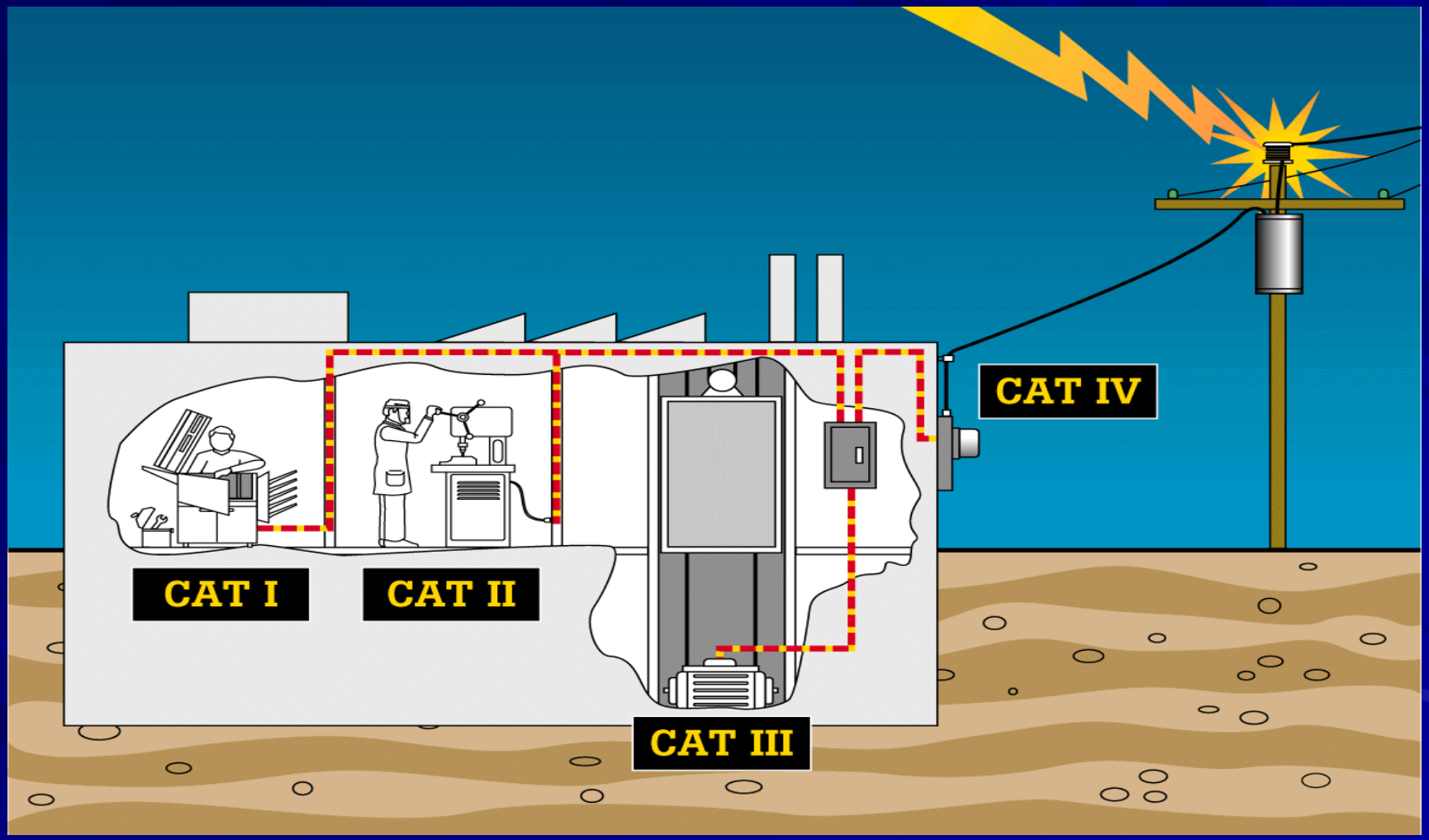
Over Voltage Category

- The level and energy of voltage impulses or surges is dependent on the location. The closer the location is to the power source, the higher the available fault current, the higher the category

- IEC 61010 defines four locations or categories:

CAT IV	"Origin of installation" Utility level and any outside cable run
CAT III	Distribution wiring, including "mains" bus, feeders and branch circuits; permanently installed loads.
CAT II	Receptacle outlet circuit; plug-in loads.
CAT I	Protected electronic circuits

Category Locations



Look for CAT III or CAT IV Markings

CAT III-
1000 V

CAT IV-600 V
CAT III-1000 V

CAT III-
600 V

Voltage Testing Equipment

- Meters
  - Use Cat III Rated 600 or 1000 Volt for Indoor Work (Fluke T3 Tester is Stocked)
  - Use Cat IV for Outdoor Work
  - Proximity – Inductive Voltage Probes
  - The Wiggy – No Longer Acceptable
- Test Before and After Use
  - LOTO after use check

Meter Safety Checklist

- Watch for:
- Cracked or oily case
- Broken input jacks

No Meter is Safe When Improperly Used.

- Use meters within their rating.
- Meter probes must also be properly rated.
- Use meters designed for measurements on power circuits.
- Use replacement fuses approved by the manufacturer

Arc-Flash Hazard and Protection

Consider this Aspect of 70E Separate from the Shock Hazard

Pertinent Definitions

- Flash Protection Boundary
  - Distance from an exposed live part within which a person could receive a 2° burn from an arc-flash
  - Incident energy necessary for a 2nd degree burn is 1.2 cal/cm2 with an exposure time of 1 second

