2005 ELECTRICAL SAFETY MEETING
LAS VEGAS, NEVADA

2005 ELECTRICAL SAFETY MEETING

Monday - November 28, 2005 - Planning Meeting 1:00 – 3:00

Tuesday - November 29, 2005

8:00 – 8:15 - Introduction
8:15 – 8:30 – Welcome
8:30 – 9:00 – National Electrical Incidents and Trends (Private Industry & DOE)
9:00 – 9:30 – Energized Electrical Work Reviews – Richard DeBusk
9:30 – 9:45 – Break
9:45 – 10:45 – SLAC Electrical Accident – Perry Anthony
10:45– 11:15 - How to Form a Bounding Arc Flash Study for Your Site – Michelle Murphy
11:15 – 12:45 - Lunch
12:45 – 1:45 – Third-Party Certification of Unevaluated Equipment – Chuck Mello
1:45 – 2:30 – 2005 NEC Changes Commercial and Industrial – James Stallcup
2:30 – 2:45 – Break
2:45 – 4:00 – 2005 NEC Changes Commercial and Industrial – James Stallcup

Wednesday - November 30, 2005

8:00 – 9:00 – Electrical Safety During Excavations and Penetrations – James Luhring
9:00 – 10:00 – High-Voltage Energy Control (Clearance Procedures) Stats and Errors – Bill Marsh
10:00 – 10:15 - Break
10:15 – 11:45 – Recurring Electrical Events – Lloyd Gordon
10:45 – 11:15 – Ground Penetrating Radar – Ben Cleary
11:15 – 12:45 - Lunch
12:45 – 1:30 – NFPA 70E, PPE and Upcoming 1910.269 Changes – Hugh Hoagland
1:30 – 1:45 - Break
1:45 – 3:00 - NFPA 70E, PPE and Upcoming 1910.269 Changes - Hugh Hoagland
3:00 – 4:00 – Moving Forward with Arc Flash PPE – Part of the Solution – Tom Neal

Thursday - December 1, 2005

8:00 – 10:00 – NFPA 70-E Class (Chapter 1) – Bobby Gray
10:00 - 10:15 – Break
10:15 – 11:30 - NFPA 70-E Class (Chapter 2) – Keith Schuh
11:30 – 12:30 – Lunch
12:30 – 2:30 - NFPA 70-E Class (Chapter 2& 3) Keith Schuh
2:30 – 2:45 – Break
2:45 – 4:45 - NFPA 70-E (Class Chapter 3) – Keith Schuh & (Chapter 4) – Bryan Drennan
4:45 – 5:00 - Closing

National Electrical Incidents and Trends

ELECTRICAL FATALITIES

Electrical Fatalities

- The first recorded electrical fatality occurred in 1879.
  - A carpenter in Lyons France contacted a 250 volt AC generator
- The first recorded electrical fatality in the United States occurred in 1881.
  - A demonstration of an electrical generator of 250 volts resulted in a person being electrocuted in Buffalo, NY

Electrical Burns

- Within the United States electrical burns account for 6.5% of all admissions to burn units.
- Of those admitted to burn units approximately 1,000 fatalities occur each year.
  - Most are occupationally related.

Electrical Energy

- India
  - **Almost 12 people die due to electrocution every day (Source -NCRB)**
  - **42 % of total fires occur due to electrical sources (Source -OISD)**
  - **8% deaths that occur in factories are due to electricity**

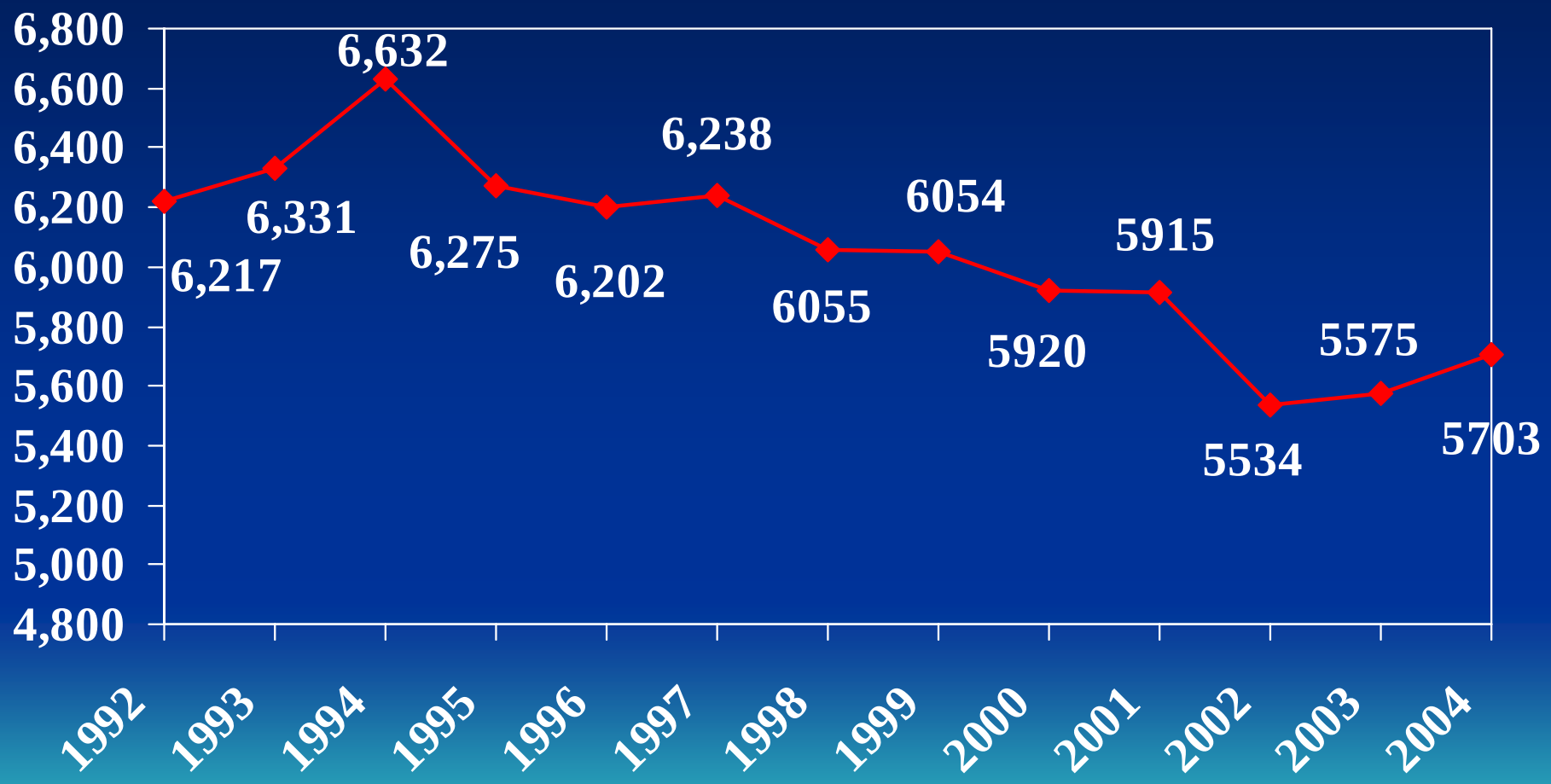
Electrical Energy

- United States
  - **25% of all fires occur due to electricity**
  - **Average of 454 deaths from job related electrical accidents per year (NIOSH)**
  - **Electrocution - the fourth leading cause of death (NIOSH)**

What Voltages are most people being Killed with Electricity?

- Most Fatalities are with High Voltage
  - Four times as many fatalities occur with high voltage as with any other voltage
    - 7200 volts has the highest number of fatalities
- Most low voltage Fatalities
  - 110- 120 volts has the highest number of fatalities

TOTAL FATALITIES BY YEAR



Electrocutions By Year

Percent of Total Fatalities By Year

Total Electrical Fatalities

- What Months are the Highest for Electrical Fatalities?
  - August
  - June
  - July

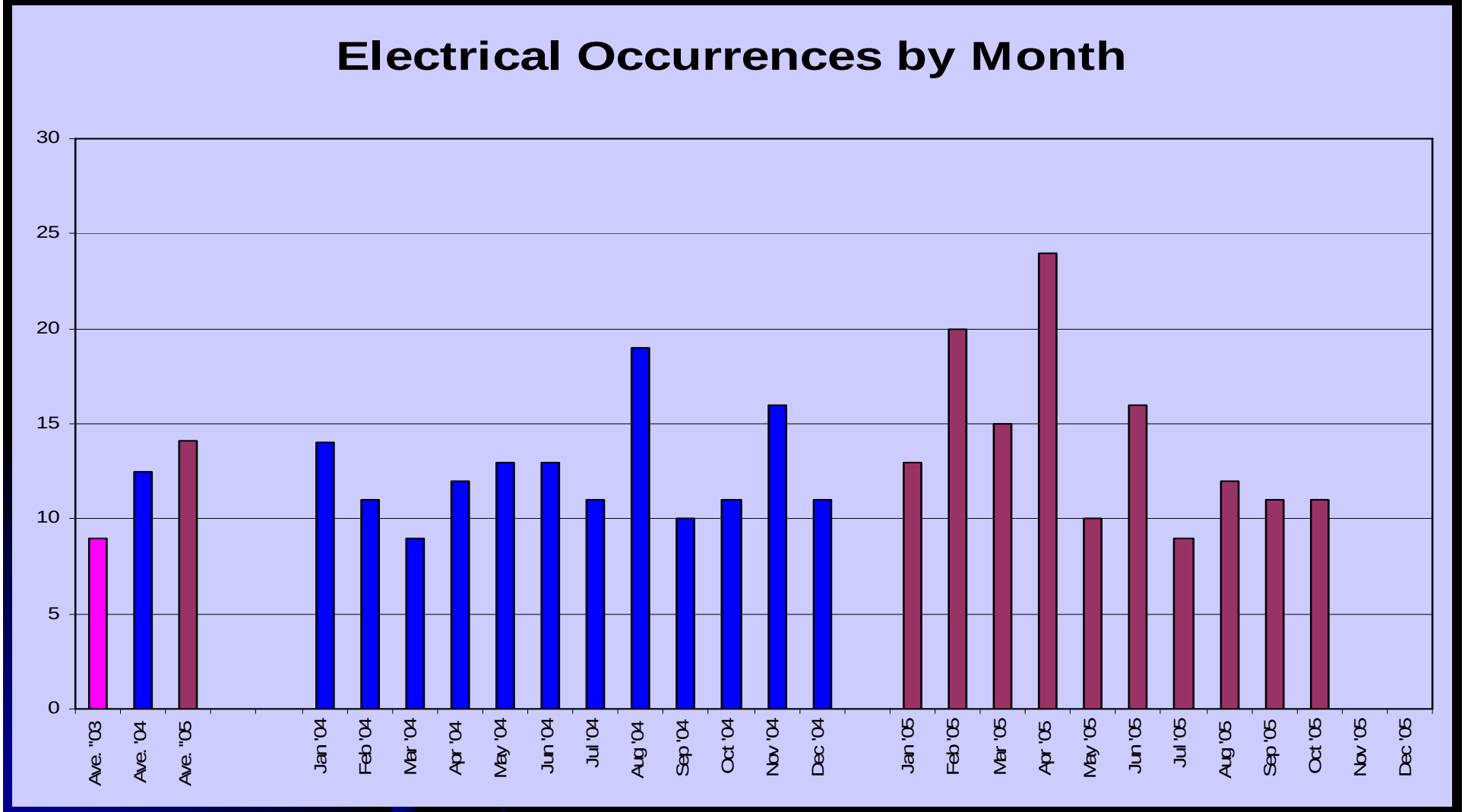
Electrical Safety In DOE

- **Electrical safety comprises the largest percentage of DOE's near miss occurrences.**

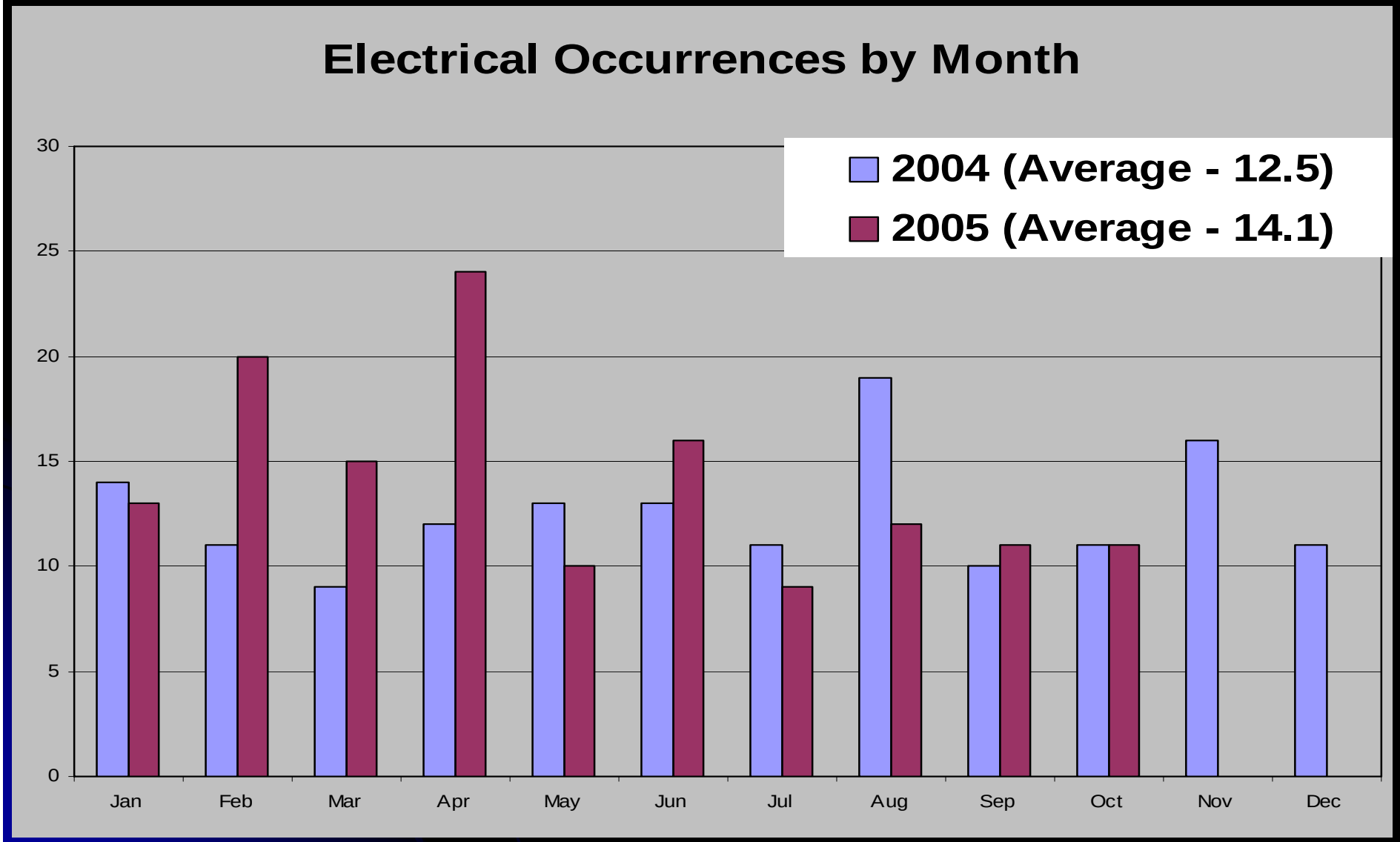
- **Recurring causes for electrical safety occurrences:**
  - **poor planning, hazard identification & training**
  - **LO/TO violations, shortcuts & lack of verification**
  - **failure to perform safe energy checks & stop work**

- **Poor conduct of operations cited as an issue in almost half of the electrical safety occurrences.**

Increasing Rate of Electrical Safety Occurrences



Increasing Rate of Electrical Safety Occurrences



Operating Experience Summary

- November 16, 2005
  - Three Electrical Events
    - Dump Truck contacts Electrical Lines (Hanford)
      - June 2, 2005 (Moab Site Project)
      - August 30, 2004 (Sandia National Lab.)
      - June 23, 2004 (Rocky Flats)
      - June 12, 2003 (Hanford)

Operating Experience Summary

- November 16, 2005
  - Three Electrical Events
    - Modifying Wiring (Hanford)

Operating Experience Summary

- November 16, 2005
  - Three Electrical Events
    - Electrical Near Miss (Hanford)
    - September 28, 2005 (Argonne)

Increasing Severity of Electrical Occurrences

- **WAPA lineman fatality and SLAC arc blast injury in 2004 were first Type A electrical safety accidents since 1997.**
  - **Approximately 50% of all Type A Accidents are Electrical**

- **Rate of electrical shocks is increasing:**
  - **Averaged 17.5 shocks per year in 2002 & 2003**
  - **25 shocks in 2004**
  - **33+ shocks in 2005 (At this rate, the number will be 40+)**

- **71% of electrical safety occurrences in 2005 were categorized as near misses.**

Electrical Occurrences by Contractors

Electrical Safety Occurrences, 2005 (thru 3rd week in July)

Los Alamos National Laboratory	19	Bechtel Nevada	2
Sandia National Laboratories	12	Brookhaven National Laboratory	2
Westinghouse Savannah River Co.	9	FERMI National Accelerator Lab.	2
Project Hanford Management Co.	7	Kaiser-Hill Company, L.L.C.	2
BWXT PANTEX	6	Oak Ridge National Laboratory	2
Bechtel BWXT Idaho, LLC.	5	Battelle Energy Alliance, LLC	1
Bechtel National River Project	5	Bechtel Hanford Incorporated	1
Argonne National Laboratory - East	4	Bechtel Jacobs Company, LLC	1
BNFL INC.	3	Babcock and Wilcox of Ohio, Inc.	1
Fluor Fernald Inc.	3	BWXT Y12	1
Lawrence Berkeley National Lab	3	CH2M HILL Hanford Group, Inc.	1
Lawrence Livermore National Lab.	3	CH2M*WG Idaho, LLC	1
Ames Laboratory	2	Idaho Operations	1

DOE Electrical Safety Campaign

- **Deputy Secretary initiated Electrical Safety Campaign:**
  - DOE-wide videoconference on April 20, 2004
  - Designated May 2004 as Electrical Safety Month

- **31 sites developed electrical safety improvement plans.**

- **HQ organizations tracked and analyzed occurrences.**

- **DOE *Electrical Safety Handbook* revised in December 2004.**

- **Despite campaign, rate of electrical occurrences increased.**

- **Secretary's April 12, 2005 letter: "We must do better."**

Energized Electrical Work Reviews

Office of Science
U.S. Department of Energy

Energized Electrical Work Reviews

Presented by:
Michael Kovacic, TMK and Associates
Electrical Safety Consultant
Richard DeBusk, Safety Manager
Berkeley National Laboratory

Disclaimer – This presentation reflects the opinion
of the authors and is not endorsed by the Department of Energy

Energized Electrical Work Reviews

Background and Purpose

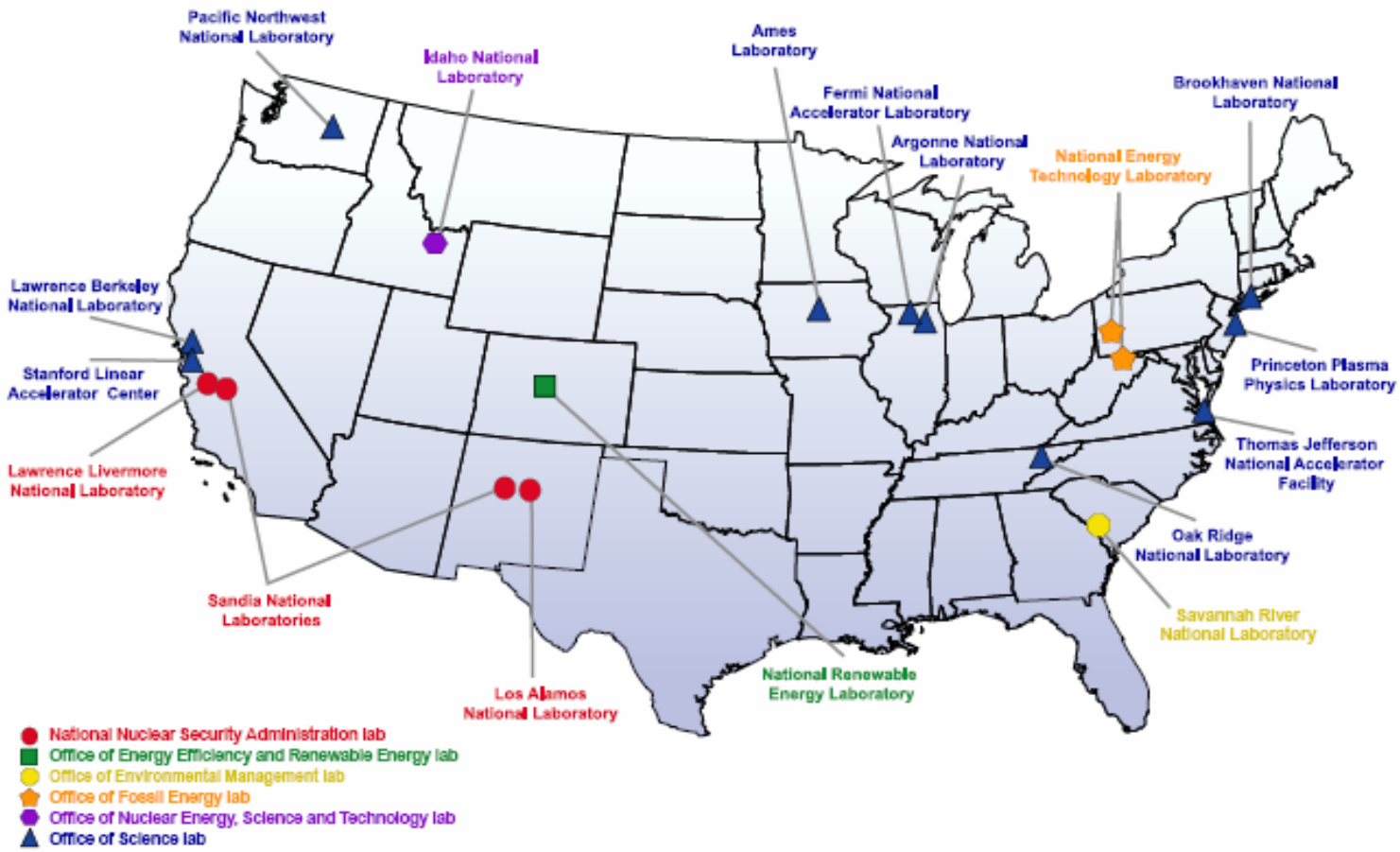
- Electrical safety accident at Stanford Linear Accelerator (SLAC) in October 2004
- Accident investigation identified weaknesses in the electrical safety program
- DOE Office of Science (DOE-OS) Laboratories implemented improvements in their electrical safety programs
- Early 2005, DOE-OS initiated assessments of planning and performance of energized electrical work to evaluate programs and improvements since SLAC accident

Energized Electrical Work Reviews

Nine of the ten Office of Science Labs were evaluated

- Berkeley National Lab
- Brookhaven National Lab
- Pacific Northwest National Lab
- Argonne National Lab
- Fermi National Accelerator Lab
- Ames Lab
- Princeton Plasma Physics Lab
- Thomas Jefferson National Lab
- Oak Ridge National Lab

Department of Energy National Laboratories



Energized Electrical Work Reviews

Assessment Process

- Pre-review of ES&H documents
- Interviews with staff, subcontractors, and management
- Review of documents on site
- Work and training observations
- Daily meetings with Lab and Site Office Management Representatives
- Report of findings

Energized Electrical Work Reviews

Topics Reviewed

- Energized work process and programs
- Implementation of those programs
- Training for NFPA 70E & energized work
- Subcontractors
- Oversight methods

Energized Electrical Work Reviews

Overall Finding

- All nine labs have achieved some level of NFPA 70E compliance, ranging from poor (infant program) to good (well on the way)
- All nine labs need to continue working towards complete implementation and enforcement of electrical safe work practices

Energized Electrical Work Reviews

Common Issues Across Labs – Programs

- Inconsistent and incomplete programs, policies and procedures were found across the laboratories
  - **More importantly across divisions *within* laboratories**
  - Programs and contracts did not specify NFPA 70E as a required compliance document
  - Use of multiple energized work permits within laboratories
  - Errors in training, documentation and procedures

Energized Electrical Work Reviews

Common Issues Across Labs – Programs

- Energized work activities and permits did not meet NFPA 70E minimum requirements.
  - Testing and troubleshooting not treated as energized work
  - Manipulative energized work as high as 250V allowed without a permit
  - Specific and appropriate justifications were not made on approved energized work permits
    - » Poor detail for type of work, PPE, etc.
    - » “Cannot be shut down”

Energized Electrical Work Reviews

Common Issues Across Labs – Programs

- Poor or nonexistent charters for Electrical Safety Committees (ESCs).
  - Poor implementation of existing charters
- No single Subject Matter Expert (SME) or Authority Having Jurisdiction (AHJ) for coordination and enforcement of safety programs and procedures
  - Roles and responsibilities of those designated poorly defined

Energized Electrical Work Reviews

Common Issues Across Labs – Programs

- Flash hazard analysis (FHA) not performed, or not performed by qualified persons
- No specific requirements for fire-rated (FR) or 100% natural fiber clothing for employees and subcontractors

Energized Electrical Work Reviews

Common Issues Across Labs – Implementation

- NFPA 70E programs & procedures not implemented
  - Poor implementation of work permits and energized work policies
  - PPE (and PPE programs) not implemented
- Poor implementation of LOTO programs
  - Improper lock application – 1 person, 1 lock
  - Use of non-contact voltage sensor for zero energy verification
  - Poor Subcontractor compliance
  - Little or no auditing (required by OSHA)

Energized Electrical Work Reviews

Common Issues Across Labs – Implementation

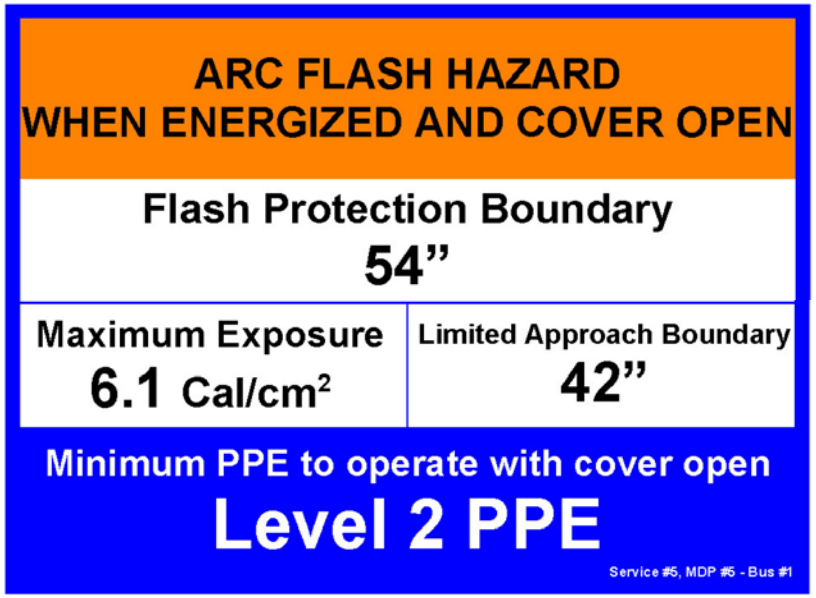
- Implementation of appropriate PPE and voltage-rated tools poor at some laboratories
  - Little or no training on proper use and application
  - No or inadequate testing
  - Improper storage
  - Improper care

- Little or no electrical system documentation (i.e. one-line diagrams)

Energized Electrical Work Reviews

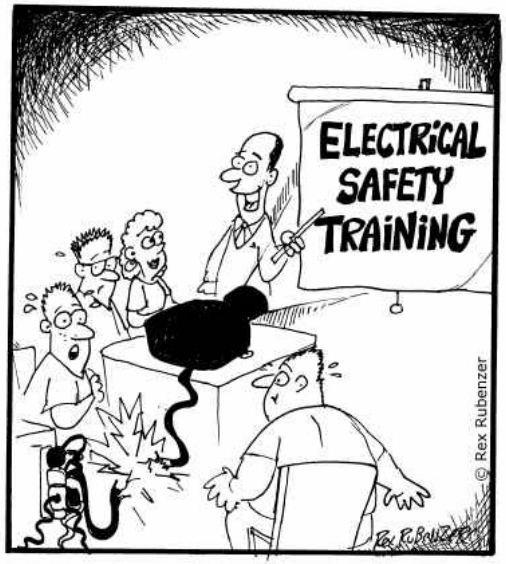
Common Issues Across Labs – Implementation

- Poor or inadequate labeling of equipment for shock and flash hazards
- Poor awareness by unqualified persons and enforcement of work zone requirements
- Little or no action plan for future implementation of NFPA 70E requirements



Energized Electrical Work Reviews

Common Issues Across Labs – Training



- Training programs not centralized, current, adequate or appropriate to address NFPA 70E issues, including for unqualified persons
  - i.e., little or no explanation of PPE purpose, use, storage and care
  - Lack of understanding of approach boundaries, or where to obtain information
- Training not consistent with program and policy changes

Energized Electrical Work Reviews

Common Issues Across Labs – Training

- Refresher training often not specified
- CPR or First Aid training not universally required
- Persons designated as SME's (Electrical Safety or Engineers) and AHJ's had little, no, or poor training

Energized Electrical Work Reviews

Common Issues Across Labs – Subcontractors

- Little or no training offered to subcontractors
- Training requirements for subcontractors not centralized, evaluated or verified
- Stop work authority often not understood or emphasized
- NFPA 70E requirements not adequately promulgated to subcontractors (not explicitly in contracts)
- PPE requirements not explained or enforced
- Little or no ownership of subcontractor safety

Energized Electrical Work Reviews

Recommendations specific to each facility were provided to assist in developing corrective action programs

Safe electrical work practices save lives!

Energized Electrical Work Reviews

Noteworthy Practices

- Engineering controls and specifications that allow workers to operate equipment with a reduced hazard of personnel injury in the event of an arc-flash/blast event. (*Princeton, Fermi, Oak Ridge, Berkeley*)
- Development of a JHA process (*Oak Ridge*)
- Lockout/Tagout solutions with ease-of-use that encourage everyone to follow LOTO procedures (*Argonne*)

Energized Electrical Work Reviews

Noteworthy Practices

- Excellent flow-down of safety requirements (*PNNL*)
- Superb "Lessons Learned" program (*PNNL*)
- Superb one-line diagram and electrical system documentation programs (*Princeton, Oak Ridge*)
- In-house subcontractor training programs for "qualified" workers and subcontractor orientation programs (*Princeton, Argonne. Princeton's "open-door" training policy was also cited as noteworthy.*)

Energized Electrical Work Reviews

Noteworthy Practices

- Behavior-based safety program which encourages workers to higher levels of safety (*Berkeley*)

SLAC Electrical Accident

2005 DOE Electrical Safety Meeting
Nov. 29 – Dec. 1, 2005

SLAC Electrical Accident Review

Dr. Perry L Anthony
Electrical Safety Officer
SLAC, Stanford University

Overview

- 10/11/04 Electrical Accident
  - Setting the stage
  - Activities leading to the accident
  - Accident event
- Response to the accident
  - SLAC responses
  - Type A Investigation
    - Causes
    - Judgments of Need
  - Follow up actions
- Additional Lessons Learned
- Summary

Setting the stage:

- Original 1960 installation
  - Old electrical equipment
  - Limited maintenance of equipment
- Deficiencies in Electrical Safety Program identified
  - Jan. 2004 OSHA audit found that procedures were not being followed
  - Jan. 2004 OSHA audit identified non-compliant installation methods and unsafe equipment in use
  - Feb. 2004 Accelerator Safety Audit identified unsafe operations regarding electrical equipment
  - July 2004 Electrical Safety Action Plan identified deficiencies in SLAC's energized work permit program (program not being followed)

Setting the Stage (continued)

- Machine recently brought up after summer maintenance down time
  - Pressure to keep the machine running
  - Multiple activities ongoing, limited coordination
  - Subcontractor hired to do small electrical jobs

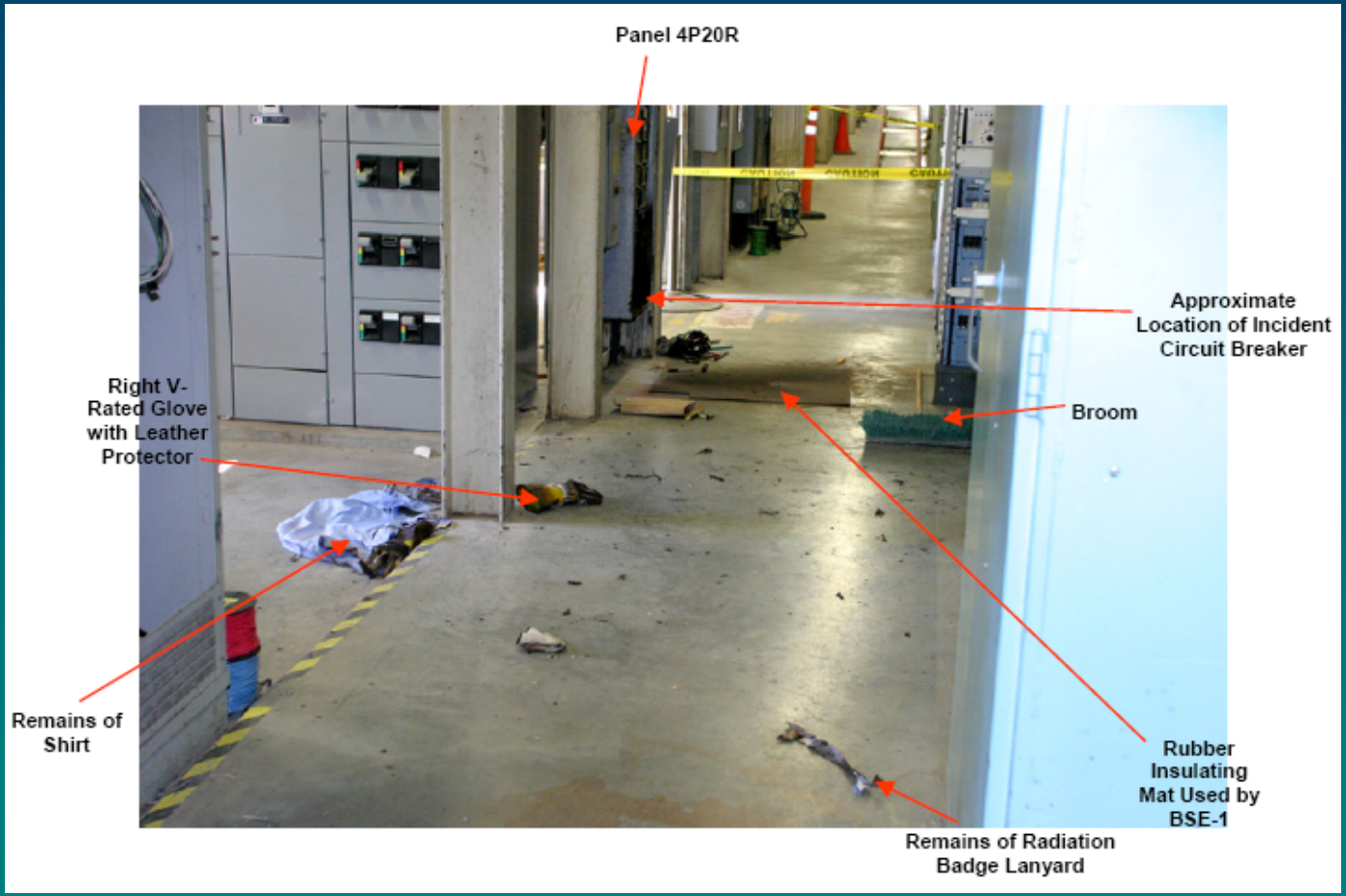
Activities leading up to the event

- Improper wiring method to a breaker being corrected:
  - During the down, it was discovered that several heaters had been wired to one breaker using an inappropriate method
  - Improper wiring had been removed
- The task, Subcontractor to:
  - Install a new breaker in the existing panel
  - Install heater wiring to the new breaker

The Accident

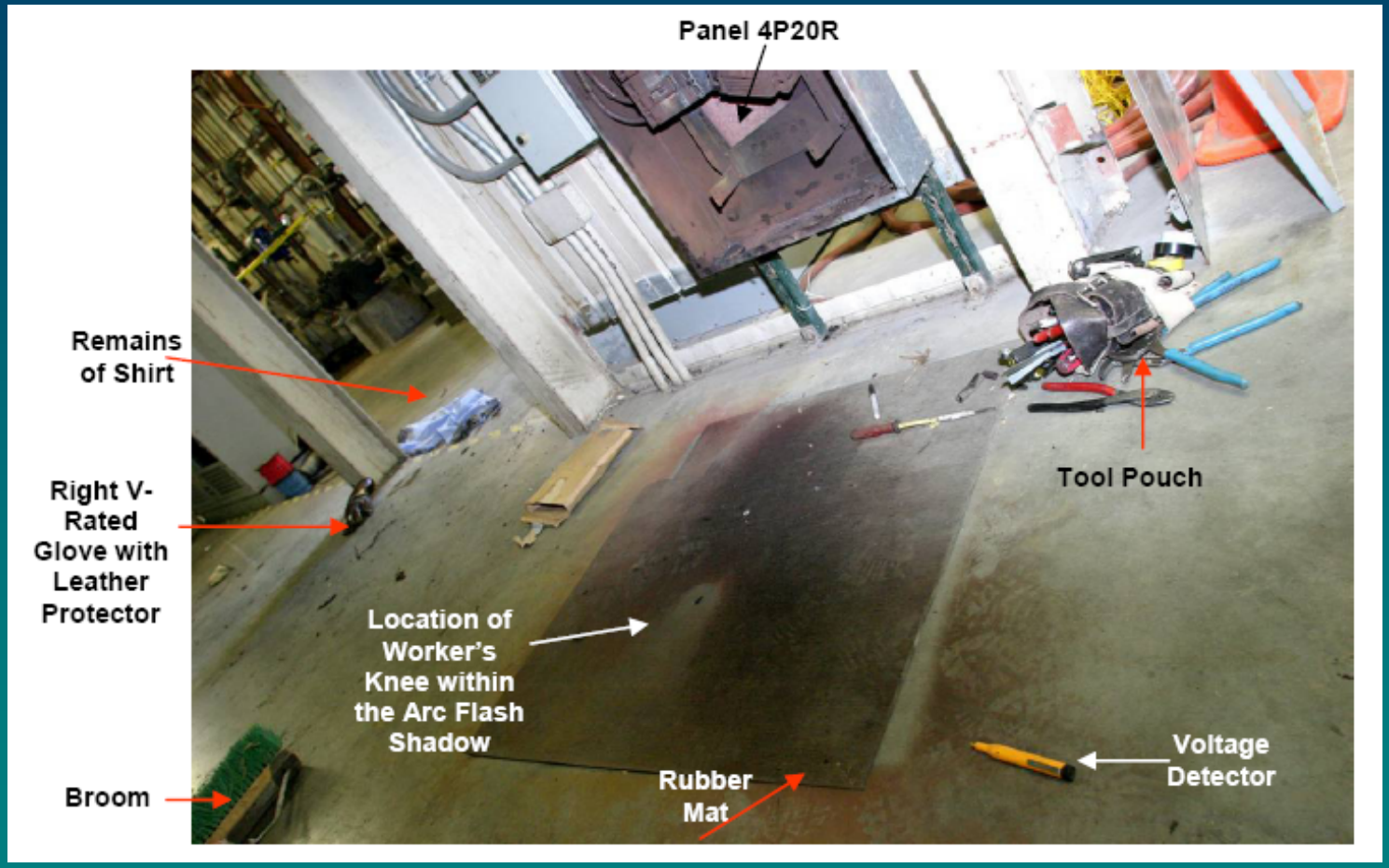
- Installation of the new breaker
  - Work being done with panel energized, no permit
  - Work being done without proper PPE
  - Work being done without proper safety watch
- While installing the breaker, an arc flash developed
  - Connection to “C” and “B” phases had been made
  - Connection to “A” phase being made when arc flash developed
  - Note, mechanical mounting screws not used to hold breaker

Scene immediately after the accident

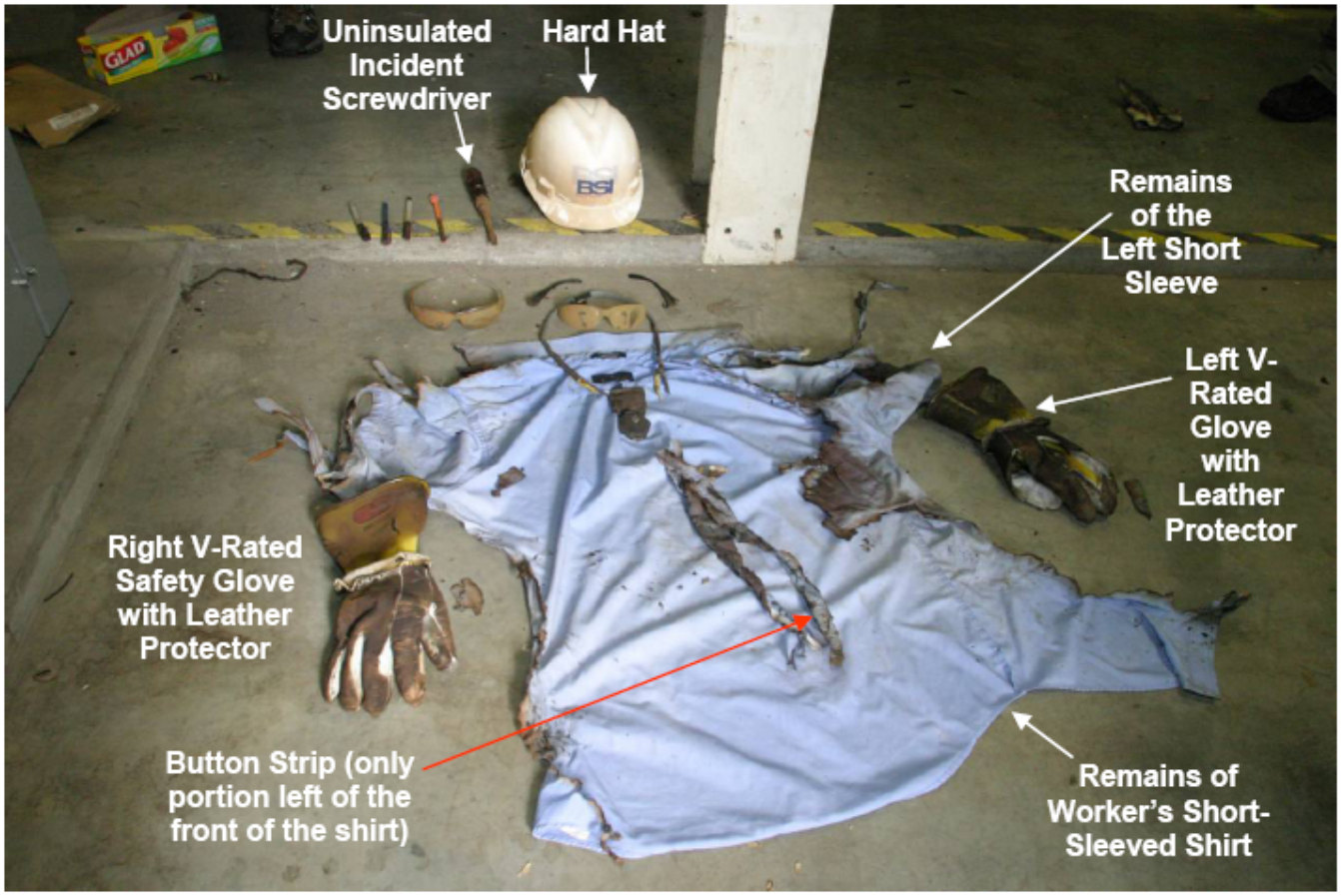


Electrical Panel after the arc flash

Floor near panel, note "shadow" of knee



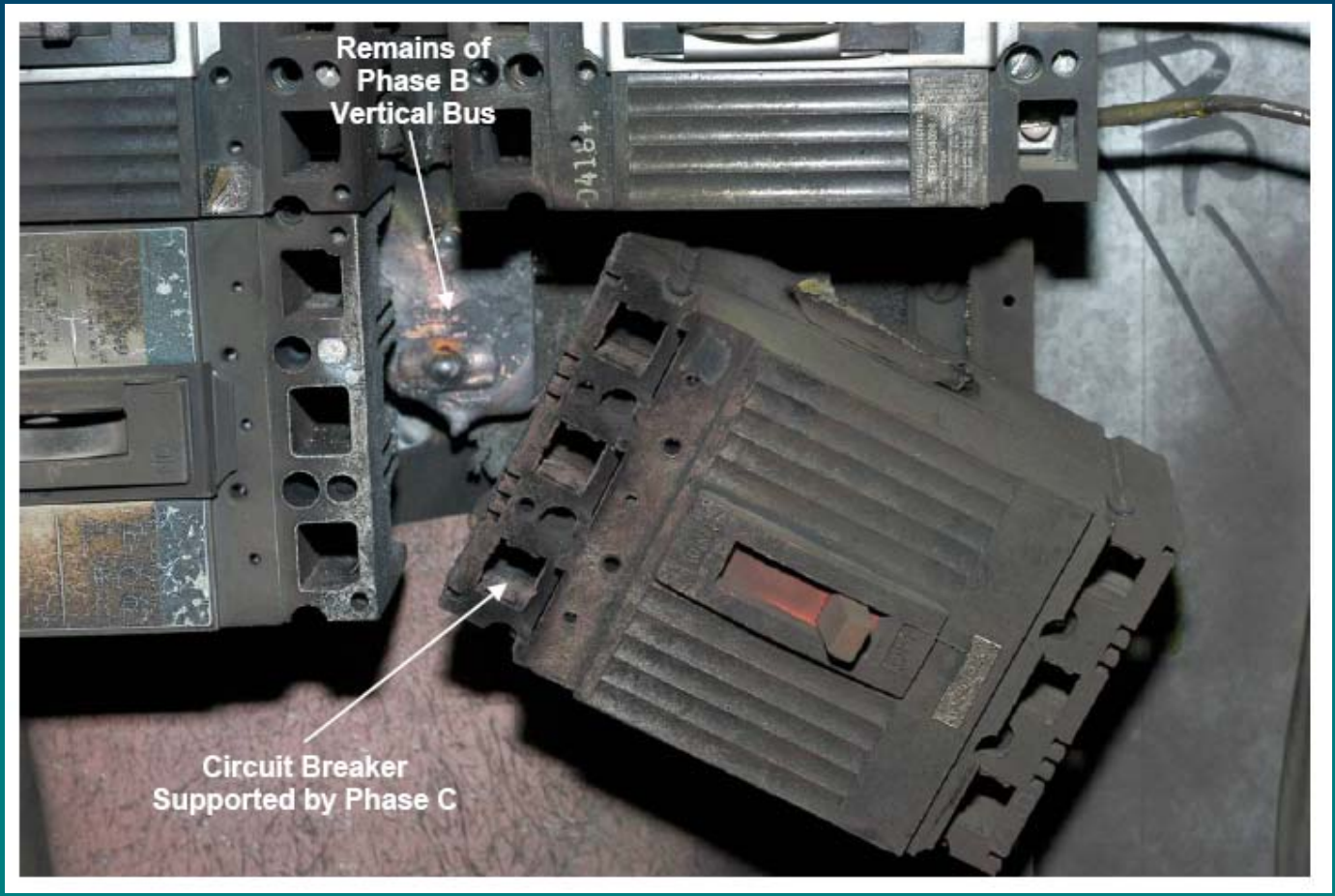
Worker equipment after accident



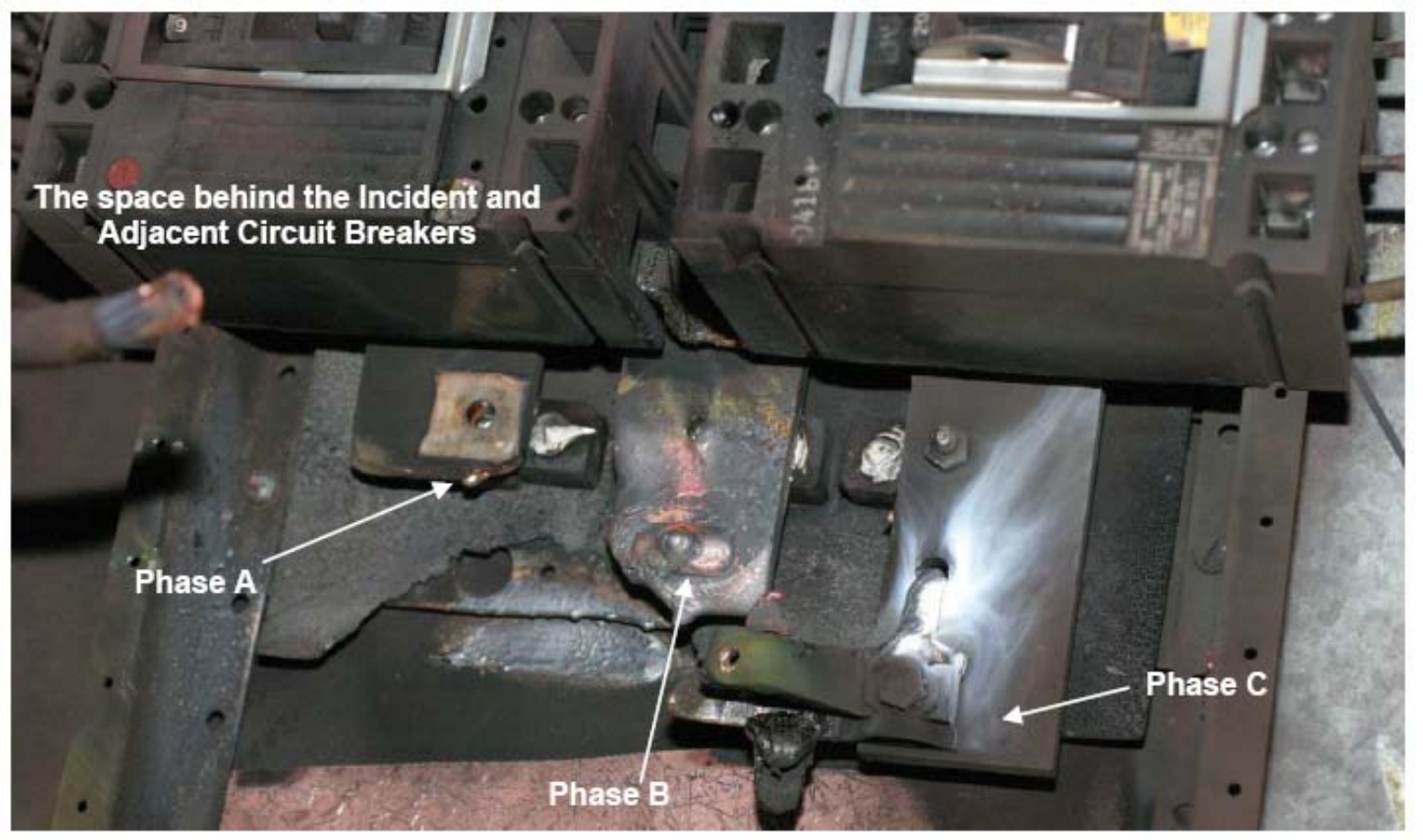
Shirt label

Detail of screwdriver

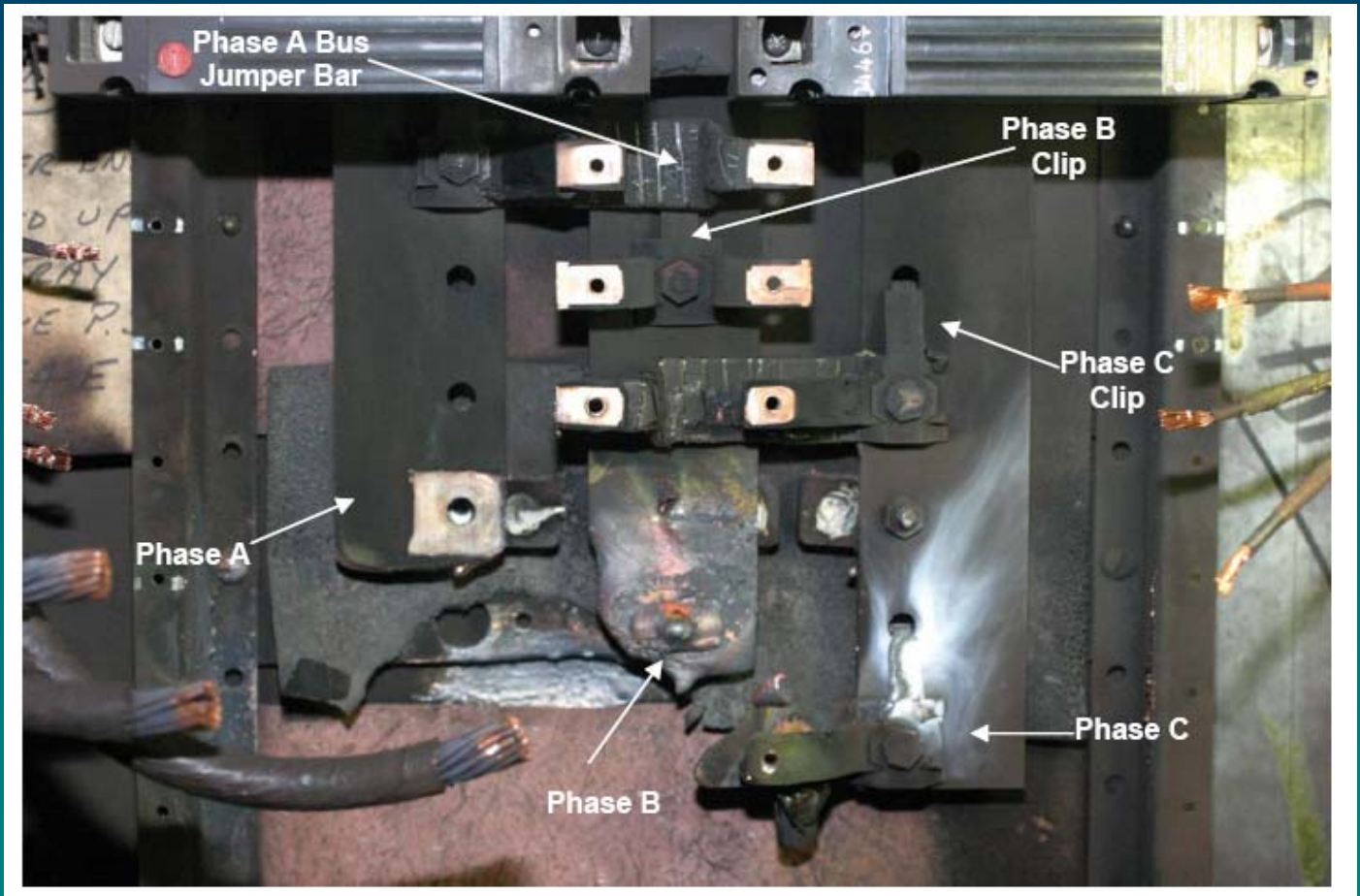
Detail of panel where arc developed



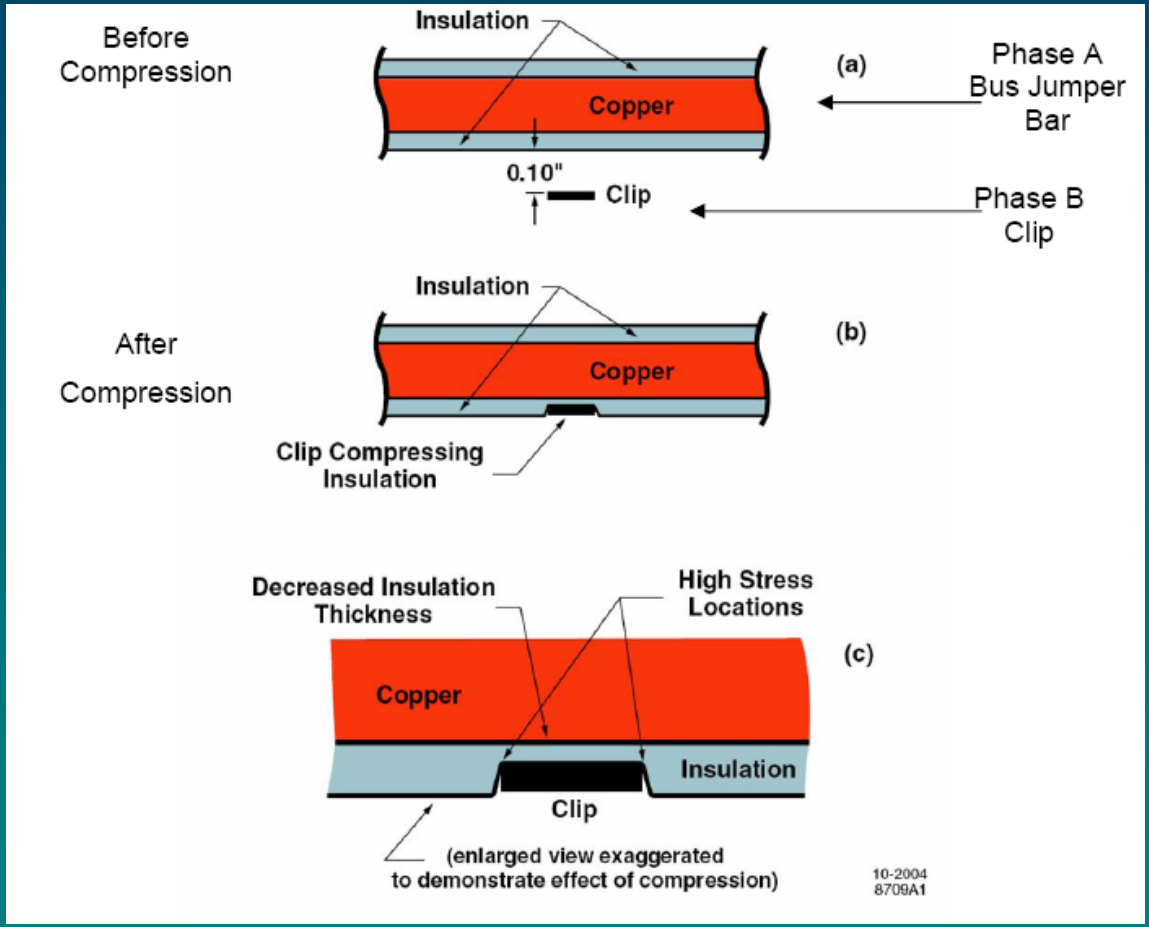
Detail of phase busses



Detail of phase busses showing "undamaged" section



Cartoon showing supposed failure mode



What happened

- Phase to Phase fault developed
- Copper bus elements vaporized
  - Copper expands over 67,000 times in the transition from solid to vapor
  - Explosive expansion of copper
  - Extremely high temperature
- Explosive force knocks two workers down
- High temperatures ignite cotton/polyester clothing of closest worker

Injuries to workers

- Electrician working on panel suffered 2nd and 3rd degree burns to 60% of his body including face
  - Hands protect by gloves
  - eyes protected by safety glasses
- Safety watch suffered sore back from impact of blast

SLAC Response

- On the day of the accident all electrical work halted
- The next day all activities in all work groups halted.
  - Included shutting down all accelerator operations
  - Work groups directed to review job descriptions, routine job hazards, mitigation plans, and training requirements
- All employees directed to take basic electrical safety training
- Return to work plan developed requiring each employee making a personal commitment to safety in the work place, ensure all required training for job up to date, ensuring job hazard analysis and mitigation plan for routine activities complete and up to date
- Accelerator operations discontinued pending completing of Type A investigation

Type A Investigation Causal Factors

- Direct cause
  - subcontractor attempting to install a breaker in an energized panel violating OSHA, DOE, SLAC, and subcontractor work practices, increasing the probability of an arc flash and the severity of the consequences.

Causal Factors (continued)

- Root Cause
  - Neither SLAC nor the subcontractor fulfilled their responsibilities under OSHA and DOE's ISM policies and procedures to maintain a workplace free of recognized electrical hazards (such as arc flash).

Causal Factors (continued)

- Contributing Causes
  - Subcontractor working on energized panel without sufficient justification
  - Safety watch did not exercise stop work authority when work being done without proper PPE
  - SLAC field coordinator directed the work without ensuring subcontractor understood the hazard and controls
  - Subcontractor oversight failure

Causal Factors (continued)

- Contributing Causes (continued)
  - SLAC safety oversight failure
  - DOE SSO safety oversight failure
  - DOE SSO and SLAC failure to apply lessons learned from numerous sources to improve electrical work practices
  - DOE SSO did not direct SLAC to take immediate, effective corrective actions in response to the July Electrical Safety Action Plan

Failure to follow ISMS

- The Type-A Board concluded:

  "The events that occurred on October 11, 2004, violated all of the Integrated Safety Management Guiding Principles and Core Functions"

Judgments of Need

- Twelve Judgments of Need developed
  - 8 directed at SLAC to improve programs, policies, and procedures
  - 4 directed at the DOE Stanford Site Office to improve oversight of the site and determine proper SSO staffing levels to carry out responsibilities

Judgments of Need Detail

- SLAC needs to enforce applicable OSHA standards and all sections of NFPA 70E.
- SLAC needs to ensure that SLAC's employees who work on or near exposed energized electrical conductors are trained on the implementation of electrical safety-related work practices.
- SLAC needs to verify that subcontractor employees who work on or near exposed energized electrical conductors are trained on the implementation of electrical safety-related work practices.
- SLAC and subcontractor supervisors and managers need to receive the same training as the workers.

Judgments of Need Detail

- SLAC needs to revise the contracting process to ensure that subcontractor workers can protect themselves from SLAC-related hazards in the same way that SLAC workers protect themselves. The terms and conditions of subcontracts should not encourage workers to take risks.
- The SLAC Director needs to balance the priorities between operations and safety to:
  - Evaluate whether it is appropriate for the Technical Division to be responsible for scheduling LINAC operations and safely maintaining the LINAC infrastructure.
  - Achieve effective, proactive ES&H Division involvement.
  - Encourage SE&M employees to work safely and to exercise their stop work authority.

Judgments of Need Detail

- SLAC needs to develop and implement safety oversight programs designed to identify deficient electrical work practices and correct them in a timely manner that achieves continuous improvement.
- The SLAC Director needs to ensure that employees at all levels fully understand that concern for mission accomplishment does not outweigh the need for safe operations.
- SSO needs to exercise the existing SLAC contract clauses, terms, and conditions that hold SLAC accountable for unacceptable safety performance, including stop work authority or the embargo of funds until SLAC demonstrates satisfactory electrical safety performance.

Judgments of Need Detail

- SSO needs to ensure that legal interpretations by SLAC to establish each employer's worker protection responsibilities are consistent with OSHA's interpretations on multiemployer workplaces.
- SSO needs to develop and implement safety oversight programs designed to identify deficient electrical work practices and correct them in a timely manner that achieves continuous improvement.
- SSO needs to do a workload study to determine the resource level and skills mix necessary to fulfill their safety responsibilities.

Follow up actions

- SLAC developed 29 corrective actions to address the 8 Judgments of Need
- Electrical Safety Officer (ESO) appointed to oversee implementation of the Electrical Safety Action Plan and enhancements of SLAC's Electrical Safety Program mandated by the Judgments of Need

Follow up actions

- SLAC committed itself to provide full resources to the ESO to address all issues raised in the July 2004 Electrical Safety Action Plan, including:
  - New procedures to implement NFAP-70E work practices into SLAC policies and procedures
  - Revamping electrical safety training to ensure all employees have training appropriate to their jobs
  - Establishing an Electrical Equipment Inspection Program to evaluate and accept/reject all non-NRTL evaluated electrical equipment. Two notable results:
    - Equipment inspected under SLAC's program has been accepted for use at Lockheed without requiring inspection under their program
    - Wiener Plein & Bau modified their equipment to meet SLAC EEIP requirements (VME crates).

Follow up actions

- Electrical Safety Support Group (under the ESO) established to provide a resource to the line to evaluate and develop controls for workplace electrical hazards and comply with Electrical Safety related requirements
- Established a phased effort to validate workgroup compliance with ISMS and safety policies and procedures for accelerator startup:
  - SSRL validated and returned to operations in Jan. 2005
  - BaBar/PEPII/LINAC validated and returned to operations in Mar. 2005

Additional Lessons Learned

- Roles and Responsibilities need to be clearly defined including Ownership for facility infrastructure
  - The operators of a facility need to feel ownership for all aspects of that facility to ensure maintenance a safe workplace
- Importance of Configuration Management
  - Numerous examples of breakers not rated for the available fault current were discovered
  - Many electrical installations had unacceptably high arc hazard ratings (some in excess of category 4)

Summary

- Supervisors need training to understand the hazards and control of those hazards that workers they supervise may face.
- Subcontractor supervisors need to understand the hazards and their controls associated with a task to properly evaluate subcontractor work plans.
- Management needs to properly balance the priorities of operations and worker safety.
- Effective self assessment processes are needed to ensure compliance and continued improvement in work place safety practices.
- Effective Configuration Management processes are needed to ensure safe facility design and maintenance.

How to Form a Bounding Arc Flash Study for Your Site

How to Form a Bounding Arc Flash Study for Your Site

Michelle Murphy (Palizzi)
Bechtel Nevada
B.S.E.E, Virginia Tech

Sunil Kabra, P.E.
Bechtel Power
M.S.E.E, Virginia Tech

What is an Arc Flash Hazard?

Introduction

Background

- Methods for quantifying this type of hazard have not been available until recently
- NFPA 70E – Default tables
- IEEE 1584 – Analysis of each device

Applications of a Bounding Study

Arc Flash *Bounding* Study?

The overall method for developing a bounding study for a site is to devise a comprehensive list of devices that envelop a range of clearing and trip times for the site and to consider these devices against an array of input data, such as short circuit levels, voltage levels and protective device settings.

Methodology & Assumptions:

Comprehensive list of protective devices

50? 100? 1,000?

Use good engineering judgment

Goal is to envelop the types, manufacturers and sizes

Assume they work properly

Time-current characteristic curves

Device settings: worst-case is max

The device, in the end, is upstream

Methodology & Assumptions:
Protective Device Settings

- **Molded Case Circuit Breakers (MCCB) up to 2500AT were considered with high & low settings (INST)**
- **Vacuum Interrupters (G&W) installed at 4160V with Oil Fuse Cutout & E-Slow Fuse emulations with standard settings at all trip ranges (15-600A)**
- **Electronic Trip Units (LSI type), Relays**

Methodology & Assumptions:

Protective Device Settings: ETU example

	STPU	STD	INST
(1)	max	0.3	4
(2)	max	0.3	6
(3)	max	0.3	10
(4)	max	0.3	max

Note 1: Long time settings at maximum.

Note 2: These were selected as possible break points after a preliminary review.

Methodology & Assumptions:
Short Circuit Levels

- Short circuit vs. arcing current
- Assumptions from previous studies revisited: low & high values important
- Range correlates with system configuration:
  - Large industrial motor loads
  - Rural electric system

IEEE 1584 Calculator

Device	Volts	Short Circuit Level	Arcing Current	Trip Time	PPE & Boundary
500AT CB	480V	1kA	0.5kA	2 sec	PPE 2, 1190 mm
		5kA	2.3kA	2 sec	PPE 3, 2825 mm
		15kA	7.2kA	0.3 sec	PPE 1, 497 mm
		30kA	14.7kA	0.01 sec	PPE 1, 734 mm
		40kA	20kA	0.01 sec	PPE 1, 798 mm

Analyzing the Results

1. Simplify your results
2. What are the anomalies?
3. Analyze the anomalies

Analyzing the Results

- Transformers
- Generators
- Excavation near energized cables
- Temporary installations
- Maintained or aged equipment
- It may not be optimal to bound everything in one set of data

Results

240V & below

- Engineering judgment

480V, 4160V, etc.

- Enveloped protective devices against an array of data
- Trends & System Configuration
- Importance of summarizing data neatly
- Provided case study
- Chart for Labeling & General Use

Path Forward

- This paper critiqued, expanded & utilized
- Viable shortcut methods
- Make arc flash more readily available
- Cheaper methods, if viable, can save lives
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How to Form a Bounding Arc Flash Study for Your Site

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Abstract – This paper presents the concept, design, implementation and application of an original bounding study for arc flash. A bounding arc flash study, which is defined and bound by the characteristics of a particular site or plant, defines arc flash guidelines for electrical workers when the traditional method of calculation outlined in IEEE 1584 is inconvenient to use. The NFPA 70E offers default values in tables that are often used when a traditional study has not been achieved; however, these tables are not representative of all situations common to the workplace. The bounding arc flash study described is primarily designed for temporary power installations and for plants or sites that have not collected the data required by traditional methods. The design of the study is discussed in length so the process can be duplicated with specific adjustments required for your site or plant. Within the study, a typical range of equipment types is identified and then tested against an array of input data, such as short circuit levels, voltage levels, protective device settings, transformer sizes, cable lengths and emergency generation design. The paper explains how new developments affect this type of study and how to update accordingly.

Keywords – bounding arc flash study, personal protective clothing/equipment, arc flash, electrical safety, electrical hazards, industrial plants

I. INTRODUCTION

Arc flash hazards have been recognized by the industry for a relatively long time, however methods for quantifying this type of hazard have not been available until recently. An arc flash is the culmination of the circuit impedance allowing a current that exceeds the glow-to-arc transition current, so that a disruptive discharge occurs through air or over the surface of solid or liquid insulation, between parts of different potential or polarity, produced by the application of voltage wherein the breakdown path becomes sufficiently ionized to maintain an electric current. The total injury potential to personnel is not yet known but at least IEEE 1584-2002 permits the incident energy level to be calculated by the best-known technology. An enormous effort has taken place recently to test and quantify the arc flash hazard so safe recommendations can be adopted in the workplace. IEEE 1584 – 2002 outlines a method of analysis, based on empirical data gathered from testing for affects of arcs-in-boxes and theoretical formulas for affects of arcs in open air, to be used by electrical engineers to make specific recommendations for each piece of equipment that may promote a hazard on the electrical system. In order to complete this type of study the electrical system under analysis must be modeled very accurately. This includes modeling detailed information such as cable size and length, over-current protection with device information including manufacturer, type, size and settings, and accurate information about loads, transformers and generation plus electrical configuration. IEEE 1584-2002 calculators and formulas cannot be utilized to determine incident energy at working distance and arc flash boundary without this information. The NFPA 70E – 2004 offers default values that are often used when a traditional study has not been achieved, however, the guidelines outlined in the standard are not representative of all situations common to the workplace. For instance, there may be 240V devices on a particular system that will not clear within 2 cycles as required by the NFPA 70E – 2004 Table 130.7(C)(9)(a).

As a solution, a method of forming a bounding arc flash study for a site was derived and tested at a sample site with the intent of creating a method of identifying arc flash requirements either accurately or conservatively given the difficulty associated with calculating these requirements in a traditional way. The design of the study is discussed in length so the process can be duplicated with specific adjustments required for a particular site or plant. This method of performing arc flash analysis is primarily designed to help companies who must identify arc flash hazards for temporary installations or require a guideline until they have collected the data required for a more traditional study. Small companies and private contractors may also see a benefit in performing a bounding study rather than the traditional study outlined by IEEE 1584 – 2002. The bounding arc flash study heavily relies on the IEEE 1584 and NFPA 70E for its empirical data and theoretical formulas.

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II. PURPOSE AND OBJECTIVE OF STUDY

The purpose and objective of a bounding arc flash study is to establish the Personal Protective Clothing and/or Equipment (PPC/E) and Arc Flash Boundary requirements for the purpose of reducing the risk of arc flash hazards at your site. The study determines values for PPC/E, arc flash boundary and incident energy for a typical range of equipment types which are identified and then tested against an array of input data, such as short circuit levels, voltage levels, protective device settings, transformer sizes, cable lengths and emergency generation design. These values, illustrated by a chart, are designed for use in the field, to be used by a qualified electrical worker.

III. METHODOLOGY AND ASSUMPTIONS

The tables in NFPA 70E - 2004 make clear several characteristics of an arc flash hazard. For instance, it discusses how a particular task can be more hazardous than another task. This particular characteristic has been discussed at length at conferences and among industry specialists and may have some room for improvement. For instance, it may be argued that switching on a circuit breaker with a cover on may in some instances be just as harmful as switching a circuit breaker with a cover off because the cover may become a projectile object during an event and cause serious harm to the worker. For the purposes of this study it is recommended that a higher precaution be used for tasks that are rated very high by the table. Other tasks are not considered to have an individual risk associated with them by the bounding study and are instead analyzed according to equations outlined in IEEE 1584 – 2002.

The tables of NFPA 70E also assign a level 0 or 1 PPC/E risk category for 240V applications and below. According to the IEEE 1584 Working Group, testing is not yet certain about the hazards at 240V and below. While considerably less dangerous in most cases, there are instances where a high arcing current can occur and create a potentially high hazard. As pointed out in IEEE 1584 – 2002 these low voltages should be examined when it involves at least one 125kVA or larger low-impedance transformer in its immediate power supply. In this case an additional safety factor is recommended.

Other characteristics are made clear by the notes assigned to the tables in the NFPA 70E standard. Short circuit values or clearing times, when exceeding a certain value, pose a high risk and users are cautioned not to use the tables in this particular case, however, there is no alternative offered by the standard. Also, an arc flash boundary default value of 4.0 ft is given for applications 600V and below, but is recommended for devices that operate at a product of 6 cycles (0.1 seconds) and 50kA or any combination not exceeding 300. If you consider devices that clear at a product of 6 cycles and 50kA or any other combination less than 300 in the IEEE 1584 – 2002 Calculator the outcome will typically be a PPC/E of 2 or 3 with a distance above 4.0 feet. Since the IEEE 1584 – 2002 is more conservative it is used in the bounding arc flash study to determine default values for applications 600V and below and 1kV and above. Default arc flash boundaries are determined best by considering an array of devices under various conditions in the IEEE 1584 – 2002 Calculator and trending the results. The first step is to assign PPC/E categories for a given device and a set of conditions. The second step is to determine the required arc flash boundary and incident energy level for each PPC/E category.

Several characteristics of an arc flash hazard are also pointed out by the text and equations contained in the IEEE 1584 – 2002 standard. For instance, the following variables all have an affect on the outcome of the assigned PPC/E level, arc flash boundary and incident energy level for a particular device within the given system: bolted fault current, motor contribution, voltage level, trip and opening time of the protection device at the calculated arcing current, enclosure type, grounding configuration and working distance. Of course, fault current level is dependent on overall system design and operating configuration and trip and clearing times are dependent on the specifications of the protective device in question.

The overall method for developing a default system study for a site is to devise a comprehensive list of devices that envelop a range of clearing and trip times for the site and to consider these devices against an array of input data, such as short circuit levels, voltage levels and protective device settings. The desired outcome is to develop categories of equipment at each voltage with assigned PPC/E levels under various conditions. For each PPC/E level there shall be assigned an arc flash boundary based on the greatest distance dictated by the trending.

To determine PPC/E levels the IEEE 1584 - 2002 Calculator must be used. It is assumed that not enough system data is available to complete a short circuit study. Assumptions that may have been made for your site to complete a system fault study may be invalid for the purposes of arc flash, therefore, making the study itself invalid for determining arc flash requirements. Arcing current which is directly linked to the voltage can be less than half the value of the bolted fault current. Under these conditions it is important that the arcing current not be too low to prevent tripping of the device during an event. This can be an extremely hazardous condition. On the

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other hand, if the arcing current is too high the hazard can also become very dangerous. The bounding calculation is primarily designed for a system where a precise short circuit study is not available. A range of short circuit levels should be selected for the site. For instance, typical facility loads in a rural area will provide low fault levels that should be considered for contributing to low arcing currents. Large industrial motor loads and generators in a plant can contribute to high fault levels and should also be considered for contributing to high arcing currents. There should be enough information available to develop a range of fault levels for your site. For the sample study a range of short circuit values between 1kA and 40kA was considered. For large industrial loads or ranges beyond 40kA, identify these higher short circuit areas as hazardous by area and include that in the results section of the study.

There are distinctive cases that may fall outside of the typical range of short circuit values or be more hazardous for a variety of reasons. In these cases the default values for PPC/E category and arc flash boundary should be at a maximum. One of these cases is when the main source of power is an emergency or backup generator. The older equipment, which is common at many plants and sites, can be unpredictable. The older generators are often protected with devices that are set high, if protected at all, which allows roughly 200% of the full load current to pass through to devices fed from the generator. This means the generator will not trip off-line during low level faults. Since an arcing current often has the same characteristics as a low level fault it can be extremely hazardous to work on an energized device that is fed from the generator because it will not trip and the arc will not be extinguished by the protective device in a reasonable amount of time, if at all.

The assumptions made by the bounding study will be unique to the site and are vital to the outcome of your calculation. If all of the devices are solidly grounded, consider this an assumption of the calculation. When this information in unknown, an ungrounded configuration should be assumed since it is the worst-case scenario. The trip time and opening time of the devices should be limited to 2 seconds. This limitation is due to the fact that either a worker will move away from the event or be forced away by the blast in this amount of time. Workers should avoid working on energized equipment in tight spaces where they cannot move from the blast area. If working in a tight area maximum PPC/E clothing should be worn. The type of enclosure, or equipment class, may be assumed conservatively for the devices. For the sample study all devices were assumed to be in either motor control center (MCC), panelboard or switchgear type enclosures. These scenarios are considered to envelop the open air and cable configurations, which are generally not as common, since the results are more conservative.

Assumptions may also be required for various devices on your system. For instance, in the sample study, devices controlled by a variety of tripping devices were considered. One way to categorize the hazards associated with each type of tripping device is to consider various risks for several ranges of settings. This would require an individual to consider the settings before determining the arc flash risk associated with their work. This is because the settings of any type of tripping device can have a profound affect on the time-current characteristics of the device, which significantly alter the opening and trip times of the device. Since these times are so important to the outcome it is important to be both realistic and conservative. For the sample study devices controlled by relays and by electronic trip units (ETUs) were considered. If possible each device must first be categorized and trended by its settings. Since the sample site had a vast number of relay types with various types of settings, the possible combinations available were beyond reason. As a result a default PPC/E value of 4 for all work associated with a device controlled by a relay was recommended. It is recommended that relay controlled devices be considered for analysis. This requires that a list of the relays be developed and categorized effectively. This methodology was applied for the ETUs at the sample site and a similar method can be applied to devices controlled by relays at any site.

To devise a list of ETUs for analysis many trip units with various plug sizes should be considered. The plug size, not the frame size, is one of the main time-current characteristics of this type of device. ETUs without an instantaneous or short-time feature (LS and LI type) should be considered separately from the LSI type units. The long-time delay and long-time pickup settings should be set high. An exhaustive list of LSI type ETUs was included in the sample bounding study since the sample site had installed only LSI type breakers.

The devices listed for testing should be considered at the appropriate voltage (e.g., 480V, 4160V) in the IEEE 1584 – 2002 Calculator. For the purpose of the sample study the following configurations were considered:

480V, switchgear, bolted fault current = 1kA
480V, switchgear, bolted fault current = 5kA
480V, switchgear, bolted fault current = 15kA
480V, switchgear, bolted fault current = 30kA
480V, switchgear, bolted fault current = 40kA
480V, MCC/panel, bolted fault current = 1kA

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480V, MCC/panel, bolted fault current = 5kA
480V, MCC/panel, bolted fault current = 15kA
480V, MCC/panel, bolted fault current = 30kA
480V, MCC/panel, bolted fault current = 40kA
4160, switchgear, bolted fault current = 1kA
4160, switchgear, bolted fault current = 5kA
4160, switchgear, bolted fault current = 15kA
4160, switchgear, bolted fault current = 30kA
4160, switchgear, bolted fault current = 40kA

Motor contribution can be included in the selected range of fault currents as done in the sample study, so it is not required as a separate and variable input during the calculation stage. All devices were considered solidly grounded since all devices are configured this way at the sample site. Each device was modeled on a time-current curve (TCC), including the circuit breakers controlled by the ETUs. Each ETU was modeled under the following four conditions:

(1) short-time pickup = highest setting
short-time delay = 0.3
instantaneous = 4
(2) short-time pickup = highest setting
short-time delay = 0.3
instantaneous = 6
(3) short-time pickup = highest setting
short-time delay = 0.3
instantaneous = 10
(4) short-time pickup = 4
short-time delay = 0.3
instantaneous = highest setting

These settings were selected as possible break points after reviewing the time-current characteristics with many setting changes against the arcing currents determined by the configurations and bolted fault currents listed above.

IV. IEEE 1584 - 2002 CALCULATOR

An array of voltages, fault levels, device size, device type and device settings, equipment class and grounding configurations, as described above, are the required input for the IEEE 1584 – 2002 Calculator. This input is required entry in the columns on the "Data Normal" Sheet of the Excel based program. A range of bolted fault currents (Column C) has been selected as input since a specific model is not available. Since this range is inclusive of the motor contribution, the motor contribution entered into the calculator is zero. The voltage (Column B), working distance (Column L), equipment class (Column M) and grounding type (Column N) should all be specified. The arcing current and reduced arcing currents are calculated from this data and displayed in Columns F and I. A list of devices has been selected for testing and should envelop the types of devices at your site. In Column O the protective device type should be specified as "0" for general. Once the TCC curves have been obtained, the opening and clearing times at the arcing current levels (Column F) and reduced arcing current levels (Column I) for each device can be entered into the calculator. The required output from the calculator is the PPC/E category and arc flash boundary.

V. TRENDS FOR PPC/E

The output from the calculator must be organized for the purpose of trending the output data and determining the appropriate PPC/E category. In the sample study two main tables were created. The first table (see Table 1) had each 4160V device assigned to a row, from smallest size to largest size (according to trip or plug value). Five columns were provided for each input fault current level (1kA, 5kA, etc.) and the table shows the worst-case PPC/E and arc flash boundary on the given matrix. The second table (see Table 2) was designed in a similar manner for 480V devices. Since the circuit breakers controlled by the ETUs are installed at 480V at the sample site it was important to compare these results by giving each group of settings a unique row, yet next to each other for easy comparison.

Notes from the first table are taken down for each device, such as "PPC/E = 1 or less under all conditions" or "200A fuses require PPC/E 3 when 1kA or less, else PPC/E 0" or "1000A fuses require PPC/E 3 when 1kA or less, else PPC/E 2", and are aimed at determining default arc flash PPC/E category requirements for 4160V applications. In the second table, for 480V applications, notes such as "200A ETUs require PPC/E 4 when 1kA or less, else PPC/E 2. This is true regardless of the settings" or "1200A ETUs require PPC/E 4 if the instantaneous setting is higher than 4 or when 5kA or less, else PPC/E 2" are taken down for each device. These notes are required to determine default arc flash PPC/E category requirements for 480V applications.

TABLE 1 (only 2 devices shown)

	4160V PPC/E & Boundary Results @ Given Short Circuit Level in kA					**Notes**
Device	1	5	15	30	40	
120A Vac. Int.	PPC /E 0 47 mm	PPC /E 0 270 mm	PPC /E 0 897 mm	PPC /E 1 1913 mm	PPC /E 1 2620 mm	PPC/E = 1
200A fuses	PPC /E 3 7094 mm	PPC /E 0 754 mm	PPC /E 0 505 mm	PPC /E 0 801 mm	PPC /E 0 723 mm	200A fuses require PPC/E 3 when 1kA or less, else PPC/E 0

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TABLE 2 (only 2 devices shown)

	480V PPC/E & Boundary Results @ Given Short Circuit Level in kA					Notes
Device	1	5	15	30	40	
200AT ETUs **	PPE = 2 1060 mm	PPE = 0 380 mm	PPE = 1 706 mm	PPE = 2 1070 mm	PPE = 2 1276 mm	200A ETUs require PPE 3 when 1kA or less, else PPE 2 This is true regardless of the settings.
200AT ETUs ***	PPE = 3 1905 mm	PPE = 0 380 mm	PPE = 1 706 mm	PPE = 2 1070 mm	PPE = 2 1276 mm	
200AT ETUs ****	PPE = 3 1905 mm	PPE = 0 380 mm	PPE = 1 706 mm	PPE = 2 1070 mm	PPE = 2 1276 mm	
200AT ETUs *****	PPE = 2 1359 mm	PPE = 0 380 mm	PPE = 1 706 mm	PPE = 2 1070 mm	PPE = 2 1276 mm	
500AT CBs	PPE = 3 1905 mm	PPE = X 5096 mm	PPE = 0 448 mm	PPE = 1 573 mm	PPE = 1 674 mm	500A CBs require PPE X when 5kA or less, else PPE 1

*X signifies that the incident energy level is higher than 40 cal/cm^2
** All ETUs are modeled with STPU set at the highest setting, a STD of 0.3 and Instantaneous Value of 4.
*** All ETUs are modeled with STPU set at the highest setting, a STD of 0.3 and Instantaneous Value of 6.
**** All ETUs are modeled with STPU set at the highest setting, a STD of 0.3 and Instantaneous Value of 10.
*****All ETUs are modeled with STPU set at 4, a STD of 0.3 and the Instantaneous Value set at the highest setting.

VI. TRENDS FOR ARC FLASH BOUNDARY

A set of devices was selected in the initial list of the sample study for the sole purpose of comparing 480V applications to 4160V applications, in terms of arc flash boundary. The reason some of these devices were selected for comparison only is because not every device is installed at both voltage levels at the sample site. A portion of the 480V devices from the original list were tested at 4160V to determine the differences in the results. All of the devices were computed at both voltages in the calculator and a table (see Table 3) was created to emphasize difference in boundary requirements. The table had each device listed smallest size to largest size, and gave a unique row for the 480V device and the 4160V device, yet near each other for easy comparison. Five columns were provided for each input fault current level (1kA, 5kA, etc.) and the table listed the worst-case PPC/E and arc flash boundary on the given matrix. Notes were taken for each device, such as "1854mm-927mm=927mm (PPC/E 1), 3005mm-1276mm=1729mm (PPC/E 2)" which describe the worst-case differences between the 4160V boundary and the 480V boundary given worst-case conditions for a particular PPC/E level. These differences were used in determining the largest boundary disparity between 480V and 4160V applications for a given PPC/E category. This table was also used in determining worst-case boundaries associated with various PPC/E levels at the 480V level by placing the highest boundary associated with a PPC/E level in italics, regardless of the device type. According to the devices sampled the boundary gets increasingly higher according to the PPC/E level, regardless of device type. However, the voltage seems to have a more significant impact.

TABLE 3 (only sample devices shown)

	4160V & 480V for comparison only PPC/E & Boundary Results @ Given Short Circuit Level in kA					Notes
Device ******	1	5	15	30	40	
125AT CB @ 4160V	PPE = 1 1387 mm	PPE = 0 113 mm	PPE = 0 376 mm	PPE = 0 801 mm	PPE = 1 1097 mm	801-573 =**228mm** (PPE 0) 1097-674 =423mm (PPE 1) *573mm is max boundary for PPC/E 0 in this chart; 1470mm is max boundary for PPC/E 2 in this chart*
125AT CB @ 480V	PPE = 2 **1470 mm**	PPE = 0 209 mm	PPE = 0 388 mm	PPE = 0 **573 mm**	PPE = 1 674 mm	
200AT ETU @ 4160V	PPE = 0 53 mm	PPE = 0 310 mm	PPE = 1 1030 mm	PPE = 1 2195 mm	PPE = 1 3005 mm	1030-706 =324mm (PPE 1)
200AT ETU @ 480V	PPE = 2 1060 mm	PPE = 0 380 mm	PPE = 1 706 mm	PPE = 2 1070 mm	PPE = 2 1276 mm	
500AT CB @ 4160V	PPE = 1 2981 mm	PPE = 3 8522 mm	PPE = 0 248 mm	PPE = 0 528 mm	PPE = 0 723 mm	528-448 =80mm (PPE 0) 8522-5096 =3426mm (PPE 3/4/X)
500AT CB @ 480V	PPE = 3 1905 mm	PPE = X 5096 mm	PPE = 0 303 mm	PPE = 0 448 mm	PPE = 1 527 mm	
600AT ETU @ 4160V	PPE = 1 2981 mm	PPE = 0 191 mm	PPE = 0 635 mm	PPE = 1 1354 mm	PPE = 1 1854 mm	635-530 =105mm (PPE 0) 1854-927 =**927mm** (PPE 1)
600AT ETU @	PPE = 3	PPE = 0	PPE = 0	PPE = 1	PPE = 1	

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480V	1905 mm	286 mm	530 mm	783 mm	**927 mm**	*927mm is max boundary for PPC/E 1 in this chart*
800AT ETU @ 4160V	PPE = 1 2981 mm	PPE = 0 310 mm	PPE = 1 1030 mm	PPE = 1 2195 mm	PPE = 1 3005 mm	1030-706= 324mm (PPE 1)
800AT ETU @ 480V	PPE = 3 1905 mm	PPE = 3 2844 mm	PPE = 1 706 mm	PPE = 2 1070 mm	PPE = 2 1276 mm	
1200 AT ETU @ 4160V	PPE = 1 2981 mm	PPE = 3 8565 mm	PPE = 1 1030 mm	PPE = 1 2195 mm	PPE = 1 3005 mm	1030-706= 324mm (PPE 1) 8565-5096=**3469mm** (PPE 3/4/X)
1200 AT ETU @ 480V	PPE = 3 1905 mm	PPE = X 5096 mm	PPE = 1 706 mm	PPE = 2 1070 mm	PPE = 2 1276 mm	
2000 AT ETU @ 4160V	PPE = 1 2981 mm	PPE = 3 17285 mm	PPE = 1 1030 mm	PPE = 1 2195 mm	PPE = 1 3005 mm	n/a = will not work on energized
2000 AT ETU @ 480V	PPE = 3 1905 mm	PPE = X 5096 mm	PPE = X 5549 mm	PPE = 3 4712 mm	PPE = 4 **5618 mm**	*5618mm is max boundary for PPC/E 4 in this chart*
2500 AT ETU @ 4160V	PPE = 1 2981 mm	PPE = 3 17285 mm	PPE = 1 1030 mm	PPE = 1 2195 mm	PPE = 1 3005 mm	n/a = will not work on energized

*X signifies that the incident energy level is higher than 40 cal/cm^2

****** All ETUs are modeled with STPU set at the highest setting, a STD of 0.3 and Instantaneous Value of 4.

VII. INCIDENT ENERGY LEVEL

Each PPC/E category has an associated arc rating expressed in cal/cm^2. Incident energy is measured in cal/cm^2. After the incident energy level at a particular device at a particular location on the system is calculated by IEEE 1584-2002, the corresponding PPC/E category can be determined for the work. The category corresponds with certain clothing and equipment requirements outlined by NFPA 70E. The range of incident energy levels is defined by the NFPA 70E-2004 as follows:

Incident energy from 0 to 1.2 cal/cm^2 for PPC/E 0
Incident energy above 1.2 to 4 cal/cm^2 for PPC/E 1
Incident energy above 4 to 8 cal/cm^2 for PPC/E 2
Incident energy above 8 to 25 cal/cm^2 for PPC/E 3
Incident energy above 25 to 40 cal/cm^2 for PPC/E 4

The clothing at the sample site is rated at a maximum energy level in each category. The outcome of each device tested in the bounding study was within the ranges noted above. Since PPC/E categories are determined for a range of devices under certain conditions in the study, the incident energy is not exact, but within the range given above. This means that first the PPC/E category may be determined for a given set of devices under certain conditions and then the maximum incident energy level for that category may be specified for the work. This approach is conservative and realistic because it gives an exaggerated incident energy level, but maintains the PPC/E requirements for the particular task. This requires the site or plant to have equipment and clothing that is rated at a maximum for each PPC/E category.