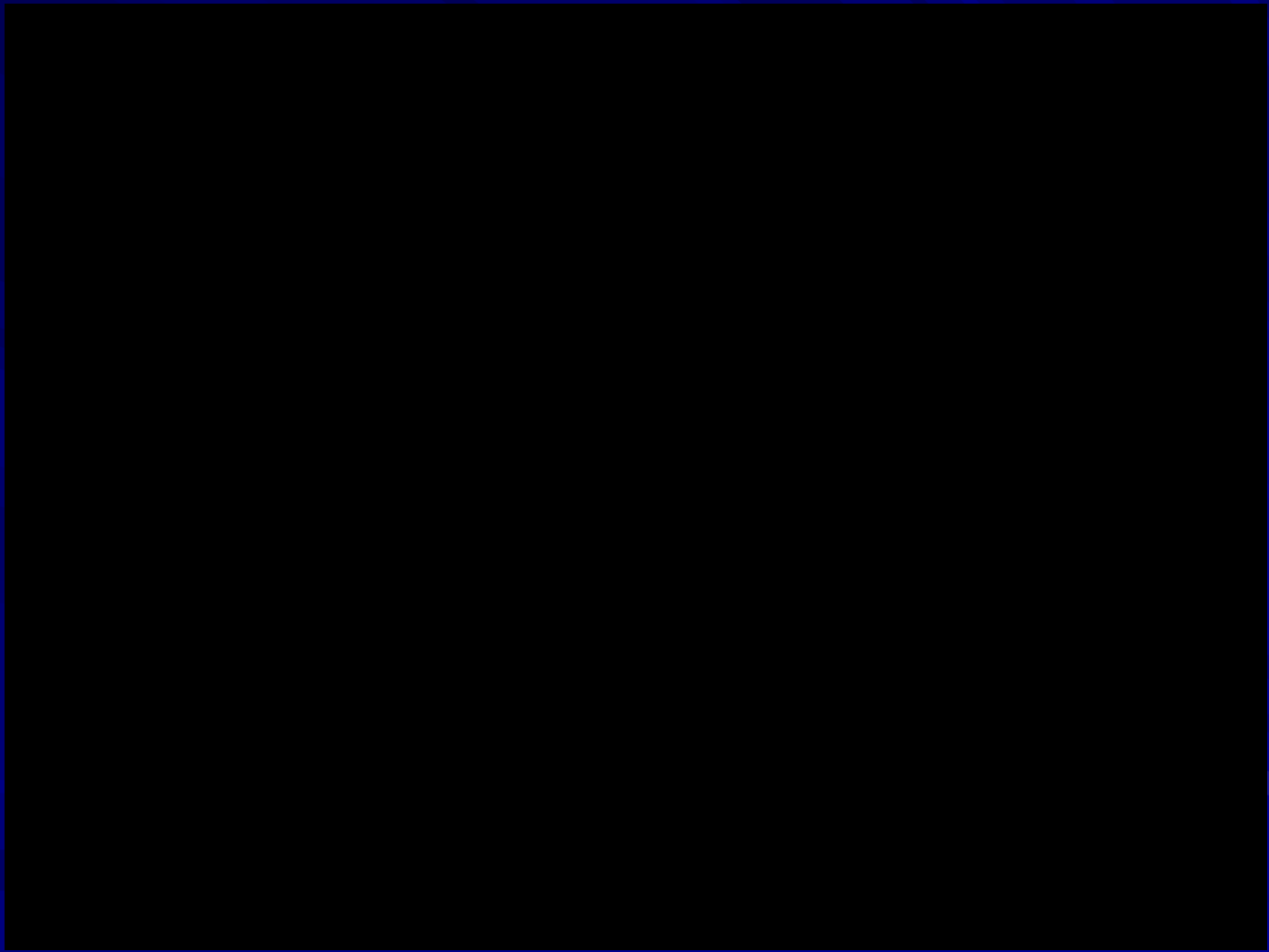
Pertinent Definitions

- Arc Rating
  - A value associated with PPE such as face shields, hoods, jackets, coats and coveralls that describes their performance to an electrical discharge expressed in cal/cm2
- Flame-Resistant (FR)
  - The property of a material whereby combustion is prevented, terminated, or inhibited following the application of a flaming or non-flaming source of ignition, with or without subsequent removal of the ignition source

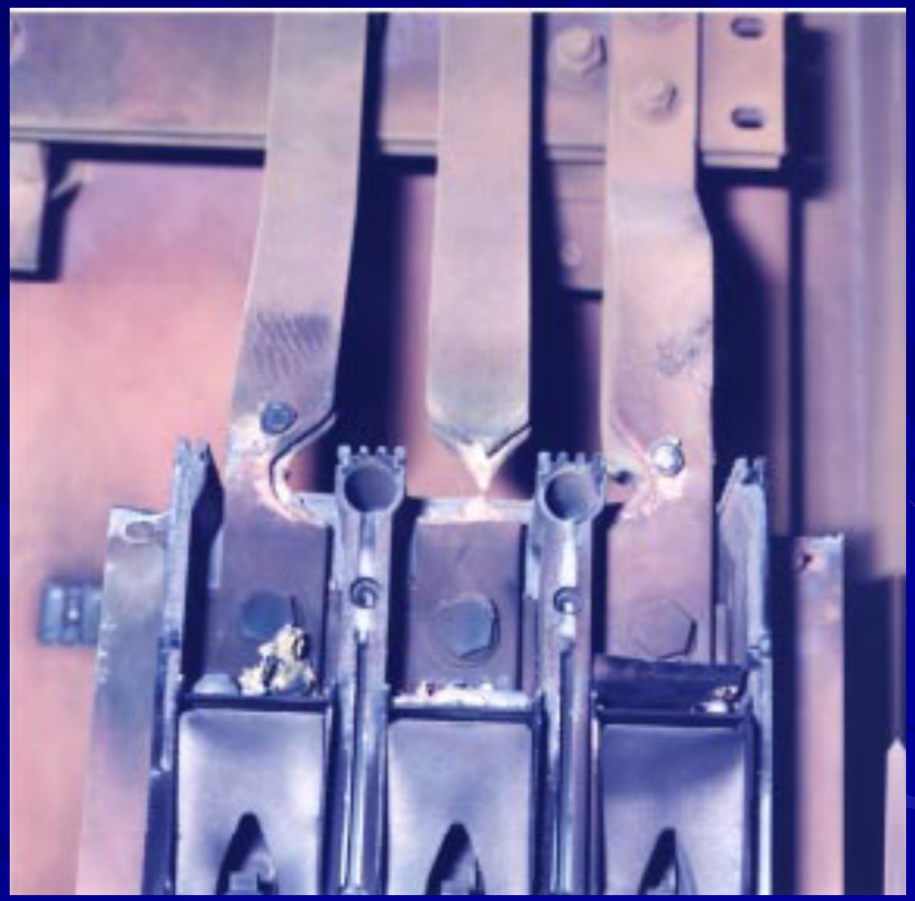
Arc-Flash

- Conduction of electrical current through the air
- Can start as an arc from an energized conductor to ground, neutral or another energized phase
- Most serious arcs are those in 3-phase systems that turn into 3-phase faults

Arc-Flash



1997 Arc-Flash Accident at F0 Compressor Room



Arc-Flash Hazard and Protection

- There is No One Solution for Protection from a Prospective Arc-Flash
  - All arc-flashes are not created equal
  - Bottom line is to establish a Flash Protection Boundary, determine a Hazard/Risk Category, and then to protect the worker
  - Quantifying arc-flash exposure and protection
    - The Flash Hazard Analysis
    - Article 130 Tables

Fault Current and Duration

Determine the Incident Energy of the Arc-Flash

What about Voltage?

- Assuming the resistance of an arcing fault to be essentially constant
- The arc Current = Potential / Resistance
  - $V / R = I$
- If the voltage is doubled,
  - $2V / R = 2I$
- So the effect of the system voltage is already accounted for in the calculated arc current

Fault Current

- Short Circuit or Bolted Fault Current
- Available Fault Current is Not Infinite
  - Limited by the Utility Generator, Transformers, Conductor Sizes and Length
- Different Values within the Circuit
- Transformer Impedance (%IZ)
  - Fundamental to the Value of the Short Circuit Current of a Transformer

First Calculate the Transformer's Full Load Current

- I FLA = (Transformer KVA Rating x1000)/ (Secondary Voltage Line to Line X 1.732)

2,000 KVA, 13.8KV to 480 VAC	2,406 Amps
1500 KVA, 13.8 KV to 480 VAC	1,804 Amps
750 KVA, 13.8 KV to 480 VAC	902 Amps
500 KVA, 13.8 KV to 480 VAC	601 Amps
75 KVA, 480 VAC to 120/208 VAC	208 Amps
45 KVA, 480 VAC to 120/208 VAC	125 Amps

Then Calculate the Short Circuit Current

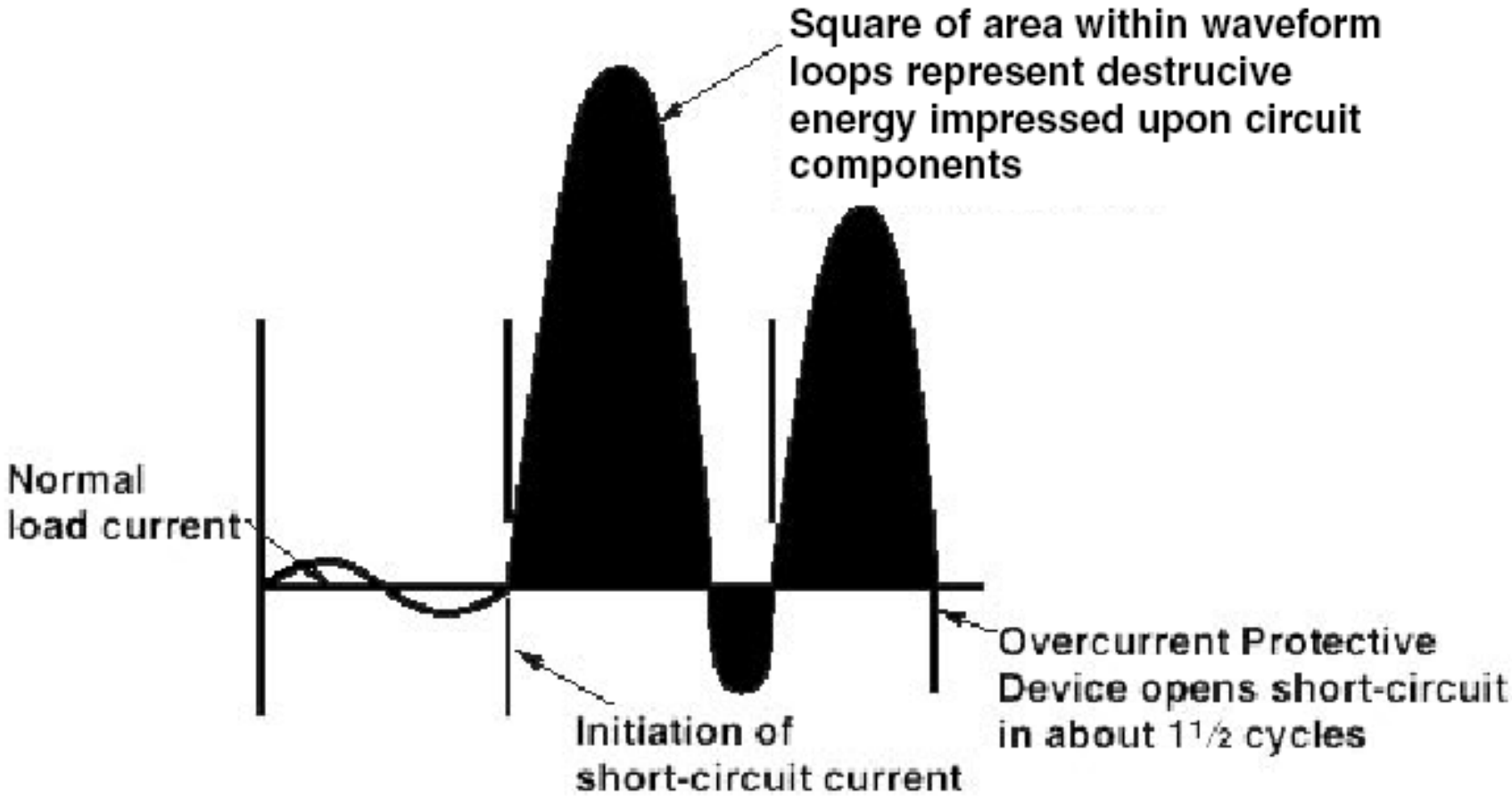
- I SCA = (1FLA X 100) / (Transformer %IZ x 0.9)

2000 KVA 480 VAC Out with 5.8%IZ	46,086 Amps
1500 KVA 480 VAC Out with 5.7%IZ	35,171 Amps
750 KVA 480 VAC Out with 5.75%IZ	17,433 Amps
500 KVA 480 VAC Out with 2.3%IZ	29,054 Amps
75 KVA 120/208 VAC Out with 4.3%IZ	5,379 Amps
45 KVA 120/208 VAC Out with 4.1%IZ	3,385 Amps

Duration of Fault Current

- Expressed in Time or Line Cycles
- Determined by Overcurrent Protective Devices Upstream of the Fault Site
  - Circuit Breakers or Fuses
  - Trip Time is Dependent on the Fault Current
    - Circuit Breaker – 3-10 Line Cycles
    - Current Limiting Fuse – Less than 1 Line Cycle