VIII. SHORT CIRCUIT CLASSIFICATION

One of the main components of arc flash energy is the fault level available at the device. As discussed before, the arcing current is a percentage of the fault level and should ideally be high enough to trip the device in the instantaneous region and low enough to prevent a large arc. If a study has not been developed to show the short circuit levels at each low and medium voltage bus at your plant or site, you will need to identify if an arc flash hazard may occur due to the low or high arcing currents using another approach. In order to do this, you must identify if you have potential for low arcing currents, high arcing currents or both.

The next step is to establish a fault level at the source(s) (e.g., substation, incoming transformer). A combination of downstream cable sizes, cable lengths, transformer sizes, transformer impedances, generation and motor capability contributes to the final fault level at a given location. The aim of the bounding study is to establish whether the fault level is dangerously high or dangerously low at the device, based on its location within the plant or site.

When dealing with the possibility of low arcing currents the parameters of cables and transformers become essential. Usually, assumptions can be made concerning cable size. For example, in the sample study there was a concern for low arcing currents in the range of 1kA to 5kA, which trends indicated that devices 400A and larger at 480V were problematic in this range. This size device is usually sized for a load of 300A or more and usually requires 500 kcmil cable. This same methodology can be duplicated to

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select a cable size for study purposes to be used at other voltages, such as 4160V. When the voltage is above 5kV, say 15kV, the cable length should be determined by reviewing the system. Usually a particular size is used on the main utility distribution line and can be utilized for study purposes. The next step is to determine how to approach the bounding study from this point forward. The sample site had several sources (12.47kV substations) and low and medium voltage devices installed in facilities spread over a wide-area. As a result, the study determined a maximum distance, from each source to the 12.47kV-480V transformer and then determined a maximum distance from each transformer to the device. In order to stay above 5kA when the source bus at the main substation is 1kA the distances are limited to 10 miles from substation to transformer at 12.47kV and 400 feet from transformer to device at 480V. Similarly, all 4160V runs from the upstream transformer to the device are limited to 2000 feet or less. Additional cases were run to determine when the source provided less then 1kA to see if the short circuit provided to the transformer with the low and medium voltage on the secondary was high enough to provide the same 2000ft (4160V) and 400 feet (480V) recommendations mentioned above. Also, areas more than 10 miles from the main substation were analyzed in the same manner. In completing a bounding study for a plant, it is best to identify one source bus to several main locations within the plant and then identify the maximum length for your 4160V and 480V distances from that point on. Ultimately, the characteristics of a site will determine the approach.

The transformers, considered only nodes in the cable study, must be evaluated separately. For the sample study transformer impedances dictated by IEEE Std 141-1986 were used. Given an infinite bus it was determined how various transformer sizes affected short circuit availability. For instance, a 150kVA transformer allows 7.2kA fault current through to the 480V side. After reviewing the full range of transformer sizes, the only problematic configuration at 480V, given typical transformer impedance, is for very small transformers (smaller than 150kVA) and devices larger than 400A. This configuration is not realistic at 480V so there becomes no actual limitation on transformer size at the sample site at 480V. These limitations, in combination with the cable length limitations can be used to identify hazards at a location. Looking upstream from the device one can determine the source, distance from the source and upstream transformer size to decide if an extreme arc flash hazard exists.

If your concern is instead for high arcing currents, you will want to consider transformer size and motor contribution. For instance, when working near a large motor load the fault current is high, and therefore, arcing current is high enough to create a potential hazard. Often, you will also need to identify sources of generation which contribute to high fault levels. These locations also need to be identified as extremely dangerous. Considering the short circuit level on the secondary side of a transformer given an infinite bus may also be useful, since large transformers allow for a potentially high fault current and small transformers limit the fault on secondary busses. Again, the characteristics of your site or plant will determine the exact approach for your study.

IX. RESULTS

At 240V and below, engineering judgment is required for determining the arc flash requirements. The NFPA 70E table recommends either a PPC/E of 0 or 1 for all tasks, unless the expected short circuit is higher than 25kA with a fault clearing time of 2 cycles. The IEEE 1584 recommends analysis when the device under consideration involves at least one 125kVA or larger low-impedance transformer in its immediate power supply. As a result we considered the NFPA 70E tables at 240V and below, except when the transformer upstream from the device was 125kVA or larger. In these situations a PPC/E value of 2 was recommended. This is conservative, since many of the transformers on the sample site are not low-impedance.

Category 3 PPC/E was eliminated as an option for PPC/E since the sample site only invested in category 4 PPC/E clothing. As a result, all tasks requiring category 3 PPC/E default to category 4 PPC/E at the sample site. This is commonly done by industry since both category 3 and category 4 PPC/E requires an arc flash suit or several layers of uncomfortable clothing. This approach is cost-effective since the clothing is very expensive to purchase.

The size and type of device was one of the main determining factors governing the hazard level associated with arc flash. Typically smaller devices are less hazardous to work around since they react faster under arcing conditions. By definition the size of a device could be one of many attributes: trip size, frame size, plug size, etc. For arc flash applications, the tripping characteristics are the only features, in terms of size, that affect the analysis. For example, an ETU's plug size and trip setting are critical to the outcome, not the frame size. It is important to develop categories by the size and type of device, and for each of these categories to consider a range of

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conditions in order to assign the appropriate PPC/E level.

In regards to the LSI type ETUs, it was ascertained that if the instantaneous value was set above a certain value, the short-time pickup setting would cause the curve to change considerably, especially when the instantaneous setting was set high. These settings were determined to be the most important settings since the long-time pickup and long-time delay were assumed high. Given the device list created for the sample site, two major breakpoints were determine for 480V applications; the hazard increased when the instantaneous was above 4 and the hazard increased when the instantaneous was set higher than 6 or "off". The short-time pickup setting breakpoints were enveloped in our recommendations because the majority of the disturbances in the short-time pickup setting were above the instantaneous setting of 6.

As mentioned previously, the method of assigning arc flash PPC/E by task in NFPA can be misleading. As a result, only the tasks which are most cautioned about in the table are considered an additional hazard by the arc flash bounding study. For a few tasks, it is recommended that either the highest level of caution be observed, or for smaller devices an additional level of caution be used.

Since relays were not considered in the sample study but are usually installed at medium voltages, equipment that is controlled by this type of device at 4160V had an unpredicted outcome. The worst-case scenario, or a PPC/E category of 4 was assigned for all work associated with the relay controlled device at the sample site.

As discussed before, the default value of 4.0 feet in NFPA 70E is not valid or accurate under all conditions. As a result the IEEE 1584 was used to determine the maximum boundary required for 480V applications, given the device list chosen for the sample site and the trends shown in Table 3. The outcome, listed below, is based on devices modeled at the sample site and should only be regarded as an example only.

Assigned PPC/E Category	Boundary @ 480V
0	2 feet
1	3 feet
2	5 feet
4	19 feet

The deviation between these boundaries and the boundary requirements at 4160V were also considered in the bounding study. Given the 480V equipment list determined for the sample site and the 4160V comparison of these devices, the largest disparity was found to be 1 foot for PPC/E level 0, 3 feet for PPC/E level 1, 10 feet for PPC/E level 2 and 12 feet at PPC/E level 4. All of these values were determined by comparing the 480V and 4160V devices in Table 3 at similar short circuit levels which also had time-current characteristics that were similar in nature. Unless working on a very small device a category 0 is not recommended at 4160V. The outcome at 4160V, listed below, is based on devices modeled at the sample site and should only be regarded as an example only.

Assigned PPC/E Category	Boundary @ 4160V
0	3 feet
1	6 feet
2	15 feet
4	25 feet*

*Most of the 4160V devices actually have faster clearing times than the devices chosen for comparison purposes which are common only at 480V. So the disparities discovered by Table 3 are conservative. The arc flash boundary disparity determined by Table 3 for PPC/E 4 was determined to be 12 feet, however, only 6 feet was used resulting in a 4160V Arc Flash Boundary of 25 feet. This is considered acceptable since the arc flash boundaries determined in Table 1 and Table 3 for 4160V devices do not exceed 25 feet in any case.

Cable distance and transformer size may be limited to certain values to prevent hazardous arcing conditions at the sample site. When the values are exceeded higher PPC/E is recommended. The values are largely dependent on your system's characteristics and require full consideration so good results may be obtained.

X. CONCLUSIONS

The findings from the study must be implemented in the field so qualified electrical workers can work as safely as possible. One way to implement the findings of an arc flash study is to create a table that outlines the requirements, assigns a default PPC/E category according to the device worked on and for a given set of conditions, and then finds the corresponding boundary for that level of PPC/E. The PPC/E should be rated for the maximum incident energy level mentioned in Section VII. These tables can either be used by a cognizant engineer or field worker to label equipment on the system or the tables can be developed for electrical workers to use on the job. This second approach is especially advantageous for temporary installations. Tables were developed for the sample site based on the results and trends observed in the arc flash bounding study for the sample site. One of these sample tables is illustrated in Appendix A and was developed for field personnel at the sample site. This chart is an example only, since it is based on devices, assumptions, and input data associated with the sample site.

In the future, engineering personnel should make it a standard process to set equipment to clear as fast as possible given that the requirements are met for proper coordination. This is primarily in the short-

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time and instantaneous region of the time-current curve of devices. This strategy will increase the overall number of devices on your system that will trip effectively under arcing conditions and lower the arc flash hazard associated with the device.

The bounding study should be revisited on a regular basis, possibly annually, to determine if the calculation still maintains its bounding properties. The device list should be revisited to verify if it still encompasses the range of time-current characteristics of equipment onsite. As technology changes, new devices are sometimes introduced to the system, which may need arc flash consideration. Also, the short circuit range selected reflects system design, including motor contribution, generation and cable length and size and transformer data. If there are major changes to these items, the range selected for the study may need revised.

Another reason the bounding study should be revisited is to include developments in arc flash technology. Since this field is emerging, it is expected that more testing will alter the equations and recommendations of the IEEE 1584 and NFPA 70E. These equations and recommendations, in addition to OSHA requirements, should be taken into account.

XI. ACKNOWLEDGEMENTS

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XII. REFERENCES

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[3] Presentation "Arc Flash Hazard Calculations: Why? How? What's Next?" – Daniel Doan, Dupont, Engineering Safety Conference 2004.

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[5] IEEE Std. 141-1986, "IEEE Recommended Practice for Electric Power Distribution for Industrial Plants", Copyright© 1986 by the Institute of Electrical and Electronics Engineers, Inc.

XIII. VITA

Michelle Palizzi (IEEE Member '05) received a Bachelors of Science degree in Electrical Engineering from Virginia Tech. Michelle has had the opportunity to work on many aspects of power engineering design during her career. She currently performs system studies for Bechtel Nevada, one of the main contractors of the Nevada Test Site. She also has experience in utility distribution planning and design, nuclear plant design and power plant construction. Her most recent achievements have been the preparation of a sample arc flash bounding study and attaining membership on the IEEE 1584 Working Group committee.

Sunil Kabra received a Masters of Science degree in Electrical Engineering from Virginia Tech. He obtained his Bachelors degree in Electrical Engineering at IIT Roorkee (formerly University of Roorkee). He is currently employed as an Electrical Engineer at Bechtel Power Corporation where he performs a variety of systems design calculations. He also has experience in design of fossil and nuclear plant distribution systems, emergency diesel and UPS systems, and protection & metering systems. He is a licensed Professional Engineer.

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Appendix A: 480V AC Arc Flash PPE Table for Area X where the fault current at the main sub is 1kA & no medium voltage exists in the run

Start with Condition 1 and continue to Condition 6. The FIRST Condition that is true gives the selected row.

Also, start left and move right to check each column description. The FIRST true statement gives the selected column.

	larger than 1600A trip (ANY device)	Controlled by a relay or recloser	Controlled by an Electronic Trip Unit rated 1200A & up	Controlled by an Electronic Trip Unit rated 800A & up	Controlled by an Electronic Trip Unit rated 400A-799A	800A trip or higher (fuse or breaker)	400A trip or higher (fuse or breaker)	200A - 399A trip (fuse or breaker or ETU)	100A-199A (fuse, breaker or ETU)	99A trip or less (fuse, breaker or ETU)
Condition 1	X*	4	4	4	4	4	4	4	4	4
Condition 2	X*	4	4	4	4	4	4	4	4	2
Condition 3	X*	4	4	4	4	4	4	4	2	1
Condition 4	X*	4	4	4	4	4	4	2	2	1
Condition 5	X*		4	4	2					
Condition 6	X*		4	2	1					
None of the above	4	4	2	2	1	2	1	1	1	0

*X = Do not work on or near the device when energized.

Condition 1: The task involves insertion or removal of a starter bucket, or insertion or removal of CBs from cubicles.

Condition 2: The distance from the main substation is more than 10 miles.

Condition 3: The distance or cable length from the device to the main transformer exceeds 400 feet.

Condition 4: The nearest upstream transformer is 150kVA or smaller.

Condition 5: The Instantaneous setting on the electronic trip unit is set higher than 6 or is OFF.

Condition 6: The Instantaneous setting on the electronic trip unit is set higher than 4 .

The above chart is recommended for all work "on" or "near" 480V energized devices. This includes working on or near exposed 480V parts of the device. This includes tasks such as working on control circuits near exposed energized parts, opening hinged covers to exposed parts, removing bolted covers to exposed energized parts and switching with or without covers.

This chart dictates the Arc Flash Boundary and Incident Energy for 480V applications, once the PPE has been selected from the table above.

Selected Arc Flash PPE	Required Arc Flash Boundary	Assigned Incident Energy Level	Clothing Description**
0	2 feet	1.2 cal/cm^2	Long-sleeve shirt & pants
1	4 feet	4.0 cal/cm^2	FR shirt & pants
2	6 feet	8.0 cal/cm^2	FR shirt & pants + Flash hood (or 8 cal face shield) + Leather gloves + Ear plugs
4	20 feet	40.0 cal/cm2	Flash Suit + Flash hood + FR Shirt & Pants + Leather gloves + Ear plugs

**All PPE classes require safety glasses and hard hat. A t-shirt is required under all FR and Arc Flash Clothing.

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Third-Party Certification of Unevaluated Equipment

Underwriters Laboratories Inc.®

Third-Party Certification of Unevaluated Equipment

Presented to:

2005 Electrical Safety Meeting

Las Vegas, Nevada November 29, 2005

By:

Chuck Mello – Underwriters Laboratories

Introduction

- Program Manager Field Evaluations – Underwriters Laboratories
- BS EPT Oregon State University
- NICET Certified as SET (Senior Engineering Technician)
- Principle Member NEC CMP 5
- Qualified Code Instructor State of OR, WA, ID
- National Speaker on Code, F.E., and Elect. Safety
- IAEI International Board Member
- Over 27 years experience in power system inspection, testing and certification

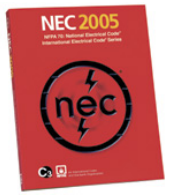
Overview

- North American Electrical Safety System
- What is “unevaluated” equipment
- Laws, Rules, Ordinances, Policies
- Options
- Field Evaluation Process
- How to set specifications and purchase products to avoid unexpected delays or problems

The North American Electrical Safety System

Installation Codes

NEC,
CEC,
MEC



Product Standards and Certification

Inspection and Enforcement

UL, CSA, ANCE

IAEI, OSHA

Safe Products and Safe Installations

Unevaluated Equipment

- Definition from “Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation”

  Unlabeled or Unlisted Equipment – *Equipment that does not have any evidence of listing, or recognition as evidenced by a label or mark of a recognized testing agency recognized by the AHJ.*

Unevaluated Equipment

‘CE’ is not a mark that satisfies this purpose nor is it accepted by Authorities Having Jurisdiction in most of the United States

- ‘CE’ only means the product was “self certified” for ease of movement into and within European Union and to European Union Directives

Laws, Rules, Ordinances etc.

- Federal OSHA – 29 CFR Subpart ‘S’
- State statues
  - ORS 479.610
  - RCW 19.28.010
  - Florida Building Code
- Ordinances
  - City of Boise
  - City and County of San Francisco
  - City of Fort Worth
  - Shelby County Alabama

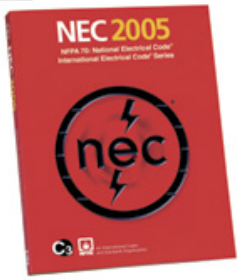
Federal OSHA

- 29 CFR 1910.303 requires all electrical products in the workplace to be “approved”

  1910.303(a)

  Approval. The conductors and equipment required or permitted by this subpart shall be acceptable only if approved.

- Similar to NEC wording in 110.2



Federal OSHA

- 29 CFR 1910.399(a) defines these terms as follows:

  Approved. Acceptable to the authority enforcing this subpart. The authority enforcing this subpart is the Assistant Secretary of Labor for Occupational Safety and Health. The definition of "acceptable" indicates what is acceptable to the Assistant Secretary of Labor, and therefore approved within the meaning of this Subpart

Federal OSHA

29 CFR 1910.399(a) “Acceptable”

Acceptable. An installation or equipment is acceptable to the Assistant Secretary of Labor, and approved within the meaning of this Subpart S:

The next three parts are how this is achieved

Federal OSHA

29 CFR 1910.399(a) “Acceptable”

(i) If it is accepted, or certified, or listed, or labeled, or otherwise determined to be safe by a nationally recognized testing laboratory; or

Federal OSHA

29 CFR 1910.399(a) “Acceptable”

(ii) With respect to an installation or equipment of a kind which no nationally recognized testing laboratory accepts, certifies, lists, labels, or determines to be safe, if it is inspected or tested by another Federal agency, or by a State, municipal, or other local authority responsible for enforcing occupational safety provisions of the National Electrical Code, and found in compliance with the provisions of the National Electrical Code as applied in this subpart; or

Federal OSHA

29 CFR 1910.399(a) “Acceptable”

(iii) With respect to custom-made equipment or related installations which are designed, fabricated for, and intended for use by a particular customer, if it is determined to be safe for its intended use by its manufacturer on the basis of test data which the employer keeps and makes available for inspection to the Assistant Secretary and his authorized representatives. Refer to 1910.7 for definition of nationally recognized testing laboratory.

CAUTION
Airports

Federal OSHA

29 CFR 1910.399(a)

Accepted. An installation is "accepted" if it has been inspected and found by a nationally recognized testing laboratory to conform to specified plans or to procedures of applicable codes.

NO SMOKING

Statues & Rules

- State of Oregon has ORS 479 “Electrical Safety Law”

  479.610 Installation, sale or disposal of uncertified electrical product prohibited. Except as provided under ORS 479.540, a person may not install, sell or dispose of an electrical product by gift or otherwise in connection with the person’s business unless the product is certified under ORS 479.760. [1959 c.406 §9; 1981 c.815 §12; 1995 c.706 §2; 2003 c.14 §325; 2003 c.299 §4]

Statues & Rules

- Rules for implementation are found in OAR 918-305 and OAR 918-306
  - Recognizes
    - Listing of non-exempt products by a NRTL
    - Field Evaluation of non-exempt products by State approved firm
    - Special Deputy inspection
    - Other methods as approved by the Electrical and Elevator Board

Statues & Rules

- OAR 918-306 also
  - Recognizes NRTLs for listing
  - Sets requirements for qualification of Field Evaluation firms

Statues & Rules

- State of Washington statute is RCW 19.28.010

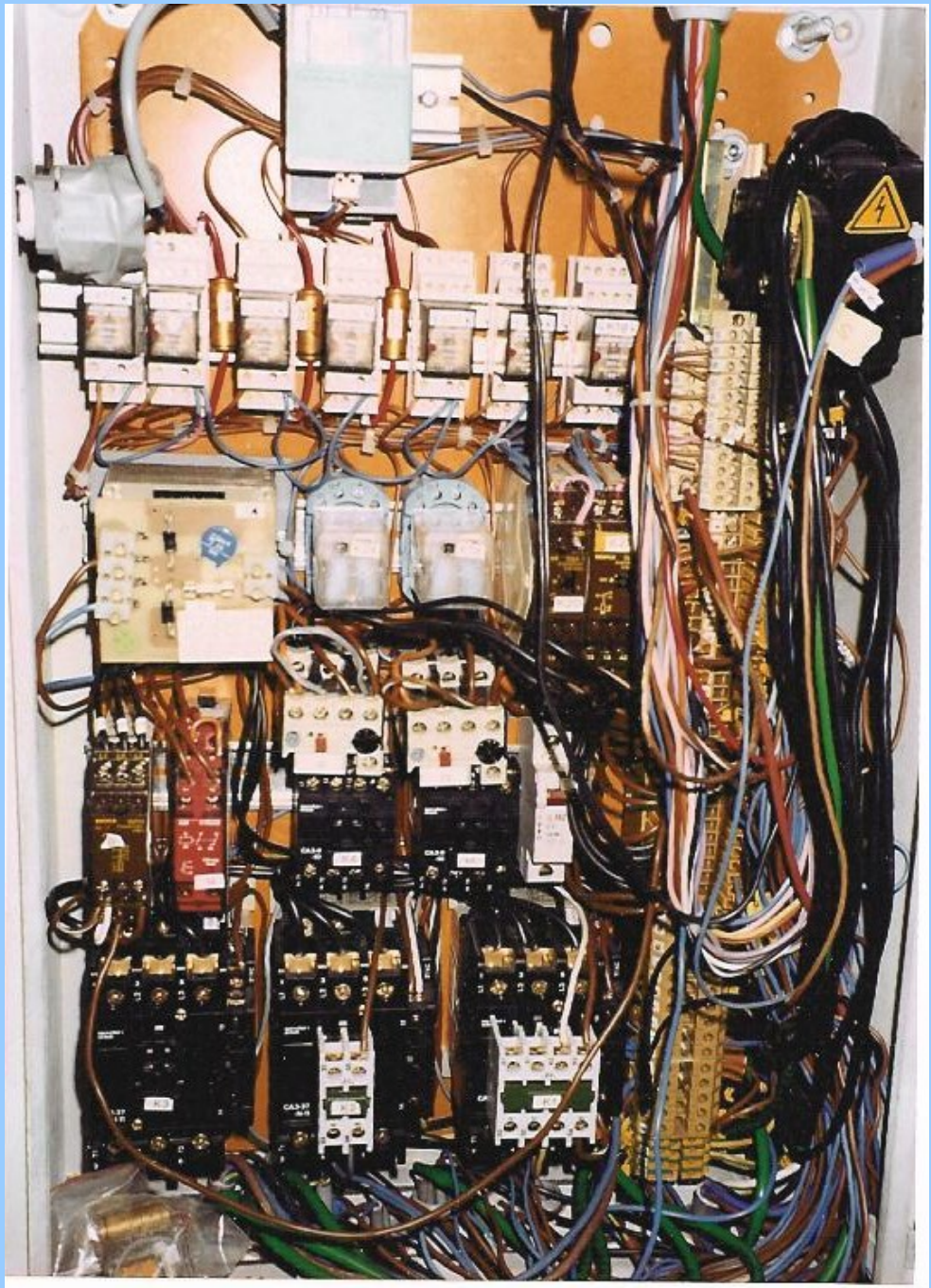
  RCW 19.28.010

  Electrical wiring requirements -- General – Exceptions

  …All materials, devices, appliances, and equipment used in such installations shall be of a type that conforms to applicable standards or be indicated as acceptable by the established standards of any electrical product testing laboratory which is accredited by the department. Industrial control panels, utilization equipment, and their components do not need to be listed, labeled, or otherwise indicated as acceptable by an accredited electrical product testing laboratory unless specifically required by the National Electrical Code, 1993 edition.

Statues & Rules

- Washington also has administrative rules for implementation in
  - WAC 296-46B-020 - Definitions
  - WAC 296-46B-030 – Industrial control panel and industrial utilization equipment inspection
  - WAC 296-46B-999 - Electrical testing laboratory requirements



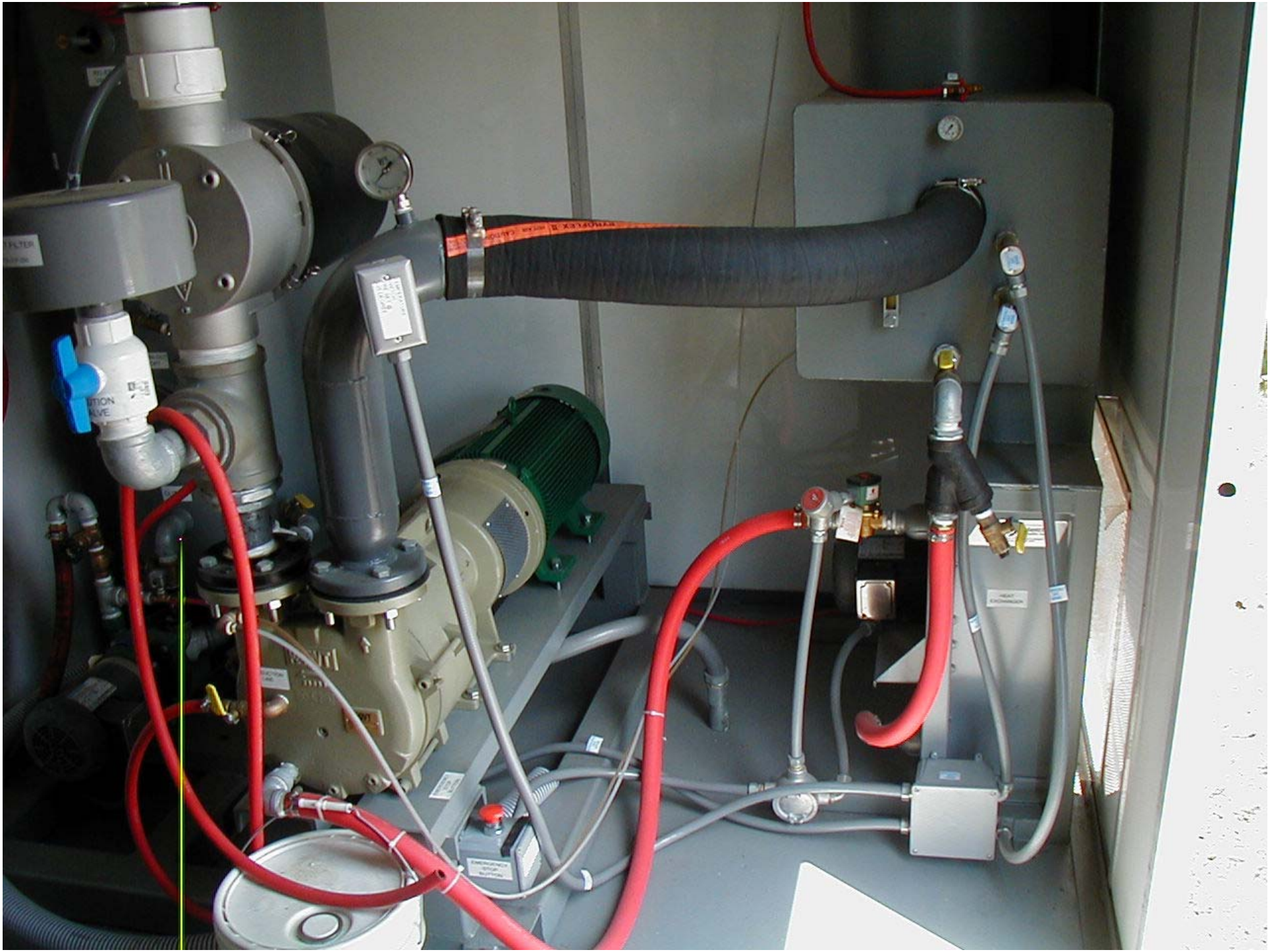
Ordinances

- In addition to Federal or State statutes, many cities and counties have specific ordinances
  - Several Washington cities have specifically not accepted the breath of product standards or exemptions as adopted by the State
  - City of Boise Idaho has an Ordinance Title 4 section 4.05
  - Shelby County states the following:

    A-108.3 APPROVED MATERIALS, APPARATUS, EQUIPMENT AND METHODS

(b) Approved Electrical Goods Defined

No electrical material, apparatus, fitting, appliance, device and/or appurtenance shall be sold, offered or exposed for sale, at retail and/or wholesale or disposed of by gift, premium and/or other similar manner by any person, firm or corporation until such material, apparatus, fitting, appliance, device and/or appurtenance shall have been submitted to a qualified nationally recognized electrical testing laboratory for examination and testing. Only electrical materials, apparatus, fittings, appliances, devices and/or appurtenances labeled or listed by a qualified nationally recognized electrical testing laboratory, shall be considered as having complied with the foregoing regulation or requirement.



Other Locations

- Florida Building Code
  - Requires all construction products to be listed or otherwise certified by a Nationally Recognized Testing Laboratory
- North Carolina
  - Regulates all electrical materials and laboratory recognition through the Department of Insurance
- Maryland
  - All consumer and construction materials required to be certified as regulated by State Fire Marshall's Office

Options

- There are two options generally acceptable to Authorities Having Jurisdiction
  - Specify, purchase and install only equipment Listed by a recognized testing laboratory such as UL
  - Where such Listed equipment is not available, specify and require a Field Evaluation of the equipment by a recognized testing laboratory such as UL

Field Evaluation Process

- June 2003 - American Council for Electrical Safety issued a recommended practice for how to complete a Field Evaluation
  - October 2003 – State of Oregon adopted this Recommended Practice by reference (OAR 918-306-010(2)(c))
  - Los Angeles County is using as guide when evaluating qualifications of Field Evaluation laboratory performance
  - Is being used by UL as part of overall Field Evaluation process guide

Recommended Practice

- Eight parts
  - Purpose and Scope
  - Definitions
  - Selection of applicable product safety standard(s)
  - Pre-site inspection preparation
  - Construction inspection and evaluation
  - Electrical testing
  - Documentation and reporting
  - Label application and control

Purpose and Scope

The primary purposes of this document are twofold. First, this recommended practice is to provide information on the basic evaluation process to Authorities Having Jurisdiction (AHJ) so they might have something to use in determining the adequacy and completeness of completed evaluations and evaluation reports submitted by recognized third party evaluation providers. Secondly this document, when adopted and implemented by third parties, provides for uniformity and consistency in the overall evaluation process used to complete evaluations and evaluation reports on unlabeled equipment.

Procedures Overview

The first step is to determine the appropriate product safety standard that applies to the equipment to be evaluated. Where no one product safety standard can be found, a compilation of applicable parts of other product safety standards is to be assembled.

Preparation

- The following information/material should be made available to the evaluator prior to or upon arrival on site.
  - For complex equipment, at least one complete set of accurate drawings for the specific equipment to be evaluated. For simple equipment one set of basic electrical schematics of the power circuits should be provided.

Preparation

- Layout drawing showing components with designators that match the schematic and actual marks on or adjacent to the components

- Schematic of all the power circuits, line voltage, control, safety interlock and EMO

Preparation

- Bill of material for all critical components including certification(s)
- Conditions of acceptability for any recognized components.
- Notify the Authority Having Jurisdiction of the pending Field Evaluation
  - Stops the clock on correction notices

Construction Inspection

- Perform the construction inspections using the mechanical construction sections of the standard or standard(s) as the guide for this part. This part would include evaluation of the components and markings such as the following examples:
  - Nameplate is complete
  - Provisions for mounting
  - Installation instructions
  - Adequate wire bending space

Construction Inspection

- Enclosure construction
- Main disconnecting means provided
- Main overcurrent protection
- Supply conductor connection point clearly identified
- Component inspection and verification
- Overcurrent protection applications
- Wiring
- Markings
- Grounding

SEP 30 2003

Electrical Testing

- The test program will follow as closely as practical the requirement of the applicable standard, taking into consideration the limits of the non-laboratory setting and the need for the equipment being evaluated to perform its intended function after the test(s).
  - Insulation resistance test
  - Ground continuity of bonded parts
  - Measure the input voltage

Electrical Testing

- Measure the input full load current while at the maximum design load normal operation
- Temperature rise testing
- Safety interlock circuit function testing
- EMO shutdown
- Leakage current *
- Dielectric withstand (hipot) *
- Other production tests as specified *

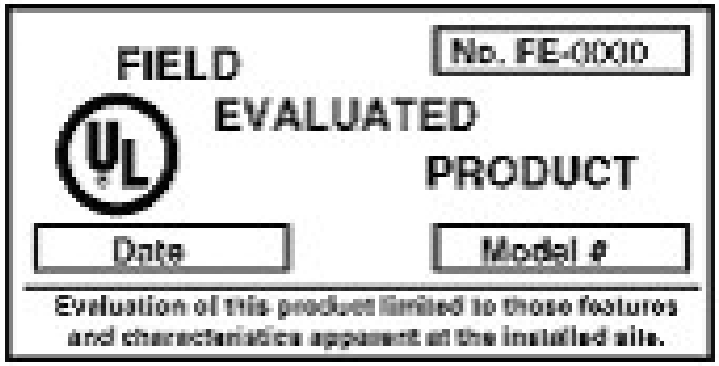
  * Completed only when specified by the standard

Documentation

Each project shall have a complete engineering report written documenting the evaluation process and the evaluation results. The report may be done in stages with the first being a preliminary assessment or discrepancy report where the client needs to resolve issues before the evaluation can proceed. However the communication on unacceptable issues is completed, at the conclusion of the evaluation, the final written report will be prepared, reviewed and issued.

Label Application

When all identified issues are fully resolved, all electrical testing is satisfactorily completed and the evaluation has determined the equipment meets the essential requirements of the standard(s) being applied, then a label is to be applied to the equipment



Specification

All electrical equipment provided and installed for this project shall meet the requirements of Underwriters Laboratories Standards for safety or other equivalent Nationally Recognized standards (e.g.. ANSI) for the specific product and are structured to ensure installations can be completed in accordance with the National Electrical Code. The only acceptable means of meeting the above shall be one of the following:

Specification

1) Listing or Classification by an independent testing laboratory recognized by the Authority Having Jurisdiction. Evidence shall be present on each product, or the packaging in the case where marks are permitted on packaging, in the form of a listing mark, or classification mark applied by the manufacturer at the point of manufacturing, and publication in a list available to the public. The listing and mark signify the product meets the requirements of the applicable standard and that the production is under a follow-up surveillance program.

Specification

2) An evaluation, also known as a “field evaluation” of the equipment by an independent testing laboratory or evaluation firm recognized by the Authority Having Jurisdiction. This option applies only for products that do not normally carry a Listing or Classification because they are unique, limited production, modified from the original listing or used outside the listing parameters.

Specification

The evaluation shall follow the “Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation”, published by the American Council for Electrical Safety dated June 2003. A full engineering report in the form specified in the Recommended Practice shall be provided directly to the Authority Having Jurisdiction by the testing agency completing the evaluation. Once one firm commences an evaluation, there shall not be a substitution of evaluators without the express written consent of the Authority Having Jurisdiction.

Specification

The above options provide for all products that are “mass produced” for distribution in the marketplace or “specially engineered” for this project.

Specification

Recognized testing laboratories for Listing or Classification shall include Underwriters Laboratories for any and all products or other Nationally Recognized Testing Laboratories (NRTL) in accordance with any limits on their recognition by Federal OSHA and published on the Federal OSHA website. Testing Laboratories or evaluation firms that are recognized for Field Evaluations include Underwriters Laboratories or other equivalent Nationally Recognized Testing Laboratories (NRTL) that have made proper submittal to the Authority Having Jurisdiction and have been approved.

Specification

As part of the submittal for approval of all electrical equipment specified for this project, evidence of Listing or Classification shall be provided, or evidence of contracting with a recognized Field Evaluation firm shall be provided to the engineer with the submittal.

Summary

- The North American Safety System is built on a checks and balances type of network
- Certified electrical products are required by Federal Law, in the workplace, and by many local electrical jurisdictions
- There are options for Listing or Field Evaluations
- Listing and Field Evaluations must be from qualified and recognized laboratories
- Starting with the purchase specifications assists in preventing delays during installation

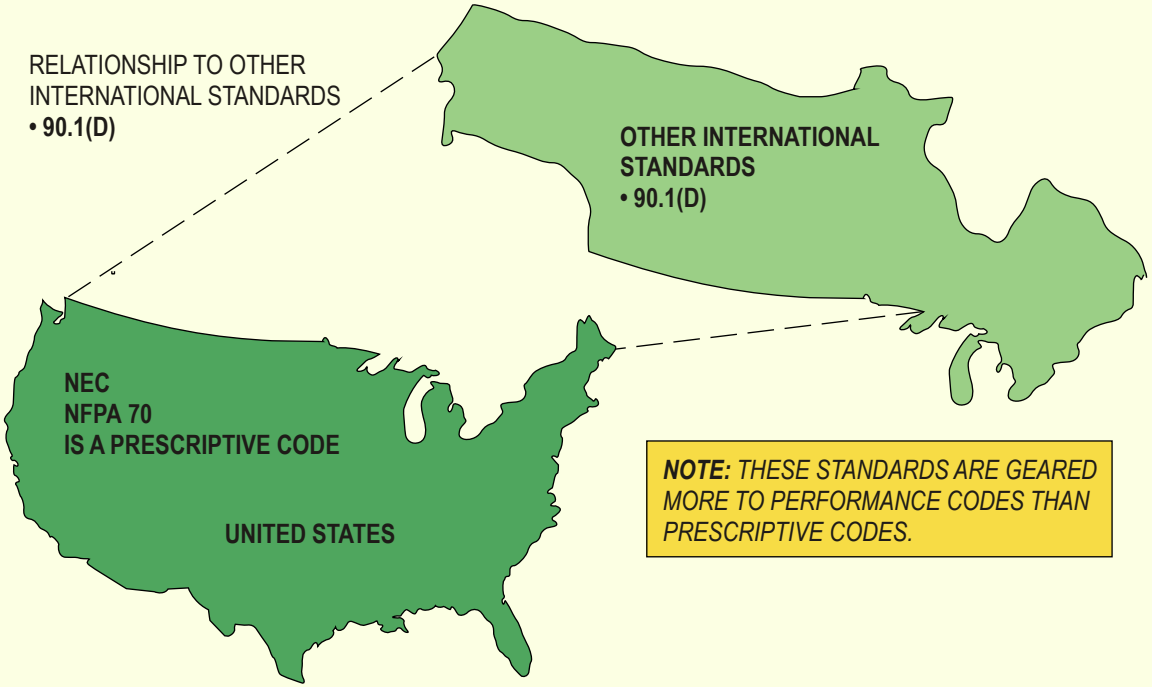
Questions

2005 NEC Changes Commercial and Industrial

2005 NEC

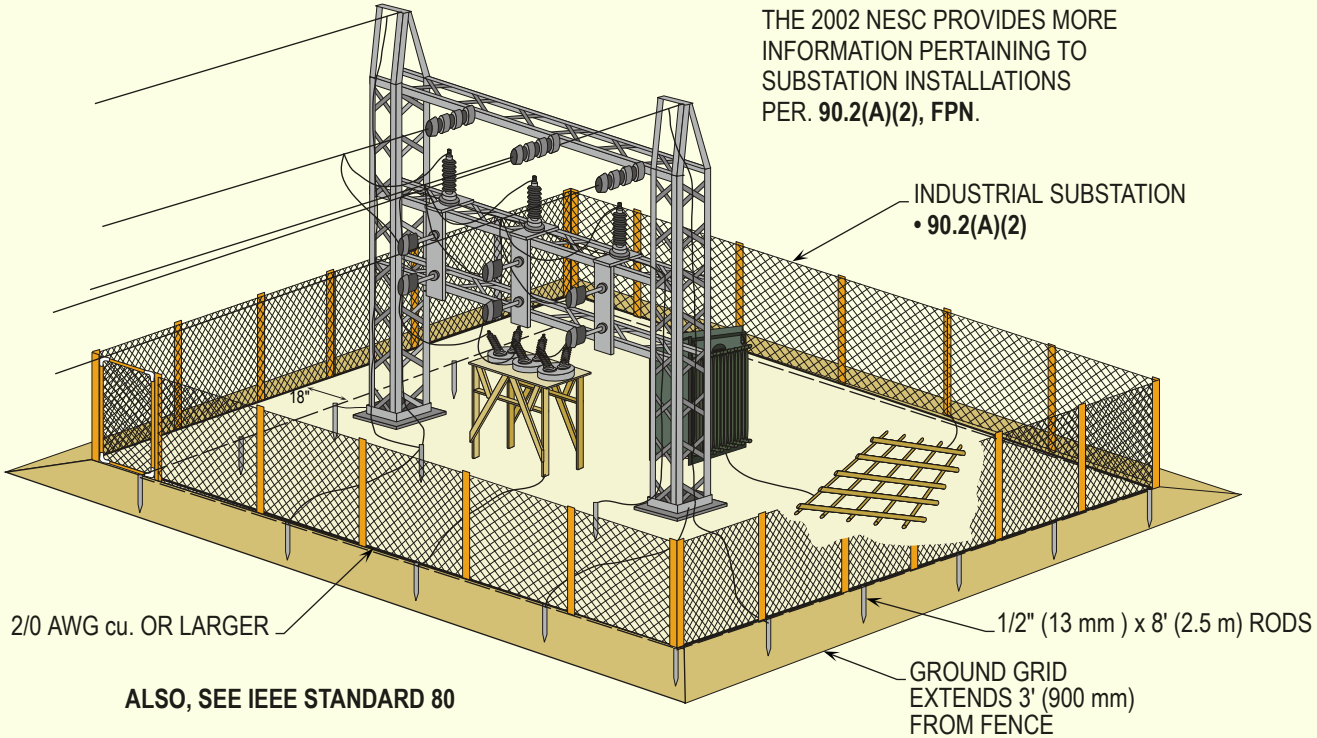
CHANGES

COMMERCIAL AND INDUSTRIAL



RELATION TO OTHER INTERNATIONAL STANDARDS
90.1(D)

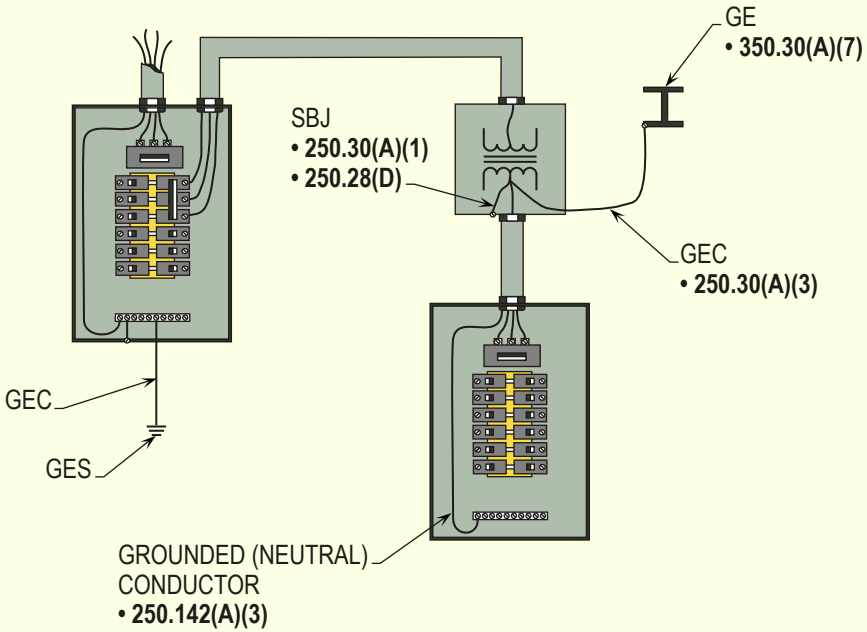
Purpose of Change: The title head was revised to include other international standards.



ALSO, SEE IEEE STANDARD 80

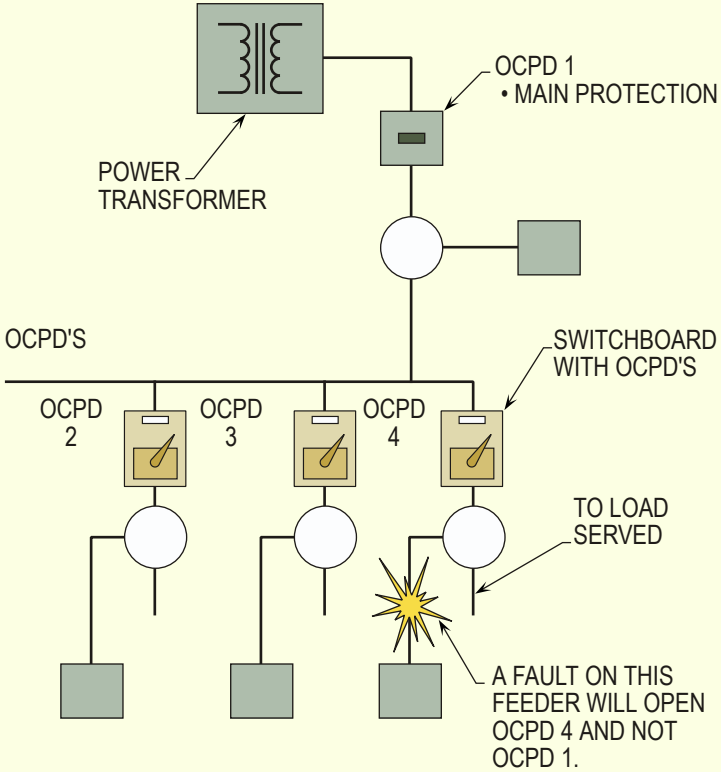
COVERED
90.2(A)(2), FPN

Purpose of Change: To reference the latest publication of the *National Electrical Safety Code* (NESC), which is in the 2002 edition.



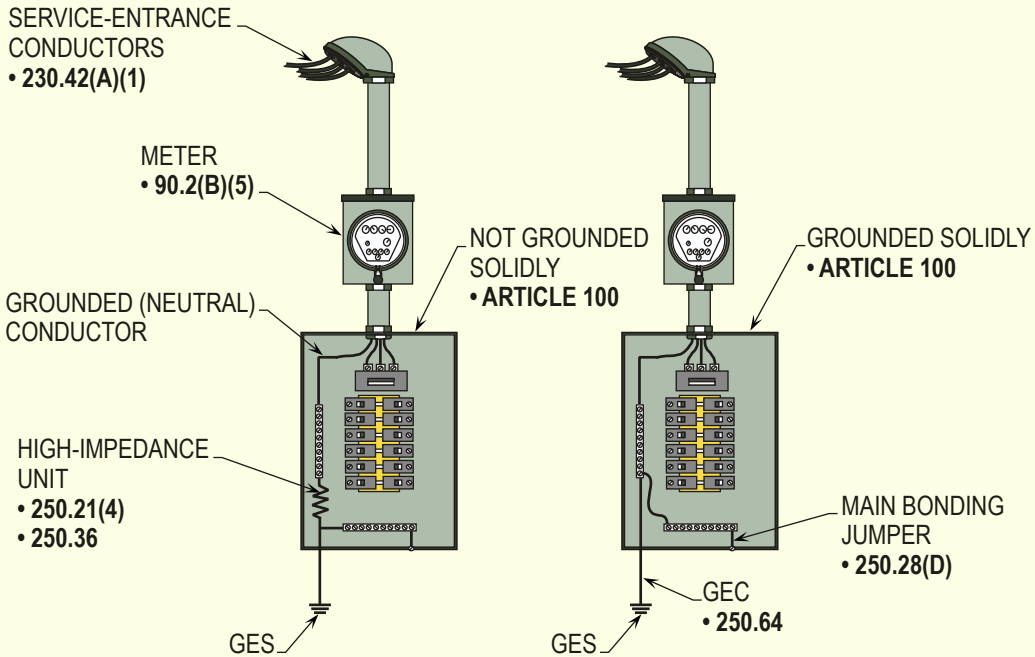
DEFINITIONS - PART I
BONDING JUMPER, SYSTEM
ARTICLE 100

Purpose of Change: To provide a definition for "bonding jumper, system," as used for bonding a separately derived system.



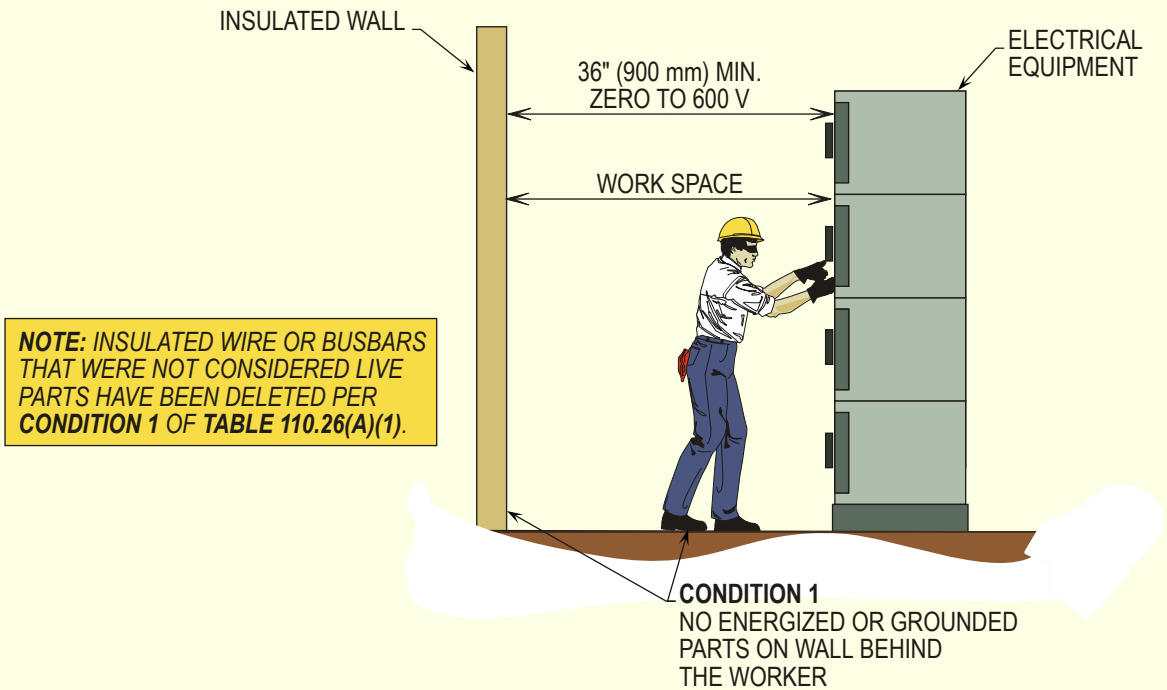
DEFINITIONS - PART I
COORDINATION (SELECTIVE)
ARTICLE 100

Purpose of Change: To provide a definition for the term “coordination (selective)” as used in **Article 100**.



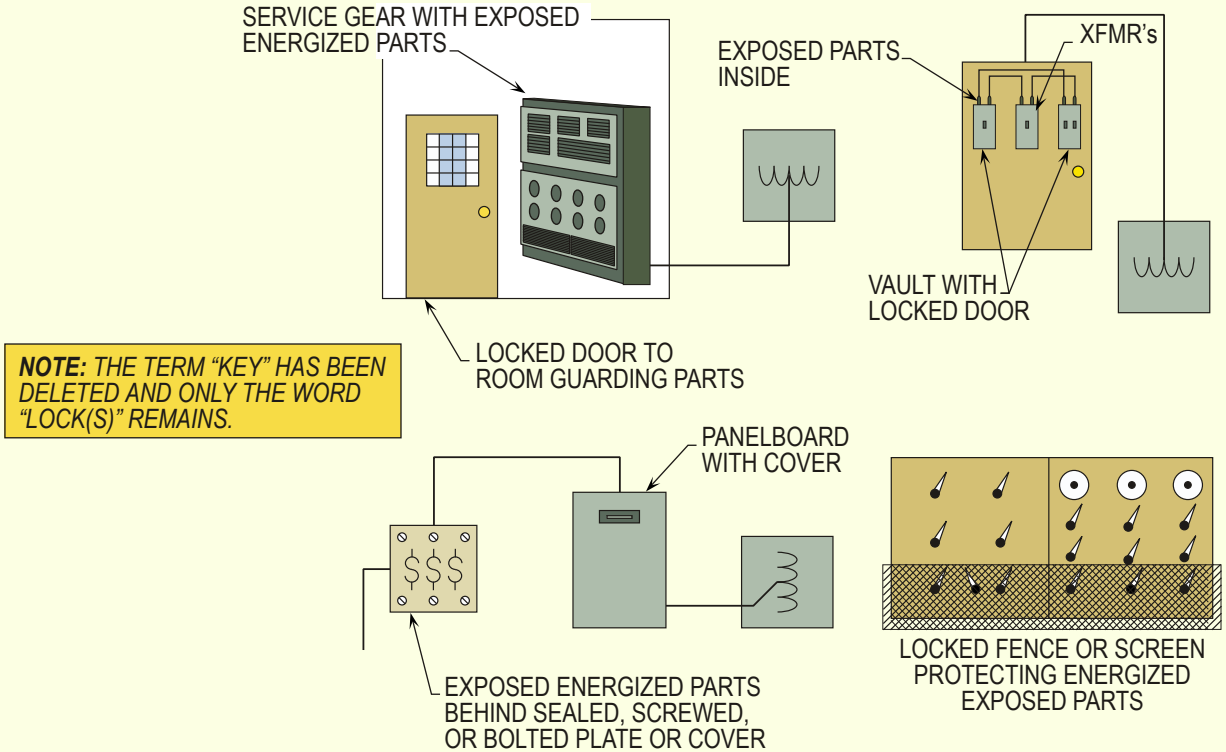
DEFINITIONS - PART I
GROUNDED SOLIDLY
ARTICLE 100

Purpose of Change: To provide a definition for the term “grounded solidly” as used in **Article 100**.



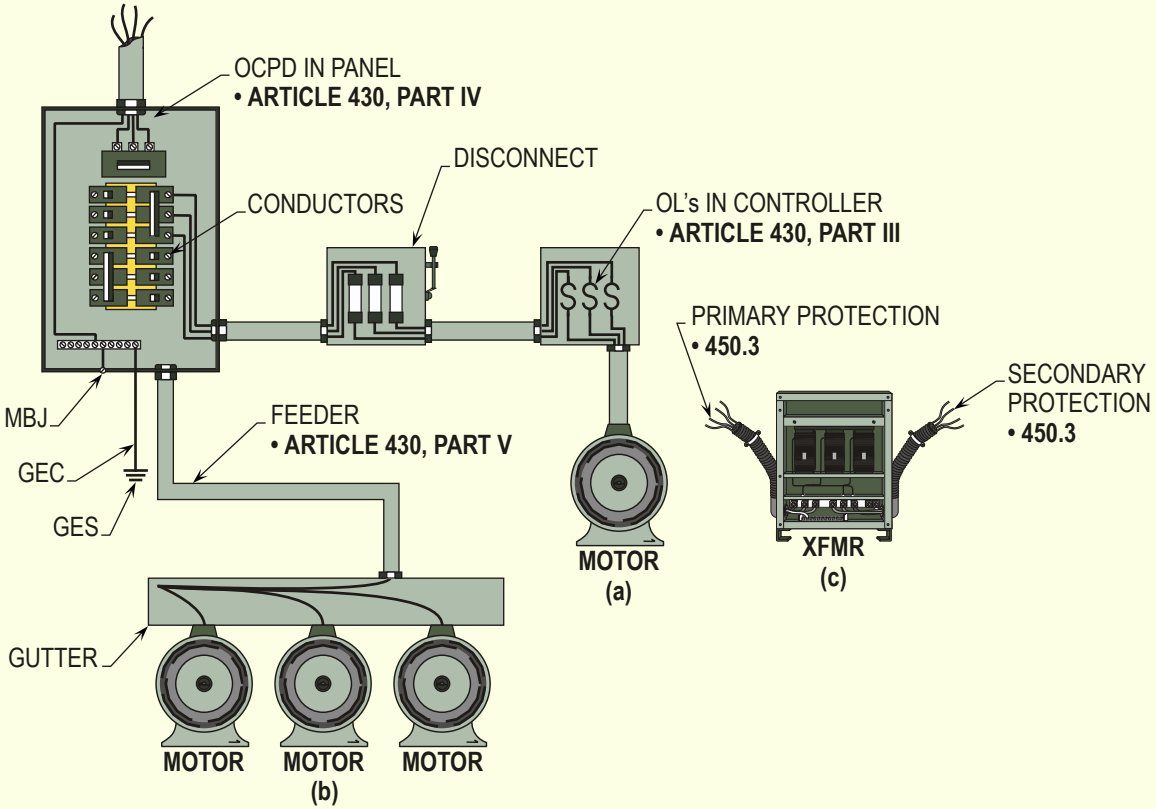
DEPTH OF WORKING SPACE
TABLE 110.26(A)(1), CONDITION 1

Purpose of Change: To more adequately clarify the intended enforcement issues of **Condition 1** to **Table 110.26(A)(1)**.



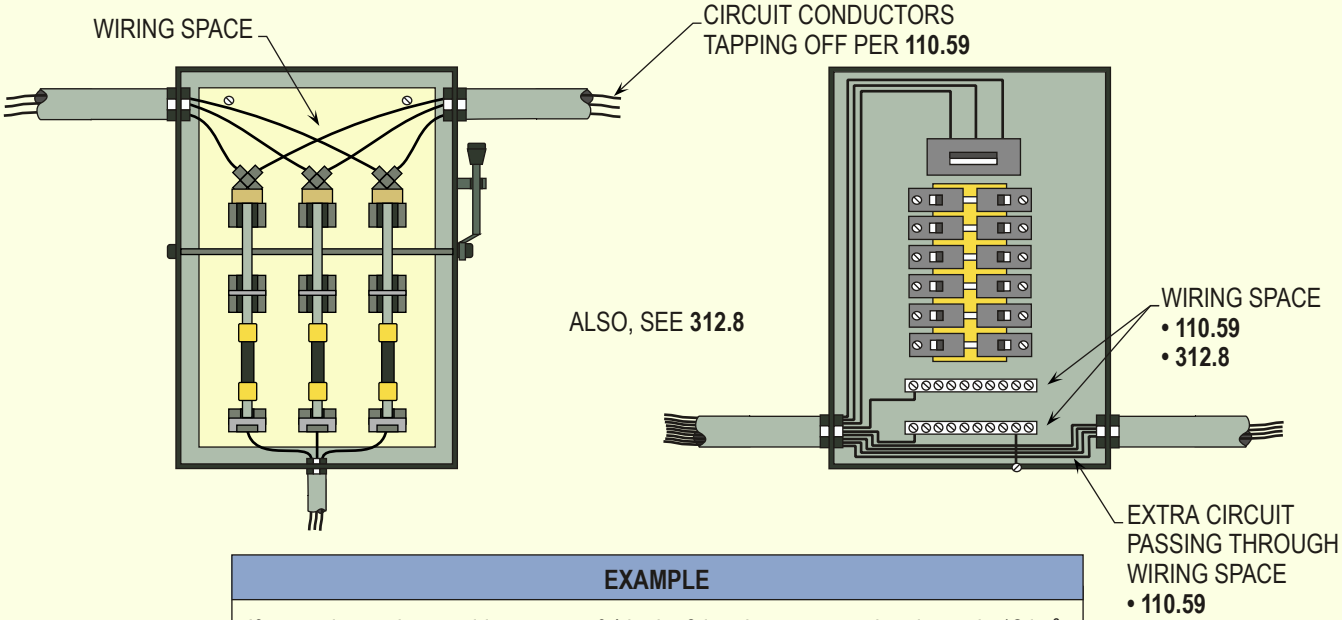
ENCLOSURES FOR ELECTRICAL INSTALLATIONS
110.31

Purpose of Change: To delete the requirement for a key while emphasizing the use of a lock(s).



OVERCURRENT PROTECTION
110.52

Purpose of Change: To reference specific parts and sections of the NEC for motor and transformer protection.

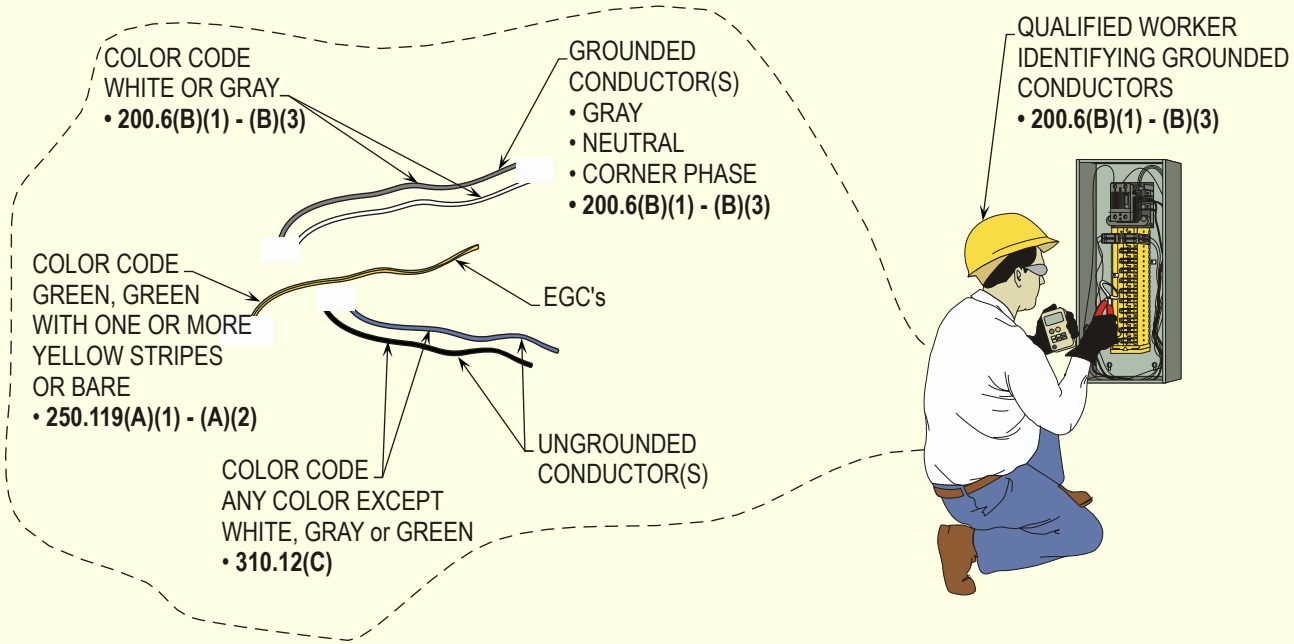


EXAMPLE

If an enclosure has a wiring space of 4 in. by 3 in., the cross-sectional area is 12 in.^{2}. Thus, the total conductor fill (see Chapter 9, Table 5 for dimensions of conductors) at any cross section cannot exceed 4.8 in.^{2} (40 percent of 12 in.^{2}), and the maximum space for conductors and splices or taps at any cross section cannot exceed 9 in.^{2} (75 percent of 12 in.^{2})

ENCLOSURES
110.59

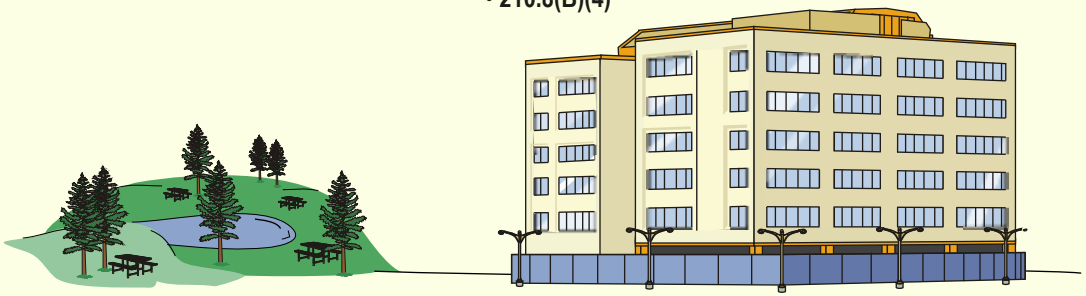
Purpose of Change: To refer the user of the NEC to **312.8** for calculating wiring space.



SIZES LARGER THAN 6 AWG
200.6(B)(1) THRU (B)(3)

Purpose of Change: To clarify that gray tape or similar markings shall be permitted to be used to identify the grounded conductor(s).

A PUBLIC SPACE IS ANY SPACE THAT IS FOR USE BY, OR IS ACCESSIBLE, TO THE PUBLIC
• **210.8(B)(4)**



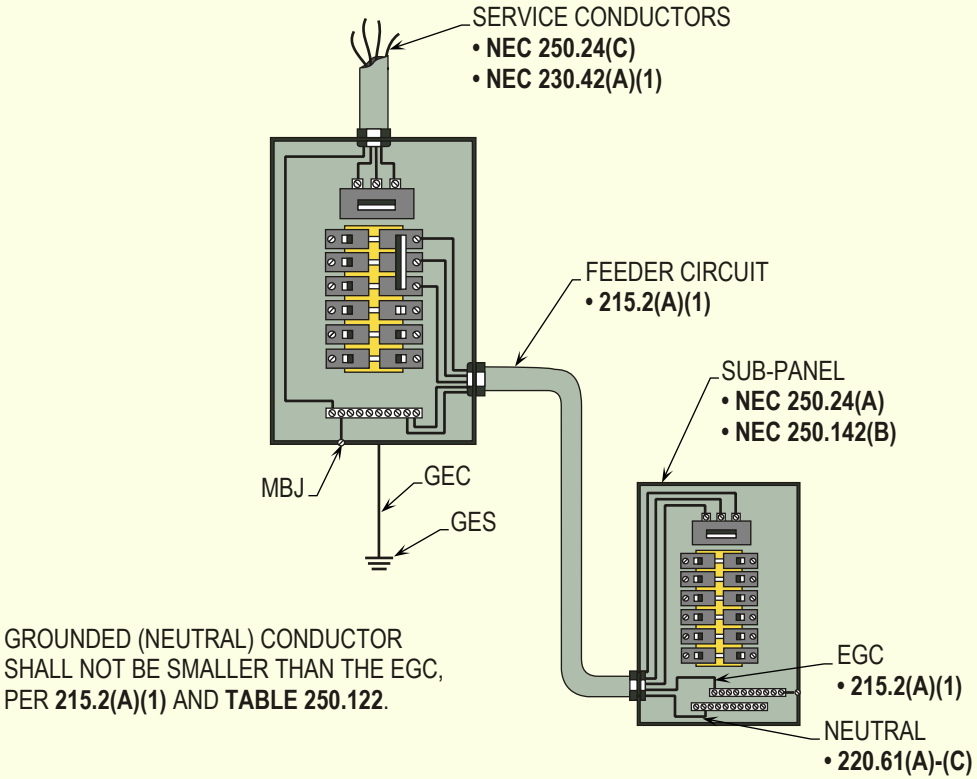
OUTDOORS IN PUBLIC SPACES
• **210.8(B)(4)**

COMMERCIAL OR INDUSTRIAL SITE

RECEPTACLE OUTLETS SHALL BE GFCI PROTECTED
• **210.8(B)(4)**

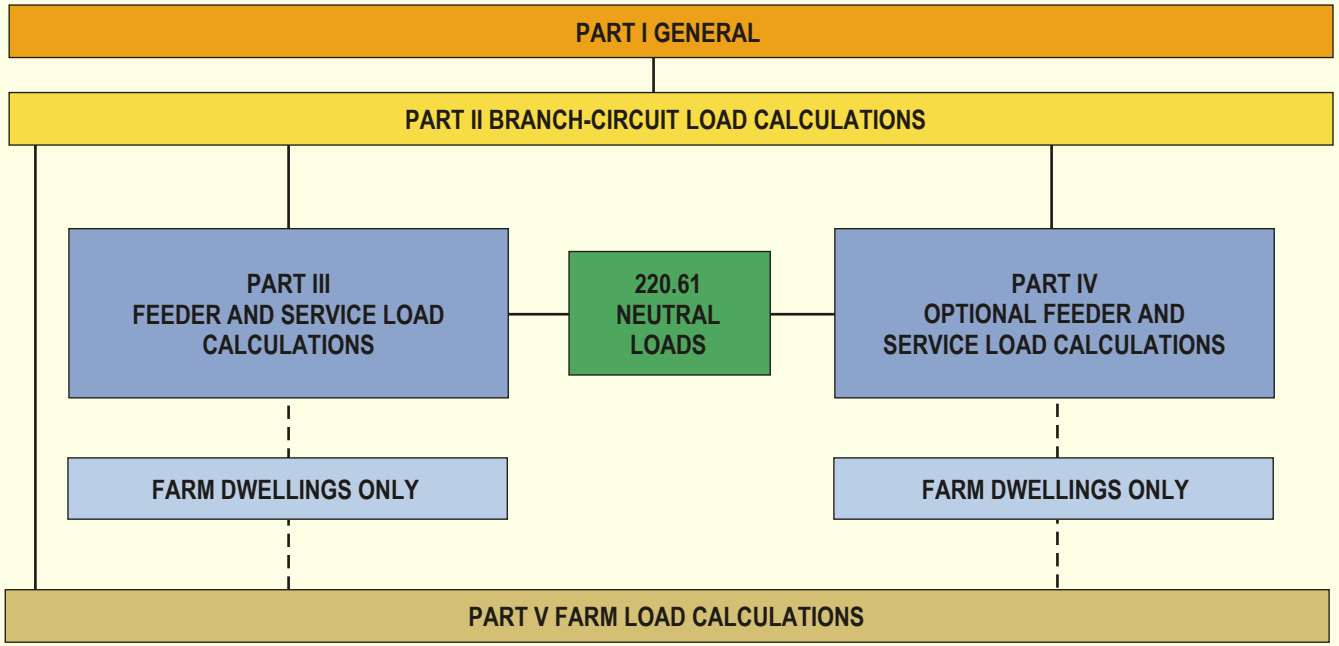
OTHER THAN DWELLING UNITS
210.8(B)(4)

Purpose of Change: To define a public space.



FEEDER CIRCUIT – GENERAL
215.2(A)(1)

Purpose of Change: To clarify that the grounded conductor (neutral) shall be as large as the equipment grounding conductor (EGC).



SCOPE
220.1

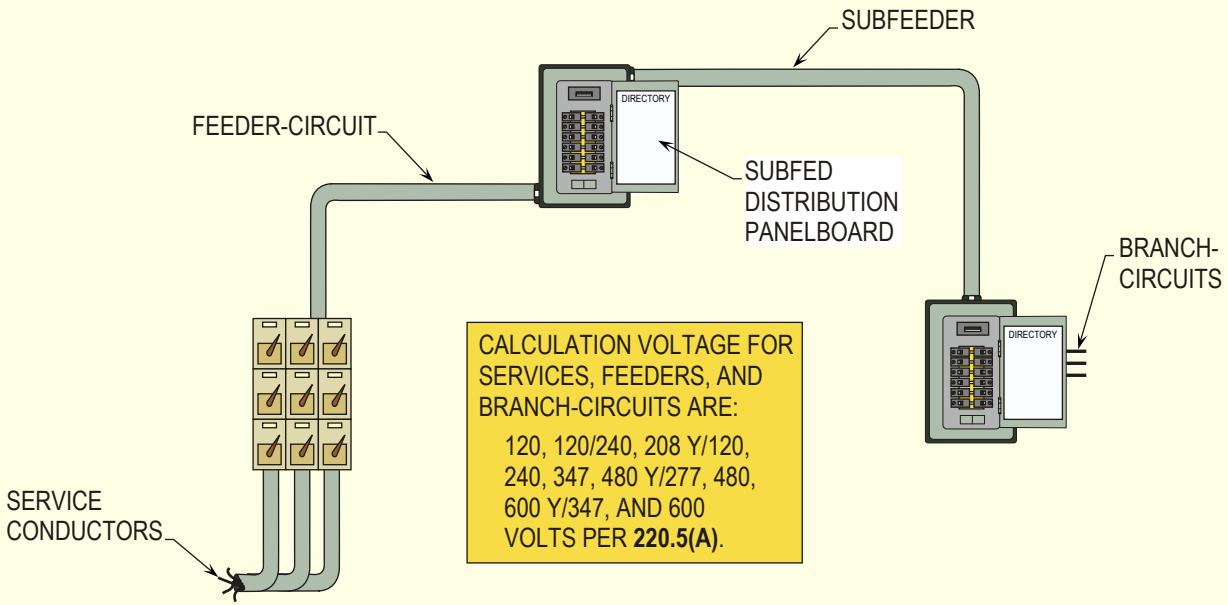
Purpose of Change: To arrange the calculation requirements for services, feeders, branch-circuits, and farm loads in a user friendly manner.

NOTE: *THIS TABLE IS AN EXAMPLE FOR SOME OF THE ADDITIONAL LOAD CALCULATIONS REFERENCED IN OTHER ARTICLES.*

CALCULATIONS	ARTICLE	SECTION (OR PART)
AIR-CONDITIONING AND REFRIGERATING EQUIPMENT, BRANCH-CIRCUIT CONDUCTOR SIZING	440	PART IV
MOTORS, FEEDER DEMAND FACTOR	430	430.26
MOTORS, MULTIMOTOR AND COMBINATION-LOAD EQUIPMENT	430	430.25
MOTORS, SEVERAL MOTORS OR A MOTOR(S) AND OTHER LOAD(S)	430	430.24
INDUSTRIAL MACHINERY, SUPPLY CONDUCTOR SIZING	670	670.4(A)
SENSITIVE ELECTRICAL EQUIPMENT, VOLTAGE DROP (MANDATORY CALCULATION)	647	647.4(D)

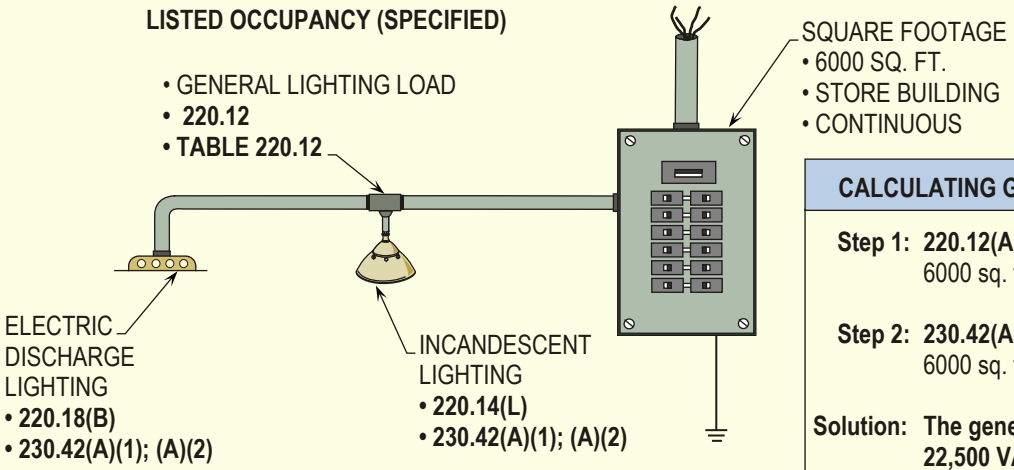
APPLICATION OF OTHER ARTICLES
220.3; TABLE 220.3

Purpose of Change: To reference other Articles, Parts, and Sections of the NEC for calculation loads.



CALCULATIONS (VOLTAGES)
220.5(A)

Purpose of Change: To relocate and renumber rules in **220.2(A)** to **220.5(A)**.



CALCULATING GENERAL LIGHTING LOAD

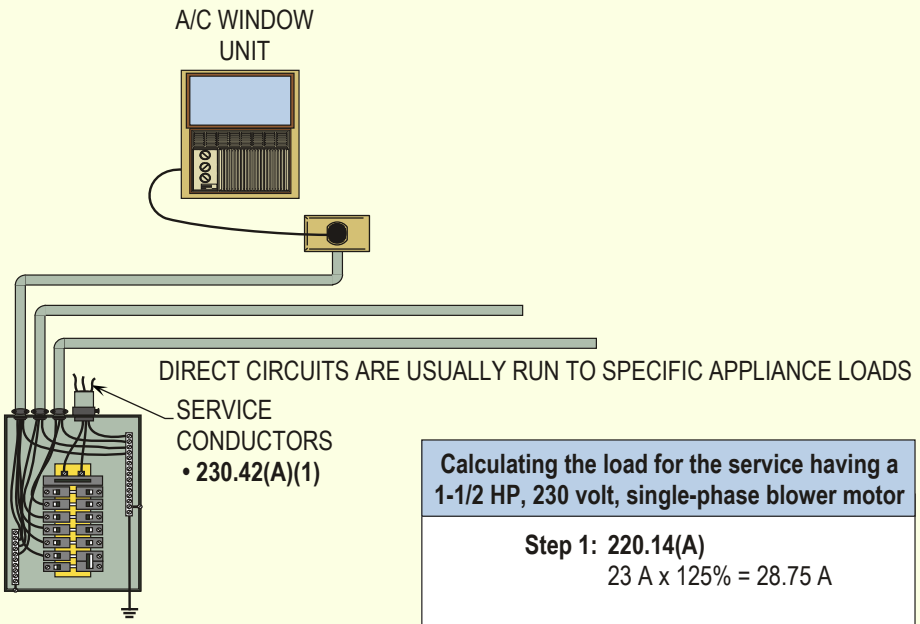
Step 1: 220.12(A); Table 220.12(A)
6000 sq. ft. x 3 VA = 18,000 VA

Step 2: 230.42(A)(1)
6000 sq. ft. x 3 VA x 125% = 22,500 VA

Solution: The general lighting load is 22,500 VA.

LIGHTING LOAD FOR SPECIFIED OCCUPANCIES
220.12; TABLE 220.12

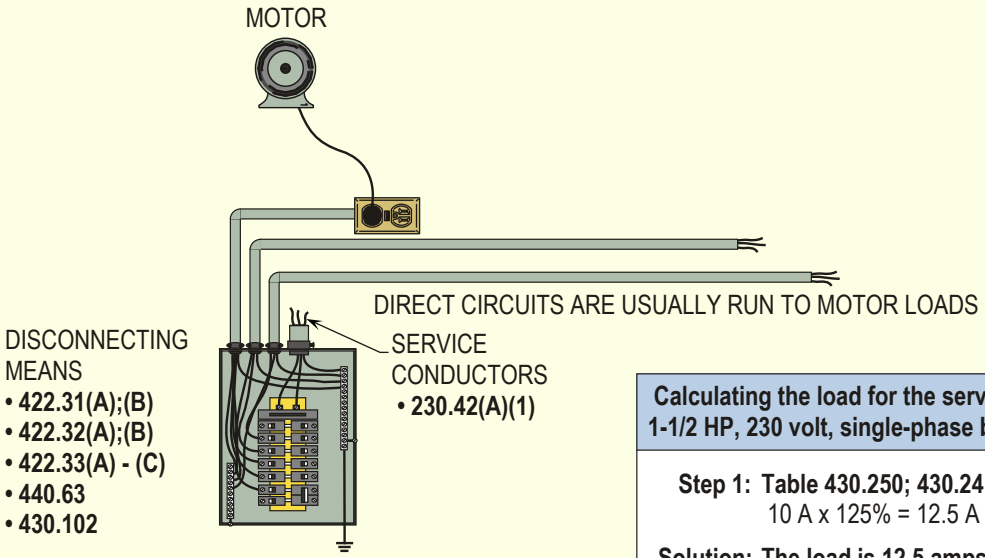
Purpose of Change: To relocate and renumber rules in **Table 220.3(A)** to **Table 220.12**.



Calculating the load for the service having a 1-1/2 HP, 230 volt, single-phase blower motor
Step 1: 220.14(A) 23 A x 125% = 28.75 A **Solution: The load is 28.75 amps.**

SPECIFIC APPLIANCES OR LOADS
220.14(A)

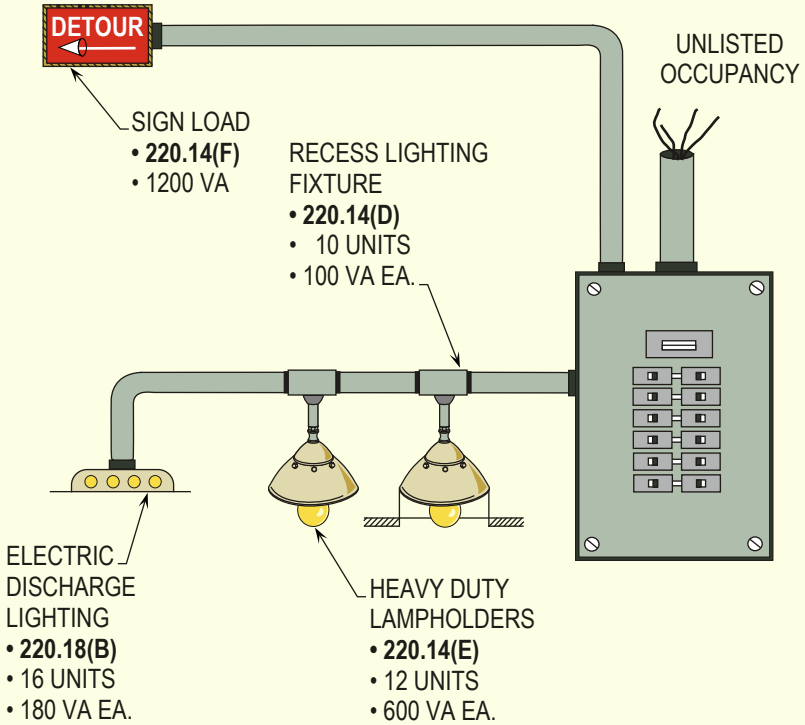
Purpose of Change: To relocate and renumber rules in **220.3(B)(1)** to **220.14(A)**.



Calculating the load for the service having a 1-1/2 HP, 230 volt, single-phase blower motor
Step 1: Table 430.250; 430.24; 220.14(C) 10 A x 125% = 12.5 A **Solution: The load is 12.5 amps.**

MOTOR LOADS
220.14(C)

Purpose of Change: To relocate and renumber rules in **220.3(B)(3)** to **220.14(C)**.



Calculating Unlisted Occupancy

Step 1: Calculating total VA
220.4(B); 220.3(B)(4); 220.3(B)(11)

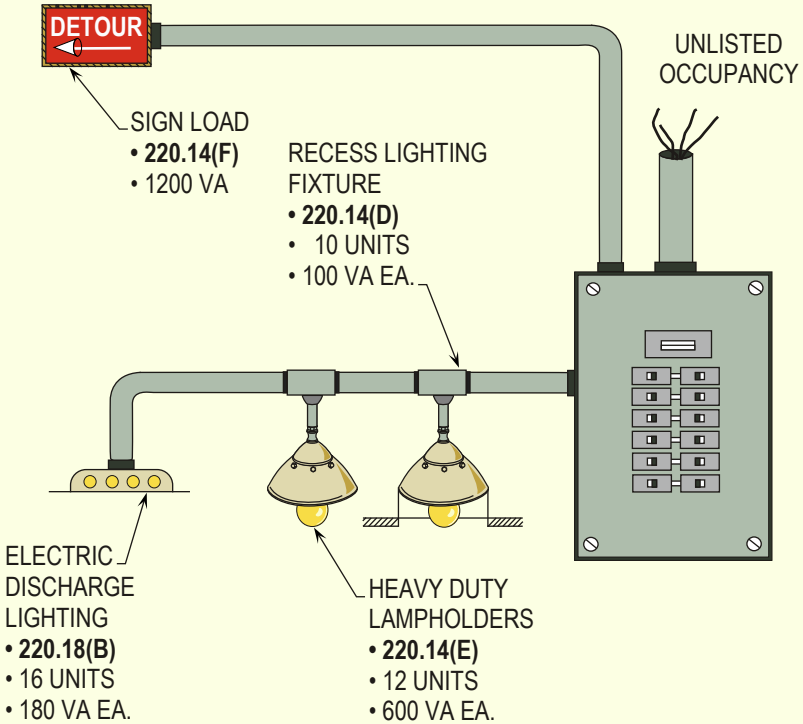
180 VA x 16 =	2880	VA
600 VA x 12 =	7200	VA
100 VA x 10 =	1000	VA
1200 VA	1200	VA
Total VA =	12,280	VA

Step 2: Calculating continuous VA
230.42(A)(1)
12,280 VA x 125% = 15,350 VA

Solution: **The unlisted occupancy load is 15,350 VA.**

LUMINAIRES (LIGHTING FIXTURES)
220.14(D)

Purpose of Change: This revision clarifies that there are many outlets supplying luminaires with a load in excess of 180 volt-amperes.



Calculating Unlisted Occupancy

Step 1: Calculating total VA
220.4(B); 220.3(B)(4); 220.3(B)(11)

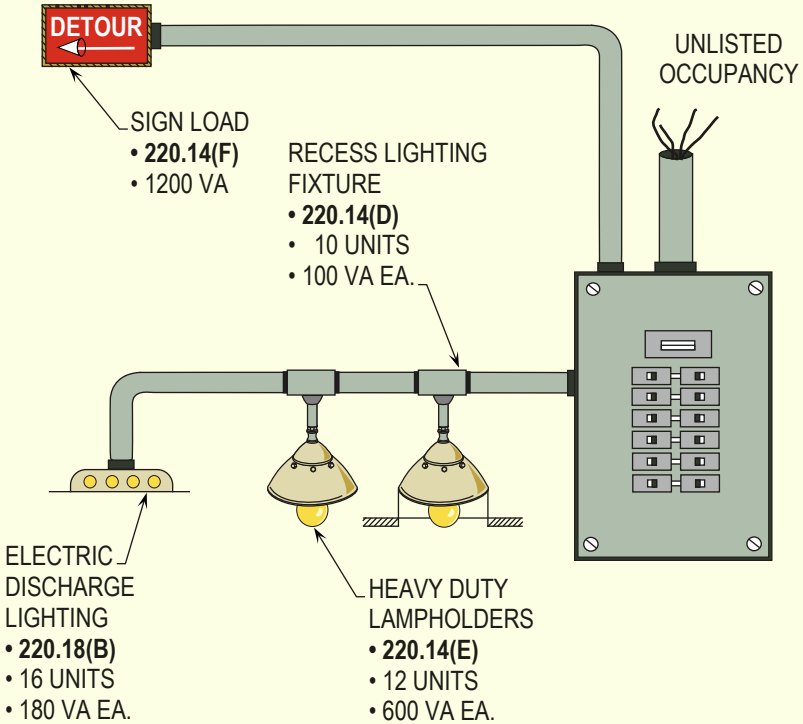
180 VA x 16 =	2880	VA
600 VA x 12 =	7200	VA
100 VA x 10 =	1000	VA
1200 VA	1200	VA
Total VA =	12,280	VA

Step 2: Calculating continuous VA
230.42(A)(1)
12,280 VA x 125% = 15,350 VA

Solution: **The unlisted occupancy load is 15,350 VA.**

HEAVY-DUTY LAMPHOLDERS
220.14(E)

Purpose of Change: To relocate and renumber rules in **220.3(B)(5)** to **220.14(E)**.



Calculating Unlisted Occupancy

Step 1: Calculating total VA
220.18(B); 220.14(D); 220.14(E)

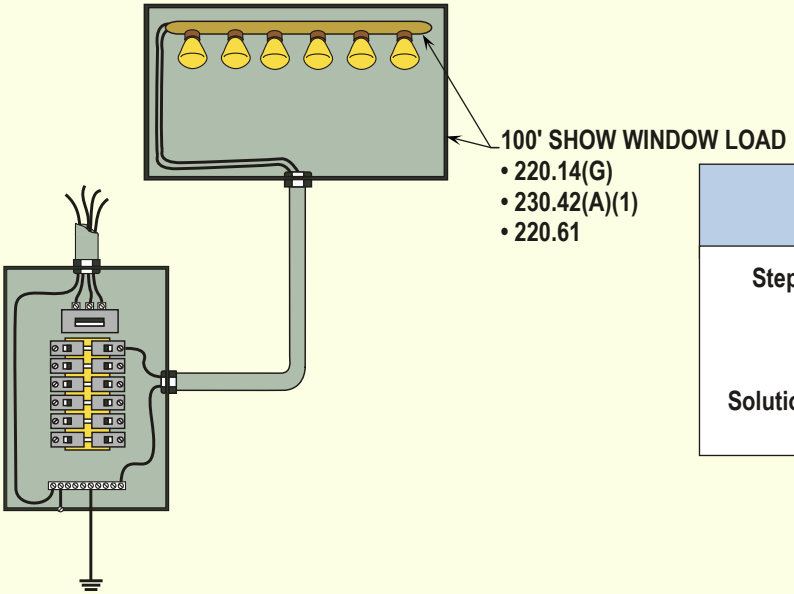
180 VA x 16 =	2880	VA
600 VA x 12 =	7200	VA
100 VA x 10 =	1000	VA
1200 VA	1200	VA
Total VA =	12,280	VA

Step 2: Calculating continuous VA
230.42(A)(1)
12,280 VA x 125% = 15,350 VA

Solution: **The unlisted occupancy load is 15,350 VA.**

SIGN AND OUTLINE LIGHTING
220.14(F)

Purpose of Change: To relocate and renumber rules in **220.3(B)(6)** to **220.14(F)**.