NEC® 110.10 Component Protection

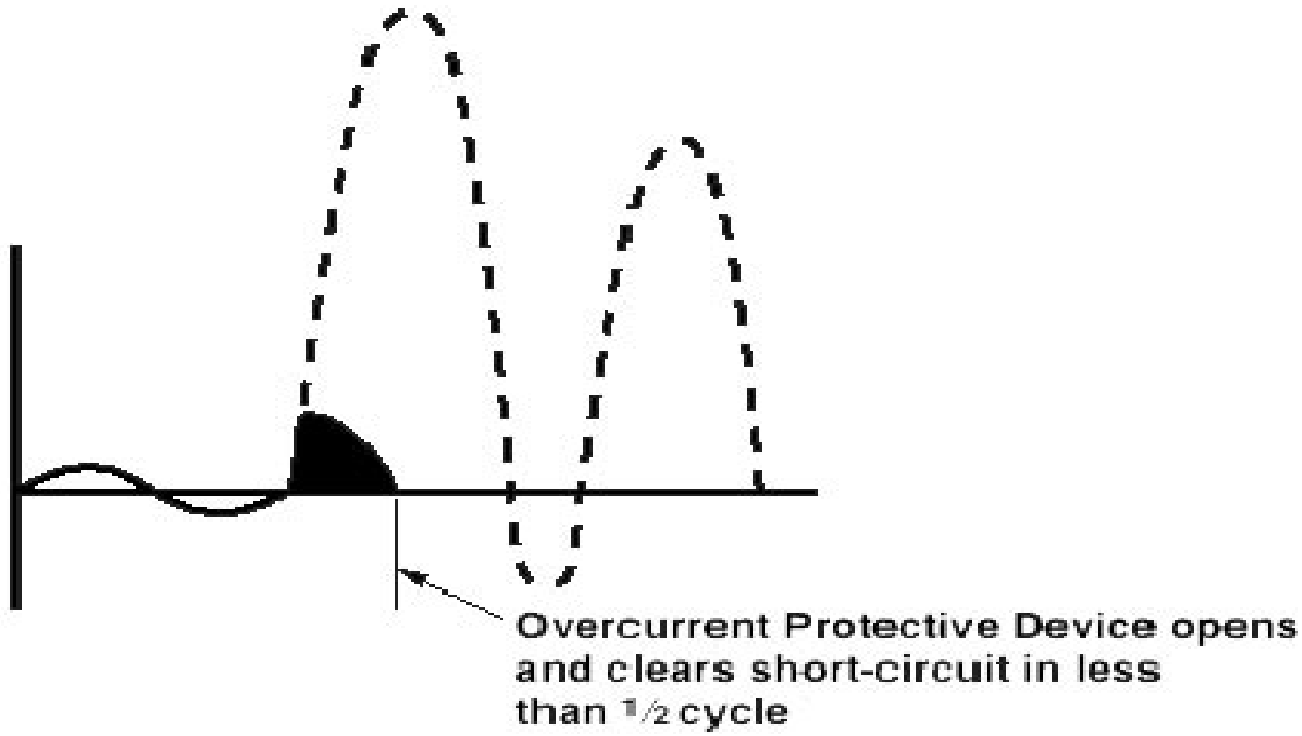


ACTION OF NON-CURRENT-LIMITING OVERCURRENT PROTECTIVE DEVICE

© 2003 Cooper Bussmann, Inc.

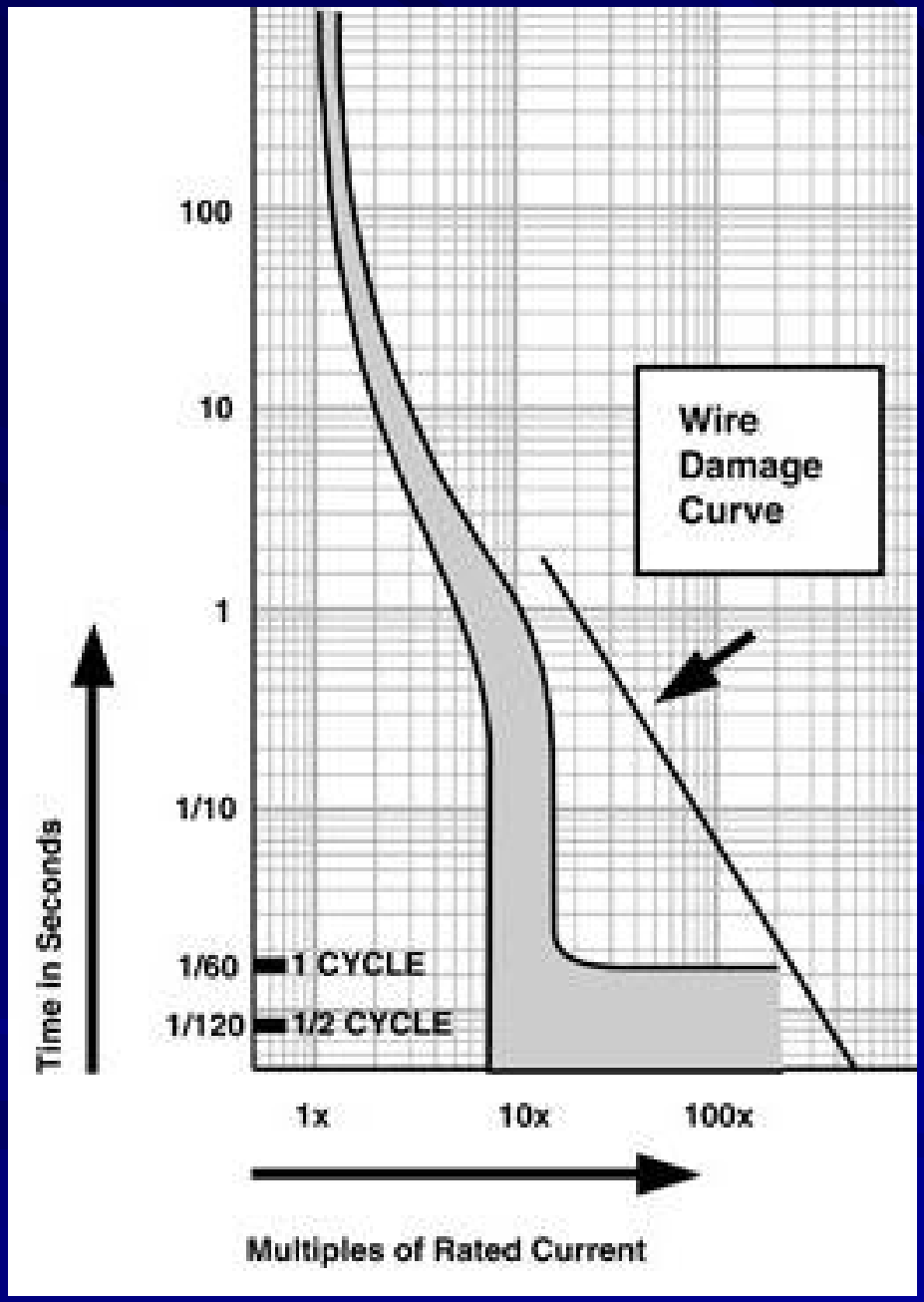
NEC® 110.10 Component Protection

- May require the use of current limiting devices



ACTION OF CURRENT-LIMITING OVERCURRENT PROTECTIVE DEVICE

© 2003 Cooper Bussmann, Inc.



Typical Trip Curve

Typical Trip Times

- Circuit Breakers
  - 0.1 second or 6 cycles typical. Varies by Manufacturer and Current. See Trip Curves.
- Current Limiting Fuses
  - Generally one-half of a line cycle.
  - Classes RK1, J, T and L are best.
- Yard Transformers:
  - Consult with FESS (Joe Pathiyil) for specific location trip times

Other Factors to Consider

- Longer and smaller conductors also serve to limit the available short circuit current due to the natural resistance of the wire
- Short Circuit Currents for Utilization Equipment are Most Always Less than those of the Sourcing Panelboard
- Exposure depends on distance to incident energy. 18 Inches is a typical value used.
- “Open” or apply the “Box Factor”

Flash Hazard Analysis

- The Flash HA determines the Flash Protection Boundary and the protective clothing and PPE required
  - Refer 130.3 on page 25
- Requires knowledge of
  - Fault current
  - Duration of the fault current
  - Location of potential arc-flash and
  - Worker body position

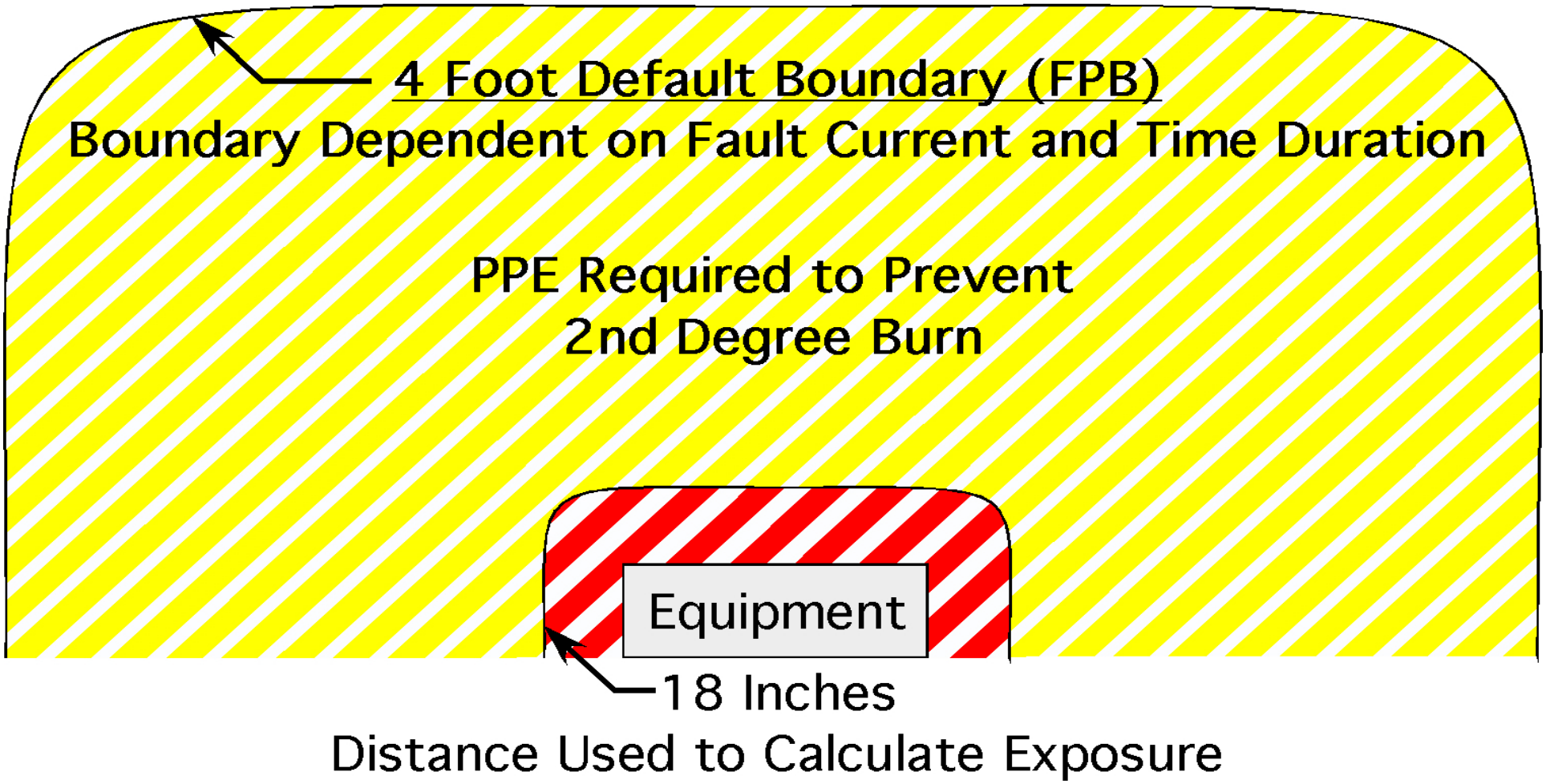
Flash Protection Boundary

- NFPA 70E 130.3 (A):
  D FPB = (2.65 X MVA bf X t)1/2

2000 KVA with t = 0.1	2.4 Feet
1500 KVA with t = 0.1	2.1 Feet
750 KVA with t = 0.1	1.5 Feet
500 KVA with t = 0.1	1.9 Feet
75 KVA with t = 0.05	0.4 Feet
45 KVA with t = 0.05	0.3 feet

- Systems 600 volts or less default boundary 4’

Flash Protection Boundary



Calculators

Available for Fault Current Flash Protection Boundary and Heat of the Prospective Flash

Generally Reserved for the Dedicated Student

Selecting Appropriate Arc-Flash Clothing & PPE

- What is the Work?
- What is My Exposure?
- What is the PPE that I Must Wear?
- NFPA 70E Tables
  - Table 130.7(C)(9) or “C9” (Pages 30-34)
  - Table 130.7(C)(10) or “C10” (Pages 35-36)
  - Table 130.7(C)(11) or “C11” (Page 37)

130.7 (C)(11)

- Table 130.7 (C)(11) Provides minimum levels of arc-rated PPE for each Hazard Risk Category

Table 3 - Adapted from NFPA 70E 2009 - Table 130.7(C)(11) Protective Clothing Characteristics

Hazard/Risk Category	Clothing Description	Required Minimum Arc Rating of PPE [J/cm2(cal/cm2)]
0	Nonmelting, flammable materials (i.e. untreated cotton, wool, rayon, or silk, or blends of these materials) with a fabric weight at least 4.5 oz/yd^2	N/A
1	Arc-rated FR shirt and FR pants or FR coverall	16.74 (4)
2	Arc-rated FR shirt and FR pants or FR coverall	33.47 (8)
3	Arc-rated FR shirt and FR pants or FR coverall, and arc flash suit selected so that the system arc rating meets required minimum	104.6 (25)
4	Arc-rated FR shirt and FR pants or FR coverall, and arc flash suit selected so that the system arc rating meets required minimum	167.36 (40)

130.7(C)(10)

- Table 130.7(C)(10) Provides a Listing of Clothing and PPE Required for Each Hazard/Risk Category
  - Lots of Footnotes
  - Introduces and additional Hazard Risk Category 2*
  - Note that Safety Glasses, Hearing Protection and Leather Gloves are Always Required

130.7 (C)(10)

Table 2 - Adapted from NFPA 70E 2009 - Table 130.7(C)(10)
Protective Clothing and Personal Protective Equipment (PPE)