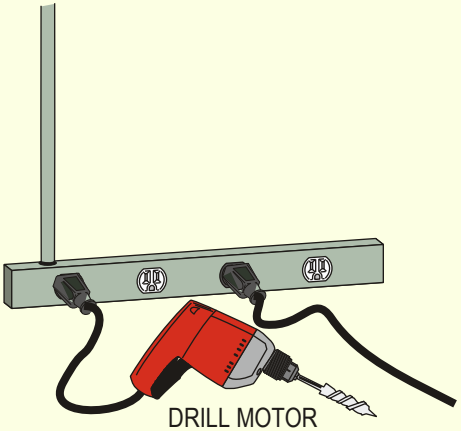
CALCULATING LOAD FOR SHOW WINDOW	
Step 1:	Calculating VA **220.14(G); 230.42(A)(1)** 100' x 200 VA = 20,000 VA
Solution:	**The show window load is 20,000 VA.**

SHOW WINDOWS
220.14(G)

Purpose of Change: To relocate and renumber rules in **220.3(B)(7)** to **220.14(G)**.

MULTIOUTLET ASSEMBLY

- 200 FT.
- **220.14(H)(1)**
- **220.14(H)(2)**
- APPLIANCES MAY OR MAY NOT BE USED SIMULTANEOUSLY

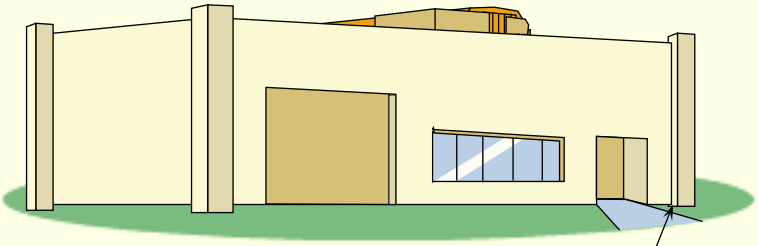


CALCULATING LOAD FOR MULTIOUTLET ASSEMBLY	
Step 1:	Calculating VA **220.14(H)(1)** 200' ÷ 5' x 180 VA = 7200 VA
Solution:	**The assembly load is 7200 VA.**

CALCULATING LOAD FOR MULTIOUTLET ASSEMBLY	
Step 1:	Calculating VA **220.14(H)(2)** 200' x 1' x 180 VA = 36,000 VA
Solution:	**The assembly load is 36,000 VA.**

OTHER LOADS – ALL OCCUPANCIES
220.14(H)(1); (H)(2)

Purpose of Change: To relocate and renumber rules in **220.3(B)(8)** to **220.14(H)**.



OFFICE BUILDING
- 20,000 SQ. FT.
- NUMBER OF RECEPTACLES IS UNKNOWN

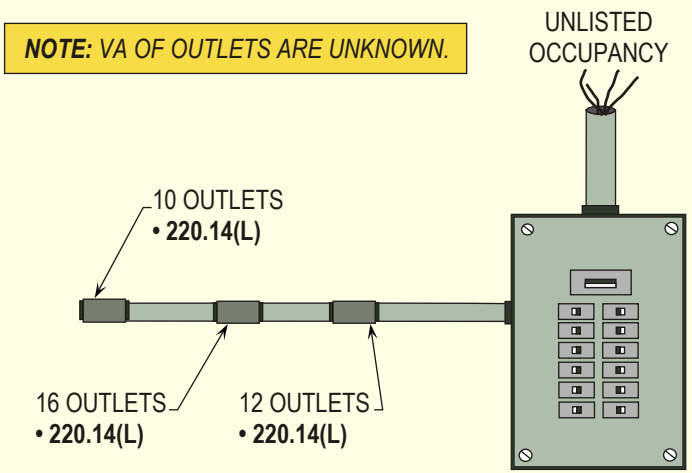
General Lighting Load
Table 220.12; 220.12
20,000 sq. ft. x 3.5 VA = 70,000 VA

Receptacle Load
Table 220.12; 220.14(K)
20,000 sq. ft. x 1 VA = 20,000 VA

NOTE: *THE NONCONTINUOUS AND CONTINUOUS OPERATION RULES OF* ***220.14(I)*** *AND* ***230.42(A)(1)*** *HAVE NOT BEEN APPLIED.*

BANKS AND OFFICE BUILDINGS
220.14(K)

Purpose of Change: To clarify the appropriate procedure for calculating an unknown number of receptacle outlets.



Calculating Load of Outlets

Step 1: Calculating total VA
220.14(L)
180 VA x 16 = 2880 VA
180 VA x 12 = 2160 VA
180 VA x 10 = 1800 VA
Total VA = 6840 VA

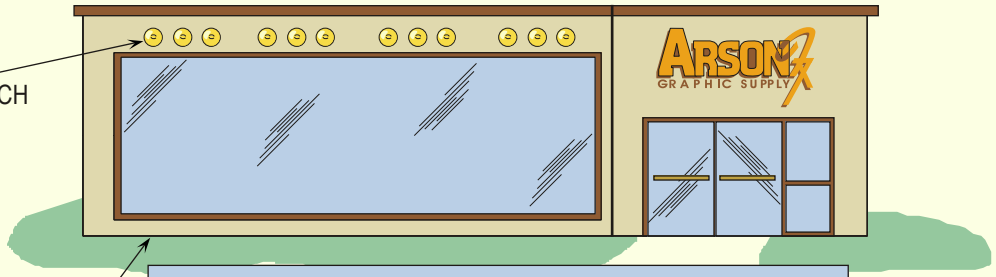
Step 2: Calculating continuous VA
230.42(A)(1)
6840 VA x 125% = 8550 VA

Solution: **The unlisted occupancy load is 8550 VA.**

OTHER OUTLETS – ALL OCCUPANCIES
220.14(L)

Purpose of Change: To relocate and renumber rules in **220.3(B)(11)** to **220.14(L)**.

LIGHTING UNITS
- 90 AT 180 VA EACH WERE ADDED



EXISTING COMMERCIAL BUILDING
- 6000 SQ. FT. ADDITION ADDED TO REAR OF FACILITY

What is the load for an addition to an existing building?

Step 1: Calculating VA per sq. ft.
Table 220.12; 220.16(B)
6000 sq. ft. x 3 VA = 18,000 VA

Step 2: Calculating continuous load
220.16(B); 215.2(A)(1)
18,000 VA x 125% = 22,500 VA

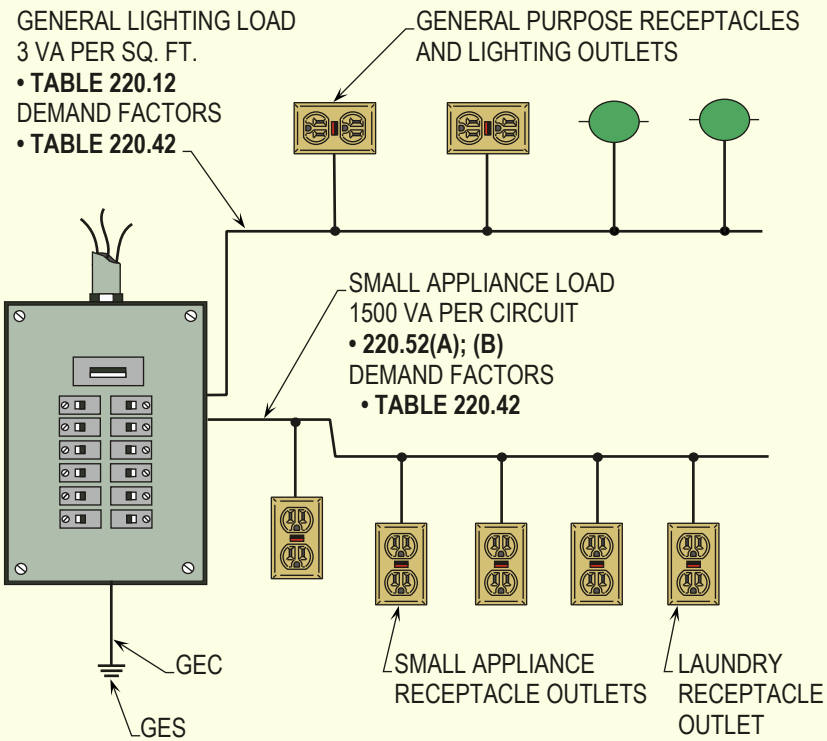
Step 3: Calculating # of outlets
220.14; 220.16(B)
90 x 180 VA = 16,200 VA

Step 4: Calculating continuous load for OCPD
220.16(B); 215.2(A)(1)
16,200 VA x 125% = 20,250 VA

Solution: The load is 22,500 VA, based on the larger calculation.

OTHER THAN DWELLING UNITS
220.16(B)

Purpose of Change: To relocate and renumber rules in **220.3(C)(2)** to **220.16(B)**.



What is the demand load for the general lighting load of a 3500 sq. ft. dwelling unit?

Step 1: Calculating the VA
Table 220.12
3500 sq. ft. x 3 VA = 10,500 VA

Step 2: Small appliance load
220.52(A)
1500 VA x 2 = 3,000 VA

Step 3: Laundry load
220.52(B)
1500 VA x 1 = 1,500 VA

Step 4: Total loads

General lighting load	=	10,500 VA
Small appliance load	=	3,000 VA
Laundry Load	=	1,500 VA
Total	**=**	**15,000 VA**

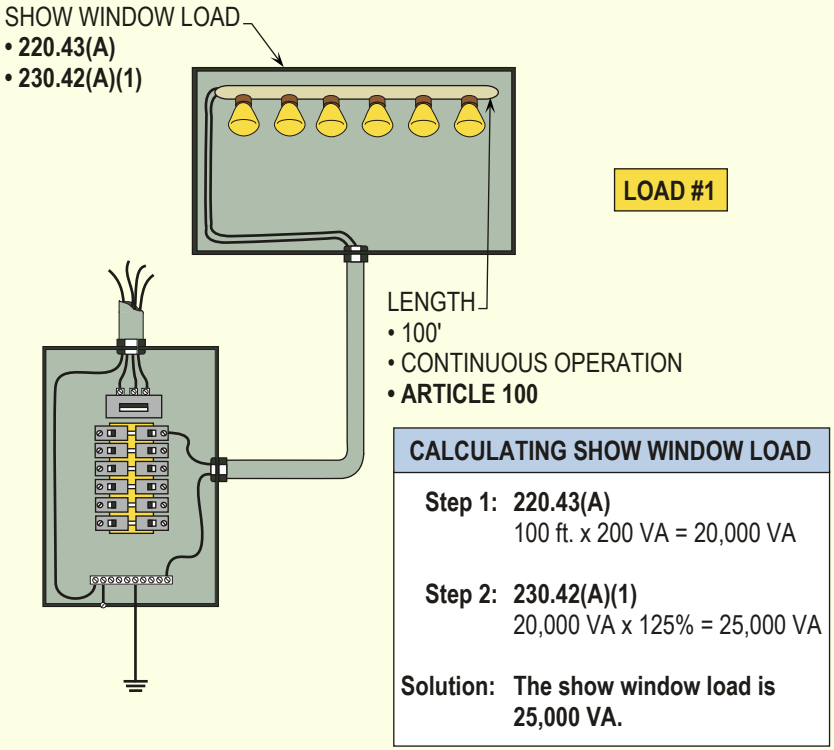
Step 5: Applying demand factors
Table 220.42

First 3000 VA x 100%	=	3,000 VA
Next 12,000 VA x 35%	=	4,200 VA
Total	**=**	**7,200 VA**

Solution: **Demand load 1 is 7200 volt amps.**

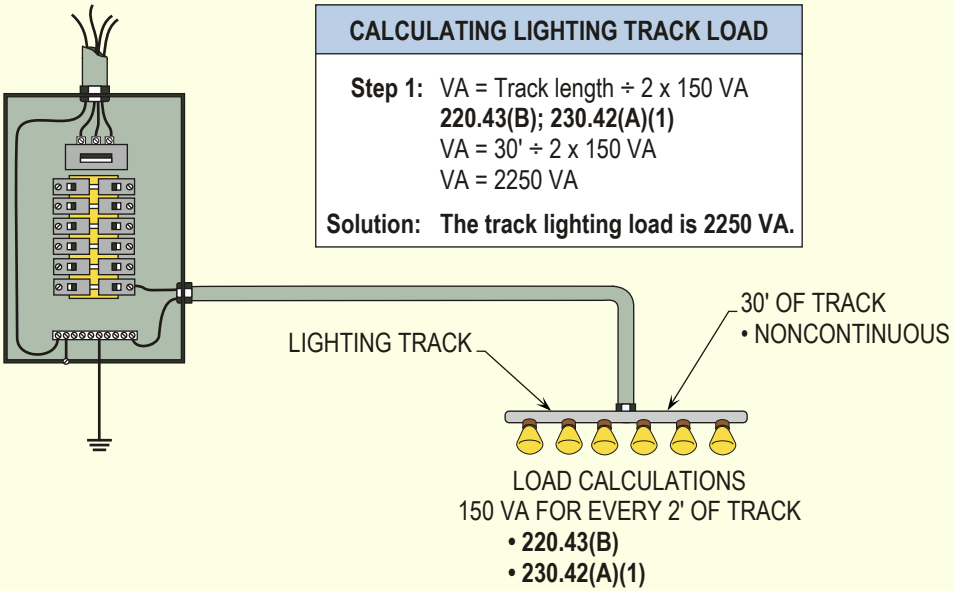
GENERAL LIGHTING
220.42; TABLE 220.42

Purpose of Change: To relocate and renumber rules in **Table 220.11** to **Table 220.42**.



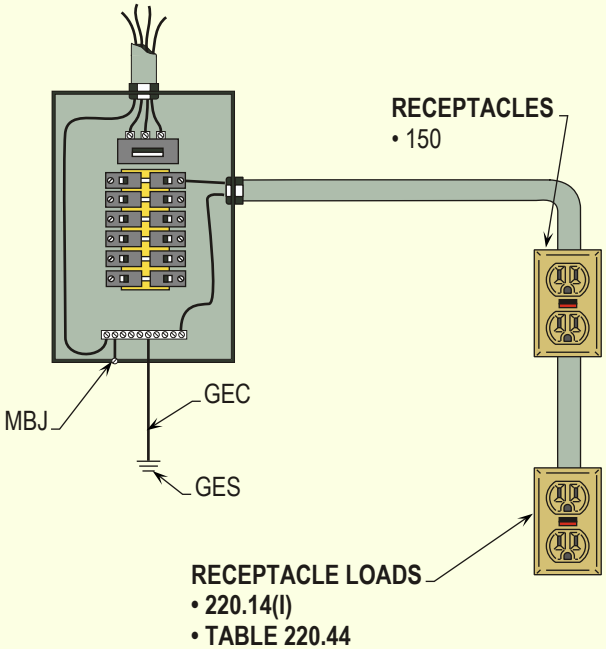
SHOW WINDOWS
220.43(A)

Purpose of Change: To relocate and renumber rules in **220.12(A)** to **220.43(A)**.



TRACK LIGHTING
220.43(B)

Purpose of Change: To relocate and renumber rules in **220.12(B)** to **220.43(B)**.



CALCULATING RECEPTACLE LOAD AND APPLYING DEMAND FACTORS

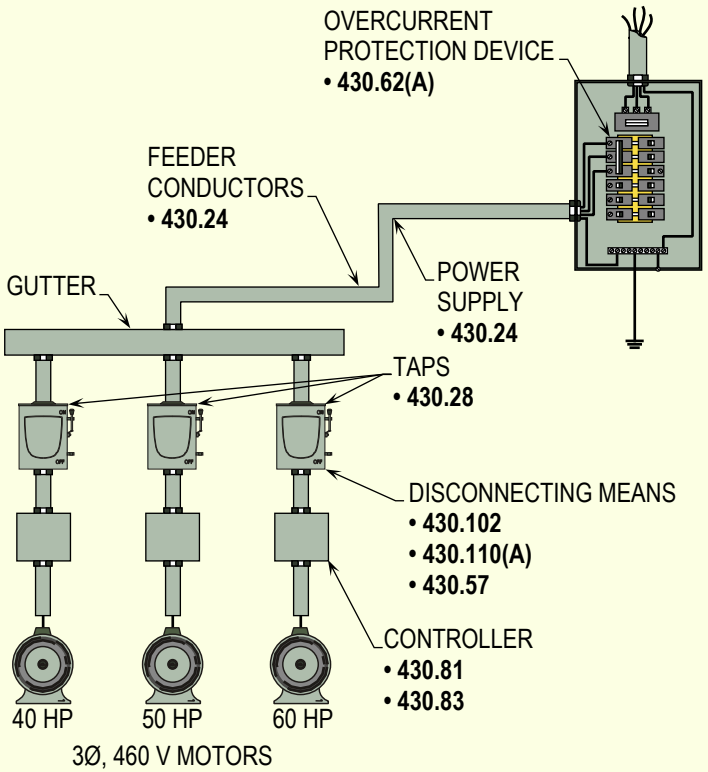
Step 1: Calculating VA
220.14(I); 230.42(A)(1)
150 x 180 VA = 27,000 VA

Step 2: Applying demand factors
Table 220.44
First 10,000 VA x 100% = 10,000 VA
Next 17,000 VA x 50% = 8,500 VA
18,500 VA

Solution: **The demand load for the receptacles is 18,500 VA.**

RECEPTACLE LOADS – OTHER THAN DWELLING UNITS
220.44; TABLE 220.44

Purpose of Change: To relocate and renumber rules in **220.13** to **220.44**.



FINDING MOTOR LOAD

Step 1: Finding amperage
220.50; 430.6(A)(1); Table 430.250
40 HP = 52 A
50 HP = 65 A
60 HP = 77 A

Step 2: Calculating amperage
430.24

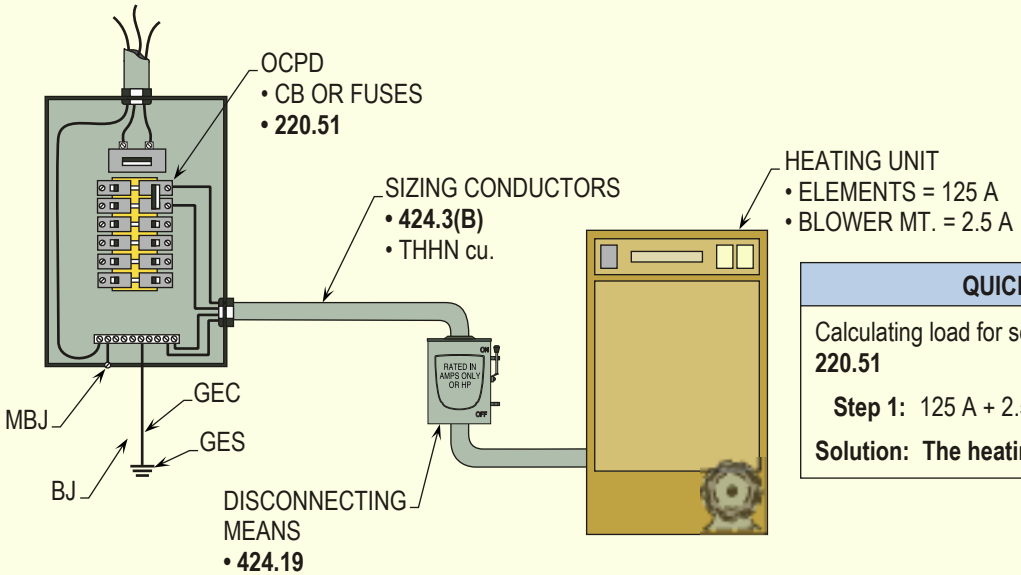
77 A x 125% =	96.25	A
	65	A
	52	A
Total load	**= 213.25**	**A**

Solution: **The motor load is 213.25 amps.**

Note: *See **Table 220.3**, which refers user to **Article 430**.*

MOTORS
220.50

Purpose of Change: To relocate and renumber rules in **220.14** to **220.50**.



QUICK CALC

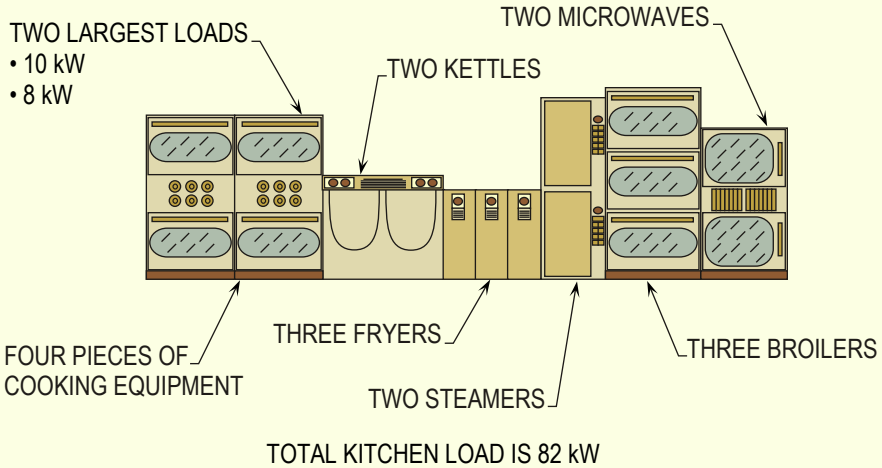
Calculating load for service
220.51

Step 1: 125 A + 2.5 A x 100% = 127.5 A

Solution: The heating load is 127.5 amps.

FIXED ELECTRIC SPACE HEATING
220.51

Purpose of Change: To relocate and renumber rules in **220.15** to **220.51**.



CALCULATING LOAD FOR COOKING EQUIPMENT

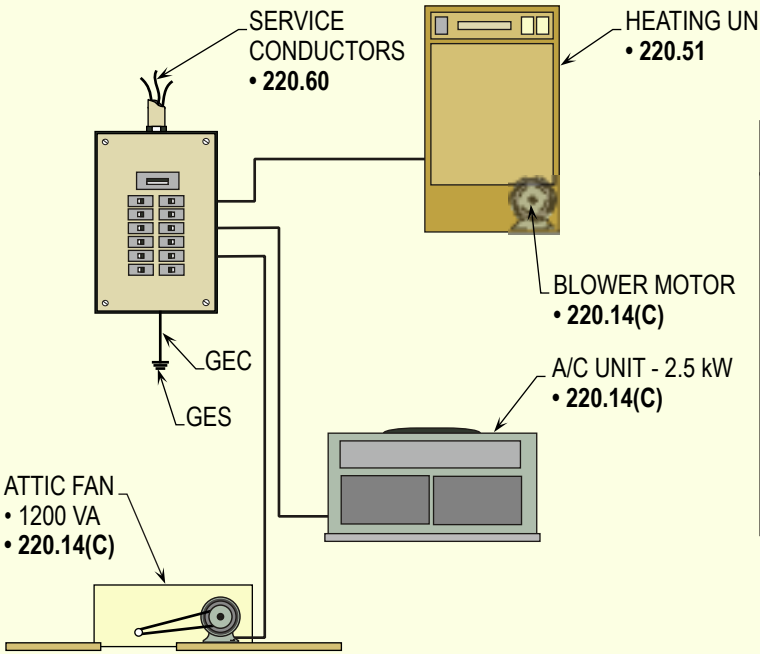
Step 1: Calculating percentage
Table 220.56
16 pieces allowed 65%

Step 2: Applying demand factors
Table 220.56; 220.56
82 kW x 65% = 53.3 kVA

Solution: **The demand load of 53.3 kVA is greater than the two largest loads of 18 kVA.**

KITCHEN EQUIPMENT – OTHER THAN DWELLING UNIT(S)
220.56; TABLE 220.56

Purpose of Change: To relocate and renumber rules in **Table 220.20** to **Table 220.56**.



COMPUTING THE LARGEST LOAD - 220.60

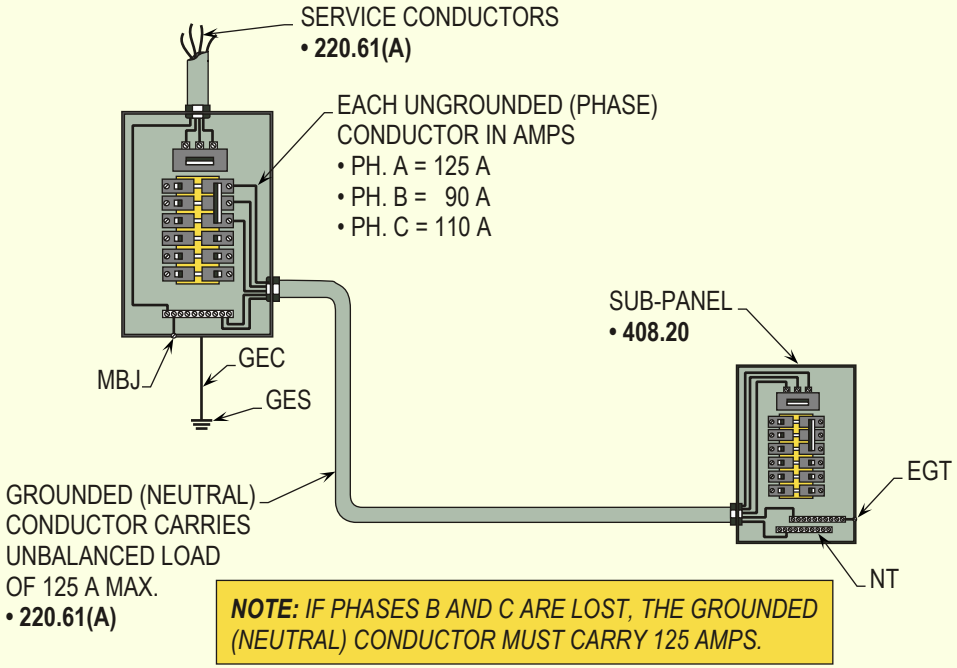
Step 1: Attic fan
1200 VA x 100% = 1200 VA
Heating load
20 kW x 1000 x 100% = 20,000 VA
A/C load
2.5 kW x 1000 x 100% = 2500 VA

Solution: The largest load is 20,000 VA

Note: *The attic fan and A/C load can be dropped.*

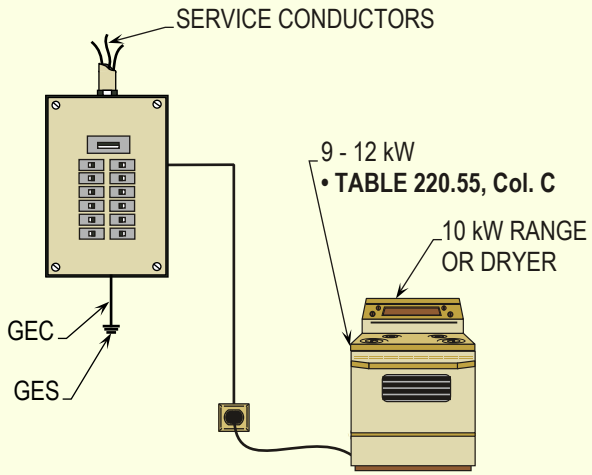
NONCOINCIDENT LOADS
220.60

Purpose of Change: To relocate and renumber rules in **220.21** to **220.60**.



BASIC CALCULATION
220.61(A)

Purpose of Change: To relocate and renumber rules in **220.22** to **220.61(A).**



What is the demand load for a 10 kW range?
Finding demand load for a range in VA.

Step 1: Finding Demand Load.
Column C to Table 220.55
1 - 10 kW = 8 kW

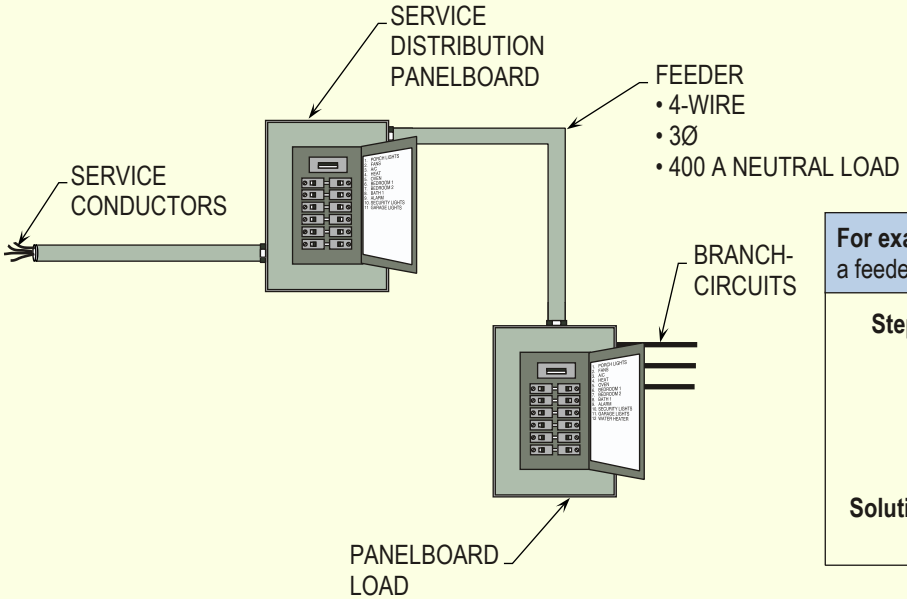
Step 2: Finding VA (k = 1000)
8 kVA x 1000 = 8000 VA

Step 3: Finding neutral load
220.61(B)(1)
8000 VA x 70% = 5600 VA

Solution: **The neutral load is 5600 VA.**

PERMITTED REDUCTIONS
220.61(B)(1)

Purpose of Change: To relocate and renumber revised rules in **220.22** to **220.61(B)(1)**.



For example: What is the demand neutral load for a feeder-circuit with a resistive load of 400 amps?

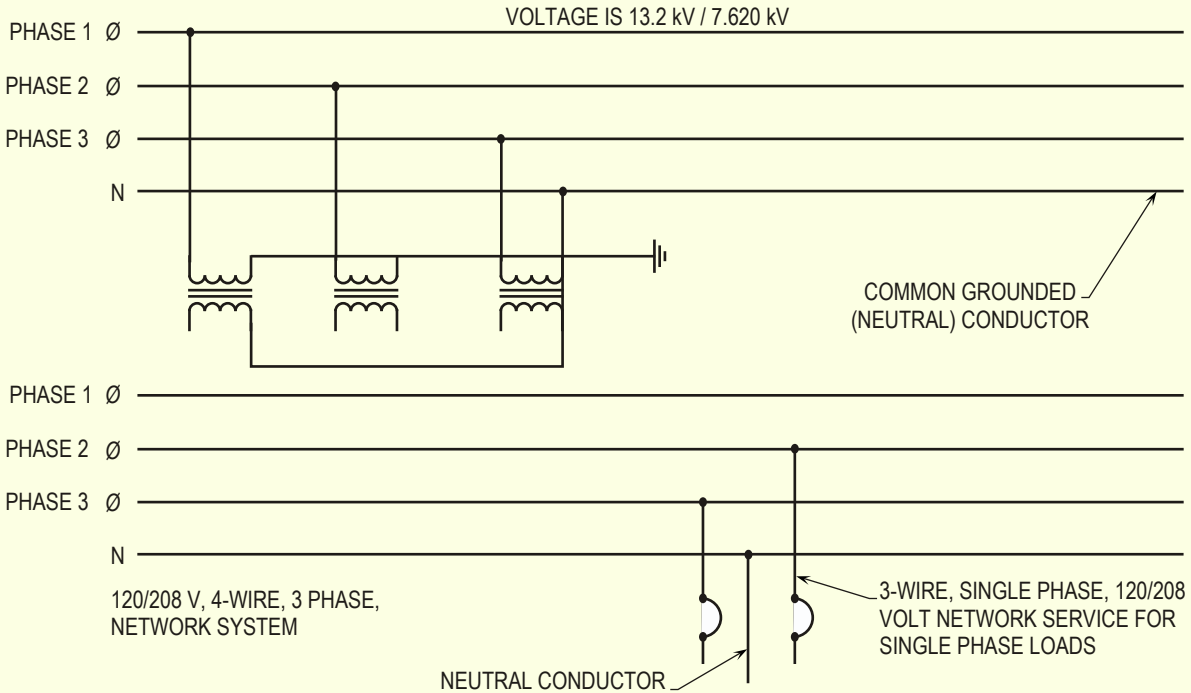
Step 1: Calculating neutral load
220.61(B)(2); 310.15(B)(4)(c)

First 200 A x 100%	= 200 A
Remaining 200 A x 70%	= 140 A
Total load	= 340 A

Solution: **The demand resistive neutral load is 340 amps.**

PERMITTED REDUCTIONS
220.61(B)(2)

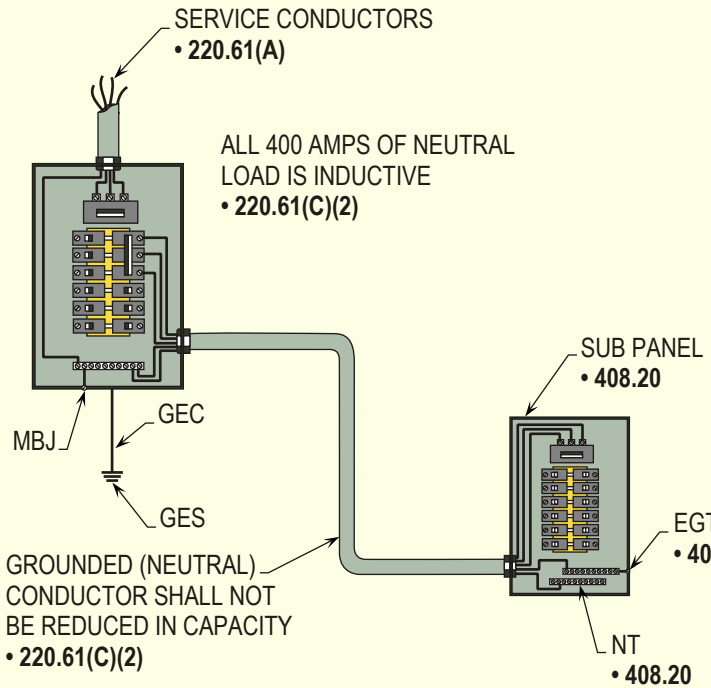
Purpose of Change: To relocate and renumber revised rules in **220.22** to **220.61(B)(2)**.



NOTE: *NEUTRAL OF 3-WIRE, 3Ø SYSTEM MUST BE AS LONG AS THE UNGROUNDED (PHASE) CONDUCTORS.*

PROHIBITED REDUCTIONS
220.61(C)(1)

Purpose of Change: To relocate and renumber revised rules in **220.22** to **220.61(C)(1)**.



PROHIBITED REDUCTIONS
220.61(C)(2)

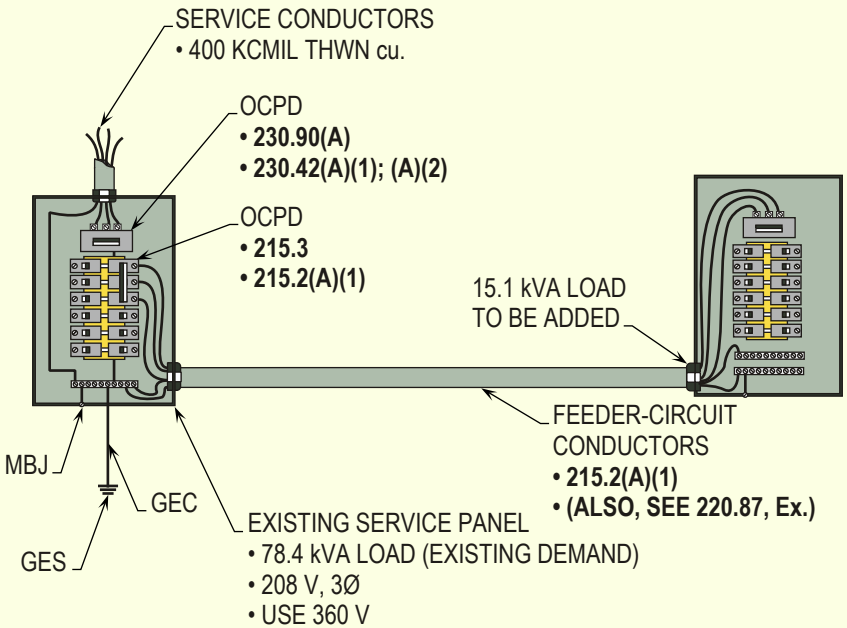
For example: What is the neutral load for a feeder-circuit with an inductive load of 400 amps?

Step 1: Calculating neutral load
220.61(C)(2); 310.15(B)(4)(c)

First 200 A x 100%	= 200 A
Remaining 200 A x 100%	= 200 A
Total load	= 400 A

Solution: **The total inductive neutral load is 400 amps.**

Purpose of Change: To relocate and renumber revised rules in **220.22** to **220.61(C)(2)**.



CALCULATING LOAD IN AMPS

Step 1: Finding demand
220.87
Maximum demand = 78.4 kVA

Step 2: Calculating existing demand
78.4 kVA x 125% = 98 kVA

Step 3: Calculating total kVA
230.42(A)(1)
98 kVA + 15.1 kVA = 113.1 kVA

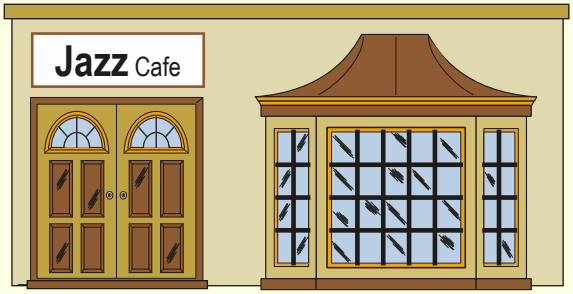
Step 4: Calculating amperage
Table 310.16; 220.87
400 KCMIL THWN copper = 335 A
113.1 kVA x 1,000 = 113,100 VA
113,100 VA ÷ 208 x 1.732 = 314 A
314 A is less than 335 A

Solution: **The 15.1 kVA demand load can be applied to the existing service without upgrading the elements.**

DETERMINING EXISTING LOADS
220.87

Purpose of Change: To relocate and renumber rules in **220.35** to **220.87**.

RESTAURANT



GIVEN LOADS			
Lighting Loads	=	16,450	VA
Receptacle Loads	=	15,300	VA
Special Loads	=	95,015	VA
Heating or A/C Loads	=	40,000	VA
Motor Loads	=	6,809.9	VA

CALCULATING LOAD IN VA

Calculating total VA
220.88

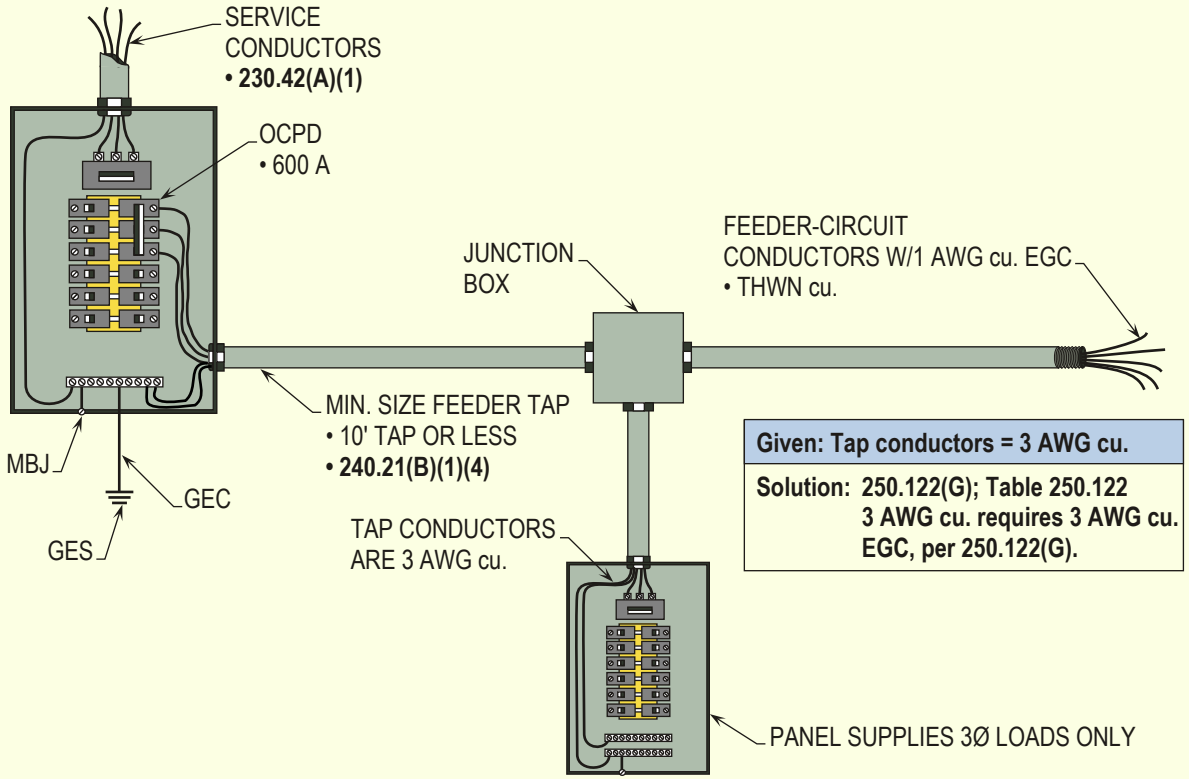
Lighting loads	=	16,450	VA
Receptacle loads	=	15,300	VA
Special loads	=	95,015	VA
Heating or A/C loads	=	40,000	VA
Motor loads	=	6,809.9	VA
Total Loads	**=**	**173,574.9**	**VA**

Applying demand factors
Table 220.88
Demand load = VA x demand factor
Demand load = 173,574.9 VA x 80%
Demand Load = 138,860 VA

Solution: The demand load in VA for the restaurant is 138,860 VA.

NEW RESTAURANTS
220.88

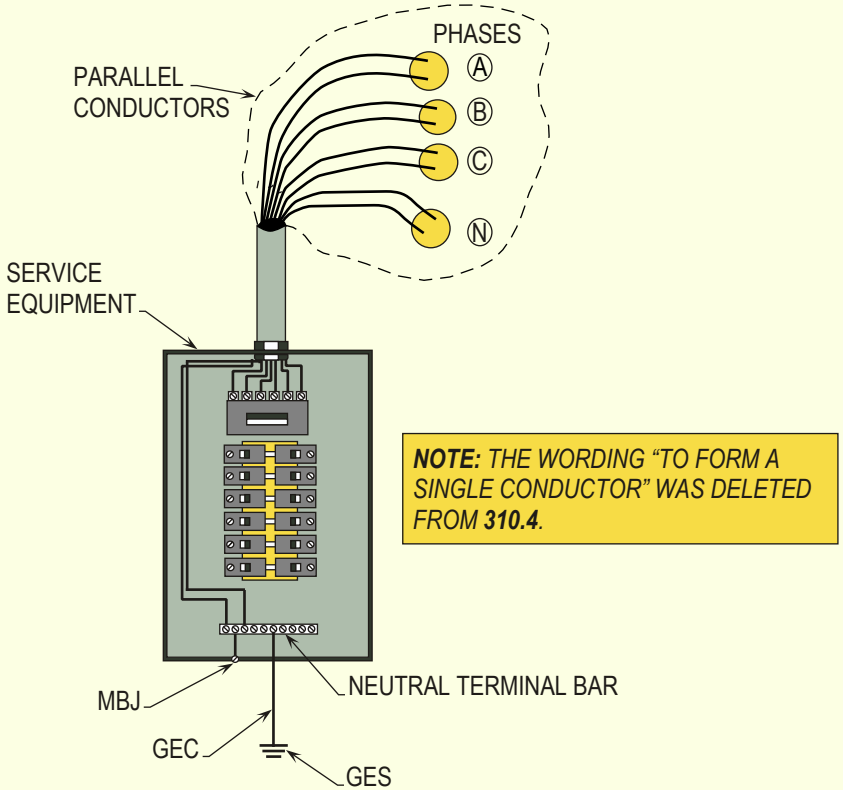
Purpose of Change: To relocate and renumber rules in **220.36** to **220.88**.



Given: Tap conductors = 3 AWG cu.
Solution: 250.122(G); Table 250.122 3 AWG cu. requires 3 AWG cu. EGC, per 250.122(G).

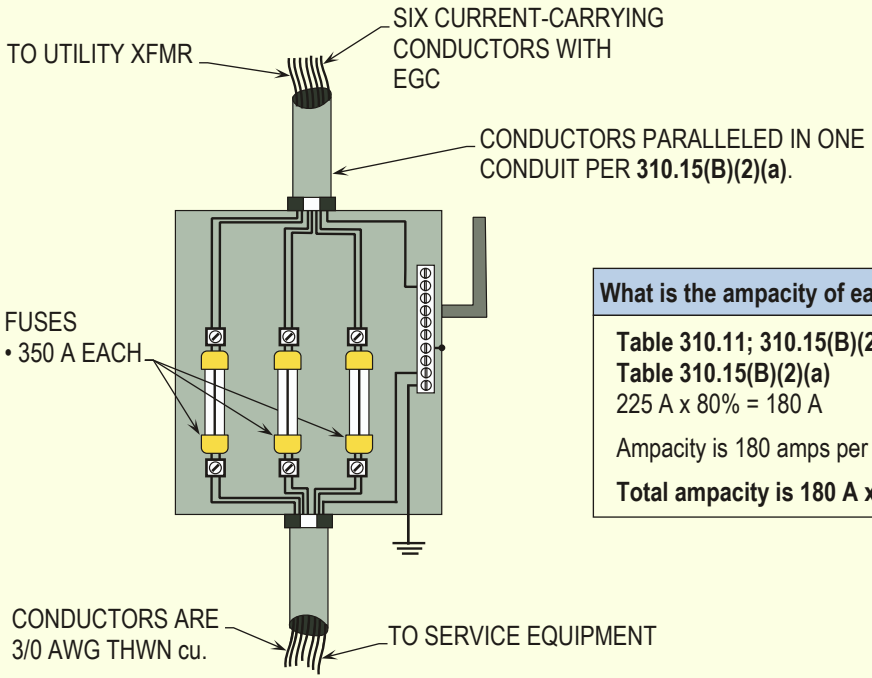
FEEDER TAPS
250.122(G)

Purpose of Change: To clarify the appropriate procedure for sizing EGC's run with feeder taps.



CONDUCTORS IN PARALLEL
310.4

Purpose of Change: To delete a parenthetical phrase that was confusing to users.



What is the ampacity of each conductor?

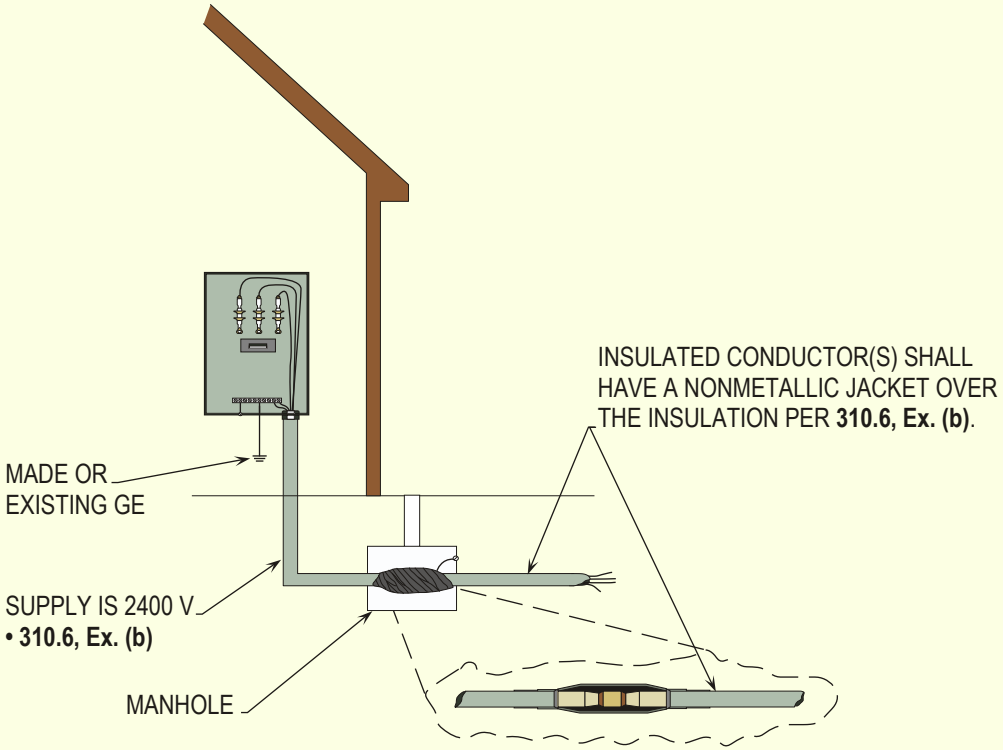
Table 310.11; 310.15(B)(2)(a);
Table 310.15(B)(2)(a)
225 A x 80% = 180 A

Ampacity is 180 amps per phase.

Total ampacity is 180 A x 2 = 360 A

ADJUSTMENT FACTORS
310.15(B)(2)(a)

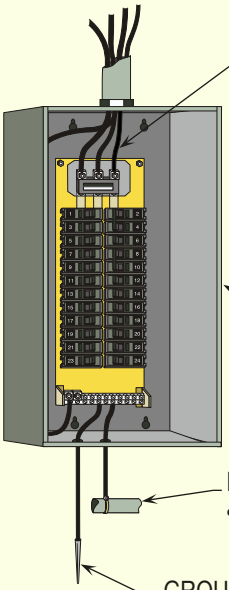
Purpose of Change: To clarify each current-carrying conductor for paralleled conductors shall be counted as a current-carrying conductor.



SHIELDING
310.6, Ex. (b)

Purpose of Change: To delete confusing wording and change operating voltage.

NOTE: *AMPACITIES OF CONDUCTORS CAN BE DETERMINED BY USING ENGINEERING SUPERVISION PER* ***310.15(C)****.*



NONCONTINUOUS LOAD = 95 A
CONTINUOUS LOAD = 98 A
• 3 CURRENT-CARRYING CONDUCTORS

SERVICE PANEL
• **230.42(A)**
• **230.90**

MWP
• **250.52(A)(1)**

GROUND ROD
• SUPPLEMENTARY
• **250.53(D)(2)**

What size OCPD and THWN cu. conductors are required to supply loads per 310.15(A)(1) and 310.15(B)?

Step 1: Calculating load
230.90; 230.42(A)(1)

95 A x 100%	=	95 A
98 A x 125%	=	122.5 A
Total load = 217.5	=	218 A

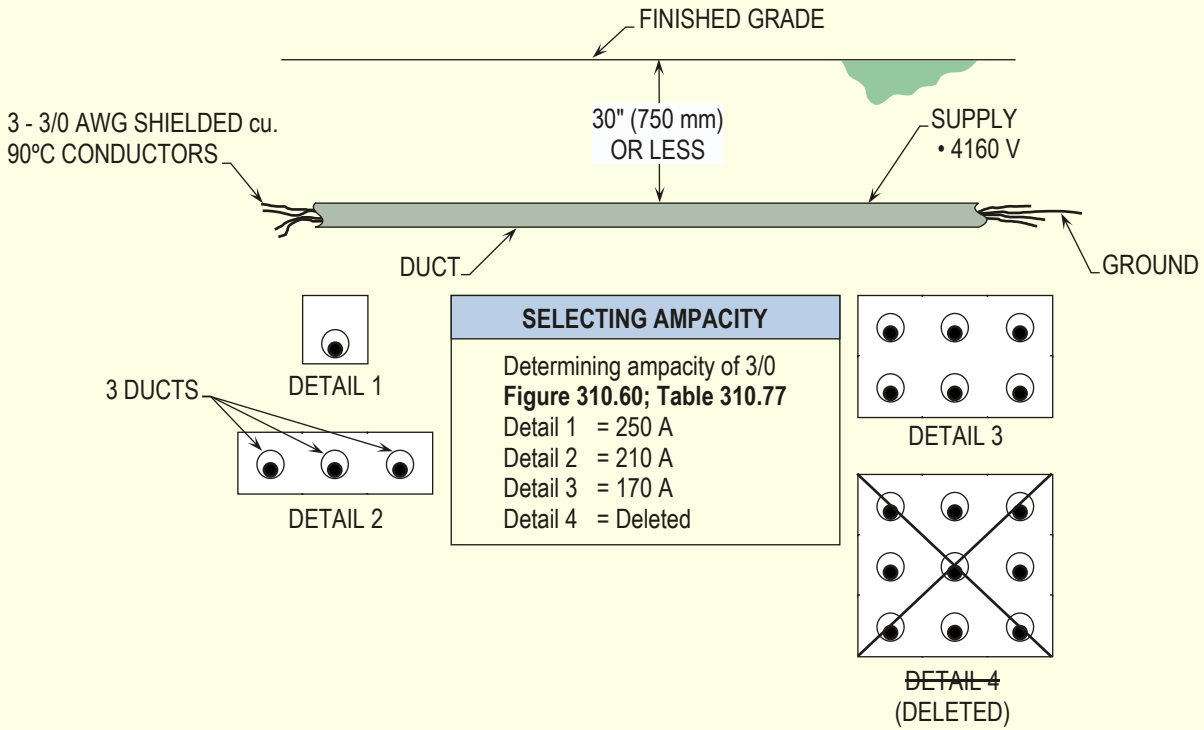
Step 2: Finding OCPD (based on load)
230.90; 240.4; 240.6(A)
218 A requires 225 A OCPD

Step 3: Finding conductors (based on load and OCPD)
310.15(A)(1); Table 310.16
225 A requires 4/0 AWG THWN

Solution: 4/0 AWG THWN cu. conductors and a 225 amp OCPD is required.

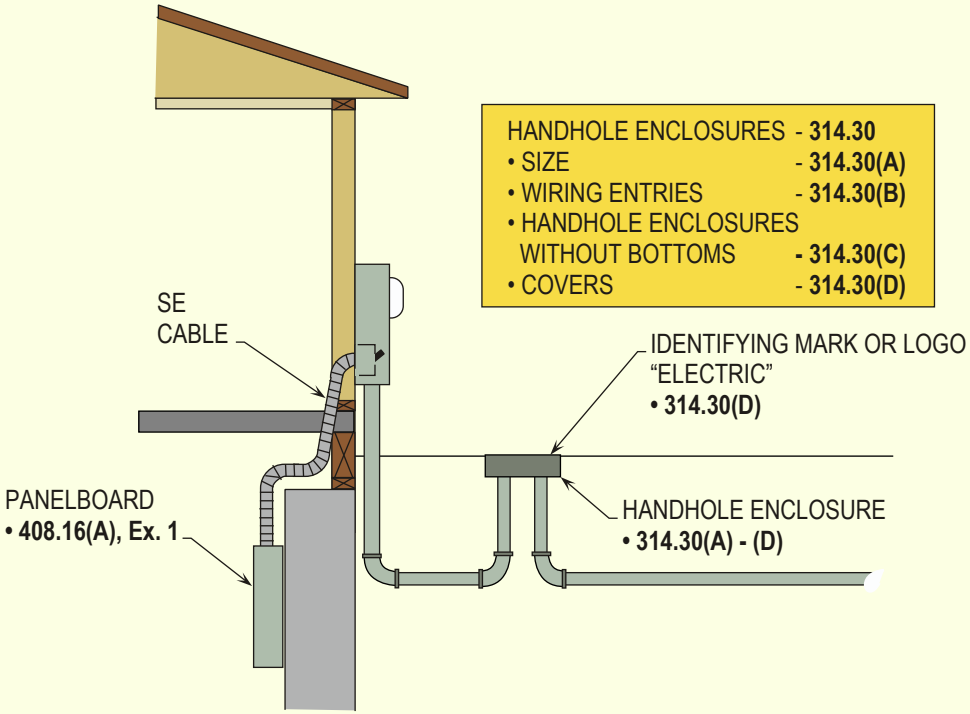
TABLES OR ENGINEERING SUPERVISION
310.15(A)(1)

Purpose of Change: To verify that **Tables 310.16** through **310.19** can be used by designers, installers, and inspectors without the need to employ an electrical engineer.



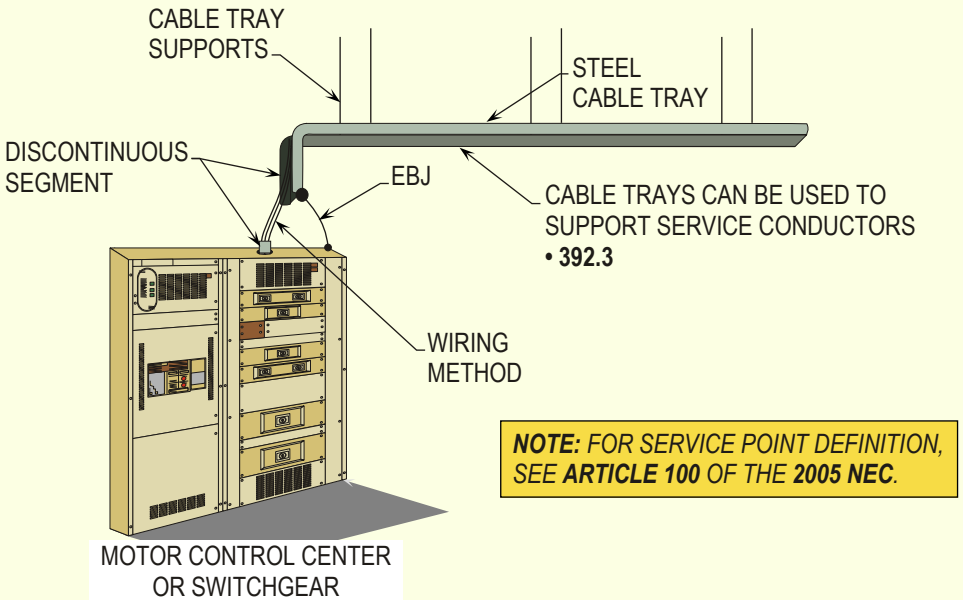
ELECTRICAL DUCTS IN FIGURE 310.60
310.60(C)(3)

Purpose of Change: To delete Detail 4 in **Figure 310.60** because it was seldom used and could only be calculated by engineering supervision.



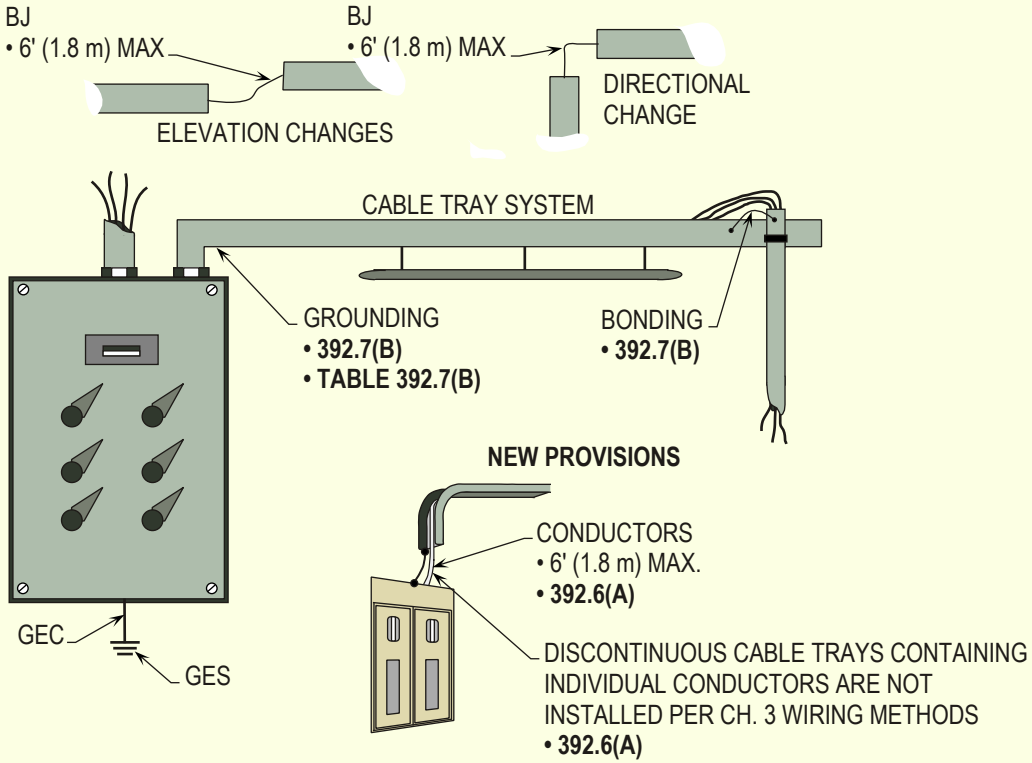
HANDHOLE ENCLOSURES
314.30(A) THRU (D)

Purpose of Change: To add a section pertaining to requirements governing handhole enclosures.



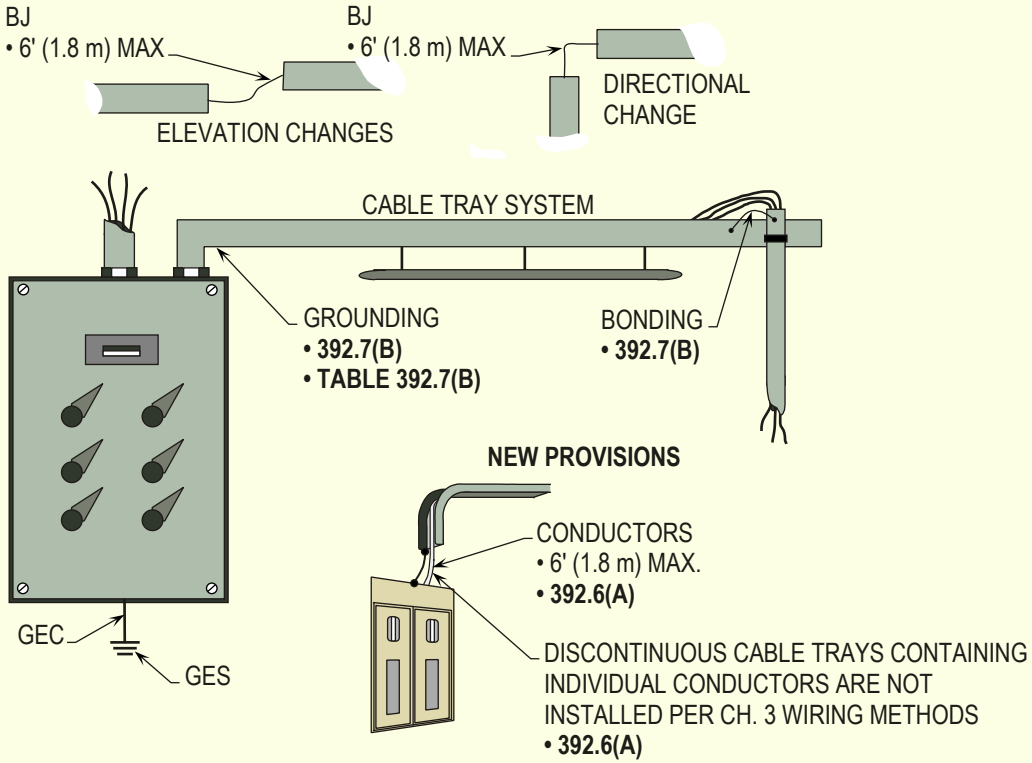
USES PERMITTED
392.3

Purpose of Change: To replace the word “services” with “service conductors” to correlate with **392.2** of the **2005 NEC**.



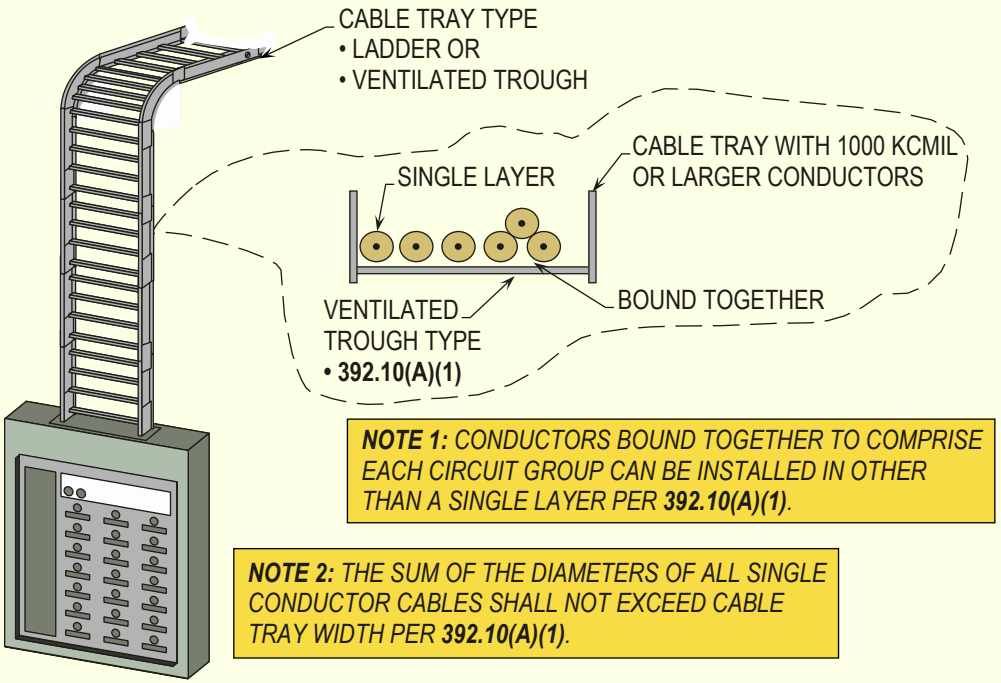
METALLIC CABLE TRAYS
392.7(A)

Purpose of Change: To reference only **250.96** instead of the entire Article.



METALLIC CABLE TRAYS
392.7(A)

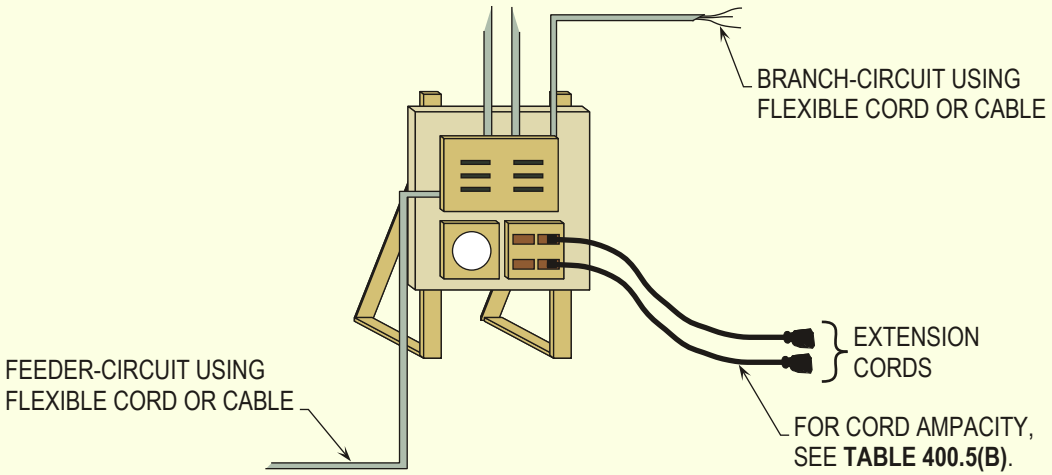
Purpose of Change: To reference only **250.96** instead of the entire Article.



LADDER OR VENTILATED TROUGH CABLE TRAYS
392.10(A)(1)

Purpose of Change: To outline the requirements for installing single conductor and multiconductor cables in a single layer in a cable tray system.

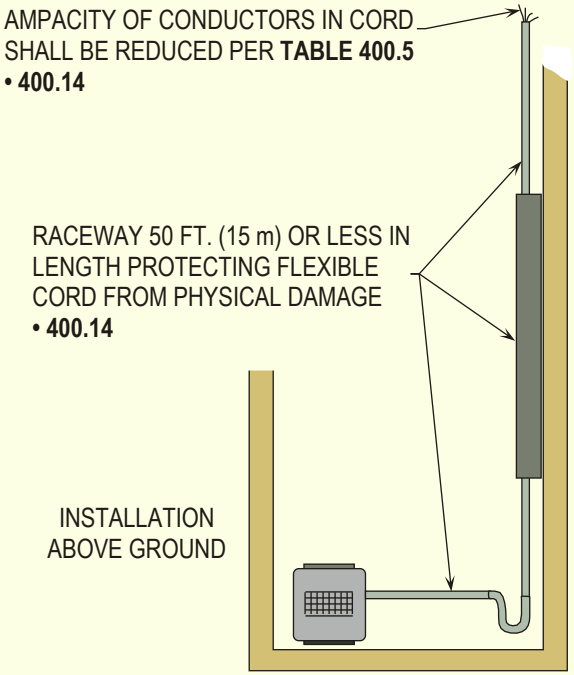
TEMPORARY INSTALLATIONS PER **ARTICLE 590**



NOTE: *WHERE CORDS ARE RUN IN AMBIENT TEMPERATURES EXCEEDING 86ºF (30ºC), CORRECTION FACTORS PER* ***TABLE 310.16*** *SHALL BE APPLIED, BASED ON SUCH TEMPERATURES PER* ***400.5****.*

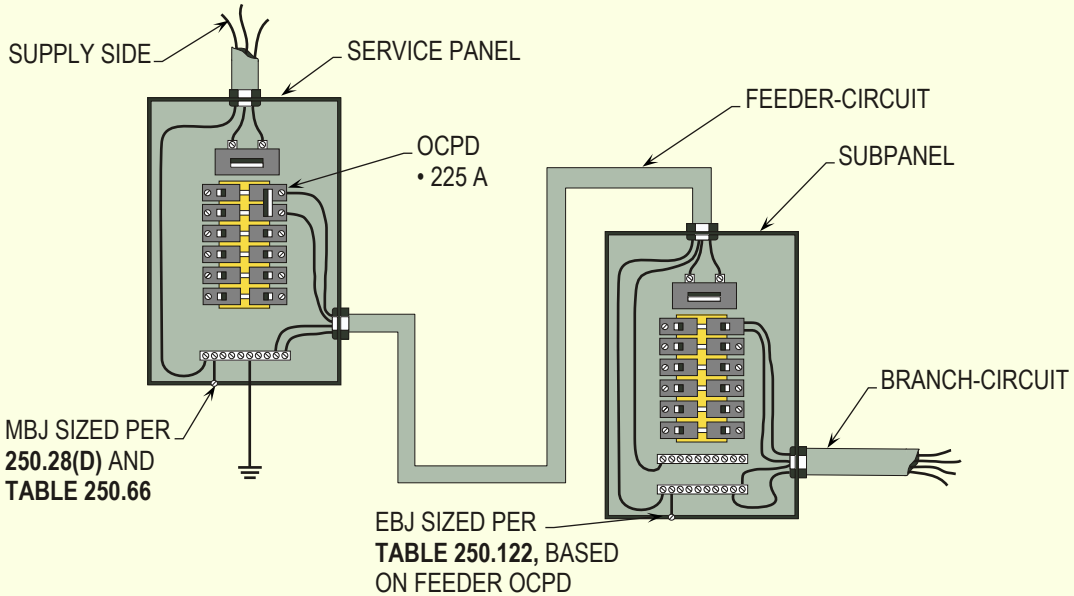
AMPACITIES FOR FLEXIBLE CORDS AND CABLES
400.5

Purpose of Change: To refer the user to Tables for selecting ampacities and correction factors where there are excessive temperatures surrounding the cords and cables.



PROTECTION FROM DAMAGE
400.14

Purpose of Change: To recognize the use of a raceway to protect a flexible cord from physical damage.



Example: Supply 400 kcmil cu. **Solution: A 400 kcmil cu. requires a 1/0 AWG MBJ.**	**Example:** Feeder OCPD 225 A **Solution: A 225 A CB requires a 4 AWG EBJ.**

USED AS SERVICE EQUIPMENT
408.3(C)

Purpose of Change: To clarify the procedure for sizing the main bonding jumper and the equipment bonding jumper on the supply and load side of the electrical system.

DISCONNECTING MEANS
• **409.30**

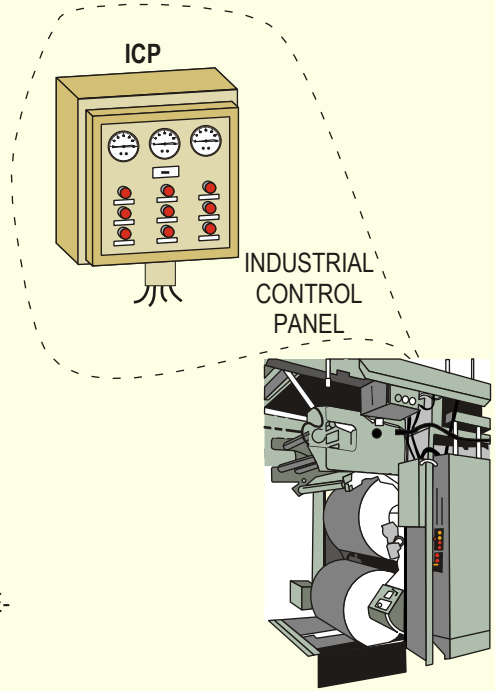
ENCLOSURES
• **490.100**

MARKING
• **409.110**

WIRING SPACE
(GENERAL) IN ICP's
• **409.104(A)**

WIRE BENDING
SPACE
• **409.104(B)**

WHERE USED AS SERVICE-
ENTRANCE EQUIPMENT
• **430.108**



GROUNDING RULES
• **409.60**

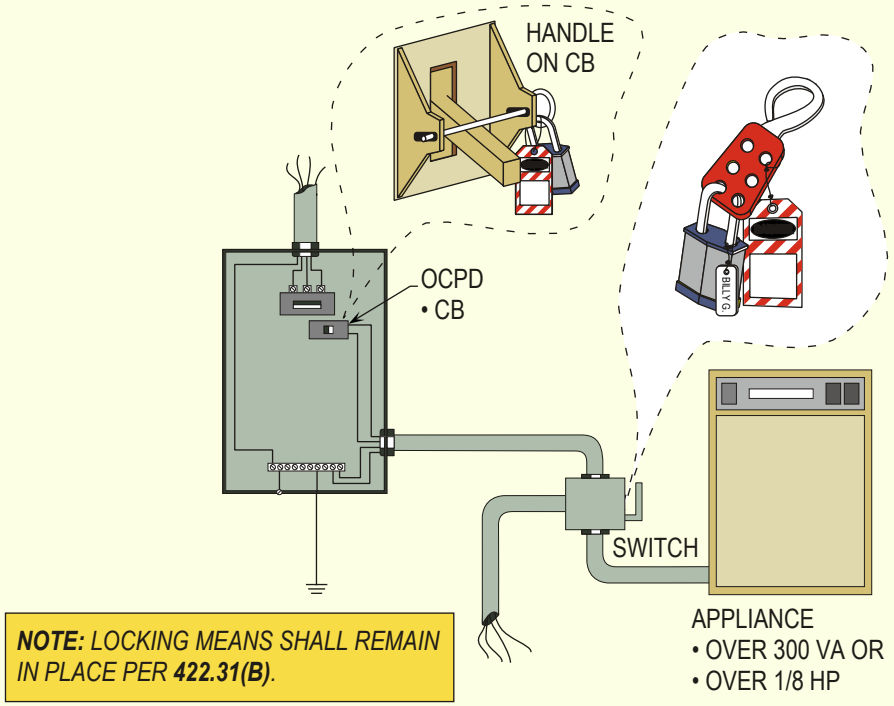
BUSBARS AND CONDUCTORS
• **409.102**

SUPPORT & ARRANGEMENT
• **409.102(A)**

PHASE ARRANGEMENT
• **409.102(B)**

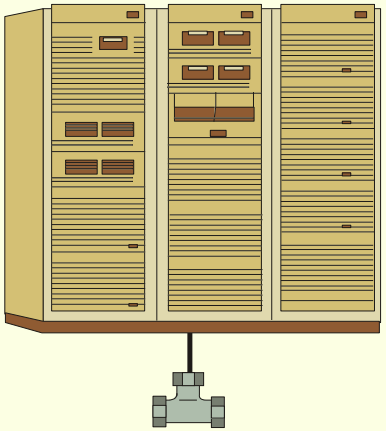
CONSTRUCTION SPECIFICATIONS
409.100 THRU 409.110

Purpose of Change: To outline the construction specifications for installing industrial control panels operating on electrical systems rated 600 volts or less.



APPLIANCES RATED OVER 300 VOLT-AMPERES OR 1/8 HORSEPOWER
422.31(B)

Purpose of Change: New wording was added, and as a result, a provision for the locking means to remain in place is required.

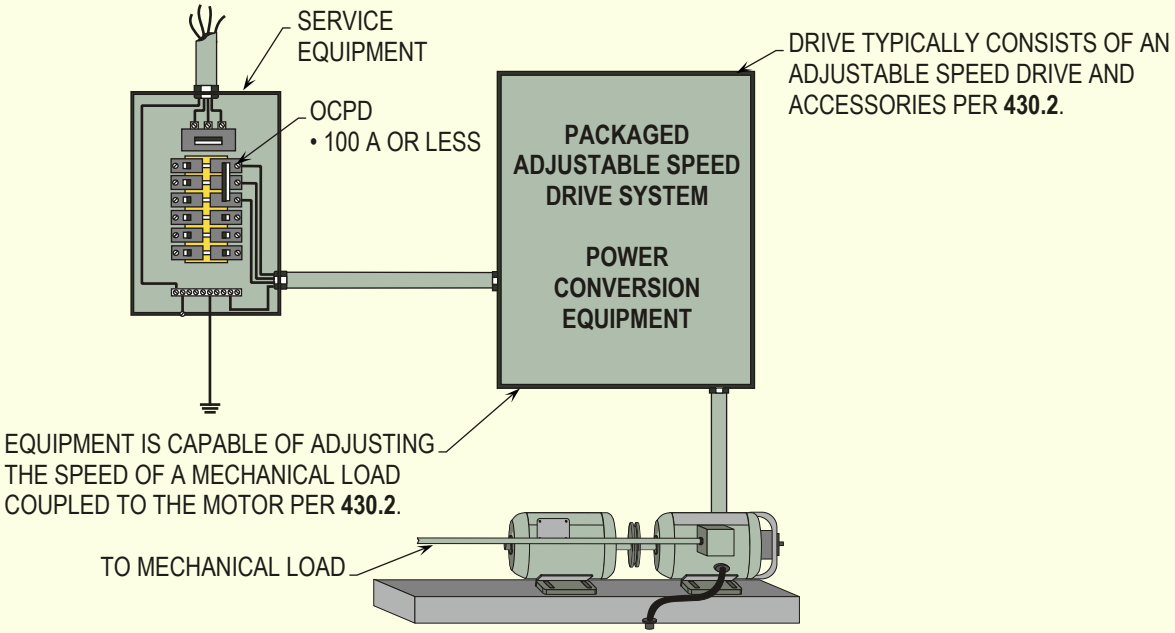


ADJUSTABLE SPEED DRIVE PER 430.2 IS A COMBINATION OF:

- THE POWER CONVERTER
- MOTOR
- AUXILIARY DEVICES (MOTOR)
  - ENCODERS
  - TACHOMETERS
  - THERMAL SWITCHES AND DETECTORS
  - AIR BLOWERS
  - HEATERS
  - VIBRATION SENSORS

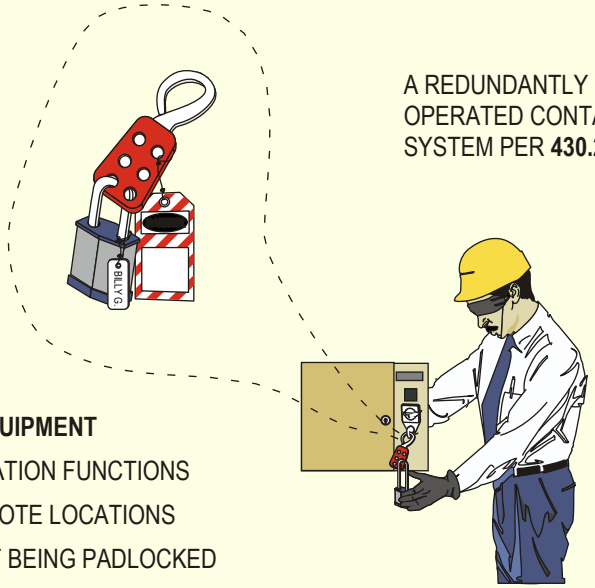
ADJUSTABLE SPEED DRIVE
430.2

Purpose of Change: To define an adjustable speed drive and its accessories.



ADJUSTABLE SPEED DRIVE SYSTEM
430.2

Purpose of Change: To define an adjustable speed drive system and its ability to speed control a mechanical load.



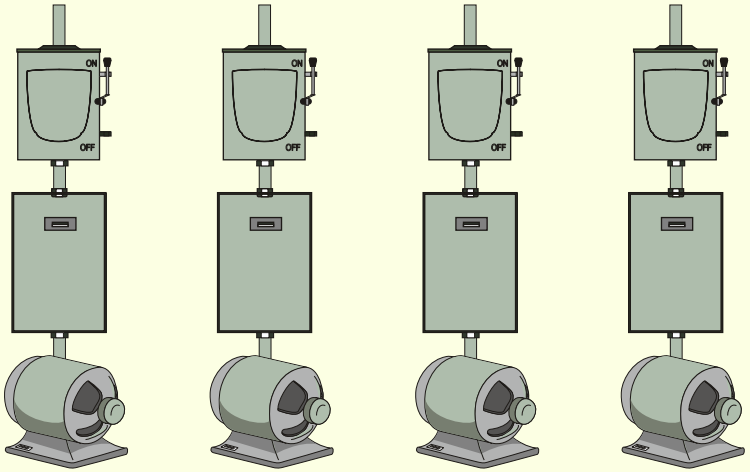
A REDUNDANTLY MONITORED, REMOTELY OPERATED CONTACTOR ISOLATING SYSTEM PER **430.2**.

SYSTEM ISOLATION EQUIPMENT

- CONTAINS DISCONNECTION/ISOLATION FUNCTIONS
- OPERATION FROM MULTIPLE REMOTE LOCATIONS
- LOCKOUT SWITCHES CAPABLE OF BEING PADLOCKED IN THE “OFF” (OPEN) POSITION

SYSTEM ISOLATION EQUIPMENT
430.2

Purpose of Change: To define what “system isolation equipment” is and how it can provide a service in a motor system.



15 HP, DC
1Ø, 240 V

2 HP, AC
1Ø, 208 V

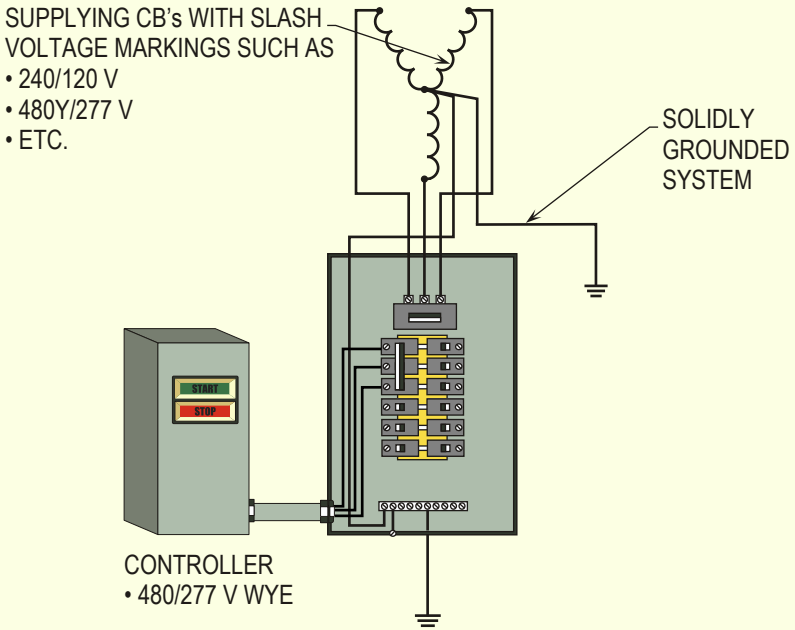
10 HP, AC
2Ø, 460 V

50 HP, AC
3Ø, 460 V

~~2002 NEC~~	**2005 NEC**		
~~TABLE 430.147~~	**TABLE 430.247**	15 HP, 1Ø, 240 V	FLC = 55 A
~~TABLE 430.148~~	**TABLE 430.248**	2 HP, 1Ø, 208 V	FLC = 13.2 A
~~TABLE 430.149~~	**TABLE 430.249**	10 HP, 2Ø, 460 V	FLC = 12 A
~~TABLE 430.150~~	**TABLE 430.250**	50 HP, 3Ø, 460 V	FLC = 65 A

TABLE VALUES
430.6(A)(1)

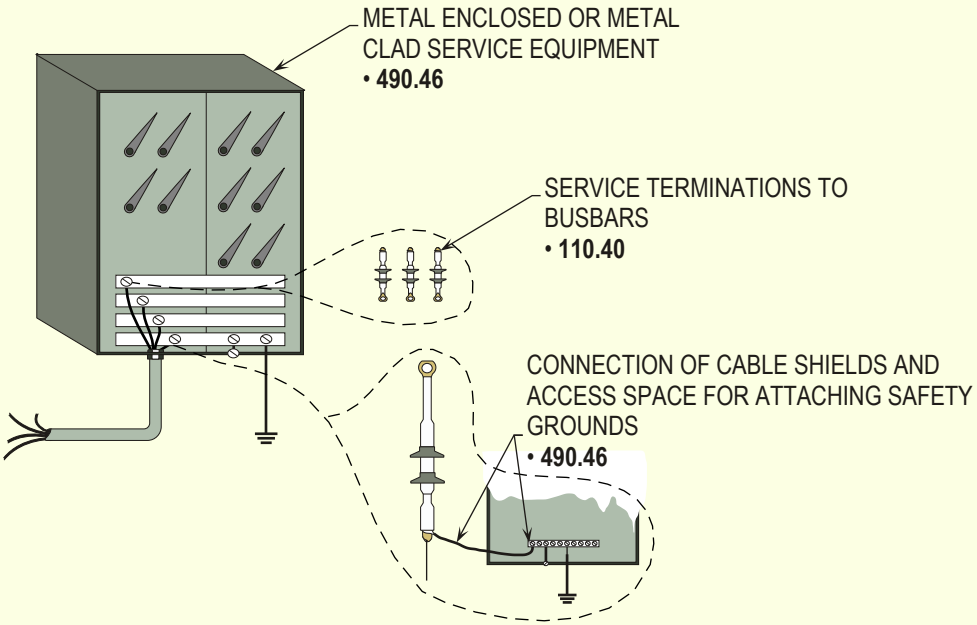
Purpose of Change: To add the new number of **Tables 430.247** through **430.250** to **430.6(A)** of the **2005 NEC**.



NOTE: *CONTROLLERS WITH A SLASH RATING SHALL BE USED ONLY ON A SOLIDLY GROUNDED SYSTEM PER* ***430.83(E)****.*

VOLTAGE RATING
430.83(E)

Purpose of Change: To make it clear that controllers with a slash rating shall be used, in a solidly grounded system only.



METAL ENCLOSED AND METAL CLAD SERVICE EQUPMENT
490.46

Purpose of Change: To provide requirements pertaining to service equipment rated over 600 volts.

Applying NFPA 70-E to R&D Equipment

Applying the 2004 NFPA 70E to R&D Equipment

November 30, 2005

Lloyd B. Gordon
Los Alamos National Laboratory

Outline

- History of NFPA 70E
- Requirements for Safe Electrical Work
- Qualified Worker
- Modes of Work
- Types of Electrical Equipment
- Voltage, Current, Power, and Energy
- PPE for Shock Protection
  - facility sources
  - R&D equipment
- PPE for Arc Flash Protection
  - facility sources
  - R&D equipment
- Summary

Lecture Objectives

- to summarize the requirements in NFPA 70E - Standard for Electrical Safety in the Workplace
- to understand requirements for electrical shock protection for facility and R&D electrical work
- to understand requirements for arc flash protection for facility work
- to apply arc flash protection principles to work on R&D equipment

Key Issues

- In most cases, the first PPE that a facility worker requires is for arc flash protection.
- In most cases, the first PPE that an R&D workers requires is for shock protection.
- If an R&D worker keeps all body parts outside of the arc flash and shock boundaries they may NOT need PPE (exception may be inadvertent movement).
- Thus, performing testing and measurement with properly rated instruments may NOT require PPE.
- R&D workers seldom approach R&D equipment within the arc flash boundary EVEN for verification.

History of NFPA 70E

- 1979 - first issued, only *Part I - Installation Safety Requirements*
- 1981 - 2nd edition - added *Part II - Safety-Related Work Practices*
- 1983 - 3rd edition - added *Part III - Safety-Related Maintenance Requirements*
- 1988 - 4th edition - minor changes
- 1995 - 5th edition
  - Part I - updated to 1993 NEC
  - Part II - introduced:
    - limits of approach
    - flash protection boundary
    - electrically safe work condition
    - requirement for PIC for LOTO

History of NFPA 70E - cont

- 2000 - 6th edition
  - Part I - updated to 1999 NEC
  - Part II - Focused on arc flash protection requirements, including:
    - incident energy concepts
    - methods to establish Flash Protection Boundaries
    - the proper use of PPE
    - added charts for PPE for common tasks
  - added Part IV - Safety Requirements for Special Equipment

History of NFPA 70E - cont

- 2004 - 7th edition
  - reorganized to emphasize safe work practices
    - Part I - Safety-Related Work Practices
    - Part II - Safety-Related Maintenance Requirements
    - Part III - Safety Requirements for Special Equipment
    - Part IV - Installation Safety Requirements
  - style changed
  - energized electrical work is last alternative
  - Energized Electrical Work Permit added
  - Part IV - Installation Safety Requirements updated to 2002 NEC

Some History of DOE and LANL Electrical Safety

- Qualified Worker must have training
  - DOE - Jan 1998
  - LANL - Dec 1996
  - (NEC - 2002)
  - (NFPA 70E - 2004)
- De-energized condition preferred
  - DOE - Jan 1998
  - LANL - Dec 1996
  - (NFPA 70E - 2004)
- Energized Electrical Work Permit
  - LANL - SEWP - Dec 1996
  - (NFPA 70E - 2004)

Requirements for Safe Electrical Work

- Principles of protection of the worker
- Qualification
- Energized work vs De-energized
- Testing and Measurement
- Energized electrical work
- PPE

Principles of Protection of the Worker

- Assure qualification of the worker
- If at all possible, plan electrical maintenance, testing, and operations to avoid possible exposure to electrical hazards
- Design electrical equipment to minimize the electrical hazards
- Conduct shock and arc flash hazard analyses for each task where there is potential for exposure and injury
- Select PPE that is suitable for the maximum possible exposure to electrical energy

Qualified Worker

- The user/operator
- The electrical worker

A User or Operator of Electrical Equipment

- When approved engineering controls protect the user, qualification for electrical hazards are generally not required
- Engineering controls assurance such as NRTL listing, and installation according to the NEC protect us at home and in the public
- Engineering controls assurance such as NRTL listing and ESO approval protect the user/operator in the R&D lab

OSHA Requirements for Electrical Worker Qualification

- Only qualified persons may
  - work on energized electric circuits
  - may perform tests on electric circuits and equipment
  - may work on or with exposed lines or parts of equipment
  - may work in areas containing unguarded, uninsulated energized lines or parts of equipment operating at 50 V or more

OSHA Requirements for Qualification

- A qualified employee must be trained and competent to:
  - distinguish live parts from other parts of equipment
  - determine the nominal voltage of live parts
  - know the minimum approach distances to live parts
  - know what precautions to take to work safely, including:
    - how to carry out lockout/tagout procedures
    - how to manage and maintain a safe work area
    - how to use protective grounds
  - know how to use PPE
  - know how to use insulating and shielding materials
  - know how to use insulated tools

Modes of Work (LANL)

- Mode 1 - De-energized
- Mode 1.5 - Achieving De-energized
- Mode 2 - Testing and Measurement
- Mode 3 - Energized Work

Mode 1.5 was created this year to reinforce to workers, and to better manage the process of energy removal and verification.

Types of Electrical Equipment

- 60 Hz power distribution
- dc power supplies
- capacitors
- inductors
- batteries
- pulsed systems
- rf systems (> 3000 Hz)

NOTE: NFPA 70E clearly applies to 60 Hz power distribution, but does not immediately apply to other forms of electrical energy

Voltage, Current, Power, and Energy

- voltage - nominal operating voltage, rms or dc, in Volts (V)
- current - both operating current and fault current, in Amps (A)
- power = V x I, in Watts (W), may be instantaneously very high during faults
- energy = P x t, in Joules (J)

Current is the primary parameter in electrocution, energy is the primary parameter in arc flash burns

General Principles of PPE

- PPE is the last line of defense
- PPE is usually a single point failure
- PPE cannot prevent all injuries, but PPE lessens the impact of an arc flash
- The selection of PPE should be a balance between the calculated estimated incident energy exposure and the work activity being performed while meeting the following concerns:
  - In all cases, provide enough protection to prevent injury from shock, and to prevent a second degree burn
  - Avoid having more protection than is needed and the consequent risk of heat stress, poor visibility, oxygen deprivation, and limited body movement.

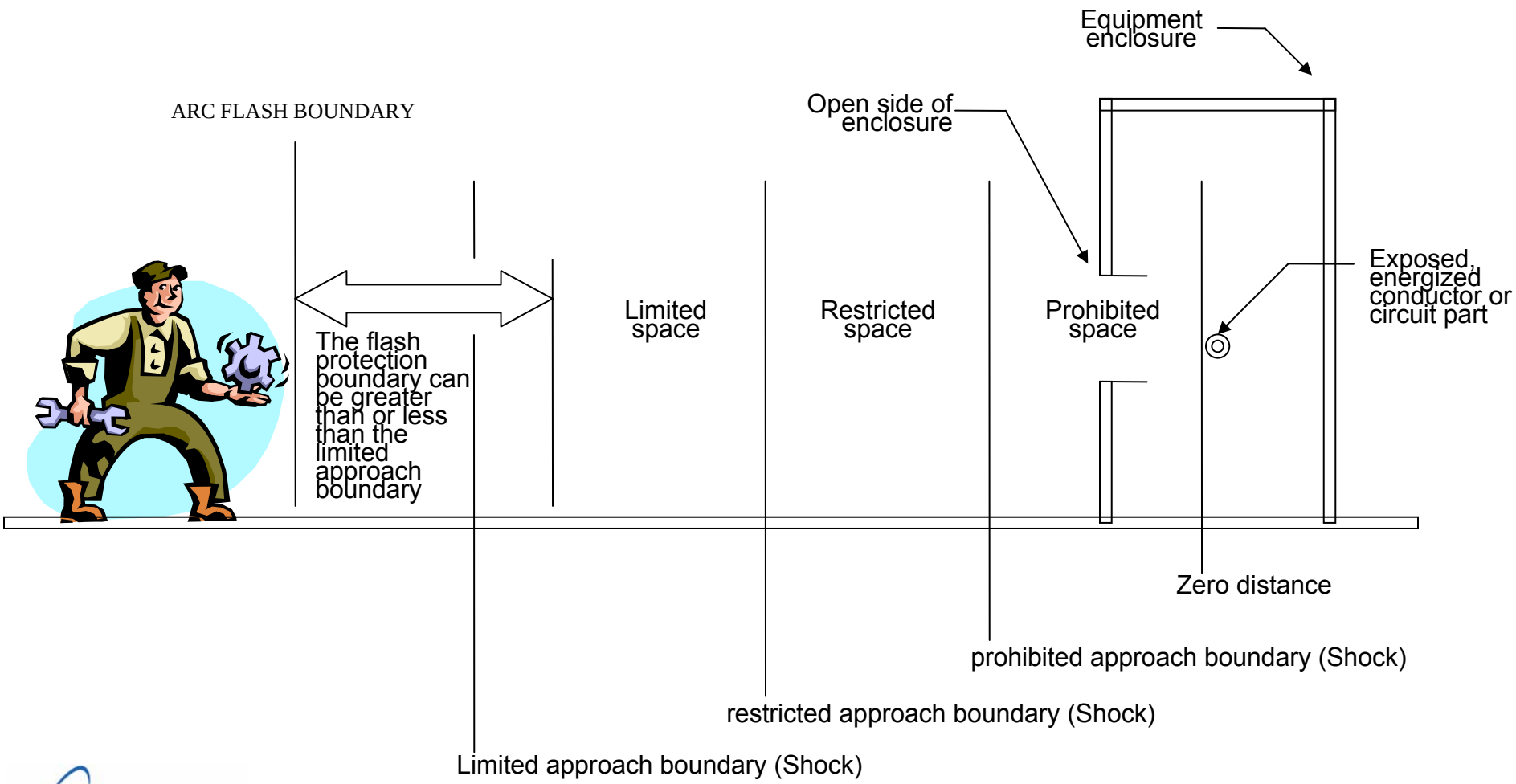
PPE for Shock Protection

- Boundaries in NFPA 70E
- PPE for shock protection
- R&D issues

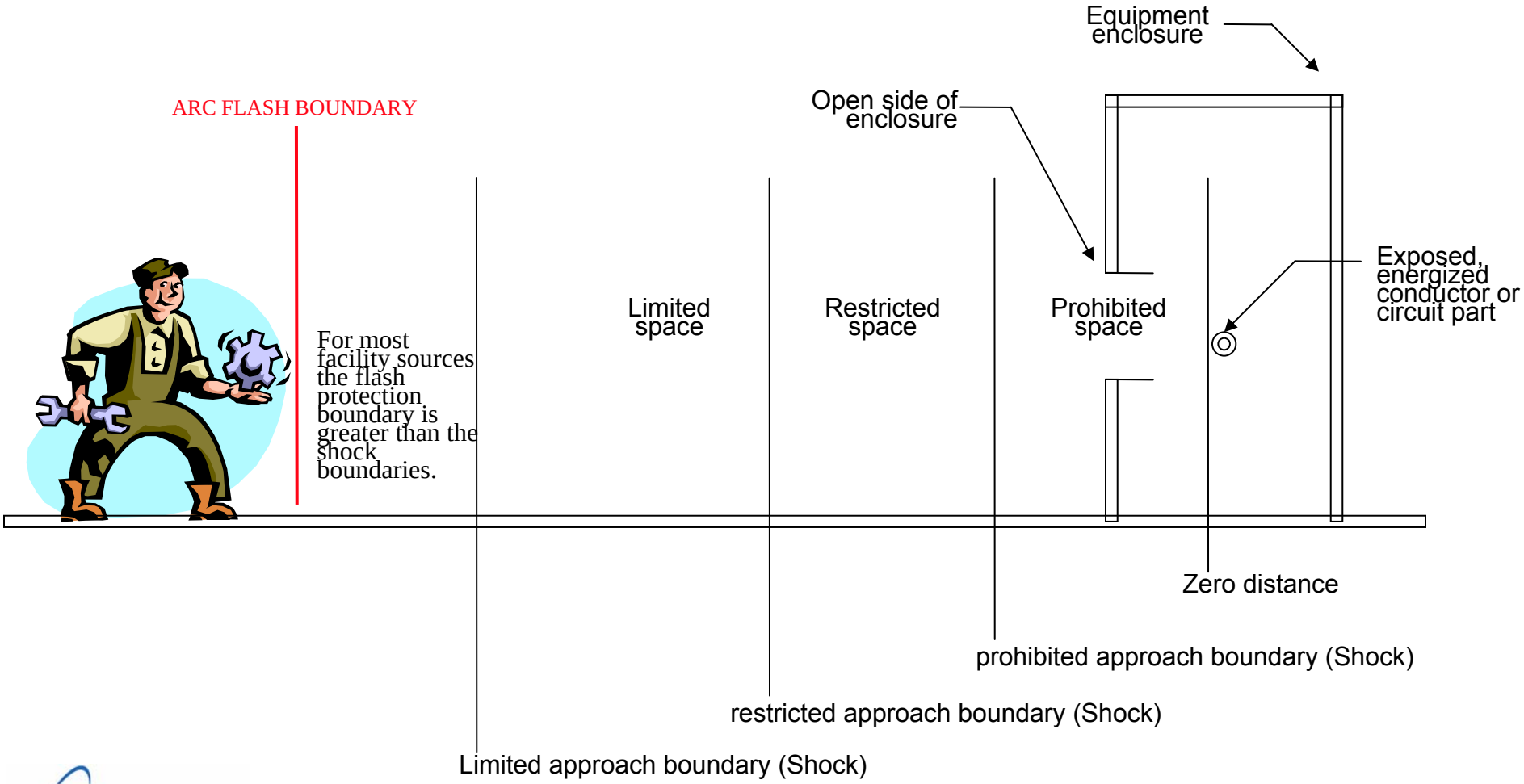
Boundaries in NFPA 70E

- Limited Approach Boundary
  - a distance from an exposed live part within which a shock hazard exists
- Restricted Approach Boundary
  - a distance from an exposed live part within which there is an increased risk of shock, due to electrical arc over (through the air to the person) combined with inadvertent movement
- Prohibited Approach Boundary
  - a distance from an exposed live part within which work is considered the same as making contact with the live part
- Flash Protection Boundary
  - a distance from exposed live parts within which a person could receive a second degree burn if an electrical arc flash were to occur

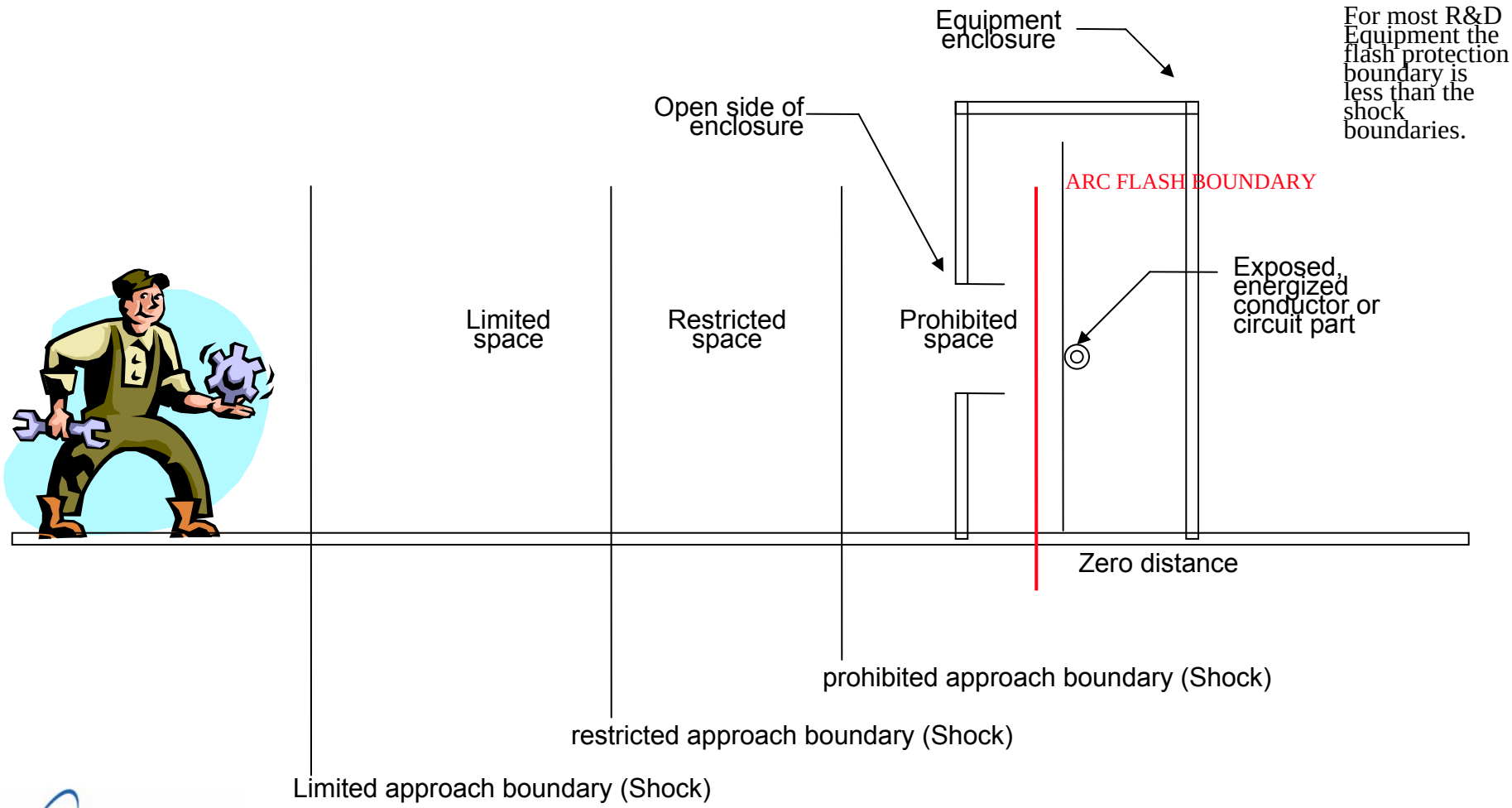
Boundaries for Electric Hazards



Boundaries for Facility Electric Hazards



Boundaries for R&D Electric Hazards



Rules for Working Outside the Limited Approach Boundary

- When one or more unqualified persons are working at or close to the Limited Approach Boundary, the designated PIC of the work space where the electrical hazard exists shall:
  - advise the unqualified person(s) of the electrical hazard, and
  - warn him/her to stay outside of the Limited Approach Boundary

Rules for Entering the Limited Space

- Between the Limited Approach Boundary and the Restricted Approach Boundary
- A shock hazard exists
- Qualified person may enter
- Unqualified person may enter only if continually escorted by a qualified person

Rules for Entering the Restricted Space

- Between the Restricted Approach Boundary and the Prohibited Approach Boundary
- An increased risk of shock
- Qualified person may enter and must
  - have a plan that is documented and approved by authorized management
  - use appropriate PPE for inadvertent contact that is rated for voltage and energy
  - be certain that no unprotected part of the body enters the Prohibited Space
  - Minimize risk from inadvertent movement by keeping as much of the body out of the Restricted Space as possible
- Unqualified person is NOT allowed under any circumstance

Rules for Entering the Prohibited Space

- Same as making contact with the energized part(s)
- Qualified person must:
  - (1) Have specified training to work on energized conductors or circuit parts
  - (2) Have a documented plan justifying the need to work that close
  - (3) Perform a risk analysis
  - (4) Have (2) and (3) approved by authorized management
  - (5) Use PPE appropriate for direct contact, that is rated for voltage and energy
- Unqualified person is NOT allowed under any circumstance

Rules for Entering Flash Protection Boundary

- The Flash Protection Boundary must be established prior to work through proper analysis and PPE must be appropriately chosen
- Methods of analysis include:
  - using the Hazard/Risk Category Classifications, if appropriate NFPA 70E Table 130.7(C)(9)(a)
  - using the two part method
  - using the NFPA 70E methods for calculations of the flash protection boundary and incident energy
  - using the IEEE methods for selecting protective clothing and PPE
- Qualified persons must:
  - determine the flash protection boundary
  - be trained to use the appropriate PPE
  - use the appropriate PPE
- Unqualified persons must:
  - wear appropriate PPE
  - be under close supervision of a qualified person

Rules for Boundaries - Summary

- Limited Space
  - qualified person may enter - caution
  - unqualified person must be continuously accompanied
- Restricted Space
  - qualified person must wear appropriate PPE for shock
  - unqualified person may NOT enter
- Prohibited Space
  - qualified person must wear appropriate PPE for direct contact
  - unqualified person may NOT enter
- Flash Protection Boundary
  - qualified person must determine Flash Protection Boundary and use appropriate PPE
  - unqualified person must wear appropriate PPE and be under close supervision

Exposure to Electrical Hazards

- **Exposed** - 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.
- **Working on** (live parts) - Coming in contact with live parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the PPE a person is wearing. Note: Being in the Prohibited Space is the same as Working On
- **Working Near** (live parts) - Any activity inside a Limited Approach Boundary (i.e., activity in the Limited or Restricted Space

Shock Boundaries Notes

- See NFPA 70E Table 130.2(C) for voltages above 121 kV
- See NFPA 70E Table 130.2(C) for column (2) Limited Approach Boundary for Exposed Movable Conductor
- Some values are rounded up for simplicity
- Highest power distribution voltage in Los Alamos county is 115 kV

Shock Boundaries

Nominal System Voltage, Phase to Phase	Limited Approach Boundary, Exposed Fixed Circuit Part	Restricted Approach Boundary	Prohibited Approach Boundary
< 50 V	not specified	not specified	not specified
50 to 300 V	1 m	Avoid contact	Avoid contact
301 to 750 V	1 m	30 cm	2.5 cm
751 V to 15 kV	1.5 m	66 cm	18 cm
15.1 kV to 36 kV	1.8 m	0.8 m	25 cm
36.1 kV to 46 kV	2.4 m	0.84 m	43 cm
46.1 kV to 72.5 kV	2.4 m	1 m	63 cm
72.6 kV to 121 kV	2.4 m	1 m	0.8 m

Shock Boundaries for DC

- NFPA 70E Shock Boundaries are based on air breakdown (arc over) plus allowance for inadvertent movement
- the same principles can be applied to DC
- Peak voltage of phase to phase voltage = 0.82 x phase to phase voltage
- Thus, to choose a DC value similar to AC phase to phase would be more conservative for air breakdown
- For simplicity ranges are simplified, conservative value is chosen
- This does NOT account for other hazards such as shrapnel from failing components (e.g., capacitors)
- Personnel should never enter into regions with DC above 150 kV

Proposed Shock Boundaries for DC

DC Voltage	Limited Approach Boundary, Exposed Fixed Circuit Part	Restricted Approach Boundary	Prohibited Approach Boundary
< 50 V	not specified	not specified	not specified
50 to 300 V	1 m	Avoid contact	Avoid contact
301 to 750 V	1 m	30 cm	2.5 cm
751 V to 15 kV	1.5 m	66 cm	18 cm
15.1 kV to 60 kV	2.4 m	1 m	63 cm
60.1 kV to 150 kV	3.0 m	1 m	1 m

R&D Issues for Shock Protection

- NFPA 70E does NOT account for electrical hazards other than those encountered in power systems
- DOE Electrical Safety Handbook and LANL Electrical Hazard Classification must be used
- If available shock current is less than 5 mA, injury from shock is minimal. Reflex action must be taken into account. Shock boundaries may NOT apply over 50 V.
- If available power in a conductor is greater than 1000 W, for voltages less than 50 V, burn injury must be considered and appropriate safe work practices and PPE must be determined. Shock boundaries MAY apply below 50 V.
- See current Electrical Hazard Classification

Basics of Arcs - initiation

- Arcs are formed when the voltage is high enough to break down a dielectric (electrical insulator) and current/energy is sufficient to fuel the arc, continuing to vaporize and ionize gas and solid material (both dielectric and conductor), or
- Arcs at lower voltages can also be initiated by direct contact between two conductors of different potential

Basics of Arcs - growth

- The arc grows as energy (current) continues to vaporize and ionize material, and the voltage sustains the “feeding” of the arc
- Arc energy (VxIxt) is converted to:
  - noise
  - expansion (pressure)
  - acceleration of parts
  - vaporization of metal and dielectrics (turning solids into gases)
  - ionization of subsequent gases (tearing the electrons off of the atoms
- An ionized gas (plasma) is an excellent conductor and continues to carry the current leading to rapid plasma expansion and further vaporization and ionization

Basics of Arcs - extinction - low voltage

- There is a voltage drop (a resistance) in an arc
- If the voltage is low (approximately less than 250 V), and the electrodes (the two conductors) spread apart the arc will break
- The hazard is local heat, some vaporized metal and ejected metal droplets
- PPE is typically to protect the eyes and hands
- If substantial energy is delivered, then shrapnel is a hazard
- Examples:
  - batteries
  - arc welders
  - magnet, electroplating, and filament supplies

Special problem - Inductance

- If there is substantial inductance (a large motor or a large magnet) the voltage can increase well beyond the normal operating level, as the magnetic field decays. This will continue to fuel a growing arc until the magnetic field energy is exhausted.
- The correct measure of the hazard will be the energy stored in the inductor
- The potential arc flash hazard of an inductive system, even low voltage, must be considered

Basics of Arcs - extinction - limited energy

- An arc is a very low resistance (less than 1 ohm)
- This “short circuit” will drain the energy of most electrical equipment immediately
- If the energy is limited the arc will quickly extinguish, even though the fault current can briefly be very high
- Power distribution systems, however, essentially have infinite energy, only limited by the overcurrent protection action
- Examples of limited energy:
  - dc power supplies
  - capacitors
  - inductors

Energy Into an Arc

- The real issue for arc flash injury is how much energy is deposited into the arc.

- $E = Pxt = VxIxt$

- V is usually well know
- I is determined by fault calculations
- t is determined by current interruption, or exhaustion of the energy

Basics of Arcs - extinction - overcurrent protection

- An arc with sufficient voltage (> 250 V) and sufficient current (> 500 A) will continue to grow until the fault current is interrupted
- Energy into the arc is determined by the power and the time that the arc exists
- Current interruption time is critical to limiting the arc energy
- E = Pxt = VxIxt
- Energy is measured in Joules (J)

Energy into Facility Arcs (60 Hz power)

- Essentially unlimited energy.
- The energy deposited into the arc is limited only by interruption of the current (overcurrent protection or fusing of the conductors).
- The speed of delivery is determined by V and I during the fault, and by impedance.

- Critical parameters are:
  - fault current
  - overcurrent protection times
  - impedance

Methods of Arc Flash Boundary Determination for 60 Hz arcs

- Use the NFPA 70E Calculations for Flash Protection Boundary and Incident Energy
- NFPA 70E two part method
- Use the NFPA 70E Hazard/Risk Category Classification Table 130.7(C)(9)(a)
- Use the IEEE methods for selecting protective clothing and PPE, IEEE Std 1584-2002

Energy into Equipment Arcs (R&D)

- Usually a very well defined energy
- Overcurrent protection upstream, to protect the equipment usually limits the fault currents to well below those in facility circuits
- Impedance of transformers can be much larger

- Critical parameters are:
  - stored energy
  - overcurrent protection
  - impedance

R&D Examples

- 60 kV, 5 mA Hi-Pot tester, 0.1 J, 20 mA fault current, fast acting overcurrent protection
- 60 kV, 1 A capacitor charging supply, 100 J, 10 A fault current, fast acting overcurrent protection
- 5 V, 5000 A magnet power supply, 10 J, 6000 A fault current, 1 V fault voltage, fast acting overcurrent protection

- NONE of these can deposit significant energy into an arc.
- In most cases, in dc power supply, the energy in the filter capacitors will supply the bulk of the fault energy, much more than fault currents through the transformer.

Injury due to Arcs

- Injury is due to:
  - very high temperatures
    - metal droplets 1,000 degrees C
    - within the arc 20,000 degrees C
  - acoustical shock
  - shrapnel
- 2nd degree burns occur at 100 degrees C
- clothing ignites at 400 to 800 degrees C

Basics of Arc Flash Injury

- Skin damage will occur based on the intensity of the heat generated by an electrical arc
- The heat reaching the skin is determined by:
  - power of the arc at the arc location
  - distance of the worker to the arc
  - time duration of the arc exposure
- The energy expands outward from the arc
- Energy density (E/area) determines damage to skin
- 5 J/cm^2 is the onset of 2nd degree burns

Estimating Energy Density to Skin

- Power of arc $P = V \times I$
- Energy into arc $E = P \times t$
- Expansion of energy - free space
  - in free space (no boundaries), energy expands spherically
  - energy density = $E/4\pi r^2$
- Expansion of energy - from a box
  - with boundaries the energy expands forward with a higher energy density
  - typical estimate is energy density = $3 \times E/ 4\pi r^2$

Example Energies in power arcs

Bus voltage	Short Circuit Current	Power	Clearing Time of Fault	Energy in Arc	Typical Arc Flash Boundary
120 V	3,000 A	460 kW	0.1 s	50 kJ	
240 V	10,000 A	2.4 MW	0.1 s	0.2 MJ	
480 V	15,000 A	7.2 MW	0.1 s	0.7 MJ	1 m
4160 V	25,000 A	104 MW	0.1 s	10 MJ	2.2 m
13.8 kV	31,000 A	430 MW	0.1 s	400 MJ	4 m

Note: Clearing time can be reduced by fast acting fuses

Assumptions for Arc Flash Boundary Calculations for Capacitors

- All of energy is converted into radiant heat (**worst case**)
- Energy in a box (x 3 energy of free space)
- 5 J/cm^2 limit for 2nd degree burn

- Does not account for acoustic and shrapnel hazards

Example Energies in Capacitor arcs

Type	Voltage	Energy	Arc Flash Boundary
Cathode Ray Tube	40,000 V	0.1 J	0.6 mm
High Pot Tester	60,000 V	0.1 J	0.6 mm
Microwave Oven	4,000 V	10 J	0.7 cm
High Power Laser	10,000 V	1000 J	7 cm
X-ray Source	100,000 V	10 J	0.7 cm
Energy storage Cap	60,000 V	200 kJ	1 m
Large Capacitor Bank	60,000 V	1 MJ	2 m

Note: most of these are well within the Prohibited Approach Boundary

Conclusions - Arc Flash Boundaries for Equipment

- Except for large capacitor banks, the Arc Flash Boundary is well within the Prohibited Approach Boundary. Thus, electrical shock safety is sufficient
- For low energy equipment, the Arc Flash Boundary is shorter than a proper test probe or grounding device. Thus, arc flash PPE is not needed
- For energy storage (capacitors and inductors) other hazards of rapid energy release outweigh arc flash hazards, and the equipment should never be approached or worked on energized, such as:
  - magnetic forces of faults
  - acoustic energy release
  - shrapnel and moving parts
  - intense UV and IR

Arc Flash Boundary

- Before approaching exposed electrical conductors, an Arc Flash Boundary analysis must be performed, including:
  - Energy removal and verification to achieve Mode 1 (a de-energized state)
  - Testing and Measurement, Mode 2
  - Energized Electrical Work, Mode 3

PPE for Arc Flash Protection - R&D

- With very few exceptions, once past the power supply with its overcurrent protection, either:
  - arc flash hazards are very low, no arc flash PPE required, or
  - other hazards of stored energy require never approaching energized

Warnings for Electrical Hazards

- Warning labels on the outside of electrical equipment likely to be worked on should include:
  - shock hazard, specifically voltage
  - arc flash hazard
- The warning label should remind the qualified worker who intends to open the equipment that a serious hazard exists and that the worker should:
  - analyze the hazard
  - determine the appropriate PPE
  - follow the appropriate safe work practices
  - wear the appropriated PPE
- An unqualified worker should NOT open the equipment
- The owner or installer of the equipment must label the equipment for the hazard contained within

Overview

- Energized Electrical Work is NOT Permitted, unless
  - only removal of stored energy and verification
  - diagnostics and testing
  - compelling reason

Summary - key Issues

- The principles of NFPA 70E should be applied to all hazardous electrical equipment
- NFPA 70E does NOT provide the tools for determination of arc flash boundaries for DC, capacitors, RF, batteries, etc.
- R&D workers must understand shock and arc flash hazards
- R&D workers must be able to determine shock and arc flash boundaries for their work
- For most complex R&D systems, we have positive identification of the circuits, AND remote methods of energy removal and verification.
- For large capacitor banks we have REMOTE and REDUNDANT methods of energy removal and verification.

Summary - key issues

- There are very few arc flash hazards for R&D workers on R&D equipment
- R&D workers should not work within arc flash boundaries, at all
- R&D workers should avoid working within Restricted Approach Boundaries
- Use of test instruments must account for shock boundaries and rules followed
- Shock and arc flash boundaries must be followed for energy removal (ground hooks) and verification procedures

Electrical Safety During Excavations and Penetrations

Electrical Safety

DOE Electrical Safety Meeting

November 2005

Electrical Safety During Excavations and Penetrations

Jim Luhring

Savannah River Site

Topics of Discussion

- DOE Electrical Safety Handbook
- ORPS Reported Events 2004
- ORPS Reported Events 2005
- Success Stories
- Work yet to be done

DOE Electrical Safety Handbook

DOE-HDBK-1092-2004

- Chapter #11

<u>Electrical Safety During Excavations</u>

This is a new Chapter that was added to the Handbook in 2004

Chapter # 11

- **Utilities Identification**
- **Utilities Verification & Marking**
- **Utilities Disposition**
- **Work Control During Excavations**
- **The Excavation Process**
- **As-Built Drawings**

ORPS Reported Events

2004

Incidents reported during

Excavations
and
Penetrations

ORPS 2004 cont'd.

- **There were a total of 148 electrical safety events reported in ORPS for 2004**

  - more than 20 were excavation/penetration events

OA Inspections 2004

The Office of Independent Oversight and Performance Assurance (OA) issued a report in January 2005, documenting their inspections at four sampled DOE sites during 2004. The Electrical Safety During Excavations and Penetrations lessons learned report recognized a number of program improvements at all of the sites visited.

OA Inspections cont'd.

Weaknesses were also identified :

1. Configuration control programs at most sites do not include current and accurate drawings.

2. Effectiveness of utility location surveys is reduced because of weaknesses in personnel training **and** selection and use of equipment.

Weaknesses cont'd

3. Procedures and process are not sufficiently rigorous.

4. Management has not ensured strict adherence to requirements.

   - noted that site-specific excavation procedures are written by prime contractors, while many excavation work activities are performed by subcontractors. Some subcontracts did not fully address expectations for compliance with site procedures.

ORPS Reported Events

2005

Electrical Safety Occurrences involving excavations or penetrations

January through November 14th 2005

January 2005

"During excavation activities, a subcontractor severed a conduit with his backhoe that contained two previously unidentified energized electrical lines "

January cont'd.

"While drilling through a metal battery exhaust duct hood, an employee's drill bit went into an energized battery cable and caused an electrical arc"

February 2005

“ During construction excavation activities, a backhoe operator unexpectedly struck an electrical conduit which contained un-energized electrical circuits of less than 600 volts.”

February cont'd.

- "While securing a Heating/Ventilation and Air Conditioning unit to a building external wall, a subcontract employee performing a wall penetration, with four-inch lag bolts, contacted an energized 120 volt electrical line, causing an electrical arc."

February cont'd.

" During concrete penetration (coring) activities an electrical near-miss occurred when the coring machine unexpectedly contacted two energized electrical lines embedded in the concrete."

March 2005

“ Subcontractor hits conduit containing an energized 120 volt electrical line while performing a blind penetration through a concrete floor.”

March cont'd.

" While coring a six-inch diameter hole in a concrete floor, an electrical near-miss occurred when the subcontract work crew severed energized electrical conductors inside an embedded conduit."

March cont'd.

" During excavation activities, a backhoe severed a two-inch conduit containing energized 240 volt electrical wires."

April 2005

“ During excavation activities at the construction site, a backhoe operator damaged an underground conduit containing de-energized 115 volt electrical wiring.”

April cont'd.

" During excavation activities, a backhoe operator contacted two separate conduits containing energized wiring."

April cont'd.

" While excavating underground utilities (manholes and sewer lines) subcontract workers inadvertently pulled a conduit containing an energized 208 volt underground line out of its meter housing on the exterior wall of an adjacent bldg. This resulted in an electrical arc."

April cont'd.

"Following electrical work inside a building, site personnel removed a lockout, re-energized the panel, and noticed that a breaker tripped, and would not reset. Inspection determined that a screw used to install medical cabinets on the metal stud wall, had penetrated a flexible metal-jacketed cable."

May 2005

“ ….. A trackhoe excavating for a cathodic protection line tie-in, struck and damaged an energized 400amp/480 volt buried temporary power line.”

June 2005

“ Plant personnel were using a backhoe to clean ditches and culverts west of bldg., when they unexpectedly severed five de-energized electrical wires.”

June cont'd.

" During demolition of the building concrete pad, a backhoe was dragging rubble into a pile when it snagged and damaged an electrical conduit containing energized 110 volt wiring not previously identified."

July 2005

There were a total of 9 events reported.

- 3 Shocks
- 5 Shorts/Arcs
- 0 Penetration/Excavation events*

* Only month, to date, in 2005

August 2005

"During an excavation at the …project, a construction worker struck and damaged a buried electrical conduit that contained an energized 120 volt lighting circuit, tripping the breaker. The conduit had been identified during ground scans and properly marked."

September 2005

"During routine removal of drifted sand by maintenance personnel at an entry point, a heavy equipment operator struck and damaged a set of in-ground energized 240 volt PVC electrical conduits."

September cont'd.

"During excavation activities …, a trenching machine cut into an energized 480 volt electrical feed line and knocked out power to a building."

September 2005

"An electrical near-miss occurred at…, when a worker drilled 8 holes into an electrical enclosure containing energized 1,400 volt feeder cables in order to install four **<u>Danger-High Voltage</u> signs."**

September cont'd.

"During excavation activities near the … building, a trackhoe operator unearthed an electrical conduit containing de-energized wiring."

October 2005

Subcontractor employee drilled into an embedded conduit containing energized cables during anchor bolt installation on a building roof.

November 2005

Subcontractor was removing asphalt from a street repair when the backhoe struck and damaged an energized cathodic protection cable.

November cont'd.

Subcontractor backhoe broke a buried two inch conduit containing ten electrical wires

(110-volt, 220-volt and 480-volt)

November cont'd.

Trackhoe excavating an abandoned conduit discovered it contained an energized 110-volt cable.

2005 Summary

Of the 20 Events we reviewed :

- **15 involved subcontractors**
- **15 involved backhoes, trackhoes or heavy equipment**
- **15 involved contact with energized electrical conductors**

Success Stories

Many DOE Sites are taking positive steps to improve their performance in the area of excavations and penetrations.

- **New technologies being employed. New locator equipment being purchased.**
- **Locator Operators being trained on specific equipment being used. Documented training required to perform utility locating at the site.**
- **Permitting enhancements. Some sites have separate <u>excavation permits</u> as well as <u>drilling/penetration permits</u>.**
- **Increased Management Ownership/Support.**

Success Stories cont'd.

- Purchase of vacuum extraction equipment for "potholing" utilities
- Use of GPS and Marker Balls for precision locating of identified utilities
- Improving As-Built Drawings requirements for excavations and penetrations.

Work Yet to Be Done

We all know that we need to keep the pressure on ourselves to improve our programs for the benefit of our employees.

* Greater subcontractor oversight ?
* Better permitting program ?
* Better locator operator training ?
* Better locator equipment ?
* More than one type of locator equipment ?
* Better As-Built Dwgs. program ?
* Better internal lessons learned program ?
* Sharing site techniques and technologies ?

Resources Are Available

ES&H Electrical Safety Program
(www.eh.doe.gov/paa/electrical)

- **Just-In-Time Reports**
- **Lessons Learned Reports**
- **Intrusion Events Summaries**
- **DOE site newsletters**
- **Site Directives from DOE offices**
- **Electrical Occurrences Analyses**
- **Electrical Safety Handbook**

Several DOE Sites are now forming an <u>Excavations/Penetrations Users Group</u>. The Group will share program successes and failures in order to achieve the best possible excavations and penetrations programs at each of their sites.

If your site would like to participate, you can have your representative contact me at :

james.luhring@srs.gov

803-557-4795

ORPS 2005

Summary of Electrical Events

J. R. Luhring
Bechtel Savannah River
11-1-05

ORPS 2005

The 2005 monthly average of electrical occurrences

14

ORPS 2005

The 2004 monthly average of electrical occurrences

12

ORPS 2005

The 2002 through 2003 monthly average of electrical occurrences

9

ORPS 2005

The <u>monthly average</u> of electrical occurrences has been <u>increasing</u> each of the past three years

Electrical Shocks

There have been

<u>33 shocks</u>

reported in 2005

Electrical Shocks

That number (33) is already

8 more

than the total number reported for all of 2004

(with two more months to go)

Electrical Burns

There have been

<u>3 burns</u>

reported in 2005

Electrical Burns

That number (3) already equals

the total number reported in 2004

(with two more months to go)

Electrical Fatalities

There have been

<u>0 fatalities</u>

so far in 2005

References

This information was derived from

Department Of Energy

Office of Corporate Performance Assessment

Electrical Safety Occurrence Reports and Summaries

High-Voltage Energy Control (Clearance Procedures) Stats and Errors

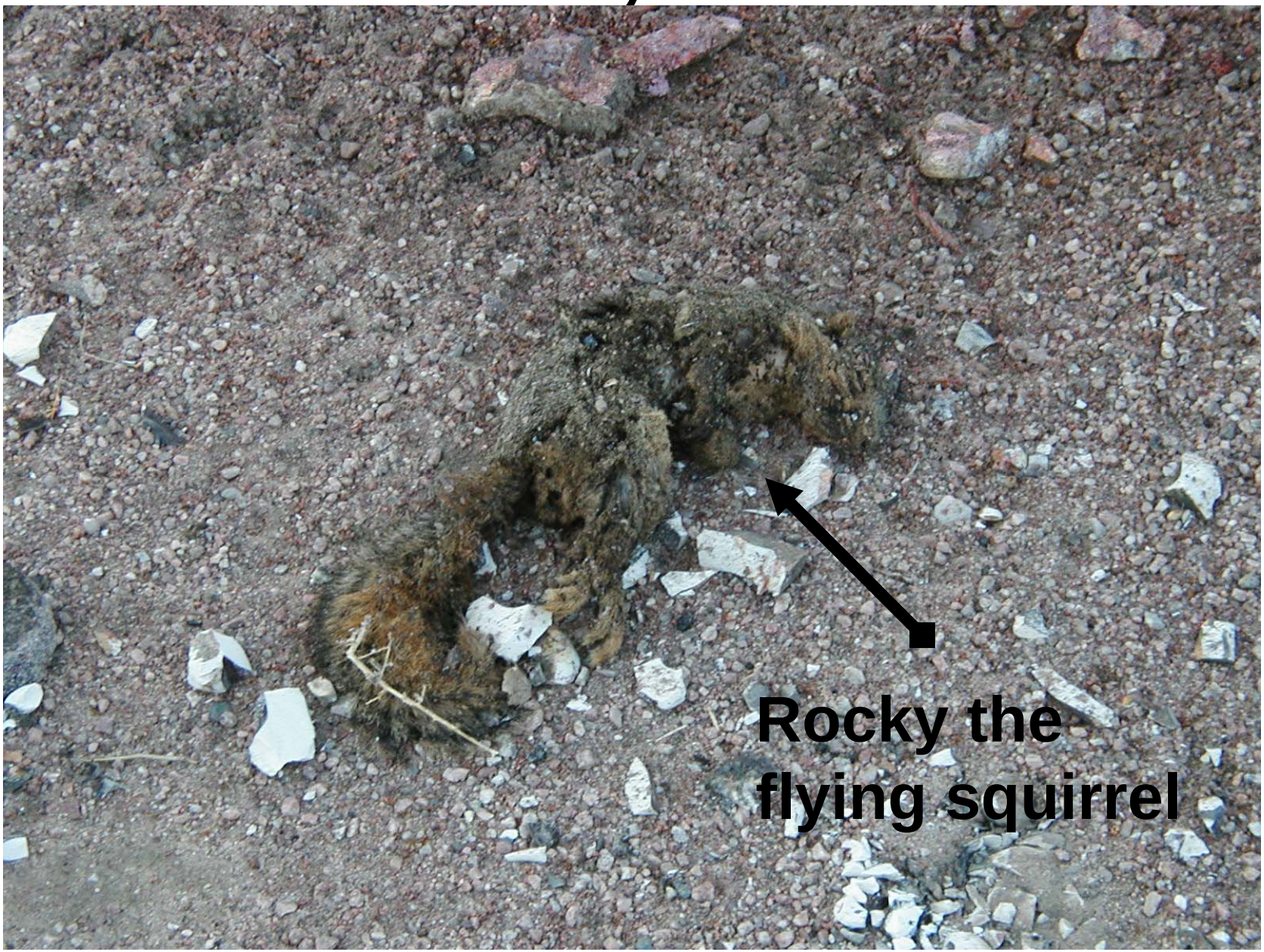
High Voltage Energy Control Statistics and Errors

Accountable Outages

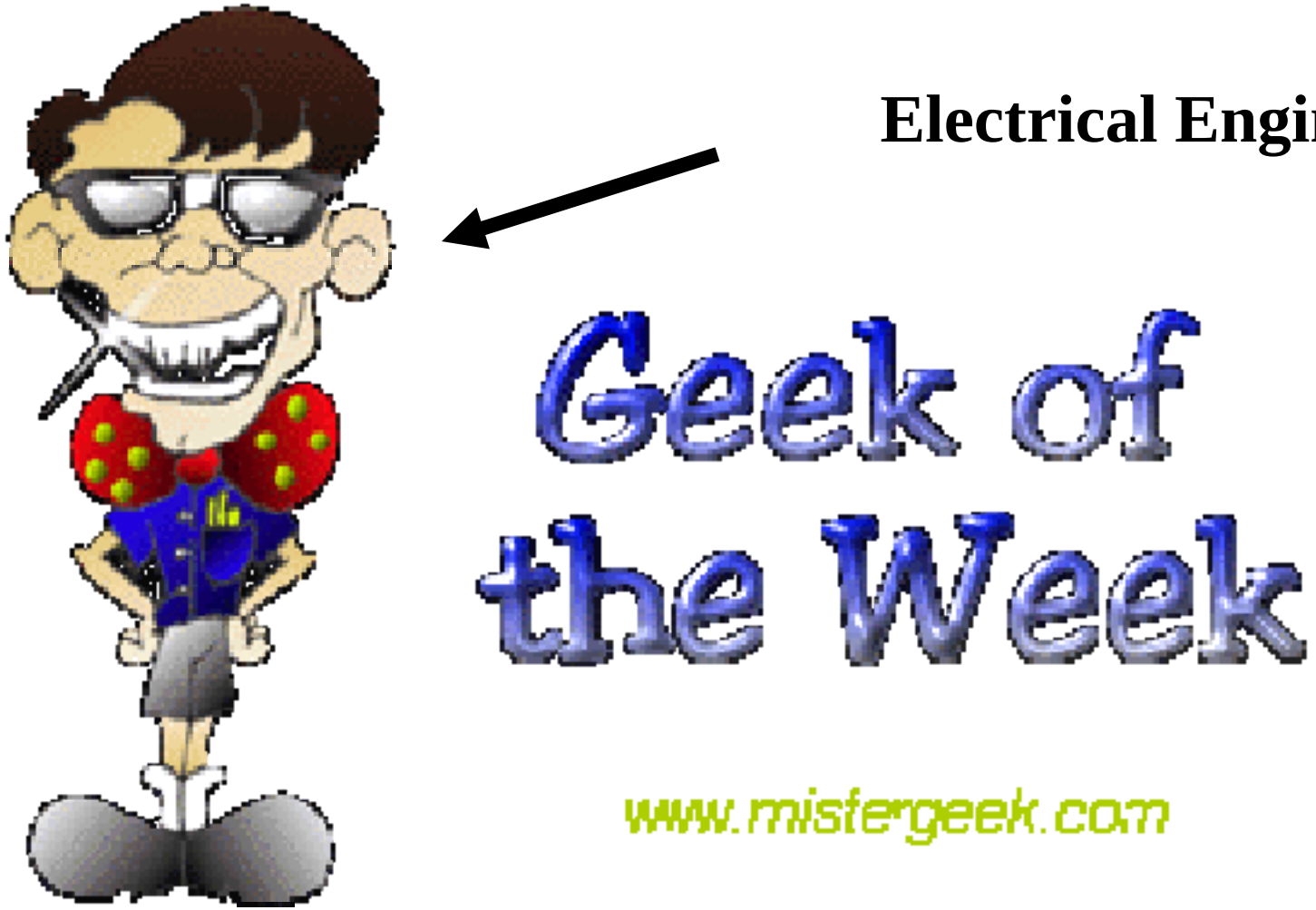
Executive Summary

On January 11, 2004 at 0846, a squirrel initiated a 3 phase fault on the secondary portion of transformer CH-KY8A. This transformer has a voltage rating of 115kV-13.8kV, and is located at the Cheyenne substation in Cheyenne Wyoming. Local protective relaying was out of service due to construction/commissioning activities at the Cheyenne yard and there was no effective means to clear the fault on the 13.8kV system. The configuration of the protective relaying scheme allowed a sustained fault and low voltage condition to promulgate throughout the 115kV system fed from the Cheyenne 115kV bus arrangement. This low voltage excursion continued for 14 minutes until Miracle Mile 1362 tripped by relay action de-energizing the Cheyenne substation and extinguishing the fault.

Primary Cause



Secondary Cause



Electrical Engineer

Quotes

- "*No one who accomplished things could expect to avoid mistakes. Only those who did nothing made no mistakes.*" Harry S. Truman
- *"I prefer to profit by others' mistakes and avoid the price of my own."* Otto von Bismarck
- *"There is a universal failure [in this command] to repeat oral orders back. This failure is certain to result in grave errors"* GEN George S. Patton
- *"The central problem of leadership…is a failure to understand the information in variation. Leadership that takes aim at people that are below average in production, or above average in mistakes, is wrong, ineffective and costly to the company."* W. Edwards Demming

The Human Ear can Deceive you!

What are accountable outages?

- Outages caused by human intervention
- Switching order errors
- Equipment malfunctions
- Vegetation right of way management issues

Things have
changed a little……
TREMPEALEAU ELECTRIC
CO-OPERATIVE

WAPA and other utilities have their facilities in a broad geographical area

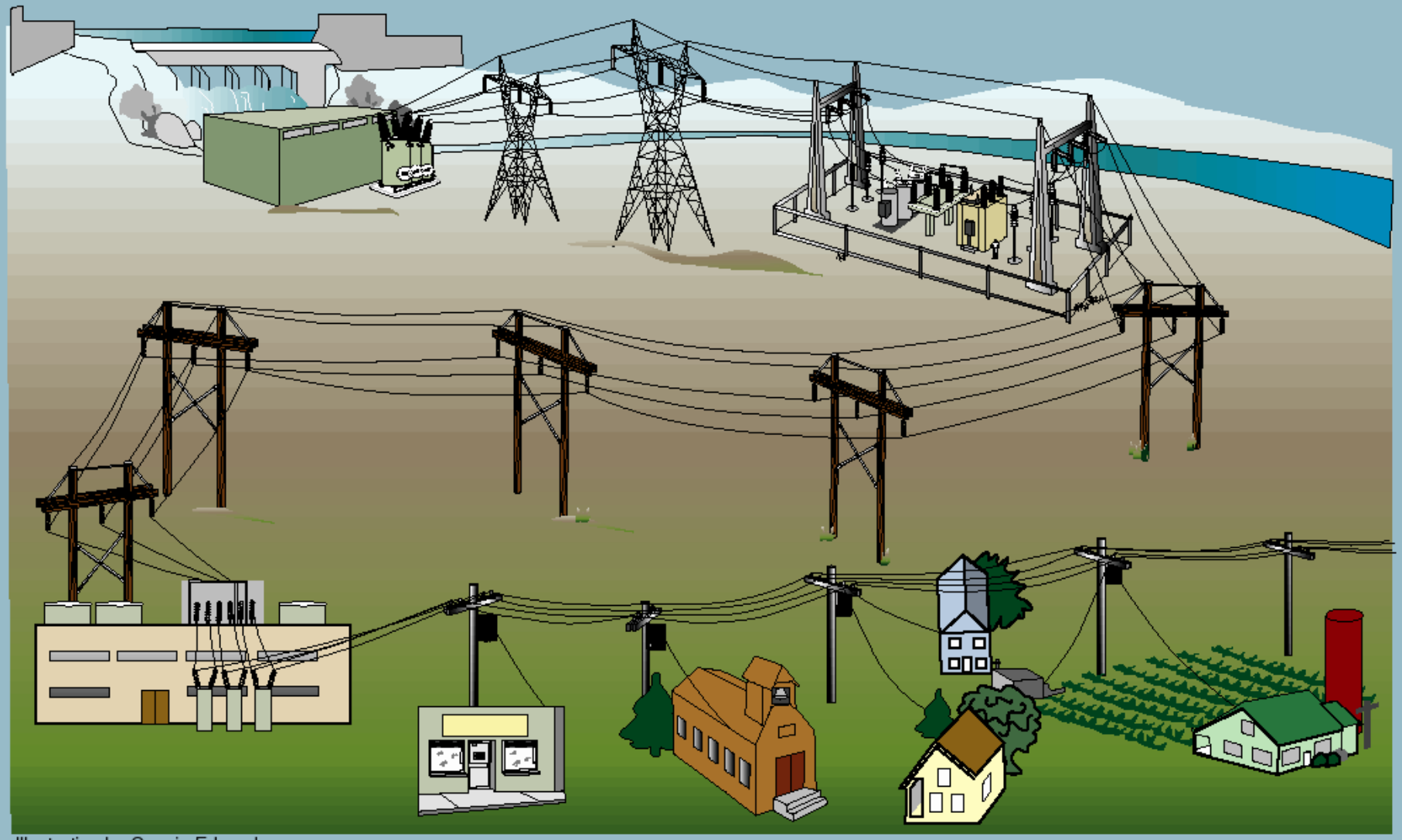


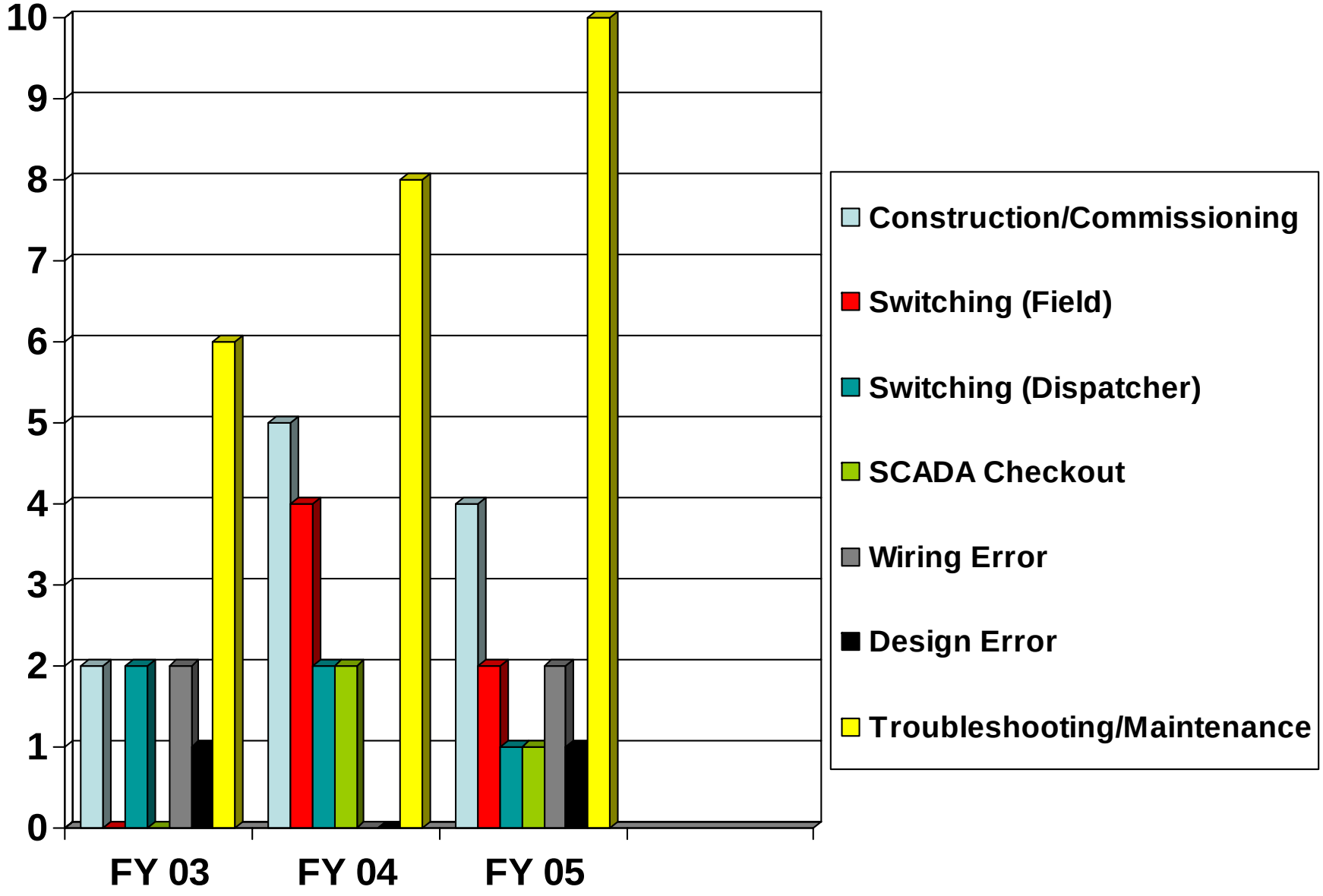
Illustration by Connie Edwards

EPRI Study

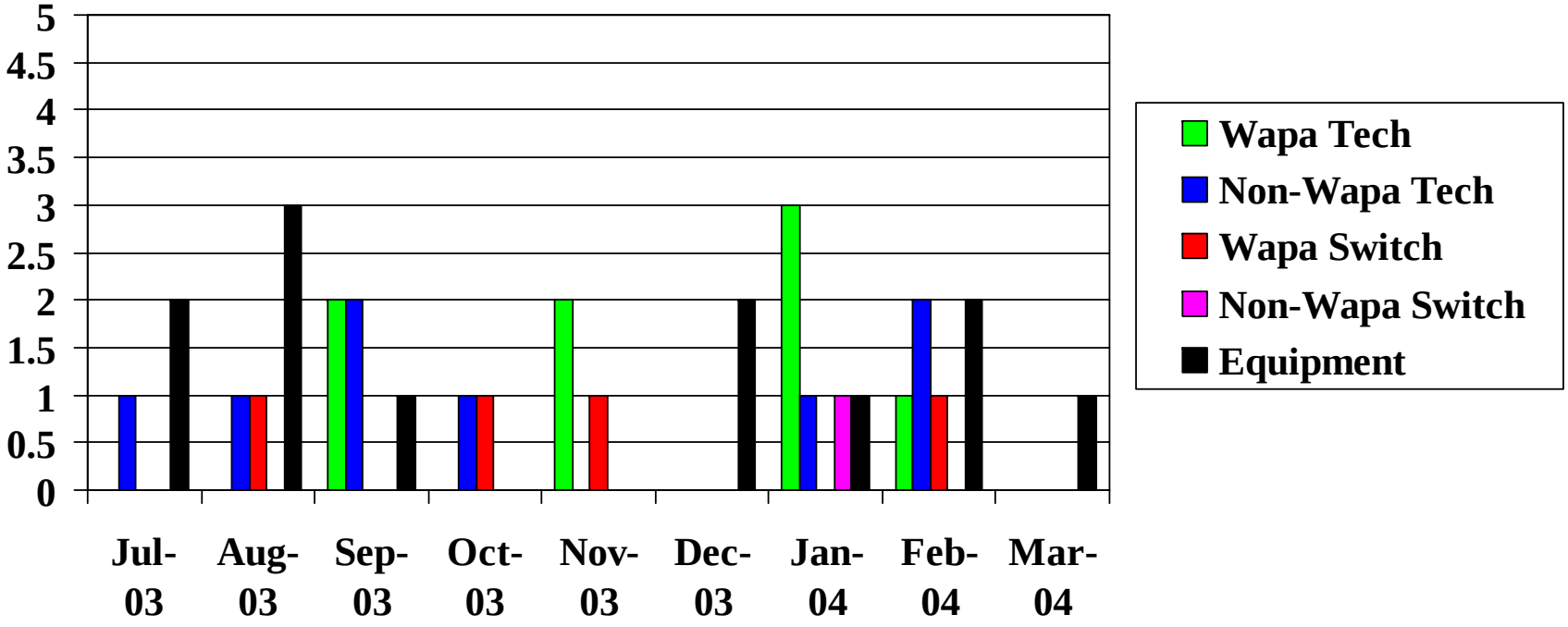
(Error & Accident Estimates)

- 1 error / 583 jobs
- 50-50 Dispatcher/Field Operator responsibility
- Majority of errors in execution, not planning
- Operating wrong equipment most common
- Results:
  - outage 51%
  - damage 4%
  - injury 1%
- 4 substation fatalities/year
- T&D fatalities 10X higher 40/year-71% electrical contact)

Outages 03-05

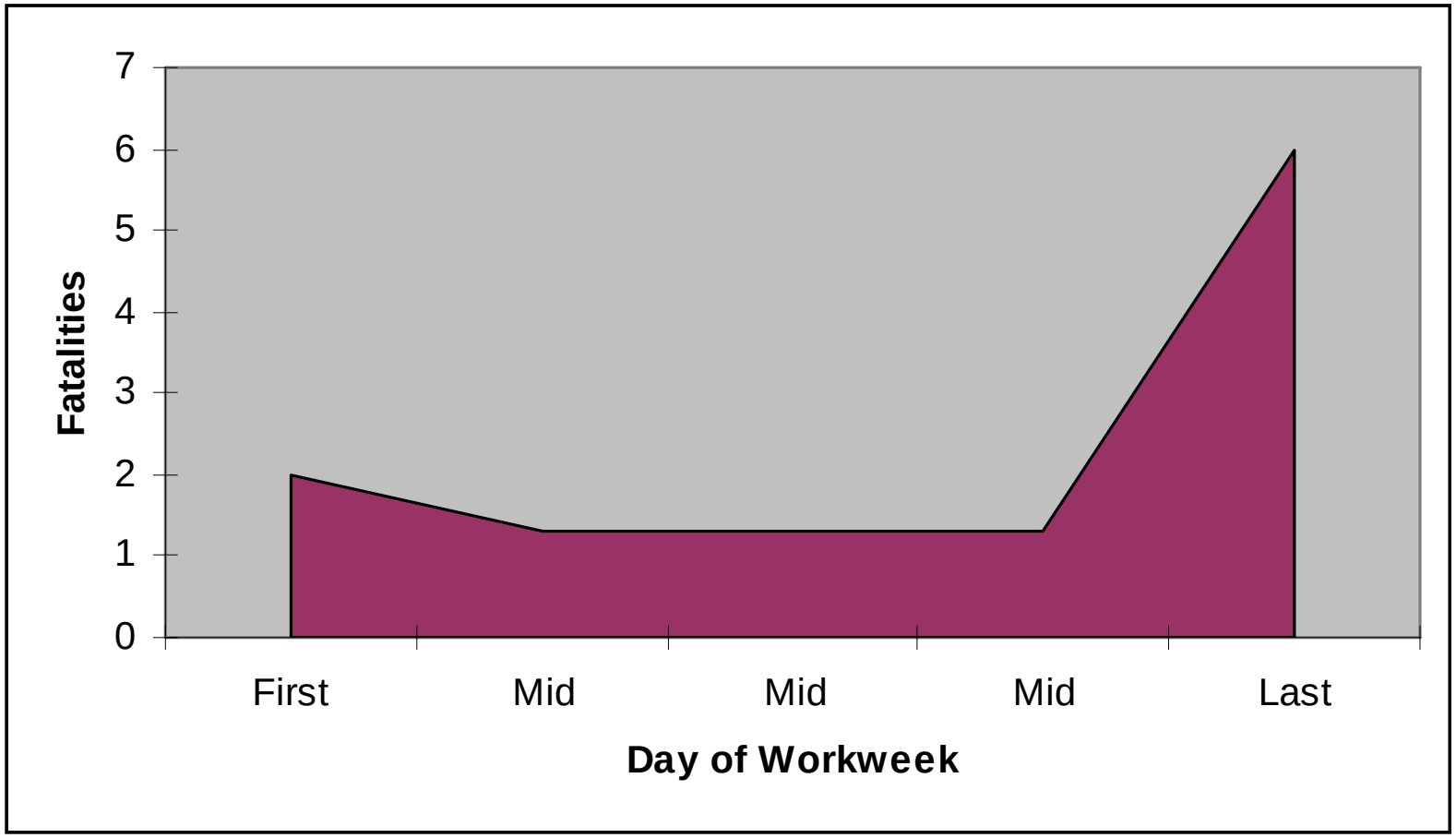


Which Category of Error Concerns us the most?

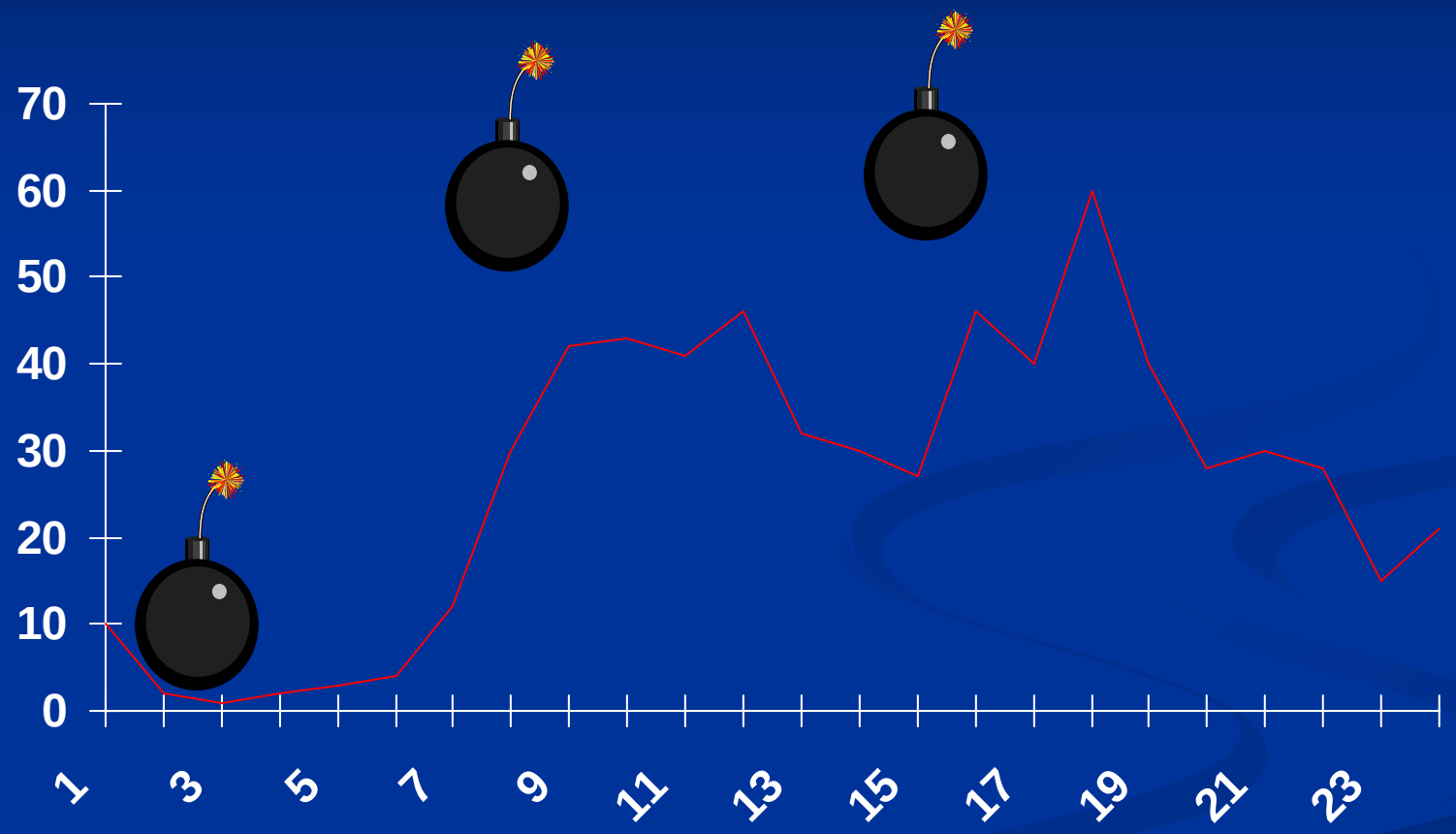


3. 21. 2003

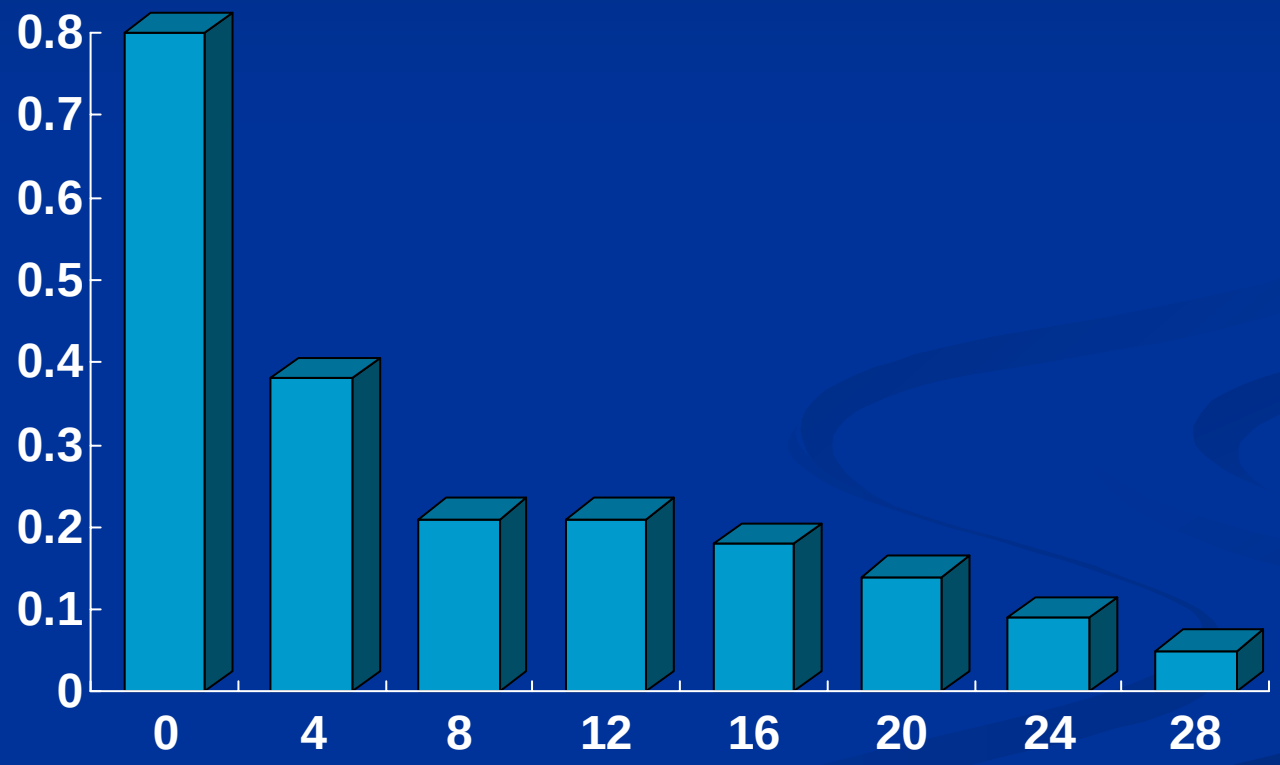
Serious Error Risk vs Day of Workweek



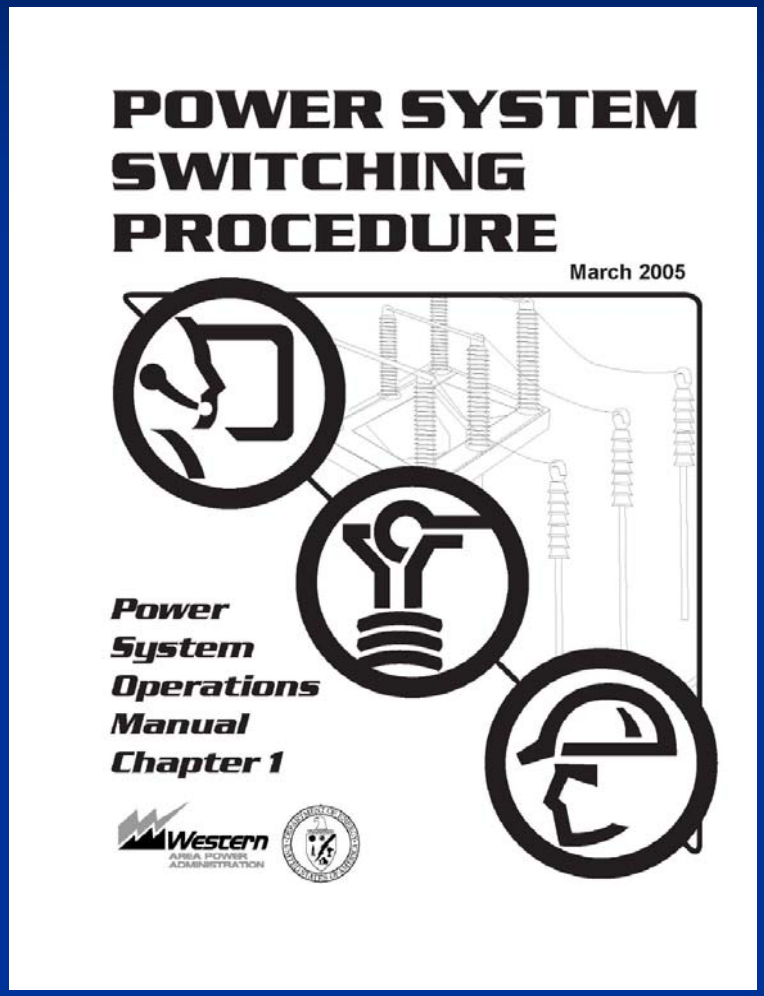
Slips vs Time of Day



Error Rate vs Experience



Where do we go, What can we do?



Where do we go, What can we do?

1.8. PRINCIPLES OF SAFE SWITCHING PROCEDURES

The following principles are considered basic to the safe operation of the Federal power system and to those systems operated for other entities by Western:

1.8.1. The following are priorities in order of importance:

1. Physical safety of employees and the public.

   Employees **shall** realize, "If I violate a procedure, Safety Tag, Hot Line Tag, or Lockout-Tagout Tag, I may kill somebody!"

2. Integrity and reliability of the Federal power system.

3. Protection of equipment.

4. Service to the customer.

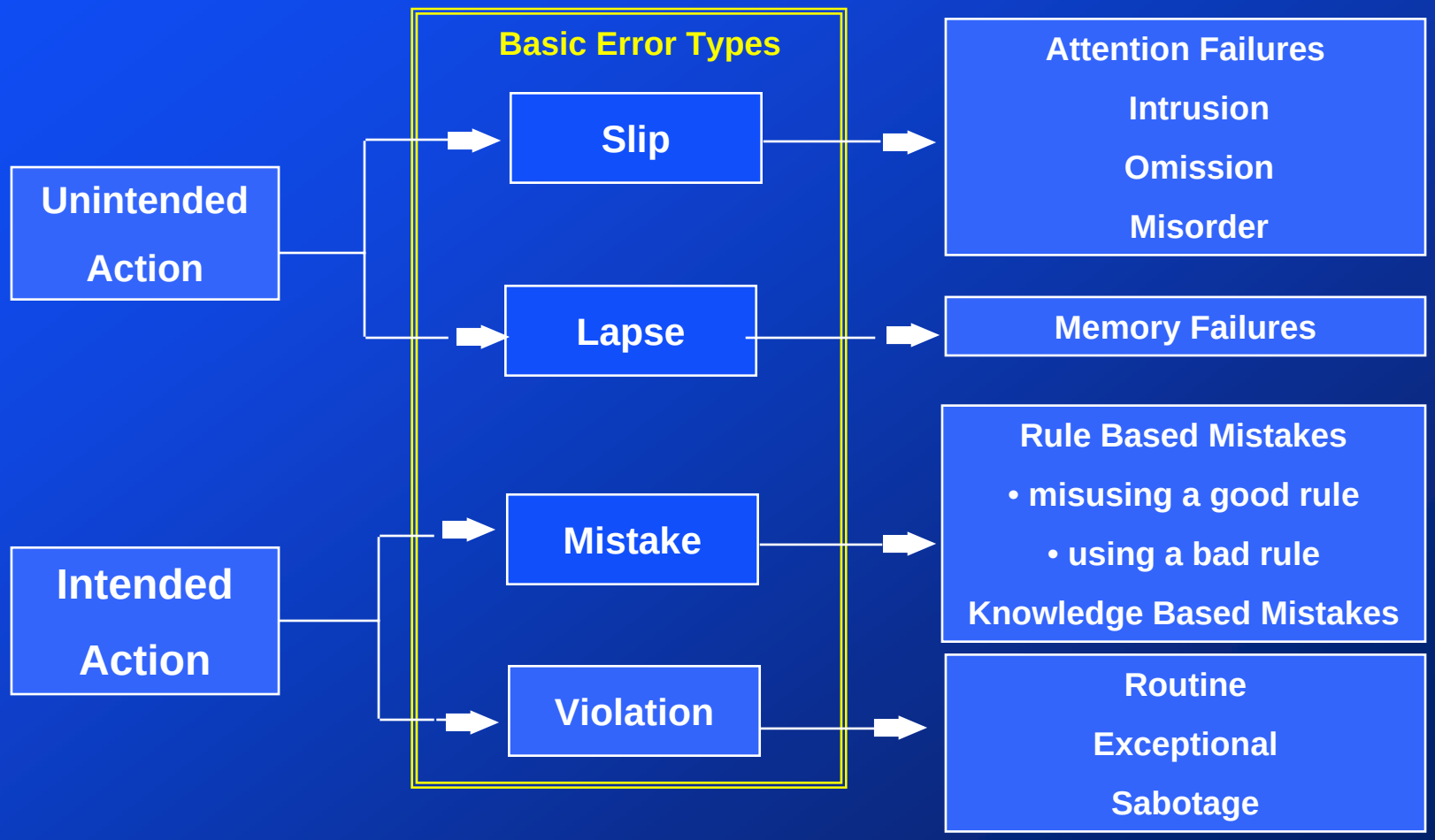
Where do we go, What can we do?

1.8.3. All switching operations **shall** be guided and tested by the fundamental principle, "Start with the correct procedure and follow it exactly", and **shall** be accomplished by following:

THE SIX BASIC STEPS OF SWITCHING:

1. Carry the switching program with you while switching.
2. Touch or point to the device identification name plate to verify its/your location.
3. Recheck the switching program for right location and right sequence.
4. Verify anticipated device position.
5. Perform requested action on the device.
6. Verify desired device position.

Error Types


Basic Error Types
Unintended Action
Intended Action
Slip
Lapse
Mistake
Violation
Attention Failures
Intrusion
Omission
Misorder
Memory Failures
Rule Based Mistakes
• misusing a good rule
• using a bad rule
Knowledge Based Mistakes
Routine
Exceptional
Sabotage

Errors are Multidimensional

- Time available
- Experience
- Training
- Ability
- Distractions
- Workload
- Quality of information
- Personal “baggage”
- Day of the week / Time of day
- Alertness
- Chance

Unplanned Outages Error Reduction Program

- Initial Training, annual recertification
- Obtain baseline information
  - error causes
  - possible solutions
- Work on biggest problems
- Implement “easy” fixes also
- Publish current information
- Continuous improvement
- Publish success stories
- Accountability

Let's not forget what's at stake here!

Questions? Comments? Concerns?

Switching Error Case Study

Glendale – KW1A Regulator
Time of Incident: 07:22
Date of incident: May 24th, 2005

Glendale – KW1A Regulator

- At 06:58 May 24th, 2005 switching was started for the removal of clearance C05-069 and C05-069A on Glendale-KW1A 12.47-kV three single phase Voltage Regulator after replacing Phase "C" and testing of all regulators. At 07:03 switching was halted to perform functional tests on the new Regulator. At 07:19 the Technician placed the Auto/Manual switch on phase "C" from the OFF position to the AUTO position at the regulator. Glendale-KW1A phase "C" tried to adjust for high voltage by automatically tapping down after a 30 second delay to Lower-1 tap. With Glendale-109, 103 and 105 closed, moving the tap changer produced a high circulating current in Glendale-KW1A phase "C" causing two explosions. The first explosion occurred at 07:20 (Event I). A Craftsman received first and second degree burns on the hands, face, back and legs from Event I. The Craftsman was taken to a nearby hospital for treatment. There was a second explosion which occurred at 07:30 (Event II). A Technician received temporary hearing loss from Event II and was taken to a nearby hospital where he was treated and released. Glendale-KW1A "C" phase was severely damaged from high current and fire. There was an extended outage of 3 hours, 37 minutes, dropping 9 MW's of load on the 12.47-kV bus which affected customers in the Glendale, Cody area, USBR, and Glendale station service. Oil containment and removal procedures were performed at the site.

Glendale – KW1A Regulator

- When Switchman #1 had completed steps 1 through 5 the Technician requested that switching stop on step #5 so that testing of Glendale-KW1A "C" phase controller could be performed. Switching was stopped on step #5 and testing began on "C" phase controller. The Craftsman requested Switchman #1call Operations to report the intent to stop the switching program for Glendale-KW1A controller tests.
- At 07:13 Switchman #1 reported to Operations that; "I've done all the way up to Step #5 but we want to run a few tests before I do the last three steps and then I'll call you back with the times". Operations Supervisor #1 stated that this would be fine .

Recurring Electrical Events

Report of the Los Alamos National Laboratory Electrical Occurrence Investigation Subcommittee

Lloyd B. Gordon

2005 Electrical Safety Meeting

November 30, 2005

Charter and Task

- DOE/NNSA LASO requested that the electrical AHJ (ESC and Chief ESO) analyze 34 electrical incidents over the past two years and provide recommendations
- The ESC subcommittee
  - self organized
  - set the agenda
  - determined the methods, and
  - produced the product (160 page report)

Report Chapter 1

Subcommittee

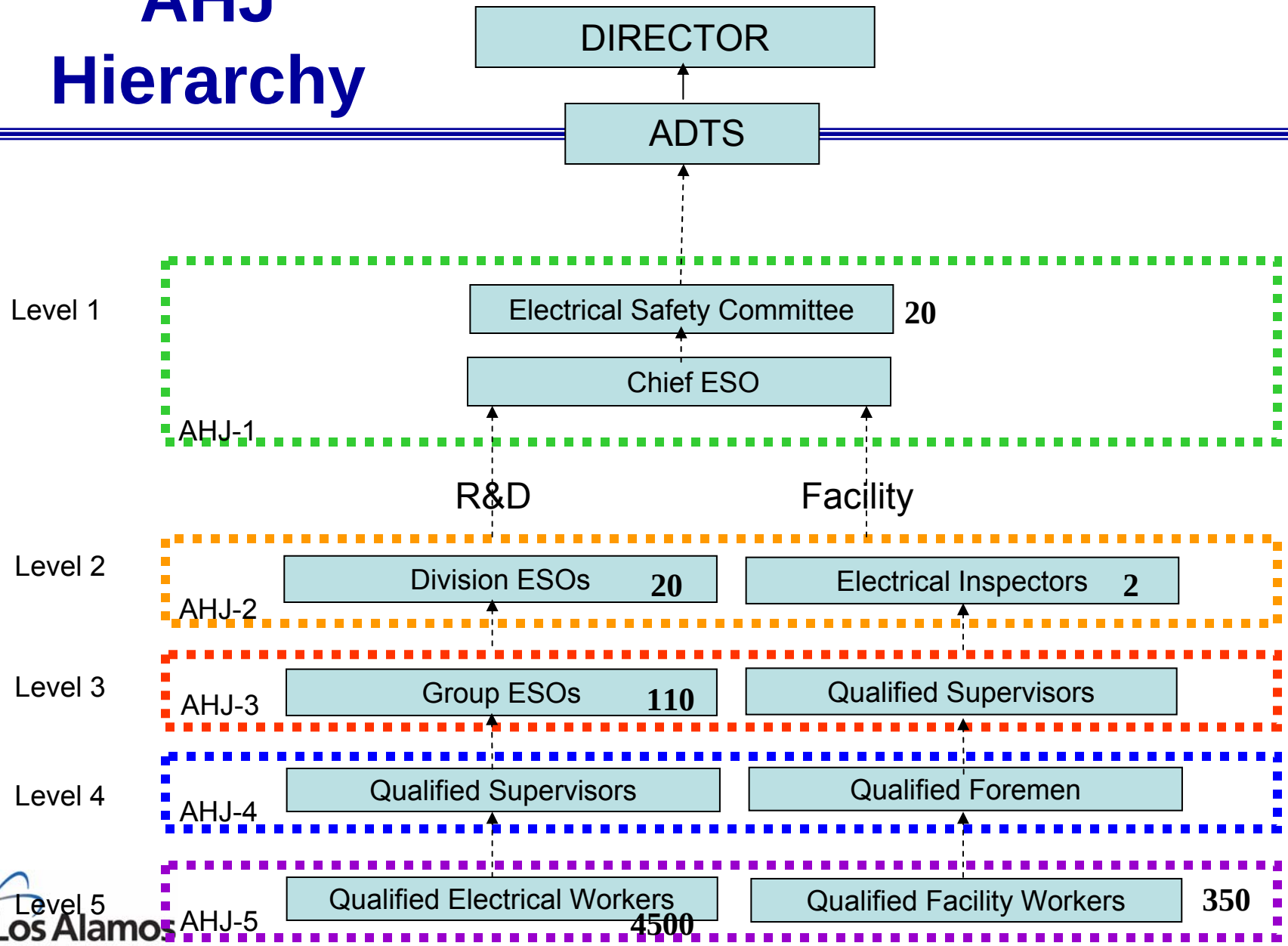
- three officers of the Electrical Safety Committee
- Chief Electrical Safety Officer
- Occurrence Analyst
- Electrical Safety Team Leader

LANL Electrical Safety Program Summary

The report contains a 36 page summary of the LANL Electrical Safety Program, Chapter 2.

- Evolution
- Comparison to other DOE/NNSA labs
- Roles and Responsibilities
- Assessments
  - Unlisted Electrical Equipment Approval Assessment
  - LOTO Briefing Paper
- Recent Improvements
  - Training
  - ESO
  - ISD development
  - Electrical Safety Action Plan
  - LOTO, HSR-5 team
  - Recent Corrective Actions

AHJ Hierarchy



LANL Statistics

NEW

- 15,000 employees
- 300 electricians
- 35 linemen
- 4500 R&D electrical workers

- Total of 5000 qualified electrical workers

- 20 member Electrical Safety Committee
- 120 Electrical Safety Officers (approx. 20 FTEs)

Analysis of Each Event included

- Category
- Severity Ranking
- Primary Cause
- Human Factors
- Lab Requirements and Code Compliance
- Comments on ORPS Corrective Actions
- Subcommittee Recommendations
- Comments on ORPS Lessons Learned
- Additional Subcommittee Lessons Learned
- Comments on ORPS Report

Report Chapter 3

Severity Ranking Tool

Severity Significance =
(Electrical Hazard Factor) *
(1 + Environment + Shock Proximity + Arc Flash Proximity + Thermal Proximity) * (Injury Factor)

This tool was used on nearly 50 electrical incident examples, and works very well, in the opinion of the subcommittee SMEs.

Report Chapter 3

Use of the Severity Ranking Tool

- to use the previous tool you must have the weighting factors for:
  - Electrical Hazard Factor (based on LANL electrical hazard classification)
  - Environment
  - PPE
  - Shock Proximity (based on NFPA 70E)
  - Arc Flash Proximity (based on NFPA 70E)
  - Thermal Proximity (based on LANL info)
  - Injury Factor

These weighting factors are not included in this brief presentation, but may be requested of the author.