Hazard/Risk Category Number	Protective Clothing and PPE
Hazard/Risk Category 0	
Protective Clothing, Nonmelting (according to ASTM F 1506-00) or Untreated Natural Fiber	Shirt (long-sleeve) Pants (long)
FR Protective Equipment	Safety glasses or safety goggles (SR) Hearing Protection (ear canal inserts) Leather gloves (AN) (Note 2)
Hazard/Risk Category 1	
FR Clothing, Minimum Arc Rating of 4 (Note 1)	Arc-rated long sleeve shirt (Note 3) Arc-rated pants (Note 3) Arc-rated coverall (Note 4) Arc-rated face shield or arc flash suit hood (Note 7) Arc-rated jacket, parka, or rainwear (AN)
FR Protective Equipment	Hard hat Safety glasses or safety goggles (SR) Hearing Protection (ear canal inserts) Leather gloves (AN) (Note 2) Leather work shoes (AN)
Hazard/Risk Category 2	
FR Clothing, Minimum Arc Rating of 8 (Note 1)	Arc-rated long sleeve shirt (Note 5) Arc-rated pants (Note 5) Arc-rated coverall (Note 6) Arc-rated face shield or arc flash suit hood (Note 7) Arc-rated jacket, parka, or rainwear (AN)
FR Protective Equipment	Hard hat Safety glasses or safety goggles (SR) Hearing Protection (ear canal inserts) Leather gloves (AN) (Note 2) Leather work shoes

130.7 (C)(10)

Table 2 - Adapted from NFPA 70E 2009 - Table 130.7(C)(10)
Protective Clothing and Personal Protective Equipment (PPE)

Hazard/Risk Category Number	Protective Clothing and PPE
Hazard/Risk Category 2*	
FR Clothing, Minimum Arc Rating of 8 (Note 1)	Arc-rated long sleeve shirt (Note 5) Arc-rated pants (Note 5) Arc-rated coverall (Note 6) Arc-rated face shield or arc flash suit hood (Note 10) Arc-rated jacket, parka, or rainwear (AN)
FR Protective Equipment	Hard hat Safety glasses or safety goggles (SR) Hearing Protection (ear canal inserts) Leather gloves (AN) (Note 2) Leather work shoes
Hazard/Risk Category 3	
FR Clothing, Minimum Arc Rating of 25 (Note 1)	Arc-rated long sleeve shirt (AR) (Note 8) Arc-rated pants (AR) (Note 8) Arc-rated coverall (AR) (Note 8) Arc-rated flash suit jacket (AR) (Note 8) Arc-rated flash suit pants (AR) (Note 8) Arc-rated flash suit hood (Note 8) Arc-rated jacket, parka, or rainwear (AN)
FR Protective Equipment	Hard hat FR hard hat liner (AR) Safety glasses or safety goggles (SR) Hearing Protection (ear canal inserts) Arc-rated gloves (Note 2) Leather work shoes

130.7 (C)(10)

Table 2 - Adapted from NFPA 70E 2009 - Table 130.7(C)(10)
Protective Clothing and Personal Protective Equipment (PPE)

Hazard/Risk Category Number	Protective Clothing and PPE
Hazard/Risk Category 4	
FR Clothing, Minimum Arc Rating of 40 (Note 1)	Arc-rated long sleeve shirt (AR) (Note 9) Arc-rated pants (AR) (Note 9) Arc-rated coverall (AR) (Note 9) Arc-rated flash suit jacket (AR) (Note 9) Arc-rated flash suit pants (AR) (Note 9) Arc-rated flash suit hood (Note 9) Arc-rated jacket, parka, or rainw ear (AN)
FR Protective Equipment	Hard hat FR hard hat liner (AR) Safety glasses or safety goggles (SR) Hearing Protection (ear canal inserts) Arc-rated gloves (Note 2) Leather w ork shoes

AN = As needed
AR = As required
SR = Selection required
Notes:
1. See Table 130.7(C)(11). Arc rating for a garment is expressed in cal/cm2.
2. If rubber insulating gloves w ith leather protectors are required by Table 130.7(C)(9), additional leather or arc-rated gloves are not required. The combination of rubber insulating gloves w ith leather protectors satisfies the arc flash protection requirements.
3. The FR shirt and pants used for Hazard/Risk Category 1 shall have a minimum arc rating of 4.
4. Alternate is to use FR coveralls (minimum arc rating of 4) instead of FR shirt and FR pants.
5. FR shirt and FR pants used for Hazard/ Risk Category 2 shall have a minimum arc rating of 8.
6. Alternate is to use FR coveralls (minimum arc rating of 8) instead of FR shirt and FR pants.
7. A face shield w ith a minimum arc rating of 4 for Hazard/Risk Category 1 or a minimum arc-rating of 8 for Hazard/Risk Category 2, w ith w rap-around guarding to protect not only the face, but also the forehead, ears, and neck (or, alternatively, an arc-rated arc flash suit hood), is required.
8. An alternate is to use a total FR clothing system and hood, w hich shall have a minimum arc-rating of 25 for Hazard/Risk Category 3.
9. The total clothing system consisting of FR shirt and pants and/or FR coveralls and/or arc flash coat and pants and hood shall have a minimum arc rating of 40 for Hazard/Risk Category 4.
10, Alternate is to use a face shield w ith a minimum arc rating of 8 and a balaclava (sock hood) w ith a minimum are-rating of 8 and w hich covers the face, head and neck except for the eye and nose areas.

Arc-Flash Hazard/Risk Categories - Required Clothing - Required PPE
Fermilab Summary for NFPA 70E

Calculated Exposure from Prospective Arc-Flash	Hazard/Risk Category	Minimum Required ATPV	Clothing Requirements	Additional PPE
Zero up to 1.2 cal/cm^2	0	NA	Long Sleeve Cotton Shirt and Pants	Safety Glasses, Hearing Protection, Leather Gloves
More than 1.2 and up to 4 cal/cm^2	1	4 cal/cm^2	FR Coverall*	Hard Hat, Safety Glasses, Arc-rated Face Shield, Hearing Protection, Leather Gloves, Leather Work Shoes
More than 4 and up to 8 cal/cm^2	2	8 cal/cm^2	Cotton Clothing Under FR Coverall*	Hard Hat, Safety Glasses, Arc-rated Face Shield, Hearing Protection, Leather Gloves, Leather Work Shoes
More than 4 and up to 8 cal/cm^2	2*	8 cal/cm^2	Cotton Clothing Under FR Coverall*	Hard Hat, Safety Glasses, Flash Suit Hood, Hearing Protection, Leather Gloves, Leather Work Shoes
More than 8 and up to 25 cal/cm^2	3	25 cal/cm^2	Cotton Clothing Under FR Coveralls* plus Multilayer Flash Suit Jacket & Pants	Hard Hat, FR Hard Hat Liner, Safety Glasses, Flash Suit Hood, Hearing Protection, Arc-Rated Gloves, Leather Work Shoes
More than 25 and up tp 40 cal/cm^2	4	40 cal/cm^2	Cotton Clothing Under FR Coverall* plus Multilayer Flash Suit Jacket & Pants	Hard Hat, FR Hard Hat Liner, Safety Glasses, Flash Suit Hood, Hearing Protection, Arc-Rated Gloves, Leather Work Shoes

* Coverall Rated at 8 cal/cm^2 Available from Fermilab Stockroom

Table 130.7 (C)(9)

- Applies Hazard Risk Categories (HRCs) for various tasks, and requirements for V-rated gloves and tools
  - Range of 0-4, plus a HRC 2* Category
- Uses conservative values for short circuit current and fault clearing time
  - Notes are very important, define the maximum short circuit current and fault clearing time for which the table is valid.