Categorization of Events

NEW

Category	# of Events
Exposure to Electrical Energy: work control	12
Lockout/Tagout	6
Penetration	5
Exposure to Electrical Energy: Equipment Approval	4
Excavation	3
Exposure to Electrical Energy: Defective or Faulty Equipment	2
Not an electrical event	2
Fire Hazard	1

Level 3 Events

NEW

#	OR Number	date	event description	hazard factor	envirn factor	Shock Prox	Current Prox	Arc Prox	Injury		Severity	Ranking	Log
34	CMPTRDIV-2005-0001	4/18/05	MCC arc flash	50	0	0	0	10	5		2750	3	3.4
12	HRL-2004-0001	11/5/04	480V MCC	50	5	10	0	10	1		1300	3	3.1
1	WASTEMGT-2003-0006	9/2/03	13.2kv cabinet	100	5	10	0	10	1		2600	3	3.4
8	LANL-2004-0005	2/26/04	13.2Kv crane	100	5	10	0	10	1		2600	3	3.4
11	ADOADMIN-2004-0009	11/19/04	welder 480 shock	50	0	10	0	0	3		1650	3	3.2
4	ADOADMIN-2005-0002	3/3/05	280V light switch	50	0	10	0	0	3		1650	3	3.2
16	SIGMA-2005-0002	1/1/05	Gardner Zemke 480V	50	5	10	0	10	1		1300	3	3.1
14	ACCCOMPLEX-2005-0001	1/27/05	Rectifier cabinet cap hazard	100	0	10	0	0	1		1100	3	3.0

Level 2 Events

NEW

#	OR Number	date	event description	hazard factor	envirn factor	Shock Prox	Current Prox	Arc Prox	Injury		Severity	Ranking	Log
29	PHYSCOMPLX-2004-0001	6/1/04	Student megger shock	3	0	10	0	0	3		99	2	2.0
21	RADIOCHEM-2005-0003	2/25/05	shock vacuum pumps	3	0	10	0	0	3		99	2	2.0
24	SIGMA-2005-0004	4/4/05	220V wet shock level detector	3	10	10	0	0	3		189	2	2.3
19	TSF-2005-0001	5/10/05	110V student shock furnace	3	0	10	0	0	3		99	2	2.0
23	ESHSUPT-2005-0005	6/24/05	ground water winch	3	5	10	0	0	3		144	2	2.2
22	PHYSCOMPLX-2005-0001	6/29/05	5Kv P Student shock	3	0	10	0	0	3		99	2	2.0
18	FIRNGHELAB-2005-0008	7/5/05	110V Rocker switch	3	5	10	0	0	3		144	2	2.2
6	ACCCOMPLEX-2004-0001	2/2/04	LOTO bending magnet	3	0	10	0	0	1		33	2	1.5
5	TARGETFAB-2005-0002	4/18/05	capacitors	50	0	0	0	0	1		50	2	1.7
15	LANL-2005-0002	2/9/04	backhoe secondary line	50	0	0	0	0	1		50	2	1.7

Level 1 Events

NEW

#	OR Number	date	event description	hazard factor	envirn factor	Shock Prox	Current Prox	Arc Prox	Injury		Severity	Ranking	Log
35	MATSCCMPLX-2004-0002	1/8/04	electric cord fire	3	0	0	0	0	3		9	1	1.0
25	CMPTRDIV-2003-0001	12/18/03	fish tape near miss	3	0	1	0	0	1		6	1	0.8
28	TA18-2004-0005	9/28/04	semi cut comm line	1	0	0	0	0	1		1	1	0
13	HRL-2005-0001	1/8/05	demolished MCC w/ redlock	3	0	0	0	0	1		3	1	0.5
27	SIGMA-2005-0005	4/8/05	plug box lock removed	0	0	0	0	0	1		0	1	
33	OTOWI-2005-0001	4/25/05	missing key	0	0	0	0	0	1		0	1	
2	ACCCOMPLEX-2003-0003	9/10/03	cut 120V conduit	3	0	0	0	0	1		3	1	0.5
20	PHYSTECH-2003-0007	9/30/03	lawn mower 110V	3	5	0	0	0	1		18	1	1.3
3	ESHSUPT-2003-0003	12/4/03	120V Penetration	3	0	0	0	0	1		3	1	0.5
7	ADOADMIN-2004-0002	3/1/04	208V lines demolition	3	0	0	0	0	1		3	1	0.5
9	LANL-2004-0008	6/15/04	120V backhoe	3	0	0	0	0	1		3	1	0.5
10	PHYSCOMPLX-2004-0003	10/26/04	120V wall penetration	3	0	0	0	0	1		3	1	0.5
32	RADIOCHEM-2005-0002	1/10/05	UPS batteries	3	0	0	3	0	1		12	1	1.1
17	WASTEMGT-2005-0002	2/28/05	120V Penetration	3	5	0	0	0	1		18	1	1.3
31	WASTEMGT-2005-0005	3/16/05	120V Penetration	3	0	1	0	0	1		6	1	0.8
26	SIGMA-2005-0003	3/18/05	improper faceplates	3	0	0	0	0	1		3	1	0.5

Examples of minor Electrical Events that were Not reported in the past

NEW

- semi breaks telephone line
- wall penetration finds 120 V line, full PPE
- concrete saw cuts 120 V line, even after GPR, full PPE
- backhoe breaks deep 120 V line to light pole
- mild 120 V shocks with dry hands, failed components
- LOTO key not ideally managed
- cord with red lock removed

Examples of significant Electrical Events that need corrective actions

- D&D almost contacts 13.2 kV **NEW**
- crane breaks 3 phases of 13.2 kV t-line
- arc flash from defective component, 2nd degree burns to wrists
- inadequate verification on LOTO, complex work
- lack of equipment approval (3 cases) results in shocks (one was 480 V)
- inadequate work control on complex work with capacitors, mixed workers

Some additional Examples

NEW

event description	hazard factor	envirn factor	Shock Prox	Current Prox	Arc Prox	Injury		Severity	Ranking	Log
Student microwave	50	0	10	0	0	10		5500	4	3.7
480V 3phase fault SLAC	50	0	10	0	10	20		21000	4	4.3
Jackhammer	100	5	10	0	10	100		260000	4	5.4
DX trenching	50	10	10	0	0	1		1050	3	3.0
lowest conceivable death	3	0	10	0	0	100		3300	4	3.5

Major Conclusions - good news

- Electrical Safety Program at LANL has improved over the past decade
- Reporting is much higher
- Awareness is much higher
- ESO program is excellent
- Training is excellent
- Electrical safety program requirements are under revision
- LANL is a leader in electrical safety

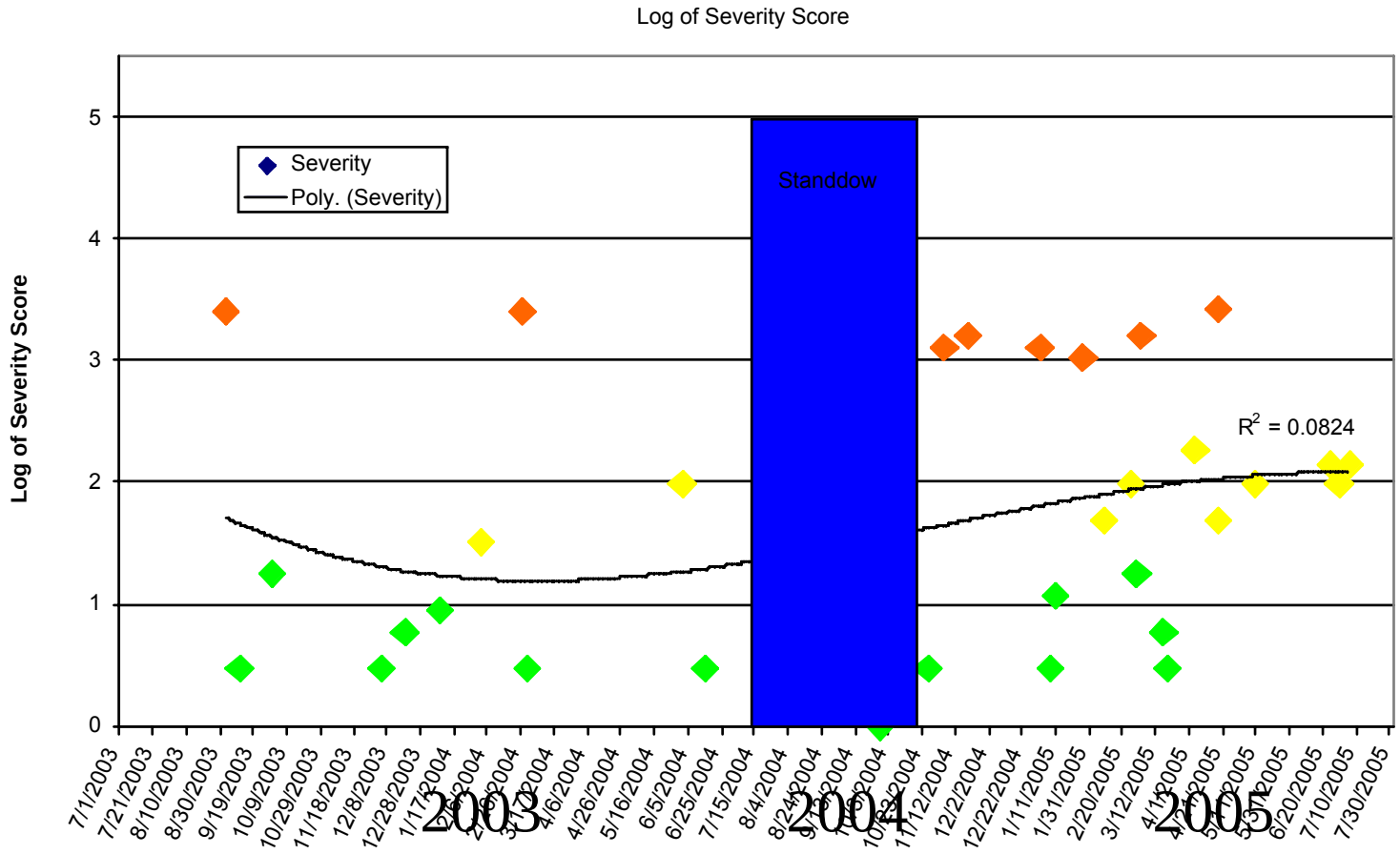
Report Chapter 3

Major Conclusions - concerns

- Some Corrective Actions and/or recommendations from previous electrical safety assessments have not been implemented
- Recent serious electrical events with subcontractors are troublesome
- Trends indicate possibility for an accident
- Problems in program implementation exist in some organizations
- AHJ roles and responsibilities lack recognition and authority across all organizations, ESC and ESOs

Report Chapter 3

Trends



Severity Score ≤ 30 = Group 1 (Green)
30 < Severity Score ≤ 330 = Group 2 (Yellow)
330 < Severity Score ≤ 3300 = Group 3 (Orange)
3300 < Severity Score = Group 4 (Red)

Report Chapter 3

Recurring Issues

- Inadequate development and implementation of corrective actions across the Lab
- Students involved in accidents
- Complex electrical work, especially involving multiple disciplines
- Subcontractor events, especially LOTO

Report Chapter 3

Other Issues

- Lack of tools lead to misapplication of the ORPS categorization process in electrical events
- SMEs are not always at electrical critiques

Report Chapter 3

Recommended Reporting Tools

- Severity Ranking Tool
- Suggestions for Electrical Event Investigation
- Electrical Hazard Classification

Chapter 5

Top Recommendations

- Need uniform program implementation across all organizations
  - ESC membership
  - ESOs - sufficient and qualified
  - Equipment Approval
- Need more oversight of subcontractors
  - training, inspection, LOTO
- Need more oversight of students
  - training, qualification, supervision, mentorship
- Need electrical inspectors
- Need better tools for electrical critiques
  - SME at every critique, Electrical Severity Ranking Tool
- Need to implement revised Electrical ISD efficiently
- LOTO Program needs revision

Report Chapter 4

Severity Ranking Tool Ranges

NEW

	Severity index	log	group
Extreme	≥ 3300	> 3.5	4
High	330 - 3300	2.5 - 3.5	3
Medium	30 - 330	1.5 - 2.5	2
Low	0 - 30	<1.5	1

The severity index is used to group the events by severity. This committee proposes that this tool be used as the basis for assigning a severity index to all electrical events in the future. This tool should be used by electrical SMEs to provide for objectively determining the level of hazard present during an electrical event at Los Alamos National Laboratory.

Summary

- This report contains a substantial amount of useful information, that can lead to program improvement, if supported and implemented.
- This report points out the successes and weaknesses in our current electrical safety program.

Bonus Material

- Normalization of Electrical Events for several labs
- LANL Proposed Electrical Hazard Classification

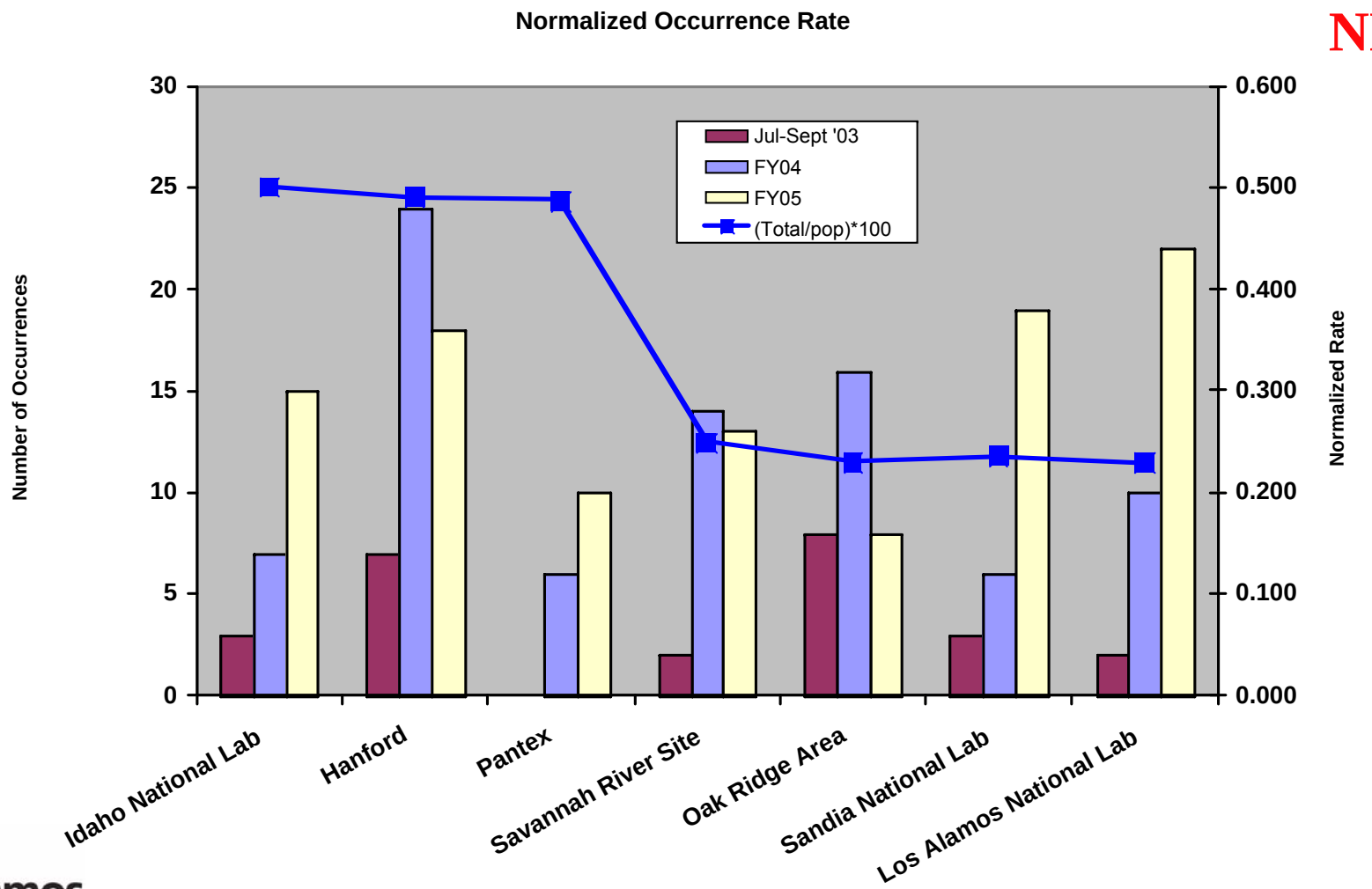
Data for Electrical Incidents for Select DOE/NNSA Labs.

NEW

	Jul-Sept '03	FY04	FY05	Total	Population	(Total/pop)*100
Idaho National Lab	3	7	15	25	5,000	0.500
Hanford	7	24	18	49	10,000	0.490
Pantex	0	6	10	16	3,291	0.486
Savannah River Site	2	14	13	29	11,680	0.248
Oak Ridge Area	8	16	8	32	13,268	0.241
Sandia National Lab	3	6	19	28	11,933	0.235
Los Alamos National Lab	2	10	22	34	14,875	0.229

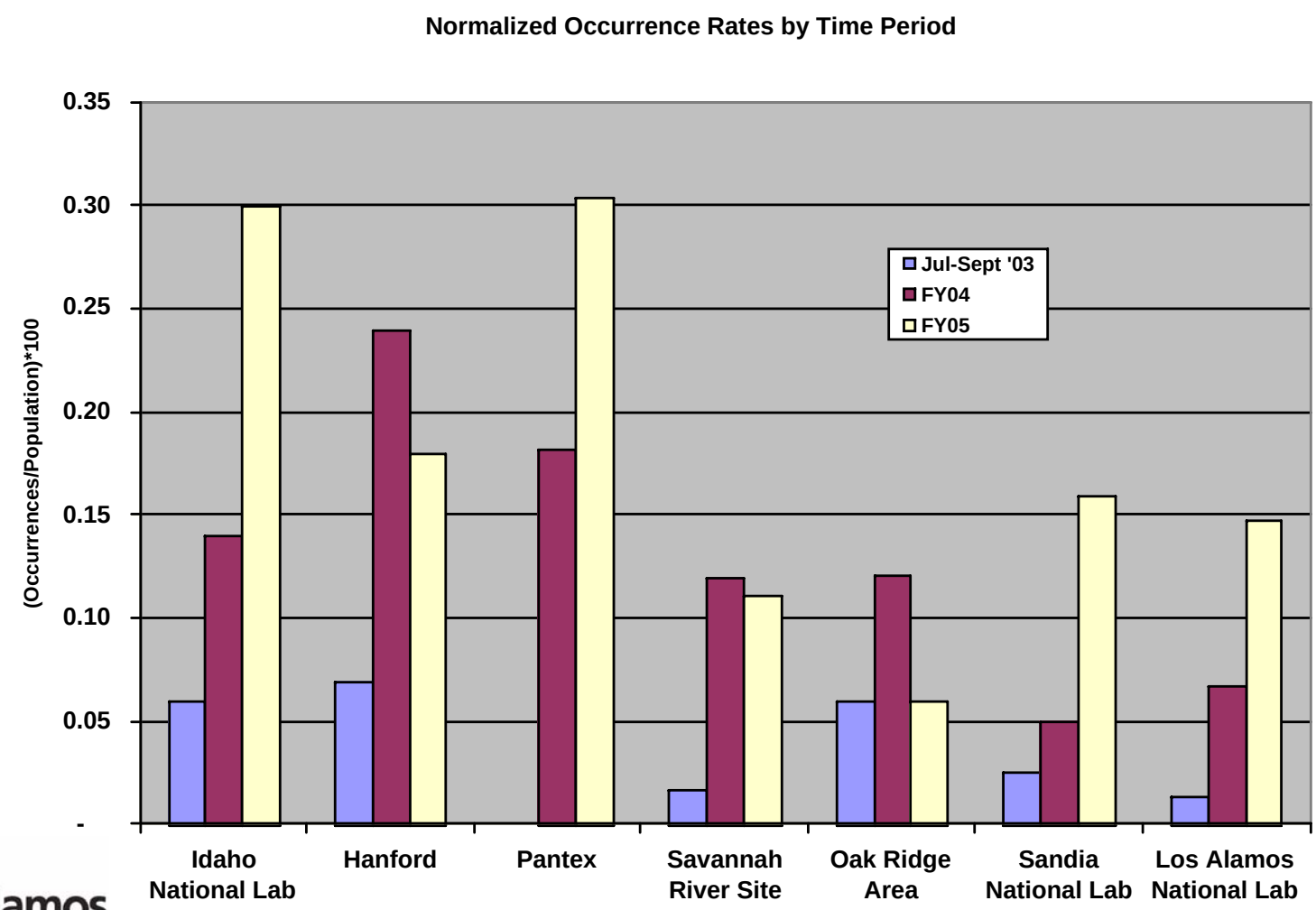
Plot of Normalized Electrical Occurrences for Seven DOE/NNSA Sites.

NEW



Normalized Electrical Occurrence Rates over Three Years.

NEW



Proposed LANL Electrical Hazard Classification Tables

Lloyd Gordon

November 3, 2005

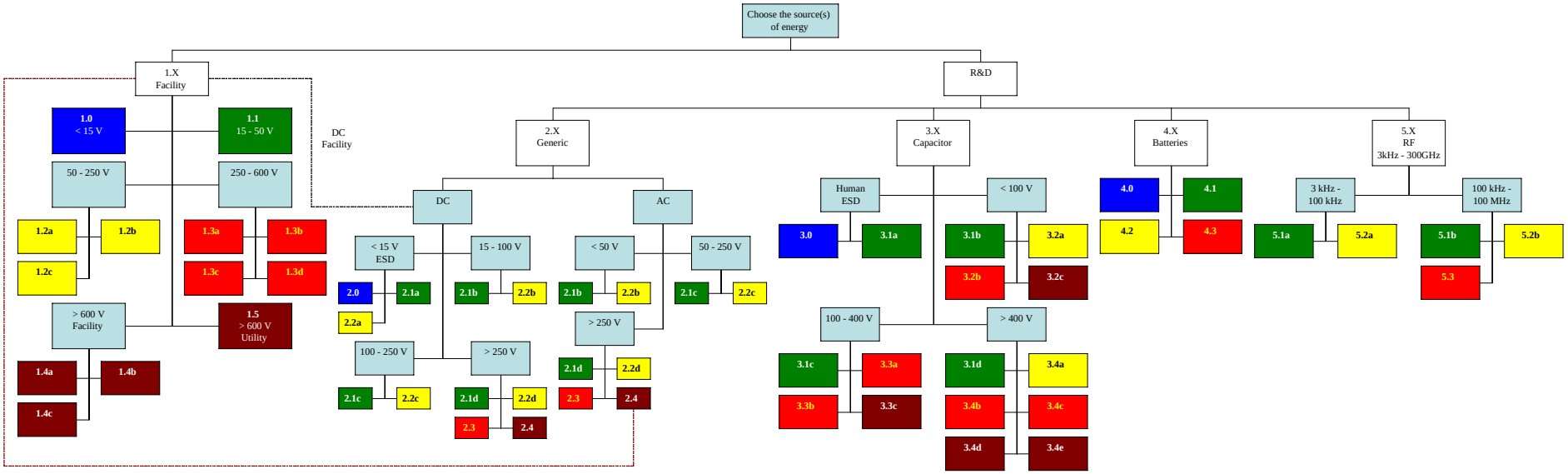
Color code for Electrical Hazard Classification

hazard level	color
no hazard	blue
low hazard	green
moderate	yellow
high	orange
very high	red

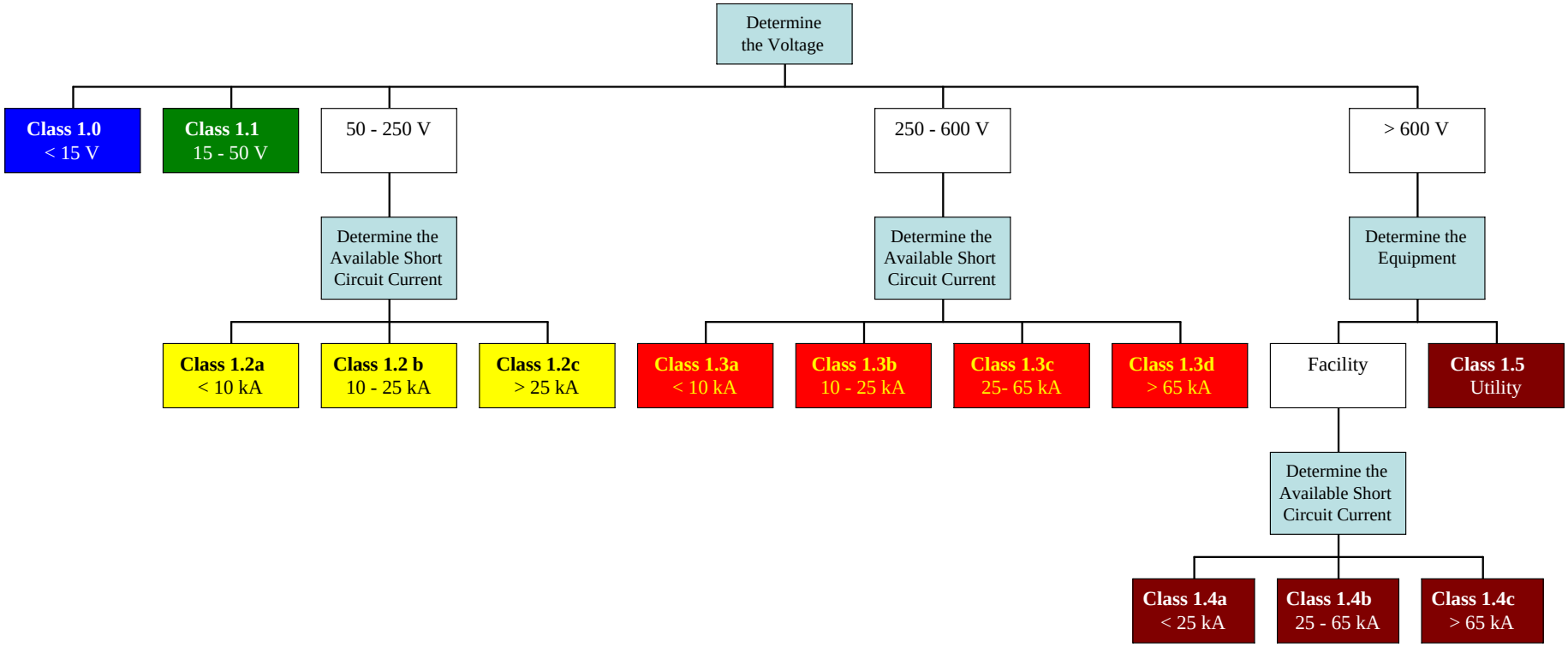
Proposed LANL Electrical Hazard Classification

- The electrical hazard tables cover seven broad areas, including facility power, R&D, capacitors, batteries, and rf. These tables, taken collectively, constitute a comprehensive list of electrical hazards found in electrical equipment. Consequently, all tables should be considered when identifying the hazards associated with any given piece of electrical equipment.

Electrical Hazard Classification Organizational Table

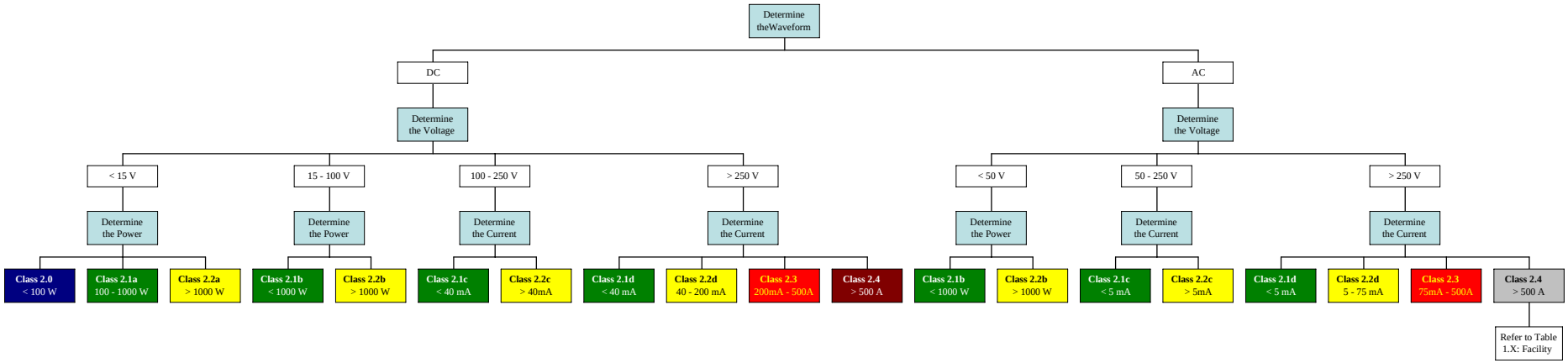


Classification Table 1.X: Facility - arc flash

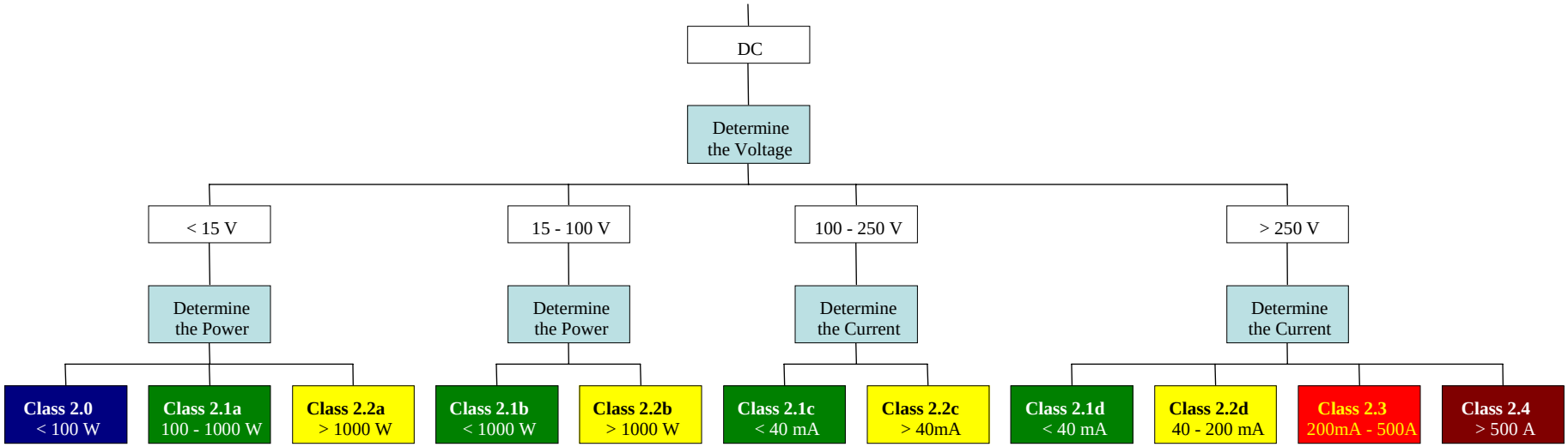


Note: for DC Facility Power refer to Table 2.X: R&D

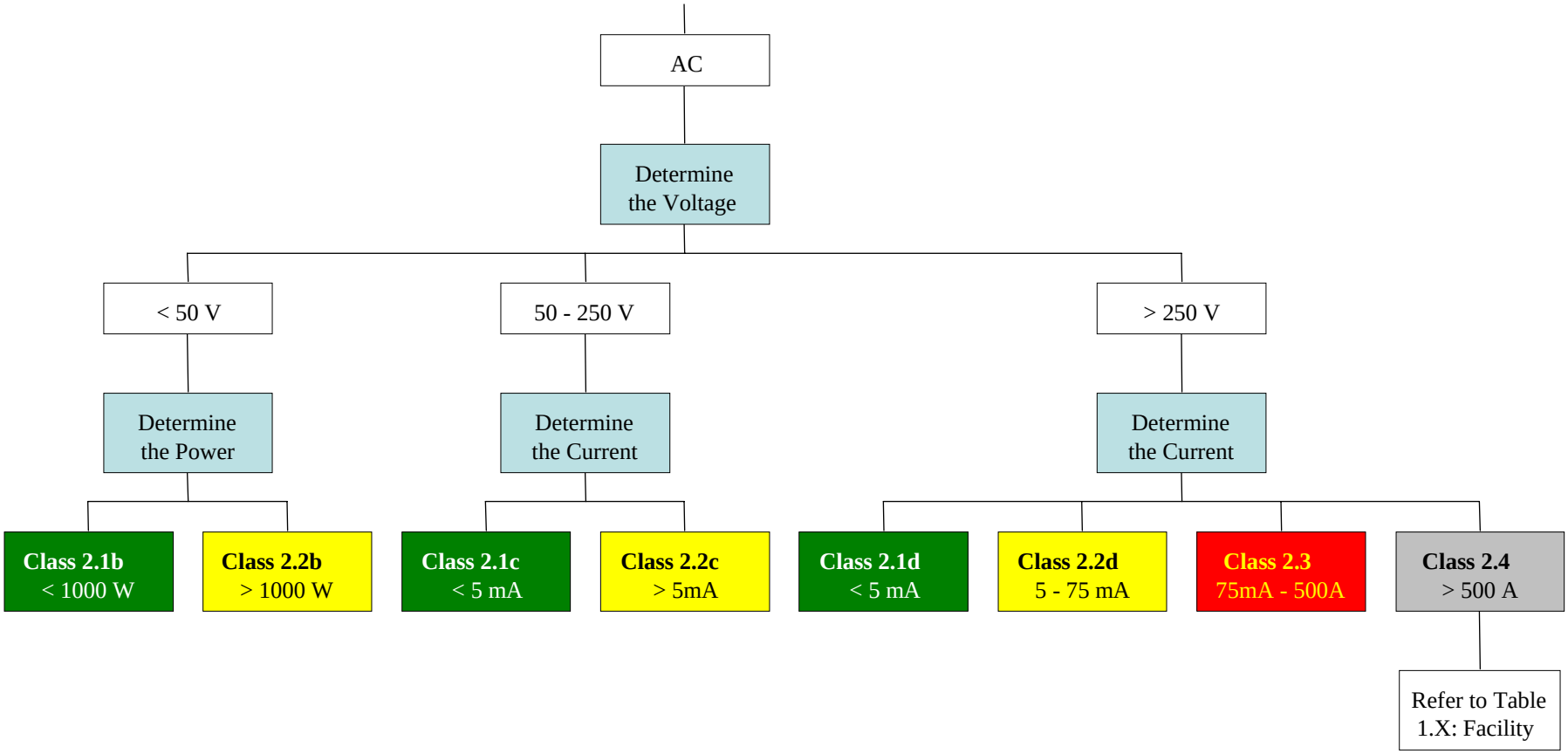
Classification Table 2.X: R&D Generic



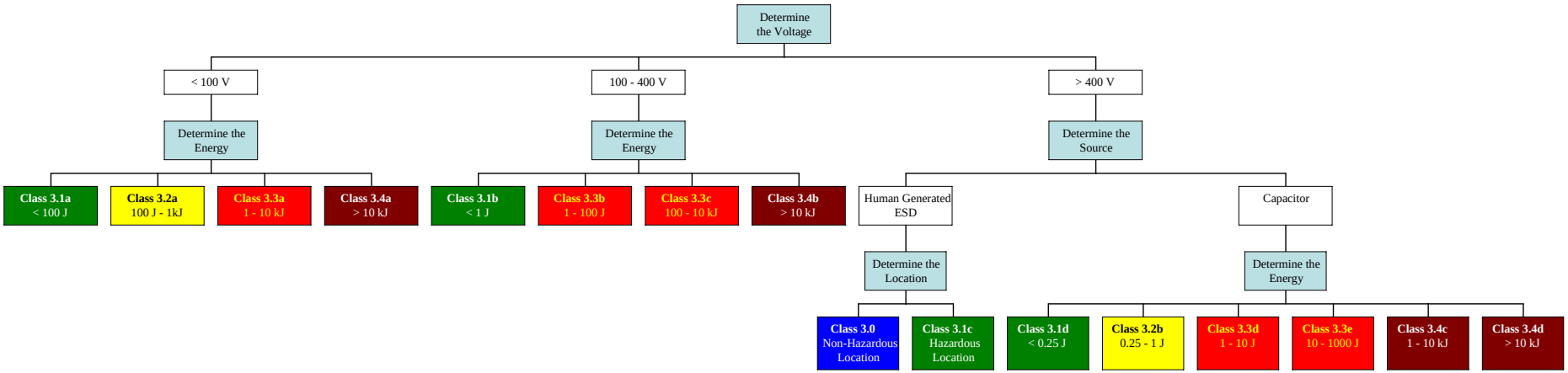
Classification Table 2.X: R&D - dc



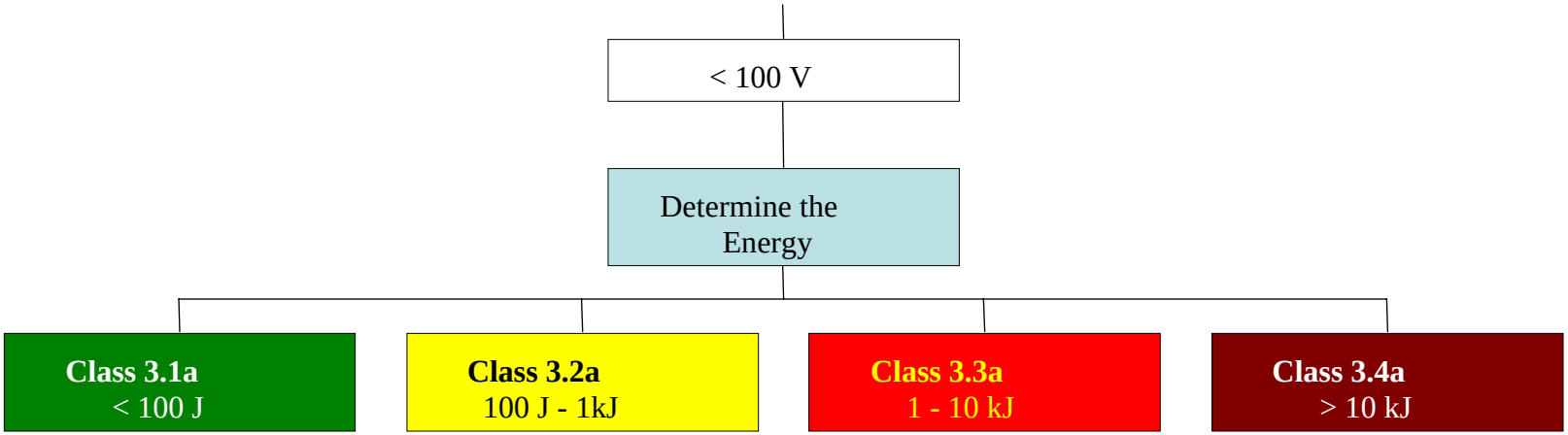
Classification Table 2.X: R&D ac



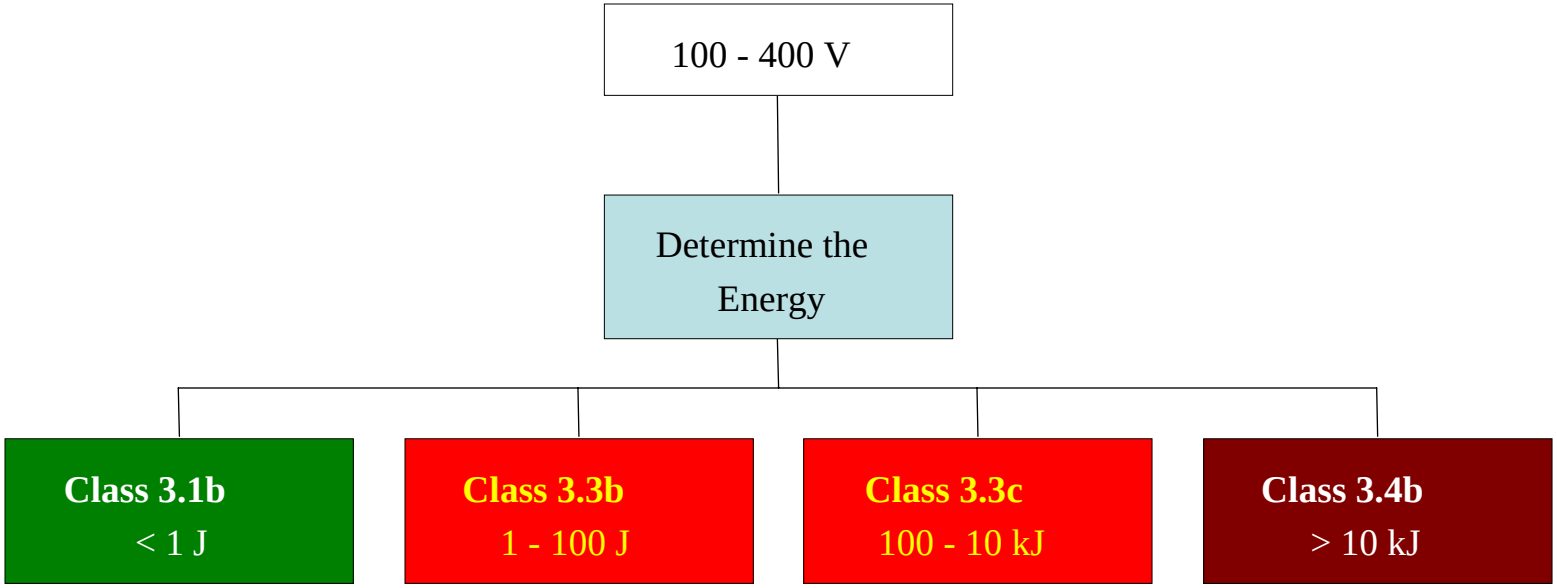
Classification Table 3.X: Capacitors



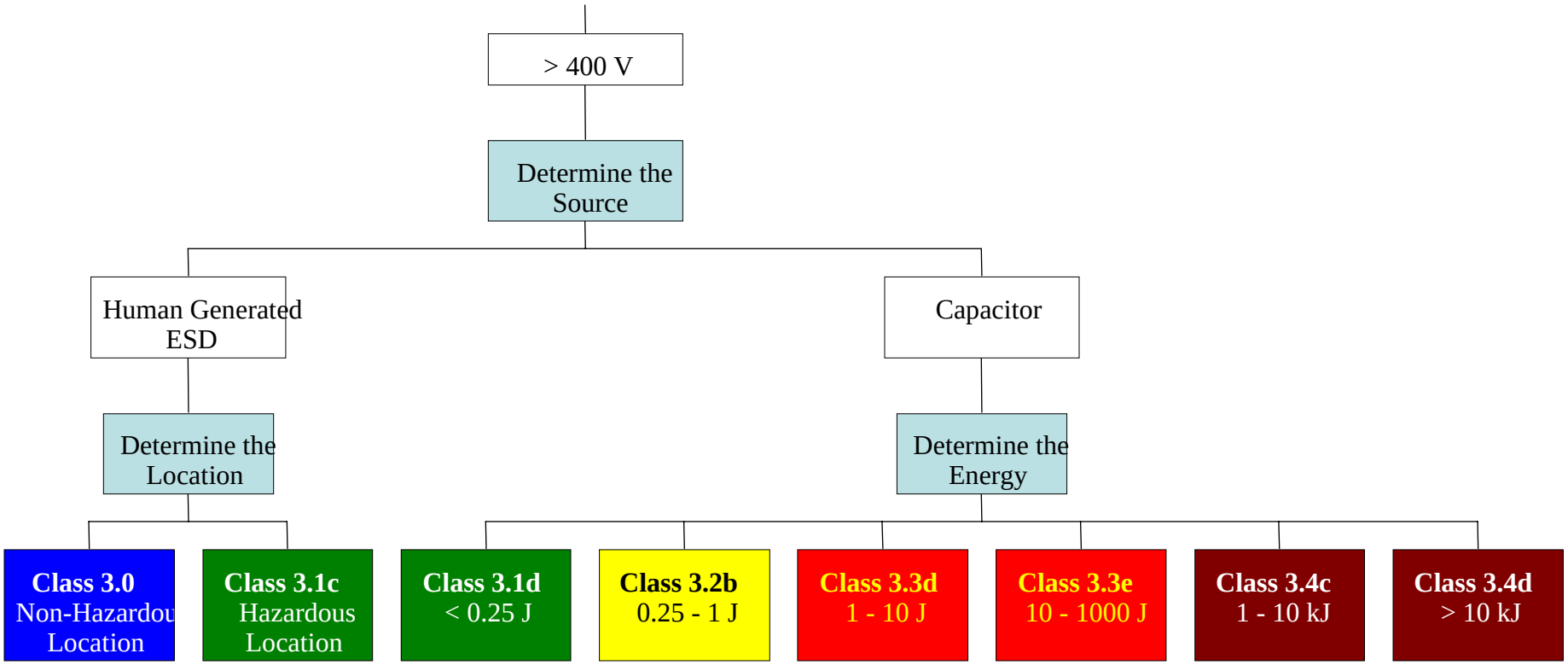
Classification Table 3.X: Capacitors < 100 V



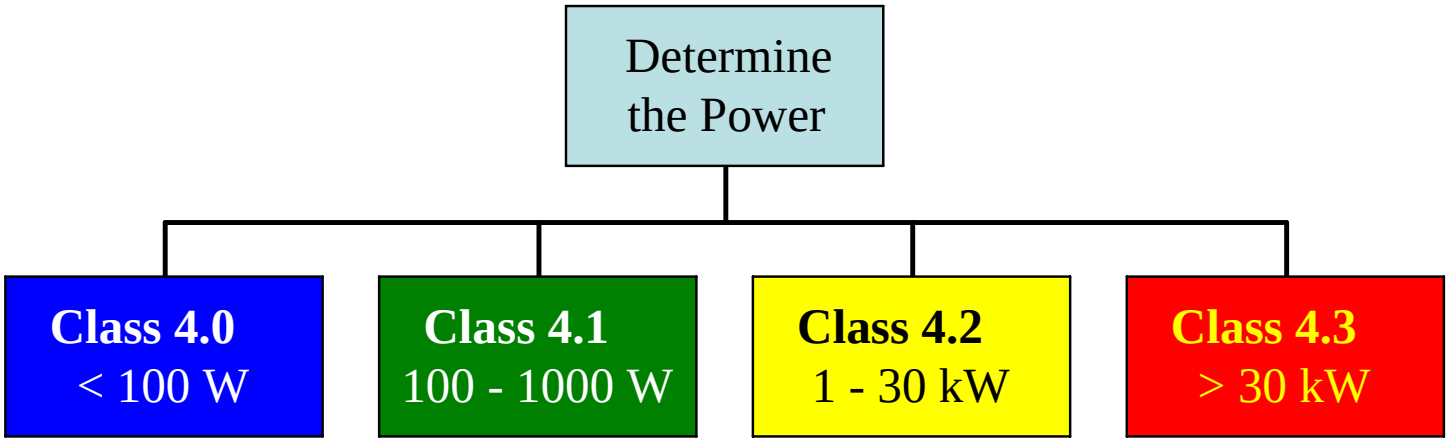
Classification Table 3.X: Capacitors 100 - 400 V



Classification Table 3.X: Capacitors > 400 V

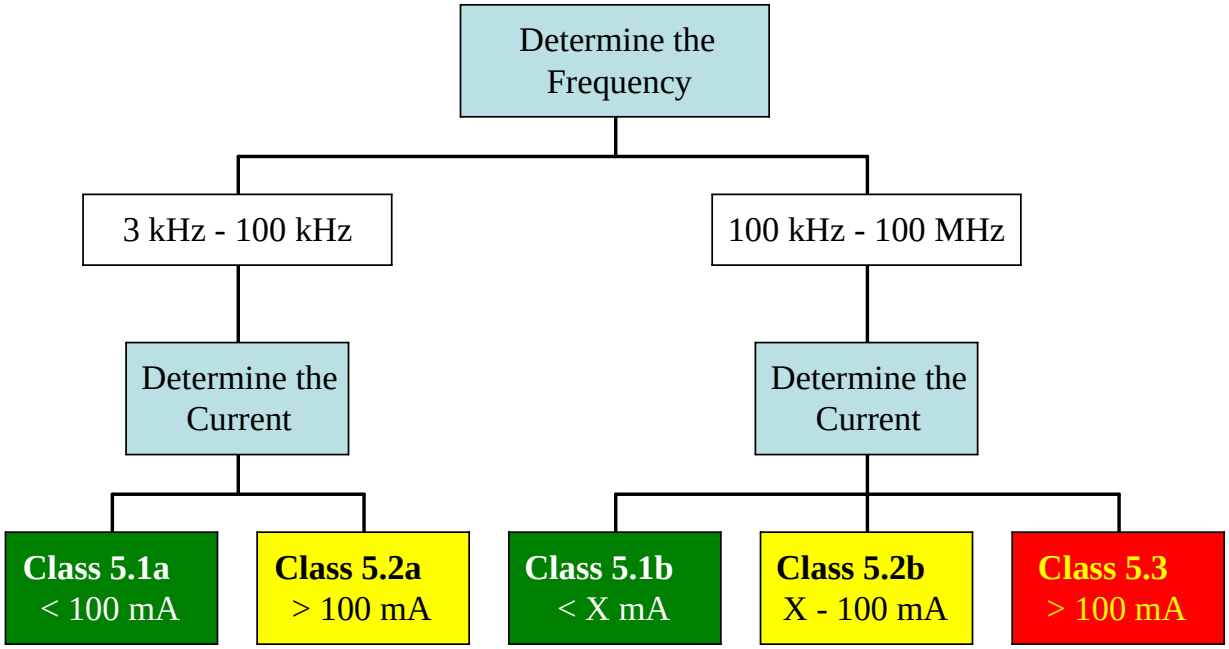


Classification Table 4.X: Batteries



Note: > 50 V also refer to Table 2.X: Generic to classify the shock hazard.

Classification Table 5.X: RF 3kHz - 300GHz

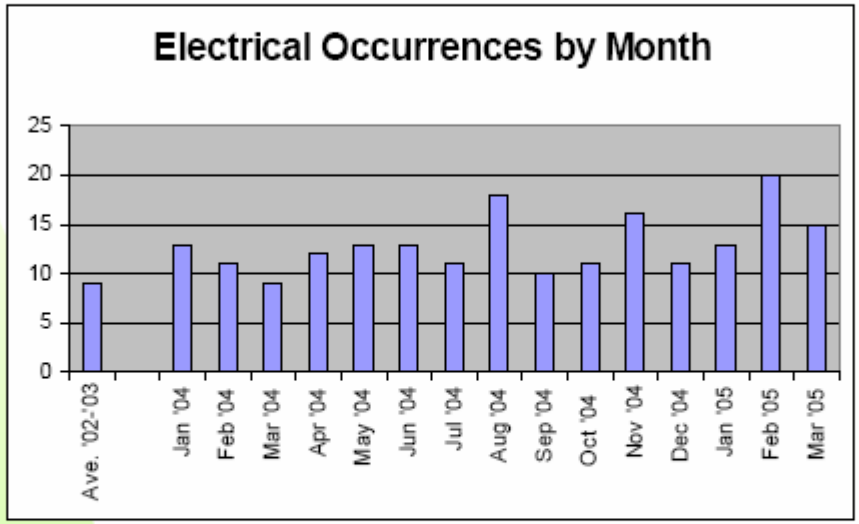


Ground Penetrating Radar

WHY USE GSSI GPR?

because….

Rate of Electrical Occurrences is Increasing



- **2002 - 2003 rate = 9 per month**
- **2004 rate = 12 per month**
- **2005 rate (Jan. through March) = 16 per month**
- **14 occurrences in only the first half of April '05**

Office of Environment, Safety and Health (EH)

History of GPR

GPR invented ~1970

Uses

To Find: Bedrock, Water Tables, and Geological Features

Nuclear power industry 1980's

Theory

- Electromagnetic Reflection (EMR)
- Ultra Wide Band frequency
- 100 MHz to 3 GHz
- 100 KHz repetition rate

Characteristics

- Average radiated power
  - .004 milliwatts
- Practical limits 15”-18” in concrete with 1.6 GHz antenna
- Up To 36” Deep with 900MHz antenna

ADVANTAGES OF GPR

- EXTREMELY ACCURATE
- FAST
- REAL TIME TARGETING
- NON-DESTRUCTIVE
- ONE SIDE ACCESS (SLAB ON GRADE)
- NON-INTRUSIVE
- DIGITAL MEDIA STORAGE

What can you identify?

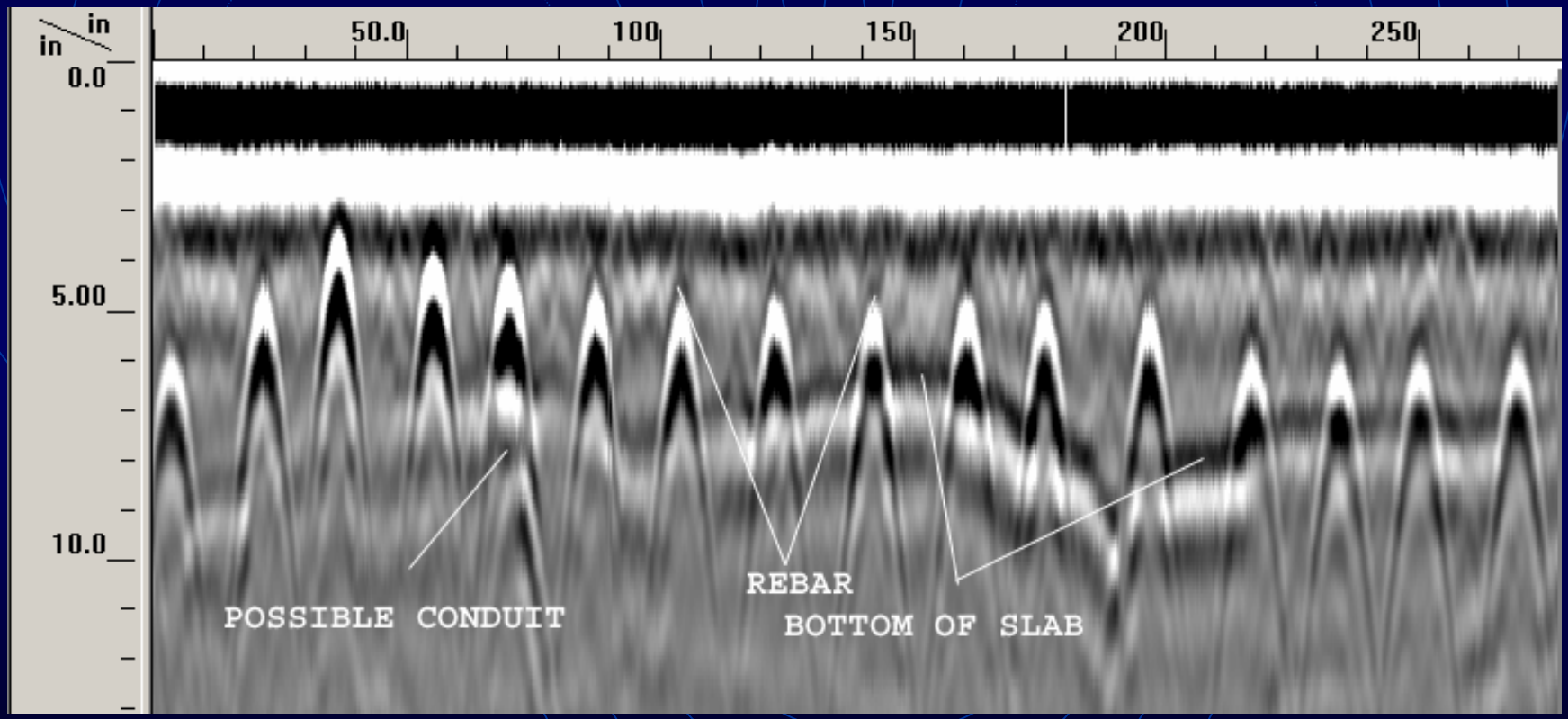
* Conduit in concrete
* PT Cables in Concrete
* Voids in Concrete
* Pipes in Concrete
* Fiber optics in Concrete
* Rebar in Concrete

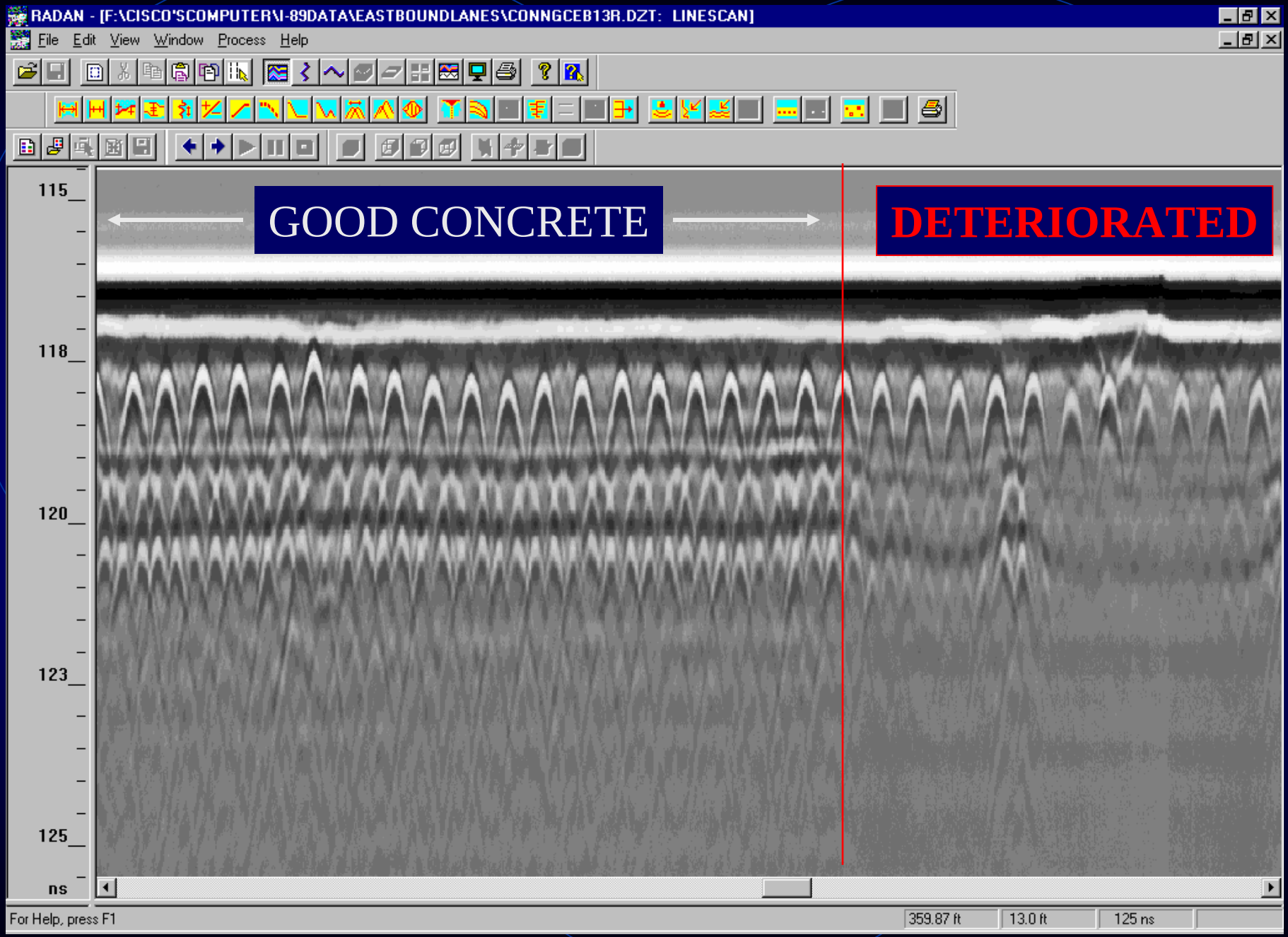
* Pipes in Soil
* Tanks in Soil
* Voids in Soil
* Buried objects
* Electric in Soil
* Accurate Depth and Location

EXAMPLES

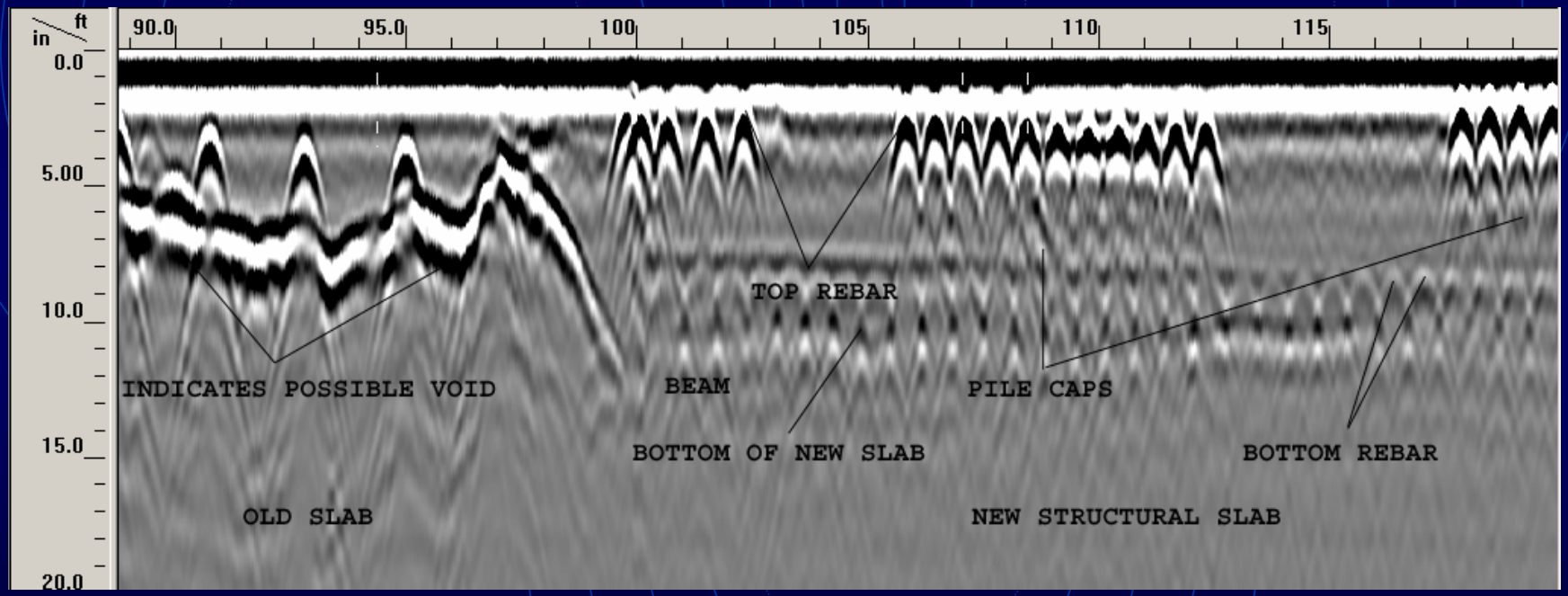
2D & 3D Data

Typical Slab on Grade



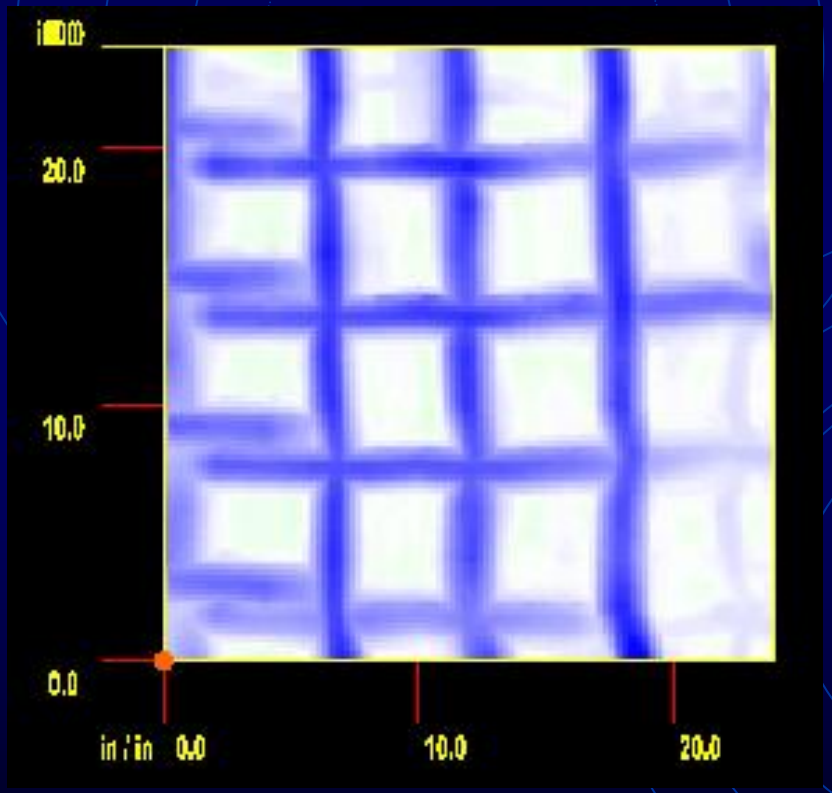

RADAN - [F:\CISCO'SCOMPUTER\I-89DATA\EASTBOUNDLANES\CONNGCEB13R.DZT: LINESCAN]
File Edit View Window Process Help
GOOD CONCRETE
DETERIORATED
115
118
120
123
125
ns
For Help, press F1
359.87 ft
13.0 ft
125 ns

Slab on Grade VS Structural Slab

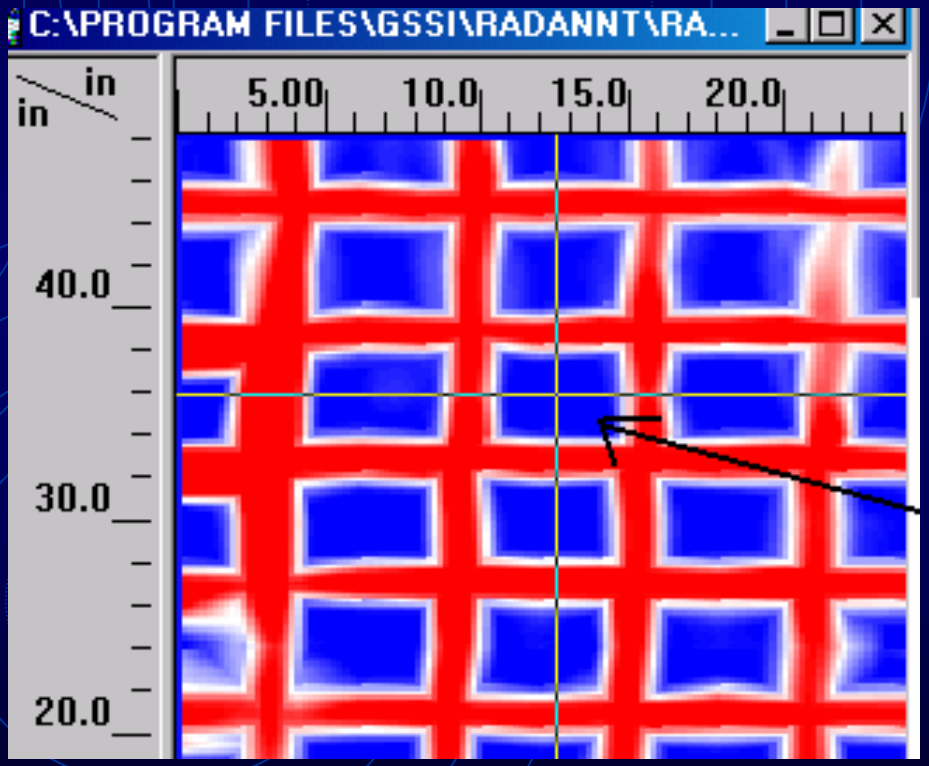


Plan-view Mapping

WIRE MESH

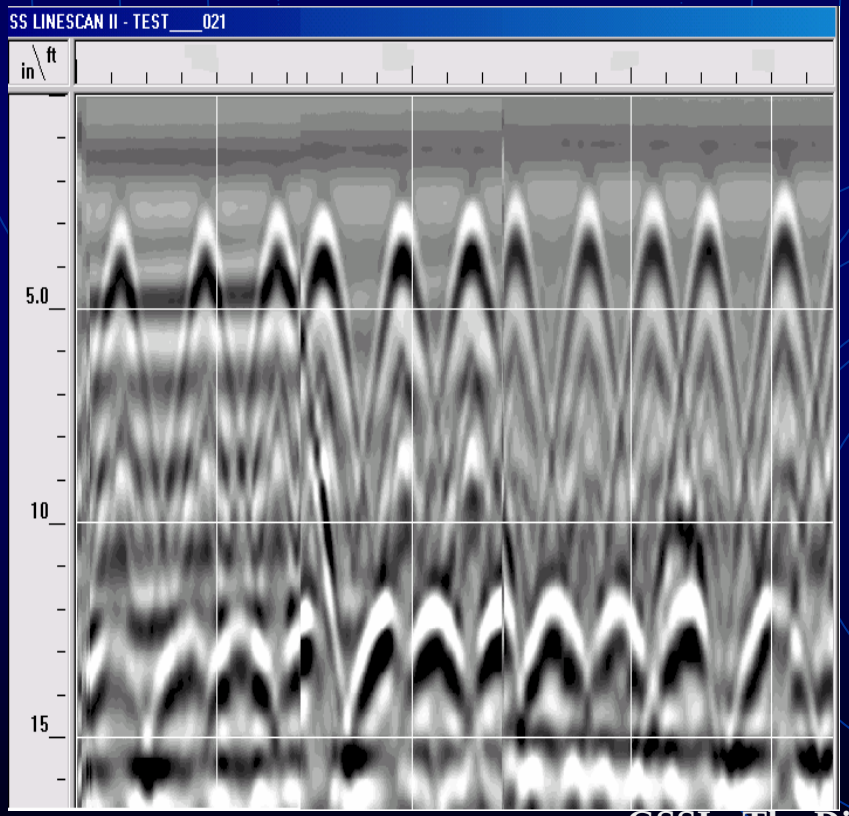


Rebar Mat

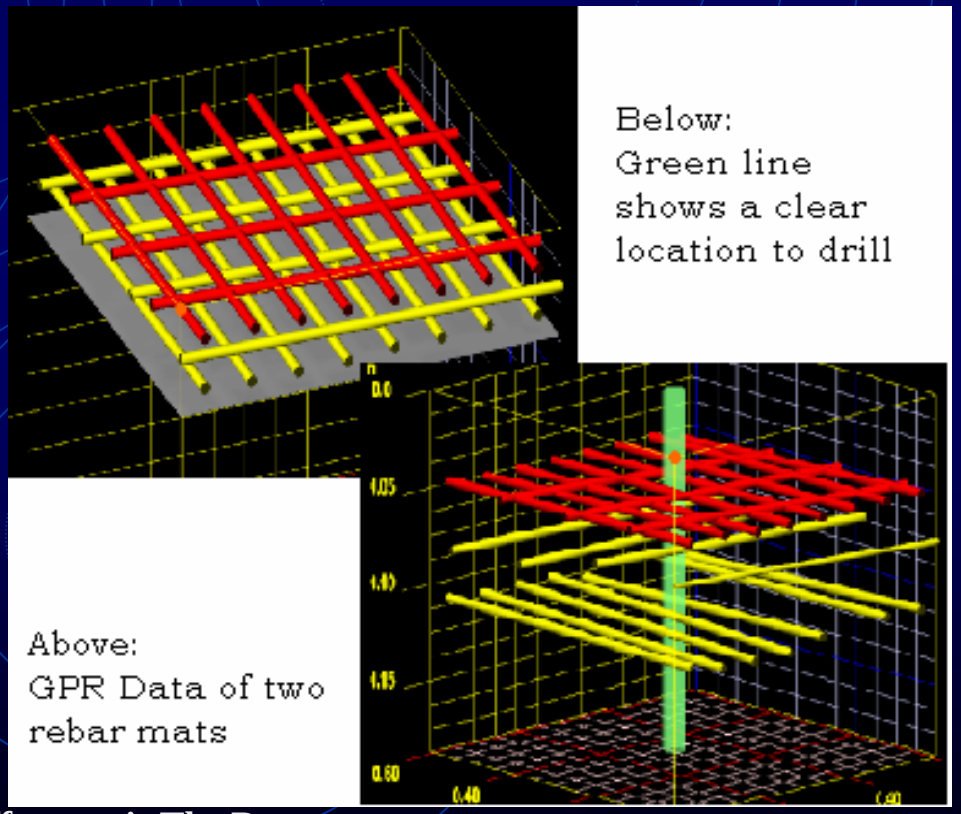


DOUBLE REBAR MAT

Dbl Rebar Matt –2 D

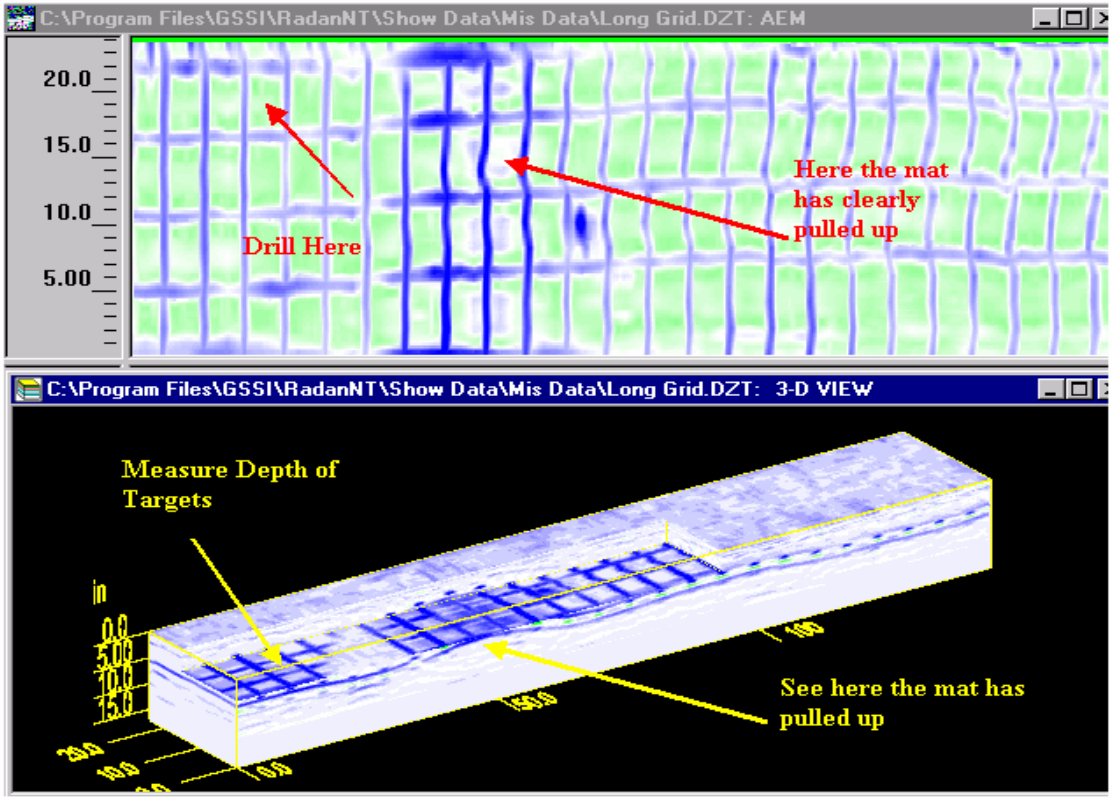


Dbl rebar Matt – 3D

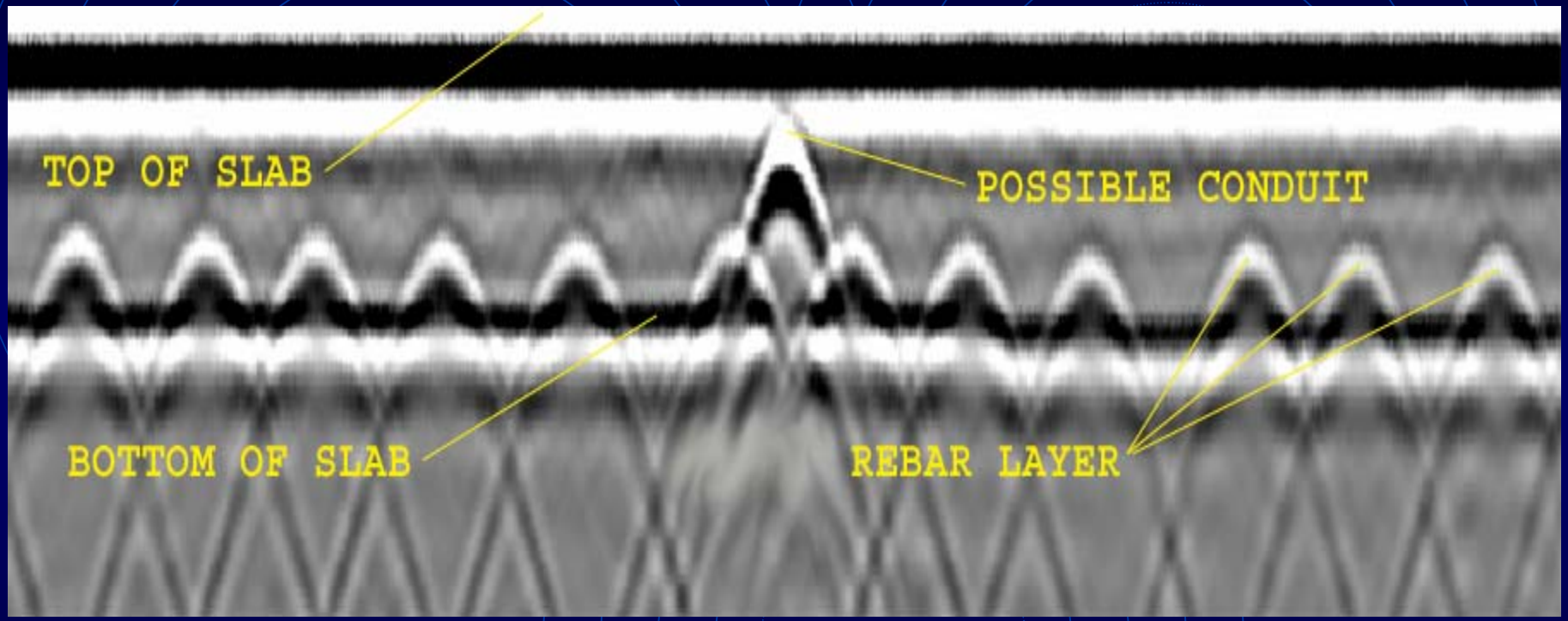


Advanced Mapping in Super 3D

Super 3D 2 x 12 radar survey Mat

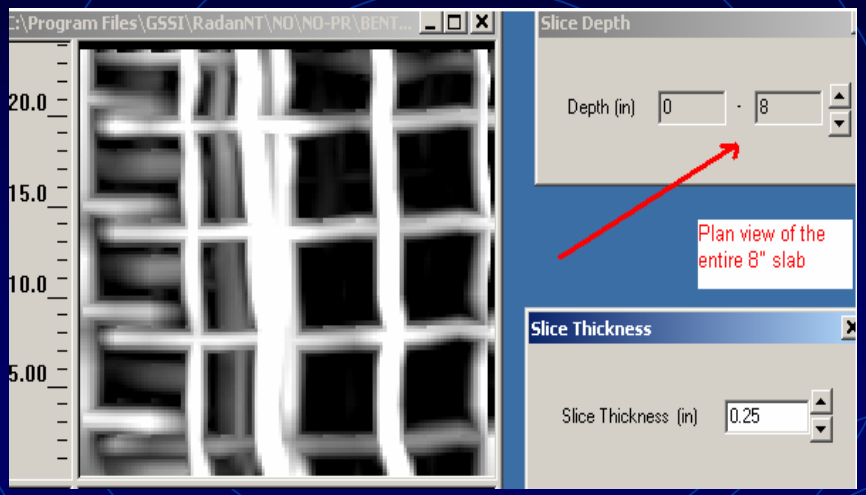


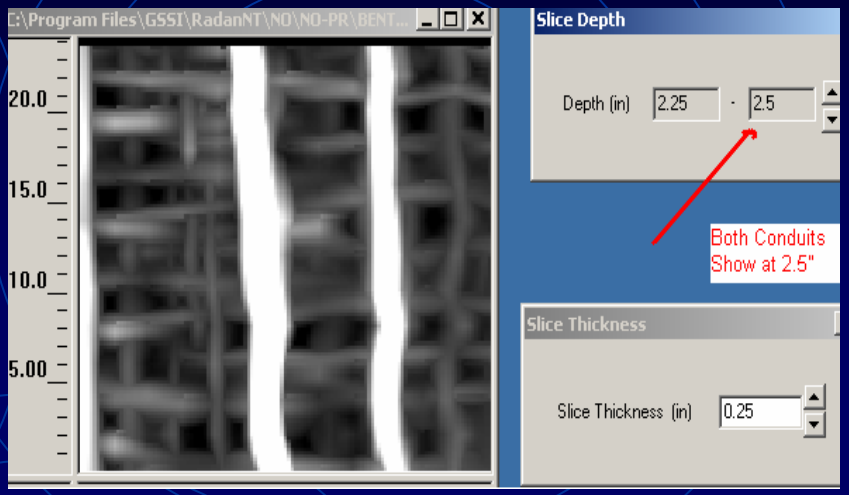
Identifying Conduit – 2D

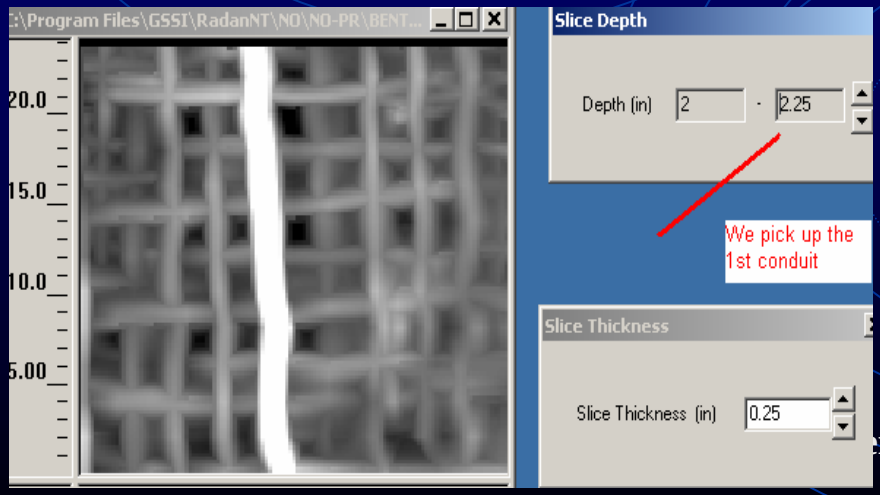


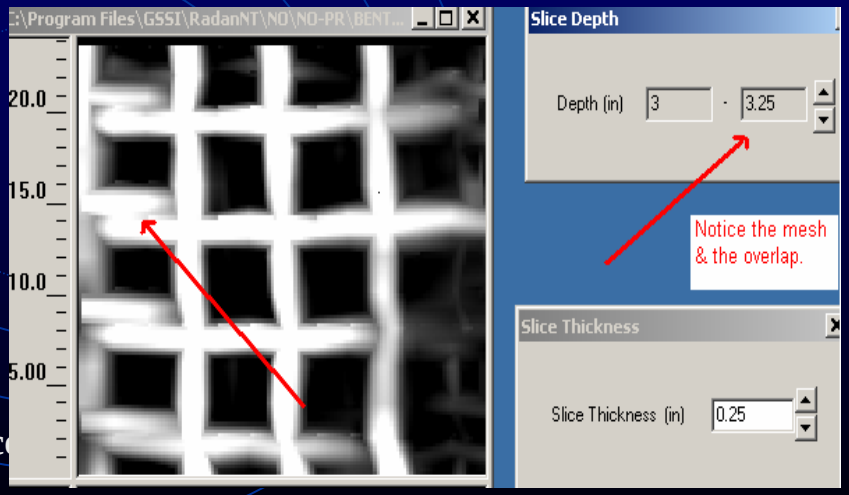
- A target that doesn't fit the rebar pattern is most likely a conduit and requires further investigation

Identifying Conduit – Slicing The Data



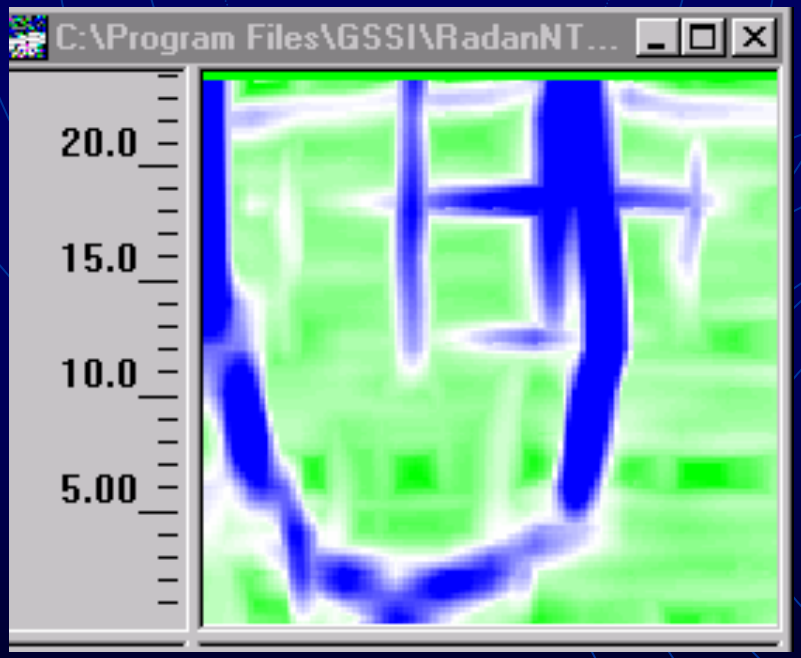


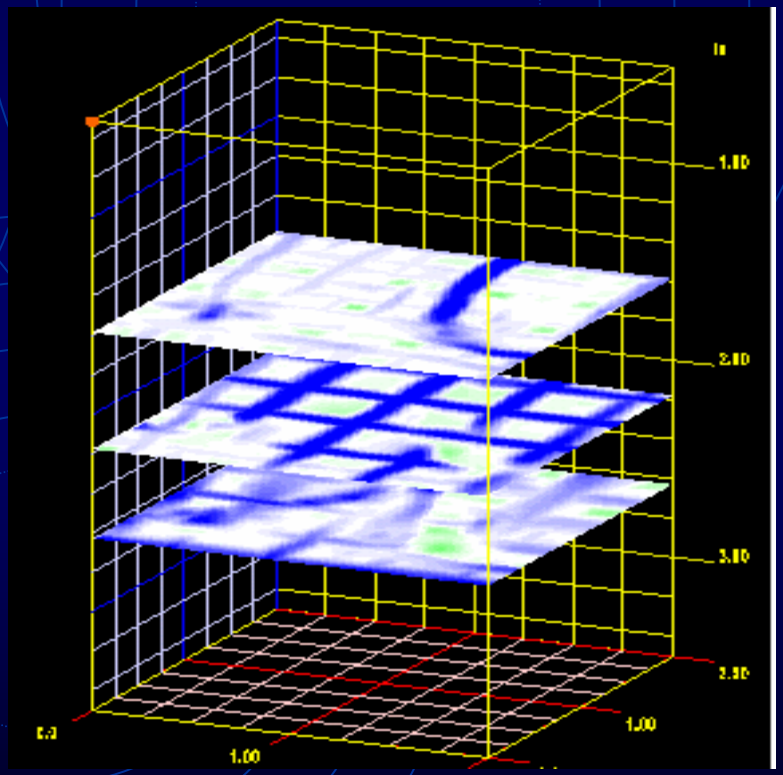




Mapping Out Radiant Heating Lines In Slab

2-D Plan View

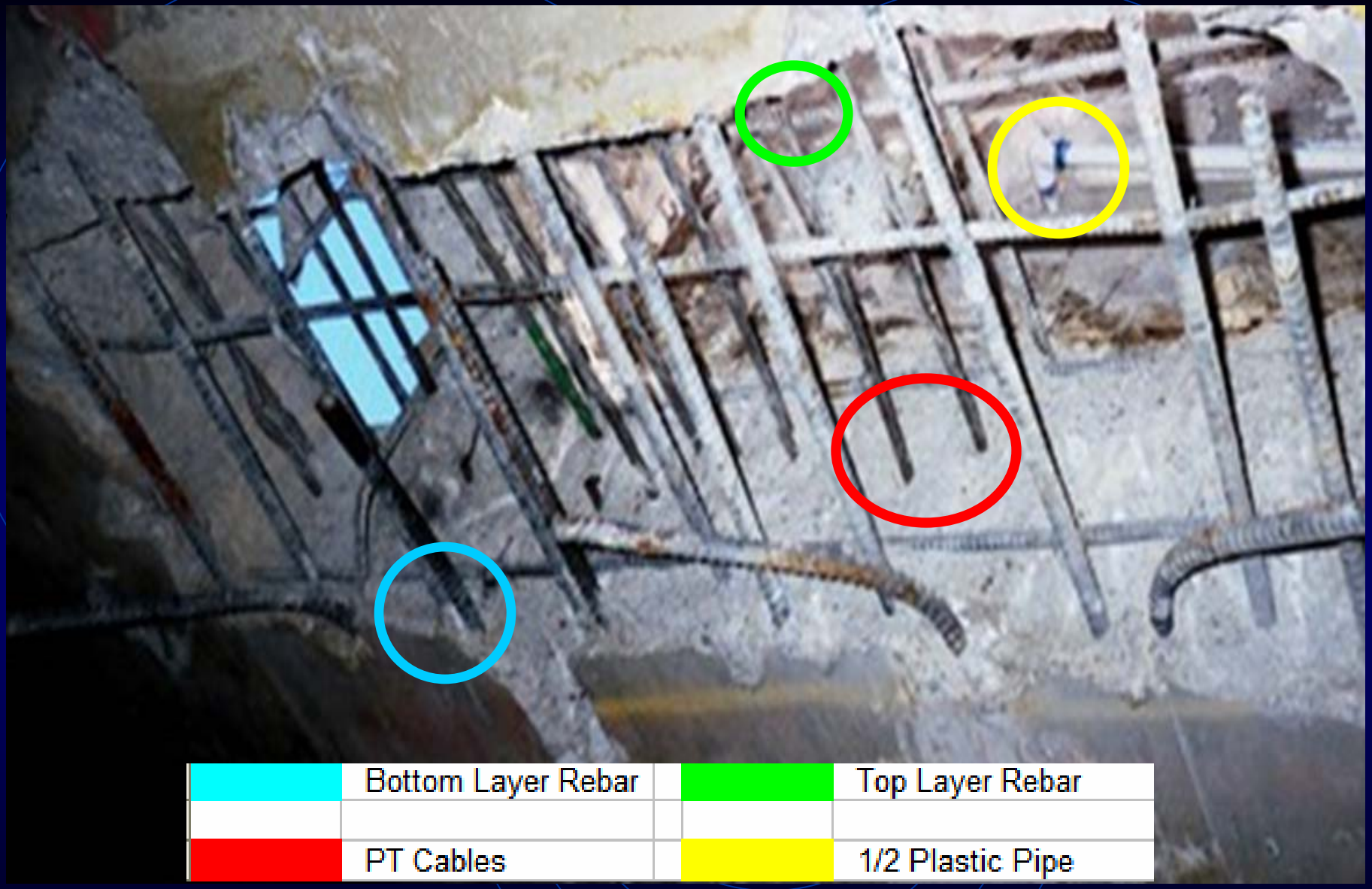




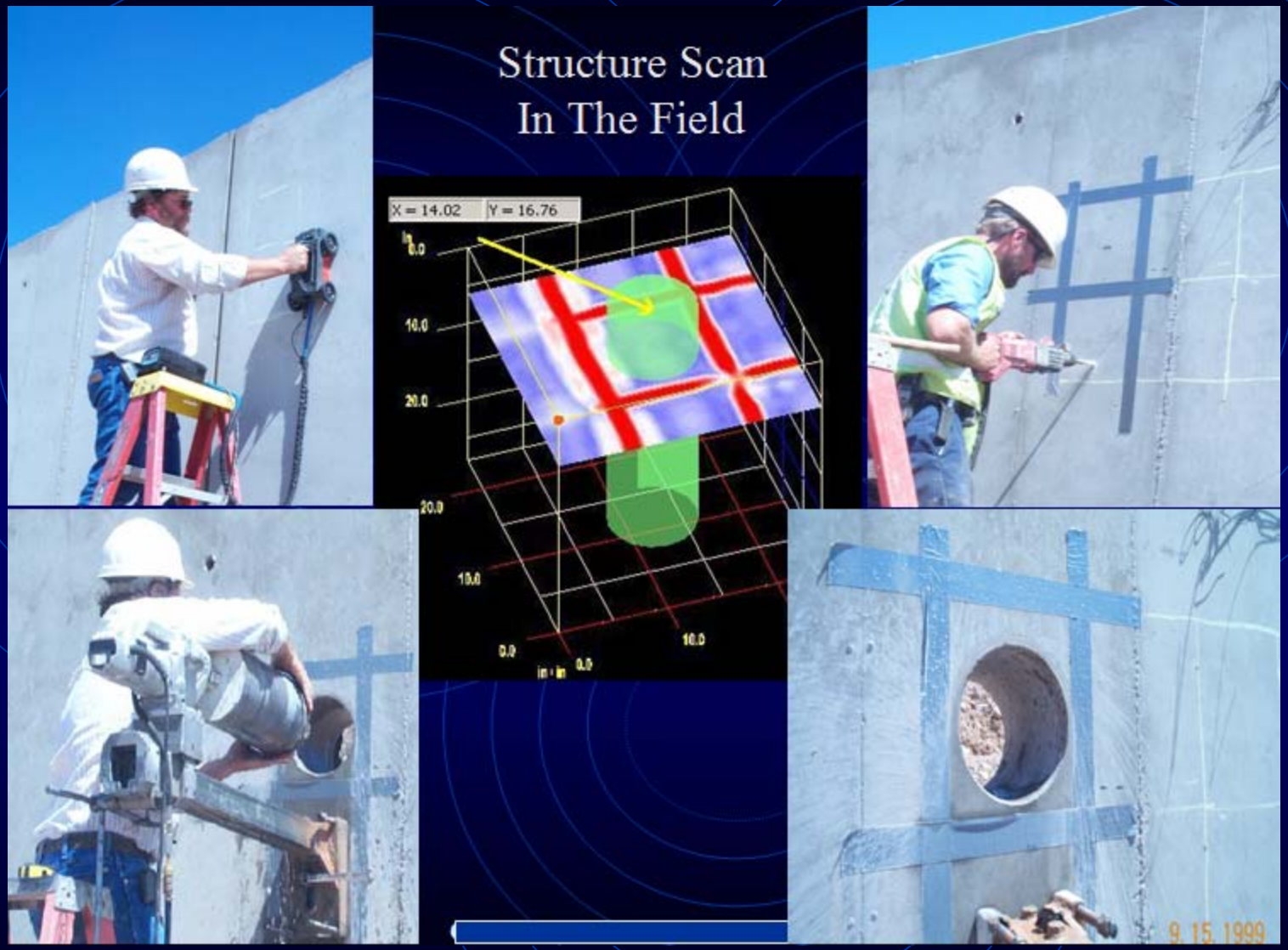
3-D Depth Slice

GSSI - The Difference is The Data.