Table 130.7 (C)(9)

- Tasks are Limited Primarily to AC Power Distribution System
- Table Assumes Equipment is Energized and Work is Done within the Flash Protection Boundary
  - Includes Testing to Verify De-Energization
- No Direct Association in C9 with Shock Protection Boundaries

Table 130.7 (C)(9)

Table 1 - Adapted from NFPA 70E 2009 - Table 130.7(C)(9) Hazard/Risk Category Classifications

Tasks Performed on Energized Equipment	Hazard/ Risk Category	Rubber Insulating Gloves	Insulated Hand Tools
Panelboards or Other Equipment Rated 240 V and Below — Note 1			
Perform infrared thermography and other non-contact inspections outside the restricted approach boundary	0	N	N
Circuit breaker (CB) or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	0	N	N
Work on energized conductors and circuit parts, including voltage testing (LOTO)	1	Y	Y
Remove/install CBs or fused switches	1	Y	Y
Removal of bolted covers (to expose bare, energized electrical conductors and circuit parts)	1	N	N
Opening hinged covers (to expose bare, energized electrical conductors and circuit parts)	0	N	N
Work on energized electrical conductors and circuit parts of utilization equipment fed directly by a branch circuit of the panelboard	1	Y	Y

Table 130.7 (C)(9)

Table 1 - Adapted from NFPA 70E 2009 - Table 130.7(C)(9) Hazard/Risk Category Classifications

Tasks Performed on Energized Equipment	Hazard/ Risk Category	Rubber Insulating Gloves	Insulated Hand Tools
Panelboards or Switchboards Rated >240 V and up to 600 V (with molded case or insulated case circuit breakers) — Note 1			
Perform infrared thermography and other non-contact inspections outside the restricted approach boundary	1	N	N
Circuit breaker (CB) or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	1	Y	N
Work on energized conductors and circuit parts, including voltage testing (LOTO)	2*	Y	Y
Work on energized electrical conductors and circuit parts of utilization equipment fed directly by a branch circuit of the panelboard	2*	Y	Y

Table 130.7 (C)(9)

Table 1 - Adapted from NFPA 70E 2009 - Table 130.7(C)(9) Hazard/Risk Category Classifications

Tasks Performed on Energized Equipment	Hazard/ Risk Category	Rubber Insulating Gloves	Insulated Hand Tools
600 V Class Motor Control Centers (MCCs) - Note 2 (except as indicated)			
Perform infrared thermography and other non-contact inspections outside the restricted approach boundary	1	N	N
CB or fused switch or starter operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch	0	N	N
CB or fused switch or starter operation with enclosure doors open	1	N	N
Work on energized conductors and circuit parts, including voltage testing (LOTO)	2*	Y	Y
Work on control circuits with energized electrical conductors and circuit parts 120 V or below, exposed	0	Y	Y
Work on control circuits with energized electrical conductors and circuit parts >120 V, exposed	2*	Y	Y
Insertion or removal of individual starter “buckets” from MCC - Note 3	4	Y	N
Application of safety grounds, after voltage test	2*	Y	N
Removal of bolted covers (to expose bare, energized electrical conductors and circuit parts) - Note 3	4	N	N
Opening hinged covers (to expose bare, energized electrical conductors and circuit parts) - Note 3	1	N	N
Work on energized electrical conductors and circuit parts of utilization equipment fed directly by a branch circuit of the motor control center	2*	Y	Y

Table 130.7 (C)(9)

Table 1 - Adapted from NFPA 70E 2009 - Table 130.7(C)(9) Hazard/Risk Category Classifications

Tasks Performed on Energized Equipment	Hazard/ Risk Category	Rubber Insulating Gloves	Insulated Hand Tools
Metal Clad Switchgear & Other Equipment, 1 kV Through 38 kV			
Perform infrared thermography and other non-contact inspections outside the restricted approach boundary	3	N	N
CB operation with enclosure doors closed	2	N	N
Reading a panel meter while operating a meter switch	0	N	N
CB operation with enclosure doors open	4	N	N
Work on energized conductors and circuit parts, including voltage testing (LOTO)	4	Y	Y
Work on control circuits with energized electrical conductors and circuit parts 120 V or below, exposed	2	Y	Y
Work on control circuits with energized electrical conductors and circuit parts >120 V, exposed	4	Y	Y
Insertion or removal (racking) of CBs from cubicles, doors open or closed	4	N	N
Application of safety grounds, after voltage test	4	Y	N
Removal of bolted covers (to expose bare, energized electrical conductors and circuit parts)	4	N	N
Opening hinged covers (to expose bare, energized electrical conductors and circuit parts)	3	N	N
Metal-enclosed interrupter switchgear, fused or unfused Switch operation, enclosure doors closed	2	N	N

Additional Guidance

Restated or New “C9” Tasks with Associated Hazard/Risk Categories

Developed and Approved by the Electrical Safety Subcommittee

Simplified Guidance for Electrical Work on Fermilab AC POWER DISTRIBUTION Equipment

Diagnostic Work Including LOTO Voltage Testing Unless Otherwise Noted, Plus Some Additional Operations

Equipment	Voltage	Rated Full Load Current	Hazard/Risk Category	Conditions or Qualifications
Primary Panelboards SWBD DHP	480/277 VAC	More than 1,200 Amps	3	Primary Transformer Larger than 1000 KVA (Assuming More Than 25,000 ISC Available with Fault Clearing Time >2 Cycles) Take Advantage of Installed Panelboard Meter for LOTO Verification if Present
Motor Control Centers MCC	480 VAC	Typical 600 Amps and Above	2*	Take Advantage of Installed Central Monitoring Unit for LOTO Verification if Present
Primary or Secondary Panelboards	480/277 VAC	400 to 1,200 Amps	2*	Proximity to Transformer Power Source Presumed
Operating 13.8 KV Disconnects with Doors Closed	13.8 KV	NA	2	Booster Brentford or RF Anode Power Supplies are Examples
Secondary Panelboards PHP LP	480/277 VAC	100 to 225 Amps	1	More Than 200 Feet from Panelboard Sourcing Power
Work in Lighting Panelboards (LP) including LOTO Verification	480/277 VAC	100 Amps	1	More Than 100 Feet from Secondary Panelboard Sourcing Power
Work in Utility Panelboards including LOTO Verification	120/208 VAC 120/240 VAC	Below 350 Amps	0	Circuits Fed With Transformers Less Than 125 kVA NFPA 70E 130.3 Exception 1 Knowing Transformer KVA and %IZ, Apply Formula for Suspect Installations
Operating Circuit Breakers and Disconnect Switches with Covers On or Closed	480/277 VAC	NA	0	Requirement Direct from NFPA 70E 130.7(C)(9)
	120/208 VAC 120/240 VAC	NA	0	Requirement Direct from NFPA 70E 130.7(C)(9)

This Simplified Table for AC Power Distribution Equipment Has Been Approved by the Electrical Safety Subcommittee.
If Stated Conditions or Qualifications Are Not Met or the Circumstances of the Work Activity Appear Unique, Refer to NFPA 70E Table 130.7(C)(9) or Consult with Your D/S Electrical Coordinator.