Locating a Clear Place To Core



GSSI - The Difference is The Data.



GSSI - The Difference is The Data.

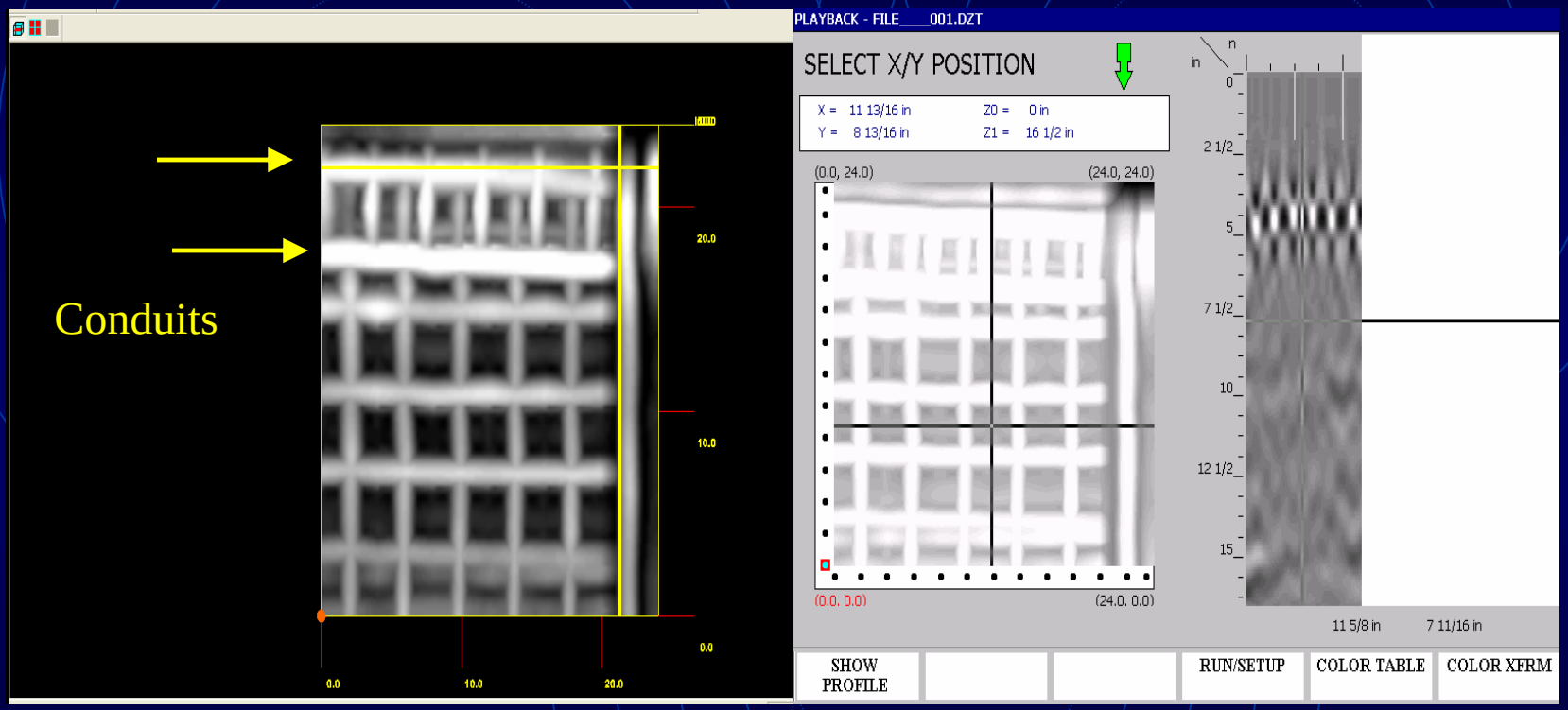
GSSI - Demonstration

Fermi National Accelerator Laboratories April 13, 2005

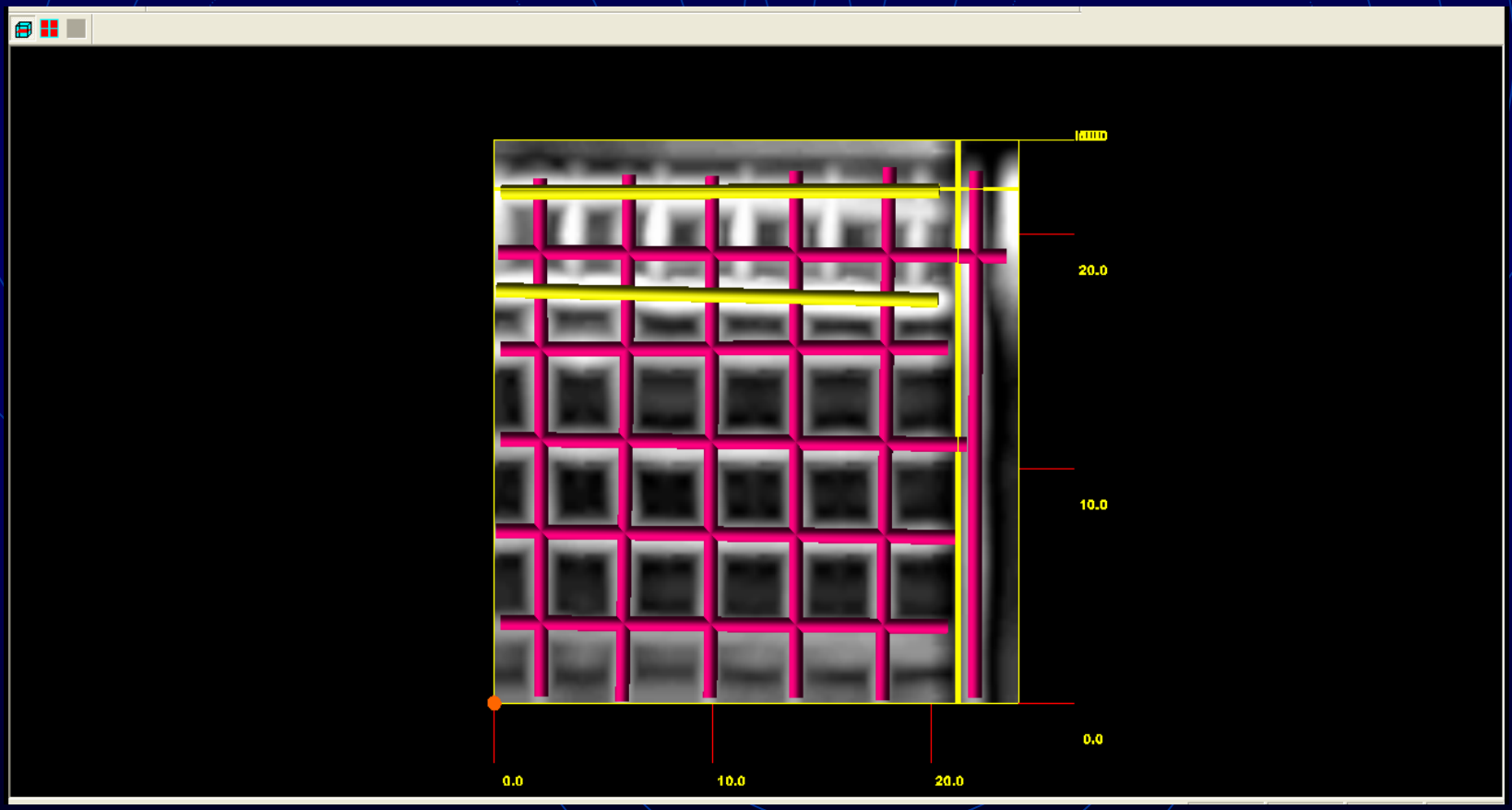
- Four Sites were chosen for the purpose to showcase GPR with known embedments inside the concrete of Fermi Labs.

- The Four Sites:
  - First Site = IBC Cryostat Area (Side) Grid 002
  - Second Site = ICB Collaring Press Saw Cut Grid 003
  - Third Site = ICB 2W Headquarters Conf Rm Grid 005
  - ICB Computer Area (Field Issues) Grid 006

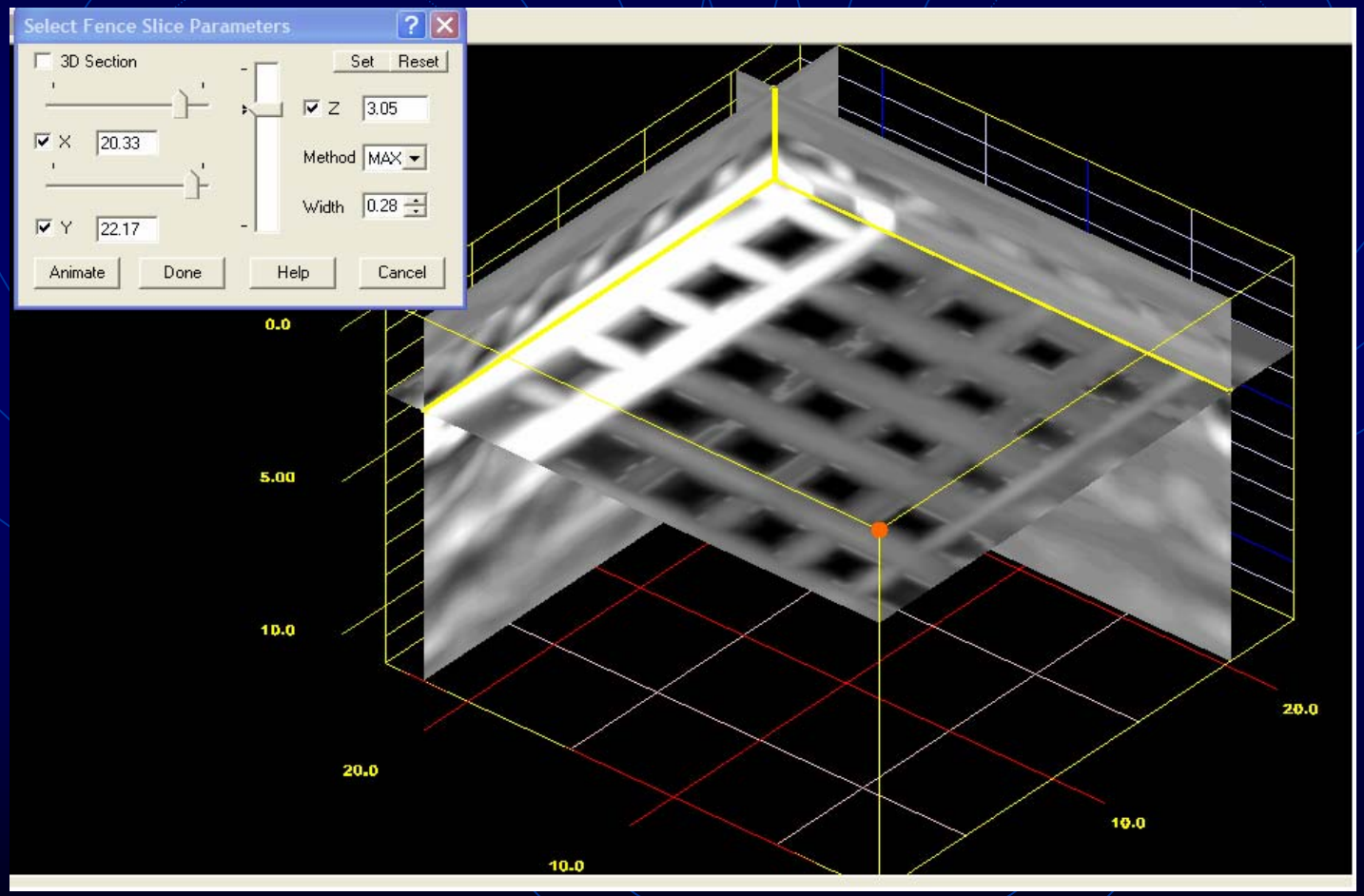
First Site = IBC Cryostat Area (Side)



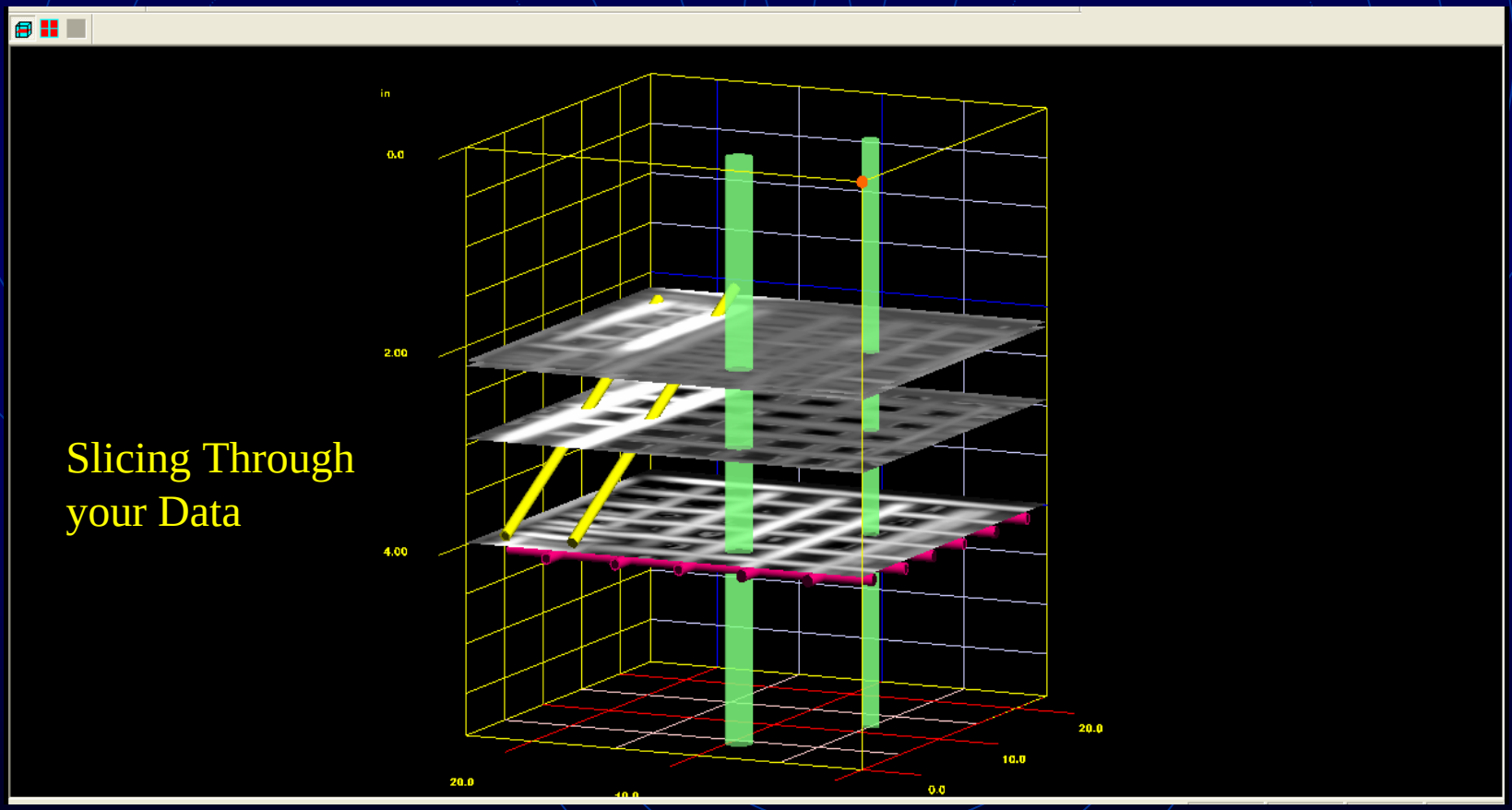
First Site = IBC Cryostat Area (Side)



First Site = IBC Cryostat Area (Side)



First Site = IBC Cryostat Area (Side)

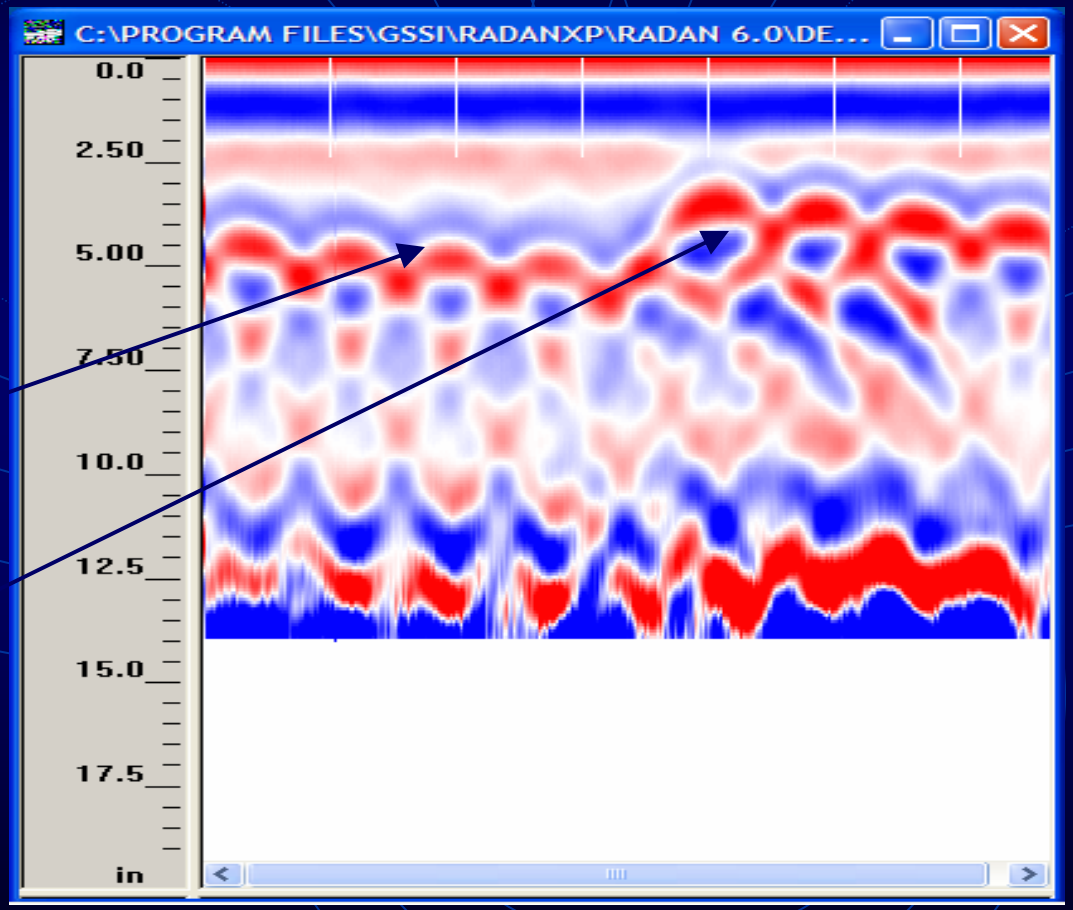


Slicing Through your Data

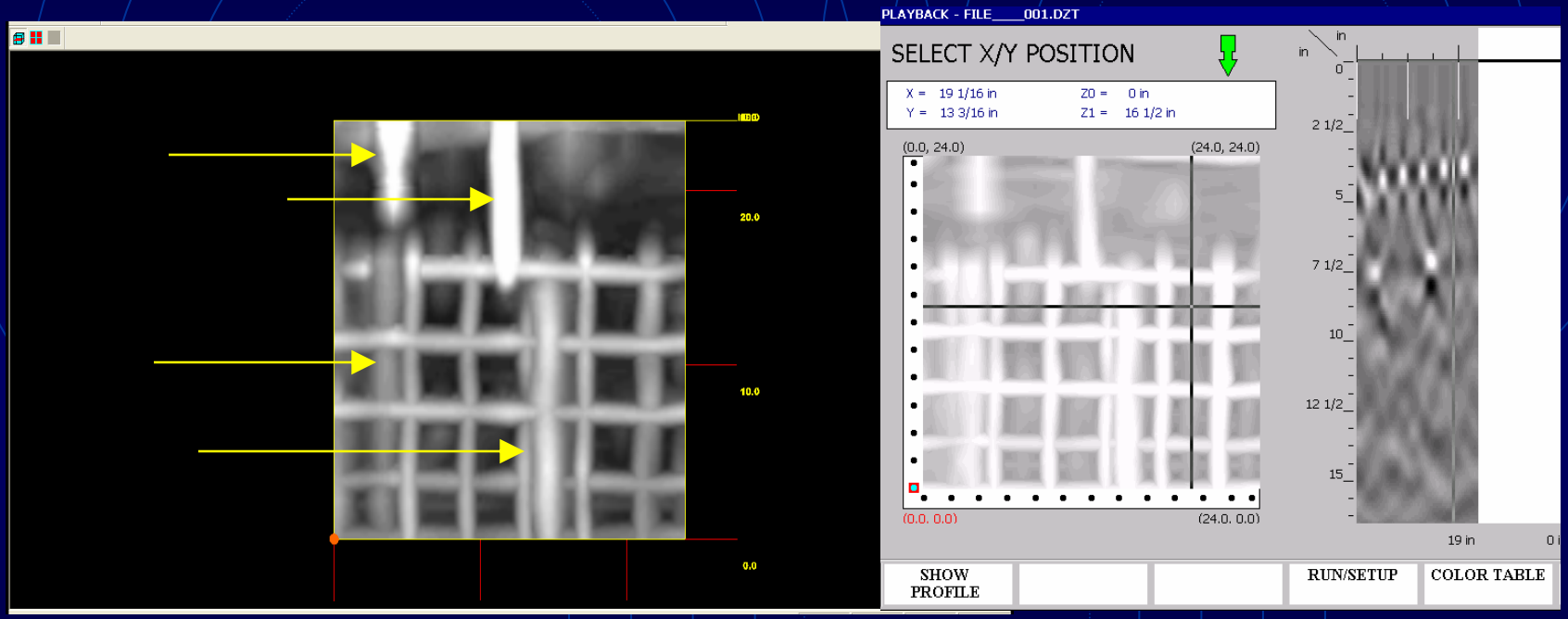
First Site = IBC Cryostat Area (Side)

New Roll of 4” Mesh

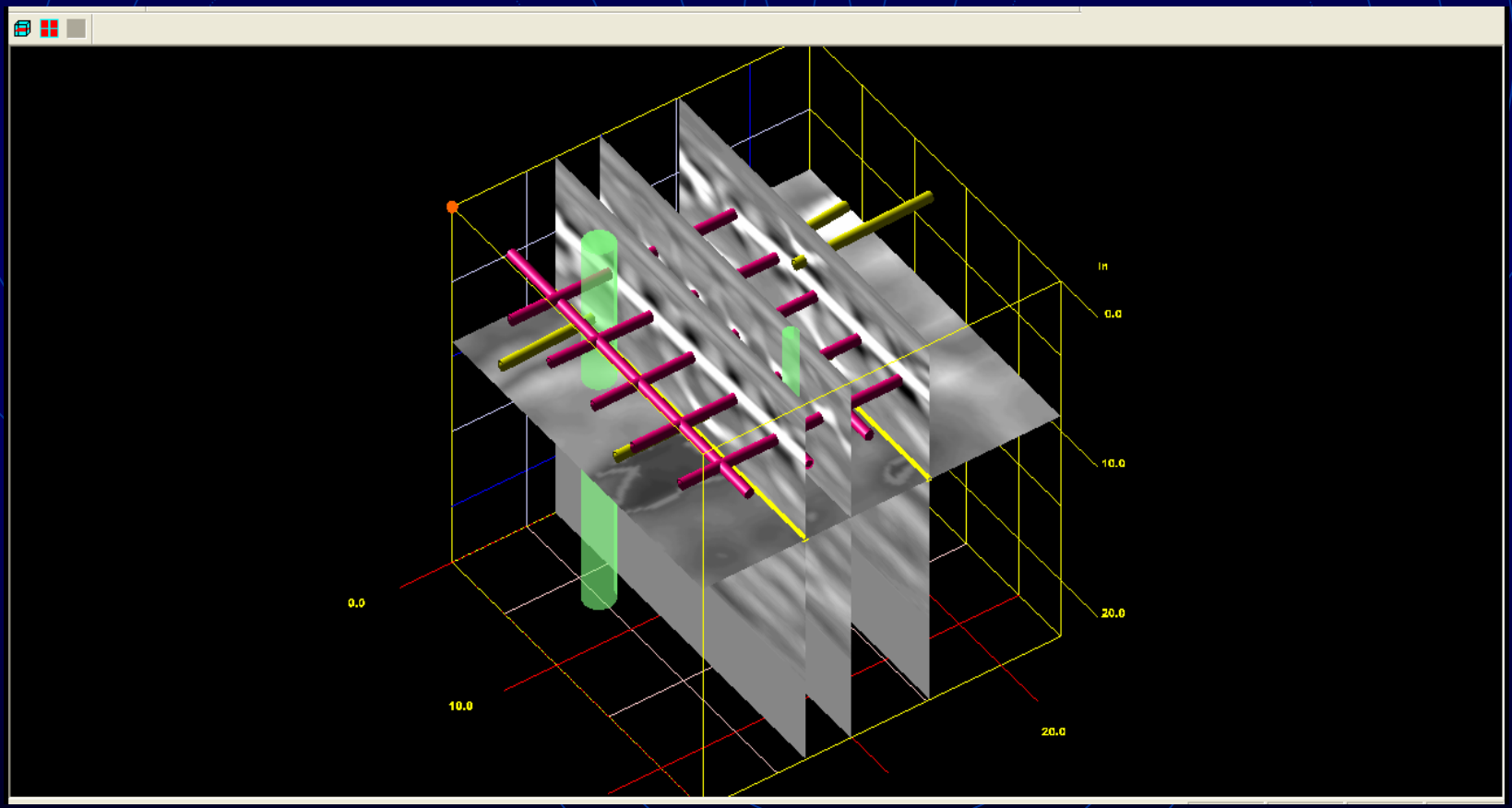
Curling End of Wire 4” Wire Mesh



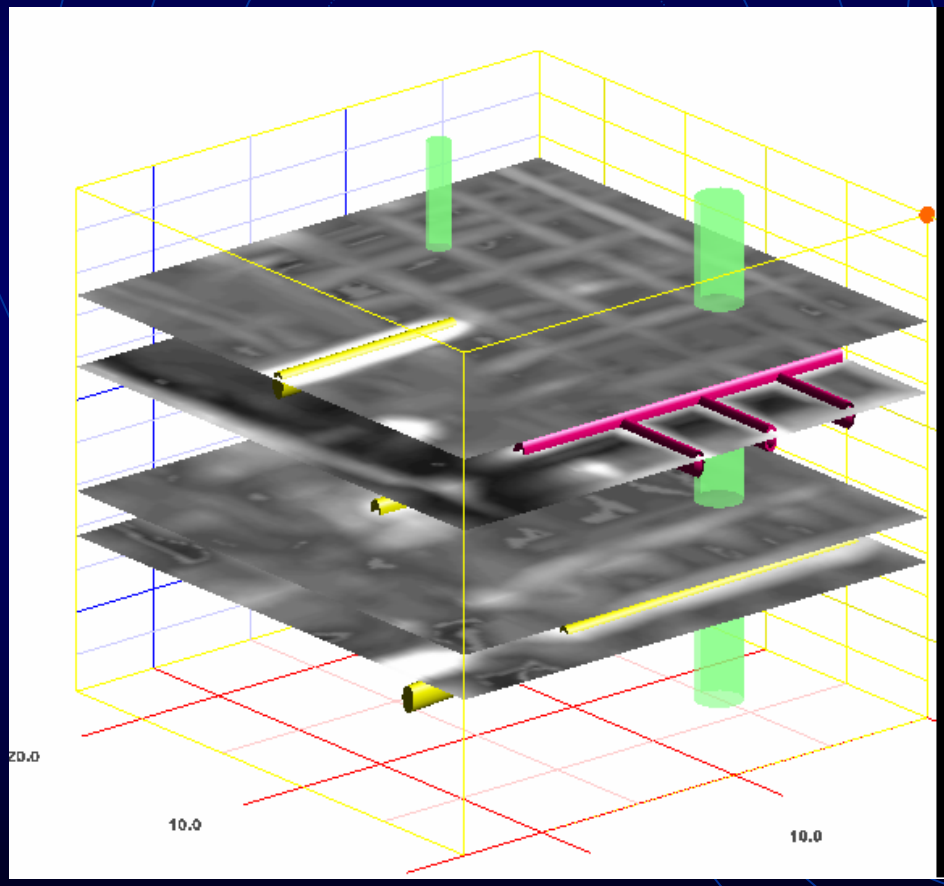
Second Site
ICB Collaring Press Saw Cut

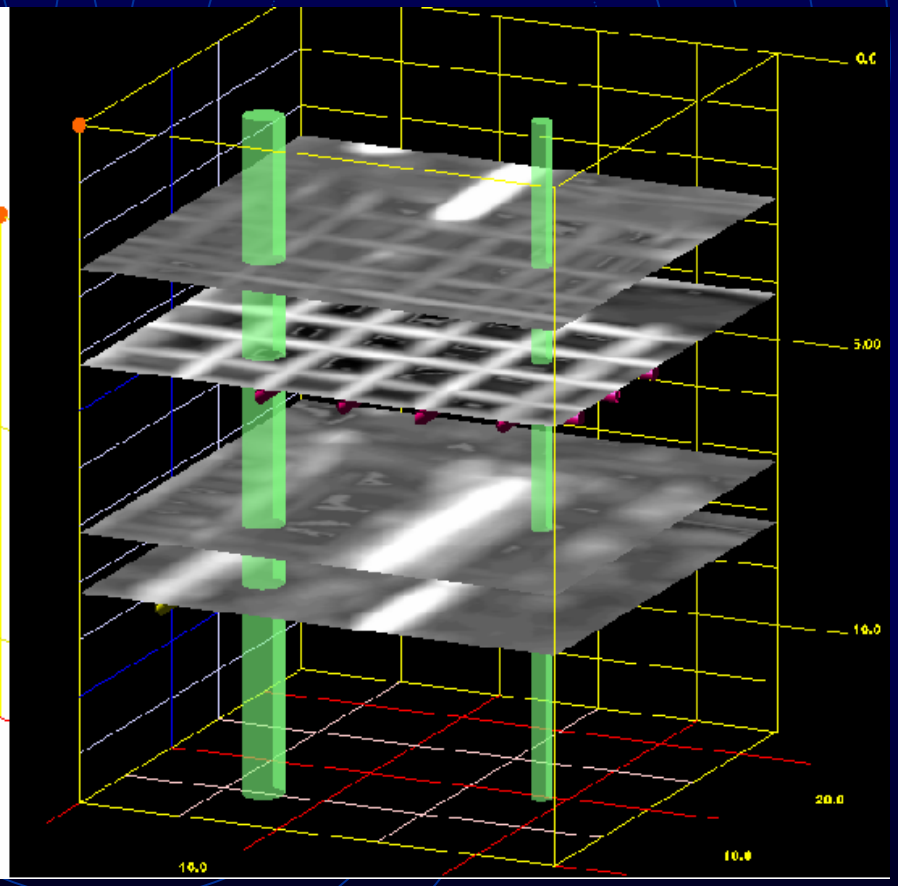


Second Site
ICB Collaring Press Saw Cut

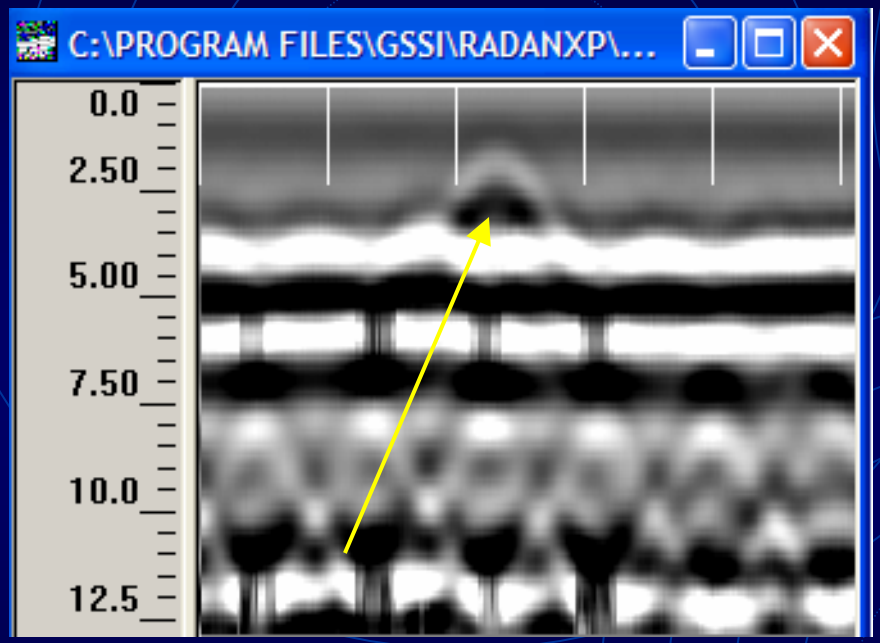


Second Site
ICB Collaring Press Saw Cut

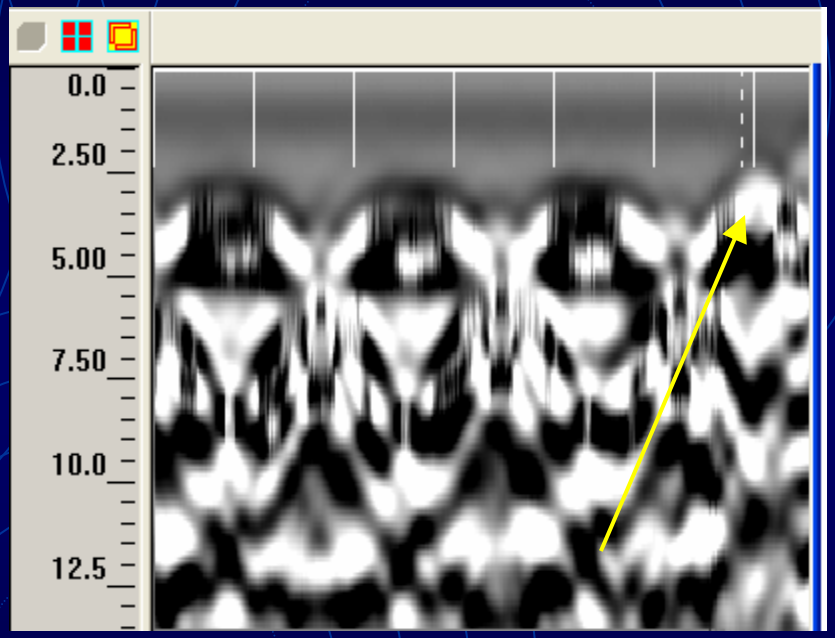




Third Site = ICB 2W Headquarters Conf Rm

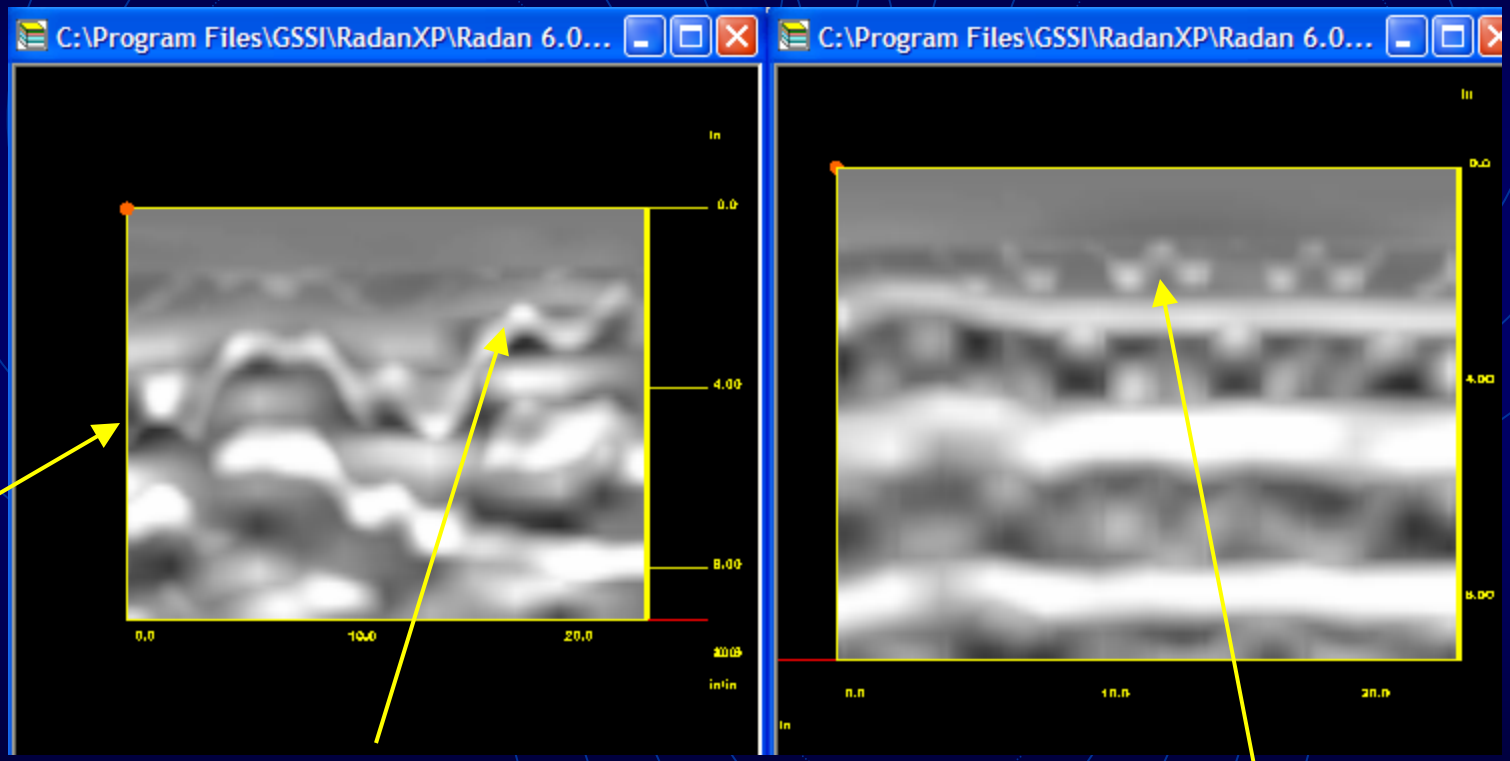


Target Under Conf Table



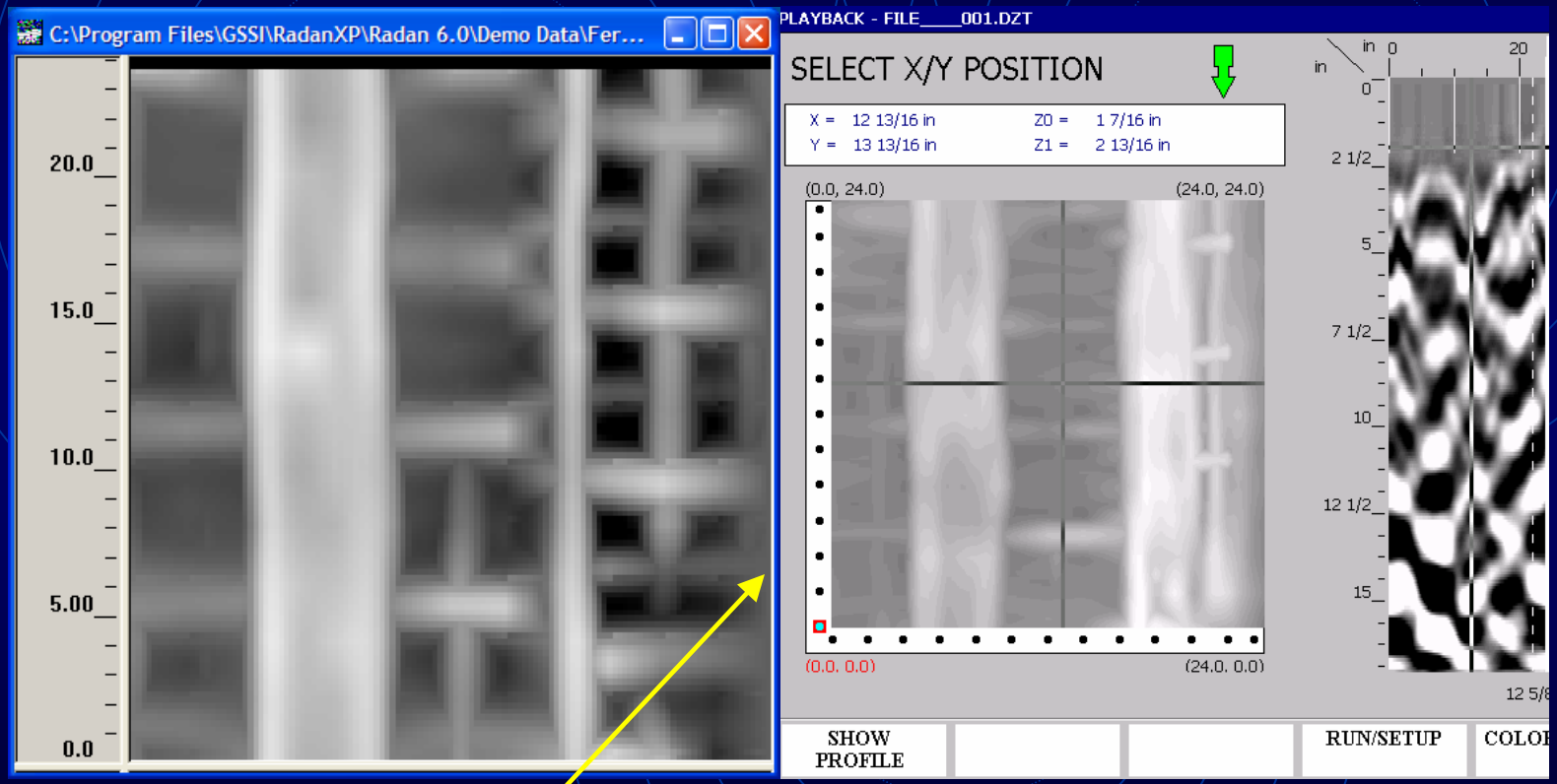
Known Conduit – See User Mark

Third Site = ICB 2W Headquarters Conf Rm



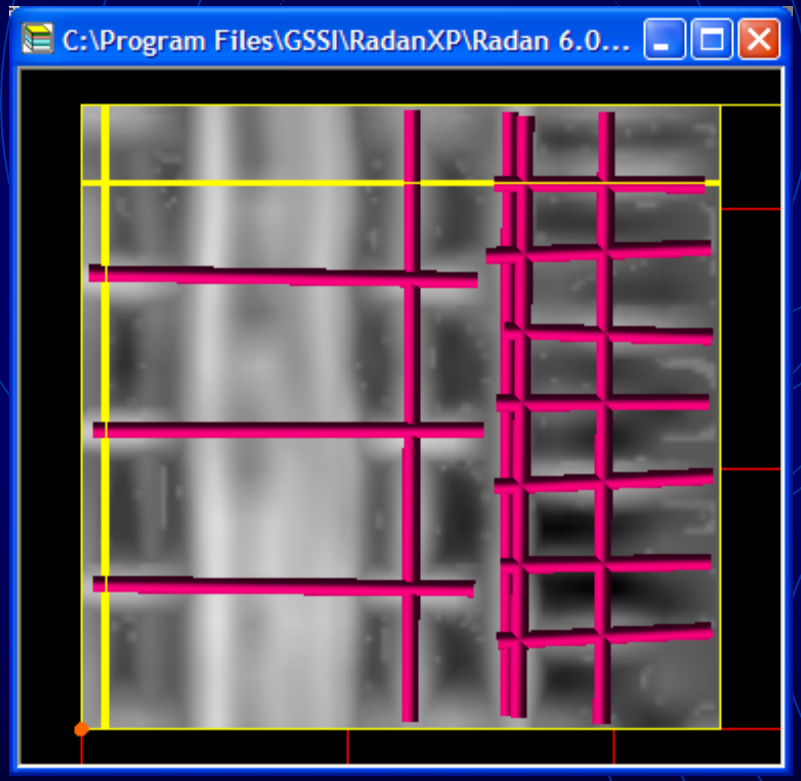
Wire Mesh

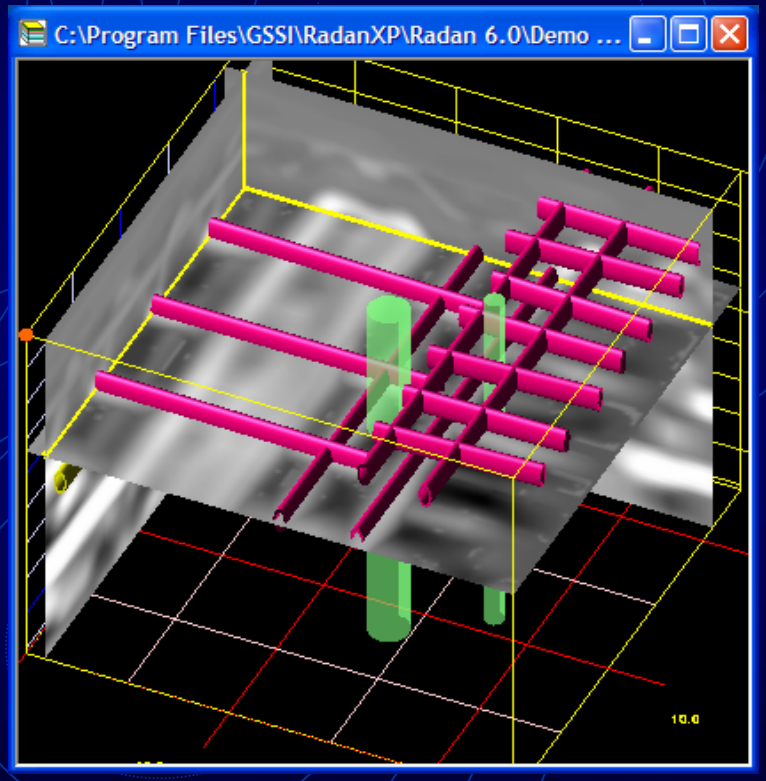
Third Site = ICB 2W Headquarters Conf Rm



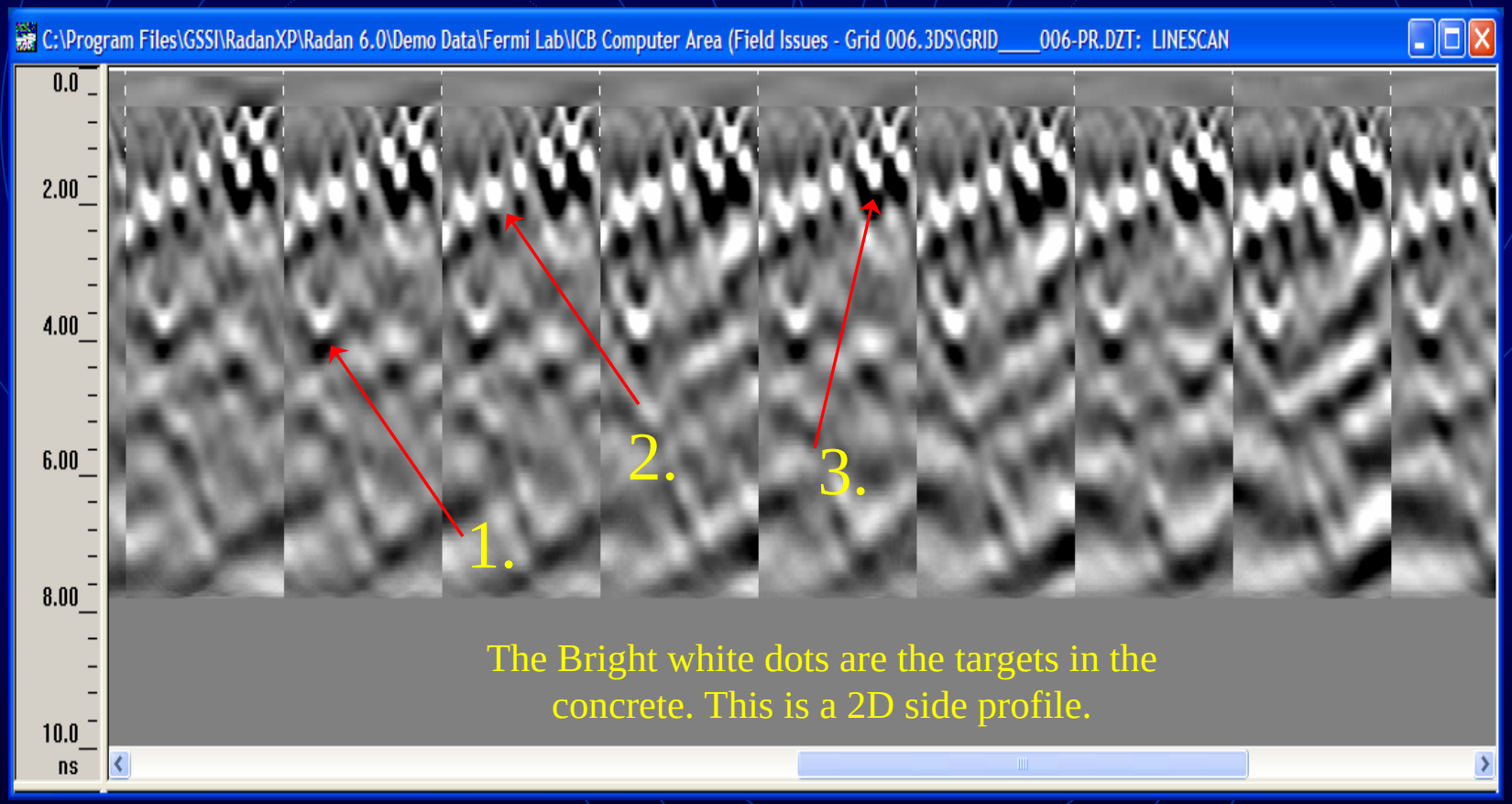
Conf Room Wall

Third Site = ICB 2W Headquarters Conf Rm



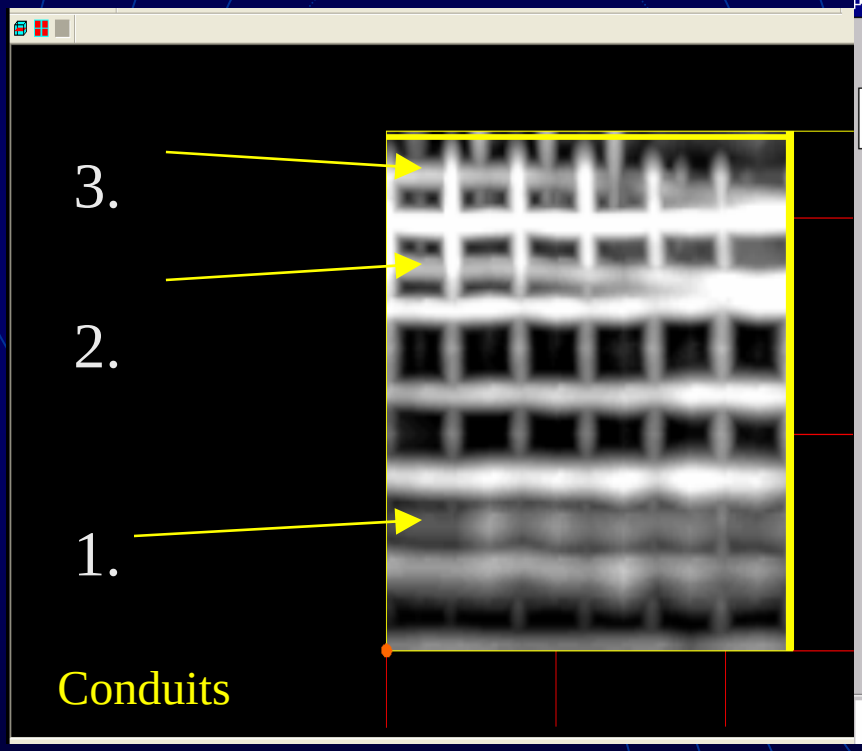


Fourth Site
ICB Computer Area (Field Issues)

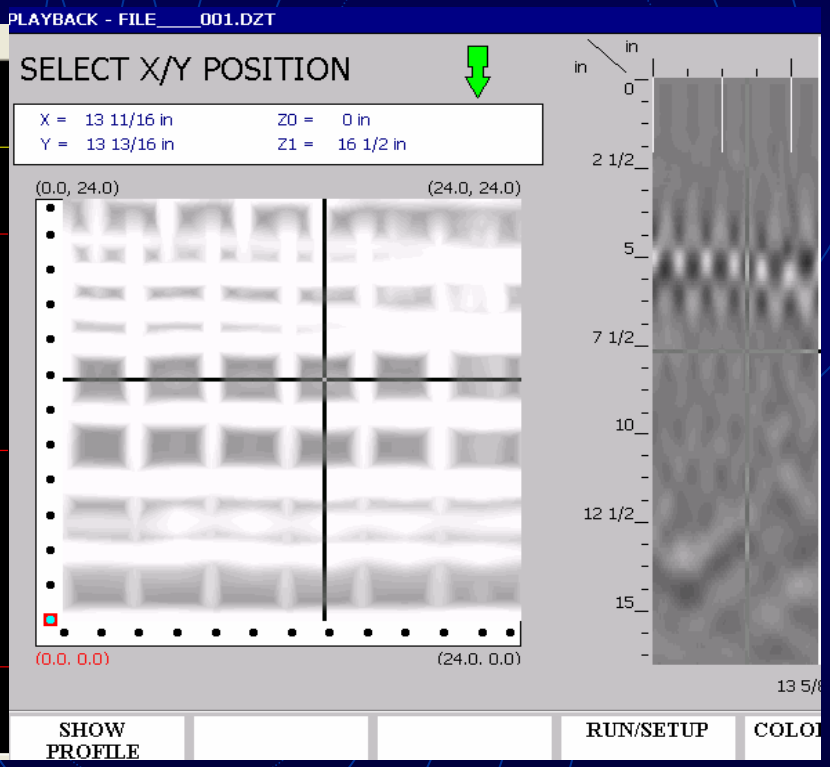


The Bright white dots are the targets in the concrete. This is a 2D side profile.

Fourth Site
ICB Computer Area (Field Issues)

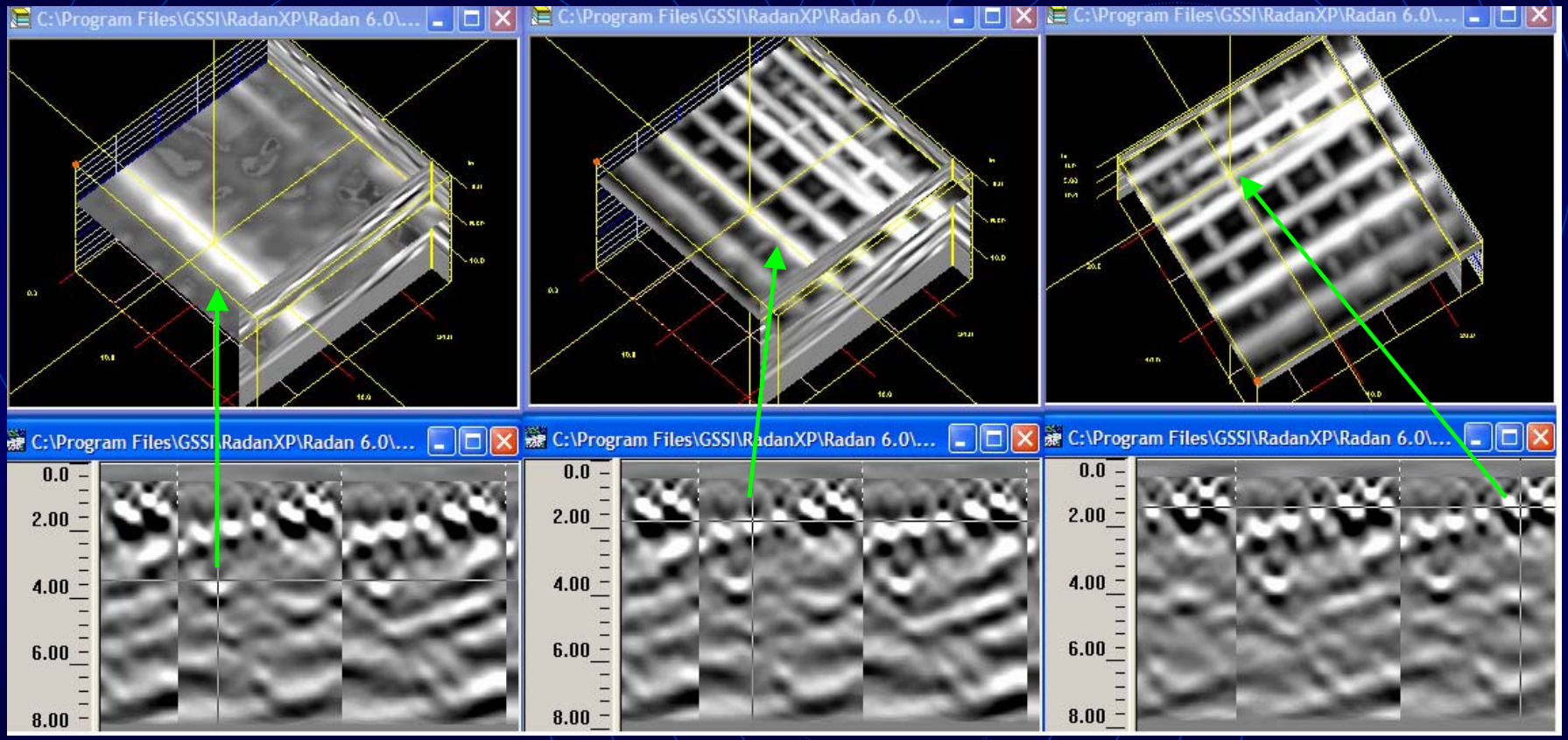


Post Processing



On Screen

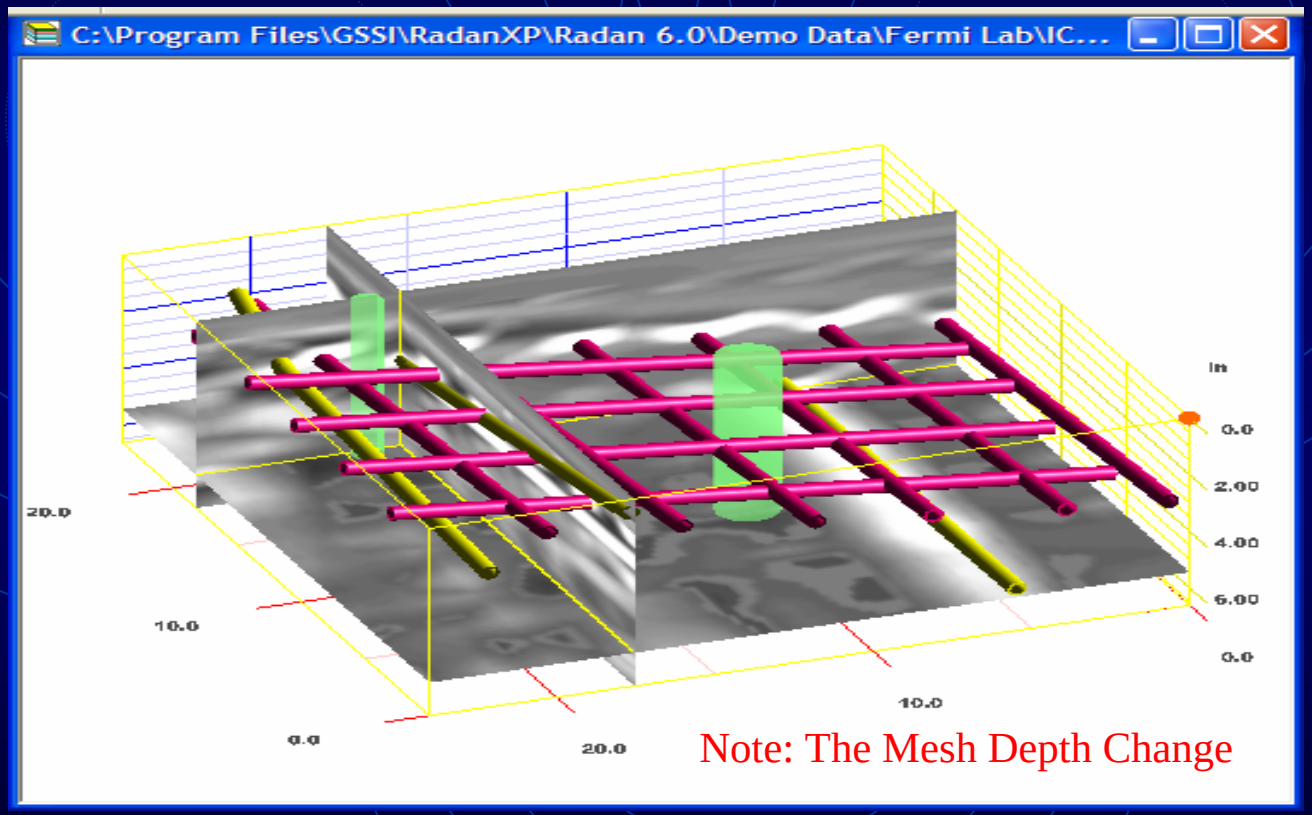
Fourth Site
ICB Computer Area (Field Issues)



Pinpoint targets in the 2D Profile view while interactive cross-hairs are shown on the 3D Cube above.

GSSI - The Difference is The Data.

Fourth Site
ICB Computer Area (Field Issues)



2x2ft Structure Scan Optic Pad – Conduits in Yellow

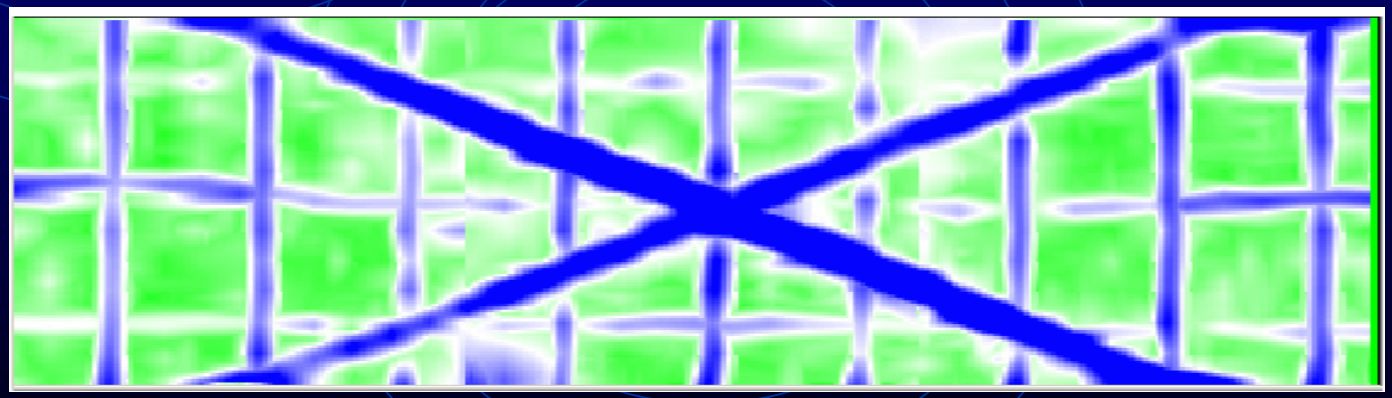
A Few GSSI GPR Customers

- Argonne National Laboratory
- Oak Ridge National Laboratory
- Lawrence Livermore National Laboratory
- Brookhaven National Laboratory
- Los Alamos National Laboratory
- Callaway Nuclear Plant
- DC Cook Nuclear Plant
- Oconee Nuclear Plant
- Fermi National Accelerator Lab(Pending)
- BWXT Pantex (Pending)

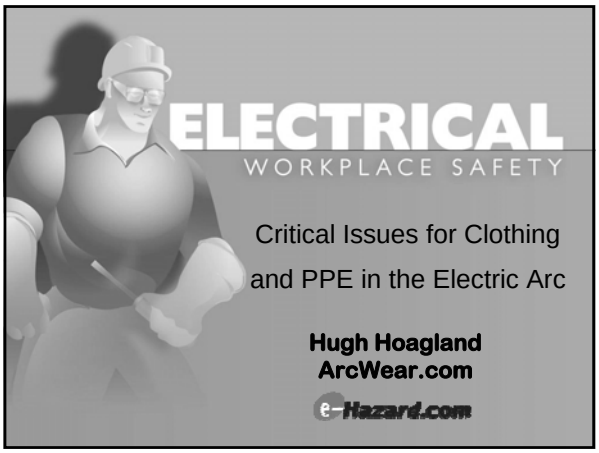
Because…
Picture worth a thousand words

Before Concrete

Results of scanning



NFPA 70-E, PPE and Upcoming 1910.269 Changes



Safety Facts

ELECTRICAL WORKPLACE SAFETY

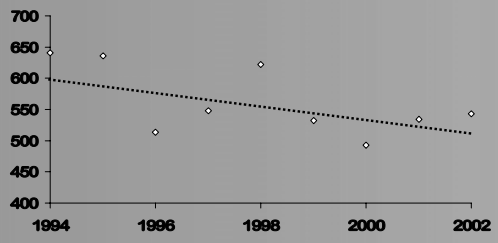
- Utility industry 10-year study of 120,000 workers
- 125 injuries per year
- 77% electrical arc injuries
- 21% permanent disabilities
- 2.4% fatalities

Based on ED France data, IEEE Presentation from M. Capelli-Schellpfeffer, M.D. Electrical Trauma Research Program (University of Chicago)

Safety Facts

ELECTRICAL WORKPLACE SAFETY

US Fatalities: Electrical Accidents w/ Potential Arc Component (Trendline 1994-2002)



Statistics from BLS website, Belinda Cannon, USDOL/OSHA. Analysis by Hugh Hoagland ArcWear.com. To see calculations visit www.arcwear.com/stats.mht

Regulations & Standards

ELECTRICAL WORKPLACE SAFETY

Strategies Embedded in NFPA 70E (2004)

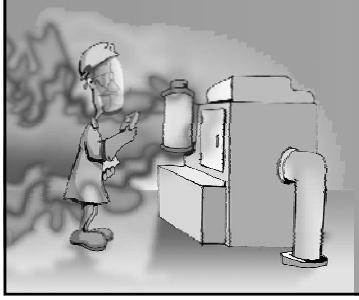
- Applies to General Industry
- Requires FR and more PPE
- More comprehensive than OSHA

The focus of this training program is 70E Chapter One, and also meets the requirements of OSHA 1910, Subpart S 331-335.

Electrical Hazards – Arc Flash

ELECTRICAL WORKPLACE SAFETY

Arc Flash: Violent eruption of energy from an electrical source.



- Arc temperature can reach 35,000°F.
- Fatal burns can occur at distances over 10 feet.
- Over half of all arc flashes occur at 277 volts.

Electrical Hazards – Arc Blast

ELECTRICAL WORKPLACE SAFETY

Pressure wave caused by the rapid heating of surrounding air. A blast can:

Vaporize copper, expanding it to 67,000 times the original volume.

Explode circuit components.

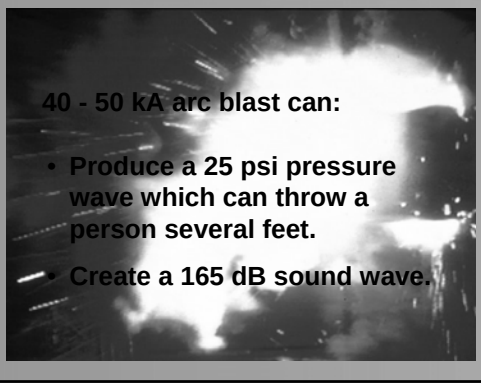
Create sonic-boom condition.

Destroy anything in its path.

Arc Blast

Electrical Hazards – Arc Blast

ELECTRICAL WORKPLACE SAFETY



40 - 50 kA arc blast can:

- **Produce a 25 psi pressure wave which can throw a person several feet.**
- **Create a 165 dB sound wave.**

Electrical Hazards – Arc

ELECTRICAL WORKPLACE SAFETY

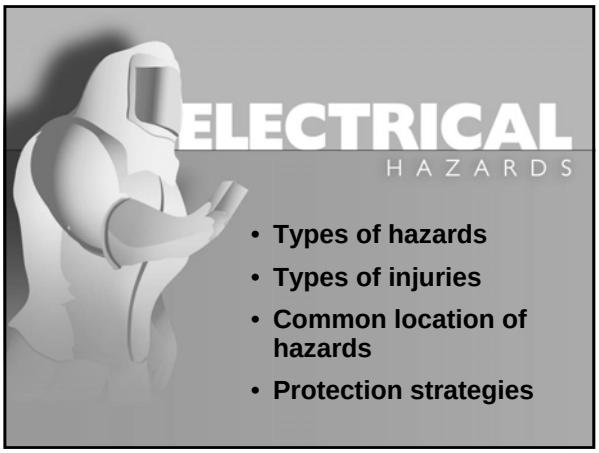
Arc in a Box

Energy can be two to twelve times greater when the arc is an *arc in a box* situation.

Arc Energy Theory

ELECTRICAL WORKPLACE SAFETY

- Current available (Amps ground fault or phase-to-phase)
- Duration of arc (cycles)
- Length of the arc (~6” max 480V)
- Distance from the arc (s^2)
- Arc voltage (70A-20kA arc voltage = 400-425V Westinghouse Protective Relay Book)
- Arc directionality (2-12X arc-in-a-box)



Electrical Hazards

ELECTRICAL WORKPLACE SAFETY

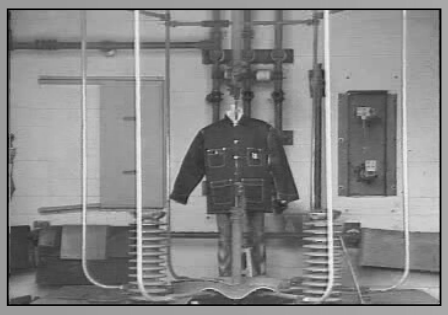
Before

During

Electrical Hazards

ELECTRICAL WORKPLACE SAFETY

100 cal/cm² arc



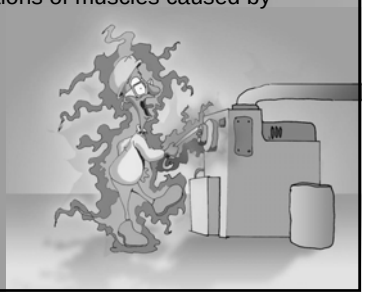
8kA, 120 cycles, FRC/FR wool jacket

Electrical Hazards - Shock

ELECTRICAL WORKPLACE SAFETY

Shock: Sudden stimulation of nerves and convulsive contractions of muscles caused by the discharge of electricity through the body.

Webster's Dictionary



Common Places for a Fault

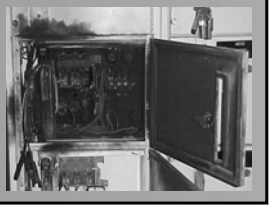
ELECTRICAL WORKPLACE SAFETY

- Uninterruptable Network (typical secondary system in large city downtown area)
  - 10-250+ kA and up
  - no definite clearing times
  - sees fault as load
- Serious Incidents in these scenarios
- Other issues come into play such as leaking oil from cables

Common Places for a Fault

ELECTRICAL WORKPLACE SAFETY

- Motor Control Centers (power plants, industrial)
  - 10-40+ kA
  - Often 20+ cycle clearing times
  - Low Voltage



Common Places for a Fault

ELECTRICAL WORKPLACE SAFETY

- Metal Clad Switchgear
  - high fault current availability (esp on secondary)
  - many deaths here
  - improper use of testing equipment
  - breaker failure

Common Places for a Fault

ELECTRICAL WORKPLACE SAFETY

- High Voltage Switching & Grounding
  - Fast Clearing Time
  - Substantial fault current
  - If deneergized before opening, no hazard
  - Distance helps when switching, not for grounding, if it becomes energized

230 kV

Common Places for a Fault

ELECTRICAL WORKPLACE SAFETY

- Padmount Switching
  - Clearing time varies
  - Substantial fault current
  - Arc-in-Box
  - Burns in some accidents > 6 ft away

Common Places for a Fault

ELECTRICAL WORKPLACE SAFETY

- Pole mount
  - Clearing time varies
  - Substantial fault current
  - Good info on this from ArcPro

Common Places for a Fault

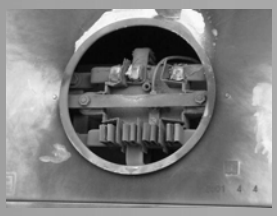
ELECTRICAL WORKPLACE SAFETY

- Equipment Failure
  - Clearing time varies
  - Substantial fault current
  - Arc in Box Potential
  - Good info on this from ArcPro

Common Places for a Fault

ELECTRICAL WORKPLACE SAFETY

- Meter Bases and Meter Banks
  - Higher fault currents of secondary side
  - Longer clearing times if phase to phase
  - Shorter clearing times if phase to ground since the lower voltages tend to self-extinguish when they go through zero



Meter de-energized but clip
Fell into energized meter below

Common Places for a Fault

ELECTRICAL WORKPLACE SAFETY

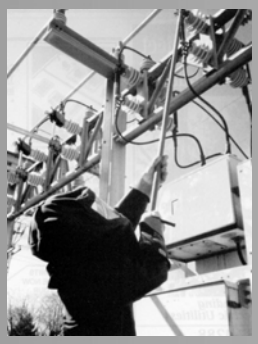
- Low Voltage Testing
  - Higher fault currents of secondary side
  - Longer clearing times if phase to phase
  - Phase-to-ground often clears ½ cycle self-extinguishing at zero
  - Drawing arc phase-to-phase
  - Very common scenario is testing on primary voltage (i.e. 4160V to 13800V with a low voltage meter.

Two workers exposed

Common Places for a Fault

ELECTRICAL WORKPLACE SAFETY

- Overhead Switching Medium Voltage
- Typically requires low level protection such as a flashsuit, gloves and protectors or a faceshield and FR clothing
- NFPA 70E requires facesheld and HRC2 for most of these operations >1000V.



Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Shirt Layering Data

- FR T-Shirts
  - Indura® UltraSoft® + FRC Knit 13.2 oz. ATPV=24.3 cal/cm²
  - 6.0 oz. Nomex®/6 oz. FR T-shirt ATPV=19 cal/cm²
- Non-FR T-Shirts
  - 4.6 oz PBI/Kevlar® 4.6 oz. Cotton ATPV= 14 cal/cm²
  - Nomex®/ 5 oz cotton t-shirt ATPV= 10 cal/cm²
- Frontline by Riverside
  - UltraSoft Denim 5.5 oz/yd² over FireWear T-Shirt 5.5 oz/yd² Arc Rating (ATPV) = 25 cal/cm²
  - UltraSoft Khaki 5.5 oz/yd² over FireWear T-Shirt 5.5 oz/yd² Arc Rating (ATPV) = 23 cal/cm²
  - Grey, Double Layer, FireWear Jersey Knit , Each layer 5.5 oz/yd² Arc Rating (ATPV) = 21.6 cal/cm²

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Current OSHA 1910.269

(l)(6)(iii) The employer shall ensure that each employee who is exposed to the hazards of flames or electric arcs **does not wear clothing that**, when exposed to flames or electric arcs, **could increase the extent of injury** that would be sustained by the employee.

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Non-FR clothing can increase the extent of your injuries.

Costs of FR vs Non-FR in a Utility: A Real Example

ELECTRICAL WORKPLACE SAFETY

Two Accidents Before FR		Two Accidents After FR
	Paid & Reserve	**Paid & Reserve**
Medical	$812,677	$32,707
Indemnity	$773,613	$6,035
Vocational	$9948	$1,903
Expenses	$931	$36
Total	**$1,597,229**	**$44,682**
Medical	$309,571	$9,213
Indemnity	$49,369	$1,890
Vocational	$9,999	$1,195
Expenses	$20	$10
Total	**$368,992**	**$12,309**

Source: PECO Presentation by Bill Mattiford, PES-IEEE Seminar
Accident 1: 7/29/93 Accident 2: 7/12/94 Accident 3: 6/1/95 Accident 4: 6/1/95
Accidents in FR were lightweight FR uniform. Actual results may vary.

Electrical Hazards – Arc

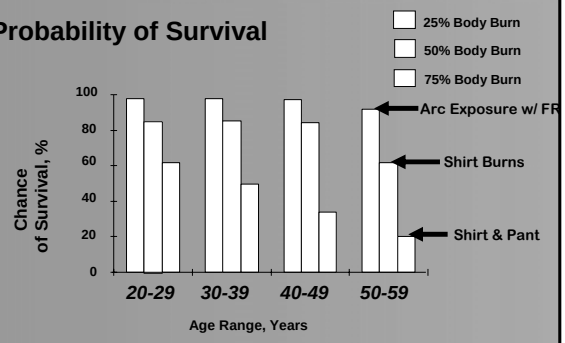
ELECTRICAL WORKPLACE SAFETY

The right stuff makes a difference

Flash Hazard PPE

ELECTRICAL WORKPLACE SAFETY

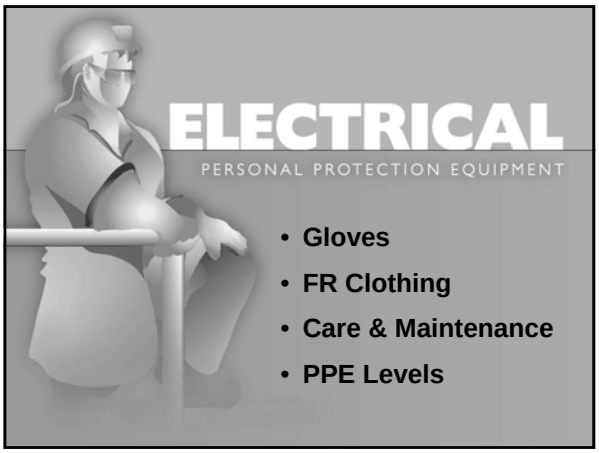
Probability of Survival



Source: American Burn Association (1991-1993 Study)

WI Food Plant Accident

ELECTRICAL WORKPLACE SAFETY



Flash Hazard PPE - Gloves

ELECTRICAL WORKPLACE SAFETY

Glove Good News

45 cal/cm²

Flash Hazard PPE - Gloves

ELECTRICAL WORKPLACE SAFETY

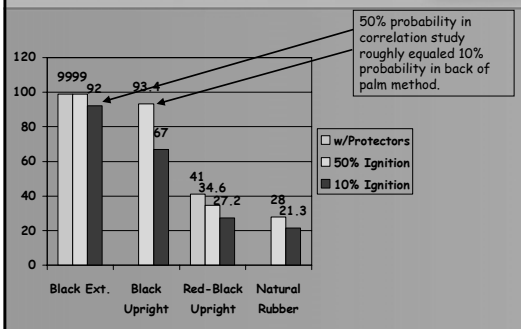
Glove Limiting Factor: Ignition

Correlation Study: Black Class 2

ELECTRICAL WORKPLACE SAFETY

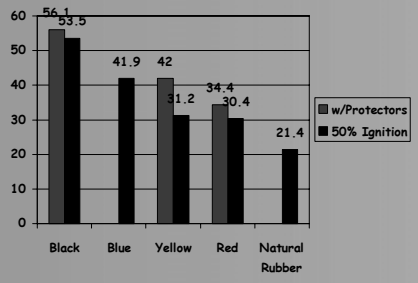
Class 2 Rubber Glove (cal/cm²)

ELECTRICAL WORKPLACE SAFETY



Class 0 Rubber Glove (cal/cm²)

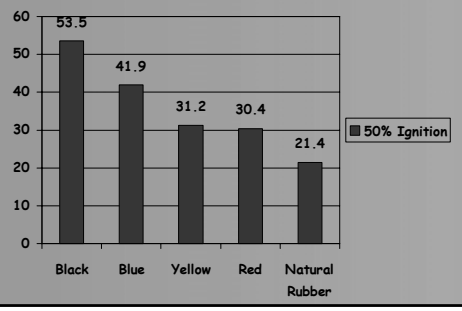
ELECTRICAL WORKPLACE SAFETY



Flash Hazard PPE - Gloves

ELECTRICAL WORKPLACE SAFETY

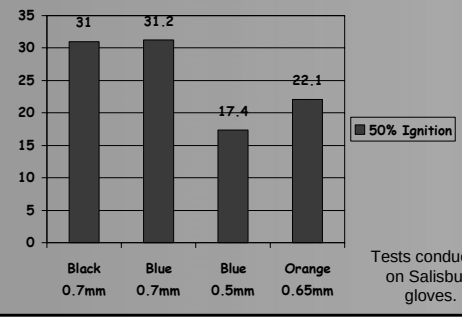
Class 0 Rubber Glove Results (cal/cm²)



Flash Hazard PPE - Gloves

ELECTRICAL WORKPLACE SAFETY

Class 00 Rubber Glove Results (cal/cm²)

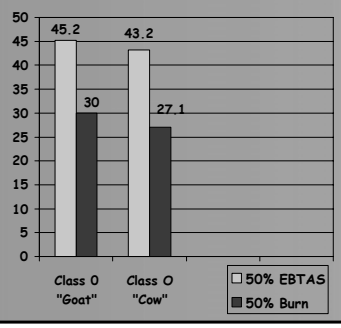


Tests conducted on Salisbury gloves.

Flash Hazard PPE - Gloves

ELECTRICAL WORKPLACE SAFETY

Leather Protector Results (cal/cm²)



Good quality all-leather work gloves may provide HRC 2 protection.

NFPA 70E 130.7 (c) (13) (c) FPN

Approved but for What?

ELECTRICAL WORKPLACE SAFETY

L: Dielectric Hardhat R: Melting Foam
~20 cal/cm²

Leather work shoes in arc

ELECTRICAL WORKPLACE SAFETY

50-60 cal/cm²

Leather work shoes in arc

ELECTRICAL WORKPLACE SAFETY

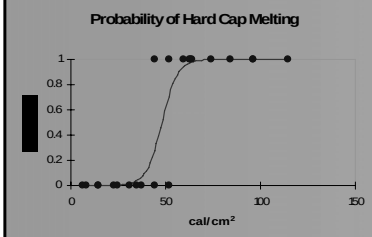
50-60 cal/cm²

Hard Hat Melting Probability

ELECTRICAL WORKPLACE SAFETY

Specific Class E Hard Hat Melting Probability

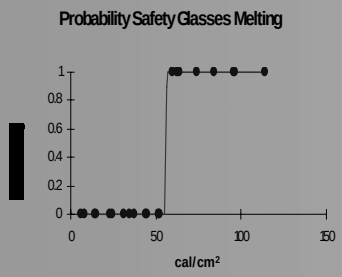
ELECTRICAL WORKPLACE SAFETY



1%	29.4	cal/cm²
5%	36.1	cal/cm²
10%	39.2	cal/cm²
20%	42.5	cal/cm²
30%	44.7	cal/cm²
40%	46.5	cal/cm²
50%	**48.1**	**cal/cm²**
60%	49.8	cal/cm²
70%	51.6	cal/cm²
80%	53.7	cal/cm²
90%	57.0	cal/cm²
95%	60.1	cal/cm²
99%	66.8	cal/cm²

Specific Safety Glasses Melting Probability

ELECTRICAL WORKPLACE SAFETY



1%	55.3	cal/cm²
5%	55.5	cal/cm²
10%	55.6	cal/cm²
20%	55.7	cal/cm²
30%	55.7	cal/cm²
40%	55.8	cal/cm²
50%	**55.8**	**cal/cm²**
60%	55.8	cal/cm²
70%	55.9	cal/cm²
80%	55.9	cal/cm²
90%	56.0	cal/cm²
95%	56.1	cal/cm²
99%	56.3	cal/cm²

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Using Non-FR Materials?

- Cotton
  - in underlayers when no breakopen risk
  - Still poses risk of ignition in tracking arc
- Wool
  - best in underlayers
- Silk
  - best in underlayers

25 cycles
FR options are available

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Arc Resistant vs. Cotton Bra

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

The Underwear Question

- If outer layer does not breakopen or ignite, non-melting undergarments have tested well.
- Arc-resistant undergarments are available.

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Laundering can be critical

L: Clean R: 100 ml hydraulic oil

~20 cal/cm^2

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

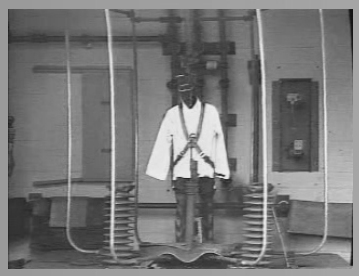
Faceshields have limits

34 cal/cm^2

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

The right PPE is vital



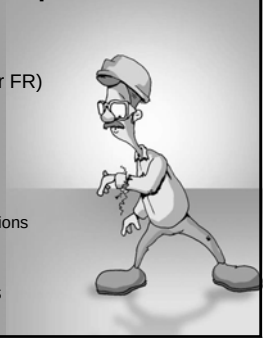
ASTM F887-2004 compliant vs. ANSI Standard Compliant Only

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Arc Flash Protection Principles

- Layering
  - Outer Layers
  - Under layers (non-melting or FR)
- Coverage
- Fit
- Maintenance of equipment
  - Laundering
    - Follow manufacturer's instructions
    - No chlorine bleach
    - No fabric softener
  - Inspect for tears and frays



Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Dangerous Clothing Characteristics

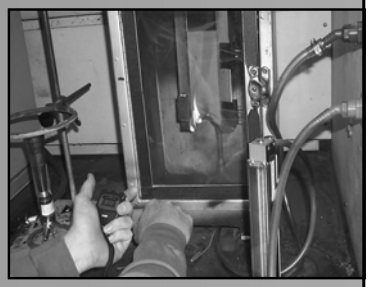
- Melting
- Flammability
- Clothing not permitted
  - Nylon, polyester, acetate or rayon
    - unless arc tested in blends

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Arc Thermal Resistant or FR?

Standard Vertical Flame Test (ASTM D6413)



Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Not all FR rainwear is arc resistant. Any FR rainwear with a melting substrate will usually increase worker injury.

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

It may LOOK the same

ANSI 107 & F1506 vs. ANSI 107 "FR"

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

FR Clothing is not invincible.

Choose it for the application

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Watch out for melting elastic

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

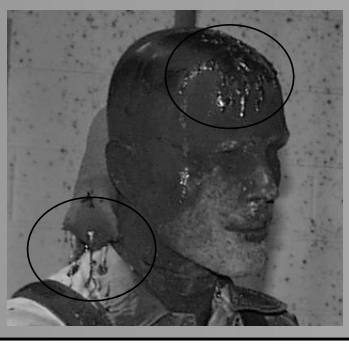
Watch out for melting "FR" accessories

- "FR" until washed or dry cleaned
- "FR" Melting always bad

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

See the "FR" melted onto the head?



Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Non-FR Cotton vs. FR Cotton

<20 cal/cm^2

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Non-FR Linings can get you burned in winter

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

FR Winter Wear a *Must* If Exposed

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

Arc Hazard Exposure Levels

- Category 0 – Up to 1.2 cal/cm²
- Category 1 – 1.2 to 4 cal/cm²
- Category 2 – 4.1 to 8 cal/cm²
- Category 3 – 8.1 to 25 cal/cm²
- Category 4 – 25.1 to 40 cal/cm²
- Over 40 cal/cm²

PPE levels are the maximum of each exposure category.
1.2 cal/cm² is the onset of second degree burns.

Flash Hazard PPE – Common Approach

ELECTRICAL WORKPLACE SAFETY

Category 2 – 8 cal/cm²

- T-shirt
- Safety glasses
- FR shirt and pants or coveralls
- Hard hat (Class E)
- Face shield or hood
- Hearing protection
- Gloves
- Leather work shoes
- For 2* add balaclava hood or flash hood

Category 4 – 40 cal/cm²

- Same as Level 2 plus switcher's suit
- Flash suit hood

Flash Hazard PPE – By Job

ELECTRICAL WORKPLACE SAFETY

Category 2 – 8 cal/cm²

- Energized Meter Work
- Distribution Line Work
- Underground line work
- Overhead line work
- Most Transmission Work

Category 4 – 40 cal/cm²

- Switching
- Other applications with energy levels >8 cal/cm²

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

100% Cotton vs. HRC 2 Clothing

<20 cal/cm^2

Flash Hazard PPE – Clothing

ELECTRICAL WORKPLACE SAFETY

HRC 4 Suit v. HRC 2

40 cal/cm² suit no 2° burn other 2 ° and 3 ° burns

Flash Hazard PPE – Standards

ELECTRICAL WORKPLACE SAFETY

- Clothing
  - ASTM F1506
- Rainwear
  - ASTM F1891
- Hoods and Faceshields
  - ASTM F2178
- Fall Protection Exposed to Electric Arc
  - ASTM F887-2004
- Gloves
  - ASTM D120
- Insulated Tools
  - ASTM F1505
- Flash Fire Clothing
  - CGSB 155.20
  - NFPA 2112

Hazard Assessment

ELECTRICAL WORKPLACE SAFETY

Arc Hazard Energy Changes

At Substation
- 8000 Amps
- 12 in arc gap
- 12,500 system
- 12 in to worker
- 10 cycle duration
- 10 cal/cm^2

1 mile away
- 3936 Amps
- 12 in arc gap
- 12,500 system
- 8 in to worker
- 20 cycle duration
- 18 cal/cm^2

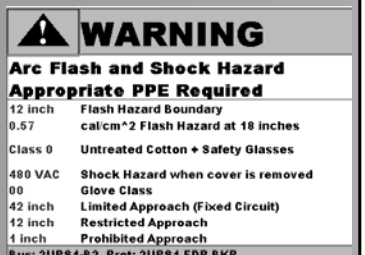
This is not Acceptable!