Simplified Guidance for Electrical Work on Fermilab UTILIZATION Equipment

Diagnostic Work Including LOTO Voltage Testing Unless Otherwise Noted

Equipment	Voltage	Sourcing Branch CB	Hazard/Risk Category	Conditions or Qualifications
Power Supplies	480 VAC	Various	Can Range from 1 to 3	Ask Your Department for an Assessment. Take Advantage of Installed Panel Meters for LOTO Verification.
Various Equipment	480 VAC or 480/277 VAC	100 to Less than 400 Amps	2	Distance from Primary Panelboards and Feed Conductors Limit Available Fault Currents
Various Equipment	480 VAC or 480/277 VAC	Less Than 100 Amps	1	Distance from Primary Panelboards and Feed Conductors Limit Available Fault Currents
Sump Pump Controllers Motor Controllers HVAC Equipment	480 VAC	60 Amps and Below	1	Distance from Primary Panelboards and Feed Conductors Limit Available Fault Currents
Ballasts and Light Fixtures	277 VAC	30 Amps and Below	0	Typical Lighting Ballast
Power Supplies	208 VAC	350 Amps and Below	0	Circuits Fed With Transformers Less Than 125 kVA NFPA 70E 130.3 Exception 1 Knowing Transformer KVA and %IZ, Apply Formula for Suspect Installations
Various Equipment	120/208 VAC	350 Amps and Below	0	Circuits Fed With Transformers Less Than 125 kVA NFPA 70E 130.3 Exception 1 Knowing Transformer KVA and %IZ, Apply Formula for Suspect Installations
Various Equipment	120 VAC	30 Amps and Below	0	Circuits Fed With Transformers Less Than 125 kVA NFPA 70E 130.3 Exception 1 Knowing Transformer KVA and %IZ, Apply Formula for Suspect Installations

This Simplified Table for Utilization Equipment Has Been Approved by the Electrical Safety Subcommittee.
If Stated Conditions or Qualifications Are Not Met or the Circumstances of the Work Activity Appear Unique, Refer to NFPA 70E Table 130.7(C)(9) or Consult with Your D/S Electrical Coordinator.

PPE in Fermilab Stockroom

- Safety Glasses
- 8.2 cal/cm2 FR Coveralls
- 10 Cal Face Shields with Hard Hat
- 10 Cal Double-Layer Switching Hoods
- Replacement Face Shields
- Leather Gloves
- No Insulating Gloves
  (See ESH&Q Section)

General Comments About Arc-Flash PPE

- Always be Sure to Wear PPE that Satisfies the Minimum ATPV Required
- Do NOT wear any non-FR clothing over your arc-flash PPE (non-melting OK underneath).
- OK to Wear Higher Rated Clothing and Face Shields, but Safety Can be Compromised
- Sometimes too much PPE or Duration of Use can Introduce New Hazards

Wear and Care of PPE

- Wear Cotton
- Avoid Scratching Eye Protection
- No Bleach or Fabric Softeners
- Wear Clothing Loose, rather than Tight
- Layering Increases Protection
- Dry is Better than Wet

Safe Work Practices

- Covered in Articles 130.4 - 130.6
  - Be Alert
  - Use Common Sense
  - No blind reaching. If view is obstructed, you cannot work on live parts. Sharp edges may cut your PPE
  - Illumination must be provided. The light-restricting properties of arc-flash face shields or hoods may require supplemental lighting.
  - Conductive articles (jewelry, clothing) shall not be worn

Safe Work Practices (SWP)

- Plan for Emergencies
  - Part of daily work planning and Hazard Analysis
  - Know how to de-energize Quickly or
  - Be prepared to pull employee free with an Insulated Rescue Hook
  - Have the Means Available to Contact Emergency Personnel - Dial 3131
  - Know CPR & Where AED's are located
    - Contact your supervisor CPR for training
- See FESHM 9180 for additional SWPs

Electrical Hazard Analysis / Work Permit (From FESHM 9110 and 9120)

- See Provided Handout of the EHAWP
- Essentially a Hazard Analysis with Electrical Specifics
- Now to be Used for AC Power Distribution Equipment and Electrical Utilization Equipment
- Specific Requirements for Shock and Arc-Flash Protection
- Establishes 4 Feet as the Bounded Default Flash Protection Boundary
- Available as a Word Document from the ES&H Section Web Site

Verification of De-Energization

- Most Important Step in LOTO
- Assume Energized
  - PPE, Voltage Rated Tools and Gloves
  - Establish Appropriate Boundaries
- Do not use Proximity Meters as your Primary Testing Tool (HV excepted)
- Test line-to-line, line-to-ground, and line-to-neutral if a neutral conductor is present.
- Know your Test Equipment is Working
  - Test Before and After Use

Subcontractors

- Contracts require compliance with NFPA 70E
- Time and Material Subcontractors
  - T&M Office will verify training
    - Make sure scope of work includes enough information for T&M Office to understand that training is expected
  - Make sure HA addresses electrical shock and arc- flash hazard mitigation
    - PPE, tools, and boundaries are identified
    - Emergency actions identified

Subcontractors

- Fixed Price Contract
  - Verify that workers are trained
    - Request training documentation
  - Verify the HA includes electrical shock and arc-flash hazard mitigation
    - PPE, tools, and boundaries are identified
    - Emergency actions identified

Where to get More Information

- ES&H Web Site Has Copies of Summary Guidance, the EHAWP, and ESS Determinations
- NFPA 70E and Handbook
- Electrical Safety Subcommittee
- Division/Section Electrical Coordinators
- Division Safety Officers
- Special Meetings

Electrical Coordinators

- Accelerator – Jim Ranson
- Computing – Mark Thomas
- ES&H – David Mertz
- FESS – Joe Pathiyil
- WDRS – Joe Pathiyil
- ND & PPD – Steve Chappa, J. Dwight Featherston, Tim Martin
- Technical – Miguel Nunez

The LAST Slide

- Twenty-Two Question Test
- Open Book
- Self-Scoring
- Questions Entertained During and After the Test
- Comments and Evaluation