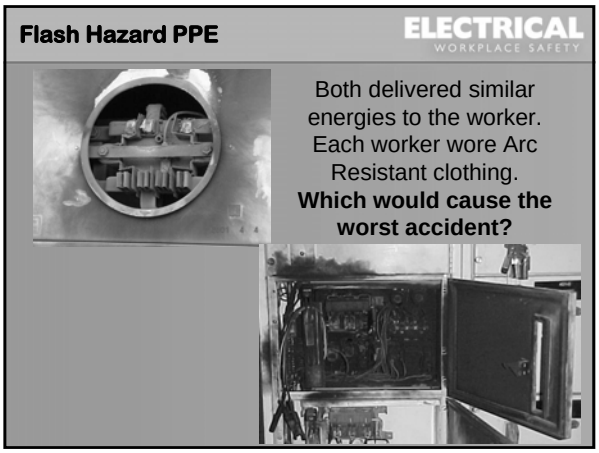
ELECTRICAL WORKPLACE SAFETY

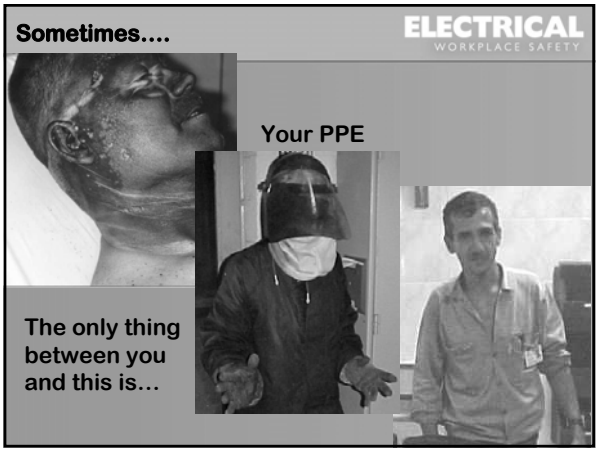
- Generic Labels may meet the NEC Requirements
- They do not meet NFPA 70E Requirements

Acceptable & Informative Labels

ELECTRICAL WORKPLACE SAFETY




Flash Hazard PPE
ELECTRICAL
WORKPLACE SAFETY
Both delivered similar energies to the worker. Each worker wore Arc Resistant clothing.
Which would cause the worst accident?


Sometimes….
ELECTRICAL
WORKPLACE SAFETY
Your PPE
The only thing between you and this is…

Moving Forward with Arc Flash PPE – Part of the Solution

Electrical Safety Meeting

Moving Forward with Arc Flash PPE Part of the Solution

December 1, 2005 Las Vegas, NV

Thomas E. Neal, PhD
Neal Associates Ltd.
Sponsored by The Oberon Company

WHAT DO I MEAN BY MOVING FORWARD?

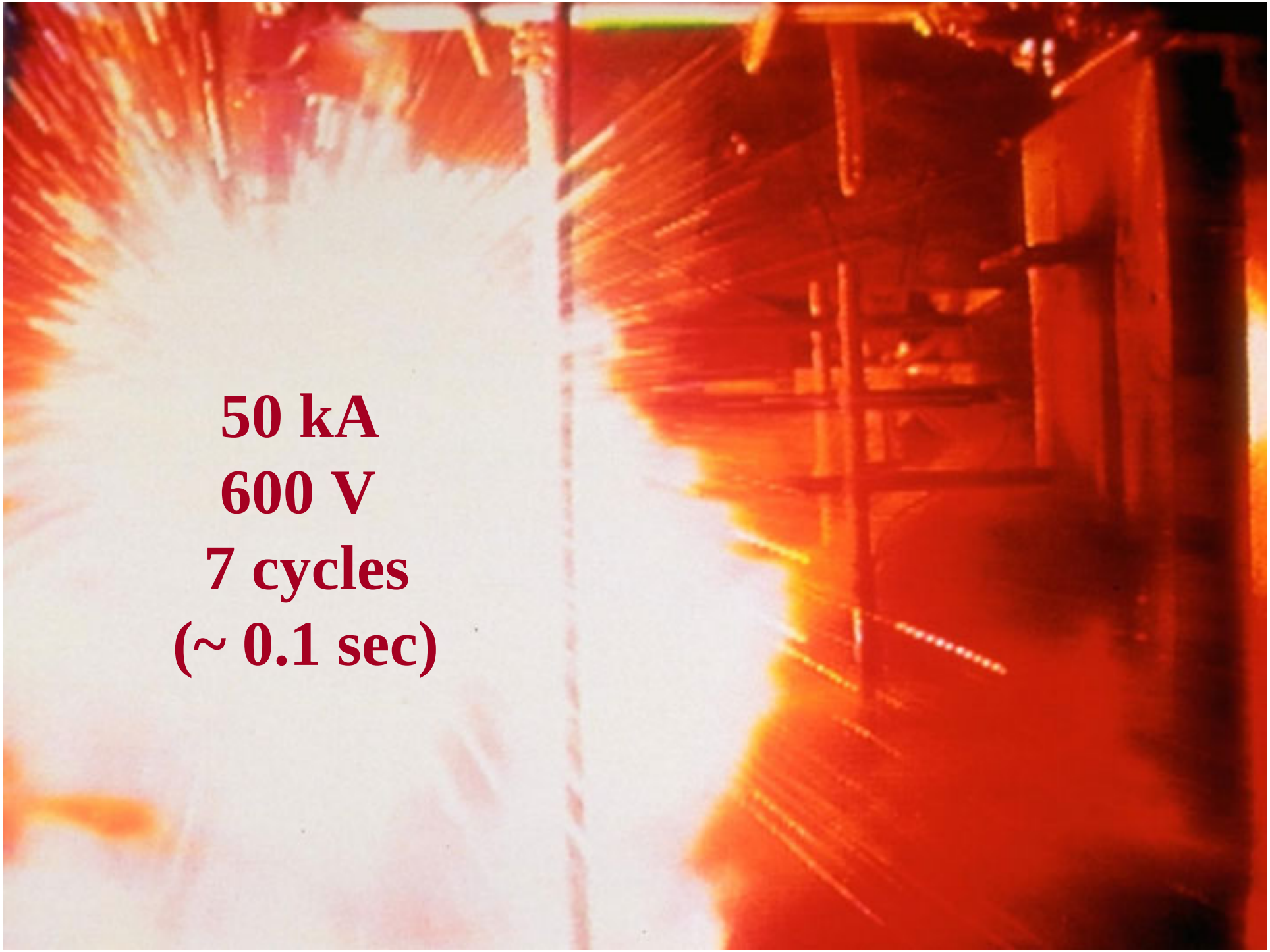
- ***PROGRESS ON MAKING PPE MORE USER FRIENDLY—LIGHTER, MORE FLEXBLE, MORE VISIBLE LIGHT TRANSMISSION***
- ***IMPLEMENTING A PPE PROGRAM WITH MORE USER FRIENDLY PPE OPTIONS***
- ***WORKERS KNOWING WHAT PPE THEY NEED AND WHY THEY NEED TO USE IT ON THE JOBS THEY DO***

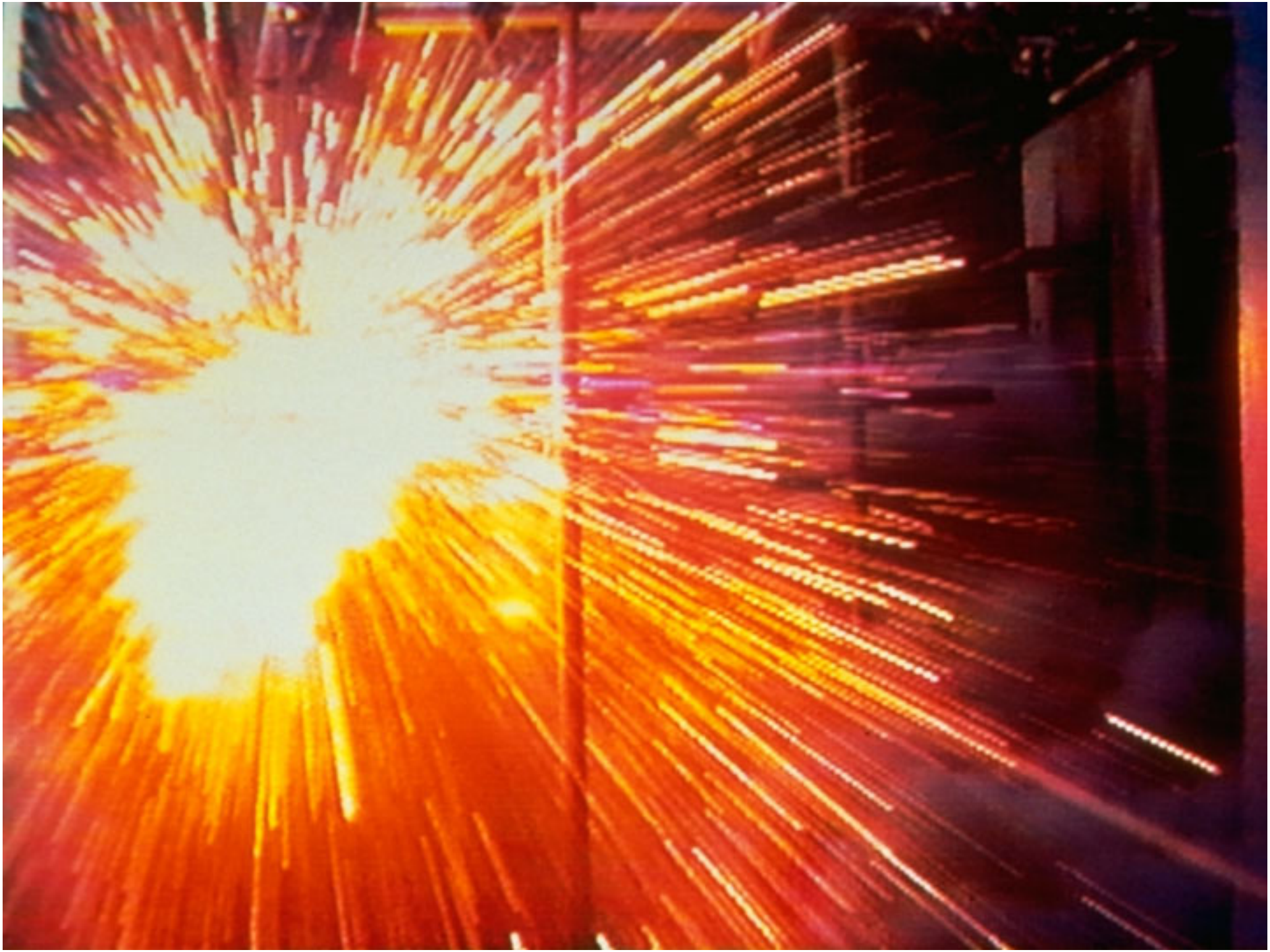
WHAT DO I MEAN BY PART OF THE SOLUTION?

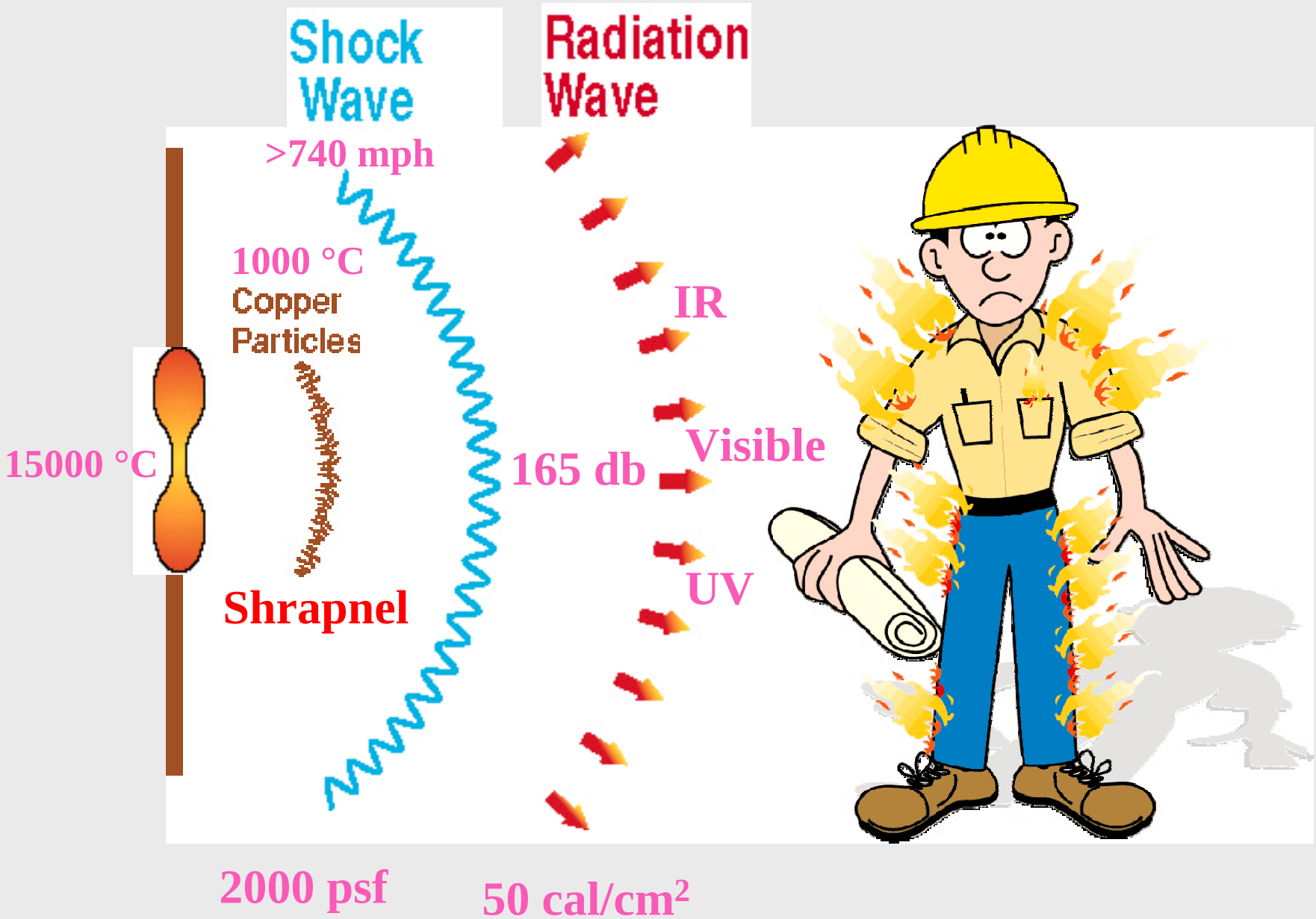
- ***PPE IS THE LAST LINE OF DEFENSE***
- ***REDUCING OR ELIMINATING HAZARDS IS THE FIRST LINE OF DEFENSE***
  - ***DE-ENERGIZING EQUIPMENT***
  - ***EQUIPMENT CHANGES***
  - ***WORK RULE CHANGES***

What Is An Electric Arc?

- The Passage of Substantial Electric Current Through Ionized Gases
- Typically Lasts Less Than 1 Second
- Radiant and Convective Energy Components
- Explosive In Nature
- Can Ignite and/or Melt Conventional Work Clothing


50 kA
600 V
7 cycles
(~ 0.1 sec)




Shock Wave
Radiation Wave
>740 mph
1000 °C
Copper Particles
15000 °C
Shrapnel
165 db
IR
Visible
UV
2000 psf
50 cal/cm²

Electric Arc Hazards

Focus For Today

Burn Injury

[No Electrical Contact]

Heat Energy Exposure

Molten Metal Splatter

Secondary Fires

&

Heat Stress Issues

Associated with

Wearing PPE

Important, But Not The Focus For Today

Shock Hazard

Shrapnel

Physical Injury Due to the Arc Shock Wave

Damaging Sound & Pressure Levels

EXPOSURE ENERGY BASICS

Copper Calorimeters or Other Types of Thermal Sensors Are Used to Measure Exposure Energy in Arc Flash Test Methods

Exposure Energy is Expressed in cal/cm^2

1 cal/cm^2 Equals the Exposure on the tip of a finger by a Cigarette Lighter in One Second

An Exposure Energy of 1 to 2 cal/cm^2 Will Cause a 2nd Degree Burn on Human Skin and 5 to 10 cal/cm^2 will ignite conventional work clothing

EXPOSURE ENERGY BASICS

- **Heat Flux Is the "Flow Rate" of Energy Onto a Surface**
- **Exposure Energy = Heat Flux x Exposure Time**
- **Typical Values**

	Flash Fire	Electric Arc
Heat Flux cal/cm^2sec	1 to 3	1 to 200
Exposure Time seconds	1 to 5	0.1 to 1
Exposure Energy cal/cm^2	2 to 12	2 to 60

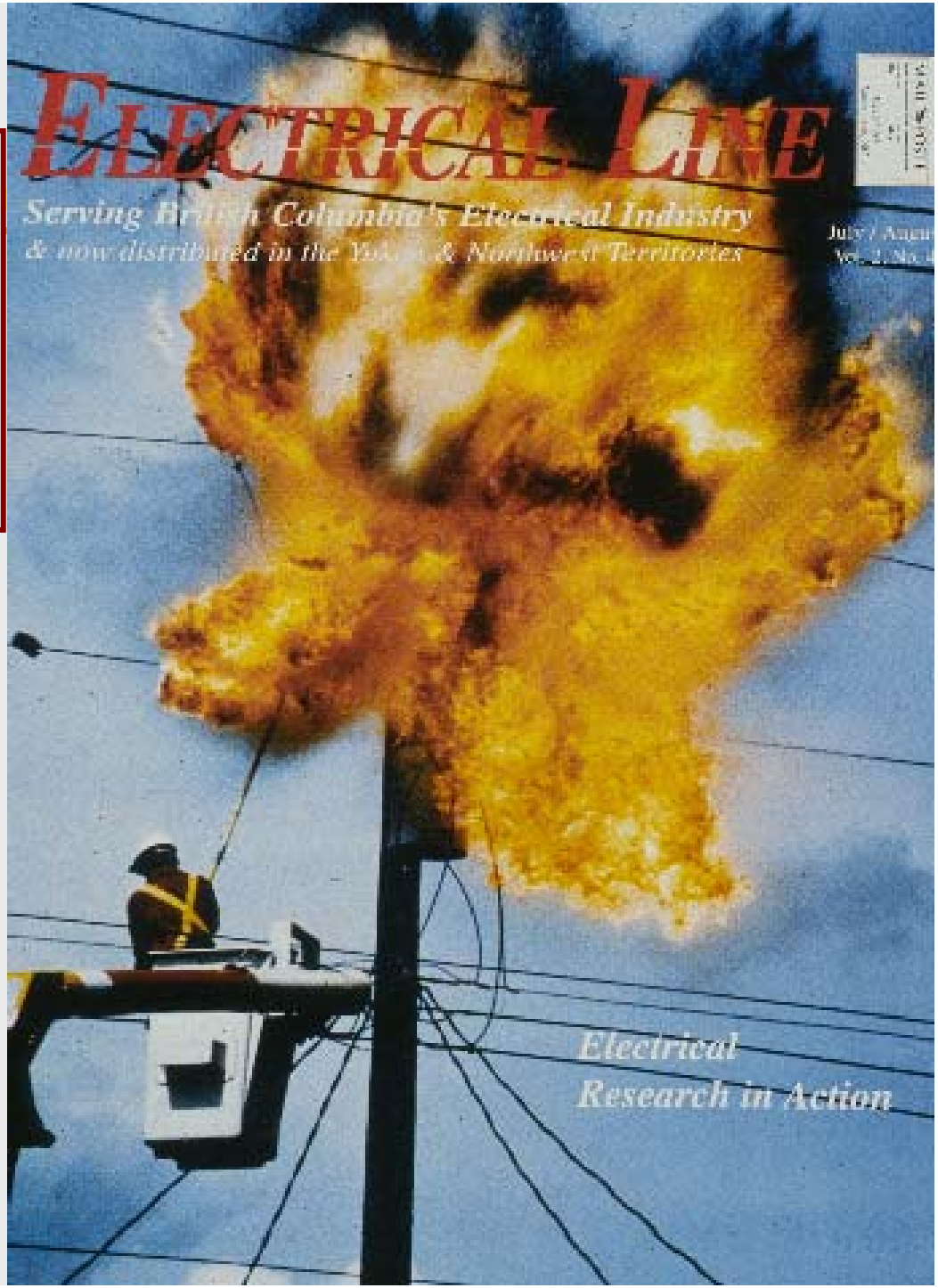
- ***ARC EXPOSURES IN A FRACTION OF A SECOND CAN BE MUCH MORE SEVERE THAN TYPICAL FLASH FIRE EXPOSURES***

Why Not Wear Conventional Work Clothes?

- **Everyday Fabrics Can Ignite, Burn and Melt When Exposed to An Electric Arc**
  - **Cotton, Wool, Silk are Flammable but Don't Melt**
  - **Polyester, Nylon, Polypropylene Melt and Burn**

If Everyday Fabric Does Ignite and Burn on the Human Body, the Severity of a Worker's Burn Injury Will Significantly Increase

Bad Things Can Happen to Good People



The Consequences Can End a Life or Last A Lifetime

Electric Arc Flash Ignition

Before Electric Arc Blast

During Electric Arc Blast

After Electric Arc Blast

5.7 oz/yd2 Untreated Cotton Shirt

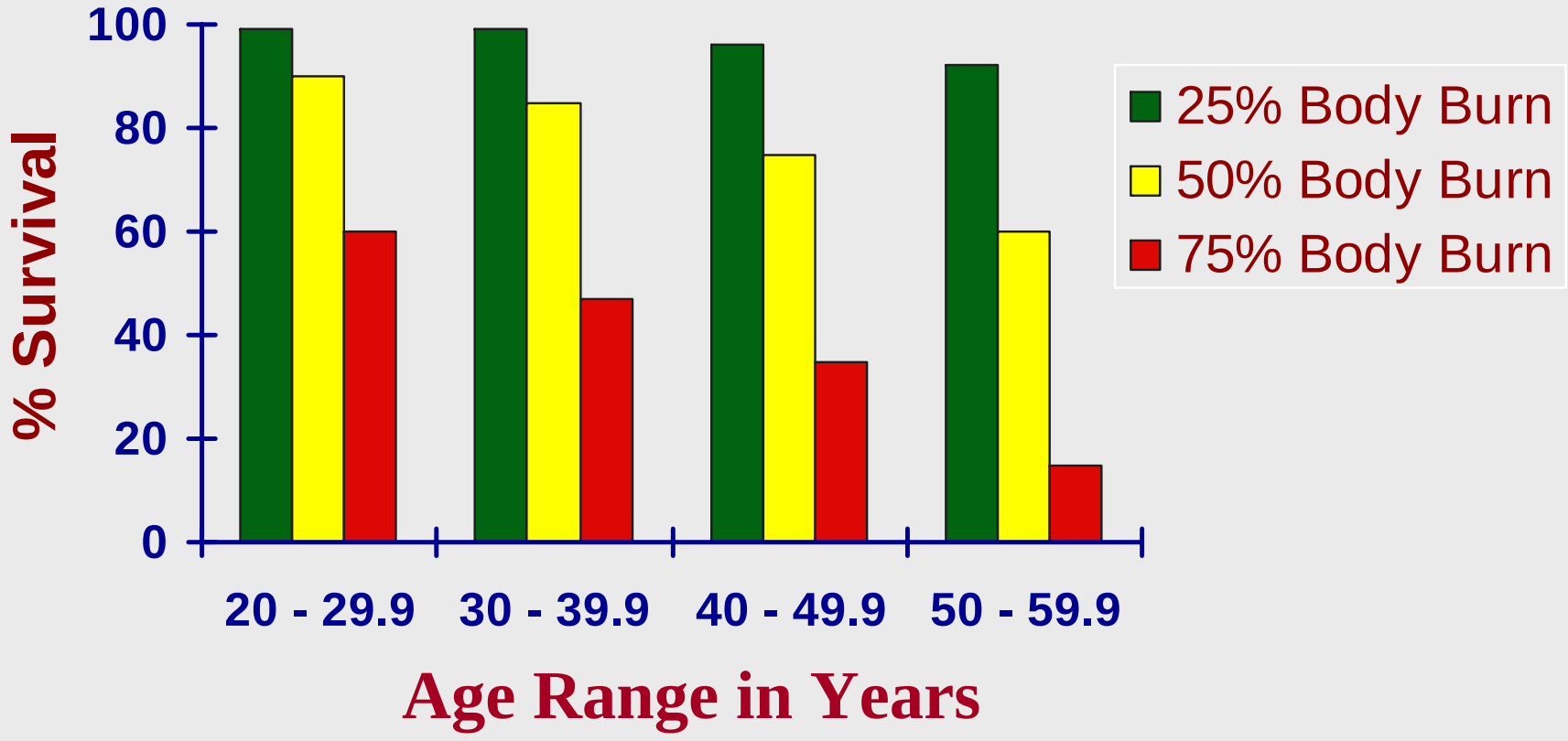
When Conventional Clothing Ignites…

Clothed Areas Can Be Burned More Severely Than Exposed Skin

WHY IS A HIGH LEVEL OF BURN INJURY A MAJOR CONCERN?

- **BURN INJURIES CAN BE FATAL**
- **SURVIVAL FROM A BURN INJURY ACCIDENT DEPENDS ON AGE, HEALTH, EXPOSURE INTENSITY AND TIME, TOTAL AREA OF THE BODY BURNED**
- ***MOST OF THIS CAN BE KNOWN BEFORE AN ARC ACCIDENT HAPPENS***

Burn Injury Probability of Survival



Source: American Burn Association (1991-1993 Study)

IN AN ARC FLASH EXPOSURE

No Clothing at All is Better Than Flammable Clothing

WHY IS BURN INJURY A MAJOR CONCERN?

- ***BURN INJURY IS VERY COSTLY—BOTH IN FINANCIAL TERMS AND HUMAN TERMS***
- **THE COST OF TREATMENT CAN EXCEED $1,000,000 FOR A SINGLE BURN CASE**
- **TREATMENT CAN REQUIRE YEARS OF SKIN GRAFTING AND REHAB**
- **THE BURN VICTIM MAY NEVER BE ABLE TO RETURN TO WORK**

WHY IS BURN INJURY A MAJOR CONCERN?

- ***FOR THE BURN VICTIM, THE PERSONAL COST IS DEVASTATING***
- **DUE TO DISFIGUREMENT AND INTENSE PAIN THE VICTIM WILL OFTEN NOT WANT TO LIVE, SEVERE DEPRESSION IS COMMON**
- **THE VICTIM'S SPOUSE AND CHILDREN WILL BE TRAUMATIZED, DIVORCE IS COMMON**
- **FOR SEVERE BURN CASES QUALITY OF LIFE CAN NEVER BE REGAINED**

BUT—IT DOESN'T HAVE TO BE THIS WAY

~15 cal/cm²
Exposure
FR Dailywear
Shirt
Polyester/Cotton
Non-FR Shirt

How Does FR Clothing & Arc Flash PPE Provide Protection From Electric Arcs?

- **Does Not Ignite, Melt or Drip**
- **Provides an Insulative Barrier to Heat**
- **The Arc Rating Can be "Matched" to the Arc Flash Exposure Level**

The Right PPE Can Reduce Burn Injury
Increase the Probability of Survival
Preserve the Quality of Life

PPE & Protective Clothing Are the Last Line of Defense

Before Clothing & PPE are Selected, Arc Hazards Need to be Reduced by:

- De-energizing Equipment
- Modifications to Equipment
- Changing Work Rules

What Happens in Real Arc Accidents

It Depends on Whether the Protective Clothing and Equipment is “Matched” to the Arc Hazard Exposure

ASTM
F1958 & F2178

Instrumented Mannequin

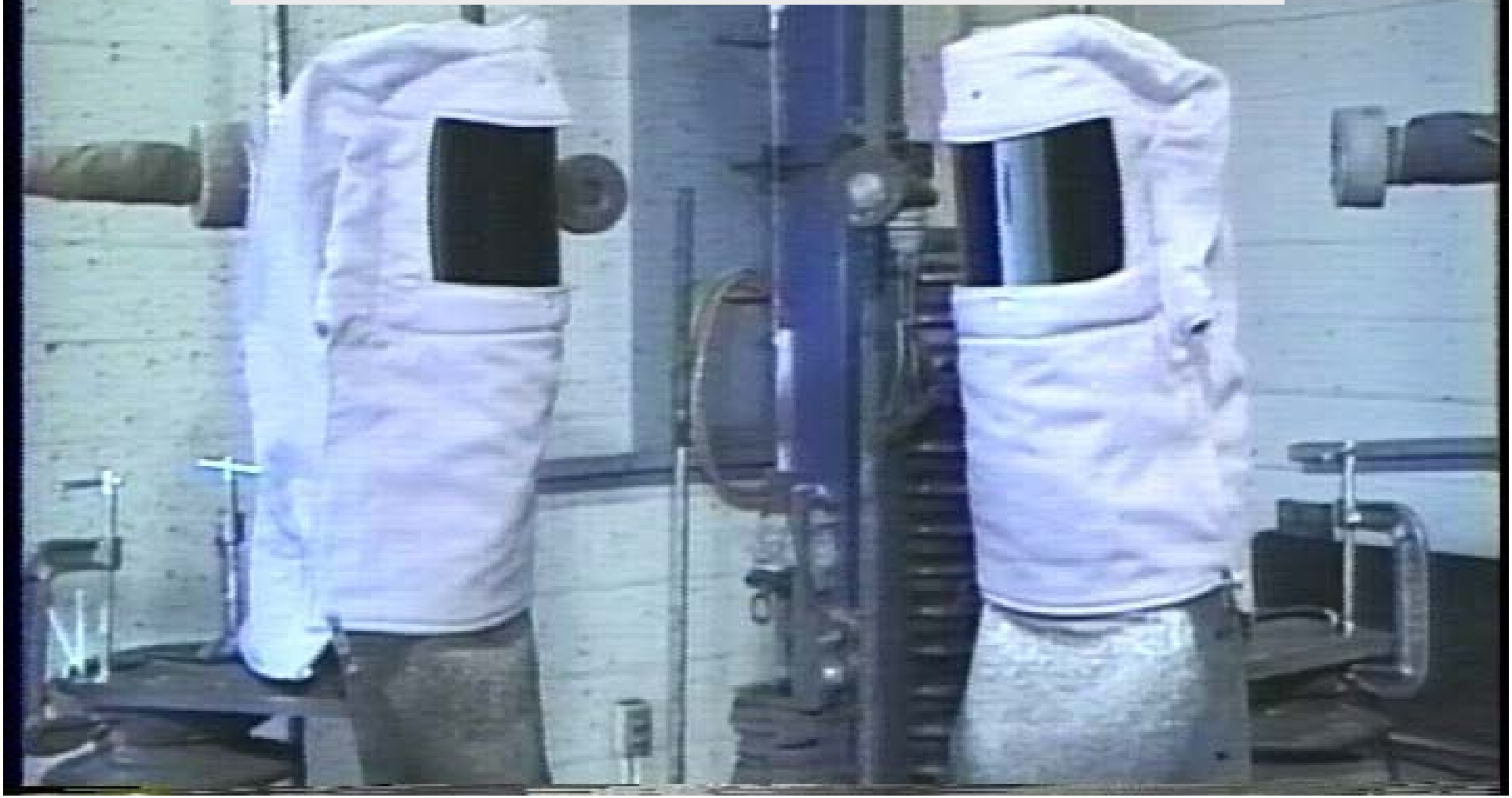
Right Side
Clear Face Shield
Flammable Shirt

No Arc Rating

Exposure
39.7 cal/cm²

Hood Arc Rating of 100 cal/cm²
Matched to the Exposure Level

Mannequin B	Mannequin A
98.0 cal/cm²	96.0 cal/cm²

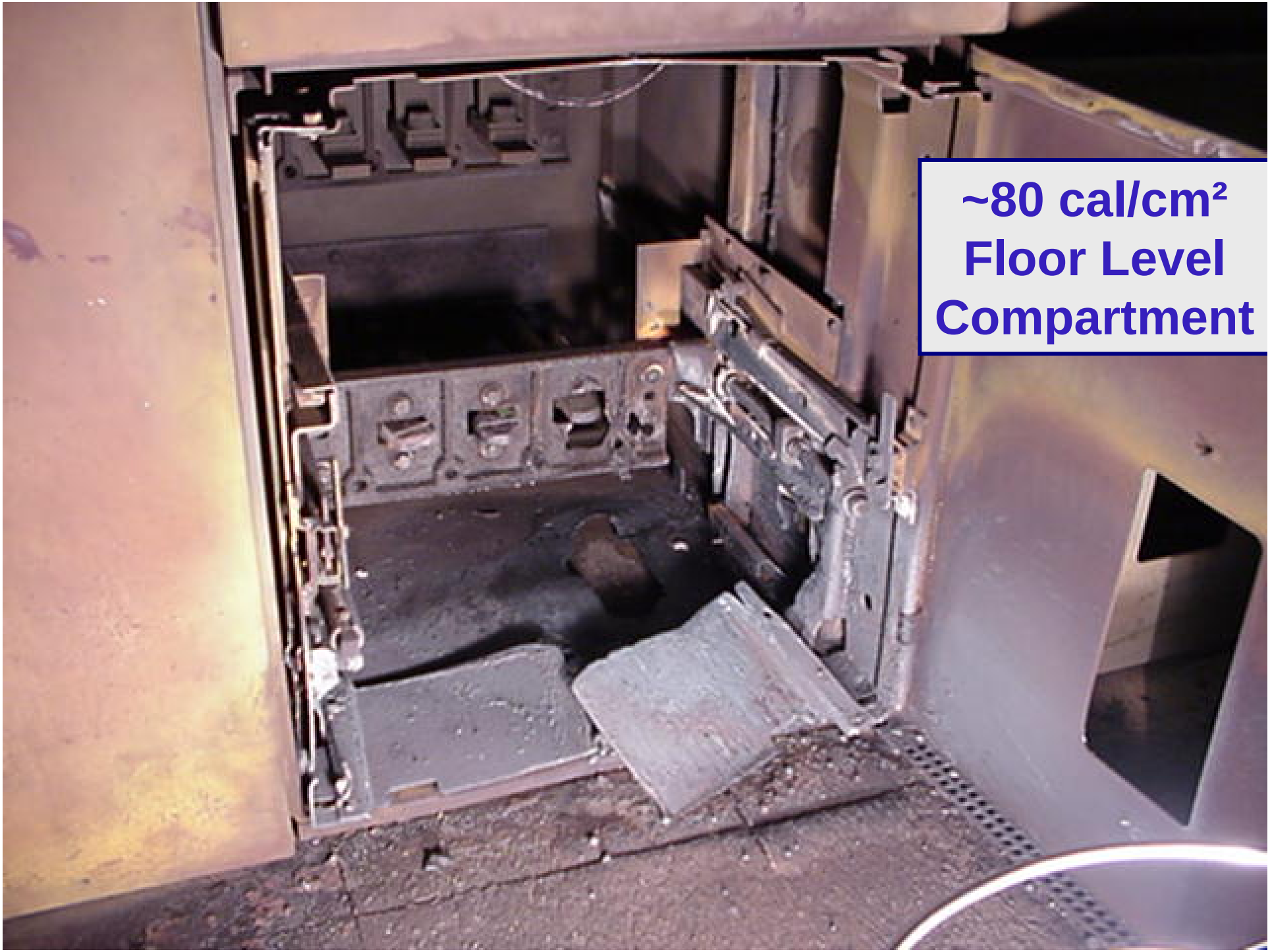


What Happens in Real Arc Accidents?

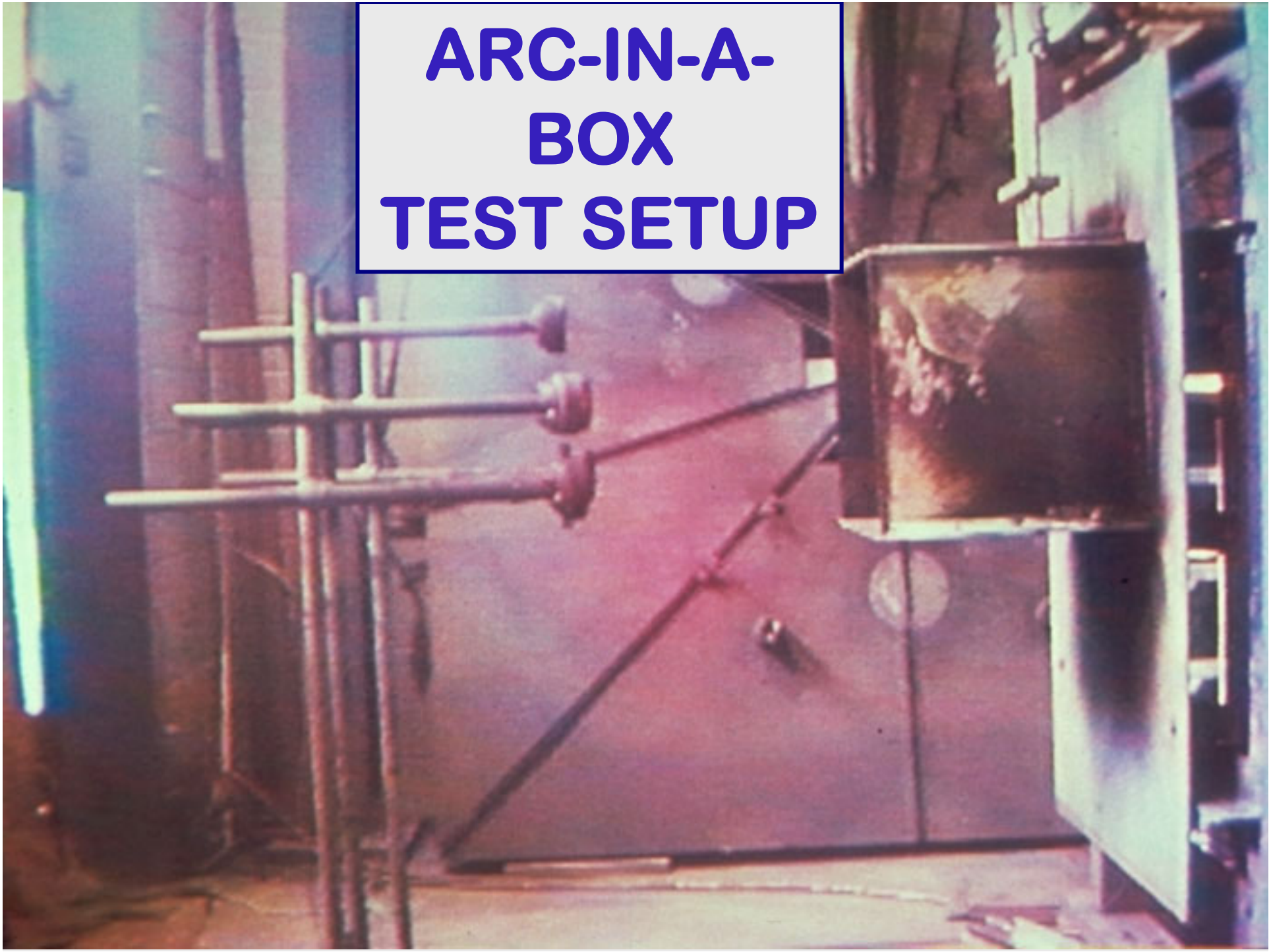
Often the Unexpected

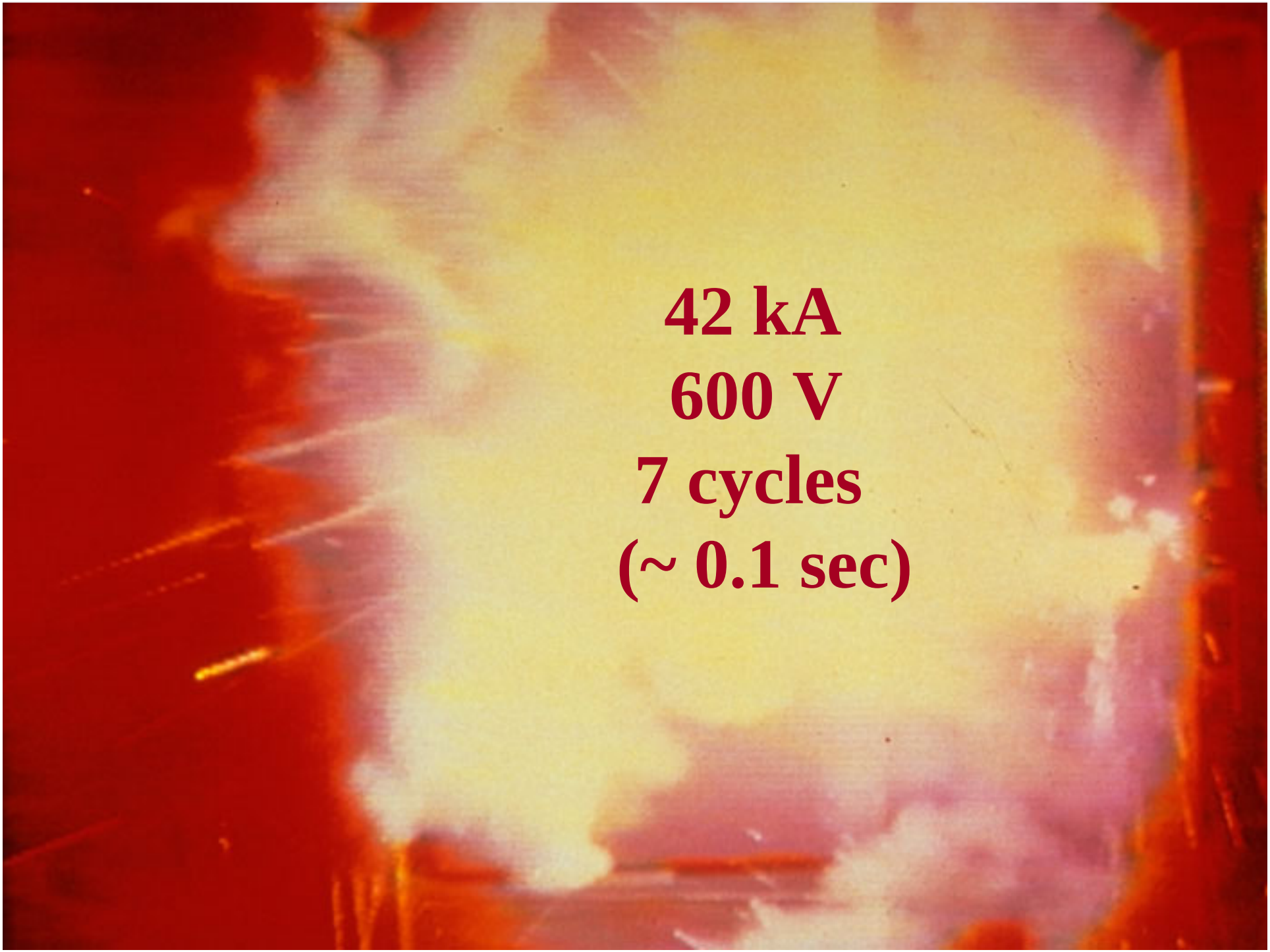
August 1999 Arc Flash Accident

- Arc Duration Longer than Expected Due to No Breaker in Compartment Where Arc Occurred
- Higher Fault Current than Expected Due to Having Both Primary and Backup Transformers As Feeds
- Arc Flash Exposure was ~80 cal/cm²
- Workers had Two FR Layers--Arc Rating 21 cal/cm²
- Two Workers Suffered Serious Burn Injuries
- One Worker Lost of >70% Use of One Hand and was Not Able to Return to Work


~80 cal/cm²
Floor Level
Compartment

ARC-IN-A-BOX TEST SETUP

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600 V
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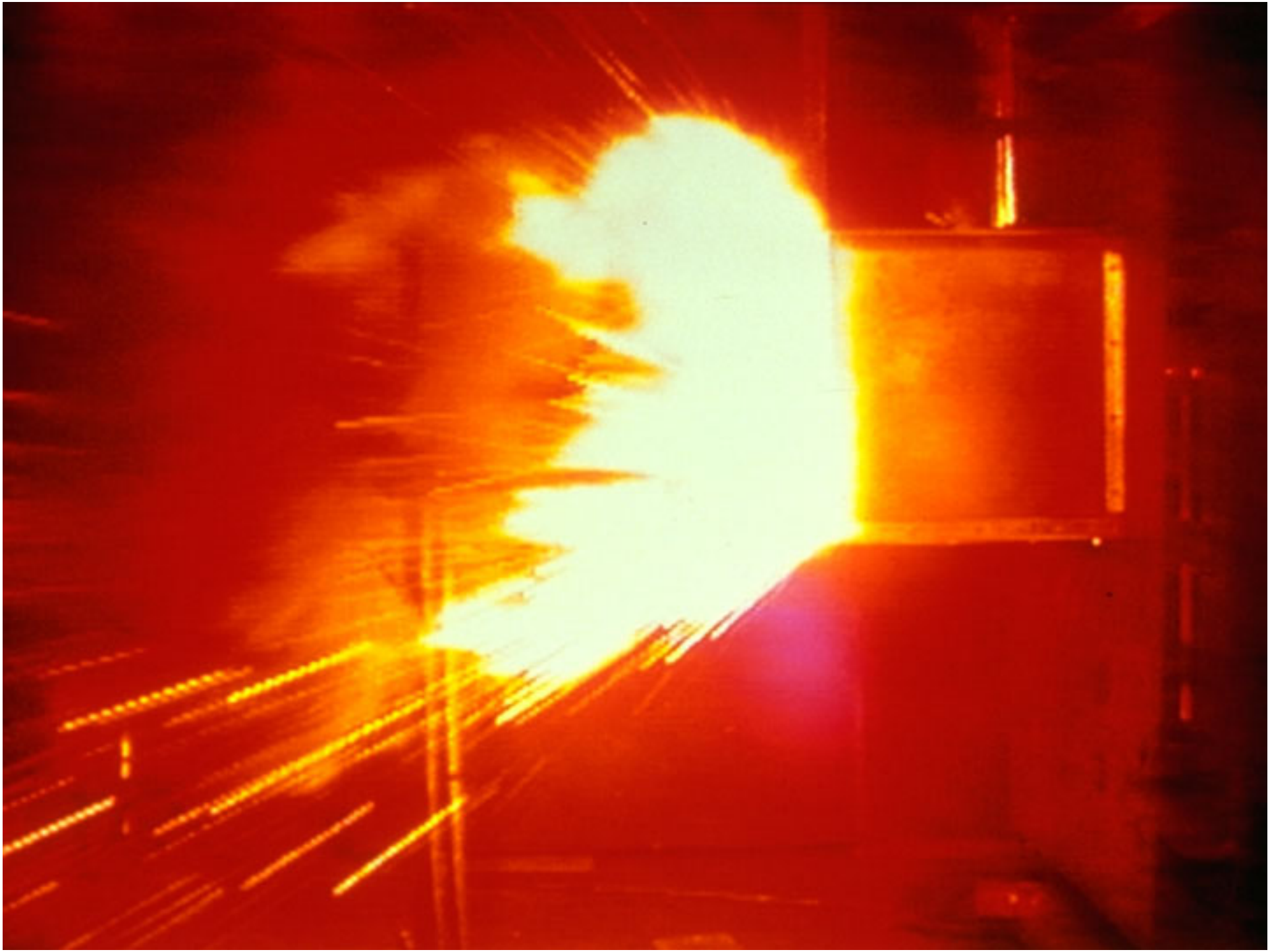


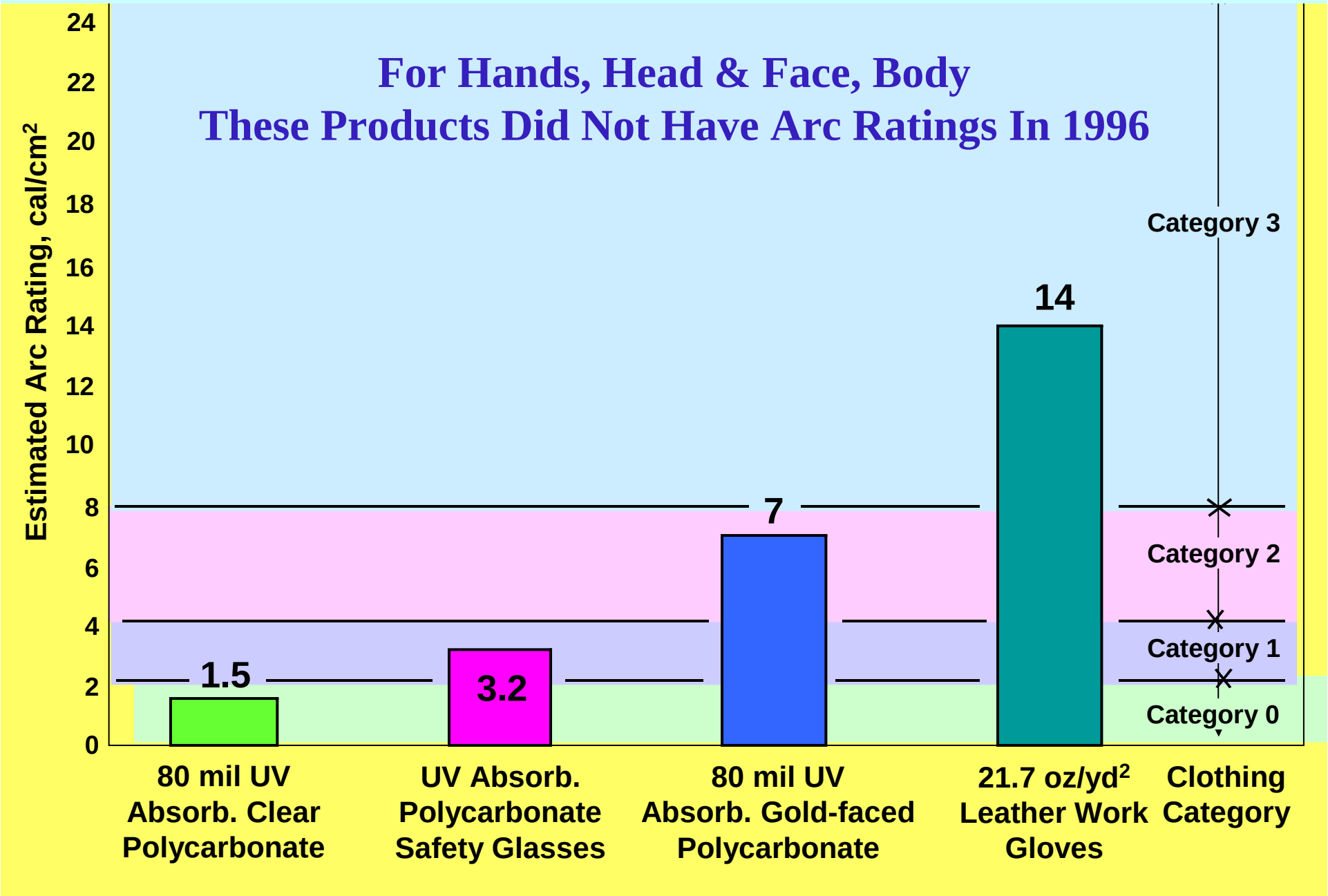
FR Clothing Must Match the Arc Flash Hazard

FR Clothing and Equipment Exposed to Arc Flash of ~ 80 cal/cm^2

System Arc Rating (2 FR Layers) Arc Rating 21 cal/cm^2

August 1999 Accident

"State of the Art" Protection in 1996



Product Improvement—Arc Rated Gloves

- In 1996 Heavy Duty Leather Gloves Were Observed to Provide a Protection Level of ~14 cal/cm²
- Rubber Gloves with Leather Protectors were Observed to Offer a Higher Level of Protection
- Recent Test Have Confirmed that a High Level of Protection, but a Glove Test Method is Not Yet Available
- ***In 2003 Three Levels of Arc Rated Gloves at 40, 65 and 100 cal/cm² were Introduced. These Arc Flash Gloves are Designed for Tasks which Don't Require a Voltage Rating***

THIRD GENERATION ARC FLASH SHIELD WINDOWS

- **Face Protection Became an Issue in 1996 when Arc Testing Indicated that Clear or Gold Coated Face Shields Blocked Minimal Levels of Arc Flash Energy**
- **At High Exposures Clear Face Shields Melted, Dripped and Ignited**
- **Products Based on Propionate Polymers Were Developed in 1997 and 1998 With Arc Ratings Up to 100 cal/cm^2 but Visible Light Transmission was Reduced**

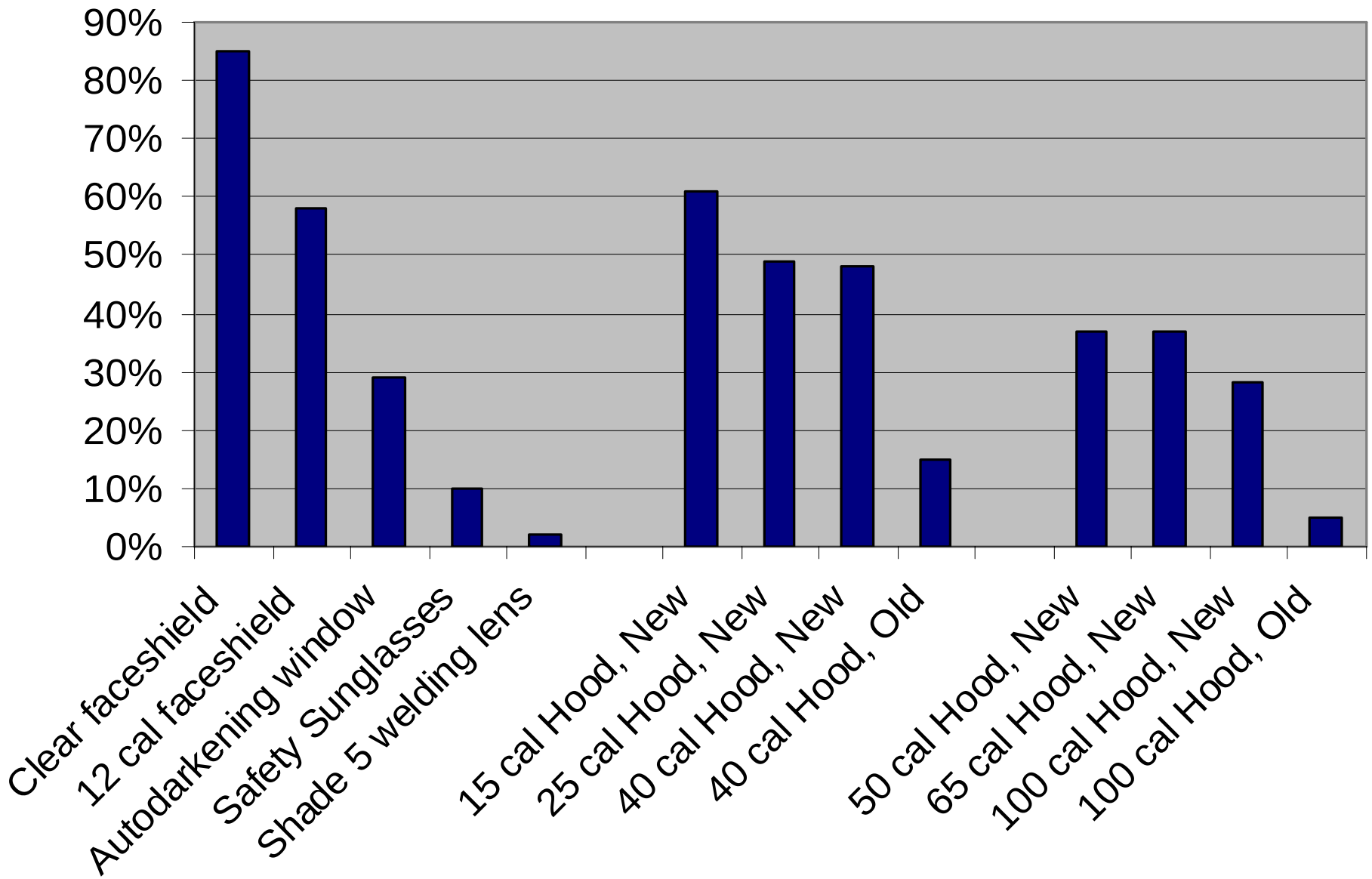
Product Improvements—Shield Windows

- 3rd Generation Arc Flash Face Shields & Hood Shield Windows Offer Important Improvements
  - Available in Polycarbonate for Impact Resistance and Surface Charring Mechanism for Increased Protection
  - Superior Scratch Resistant Coating on the Outside
  - Anti-Fog Coating on the Inside
  - ***Increased Visible Light Transmission at Every Arc Rating Level, e.g. 2.5X to 5X the Visible Light Transmission at the 40 to 100 cal/cm² level—Worker Visual Acuity is Significantly Increased***

Product Improvements—Hood Ventilation

- 3rd Generation Arc Flash Hoods Offer Improved Ventilation Inside the Hood
  - Increased Air Flow
  - Compact, Light Weight Blower Systems

Visible Light Transmission



Product Improvement—Lighter Weight

- New Layered Systems Can Provide Lighter Weight Arc Flash Suits Protection

Typical System Weights for a Range of Arc Ratings

System Rating cal/cm²	1st Generation FR Fabric Systems	2nd Generation FR Fabric Systems
8	10 oz/yd²	6.5 oz/yd²
15 to 20	13 oz/yd²	8.8 oz/yd²
25 to 31	17 oz/yd²	9.7 oz/yd²
40 to 50	24 oz/yd²	12.1 oz/yd²
65 to 76	34 oz/yd²	15.5 oz/yd²
100	41 oz/yd²	18.0 oz/yd²

Layering Options for Arc Flash Protection

NFPA 70E Hazard/ Risk Category	Required Arc Rating cal/cm^2	Single Garment Approach Arc Flash Suit		Layering Approach Examples Arc Flash Suit over Daily Wear FR Clothing NFPA 70E Recommended Protective Systems	
		Body Protection	Face & Head Protection	Body Protection	Face & Head Protection
2 or 2*	8	8 or 15 cal Dailywear 6-9 oz/yd^2	Faceshield + Hard Hat or Hood/2*	4.5 oz FR Shirt & Pants + FR Long Underwear	Face Shield + Hard Hat or Hood/2*
3	25	25 cal Flash Suit 9.7 oz/yd^2	25 cal Hood 9.7 oz/yd^2	15 cal Suit at 8.8 oz/yd^2 + FR Dailywear Shirt and Pants	25 cal Hood 9.7 oz/yd^2
4	40	40 cal Flash Suit 12.1 oz/yd^2	40 cal Hood 12.1 oz/yd^2	25 cal Suit at 9.7 oz/yd^2 + FR Dailywear Shirt and Pants	40 cal Hood 12.1 oz/yd^2

Arc Ratings for Layering Options & Revised ASTM F1959 Exposure Levels For Lower Burn Injury Probabilities

Arc Rating (ATPV) 29 cal/cm² (Linear Regression Data Analysis)			
Probability of 2nd degree Burn (Logistic Regression	25 cal/cm² Suit No Underlayers Data Analysis)	25 cal/cm² Suit over 4.5 oz/yd² HRC1 FR shirt	25 cal/cm² Suit over 4.5 oz/yd² HRC1 shirt + 6 oz FR Longjohns
50%	ATPV 30	ATPV 45	ATPV 53
40%	$ATPV_{40}$ 30	$ATPV_{40}$ 45	$ATPV_{40}$ 52
30%	$ATPV_{30}$ 29	$ATPV_{30}$ 45	$ATPV_{30}$ 52
20%	$ATPV_{20}$ 29	$ATPV_{20}$ 45	$ATPV_{20}$ 51
10%	$ATPV_{10}$ 29	$ATPV_{10}$ 44	$ATPV_{10}$ 50
5%	$ATPV_{5}$ 28	$ATPV_{5}$ 44	$ATPV_{5}$ 49
1%	$ATPV_{1}$ 27	$ATPV_{1}$ 43	$ATPV_{1}$ 47
Minimum Hood Arc Rating	25 cal/cm²	40 cal/cm²	50 cal/cm²

Heat Stress Fundamentals

- Heat Stress is Not the Same As Wearer Discomfort
- Comfort is an Individual Perception
  - ✓Under the Same Environmental Conditions Wearing the Same Clothing, One Person Feels Comfortable While Another is Uncomfortable
  - ✓Thus We have Dual Heat Controls for Automobiles and Waterbeds—Not to Mention Thermostat Wars
- Heat Stress Results When the Human Body Core Temperature Increases Beyond the Normal Body Temperature of 98.6ºF

Heat Stress Fundamentals

- Heat Stress Occurs When Heat Generation due to Metabolic Activity Exceeds Heat Loss Through Clothing and from Uncovered Skin
- As the Excess Heat Builds Up, the Core Temperature of the Human Body Increases
- A Core Temperature Increase of Just a Few Degrees Can Impair Judgment
- A Core Temperature Greater than 105ºF Can be Life Threatening
- Increasing Core Temperature is Difficult to Reverse Due the Mass and Insulation of the Human Body

Heat Stress Fundamentals

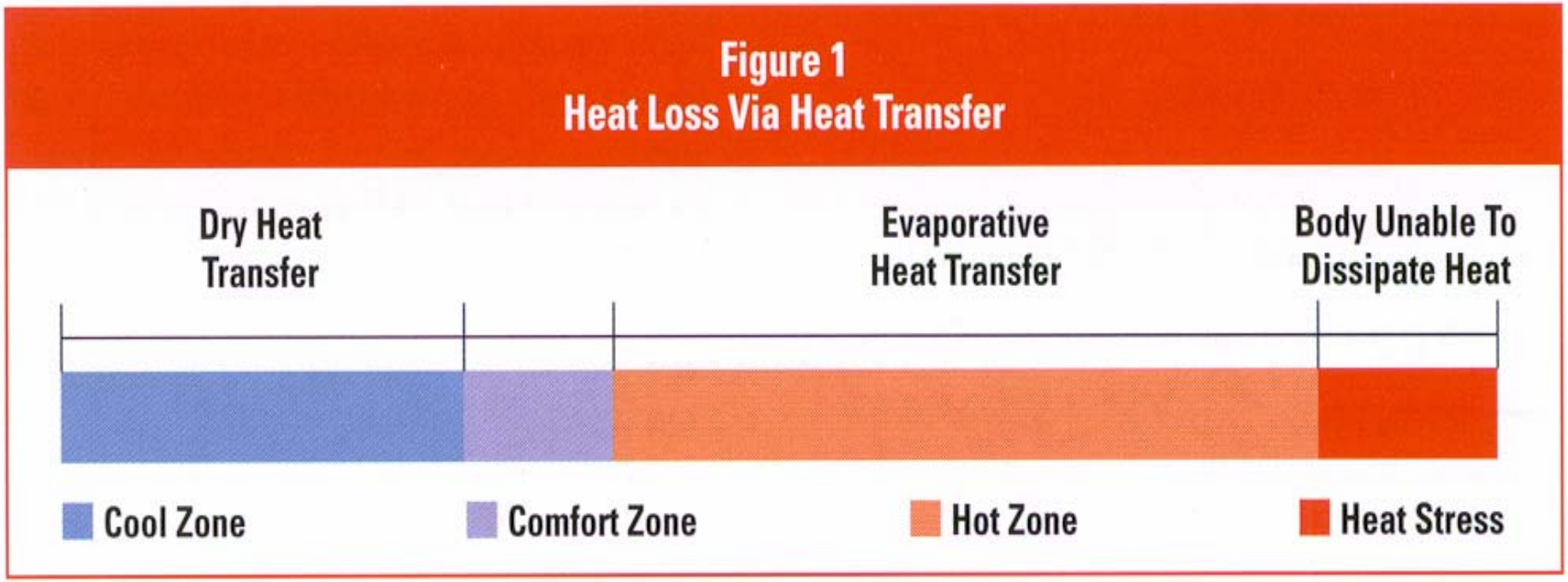
If Heat Generation from Metabolic Activity
Is Greater than Heat Loss Through Clothing
➔ Heat Stress

Conversely:
If Heat Generation by Metabolic Activity
Is Less than Heat Loss Through Clothing
➔ Hypothermia

North Carolina State University Study

Two Main Ways Our Bodies Can Lose Heat

1. Dry Heat Transfer Through Clothing
2. Evaporative Heat Transfer—Perspiration



Primary Factors Impacting Heat Stress

- Climatic Factors—Temperature, Humidity, Wind, Sun Exposure
- Work Rate—Metabolic Rates (Watts/m^2)

Standing	**70**
Walking @ 3 mph	**180**
Tennis	**260**
Heavy labor	**320 – 440**
Wrestling	**500**

- Physical Condition of the Worker
- Clothing Type—Fabric Weight, Number of Layers and Air Permeability

Does FR Clothing Impact Heat Stress

- Flame Resistant Shirts, Pants or Coveralls are as "Breathable" and Typically Lighter Weight than Conventional Cotton Work Apparel (Jeans)
- Wearer Heat Stress Potential for FR Clothing is Generally Less than or Equivalent to that of Conventional Work Apparel
- Metabolic Heat Loss through Protective Clothing Generally Decreases as Protection Level Increases
- When Arc Flash Suits with Higher Arc Ratings (>40 cal/cm²) with Multiple Layers of FR Fabrics and Hoods are Required, Heat Stress Potential Increases

Protection versus Heat Stress

- Heat Stress Potential Generally Increases as Arc Rating Increases
- The Heat Barrier Provided by PPE which Prevents Most the Arc Flash Heat from Reaching the Workers Body Surface also Acts as a Barrier to Metabolic Heat Generated by the Worker
- However—Lighter Weight, More Breathable Fabric Systems Can Provide Higher Levels of Total Heat Loss at the Same Arc Rating

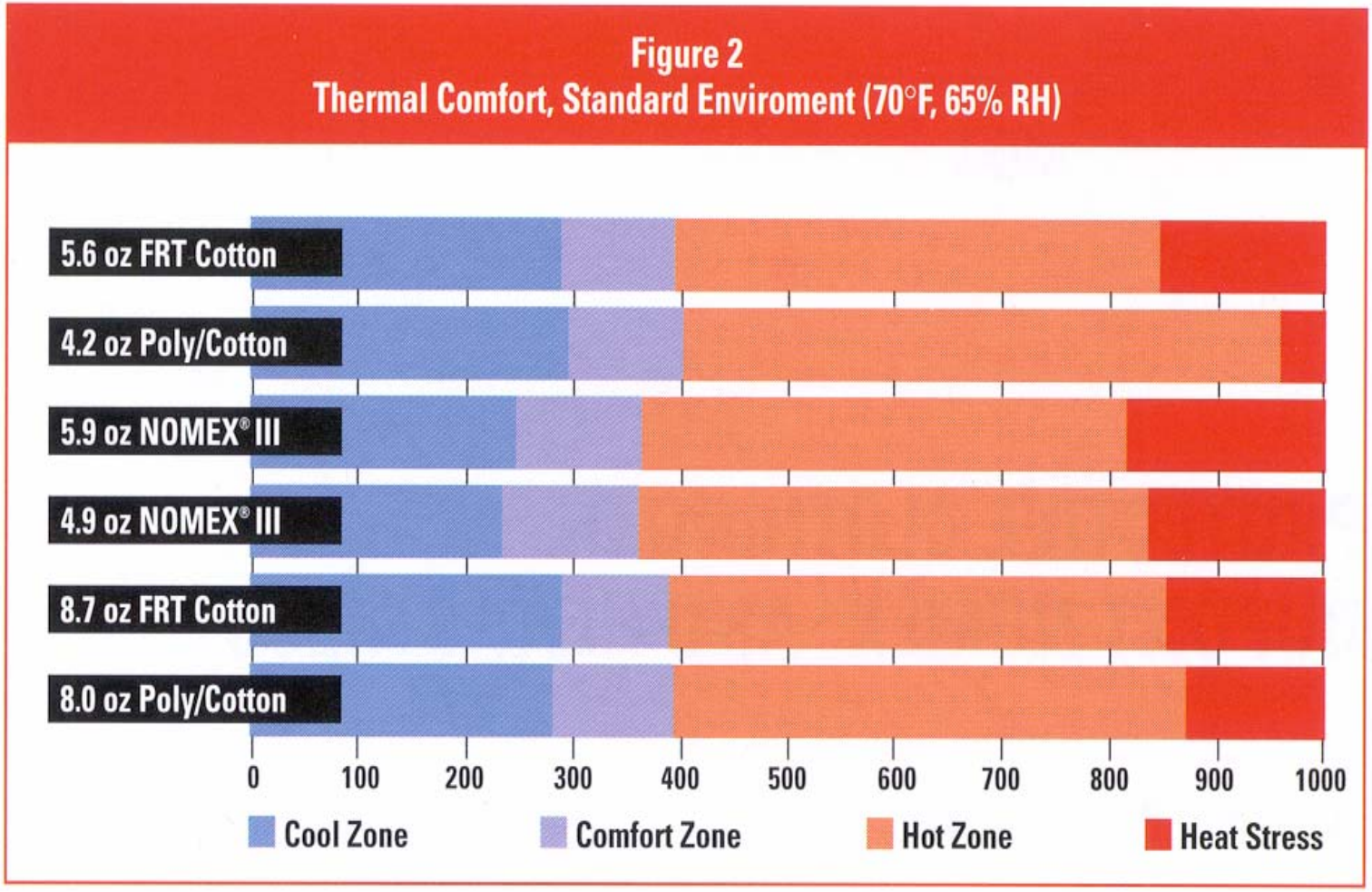
Typical Heat Loss Values Through Clothing

Total Heat Loss (THL) for Clothing is Expressed in Heat Transfer/Unit Area of Clothing Material

Clothing Material	THL in Watts/m^2
6 oz/yd^2 Cotton T-shirt Knit	688
6 oz/yd^2 Meta-Aramid FR Woven Fabric	747
Lightest HRC2 FR Shirt/Pants Fabric	500 to 600
Firefighter Turnout, non-breathable	80 to 120
Firefighter Turnout, breathable	150 to 250
HRC4 Systems—TBD	est. 300 to 400
100 cal/cm^2 Arc Flash Suits—TBD	est. 150 to 250

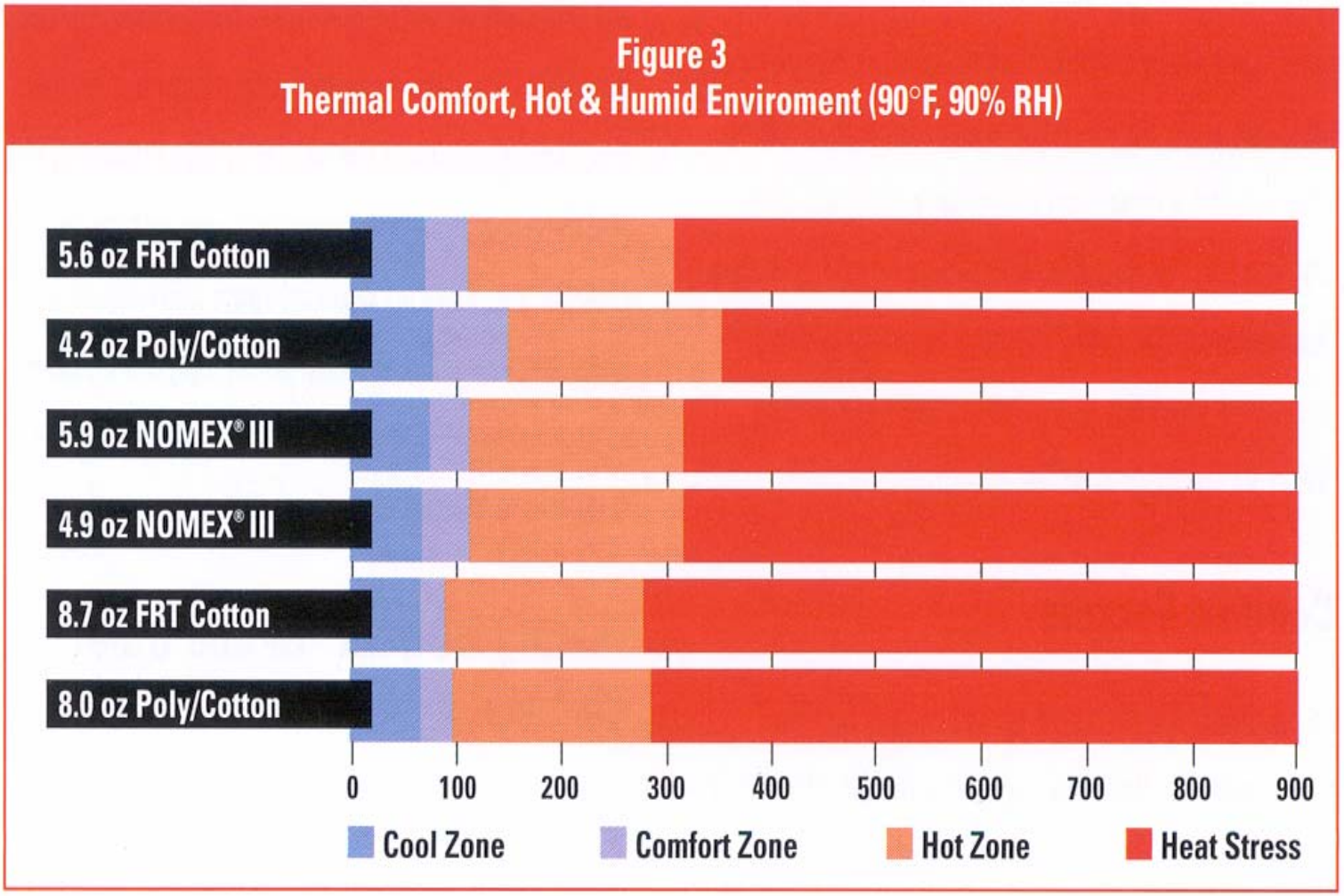
Testing at Moderate Conditions 70°F & 65% RH Heat Stress is Unlikely (NCSU Study)

All Fabrics Feel Comfortable Even at Metabolic Levels



Testing at Severe Conditions 90°F & 90% RH Heat Stress is Likely at High Activity Levels

All Fabrics Will Feel Hot at All Activity Levels



Heat Stress Reduction

- Risk of Heat Stress Can Be Reduced
  - Controlled Work Schedules—As Temperature, Humidity, and Metabolic Level Increases
  - High Fluid Intake
  - Cooling Vests and Air Flow in Hoods
  - Use of Minimum PPE Required For Hazards
  - Use of Light Weight, Breathable Arc Rated Layered Systems to Achieve Required Protection while Maintaining the Highest THL Level

Conclusions on Heat Stress

- Heat, Humidity and Metabolic Activity Levels Are the Primary Factors Contributing to Worker Comfort and Heat Stress Potential, Rather Than The Type of Fabric Worn
- Fabric Weight Has More Influence Than Fabric Type in Determining When and If Heat Stress Occurs in Hot and Humid Environments
- Heat Stress Potential Needs to be Controlled by Work Rules, Cooling Devices and Careful Selection of PPE
- When Arc Flash PPE with High Arc Rating is Required, Heat Stress Potential Can be Reduced by Selecting Lighter Weight Systems which Include FR Clothing Underlayers

IN SUMMARY

- A New Generation of FR Clothing and Arc Flash Suits can Provide High Levels of Protection at Lighter Weight for Increased Worker Comfort and Reduced Heat Stress Potential
- FR Daily Wear and PPE Layering Options Can Improve Worker Comfort, Reduce Heat Stress Potential and Reduce PPE Cost
- The Revised ASTM F1959 Arc Test Data Analysis Method can be Used to Estimate Lower Burn Injury Probability Levels than the 50% Level Associated with Arc Rating

Conclusions, Cont.

- FR Clothing and Arc Flash Suit Labeling can Clarify the Protection Level Provided by FR Daily Wear Combined with Arc Flash PPE Systems
- FR Daily Wear and PPE Layering Options Can Improve Worker Comfort, Reduce Heat Stress Potential and Reduce PPE Cost

3 Things I Have Figured Out

1. **The Most Important Reason for Using Arc Flash PPE: It Preserves the Quality of Life for a Worker Who Is Involved in an Arc Flash Accident.**
2. **The Second Most Important Reason for Using Arc Flash PPE: It Protects the Worker's Family from Tragic Loss**
3. **The Reasons for Not Using PPE, i.e. It's Too Hot, It's Too Hard to Work In, It Slows Me Down, Etc. Are Not Very Important Compared to #1 and #2 Above.**

NFPA 70-E Chapter 1

STANDARD FOR ELECTRICAL SAFETY IN THE WORKPLACE

NFPA 70E - 2004 EDITION
CHAPTER 1

BOB GRAY

ELECTRICAL SAFETY MEETING
DECEMBER 1, 2005

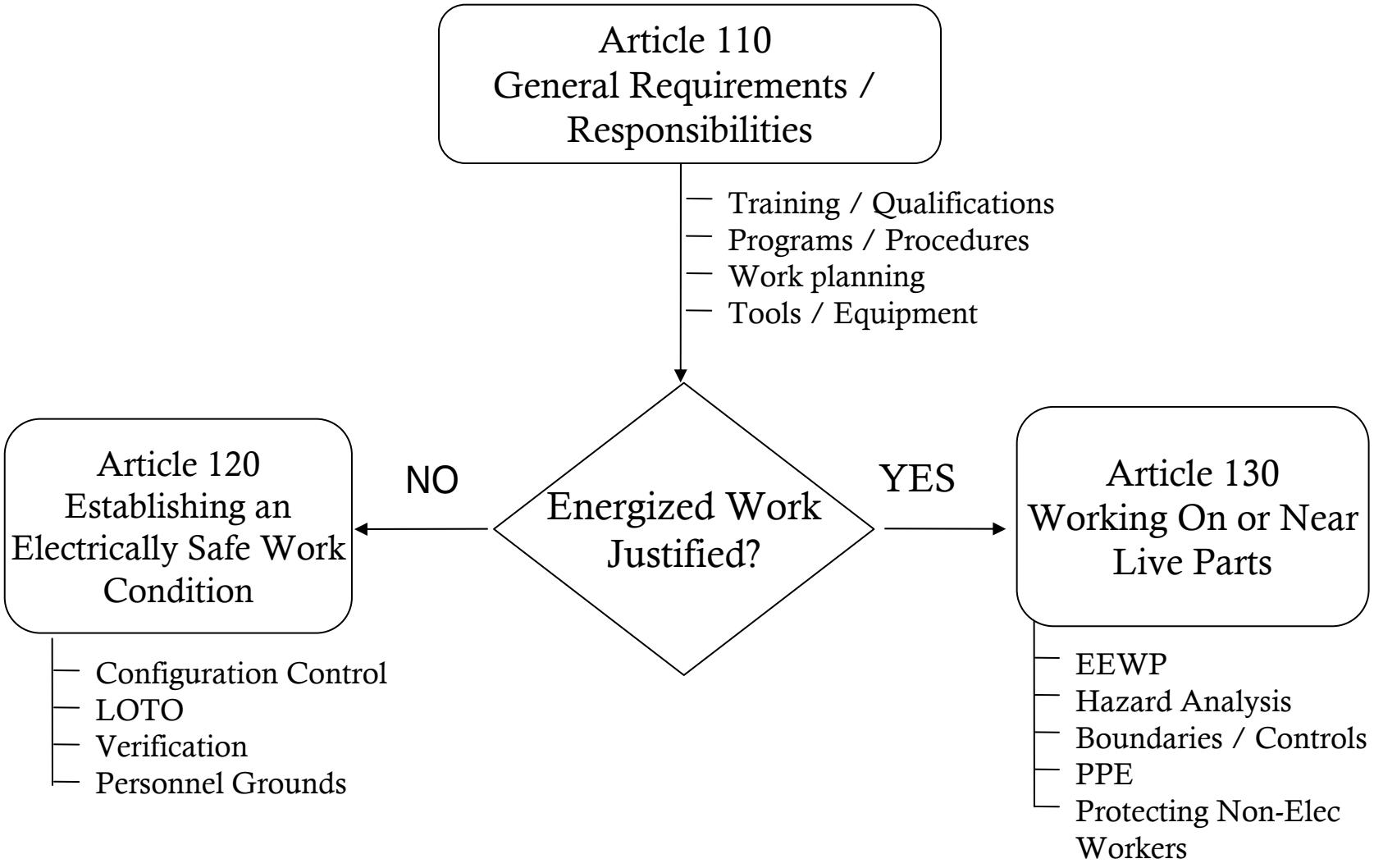
INTRODUCTION

- Safety-related work practices main focus
- Part I Chapters reduced from 5 to 3
  - General
  - Establishing an electrically safe work condition
  - Working on or near live parts

ARTICLE 100 DEFINITIONS

- Consistent with other NFPA standards
- Unique
- Do not contain requirements
- Examples

CHAPTER 1 FLOW CHART (110.5)



ARTICLE 110
GENERAL REQUIREMENTS

- Scope / purpose (110.1, 2)
- Multiemployer Relationship 110.4
- Training Requirements 110.6
- Electrical Safety Program 110.7
- Work Planning
  - Hazard Analysis 110.8(B)(1)
  - Energized Electrical Work Permit 110.8(B)(2)
  - GFCI Testing 110.9(C)

ARTICLE 120
ESTABLISHING AN ELECTRICALLY SAFE WORK CONDITION

- Six–Step Procedure to establish and verify (120.1)
- LOTO Process (120.2)
- Protective Grounding (120.3)

ARTICLE 130
WORKING ON OR NEAR LIVE PARTS

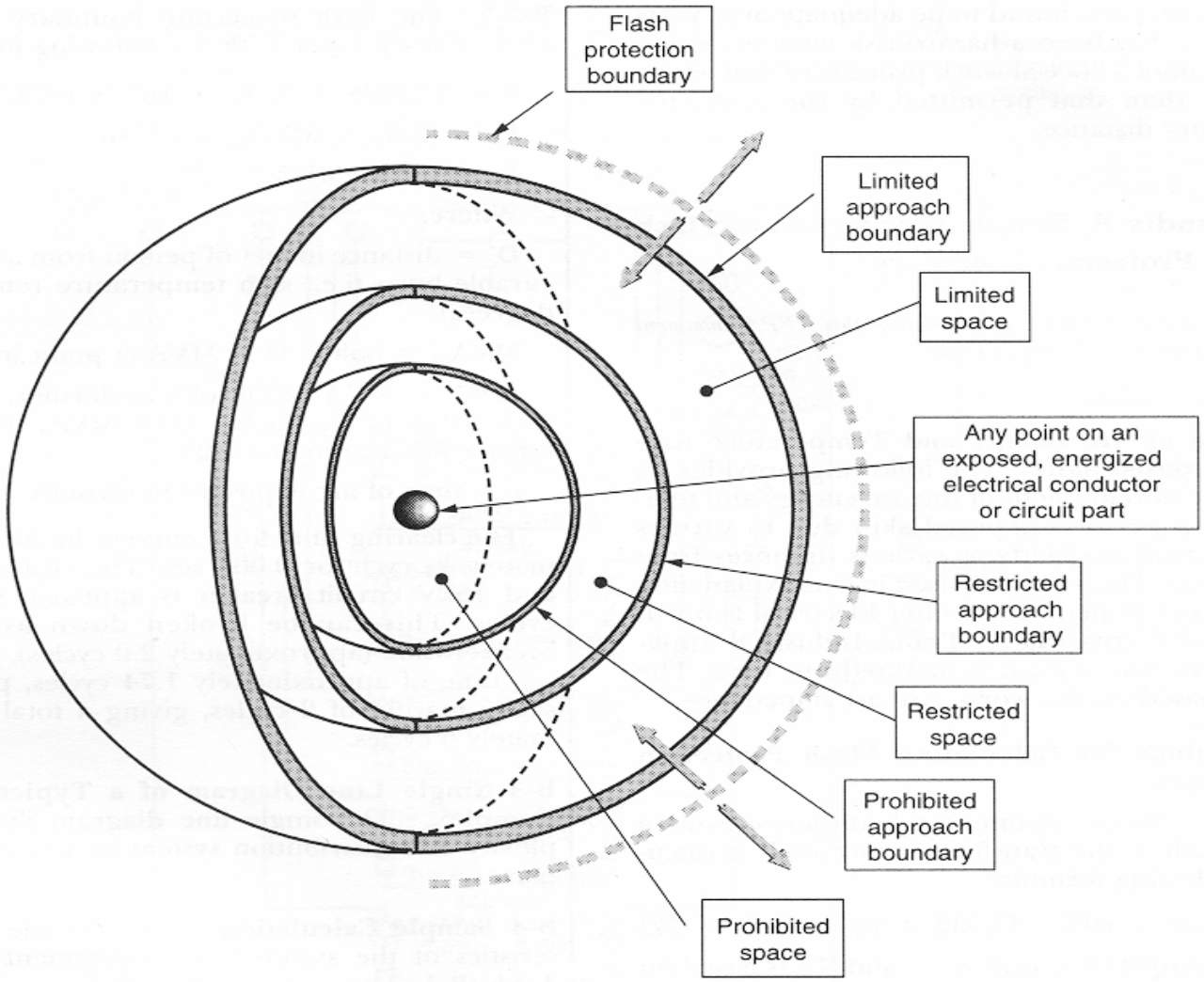
- EEWP 130.1(A)
  - Elements 130.0(A)(2)
  - Exemptions 130.1(A)(3)
- Approach Boundaries For Shock Protection 130.2, 130.3(A), Table 130.2(C)
- Flash Hazard Boundary 130.3, 130.3(A), Annex D
- Test Equipment 130.4
- Uninsulated Overhead Lines 130.5
- Other Precautions 130.6

ARTICLE 130 Cont.

- Shock Hazard Analysis 130.2(A)
  - Voltage level exposure
  - Boundary requirements
  - PPE for shock protection
- Approach Boundaries 130.2(B), Table 130.2(C)
  - Limited
  - Restricted
  - Prohibited
  - FPN
- "Exposed" Live Parts 130.3
- Limits of Approach Annex C, pg. 96
  - Bases for Distances
  - Safe Approach Distances

LIMITS OF APPROACH

Annex C



FLASH HAZARD ANALYSIS

- Purpose / Scope 130.3
  - Protect personnel from arc flash
  - Flash protection boundary
  - Determine PPE required
- Relatively New Technology
- Two Primary Components
- Boundary 130.3(A)
  - ≤ 600 v. distance is 4' 130.3(A)
  - > 600 v. distance where Incident Energy = 1.2 cal/cm² 130.3(A), Annex D or 1.5 cal/cm² if t < 0.1 sec.
  - Engineering supervision or not 300 KA cycles can use formula 130.3(A)
  - Many Variables

FLASH HAZARD ANALYSIS Cont.

- Determine Incident Energy exposure to worker 130.3(B)
  - Worker distance from source to torso
  - Apply proper FR clothing – Table 130.7(C)(11)
  - Apply proper PPE – Table 130.7(C)(10)
  - Apply PPE to parts closer to arc – Table 130.7(C)(13)(c, d)
- Table 130.7(C)(9)(a) Alternate Method
  - See 130.7(C)(9)(a) for limitations
  - Short circuit capacities
  - Fault clearing times
  - Tasks not listed

FLASH HAZARD ANALYSIS Cont.

- Table 130.7(C)(9)(a) pg. 29
  - Tentative Interim Amendment (TIA 04-1)
  - Notes 3 & 6 reduce by one
  - H/RC 2* add double-layer switching hood / hearing protections
  - Limitations
- Table 130.7(C)(10) pg. 33
  - Note 3
  - Layered is better
  - ARC Blast Protection
- Table 130.7(C)(11)
  - Use with formal analysis to determine H/RC

OTHER PRECAUTIONS 130.6

Fitness for duty	130.6(A)
Blind reaching	130.6(B)
Illumination	130.6(C)
Conductive articles	130.6(D)
Conductive materials	130.6(E)
Enclosed work spaces	130.6(F)
Housekeeping limitations	130.6(G)
Flammable materials	130.6(H)
Anticipating failure	130.6(I)
Routine operation of circuits	130.6(J)
Resetting tripped circuit breaker	130.6(K)

PROTECTIVE EQUIPMENT 130.7

- FR protection required at 1.2 cal/cm² 130.7(C)(5)
- Protect all body parts 130.7(C)(3, 4, 5, 6, 7, 13)
- Factors in selection 130.7(C)(12)
  - Layering (a)
  - Under layers (b)
  - Coverage (c)
- Other protective equipment 130.7(D)
  - Insulated tools 130.7(D)(1)
  - Physical barriers 130.7(D)(1)(i)
- Altering techniques 130.7(E)
  - Signs (1)
  - Barriers (2)
  - Attendants (3)

Summary

- Train the workers
- Plan the work
- Analyze the hazards
- Establish electrically safe work conditions
- Justify exposure
- Institute controls
- Protect the worker

NFPA 70-E Chapter 2&3

NFPA 70E Chapters 2 and 3

The things you need to know
When NFPA 70E is discussed

NFPA 70E Chapters 2 and 3

Why I talk about it.

165 proposals - 0 on parts 3 & 4.

Most training does not cover parts 2 & 3.

Part 2 is excellent resource for training building managers.

Part 3 is misunderstood and needs improving

NFPA 70

Purpose: “the practical safeguarding of persons and property from hazards arising from the use of electricity”

Scope: Article 90.2 ….installations

NFPA 70E

Purpose: …. Document applicable for electrical safety-related <u>work practices</u>….

Scope: “ This standard addresses those electrical safety requirements for employee workplaces that are necessary for the practical safeguarding of employees in there pursuit of gainful employment.”

NFPA 70E Chapter 2

SAFETY-RELATED MAINTENANCE REQUIREMENTS

It’s telling you that you need to be doing
Maintenance in order to maintain your Workplace
in an
Electrically Safe Condition
for your employees

For the purpose of Chapter 2, maintenance shall be defined as preserving or restoring the condition of electrical equipment and installations, or parts of either, for the safety of employees who work on, near, or with such equipment.

Equipment. A general term including material, fittings, devices, appliances, fixtures, apparatus, and the like used as a part of, or in connection with, an electrical installation. (NFPA 70)

NFPA 70E Chapter 2 identifies only that maintenance which is directly associated with the safety of employees who work on, near, or with such equipment.

NFPA 70E Chapter 2

Identifies 10 key areas that the employer should be aware of and should be maintaining to keep this property or equipment safe for employees.

NFPA 70E Chapter 2

Tells you that you need a plan but, it is not giving you all the tools you need to meet the requirements.

NFPA 70E Chapter 2

The inspection frequency should be as recommended by the manufacturer or as otherwise as indicated in NFPA 70B.

“Recommended Practice for Electrical Equipment Maintenance”

DOE O 433.1 – Maintenance Management Program for Nuclear Facilities

The program should include the essential elements described in NFPA 70B, Chapter 5.

"What is an Effective Electrical Preventive Maintenance (EPM) Program."

DOE-HDBK-1092-2004 Chapter 3

Guidance on how to determine inspection frequency is described in various sections of NFPA 70B (2002), including but not limited to the following sections:

1. Inspection Frequency for Planning and Developing an Electrical Preventive Maintenance Program
2. Recommended Frequency for Substations
3. Frequency of Maintenance for Switchgear Assemblies
4. Regular Inspections and Special Inspections and Repairs for Liquid-Filled Transformers

5. Regular Inspections and Special Inspections and Repairs for Dry-Type Transformers
6. Visual Inspection Intervals for Power Cables
7. Frequency of Inspections for Enclosures of Motor Control Centers
8. Recommended Inspection Frequency for Ground-Fault Circuit Interrupters
9. General Inspection and Cleaning for High-Voltage Fuses

10. Inspection Frequency for Rotating Equipment
11. Cleaning Interval for Lighting Equipment
12. Visual Inspection Before and After Each Use, Periodic Inspection of Crucial Wear Points, Excessive Dirt Accumulation, Insufficient or Improper Lubrication, and Visually Inspected Before Each Use for Portable Electric Tools and Equipment
13. Special Maintenance Tests, Frequency of Tests, Inspection Frequency and Procedures, and Insulating-Liquid Analysis for Testing and Test Methods

14. Reinspection and Retesting Within One or Two Years After Energization for General Aspects of Maintaining Medium- and Low-Voltage Distribution Systems, Frequency, Regreasing, and Frequency for Lubrication of Rotating Equipment

15. Inspections Should Be Made of All New Installations and Whenever Alterations Are Made and Record keeping for Electrostatics Static Grounding (see NFPA 77)

16. Inspection and Testing of Power Supplies, Functional Systems Testing of Interlock and Logic Systems, Visual Inspection of Level Devices, Frequency of Testing Safety and Shutdown Systems, Frequency of Testing Alarm Systems, and Visual Checking of Wiring Systems for Process Instrumentation and Control

17. Frequency for Inspection of Cable Tray System

18. Routine Maintenance for Uninterruptible Power Supply (UPS) Systems

NFPA 70E Chapter 2

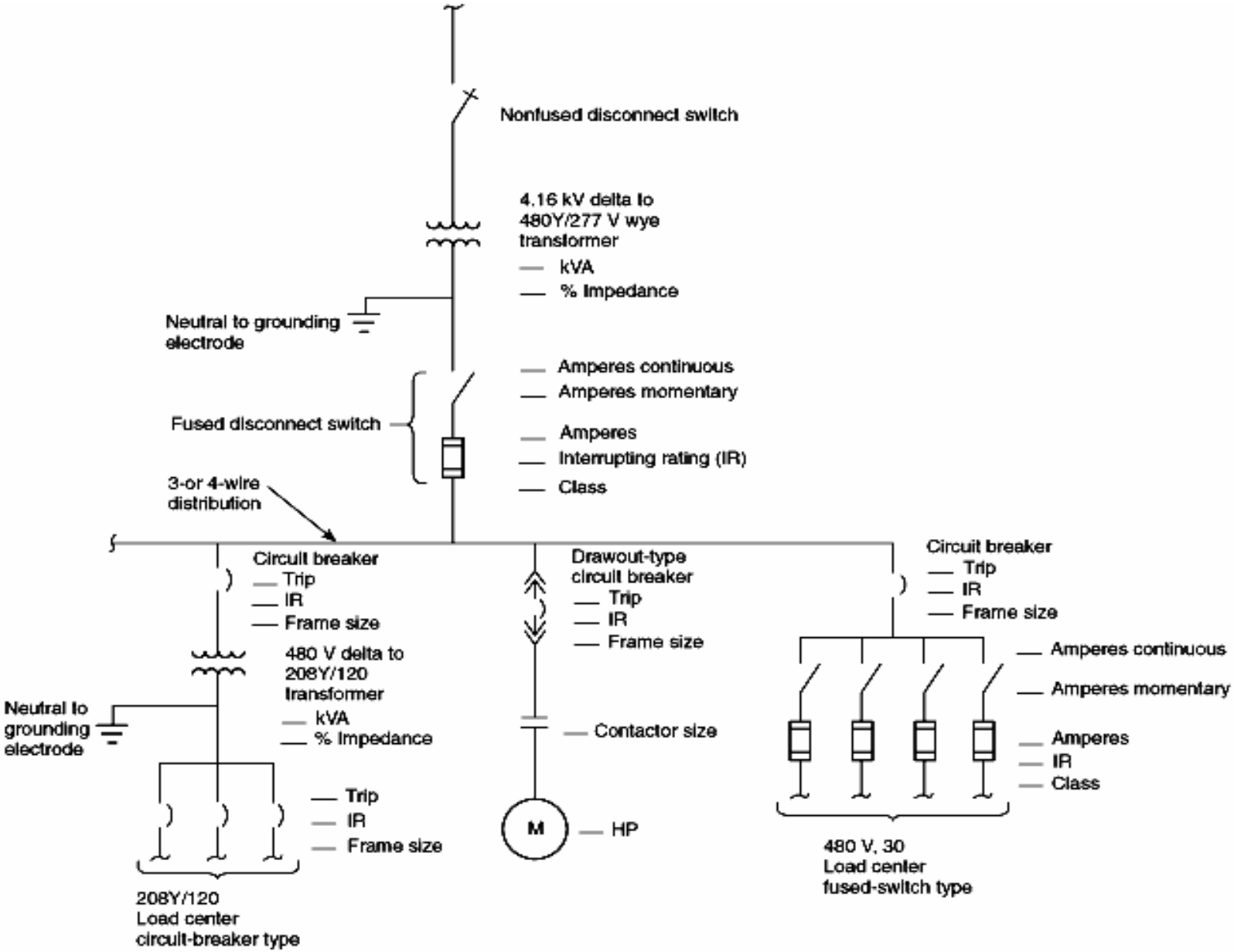
- General Maintenance Requirements (Article 205)
- Substation, Switchgear Assemblies, Switchboards, Panel boards, Motor Control Centers, and Disconnect Switches (Article 210)
- Premises Wiring (Article 215)
- Controller Equipment (Article 220)
- Fuses and Circuit Breakers (Article 225)
- Rotating Equipment (Article 230)
- Hazardous (Classified) Locations (Article 235)
- Batteries and Battery Rooms (Article 240)
- Portable Electric Tools and Equipment (Article 245)
- Personal Safety and Protective Equipment (Article 250)

NFPA 70E Chapter 2
Article 205 General Maintenance Requirements

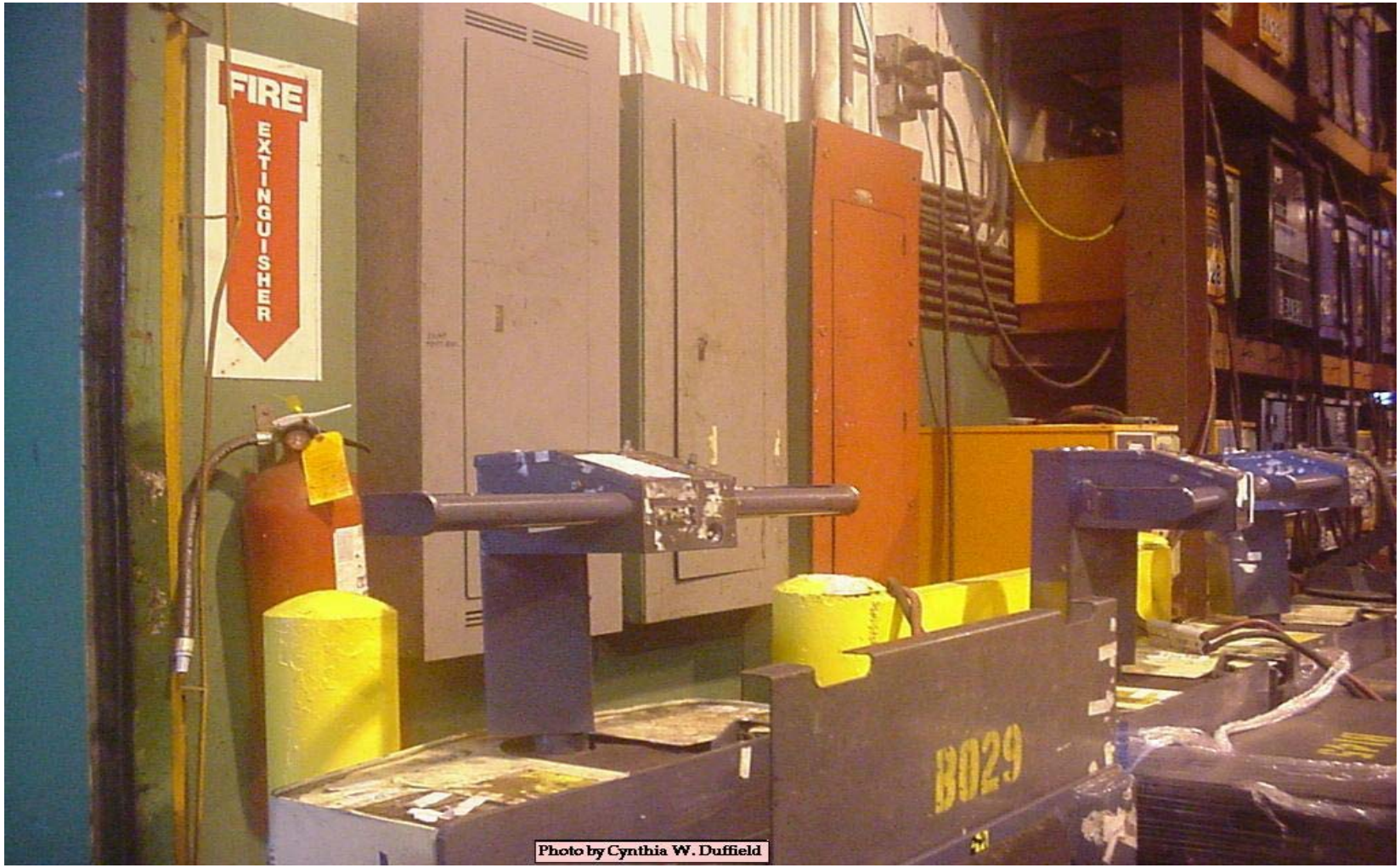
- Qualified Persons
- Single Line Diagram
- Spaces About Electrical Equipment
- Grounding and Bonding
- Guarding of Live Parts
- Safety Equipment
- Clear Spaces – (egress)
- Identification of Components - (instructions)
- Warning Signs
- Identification of Circuits
- Single and Multiple Conductors and Cables
- Flexible Cords and Cables

Who is Your Qualified Person?

Do you need single line drawings ?



DO NOT BLOCK ACCESS



You must maintain working space.

NFPA 70 E Article 400.15

Equipment, raceway, cable tray, and enclosure bonding and grounding shall be maintained to ensure electrical continuity.

DO IT RIGHT THE FIRST TIME

THIS DOES NOT ENSURE CONTINUITY

Enclosures shall be maintained to guard against accidental contact with live parts and other electrical hazards.

Locks, interlocks, and other safety equipment shall be maintained in proper working condition to accomplish control purpose.

Access to working space and escape passages shall be kept clear and unobstructed.

Identification of Components.

Identification of components, where required, and safety-related instructions (operating or maintenance), if posted, shall be securely attached and maintained in legible condition.

Warning Signs.

Warning signs, where required, shall be visible, securely attached, and maintained in legible condition.

Identification of Circuits.

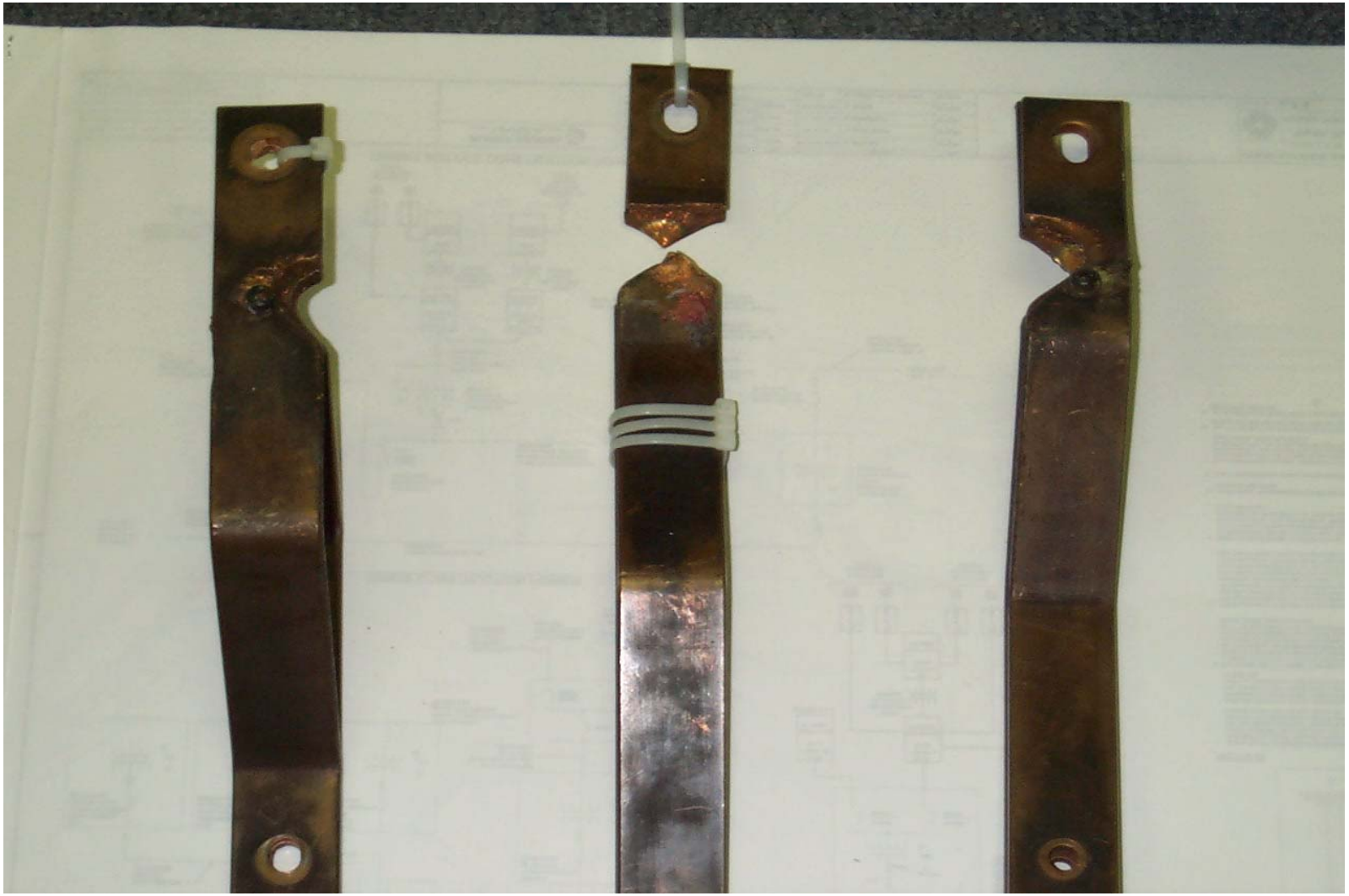
Circuit or voltage identification shall be securely affixed and maintained in updated and legible condition.

CHILLER NO. 2
CHILLER NO. 3
AC-3
DANGER
CAUTION
AC-2
H-1 HUMIDIFIER
H-2 HUMIDIFIER
HC-23

AC-3
AC-3
FAN
DANGER
May be energized
by line power or
backup generator.
RESET
CAUTION
ODH Safety System
DO NOT DISABLE
Contact Bill Noe, ext. 4553
or
Keith Schuh, ext. 4575

-CAUTION-

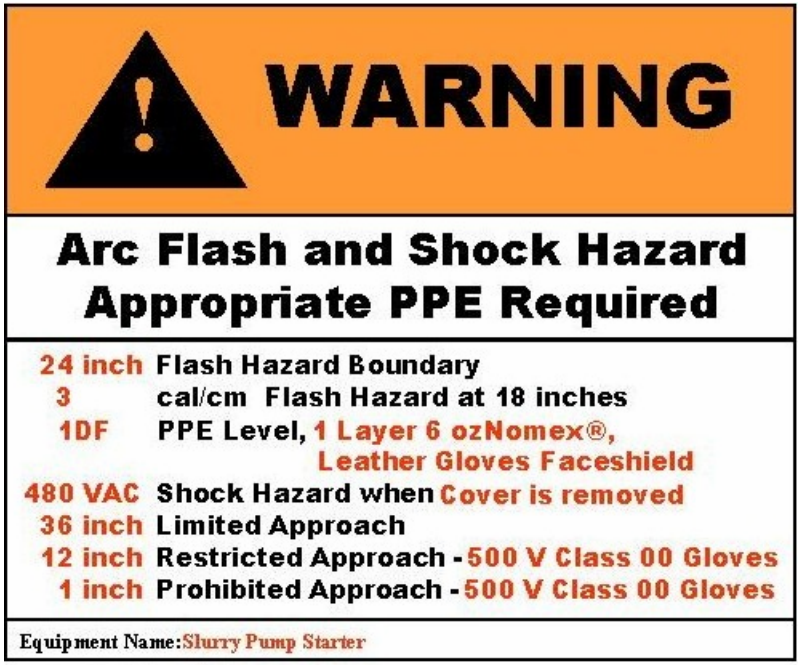
Barrier must NOT be removed or raised until both sources of voltage are removed. Test for voltage with barrier in place.



NEC 2002 110.16

FPN No. 1: NFPA 70E-2000, *Electrical Safety Requirements for Employee Workplaces*, 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.



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

MAIN
BREAKER
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42
MONO-FLAT
INSTALLATION AND REMOVAL
INSTRUCTIONS

Single and Multiple Conductors and Cables.

Electrical cables and single and multiple conductors, shall be maintained free of damage, shorts, and ground that would present a hazard to employees.

Flexible Cords and Cables.

Flexible cords and cables shall be maintained as follows:

(a) *Damaged Cords and Cables*. They shall not have worn, frayed, or damaged areas that present an electrical hazard to employees.

(b) *Strain Relief.* Strain relief shall be maintained to prevent pull from being directly transmitted to joints or terminals.

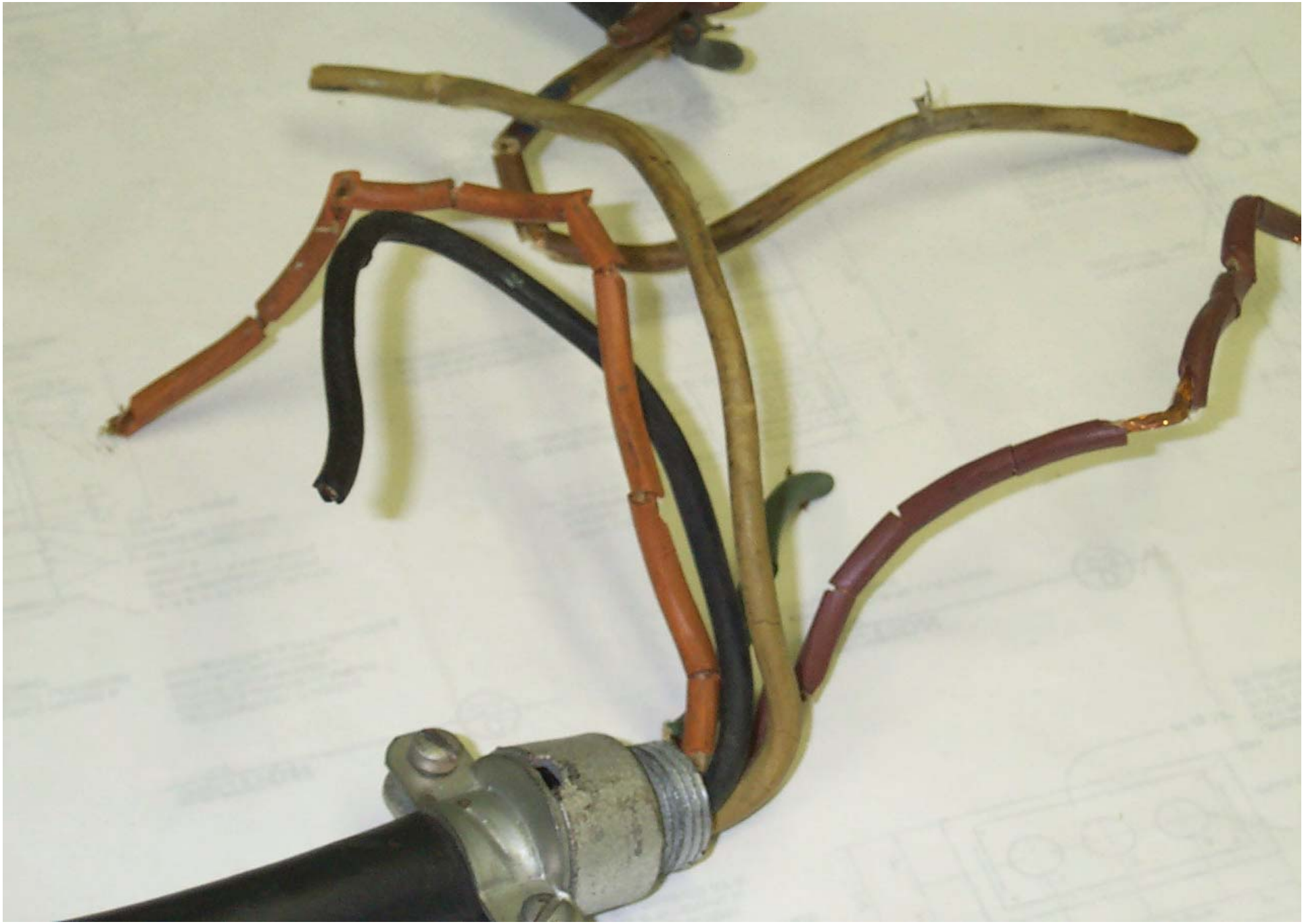


Photo from Safteng..net

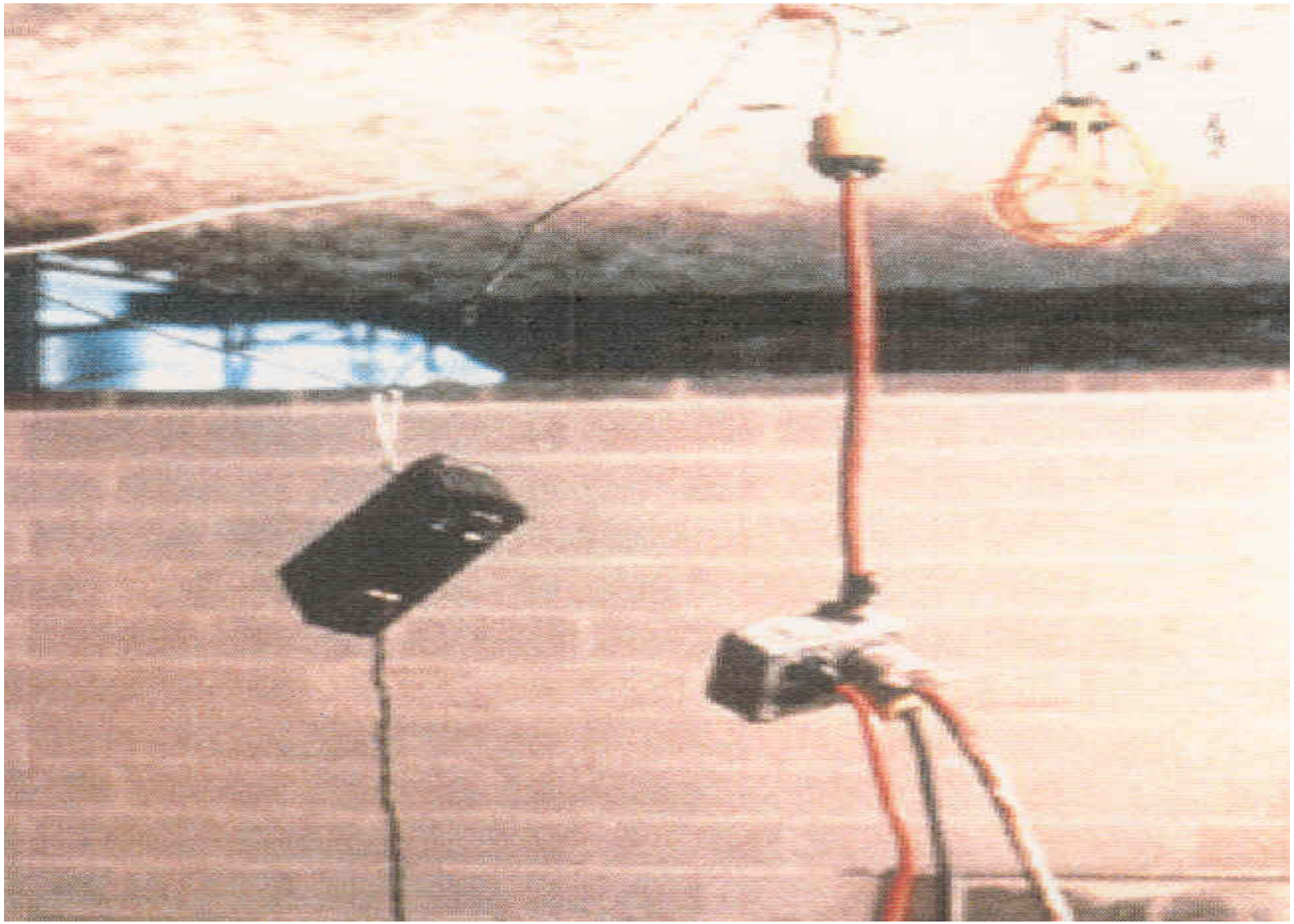


Photo from electrical-contractor.net

Maintain to Prevent

Hazard to Employee?

Damage, Shorts, Grounds

NFPA 70E Chapter 2

Article 210. Substation, Switchgear Assemblies, Switchboards, Panelboards, Motor Control Centers, and Disconnect Switches

- **Enclosures.** Enclosures shall be kept free of material that would create a hazard.

  door rods and handles

- **Area Enclosures.** Fences, physical protection

- **Conductors.** (buses, switches, disconnects, joints, and terminations) and bracing shall be maintained to:
  - (a) Conduct rated current without overheating
  - (b) Withstand available fault current

- **Insulation Integrity.** shall be maintained to support the voltage impressed.

- **Protective Devices.** shall be maintained to adequately withstand or interrupt available fault current.

Make sure fences are well maintained

Physically Protect Against

Unauthorized Access & Accidental contact

electrical-contractor.net

NFPA 70E Chapter 2
Article 215 Premises Wiring

Covers for Wiring System Components.

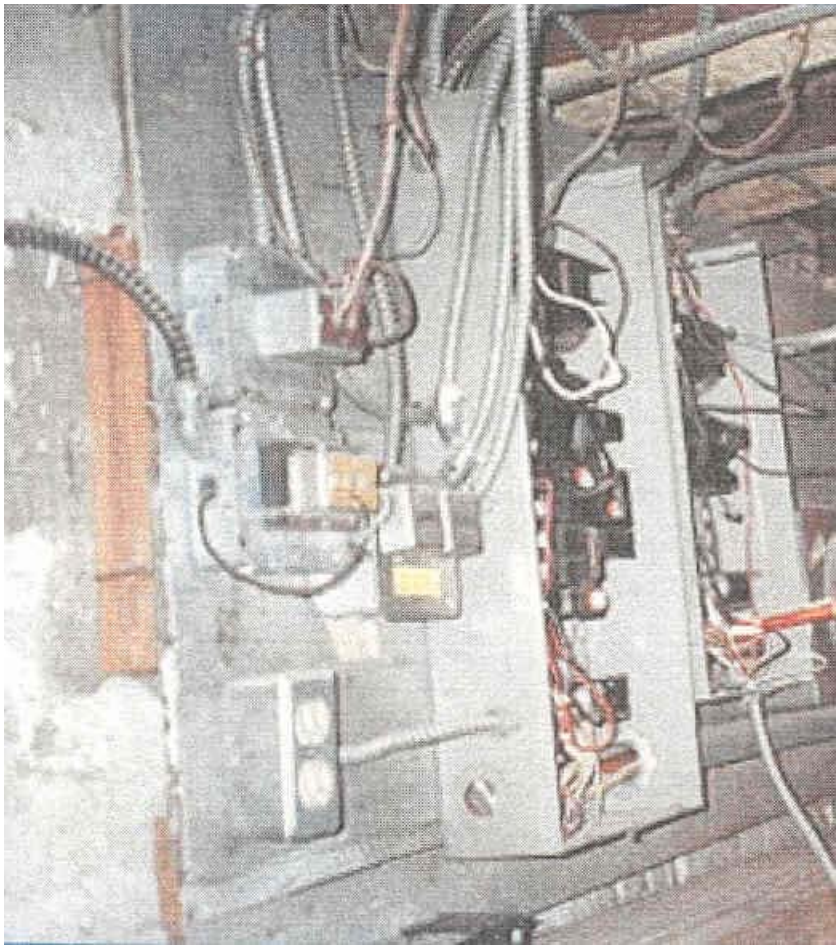
- Open Wiring Protection.
- Raceways and Cable Trays.

Cover only part of the problem

No Covers

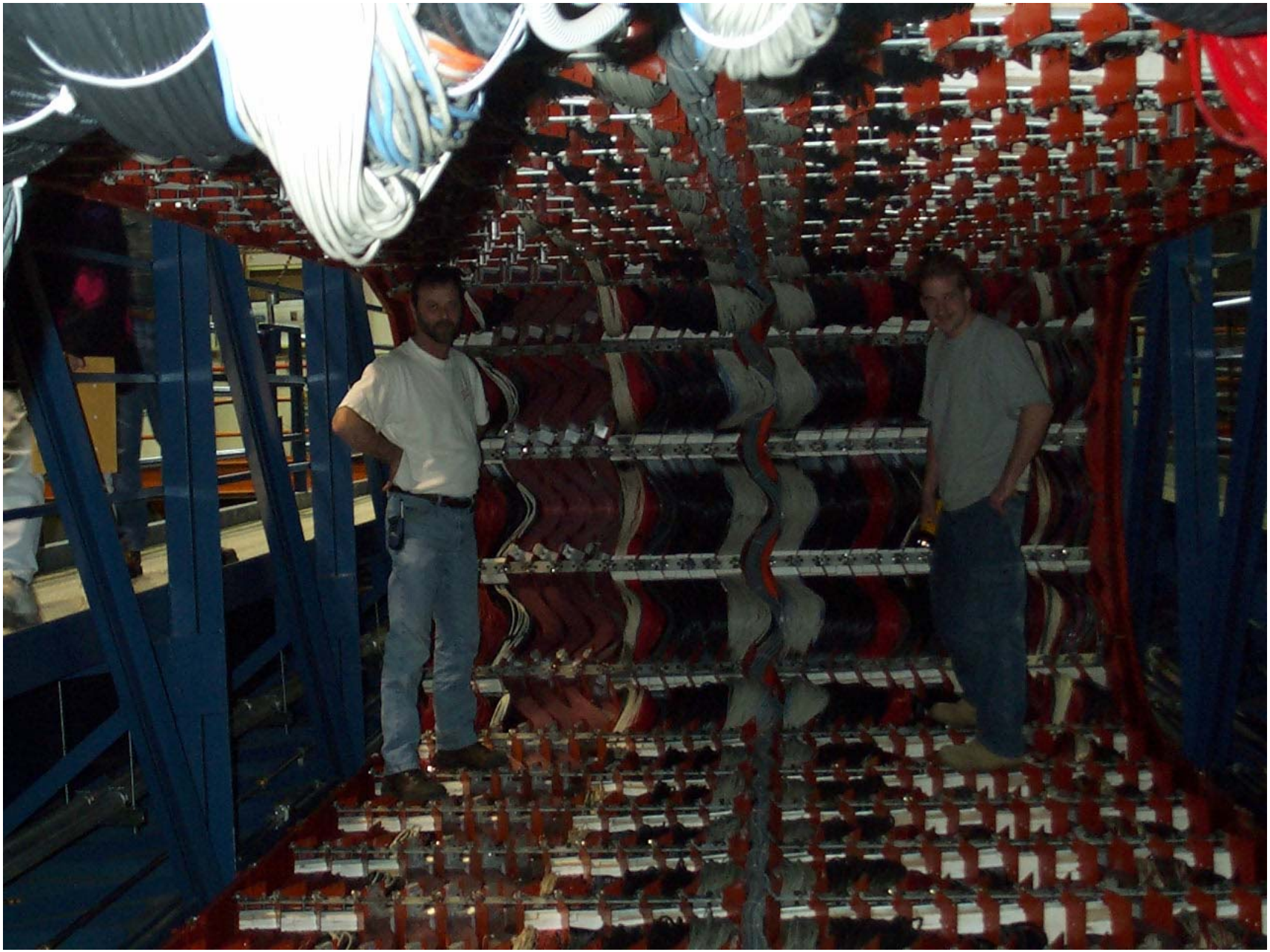
Holes

Hanging wires



PP/LB/E CKT

Trays should provide support and protection



NFPA 70E Chapter 2
Article 215 Premises Wiring - definition

Premises Wiring (System). That interior and exterior wiring, including power, lighting, control, and signal circuit wiring together with all of their associated hardware, fittings, and wiring devices, both permanently and temporarily installed, that extends from the service point of utility conductors or source of power such as a battery, a solar photovoltaic system, or a generator, transformer, or converter to the outlet(s).

Such wiring does not include wiring internal to appliances, fixtures, motors, controllers, motor control centers, and similar equipment.

NFPA 70E Chapter 2
Article 220. Controller Equipment

- Protection and Control/Circuitry

  This chapter covers controllers, which includes electrical equipment that governs the starting, stopping, direction of motion, acceleration, speed, and protection of rotating equipment and other power utilization apparatus in the workplace.

  It is intended to guard against accidental contact with live parts and prevent other electrical or mechanical hazards.

safetycenter.navy.mil

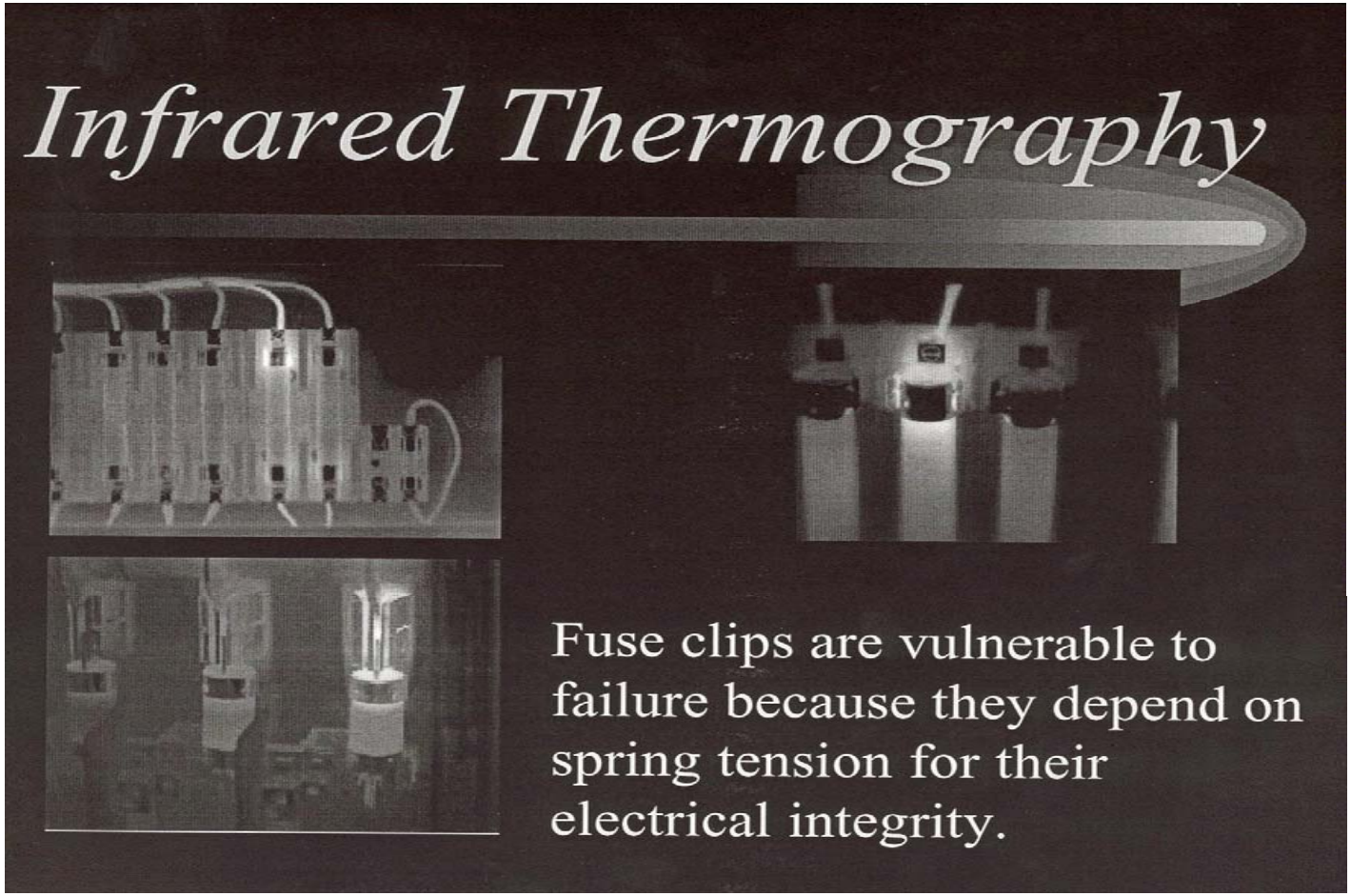
NFPA 70E Chapter 2

Article 225 Fuses and Circuit Breakers

●Fuses - shall be maintained free of breaks or cracks in fuse cases, ferrules, and insulators. Fuse clips shall be maintained to provide adequate contact with fuses.

●Molded-Case Circuit Breakers - shall be maintained free of cracks in cases and cracked or broken operating handles.

●Circuit Breaker Testing - shall be inspected and tested in accordance with the manufacturers' instructions.



Picture by: Deborah Freeze

When they fail it is usually bad

NFPA 70E Chapter 2

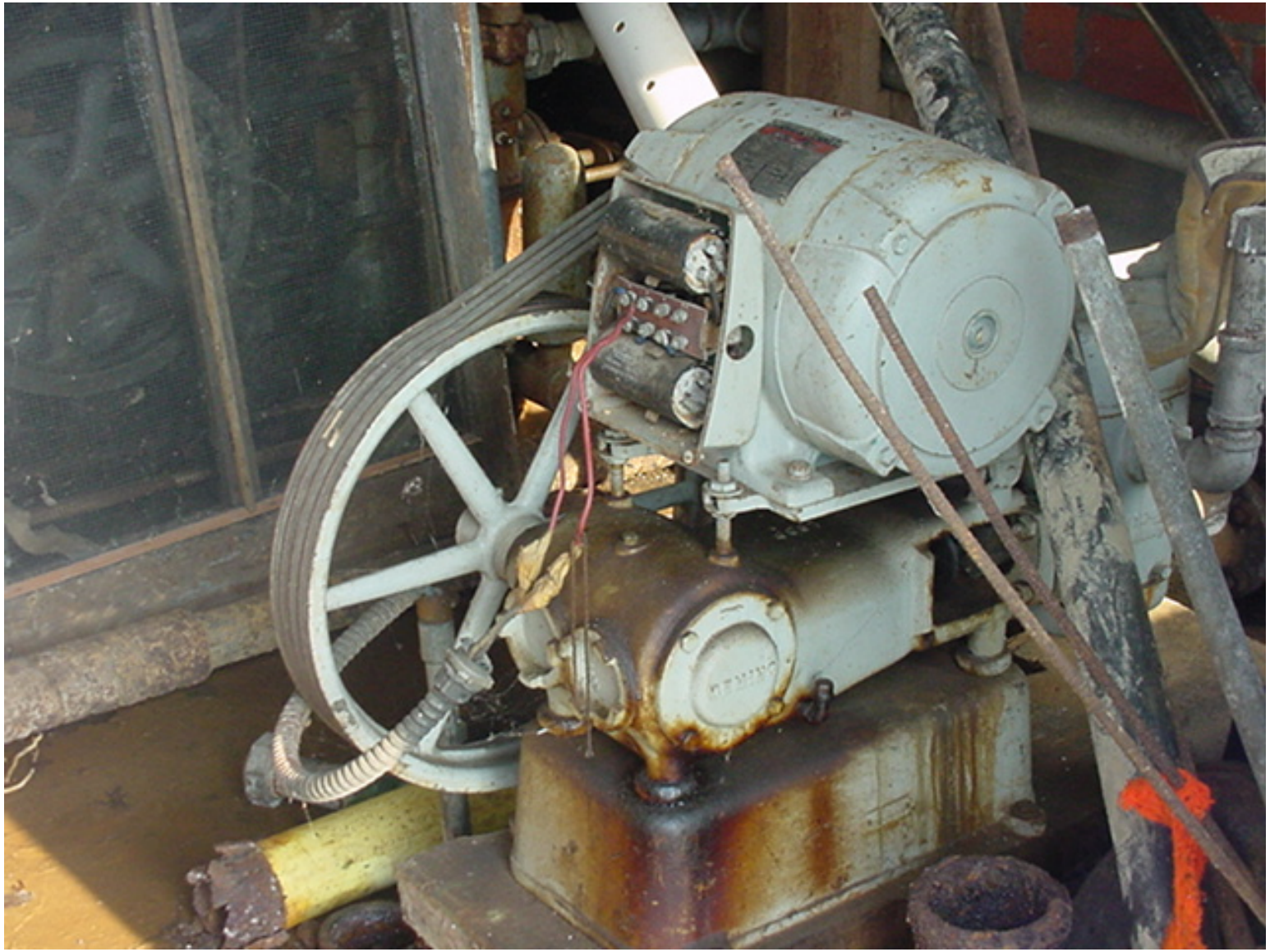
Article 230. Rotating Equipment

- Terminal Boxes – chambers , boxes , enclosures

  Guard against accidental contact with live parts and other electrical hazards.

- Guards, Barriers, and Access Plates –

  Prevent employees from contacting moving or energized parts.



NFPA 70E Chapter 2

Article 235. Hazardous (Classified) Locations

- No energized parts are exposed.
- There are no breaks in conduit systems, fittings, or enclosures from damage, corrosion, or other causes.
- All bonding jumpers are securely fastened and intact.
- All fittings, boxes, and enclosures with bolted covers have all bolts installed and bolted tight.
- All threaded conduit shall be wrench tight and enclosure covers shall be tightened in accordance with the manufacturer's instructions.

NFPA 70E Chapter 2

Article 235. Hazardous (Classified) Locations Cont.

- There are no open entries into fittings, boxes, or enclosures that would compromise the protection characteristics.
- All close-up plugs, breathers, seals, and drains are securely in place.
- Marking of lighting fixtures for maximum lamp wattage and temperature rating is legible and not exceeded.
- Required markings are secure and legible.

Summary of Class I, II, III Hazardous Locations			
CLASSES	GROUPS Art. 506 for Zone classifications	DIVISIONS	
		1	2
I Gases, vapors, and liquids (Art. 501)	A: Acetylene B: Hydrogen, etc. C: Ether, etc. D: Hydrocarbons, fuels, solvents, etc.	Normally explosive and hazardous	Not normally present in an explosive concentration (but may accidentally exist)
II Dusts (Art. 502)	E: Metal dusts (conductive,* and explosive) F: Carbon dusts (some are conductive,* and all are explosive) G: Flour, starch, grain, combustible plastic or chemical dust (explosive)	Ignitable quantities of dust normally are or may be in suspension, or conductive dust may be present	Dust not normally suspended in an ignitable concentration (but may accidentally exist). Dust layers are present.
III Fibers and flyings (Art. 503)	Textiles, wood-working, etc. (easily ignitable, but not likely to be explosive)	Handled or used in manufacturing	Stored or handled in storage (exclusive of manufacturing)

NEMA Classifications - Marked with Rated Class, Division, and Group	
NEMA 7	Class I (Gases) Indoor Hazardous Locations, Air-Break
NEMA 8	Class I (Gases) Indoor/Outdoor Hazardous Locations, Oil-Immersed
NEMA 9	Class II (Dusts) Indoor Hazardous Locations
NEMA 10	Meets U.S. Bureau of Mines Safety Requirements

Summary of NEC Classes and Group Examples

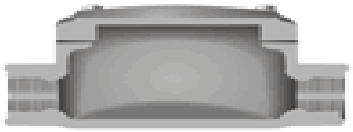
Group	Class I (Gases)	Class II (Dusts)
A	Acetylene	
B	Hydrogen, Ethylene Oxide, Propylene Oxide	
C	Ether, Hydrogen Sulfide, Hydrazine, Nitroethane	
D	Methane, Acetone, Benzene, Gasoline, Naphtha	
E		Metallic Dusts (all metals)
F		Carbonaceous Dusts (coal, asphalt, etc..)
G		Nonconductive Dusts (grain, drugs, pesticides, plastics, dyes, etc..)

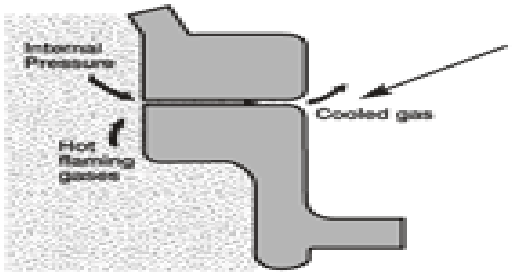
Summary of NEC Divisions

Division 1	Hazard always or frequently present, or may be present during normal operation or high probability of hazard existing at the same time as electrical malfunction
Division 2	Hazard normally not present, or highly unlikely to be present at the same time as electrical malfunction, or area adjacent to Division 1.

Material	Tensile Strength
Malleable iron	50,000 PSI
Aluminum	30,000 PSI
Gray iron	30,000 PSI

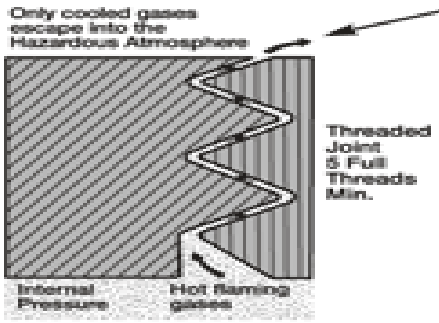
2. Enclosure cover type
   a. Bolted cover



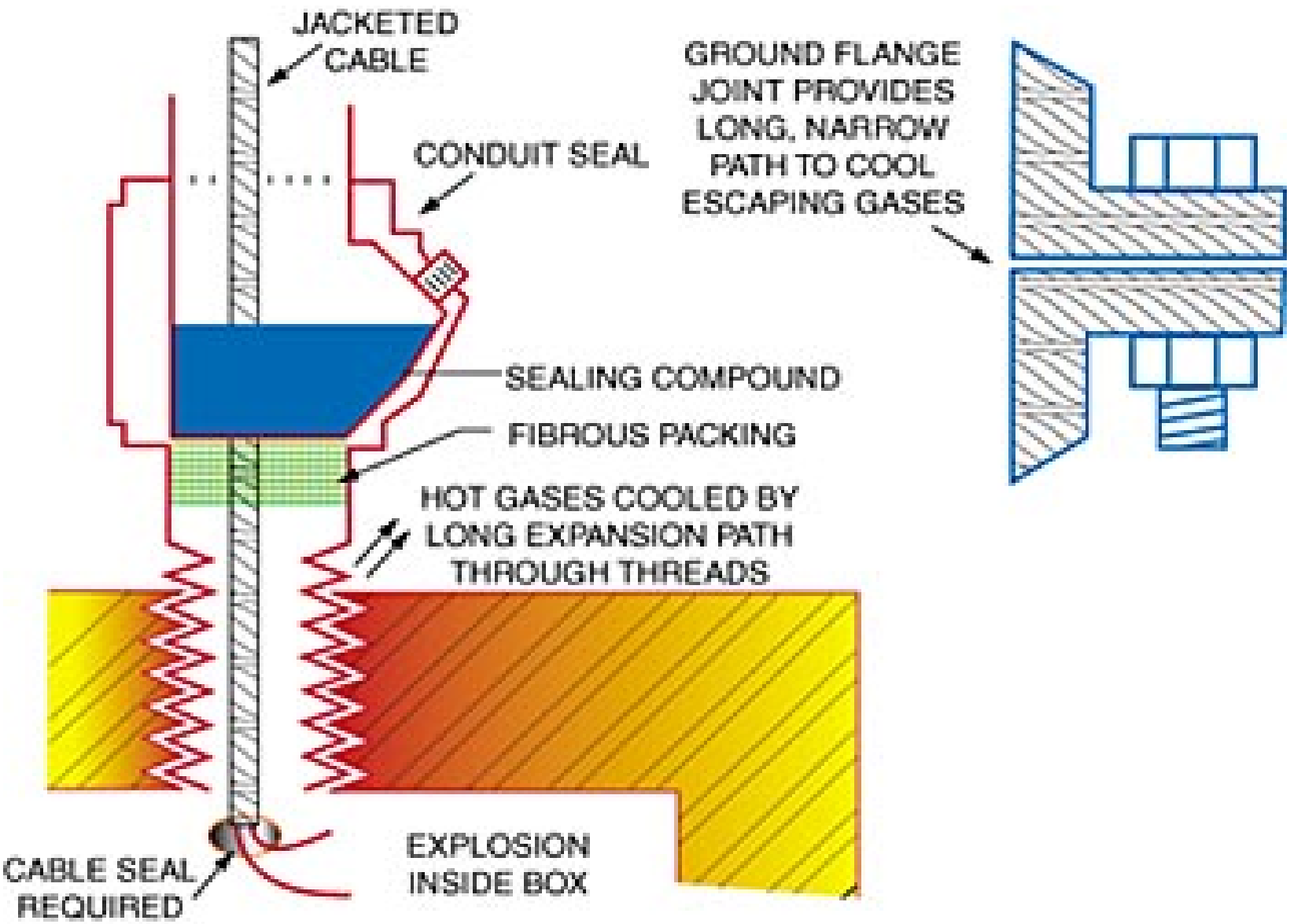


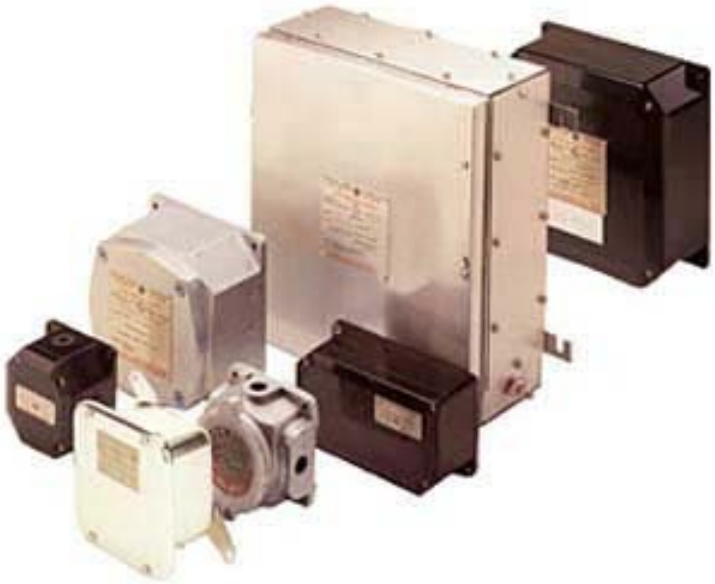
Cover and body with precision machined flat joint construction

   b. Threaded cover



Exhaust gases/ flames are cooled as they pass through many cover threads


JACKETED CABLE
CONDUIT SEAL
GROUND FLANGE JOINT PROVIDES LONG, NARROW PATH TO COOL ESCAPING GASES
SEALING COMPOUND
FIBROUS PACKING
HOT GASES COOLED BY LONG EXPANSION PATH THROUGH THREADS
CABLE SEAL REQUIRED
EXPLOSION INSIDE BOX



NFPA 70E Chapter 2

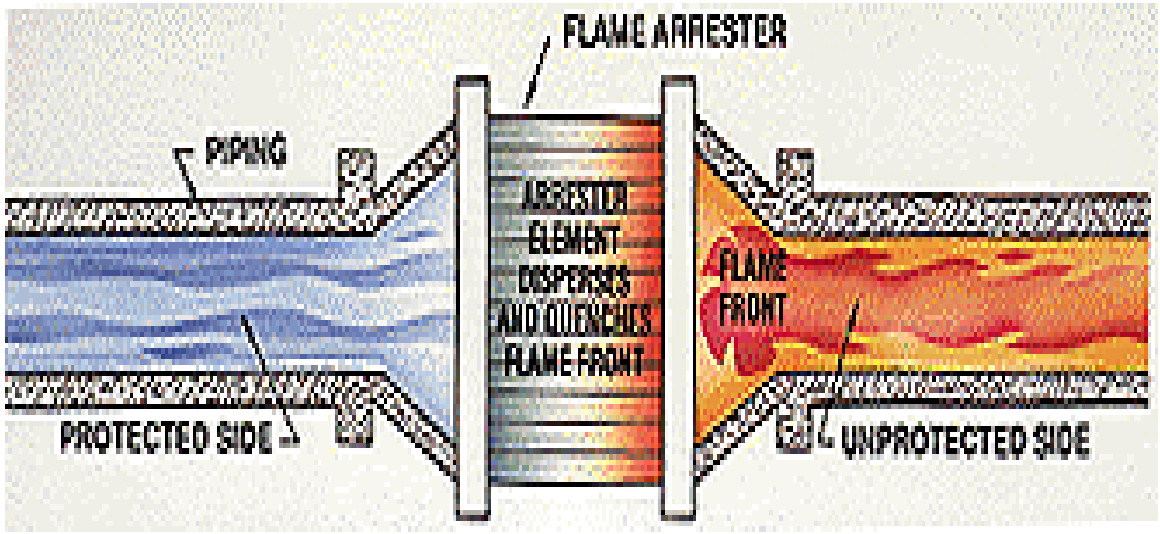
Article 240. Batteries and Battery Rooms

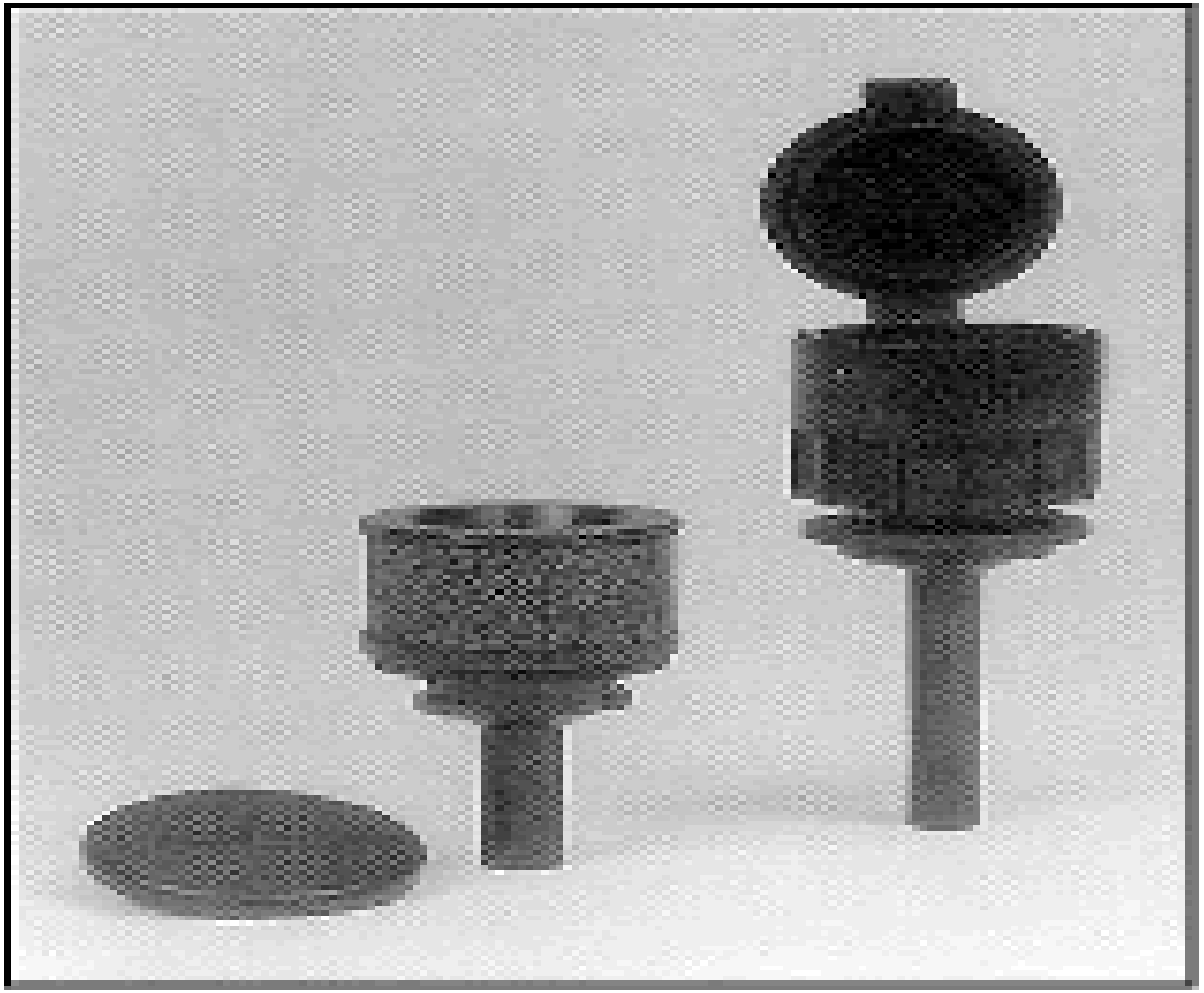
- Ventilation (test alarm system)
- Eye and Body Wash Apparatus.
- Cell Flame Arresters and Cell Ventilation.

Eye Wash, Body Wash and Other PPE

Flame Arresters

If the flammable vapor should ignite, the flame burns towards the arrester/element. As the flame attempts to pass through the element, it is slowed and cooled by contact with the metal walls of the small passages. Heat is transferred to the element until combustion cannot be maintained. The flame front is extinguished.





NFPA 70E Chapter 2

Article 245. Portable Electric Tools and Equipment

Attachment plugs, receptacles, cover plates, and cord connectors shall be maintained so that:

- (a) There are no breaks, damage, or cracks exposing live parts.
- (b) There are no missing cover plates.
- (c) Terminations have no stray strands or loose terminals.
- (d) There are no missing, loose, altered, or damaged blades, pins, or contacts.
- (e) Polarity is correct.

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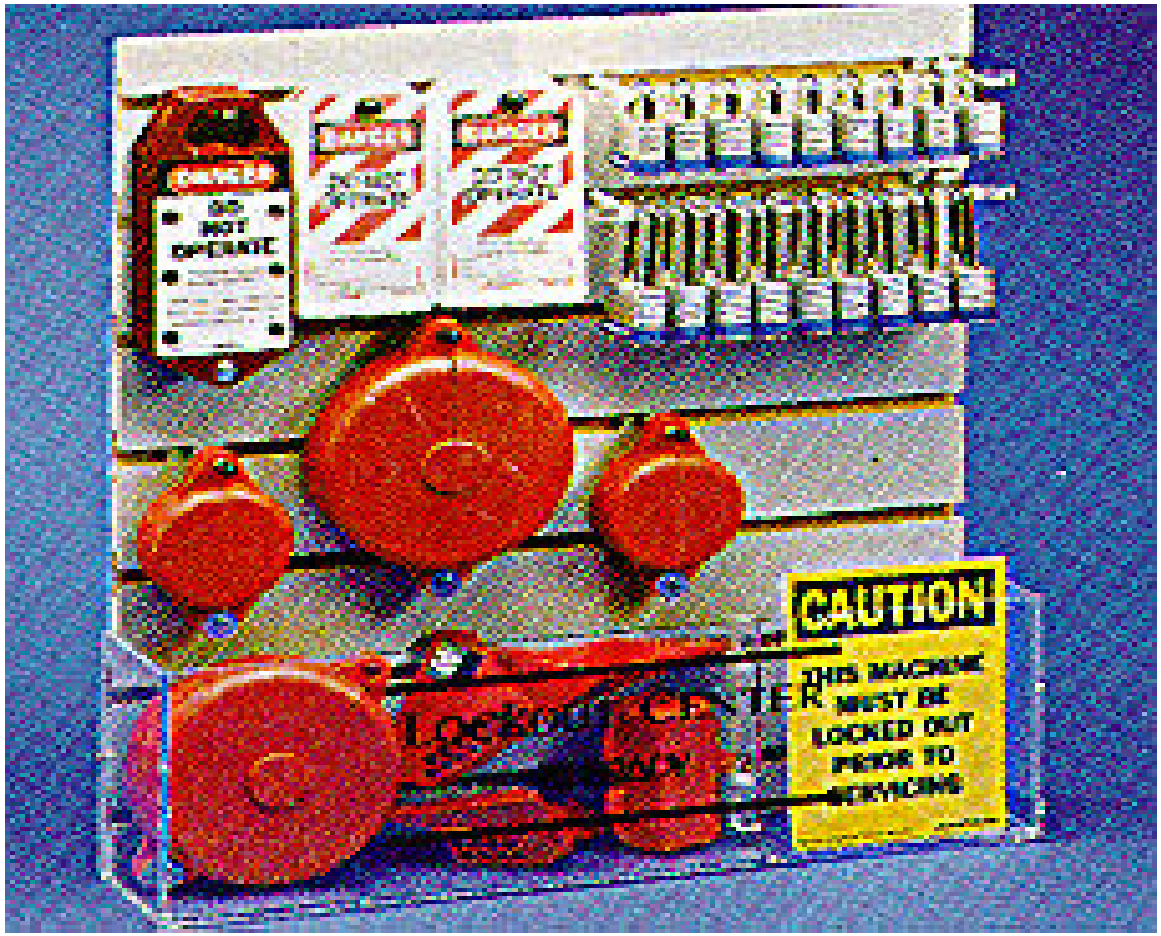
NFPA 70E Chapter 2

Article 250. Personal Safety and Protective Equipment

- Personal safety and protective equipment shall be maintained in a safe working condition.
  - Visual inspection
  - Testing.
    - Grounding equipment, Hot sticks
    - Rubber gloves, sleeves, and leather protectors
    - Voltage test indicators
    - Blanket and similar insulating equipment,
    - Insulating mats and similar insulating equipment
    - Protective barriers
    - External circuit breaker rack-out devices
    - Portable lighting units
    - Dielectric footwear
    - Protective clothing


DANGER
DO NOT OPERATE
DANGER
DANGER
CAUTION
THIS MACHINE MUST BE LOCKED OUT PRIOR TO SERVICING

NFPA 70E Chapter 2

- General Maintenance Requirements
- Substation, Switchgear Assemblies, Switchboards, Panelboards, Motor Control Centers, and Disconnect Switches
- Premises Wiring
- Controller Equipment
- Fuses and Circuit Breakers
- Rotating Equipment
- Hazardous (Classified) Locations
- Batteries and Battery Rooms
- Portable Electric Tools and Equipment
- Personal Safety and Protective Equipment

NFPA 70E Chapter 3

Safety requirements for Special Equipment

- Chapter 3 covers electrical safety installation requirements and safety-related work practices and procedures for employees who work on or near special electrical equipment in the workplace. Chapter 3 supplements or modifies the general requirements of Chapter 1 and Chapter 4.

NFPA 70E Chapter 3

Safety requirements for Special Equipment

It applies to:

- Electrolytic cells line as described in Article 430.8
- Batteries and battery rooms.
- Lasers.
- Power electronic equipment.

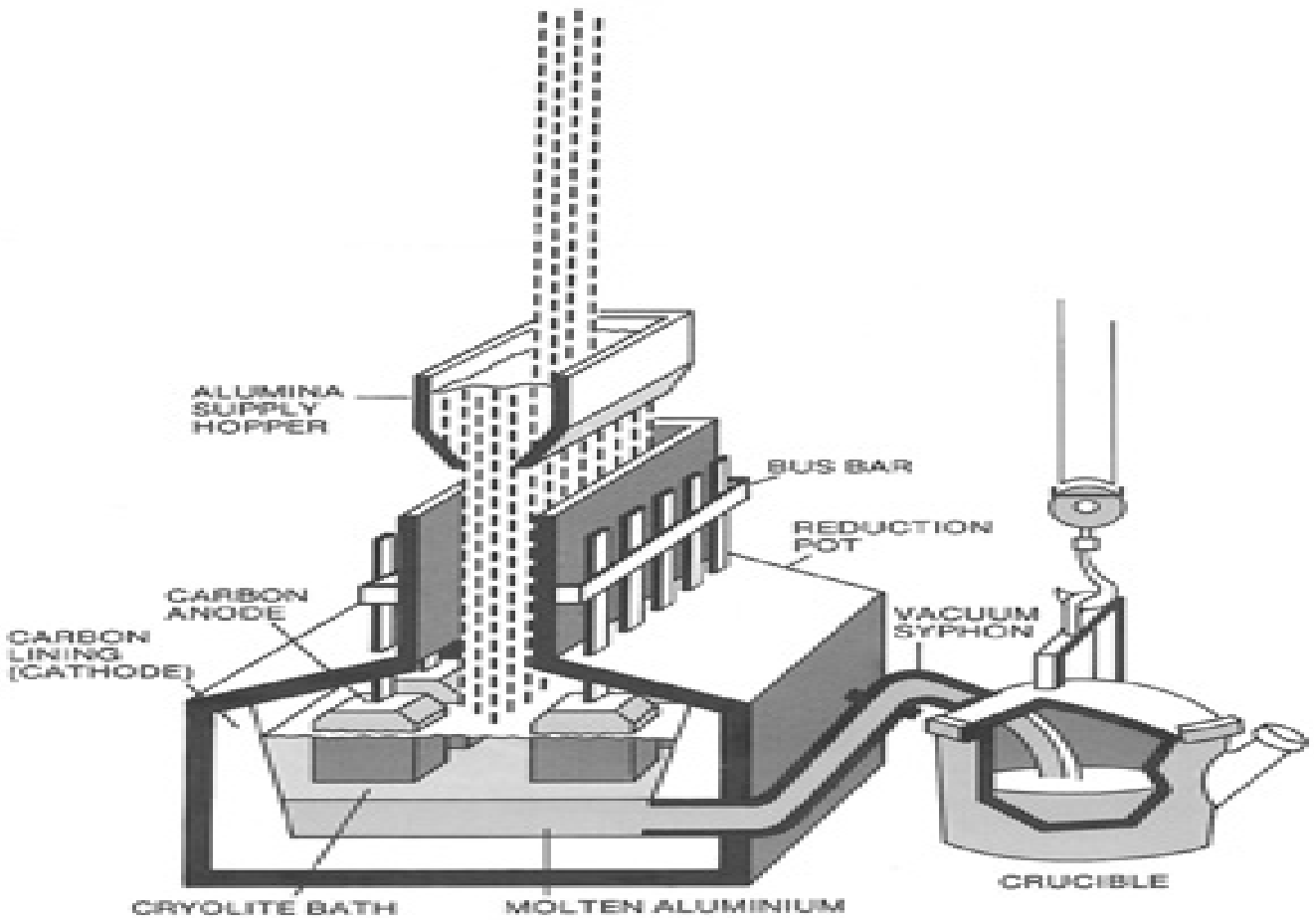
NFPA 70E Chapter 3
Electrolytic Cell Line

What is a Electrolytic cell line ? NEC Art. 668

An assembly of tanks or vats in which electrochemical reactions are caused by applying energy for the purpose of refining or producing metals.

Diagram of One Cell
4-5 Volts but 50K to 280K Amps

900 degrees C



NFPA 70E Chapter 3

Electrolytic Cell Line

300 Pots per Line

Typical

NFPA 70E Chapter 3

Electrolytic Cell Line

NOTE: For further information, see IEEE Standard for Electrical Safety Practices in Electrolytic Cell Line Working Zones, IEEE Std 463-1993.

Portable cut out type switches are used to jumper out cell lines.

Electrolytic cells can exhibit characteristics similar to an electrical storage battery, and thus a hazardous voltage may exist after the power supply is disconnected from the cell line.

NFPA 70E Chapter 3

Electrolytic Cell Line

Safeguards

Operation and maintenance of electrolytic cell lines may require contact by employees with exposed energized surfaces such as buses, electrolytic cells, and their attachments. The approach distances referred to in Table 130.2 (C) of Chapter 1 shall not apply to work performed by qualified persons in the cell line working zone.

Employees with implanted pacemakers, ferromagnetic medical devices, or other electronic devices vital to life shall not be permitted in cell areas unless written permission is obtained from the employee's physician.

NFPA 70E Chapter 3

Electrolytic Cell Line

Article 310.5 (C) says that the requirements of 130.3 – flash hazard analysis - do not apply to electrolytic cell line work zones.

This is referring to the methods described in 130.3.

A flash hazard analysis still needs to be done.

Authorized Management determines which PPE is needed and many of the safe work practice requirements.

NFPA 70E Chapter 3

Battery Rooms & Batteries

The scope of Article 320 says.

This Part only applies to systems that operate between 115 volts and less then 600volts, or have a stored capacity exceeding 1 kWh.

But then in chapter 320.7 we include systems of 50 volt or more.

NFPA 70E Chapter 3

Battery Rooms & Batteries

NOTE: For further information, refer to the following documents:

NFPA 70-2005, *National Electrical Code*, Article 480 Storage Batteries

IEEE Std 484-1996, *Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications*

IEEE Std 937-1987 (R1993), *Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic Systems*

IEEE Std 1187-1996, *Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications*

OSHA 1926.403, *Battery Rooms and Battery Charging*

OSHA 1910.178(g), *Changing and Charging Batteries*

OSHA 1910.305(j)(7), *Storage Batteries*

Worlds Largest Battery Room

Needs Ventilation to keep hydrogen below 1%

NFPA 70E Chapter 3

Battery Rooms & Batteries

Alarms shall be provided for early warning of the following abnormal conditions of battery operation:

For vented batteries:

(1) Overvoltage

(2) Undervoltage

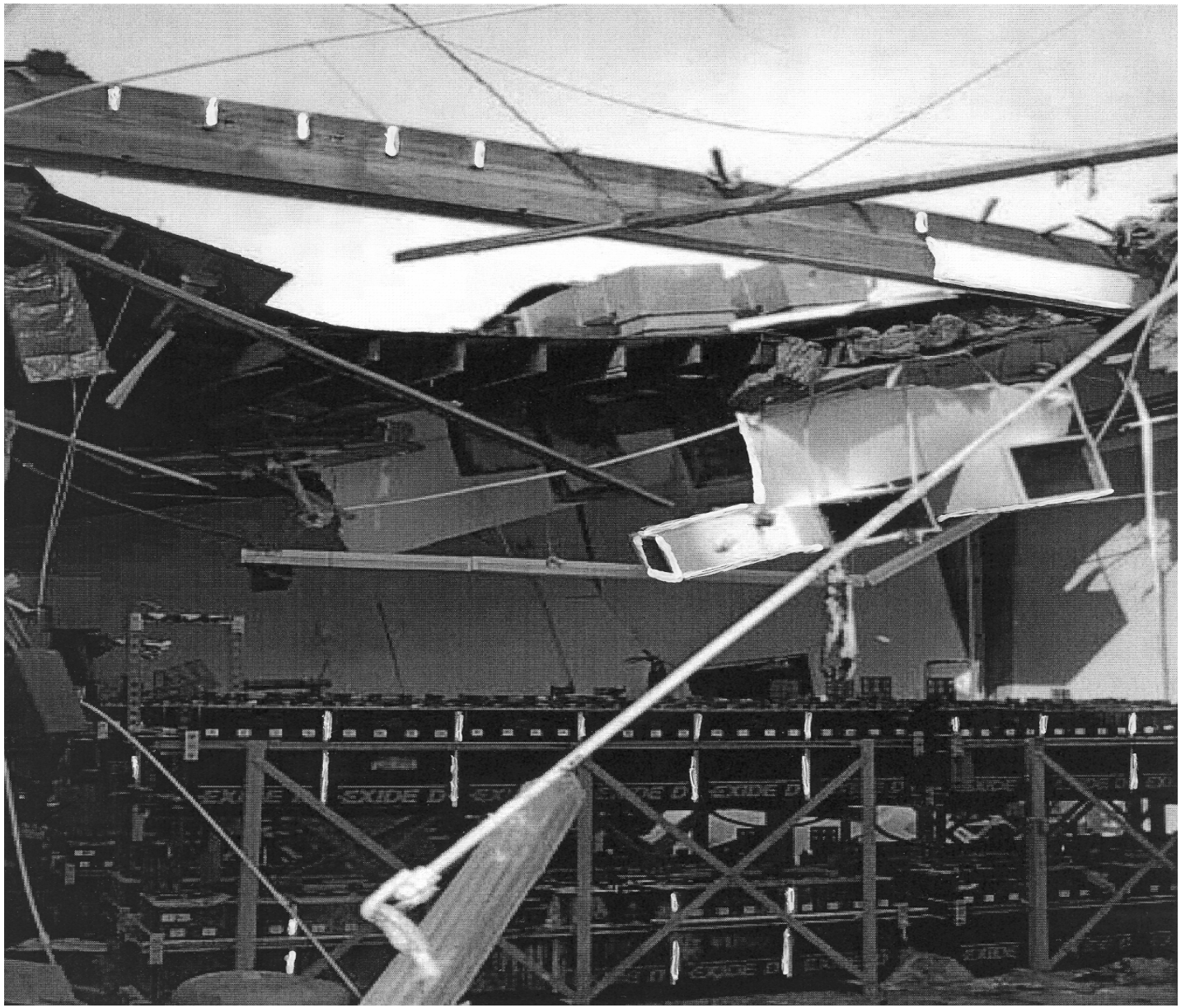
(3) Overcurrent

(4) Ground-fault

For VRLA batteries: Valve-regulated lead-acid storage battery.

(1) through (4), plus (5) over-temperature, as measured at the pilot cell

The alarm system should provide an audible alarm and visual indication at the battery location, and where applicable, at a remote manned control point.


EXIDE

NFPA 70E Chapter 3

Battery Rooms & Batteries

Battery Room Requirements

(1) The battery room and enclosure doors shall open outward. The doors shall be equipped with quick-release, quick-opening hardware.

(2) The battery room shall be located so that access to the batteries is unobstructed. DC switching equipment, rotating machinery other than exhaust fans, and other equipment not directly part of the battery and charging facilities shall be external to the battery room. Alternatively, dc switching equipment shall be separated from the battery by a partition of minimum height 6 ft 6 in. (2 m) and of sufficient length to prevent accidental contact with live surfaces.

(3) Foreign piping shall not pass through the battery room.

NFPA 70E Chapter 3

Battery Rooms & Batteries

Battery Room Requirements cont.

(4) Passageways shall be of sufficient width to allow the replacement of all battery room equipment.

(5) Emergency exits shall be provided as required.

(6) Access and entrance to working space about the battery shall be provided as required by Chapter 4 - Article 415.

NFPA 70E Chapter 3

Battery Rooms & Batteries - Layout

The battery layout and floor area shall meet the following requirement:

(1) The installation shall be so designed that, unless there is a physical barrier, potential differences exceeding 120 volts shall be separated by a distance of not less than 36 in. (900 mm) measured in a straight line in any direction.

NFPA 70E Chapter 3

Battery Rooms & Batteries – Layout cont.

(2) The floor area shall allow for the following clearances:

a. Aisle Width. The minimum aisle width shall be 36-in. (900 mm).

b. Single Row Batteries. In addition to the minimum aisle width, there shall be a minimum of 1-in. (25-mm) clearance between a cell and any wall or structure on the side not requiring access for maintenance. This does not preclude battery stands touching adjacent walls or structures, provided that the battery shelf has a free air space for no less than 90 percent of its length.

c. Double-Row Batteries. The minimum aisle width shall be maintained on one end and both sides of the battery. The remaining (1) end shall have a minimum clearance of 4 in. (100 mm) between any wall or structure and a cell.

NFPA 70E Chapter 3

Battery Rooms & Batteries – Layout cont.

d. Tiered Batteries. Tiered batteries shall meet the requirements of (a), (b), and (c) above. In addition there shall be a minimum clearance of 12 in. (300 mm) between the highest point of the battery located on the bottom tier and the lowest point of the underside of the upper runner bearers.

e. Where a charger, or other associated electrical equipment, is located in a battery room, the aisle width between any battery and any part of the battery charging equipment (including the doors when fully open) shall be at least 36 in. (900 mm).

NFPA 70E Chapter 3

Battery Rooms & Batteries - **Protection**.

General:

(1) When the battery capacity exceeds 100 ampere hours or where the nominal battery voltage is in excess of 50 volts, suitable warning notices indicating the battery voltage and the prospective short-circuit current of the installation shall be displayed.

(2) Each output conductor shall be individually protected by a fuse or circuit breaker positioned as close as practicable to the battery terminals.

(3) Protective equipment shall not be located in the battery compartment of the enclosure.

NFPA 70E Chapter 3

Battery Rooms & Batteries - Protection cont.

Switching and Control Equipment.

Switching and control equipment shall comply with the *NEC* and shall be listed for the application.

Ground-Fault Protection.

For an ungrounded battery of nominal voltage in excess of 120 volts, a ground-fault detector shall be provided to initiate a ground-fault alarm.

Main Isolating Switch.

The battery installation shall have an isolating switch installed as close as practicable to the main terminals of the battery. Where a busway system is installed the isolating switch may be incorporated into the end of the busway.

NFPA 70E Chapter 3

Battery Rooms & Batteries - Protection cont.

Section Isolating Equipment.

Where the battery section exceeds 120 volts the installation shall include an isolating switch, plugs, or links, as required, to isolate sections of the battery, or part of the battery for maintenance.

Warning Signs.

The following signs shall be posted in appropriate locations:

(1) Electrical hazard warning signs indicating the shock hazard due to the battery voltage and the arc hazard due to the prospective short-circuit current

(2) Chemical hazard warning signs indicating the danger of hydrogen explosion from open flame and smoking and the danger of chemical burns from the electrolyte

(3) Notice for personnel to use and wear protective equipment and apparel

(4) Notice prohibiting access to unauthorized personnel

NFPA 70E Chapter 3

Battery Rooms & Batteries

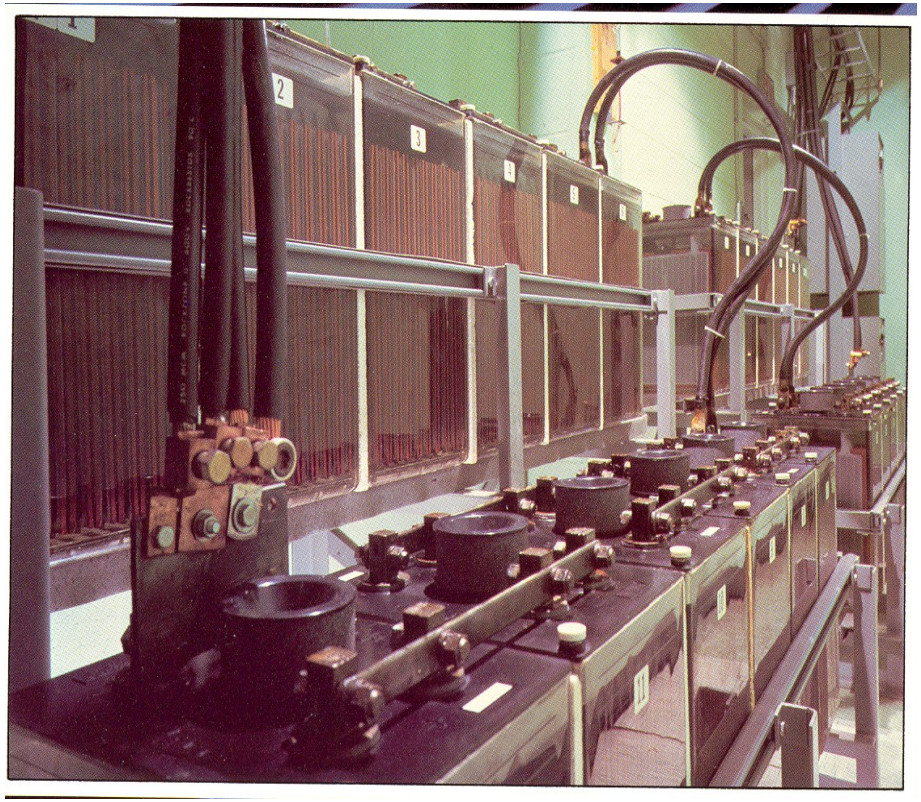
The busbars should be insulated,rated at max short circuit current.

Cells should be spaced 1 inch apart and readily accessible.

Terminal and connections should resist corrosion.

Take-off points should be protected.

Cables shall be effectively clamped and sufficient support shall be provided throughout the length of cables to minimize sag, and prevent undue strain from being imposed on the cable.



NFPA 70E Chapter 3

Battery Rooms & Batteries

NFPA 70E Chapter 3 - Lasers

Electrical Hazards

Most lasers contain high-voltage power supplies and often large capacitors or capacitor banks that store lethal amounts of electrical energy. In general, systems that permit access to components at such lethal levels must be interlocked; however, during maintenance and alignment procedures, such components often become exposed or accessible. This has caused numerous serious and some fatal shocks at other research facilities.

NFPA 70E Chapter 3 - Lasers

Electrical Safety Guidelines

• No one should work on lasers or power supplies unless qualified and approved to perform the specific tasks.

• Prior to working with electrical equipment, de-energize the power source. Lock and tag out the disconnect switch.

• Check that each capacitor is discharged, shorted, and grounded prior to working in the area of the capacitors.

NFPA 70E Chapter 3 - Lasers - Training

Employers shall provide training for all operator and maintenance personnel.

The training should include, but is not limited to the following:

(1) Familiarization with laser principles of operation, laser types, and laser emissions

NFPA 70E Chapter 3 - Lasers – Training cont.

(2) Laser safety including:

a. System operating procedures

b. Hazard control procedures

c. The need for personnel protection

d. Accident reporting procedures

e. Biological effects of the laser upon the eye and the skin

NFPA 70E Chapter 3 - Lasers – Training cont.

(2) Laser safety including:

f. Electrical and other hazards associated with the laser equipment, including:

(i) High voltages [> 1 kV] and stored energy in the capacitor banks

(ii) Circuit components, such as electron tubes, with anode voltages greater than 5 kV emitting X-rays

(iii) Capacitor bank explosions

(iv) Production of ionizing radiation

(v) Poisoning from the solvent or dye switching liquids or laser media

(vi) High sound intensity levels from pulsed lasers

NFPA 70E Chapter 3 - Lasers – **Safeguarding**

Employees shall be provided with eye protection as required by federal regulation.

Warning signs shall be posted at the entrances to areas or protective enclosures containing laser products.

High power laser equipment shall include a key-operated master control.

High power laser equipment shall include a fail-safe laser radiation emission audible and visible warning when it is switched on or if the capacitor banks are charged.

NFPA 70E Chapter 3 - Lasers –**Safeguarding** cont.

Beam shutters or caps shall be utilized, or the laser switched off, when laser transmission is not required. The laser shall be switched off when unattended for 30 minutes or more.

Laser beams shall not be aimed at employees.

Laser equipment shall bear a label indicating its maximum output.

Personnel protective equipment shall be provided for users and operators of high power laser equipment.

NFPA 70E Chapter 3

Safety Related Work Practices: Power Electronic Equipment

(1) Electric arc welding equipment

(2) High power radio, radar, and television transmitting towers and antenna

(3) Industrial dielectric and RF induction heaters

(4) Shortwave or radio frequency diathermy heaters

(heating tissue)

(5) Process equipment that includes rectifiers and inverters such as:

a. Motor drives;

b. Uninterruptible power supply systems; and,

c. Lighting controllers.

NFPA 70E Chapter 3 -

Safety Related Work Practices: Power Electronic Equipment

This chapter is to provide guidance for safety personnel to prepare specific safety-related work practices within their industry.

This chapter also describes the effects of electricity on the human body

NFPA 70E Chapter 3 -

Safety Related Work Practices: Power Electronic Equipment

Have You Ever Been Shocked?

THE BASICS

100 mA Can Kill You
15 to 20 mA You Can't Let Go
5 mA Sensing Threshold
4 to 6 mA GFCI Trip Point
15 A Typical Circuit Breaker

Effects of Electric Current in the Human Body

Current	Reaction
1 Milliampere	Perception level. Just a faint tingle.
5 Milliamperes	Slight shock felt; not painful but disturbing. Average individual can let go. However, strong involuntary reactions to shocks in this range can lead to injuries.
6-25 Milliamperes	(women) Painful shock, muscular control is lost.
9-30 Milliamperes	(men) This is called the freezing current or "let-go" range.
50-150 Milliamperes	Extreme pain, respiratory arrest, severe muscular contractions. * Individual cannot let go. Death is possible.
1,000-4,300 Milliamperes	Ventricular fibrillation. (The rhythmic pumping action of the heart ceases.) Muscular contraction and nerve damage occur. Death is most likely.
10,000- Milliamperes	Cardiac arrest, severe burns and probable death.

If the extensor muscles are excited by the electric shock, the person may be thrown away from the circuit.

Source: W.B. Kouwenhoven, "Human Safety and Electric Shock," Electrical Safety Practices, Monograph, 112, Instrument Society of America, p. 93. (Papers delivered at the third presentation of the Electrical Safety Course given in Wilmington, DE, in November 1968.)

NFPA 70E Chapter 3 -

Safety Related Work Practices: Power Electronic Equipment

Specific Measures for Personnel Safety.

The employee is responsible for:

(1) Being continuously alert and aware of the possible hazards

(2) Using the proper tools and procedures for the work

(3) Informing the employer of malfunctioning protective measures, such as enclosures and locking schemes that are faulty or inoperable

(4) Examining all documents provided by the employer relevant to the work, especially those documents indicating the hazardous components location

(5) Maintaining good housekeeping around the equipment and work space

(6) Reporting any hazardous incident

NFPA 70-E Chapter 4

NFPA 70E – Chapter 4
Installation Safety Requirements
&
NFPA 70E Protective Strategies

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NFPA 70E – Chapter 4
Installation Safety Requirements

- Scope & Intent
- Article 400 – General Requirements
- Article 410 – Wiring Design & Protection
- Article 420 – Wiring Methods, Components, and Equipment for General Use
- Article 430 – Specific Purpose Equipment and Installation
- Article 440 – Hazardous (Classified) Locations
- Article 450 – Special Systems

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Scope and Intent

- NEC installation requirements
- Correlates to 2002 NFPA 70 – NEC
- Not intended to replace NEC
- Specific Need of OSHA
- Not to be applied as design, installation, modification, or construction standard
- Committee agreed to retain Chapter 4 for:
  - “basis of OSHA enforcement of installation requirements”
  - “..important for worker safety..”

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Article 400 – General Requirements

- Minimize exposure to general public
  - Fire and shock
- Basic installation requirements for public safety (normal operational system)
- Service and maintenance NFPA 70E Chapter 1 applies
  - To equipment and worker

Article 410 - Wiring Design and Protection

- Minimize the opportunity for exposure to electrocution or shock
- Establish effective path for ground fault current to return safely to energy source
- Use of GFCI's
- Service requirements
- Portable and vehicle mounted generators

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Article 420 – Wiring Methods, Components, and Equipment for General Use

- Listing and labeling requirements
- Temporary wiring
  - General requirements
  - Time constraints
- Industrial applications
- Flexible Cords and Cables
- Receptacles in Wet Locations
- Motors and Transformers

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Article 430 – Specific Purpose Equipment and Installation

- Specific Purpose Equipment
- Modifies basic installation requirements from other Chapter 4 requirements
- Also….
  - Adds additional requirements
- Signs, Cranes/hoists, welders, x-ray, electrolytic cells, swimming pools, carnivals, Circuses, and … similar events

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Article 440 – Hazardous (Classified) Locations

- Special Attention to equipment and wiring
- Unique practices to mitigate explosion potential
- Flammable materials and atmospheres classified as hazardous
- Boundaries of each area defined

Article 450 – Special Systems

- Requirements for Special Systems different from basic installation guidance
- Emergency Systems
- Remote control, Signaling, Power limited circuits
- Communication systems
- Solar Photovoltaic systems
- Integrated Electrical systems

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NFPA 70E Protective Strategies

- Electrically Safe Work Condition
  - Turn it off !!!!!!!!!!!
  - Verify it’s off !!!!!!!!!!
- Training
  - Qualification basis !!!!!!!!!!!!!!!!!!
- Planning
  - Integrated Safety Management !!!!!!!!!!!!!!!
- PPE
  - Last protective barrier !!!!!!!!!!!!!!!!!!

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NFPA 70E

- How you can effect change!

- ***<u>Form for Proposals on NFPA Technical Committee Documents</u>***
  - **Proposal**
  - **Statement of Problem**
  - **Substantiation for Proposal**

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Questions?

Bobby and Keith will be glad to answer them

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